Office of Safety, Health & Environment

NUS LABORATORY CHEMICAL SAFETY MANUAL

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Approved by	:	Mr Saravanan s/o Gunaratnam

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DOCUMENT AMENDMENT AND REVIEW HISTORY

	DATE	REV. NO.	AMENDMENT / REVIEW	RECORDED BY
01	22 Aug 2007	01	Initial release	Ms Gisela Ho
02	13 July 2011	02	<u>Amendment includes the followings:</u> 1. Legislation update • Fire Safety (Petroleum & Flammable Materials) Regulations • Environment Protection and Management Act • Misuse of Drug Act • Environmental Public Health Act • Sewerage and Drainage Act • Globally Harmonised System of Classification and Labelling of Chemicals • SS 586 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods 2. Incorporation of OSHE SOPs into the manual: • Laboratory OSH Certification Scheme • Chemical Disposal Procedures • Chemical Weapons (Prohibition) Act - Storage, Use and Disposal Requirements • Safe Operation of Fume Hood • Managing Chemical Spills • Nanotechnology 3. New inclusion: • University safety policy • University safety directives • Procurement of chemical • Regulated Chemical Identifier • Storage of peroxides and peroxide forming chemicals • Industrial hygiene monitoring	Ms Gisela Ho

			• Medical surveillance • Accident/incident Reporting and Investigation	
03	18 July 2012	03	<u>Amendment includes the following:</u> 1. New Inclusion of SOPs into the manual: • Chemical Decontamination of Equipment & Labs • Management of hazardous wastes • Safe handling and storage of Perchloric Acid • Safe use of shared equipment 2. Web links added to applicable legislations on Hazardous Substances. All web links in the manual are updated. 3. Laboratory OSH Certification Scheme amended to Laboratory Safety & Health Management System Certification Scheme updated 4. Safety video web links have been included to relevant sections of the manual	Ms Gisela Ho
04	10 Jan 2013	04	<u>Amendment includes the following:</u> 1. Section 7.6.2 - Chemical compatibility Storage requirement for Acetic Acid 2. Section 7.7.4 – Transportation of chemical waste • Criteria for chemical waste trolley 3. Section 1.2.4 – Update OSHE office address • Change address from UHC to Ventus 4. Section 9 – Industrial Hygiene Monitoring • Mandatory for labs to conduct SQRA	Ms Gisela Ho
05	27 May 2013	05	<u>Amendment includes the following:</u> 1. New Section 7.6.8 – Storage of pyrophoric chemicals 2. Section 7.3.7 - replaced “Regulated Chemical Identifier’ to “Hazardous Materials Management System”	Ms Gisela Ho
06	21 Oct 2013	06	Deleted section 7.9 – Safe use of shared equipment	Ms Gisela Ho
07	15 Jan 2014	07	New section 7.9 – Safety Guidelines for Bench-work in Shared Laboratories	Mr Joel Swee

08	20 Feb 2014	08	<u>Amendment includes the following:</u> 1. Section 7.6.2 – Chemical Compatibility	Mr Joel Swee
09	26 March 2014	09	<u>Amendment includes the following:</u> 1. Section 3.3 – Fire Safety (Petroleum & Flammable Materials) Regulations. • Update of legislation	Mr Joel Swee
10	15 May 2014	10	<u>Amendment includes the following:</u> 1. Section 6.3.2 – update on the requirement for SDS to be available in the laboratory. The copy of SDS can be either hard or soft copy.	Mr Joel Swee
11	17 July 2014	11	<u>Amendment includes the following:</u> 1. Section 3.4 – Poisons Act • User of imported poisons shall be the license holder 2. Section 7.3.7 - Hazardous Material Management System (HMMS) • Amendment to use of ORMI 3. Section 7.4.3 – Inventory record General Requirements of Chemical Storage • Include legal requirements on register book on use of explosive precursors.	Mr Joel Swee
12	29 July 2014	12	<u>Amendment includes the following:</u> 1. Appendix G – Update on Step 1: Identify Chemical on the conduct of SQRA	Mr Joel Swee
13	05 Sep 2014	13	New Section 7.10 – Safety Guidelines for Activities Involving Use of Cytotoxic Drugs	Mr Joel Swee
14	31 Oct 2014	14	New Appendix M – Guidelines on the selection of laboratory coat	Mr Joel Swee
15	24 Feb 2015	15	<u>Amendment includes the following:</u> 1. Section 5: included requirement for staff and students to complete OSHE IVLE chemical safety training prior to working with hazardous chemicals. 2. Update of UHC Health Service telephone	Mr Joel Swee

			number	
16	07 July 2015	16	<u>Amendment includes the following:</u> 1. Section 2.1.2 – Reference is made to the NUS Safety and Health Policy instead of the Chemical Safety Policy and Radiation Safety Policy 2. Section 2.1.3 – delete the phrase, 'of Chemical Safety Policy' 3. Section 2.2 –revision to reflect the updated NUS Safety and Health Policy 4. Section 6.3.1 – a. delete the phrase, 'and by end 2013 for mixtures.' b. Rephrase, 'All containers, packaging and cylinders containing chemicals (solid, liquid or gas) must be labeled.' to 'All containers, packaging and cylinders containing chemicals (solid, liquid or gas) shall be labelled.' 5. Section 6.4.2 – revision to requirement of using eye and face protection 6. Section 7.3 – delete the phrase, 'Consistent with NUS Chemical Safety Policy,' 7. Section 7.6.1: a. Rephrased requirements for storage of licensed chemicals under lock and key. b. Delete the phrase, 'Label suspected and known carcinogens shall be segregate within secondary containment trays.' c. Rephrase - 'Store highly toxic chemicals (e.g. hydrofluoric acid (HF)) in compatible secondary containers' d. Rephrase – 'Capacity of secondary	

			containment should be at least 20% of the total volume of chemicals stored within the containment tray.' 8. Section 7.6.2 – a. Rephrase, 'Incompatible chemicals should not be stored together' to 'Incompatible chemicals shall not be stored together'. b. Rephrase storage requirements of acetic acid, a chemical with corrosive and flammable properties. 9. Section 7.7.1 – rephrase, 'Departments should use chemical containers supplied by licensed waste collectors.' 10. Section 7.7.2 – update of Table 7.2 - Classification of Waste 11. Section 7.7.3 – rephrase, 'Incompatible wastes shall NOT be stored in the same container.' 12. Section 7.7.5 – update of hyperlink to list of toxic industrial waste collectors 13. Section 10 – update on Statutory Medical Examinations requirements for staff and students 14. Section 13 – update of references 15. New Appendix N – Workflow for Exemption from Statutory Medical Examinations for Students	

1 INTRODUCTION

1.1 OVERVIEW

Chemicals are used extensively in NUS mainly for research purposes. It is important to exercise caution in the usage of chemicals as they may exist in different forms: solid, liquid and gas. They may be chemically reactive with each other and result in disastrous effect. Some are harmful to our health and some can even cause severe injury and fatality.

The purpose of this Manual is to provide guidance to all users working with chemicals in the laboratory and workshop.

In addition to the Appendices, documents referenced in this manual (underlined in the text), can be directly accessed through the NUS staff portal and student portal under the section of "Safety, Security & Sustainability". Go to NUS website > Staff or Student portal > Safety, Security & Sustainability > General Safety & Health.

This Manual should be used in conjunction with other laboratory safety manuals, i.e.:

- NUS General Laboratory Safety Manual – provides safety and health requirements on issues common to all laboratories, for example, commissioning and decommissioning of laboratory, laboratory sign posting, personal protective equipment, first aid, contractors management, etc.

- NUS Laboratory Radiation Safety Manual – provides safety and health requirements for working with ionizing and non-ionizing apparatus and radioactive materials in laboratories.

- NUS Laboratory Biorisk Management Manual – provides safety and health requirements for working with materials of biological origin, including genetically modified organisms (GMOs) in laboratories.

All personnel working with chemicals in laboratories are required to read and understand the content of this Manual before they start work. They should attend the relevant safety trainings

and be equipped with the necessary knowledge, skills and techniques to handle chemicals in such a manner so as not to threaten the safety and health of his/her own and others in the vicinity. Where exposure to certain toxic chemicals are expected or suspected, one may request for industrial hygiene monitoring to be conducted in the laboratory and medical examination to monitor personal health status.

1.2 EMERGENCY PHONE NUMBERS AND SAFETY PERSONNEL CONTACTS

1.2.1 Emergency Phone Numbers

SCDF - Ambulance/Fire	995
Police	999
Campus Security (24hrs)	x 1616 (6874 1616)
General Maintenance/ Breakdown of Services (24 hrs)	x 1515 (6516 1515)

1.2.2 University Health Centre (UHC)

Main Clinic

Kent Ridge Campus

20 Lower Kent Ridge Road

University Health Centre, Level 1

Operating Hours

Mon – Thur	8.30am – 6pm
Fri	8.30am – 5.30pm
Closed on	Sat, Sun & Public Holidays

Closed for lunch from 12.30pm – 1.30pm

Last registrations are 15 mins before closing time

General Enquiries: 6601 5035

uhc_health@nus.edu.sg

Satellite Clinic

Bukit Timah Campus

469G Bukit Timah Road

Block B, #02-01, Multipurpose Auditorium

Operating Hours

Mon/ Wed/ Fri	8.30 – 10.30am (during term only)
Closed on	Tue, Thu, Sat, Sun & Public Holidays

Last registrations are 15 mins before closing time

General Enquiries: 6467 5492

uhc_health@nus.edu.sg

1.2.3 Nearest Hospital

In the event of critical injury/ illness after office hours, proceed to the Accident & Emergency Unit of a nearby hospital. The nearest hospital in the vicinity of the University is:

National University Hospital (NUH)

Lower Kent Ridge Road

Singapore 119074

Main Line (24hr general enquiries) Tel: (65) 6779 5555

Emergency Tel: (65) 6772 5000

1.2.4 Office of Safety, Health and Environment (OSHE)

A. OSHE

Office of Safety, Health and Environment

Ventus (University Campus Infrastructure)

8 Kent Ridge Drive, #03-02

Singapore 119246

General Enquiries: 6516 1084

Fax: 6778 6031

Email: safety@nus.edu.sg

B. Faculty/ Department Safety and Health Officers/ Coordinators

Contacts for Safety & Health Officers/ Coordinators on safety and health issues pertaining to your faculty are accessible at Office of Safety, Health & Environment

2 CHEMICAL SAFETY PROGRAM ADMINISTRATION

2.1 ROLES AND RESPONSIBILITES

The Institutional Laboratory Safety Committee (ILSC) is the University level committee to oversee the development and implementation of the Chemical Safety Program. The Office of Safety, Health and Environment (OSHE) is the administrator of this Program.

2.1.1 NUS President

The President of NUS represents the University as the Employer. The ultimate responsibility for safety and health in the University rests with the President. The President may delegate the authority and responsibility to the ILSC, Deans, Administrators and Head of Departments (HODs) for the effective supervision of the occupational safety and health of staff and students under his / her management.

The ILSC and OSHE shall report any incident or conditions of non-compliance to the NUS President, Senior Deputy President, Provost, Deputy Presidents and Vice Presidents, who are entitled to partially or fully close the laboratories or facilities until all safety issues are addressed.

2.1.2 NUS Institutional Laboratory Safety Committees (ILSC)

The ILSC is appointed by the Provost. The Terms of Reference for the ILSC are:

- Review NUS Safety and Health Policy and recommend to NUS President in specific action items related to the Chemical & Radiation Safety Program.
- Review Directive, Manual and guidance documents related to chemical & Radiation safety at University, faculty and departmental level and recommend revision to the Director of OSHE.
- Serve in an advisory capacity to OSHE on all chemical related matter.
- Review NUS Chemical & Radiation Safety Program, as well as any audit and inspection findings conducted by OSHE or other independent parties or faculties and departments.
- Continually review of the Chemical & Radiation Safety Program.

2.1.3 Deans and Head of Departments

All Deans, HODs and Directors of the respective departments or research institutes/centres have

management responsibility for the implementation of NUS Safety and Health Policy and Chemical Safety Program. The HOD and Directors, with the assistance of the Departmental Safety Committee or Faculty Safety & Health Officer, is to evaluate the risk assessment of PIs.

Heads & Directors shall appoint Safety Coordinators to have oversight of shared facilities. The coordinators shall ensure the safety management system in the shared facilities including equipment, areas, handling and storage of hazardous materials and waste generated from shared equipment.

2.1.4 Principal Investigator and Supervisor

The Principal Investigators (PIs) and Laboratory Supervisors are primarily responsible to conduct risk assessment for all activities involving chemicals in the laboratory. They are responsible to ensure that all reasonably practicable control measures are implemented and the measures are effective in eliminating or minimizing the risk.

They are also responsible in communicating the chemical hazards involved, the purpose of various control measures implemented and emergency response plan to all chemical users in the laboratory. The PIs and Supervisors are to ensure that their reporting staff and students received adequate instructions on the safe handling of chemicals, undergone the required training, and received the necessary medical examination.

2.1.5 Staff, Students and Contractors

All staff members and students must comply with this University Chemical Safety Manual, as well as other university, faculty and departmental level manual, directive, standard operating procedures (SOPs), standards and guidance documents that are applicable to their area of work. All staff and students are responsible to carry out their work safely.

Supporting staff such as maintenance service personnel (include internal service staff and external contractors engaged for repair and/or maintenance of structure, facilities and equipment), waste collectors and domestic cleaning service providers whose works involve chemicals, are covered under the Chemical Safety Program. They must be informed of the nature of work of the laboratory, and of the health and safety regulations and procedures of the University.

2.1.6 Office of Safety, Health and Environment

The Office of Safety, Health and Environment (OSHE) will provide administrative support to the ILSC, maintain the University Chemical Safety Manual, manage all registration and reporting processes for the ILSC, maintain appropriate records, and serve as liaison with all faculties, departments and external agencies in the ongoing implementation of the University's Chemical Safety Programme.

OSHE will also coordinate the provision of chemical training to relevant staff and students through the NUS Structured Safety Training System (SSTS). OSHE will arrange periodic chemical safety audits and reviews on departments and faculties. OSHE is the university body tasked to coordinate any incident or accident investigations as called for by the ILSC or the President.

2.1.7 University Health Centre (UHC)

NUS Occupational Health Programme is a collaborative effort of the following offices/departments:

1. Office of Safety, Health and Environment (OSHE) is the general administrator of this programme by providing policies, standards and guidelines. The Senior OH Physician will also conduct specialist OH Clinics within UHC to address the medical surveillance, treatment of work-related conditions and fitness to work requirements.

2. University Health Centre (UHC) will provide primary healthcare for work-related incidents and the designated workplace doctors will also conduct specific periodic medical examinations.

2.2 NUS SAFETY AND HEALTH POLICY

The University is committed to ensuring a high standard of safety and health (S&H) and to the prevention of injury and ill health for its staff, students, contractors and visitors1 in association with its research, teaching and service activities at all sites owned, operated or controlled by the University. The roles and responsibilities for NUS staff, students and visitors is described in the University Safety and Health Policy.

2.3 NUS SAFETY DIRECTIVES

The NUS Safety Directives provide safety and health governance on specific issues. Please refer

to the General Safety and Health Directives for further information.

3 APPLICABLE LEGISLATIONS ON HAZARDOUS SUBSTANCES

The following information describes the requirements for all researchers in the NUS undertaking laboratory-based research projects. It is the responsibility of each PI to ensure the laboratory is in compliance. Specific requirements of chemicals on procurement, inventory record, storage, disposal and medical surveillance please refer to Chapter 7 and 10 for more information.

3.1 Workplace Safety and Health Act

The Ministry of Manpower's (MOM) Workplace Safety and Health Act (WSHA) was passed on 1 March 2006. The Act stipulates the workplace safety and health obligations to be fulfilled, as well as responsibilities of every person in the workplace.

The subsidiary legislations that are applicable to NUS include:

- WSH (General Provisions) Regulations
- WSH (Incident Reporting) Regulations
- WSH (First Aid) Regulations
- WSH (Risk Management) Regulations
- WSH (Confined Space) Regulations

With respect to chemical safety, the WSH (General Provisions) Regulations stipulate the provisions for safe handling of hazardous substances, warning labels, safety data sheet, safety precautions to prevent and minimize exposure to toxic dust and fumes, as well as ensuring personnel are not exposed to toxic substances in excess of the permissible exposure levels. Although the above requirements are currently imposed on factory only, NUS has adopted these safe practices in the General Laboratory Safety Program and Chemical Safety Program in anticipation that the WSHA and all its subsidiary legislation will expand to cover all workplaces in 2011.

The WSH (First Aid) Regulations require first aid facilities to be provided where there is exposure to toxic and corrosive substances in the workplace.

Details about the WSHA and the subsidiary legislations are available at the Ministry of Manpower website

3.2 Chemical weapons (Prohibition) act

The Chemical Weapons Convention (CWC), also known as the Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on its destruction, entered into force on 29 April 1997. Singapore ratified this convention in May 1997.

The Singapore Customs, which is the appointed Singapore National Authority for the Chemical Weapons Convention, is the national body responsible for the implementation of the treaty in Singapore. The Chemical Weapons (Prohibition) Act was passed by the Parliament on 25th April 2000 and assented to by the President on 8th May 2000. It was later revised in 31st December 2001.

The chemicals covered under the Chemical Weapons Convention are categorized into 3 schedules.

- Schedule 1 Chemicals
- Schedule 2 Chemicals
- Schedule 3 Chemicals
- Unscheduled Discrete Organic Chemicals (DOCs)

The list of chemicals that falls under the various schedule can be found in the National Authority (Chemical Weapons Convention) website.

The Act requires application of licence to use, develop, produce, acquire, stockpile, retain or transfer specified CWC chemicals.

It also requires declaration of processing, consumption and storage of scheduled chemicals to be made annually to the Singapore Customs. In NUS, OSHE administer the licensing and declaration of CWC chemicals. The purchase, ownership, storage, movement and disposal of CWC chemicals are strictly controlled in NUS.

3.3 FIRE SAFETY (PETROLEUM & FLAMMABLE MATERIALS) REGULATIONS

Chemicals regulated under the Fire Safety (Petroleum & Flammable Materials) Regulations are categorised into three groups: petroleum, flammable materials and mixtures that contain

components of petroleum and / or flammable materials.

a) Petroleum

Petroleum refers to any hydrocarbons (i.e. with only carbon and hydrogen in its molecular structure) with flash point below 93 degree C (199 degree F). This includes crude petroleum, liquefied petroleum gas and other naturally occurring hydrocarbons derived from crude petroleum, coal, shale, peat or other bituminous substances. Petroleum products are further divided into the following classes:

(i) Class 0 – Liquefied Petroleum Gas;

(ii) Class I – flash point < 23 degree C

(iii) Class II – flash point between 23 and 60 degree C

(iv) Class III – flash point above 60 degree C but not above 93 degree C

Class 0, I & II petroleum are regulated by SCDF. For Class III petroleum, diesel is the only licensable product.

b) Flammable Materials

The regulated flammable materials are based on the gazetted list in the Fire Safety (Petroleum and Flammable Materials) Regulations. There are a total of 366 groups of chemicals in the current list. This list of flammable materials is subjected to review periodically – with inclusion of additional flammable materials and / or removal of certain flammable materials in the list. The complete list of licensable products can be found in Guidebook on Application for Petroleum & Flammable Material

c) Mixtures

Any mixture that contains a component of petroleum and / or flammable materials and has a flash point of 60 degree C (141 degree F) or less is regulated by SCDF.

Flammable liquid are classified into the following categories:

(i) Category 1 – flash point < 23 degree C, boiling Point ≤ 35 degree C;

(ii) Category 2 – flash point < 23 degree C, boiling Point > 35 degree C;

(iii) Category 3 – flash point 23 - 60 degree C

(iv) Category 4 – flash point 61 - 150 degree C

In summary, petroleum & mixtures products are regulated according to its flash point (criteria-based schedule) while the flammable materials are from a list-based schedule. In NUS, a more stringent approach is adopted for the storage of flammable liquids in laboratories. All flammable liquids shall be classified as Category I. See ***Appendix A*** for the requirements and calculations for the maximum allowable quantity (MAQ) of PFM in laboratory. For more information, refer Revised Limits For Petroleum & Flammable Materials Storage in NUS

Application of licence to Singapore Civil Defence Force (SCDF) is required for the import, transport and storage of petroleum and flammable materials (PFM). Currently, the storage licence is held at the University level and administered by OSHE. Annual declaration to OSHE will be required to ensure PFM stored are within the maximum allowable quantities (MAQ) in the laboratories.

3.4 POISONS ACT

The Poisons Act regulates the importation, possession and sales of potent medicinal substances (poison) so as to prevent misuse/ illicit diversion of poisons. To obtain the list of poisons, please refer to Poisons Act (Page No.9)

The Form A Poison Licence from the Health Science Authority (HSA) is required for the purpose of import, possess for sale, sell or offer for sale any poisons. The user of the imported poisons shall be the licence holder. However, Poison Licence shall not be required if the poisons are purchased from local vendors.

3.5 ENVIRONMENTAL PROTECTION AND MANAGEMENT ACT

The Environmental Protection and Management Act (EPMA) regulates premises with hazardous installations and stipulates pollution control requirements for air, water, land, hazardous substances and noise.

With respect to chemical safety, two subsidiary regulations are applicable to NUS:

- EPM (Hazardous Substances) Regulations
- EPM (Ozone Depleting Substances) Regulations

The EPM (Hazardous Substances) Regulations require application for a Hazardous Substance Permit from the National Environment Agency (NEA) to purchase, store and/or use scheduled hazardous substances (refer to Management of Hazardous Substances for more information). The permit holder shall keep a record of the quantity of such substances stored and it can only be used for the intended purpose as stated in the permit. All personnel handling the hazardous substance shall receive adequate training to enable them to understand the nature of the danger, to handle the substances in a manner not threatening the safety and health of any person or to cause environmental pollution, as well as the emergency action plan in the event of spillage and leakage.

The EPM (Ozone Depleting Substances) Regulations prohibit the importation from and exportation of ozone depleting substances (ODS) to certain countries. In Singapore, NEA has adopted a multi-pronged approach to reduce and eventually phase out the consumption of ODS. To protect the environment, everyone in NUS are strongly encouraged not to use ODS for laboratory experiments.

Please refer to Environmental Protection and Management Act for more information.

3.6 ARMS AND EXPLOSIVES ACT

Under the Arms and Explosives Act, application of licence from the Singapore Police Force (SPF) is required for the possession, control, import, export and manufacture or dealing with gun, arms, explosives, poisonous or noxious gas or substances, and these include explosive precursors (EP).

Please refer to Arms & Explosives Licence for more details on application for licence and for the list of EP.

3.7 MISUSE OF DRUGS ACT

The Misuse of Drugs Act controls the manufacture, supply and possession of precursor chemicals necessary in the manufacture of controlled drugs as well as provides regulations on the import, export and transhipment of these chemicals. Under the Misuse of Drugs (Controlled Equipment, Material and Substances) Regulations, application of permit from the Central

Narcotic Bureau (CNB) is required for the import or export of controlled drugs, and controlled equipment, materials or substances useful for manufacturing controlled drugs. Licence from Health Science Authority is required for importation of controlled drugs listed under First and Second Schedule.

For more information on the list of controlled substances, please refer to Misuse of Drugs Act

3.8 ENVIRONMENTAL PUBLIC HEALTH ACT

The Environmental Public Health Act (EPHA) regulates the removal of waste and disposal facilities, food establishments, sanitary conveniences, swimming pools and others matter concerning environmental public health.

With respect to chemical safety, two subsidiary regulations are applicable to NUS:

- EPH (General Waste Collection) Regulations
- EPH (Toxic Industrial Waste) Regulations

The Regulations specify that only licensed waste collectors are allowed to collect or transport general wastes and toxic industrial wastes (TIW).List of TIW collectors/ PVC Waste Collectors can be found in National Environment Agency website.

The EPH (Toxic Industrial Waste) Regulations also require generators of TIW to maintain an up-to-date register, to store TIW in appropriate container and storage location, and to have emergency action plan(s) for spillage, leakage or other accidents. The Regulations require that both the waste collectors and employees are given adequate information and instruction to handle the TIW properly and safely.

3.9 SEWERAGE & DRAINAGE ACT

The Sewerage & Drainage Act (SDA) regulates the discharge of waste water into public sewer.

With respect to waste water discharge, one subsidiary regulation is applicable to NUS:

- Sewerage and Drainage (Trade Effluent) Regulations

Please refer to Requirements for Discharge of Trade Effluent into the Public Sewers for more

information on allowable limits for trade effluent discharge into the public sewer.

4 RISK MANAGEMENT

The principle of risk management is to identify the safety and health hazards associated with works involving the handling of chemicals, assessing the risk levels, prioritizing and implement measures to control the hazards and reduce the risks to acceptable level.

As part of the risk management, adequate and effective control measures are necessary to control the hazards identified during the risk assessment and reduce the risks to an acceptable level. Implementation of control measures will reduce the likelihood of occurrence of the adverse consequences but the severity of the potential injury will remain unchanged during risk assessment evaluation.

When determining the type of control measures, one should always consider the Hierarchy of Control:

a. Elimination
b. Substitution
c. Engineering control
d. Administrative control and lastly
e. Personal Protective Equipment (PPE)

Elimination of potential hazards will be given the first priority while PPE will be the last resort in all control measures implemented in laboratories. In most instances, a combination of controls is required to manage the risk effectively.

4.1 CLASSIFICATION AND LABELLING OF CHEMICALS

Singapore adopts the *United Nations Recommendations on the Transport of Dangerous Goods* (or commonly known as the "*Orange Book*") and the *United Nations Globally Harmonised System of Classification and Labelling of Chemicals* (GHS) (or "*Purple Book*"). The adaptations of both international guidelines in local context are summarized in *SS 586 Specification for Hazard Communication for Hazardous Chemicals and Dangerous Goods*.

In general, chemical hazards are differentiated into three building blocks:

- Physical hazard building block;
- Health hazard building block and

- Environmental hazard building block

Within each building block, there are one or more hazard classes and each hazard class may be sub-divided into different hazard categories.

To identify the hazard class or hazard category of a chemical, always refer to the label affixed to the packaging/container. The label should include the following information to aid users in understanding the hazards and safety and health risks involved:

- Product identifier, i.e. identify of the chemical
- Pictogram
- Signal words such as 'Danger' or 'Warning', indicating the relative hazard severity and alert readers to a potential hazard
- Hazard statement(s), describing the nature as well as the degree of hazard of a chemical
- Precautionary statement(s), describing the recommended measures that should be taken to minimise or prevent adverse effects resulting from exposure or improper storage or handling of a hazardous chemical
- Supplier information
- Supplementary information

In addition to label, the safety data sheet (SDS) which accompanies each chemical is also an important and useful reference document (see Chapter 6, 6.3.2 for more information)

4.1.1 Physical Hazards

There are 16 hazard classes under the physical hazard building blocks, i.e.:

1. Explosives
2. Flammable gases
3. Flammable aerosols
4. Oxidising gases
5. Gases under pressure*
6. Flammable liquids
7. Flammable solids
8. Self-reactive substances and mixtures
9. Pyrophoric liquids

10. Pyrophoric solids
11. Self-heating substances and mixtures
12. Substances and mixtures which, in contact with water, emits flammable gases
13. Oxidising liquids
14. Oxidising solids
15. Organic peroxides
16. Corrosive to metals

* The hazard categories under this hazard class include compressed gas, liquefied gas, refrigerated liquefied gas and dissolved gas.

4.1.2 Health Hazards

There are 10 hazard classes under the health hazard building blocks, i.e.:

1. Acute toxicity
2. Skin corrosion/ irritation
3. Serious eye damage/ eye irritation
4. Respiratory or skin sensitization
5. Germ cell mutagenicity
6. Carcinogenicity
7. Reproductive toxicity
8. Specific target organ toxicity (single exposure)
9. Specific target organ toxicity (repeated exposure)
10. Aspiration hazard

4.1.3 Environmental Hazards

There are two hazard classes under the environmental hazard building blocks, i.e.:

1. Hazardous to the aquatic environment – acute toxicity
2. Hazardous to the aquatic environment – chronic toxicity

4.1.4 Pictograms

Pictograms convey physical, health or environmental hazard that is assigned to a GHS hazard class and category. Table 4.1 shows the nine GHS pictograms:

Table 4.1 GHS Pictograms

Flame	Flame over circle	Exploding bomb
 ♦ Emits flammable gas ♦ Flammables ♦ Self-heating ♦ Self-reactives ♦ Organic peroxide ♦ Pyrophorics	 ♦ Oxidisers	 ♦ Explosives ♦ Organic peroxide ♦ Self-reactives
Corrosion	**Skull and crossbones**	**Gas cylinder**
 ♦ Corrosives	 ♦ Acute toxicity (severe)	 ♦ Gases under pressure
Health	**Environment**	**Exclamation mark**
 ♦ Aspiration toxicity ♦ Carcinogenicity ♦ Germ cell mutagenicity ♦ Target organ toxicity ♦ Respiratory sensitiser ♦ Reproductive toxicity	 ♦ Environmental toxicity	 ♦ Acute toxicity (harmful) ♦ Irritant ♦ Narcotic effects ♦ Respiratory tract irritation ♦ Skin sensitiser

Source: SS 586 Part 2

4.2 RISK ASSESSMENT

Where applicable, the risk assessment should include but not limited to the following:

- transfer and transport of chemicals (from one location to another)
- use of chemicals (e.g. dispensing, transferring, using and disposing)
- storage of chemicals
- disposal of spent chemicals and chemical wastes

Given that chemical substances exist as solid, liquid or gas and may change between these phases of matter with variation in temperature or pressure, there may be multiple hazards associated to one chemical.

Besides, chemicals can enter the human body in different ways depending on the routes of exposure: inhalation/ breathing, ingestion, eye contact and skin absorption. Hence, the risk level may vary from one exposure pathway to another.

While safety hazards such as eye injury, burn and asphyxiation may be immediate and more apparent to most chemical users, health hazards such as lead poisoning, silicosis and cancer-causing should also be given due consideration in the risk assessment.

4.2.1 Project Risk Assessment Scheme

All Principal Investigators (PIs) are responsible to conduct project risk assessment (PRA) prior to the commencement of research projects. PIs shall commence work only when their risk assessment has been approved by ILSC or IBC after OSHE has assessed the PRA.

Refer to Project Risk Assessment Scheme for the detailed risk assessment methodology, and submission and approval procedure

The Project Risk Assessment will be gradually phased out and replaced by the Laboratory OSH Certification Scheme as stated in the section below.

4.2.2 Laboratory Safety & Health Management System Certification Scheme

The Laboratory Safety & Health Management System (SHMS) Certification Scheme was launched to certify PIs who have effectively implemented laboratory-based safety and health management system. Upon award of the certification to NUS Occupational Safety and Health Management System Standard for Laboratories, PIs will not be required to submit risk assessments on a per-project basis except for animal related work research project.

All academic staff having supervisory oversight of laboratory based activities (research and/or teaching) would need to be certified to the NUS Laboratory Occupational Safety and Health Management Standard by 31 December 2011.

Prior to embarking on the scheme, the PI shall establish a safety and health management system at laboratory level according to the NUS Occupational Safety and Health (OSH) Management System Standard. The standard is an adaptation of the Occupational Health and Safety Assessment Series (OHSAS) 18001:2007 and OHSAS 18002:2000 specifications. The PI shall implement, maintain and continually improve his or her lab-based OSH Management System in a documented manner in accordance with the requirements detailed in the standard.

The PI shall submit the necessary information pertaining to his or her OSH management system to OSHE. After reviewing the information, OSHE will arrange an audit programme with the PI. The audit team will consist of OSHE staff, faculty safety and health officers and external consultants/specialists (if necessary). The audit programme will consists of an opening meeting, document review, site visit and a closing meeting.

During the audit, audit team may raise the following types of findings to the PIs:

- Areas for improvement (AFIs) – these are SOPs, practices or elements of the OSH management system that would need improvement.
- Category A findings - these are critical deficiencies in the OSH management
- system that might result in accidents or incidents in the laboratories
- Category B findings – these are notable non compliances in terms of legal compliance or not complying with University Policies or Standard Operating Procedures

For findings that are non-compliance (Cat A & B findings), PI shall take corrective actions to

address these non-compliances. Subsequent surveillance audit shall be scheduled to verify implementation of corrective actions by the Faculty Safety & Health Officer. Based on the subsequent surveillance audit, the lead auditor in OSHE would determine if the PI should be issued with the OSH certificate and the accompanying conditions (if any). The OSH certificate is valid for four years with effect from the issued date.

The PI would be subjected to an annual surveillance audit to ensure the sustainability of the PI's OSH management system. The scope of surveillance audit includes Management of Change, Maintenance of Laboratory OSH system and Legal Compliances. Please refer to Laboratory SHMS Certification Scheme for more information.

5 TRAINING

Under the Structured Safety Training System (SSTS), it is mandatory for all staff and students to complete OSHE IVLE chemical safety training prior to working with hazardous chemicals. OSHE also provides other training courses for general laboratory safety, fire safety, biological safety, radiation safety and others. Please refer to Structured Safety Training System for more information.

Notwithstanding the mandatory training, it is the responsibility of the PI and Laboratory Supervisor to ensure that his/her laboratory staff and research students receive adequate instruction and training in managing chemicals specific to his/her laboratory and the safe conduct of the experimental procedure to be adhere at all times.

Please log on to the OSHE portal for the safety videos related to Chemical Safety.

The PI and Laboratory Supervisor shall identify training needs for his or her laboratory staff, research students (including graduate, undergraduate and attachment students), visitors and any other personnel working under his or her supervision. Please refer to the directive on Supervisory & Training Responsibilities for New Users of Laboratories Managed by Academic Staff (Principal Investigators & Laboratory Supervisors) for more information.

It is important that any new laboratory user is subjected to an induction programme prior to commencing their laboratory activities. The induction programme should include but not limited to briefing on safety & health, risk assessment training, personal protective equipment, emergencies & accidents reporting.

A typical example of a Safety and Health Induction Checklist for laboratory users is available at OSHE website.

The minimum training requirements for all personnel working with chemical substances to work in laboratory are laboratory specific safety briefing and department or faculty safety induction. All lab users shall also fulfill departmental unique requirements prior to the commencement of any activities in the laboratory.

Basic training requirements for all personnel working with chemical substances should be trained in the following areas prior to the start of their experiment:

- Understanding of NUS Laboratory Chemical Safety Manual
- Experimental procedures to be carried out
- Understanding of the chemical hazards in the laboratory
- Safe transport, transfer, use and storage of chemicals
- Safe disposal of chemical wastes
- Safe handling of tools
- Standard operating procedure (SOP) of laboratory's equipment
- Emergency response procedures (e.g. chemical spill, gas leak, fire)
- Understanding of other hazards (e.g. noise, biological agent, moving objects) in the laboratory and the precautionary measures to be taken

6 OPERATIONAL CONTROL

6.1 ELIMINATION & SUBSTITUTION

The most effective way of keeping hazards at bay is to eliminate the use of the toxic chemical totally or substitute it with a less toxic chemical, which will not compromise the work to be carried out.

However, it may *not* be advisable to substitute a toxic but non-flammable solvent with a less toxic but flammable compound and vice versa.

The general principles for substitution of chemicals are:

- Volatile solvents with low boiling points and high vapour pressures should be substituted with solvents having higher boiling points and lower vapour pressures.

- Toxic substances with low permissible exposure levels should be substituted with less toxic substances having higher permissible exposure levels, taking into account the effect and target organ that will be affected.

- Liquids with low flash points should, as far as possible, be substituted with liquids having higher flash points or no flash point to minimise or prevent potential fire hazards.

- Materials in fine powder should be substituted with substances in granular, pellet or other bulk solid forms to reduce or prevent potential inhalation hazards.

- Chemicals in liquid form should be substituted with chemicals in paste, gelatinous or other viscous liquid to reduce potential exposure hazards.

6.2 ENGINEERING CONTROL

Engineering controls can be implemented in the form of:

- automation of the process,
- isolating the hazard from the target(s) (including both the user and person in the vicinity) by means of:
    - distance,
    - physical barriers (e.g. guarding, shield, chemical storage cabinet), or
    - containment equipment (e.g. secondary containment, fume hood, exhaust ventilation system).

6.3 ADMINISTRATIVE CONTROL

Administrative controls are work procedures such as safety policies, safety rules and regulations, supervision, standard operating procedures (SOP) and training. (Refer to Chapter 7 for the SOPs.)

Signs and warning notices shall be placed at all entrances to the laboratory, and at appropriate locations where hazardous chemicals are used or present. These include the storage cabinet, storage shelve, chemical bath/ tank, refrigerator, cold room and etc. Please refer to Laboratory Sign Posting and Labelling for more information.

6.3.1 Labelling

All chemical users are required to implement GHS by complying with SS 586 (see Chapter 4, 4.1) by end 2011 for single substances.

All containers, packaging and cylinders containing chemicals (solid, liquid or gas) shall be labelled. The label must be clear, legible and written in English. It must be affixed firmly on the container at all times, and be able to withstand the expected environment it is exposed to.

Please log on to the OSHE portal for the safety video related to “Hazmat labelling”.

As a minimum, the label must contain the following information:

a) Name of hazardous substances
b) Chemical formula/ composition (if relevant)
c) Chemical hazard pictograms/ symbol (see Chapter 4, 4.1 of this Manual)
d) Date of purchase
e) Date of first opening (especially important for peroxide-forming chemicals)
f) Date of preparation (e.g. for solutions)
g) Activity level and date of measurement (for radioisotopes)

6.3.2 Safety Data Sheet

The Safety Data Sheet (SDS) is an important part of chemical safety management. It is a critical piece of document in hazard communication programme. There are 16 elements in a SDS as stated in Part 3 of SS 586. It provides the following information for the users of the chemical:

a) Identification
b) Hazards identification
c) Composition/information on ingredients
d) First-aid measures
e) Fire-fighting measures
f) Accidental release measures
g) Handling and storage
h) Exposure controls/personal protection
i) Physical and chemical properties
j) Stability and reactivity
k) Toxicological information
l) Ecological information
m) Disposal considerations
n) Transport information
o) Regulatory information
p) Other information

The PI shall appoint a person to be responsible for compiling and maintaining the SDS in the laboratory. The appointed person shall ensure that each chemical purchased from the supplier is accompanied by a SDS (in hard or soft copy). For all the regulated chemicals, a copy of the SDS (ie. hard or soft copy) shall be made accessible and available in the laboratory.

The appointed person shall check that the SDS is complete (no missing pages or sections), the information is accurate (check on information such as boiling point, flash point and etc), product name found in the SDS is consistent with the product label, the supplier information is correct and the SDS is current (check the issue date of the SDS).

Chemical suppliers are required to review the information and if necessary re-issue an SDS when there is any change in the SDS. Such review should not be longer than five years from the last date of issuing an SDS. Hence, it is recommended that all SDS used in the laboratory are reviewed and updated, where necessary, once every 5 years.

The PI shall ensure that all chemical users have access to the SDS. It is the responsibility of all users to read and understand the SDS before they begin working with chemicals.

Please log on to the OSHE portal for the safety video related to Material Safety Data Sheet.

6.4 PERSONAL PROTECTIVE EQUIPMENT (PPE)

The use of PPE is necessary when feasible engineering and administrative controls are unavailable or when there is a need to supplement those controls. PPE should *NEVER* be considered as a first priority in minimising chemical exposure.

PPE should be properly selected, correctly used or comfortably fitted and regularly maintained to ensure effective protection. A suitable PPE programme should be implemented taking the preceding elements (i.e. selection, issue, fitting and maintenance) into consideration.

Personnel handling both chemicals and chemical wastes are required to put on adequate PPE like gloves and respirator to protect themselves from potential skin contact and inhalation of chemical vapours respectively.

Please log on to the OSHE portal for the safety video related to “PPE and Respiratory Protection”.

6.4.1 General Requirement

PI and Laboratory Supervisor shall ensure that all PPE users are trained on the proper use and maintenance of PPE. They should be aware of the PPE requirements like, how it protects the user and the extent of the protection, how to don–on properly, and removal of the PPE. Maintenance of PPE may include periodic inspection to check for any wear and tear, cleaning and disinfecting, and proper storage to prevent cross contamination. It is strongly recommended that no PPE outside laboratory areas to avoid contamination to the public, unless stated in Chapter 7, 7.7.1.

6.4.2 Eye and Face Protection

For all laboratories where corrosive, infectious or injurious materials are handled,

a) The Principal Investigator (PI) or laboratory supervisor shall determine the nature of eye and/or face protection that shall be worn by all personnel (including all researchers, contactors, cleaners, and visitors) working in or visiting the laboratory.
b) The nature of eye and/or face protection shall be determined through the risk assessment conducted by the PI or laboratory supervisor.
c) For research laboratories, when conducting the risk assessment, the PI shall use the criteria listed in the following table below. The safety eyewear shall comply with the American National Standards Institute (ANSI) standard Z87.1 or other equivalent standards for impact resistance.

Table 6.1 Eye and Face Protection

	Safety Glasses (Low Risk Activities)	**Safety Goggles** (Medium Risk Activities)	**Face Shield + Safety glasses/goggles** (High Risk Activities)
1	The minimum requirement when in research laboratories where corrosive, infectious and injurious materials are handled.	Required when: Working with materials[1] that have a medium hazard rating[2] (corrosive, injurious, infectious, etc) and a *moderate* splash probability exists.	Required when: Working with materials[1] that have a medium or high hazard rating[2] (corrosive, injurious, infectious, etc) and a *high* splash probability exists.
2	Examples: • Opening centrifuge tubes containing corrosive/injurious/infectious materials	Examples: • Mixing or pouring of corrosive/injurious materials out from stock bottle on the benchtop	Examples: • Conducting a reaction involving corrosive/injurious/infectious materials under pressure

			• Mixing or pouring of fuming chemicals that are highly corrosive/injurious
3	**Information on Safety Glasses**  Safety glasses are similar to normal glasses but have lenses that are impact resistant and frames that are much stronger. However, they do not provide adequate protection from significant chemical splashes.	**Information on Safety Goggles**  Like safety glasses, goggles are impact resistant. Safety goggles offer greater protection to the eye than safety glasses against chemical splashes. Safety goggles with indirect ventilation will prevent substances from draining into the eye. Some may be worn over prescription glasses. They are suitable when working with corrosive or injurious materials and a splash probability exists.	**Information on Face Shield**  Face shields provides splash protection to the wearer's entire face. They are suitable when working with corrosive or injurious materials and a high splash probability exists. Face shields should be worn with safety goggles.

[1] Materials refer to chemicals and biological agents.
[2] Refer to the relevant SDS for information on the hazard(s) posed by the material being handled.

The following table shows the effectiveness of protection against splashes offered by various type of eyewear.

Table 6.2 Effectiveness of Protection of Various Types of Eyewear

Illustrations on effectiveness of protection	Remarks
 	Prescription glasses does not protect the eyes from splashes

 	Safety glasses does not protect the eyes adequately from large splashes
 	Safety goggles offer full protection to the eyes from splashes. But not the
Illustrations above are stills from American Chemical Society Video on Safety in the Academic Chemistry Laboratory: Eye Protection. Used with permission from Safety in the Academic Laboratory: Eye Protection (www.acs.org/safety), Copyright 2009, American Chemical Society. Not to be used for commercial purposes.	

6.4.3 Respiratory Protection

Put on a respirator when exposure to hazardous air contaminants in concentrations that exceed the permissible exposure levels (PELs) is expected/ suspected (e.g. during normal operation when high concentration of toxic fumes is emitted, during emergency or large spill cleaning exercise).

Selection of respiratory protection should depend on the chemical classifications and concentration of chemicals, the protection factors provided by the manufacturer of the respirator, types of respirator, medical condition of the user and work environment. All respirator users shall undergo a fit test and medical examination conducted by OSHE Occupational Health Physician before they start to use the respirator and the fit test certificates should be kept. Workers should also conduct fit checks (positive or negative pressure fit checks) on their respirators before using them. Please refer to NUS Respiratory Protection Programme

6.4.4 Hand Protection

Selection of gloves shall depend on the type of chemicals, concentrations and temperature of the chemicals, frequency and duration of use, nature of contact (e.g. total immersion or to protect splash only), expose area of the arm to be protected (hand or forearm), requirements for grip, dexterity, puncture/ cut resistance, the need for cuff edge and size of the glove .

Use impervious gloves to prevent liquid penetration and the user shall identify the type of chemical handled and select a compatible glove. Use leather or thermally insulated gloves for handling cold materials and cryogenic liquids (e.g. liquid nitrogen). When handling cryogenic liquids (e.g. liquid nitrogen), the gloves should be impervious and sufficiently large to be readily removed should a cryogen be spilled. Watches, rings, and other jewelleries shall be removed before the user puts on the glove. .

Glove Chart (see Table 6.1) provides the functions of different types of glove materials. With reference to the use of compatible glove against the types of chemicals used, please refer to ***Appendix B*** for more information.

Table 6.1 Glove Chart

Type	Advantages	Disadvantages	Use Against
Natural Rubber	Low cost, good physical properties, dexterity	Poor for handling of oils, greases, organics; May be of poor quality	Bases, alcohols, dilute water solutions; Provide only fair protection for aldehydes, ketones
Natural Rubber Blends	Low cost, dexterity, better chemical resistance compared to natural rubber	Physical properties inferior to that of natural rubber	Same as natural rubber

Polyvinyl Chloride (PVC)	Low cost, very good physical properties, medium cost, medium chemical resistance	Plasticizers can be stripped; May be of poor quality	Strong acids and bases, salts, other water solutions, alcohols
Neoprene	Medium cost, medium chemical resistance, medium physical properties	NA	Oxidizing acids, anilines, phenol, glycol ethers
Nitrile	Low cost, excellent physical properties, dexterity	Offer poor protection against benzene, methylene chloride, trichloroethylene and many ketones	Oils, grease, aliphatic chemicals, xylene, perchloroethylene, trichloroethane; Provide only fair protection against toluene
Butyl	Specialty gloves, good against polar organics	Expensive, offer poor protection against hydrocarbons and chlorinated solvents	Glycol ethers, ketones, esters
Polyvinyl Alcohol (PVA)	Specialty glove, able to resist a broad range of organics, good	Very expensive, water sensitive; Offer poor protection against	Aliphatics, aromatics, chlorinated solvents, ketones

	physical properties	light alcohols	(except acetone), esters, ethers
Fluoro-Elastomer	Specialty glove, organic solvents	Extremely expensive, poor physical properties, offer poor protection	Aromatics, chlorinated solvents, aliphatics, alcohols
Norfoil (Silver Shield)	Excellent chemical resistance	Poor fit, easily punctures, poor grip, stiff	Use for hazmat work

Source: Ministry of Manpower (MOM), Guidelines on Prevention and control of Chemical Hazard (Page No.82)

6.4.5 Body Protection

Wear laboratory coat to protect against chemical splash on street clothing and other exposed areas like forearms. Refer to Appendix M for the guidelines on the selection of laboratory coat.

Unprotected body parts shall not come in contact with vessels or pipes that contain cryogenic liquid because extremely cold material may bond firmly to the skin and tear the flesh if separation is attempted. To provide adequate bodily protection, wear an impervious apron / coat and use tongs or compatible glove to handle objects that are in contact with cryogenic liquid. Short pants, dresses and open toed shoes are inappropriate laboratory attire.

6.4.6 Foot Protection

Wear closed-toe shoes and ensure the foot of the pants is placed over the shoe/ boot tops to prevent shoes filling in the event of a cryonic liquid spillage.

7 STANDARD OPERATING PROCEDURES

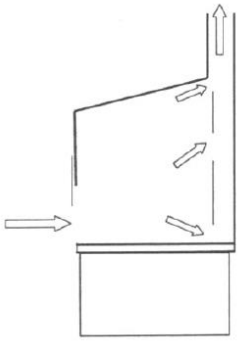
All chemical users shall adhere to all relevant Standard Operating Procedures (SOP) described in this section. There is frequent -chemical interaction in a research and teaching laboratory environment and it is paramount for all staff and students to practice safe chemical handling procedures, for their personal safety and health the co-workers and others in the vicinity. The PI and Laboratory Supervisor shall ensure that all his/her staff and students are trained on these SOPs.

7.1 OPERATION OF FUME HOOD

One of the most common containment equipment in laboratory is the fume hood. The fume hood protects the worker from chemical exposure and keeps toxic / irritant vapour out of general working area in the laboratory. The Director/HOD/PI has overall responsibility for ensuing a system is established for the safe use of the fume hood. Hence, it is the responsibility of all users to understand the correct operation and maintenance of the fume hood.

A fume hood is essentially a ventilated box with an adjustable work opening. It is designed to extract air through the front opening. The flow is to be even and non-turbulent through the open face of the hood. The air exits through a stack that exhausts to the scrubber system in the building, thus removing any vapours / fumes produced within the box and away from the worker.

Figure 7.1 Chemical Fume Hood

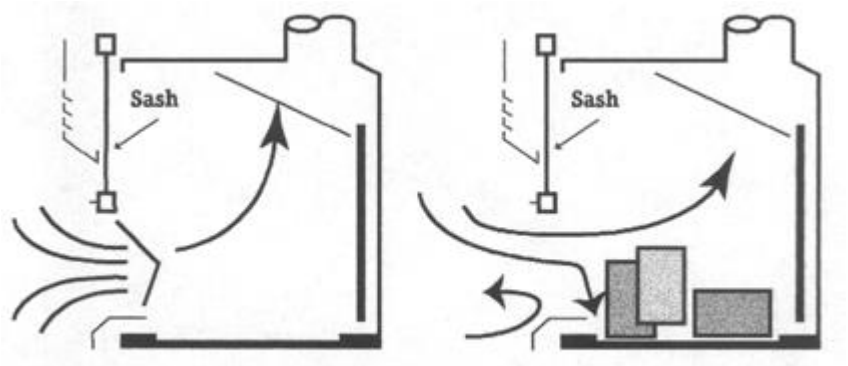


Please log on to the OSHE portal for the safety video related to “Laboratory Hoods”.

7.1.1 Preparation & Material Placement

1. Read the SDS for materials being used in a fume hood. Note and observe any precautions regarding the use of the chemical in a fume hood.
2. Always consult the manufacturer before commissioning work involving the use of radioactive chemicals/isotopes in the fume hood.
3. Do NOT use electrical-spark producing equipment in the fume hood with flammable chemicals.
4. Check the certification label affixed on the fume hood and ensures that the fume hood has been inspected in the past 12 months by a qualified technician.
5. Turn on the fluorescent light and cabinet fan 5 minutes before work begins.
6. Confirm inward air flow by holding a tissue at the middle of the edge of the viewing panel and ensuring it is drawn in.
7. Test the alarm if the cabinet is equipped with such device.
8. Place equipment at least 16 cm inside the fume hood and ensure there is a 3 – 6 cm air gap around any large bulky equipment in the hood.
9. Keep the working area of the fume hood clear of clutter and waste materials. Fume hood is *NOT to be used as* storage cabinet as it will reduce air flow and compromise fume hood extraction efficiency (see Figure 7.2).
10. Do *NOT* store items at the back of the working area in the fume hood. This is of particular relevance where a Perspex screen or lead bricks are used for radioisotope work.
11. Do *NOT* dispose waste chemicals via the fume hood sink as it is used mainly for rinsing and supply purposes.

Fi*gur*e 7.2 Airflow Patterns through Empty & Cluttered Fume Hoods



Demonstration of Airflow Patterns through empty & cluttered fume hoods.

7.1.2 Operation

1. Ensure adequate PPE is worn (e.g. Eye and face protection, lab apron or coat). The types of PPE required would depend on the findings obtained from the risk assessment.
2. Fume hood users shall attend appropriate training on the safe use of the fume hood.
3. Active work shall flow from clean to contaminated areas across the work surface.
4. Open the sash slowly and only when required. It will be open only as much as needed, in order to maintain effective capture of chemical fumes and to act as a safety shield to the worker.
5. Do *NOT* put your face inside the plane of the sash when airborne contaminants are being produced.
6. Keep traffic near the fume hood to a minimum to prevent unnecessary turbulence of the air intake.
7. Do *NOT* leave a reaction unobserved for an extended period of time. If equipment or chemicals are to be kept in the hood longer than 8 hours, all hazardous materials must be clearly and accurately labelled. Information such as the name and contact number of the person conducting the experiment, name of the experiment, and the potential hazard of the experiment must be posted on the sash.
8. Promptly clean up any chemical spills according to the requirements stipulated in the SDS.

7.1.3 Completion

1. At the end of the experiment, decontaminate the fume hood surfaces and equipment, if necessary.
2. Return equipment and chemical bottles to their respective storage cabinets.
3. Keep the sash fully closed when the fume hood is not in use.

7.1.4 Certification

1. The fume hood shall be subjected to a yearly certification by a competent/qualified professional to an international standard such as “ANSI/ASHRAE 110-1995 Method of Testing Performance of Laboratory Fume Hoods” or the “AS/NZS2243.8:2006 Safety in Laboratories - Fume Cupboards”.
2. The PI/ Laboratory Supervisor shall arrange for the yearly safety certification and

keep a copy of the certification report for verification purpose.

3. A label indicating the date of certification, the date of the next certification, to what standard test was performed, and the name of the certifier shall be affixed to the exterior of the fume hood. This label shall be provided by the certification provider of the fume hood.
4. Re-certification is required whenever the fume hood is repaired or relocated.

7.1.5 Inspection & Maintenance

1. The PI/ Supervisor shall periodically inspect the fume hood to ensure its operational performance and observe any unsafe practices by the users.
2. All users shall report any defects or breakdowns of the fume hood to their PI/ Supervisor.
3. Prohibit the use of faulty fume hood by proper identification like labelling the hood “out of service” or any other means.
4. All repairs to the fume hood shall be done a qualified technician. Any malfunction in the operation of the fume hood shall be reported and repaired before the fume hood is used again.

7.2 SAFE HANDLING AND STORAGE OF PERCHLORIC ACID

Perchloric acid is a strong mineral acid commonly used as a laboratory reagent. In addition to being a corrosive liquid, while not combustible, under some circumstances perchloric acid may act as an oxidizer and/or present an explosion hazard. Organic materials are especially susceptible to spontaneous combustion if mixed or contacted with perchloric acid. Under some circumstances, perchloric acid vapours form perchlorates in duct work, which are shock sensitive.

The following sections present information on the safe handling and storage of perchloric acid:

7.2.1 Handling Procedure

A. ≤ 72% Perchloric Acid at Room Temperature

At room temperature, perchloric acid up to concentrations of 72% has properties similar to other strong mineral acids. It is a highly corrosive substance and causes severe burns on contact with the eyes, skin, and mucous membranes. When used under these conditions, perchloric acid reacts as a strong non-oxidizing acid. The following precautions should be taken when using perchloric acid under these conditions:

1. May be conducted in a general purpose fume hood if small quantities are used in an infrequent basis. If operations are conducted frequently or in large quantities Perchloric acid digestions should be done in a perchloric acid fume hood equipped with a **water wash-down system.** The wash-down system should be turned on immediately after perchloric acid has been heated in the hood.

2. Easily accessible areas in the fume hood, which are exposed to perchloric acid, are immediately wet wiped or rinsed with a squirt bottle of distilled water after use.

3. Periodic methylene blue tests should be conducted after each perchloric acid use for the presence of any perchlorates.

4. Substitute with less hazardous chemicals when appropriate. Use dilute solutions (<60%) whenever possible.

5. Always use impact-resistant chemical goggles, a face shield, neoprene gloves, and a rubber apron when handling perchloric acid.

6. When using or storing even dilute perchloric acid solutions avoid contact with strong dehydrating agents (concentrated sulphuric acid, anhydrous phosphorous pentoxide, etc.). These chemicals may concentrate the perchloric acid and make it unstable.

7. Always transfer perchloric acid over suitable containment in order to catch any spills and afford a ready means of cleanup and disposal.

8. Perform all operations on chemically resistant surfaces. Avoid contact with cellulose materials such as wood, paper and cotton, which could result in a fire or explosion.

B. ≤72% Perchloric Acid Heated

When heated to temperatures above 150°C perchloric acid becomes a strong oxidizer and eventually becomes unstable. Vapours may also contaminate work surfaces or ventilation equipment with perchlorate residues, which may form highly unstable compounds, such as metallic perchlorates. These compounds may ignite or detonate under certain conditions. The following precautions should be followed when heating perchloric acid:

1. Perchloric acid digestions should be done in a perchloric acid fume hood equipped with a **water wash-down system.** The wash-down system should be turned on immediately after perchloric acid has been heated in the hood.

2. Perchloric acid fume hoods should have shatterproof glass.

3. Never heat perchloric acid in an oil bath or with an open flame. Electric hot plates, electrically or steam-heated sand baths, heating mantles, or steam baths are preferred. Use explosion-proof electrical equipment.

4. Avoid allowing hot perchloric acid to come into contact with any organic materials, including paper or wood, because a fire or explosion can occur. Avoid storing these materials in perchloric acid work hoods. Avoid using greases or hoses that are incompatible with perchloric acid.

5. Be sure you understand the reaction(s) that can occur when using perchloric acid. Perchloric acid may react violently with many chemicals, including acetic anhydride, alcohol, reducing agents, and many metals.

6. In wet digestions with perchloric acid, treat the sample first with nitric acid to destroy easily oxidizable matter.

7. Do not distill perchloric acid in a vacuum. Unstable anhydride may be formed and cause a spontaneous explosion.

8. Wash down perchloric acid hoods after each use

C. Anhydrous Perchloric Acid

Anhydrous perchloric acid (> 85% concentration) is very unstable and will usually explode when it comes in contact with organic materials. Follow these precautions when working with anhydrous perchloric acid.

1. Use a safety shield to protect oneself against the effects of a possible explosion.

2. Use the acid in a designated, properly designed perchloric acid hood with a minimum of equipment present. No extraneous chemicals should be present in the hood.

3. Use thick gauntlets in addition to PPE previously recommended.

4. Use only freshly prepared acid. Do not make any more anhydrous perchloric acid than is required for a day/shift**.**

7.2.2 Storage

1. The quantities of perchloric acid kept in storage should be kept to a minimum.

2. Perchloric acid should be stored in its original container within compatible secondary containment, preferably glass or porcelain.

3. Perchloric acid should be separate from other chemicals, but may be stored with other inorganic acids, preferably in a metal cabinet designed for acid/corrosive storage.

4. Small quantities may also be stored in a perchloric acid hood. Perchloric acid must be stored away from organic chemicals, flammable or combustible materials and strong dehydrating agents such as sulphuric acid and anhydrous phosphorus pentoxide.

7.2.3 Spill Procedure

To clean a spill, neutralize it with soda ash (sodium carbonate) or other appropriate neutralizing agent. Soak up the neutralized spill with an inorganic based absorbent, if possible. Do not use organic materials (e.g. paper towels) as they may spontaneously ignite upon contact with perchloric acid. If rags or paper towels are in advertently used, wet them with water and place them in a tightly sealed plastic bag. Do NOT use rags, paper towels, or sawdust and then put them aside to dry out, as such materials may spontaneously ignite. A second neutralization and rinsing of the wetted area is recommended.

Laboratory personnel must don appropriate PPE prior to attempting to manage any spill involving hazardous chemicals.

Perchloric acid waste must not be mixed with other wastes. It should be placed into acid resistant containers that are clearly labelled and held for disposal.

Please log on to the OSHE portal for the safety video related to “Accidental Release Measure & Spill Clean-up procedures – Hazwoper series”.

7.3 PROCUREMENT OF CHEMICAL

The procurement of chemicals shall be done through a centralized system at the departmental or faculty level. This is to ensure prudent purchases of chemicals and minimization of chemical inventory, thus reducing the storage space required, and the risk associated with storing large quantity and a wide variety of chemicals in the building.

A proper chemical selection and procurement procedure should be established with well-defined requirements. All new processes and procured chemicals should be evaluated for potential hazards before implementation so as to minimise the introduction of additional hazards into the workplace. Chemical users should consider issues such as applicable licence & permits, estimated usage, importation, transportation, storage capacity & location and disposal

procedures prior to the procurement of chemicals. This will help to reduce excessive and duplicate purchases, ensure safe handling and storage of chemicals and minimise the generation of chemical wastes.

Prior to the procurement of chemicals, PI may refer to Regulated Chemical Identifier (RCI) for a listing of regulated chemicals and their approving authorities (see Section 7, 7.3.7). PI shall contact and seek approval from the respective Faculty Safety & Health Officer or OSHE for more information on licensing procedures prior to the procurement of the chemicals.

7.3.1 Chemical Weapons Convention (CWC) Chemicals

1. The PI shall seek approval from OSHE prior to the purchase of any chemicals listed under the Chemical Weapons (Prohibition) Act (see Chapter 3, 3.2).
2. The PI shall first complete and submit the form 'Request for Licence / Purchase of Scheduled Chemicals Listed under the Chemicals Weapon Prohibition Act' to OSHE - (OSHE/F/CS/01) (see ***Appendix E***)
3. NA(CWC) licence is required before the commencement of any one or more of the following activities:

Activities	**Schedule 1**	**Schedule 2**	**Schedule 3**
Production	✓	✓	✓
Processing	✓	✓	X
Consumption	✓	✓	X
Storage	✓	X	X
Import / Export	✓	✓	✓
Local Sales / Distribution	✓	X	X
✓ : Indicates that a license is required			

4. OSHE may conduct a site inspection and interview PIs, staff and students prior to ensure the facilities are appropriate for the safe storage, use and disposal of these chemicals.
5. The PI shall attach a copy of the SDS of the chemical to be purchased and submit together with the above mentioned form for OSHE review and further action if necessary.
6. The PI shall not be engaged in the large scale proliferation / production of these chemicals.

7. The PI shall inform OSHE if he / she intends to use the chemicals of purposes either than those stipulated in the initial application.

7.3.2 Petroleum and Flammable Materials (PFM)

1. Prior to the purchase of any PFM (see Chapter 3, 3.3), PIs are required to identify if the chemicals fall under the PFM regulation and determine the MAQ limit for the laboratory based on compartmentalization & laboratory space (see ***Appendix A***).
2. PIs shall maintain proper documentation of SDS, inventory list, Emergency Response Plan etc.
3. All PFM shall be stored inside an approved flammable safety cabinet and quantity maintain within the MAQ.
4. OSHE shall conduct periodic PFM inspection in all laboratories that store PFM so as to verify that the quantity is kept within the MAQ and relevant documents are in order.
5. If the PFM inventory exceeds the MAQ limit, PI shall be given 1 week of grace period to comply with the MAQ determined for the laboratory unit.

7.3.3 Poisons

1. Poison Licence is not required if the PIs purchase the poisons from local vendors.
2. A licence is only required for the purpose of import, possess for sale, sell or offer for sale any poisons (see Chapter 3, 3.4). In NUS, the respective Faculty Safety & Health Officer holds the Poison Licence.

7.3.4 Hazardous Substances

1. A Hazardous Substance Licence is required for the import, deal and/or storage of hazardous substances and a Hazardous Substance Permit is required for the purchase, storage and/ or use of hazardous substances scheduled under the Environmental Protection and Management (Hazardous Substances) Regulations (see Chapter 3, 3.5).
2. In NUS, the respective Faculty Safety & Health Officer holds the Hazardous Substance Licence and Permit.

7.3.5 Explosive Precursors (EP)

1. A licence for possession and storage of EPs is required under the Arms and Explosives Act. Currently, there are 15 chemicals classified as EP (see Chapter 3, 3.6).
2. In NUS, the respective Faculty Safety & Health Officer holds the EP Licence.

7.3.6 Controlled Drugs

1. Controlled Drug Licence is not required if the PIs purchase the drugs from local vendors.
2. A license is only required for the purpose of import, export any controlled material or substances (see Chapter 3, 3.7). In NUS, the respective Faculty Safety & Health Officer holds the Controlled Drug Licence.

7.3.7 Hazardous Material Management System (HMMS)

1. Online Regulated Material Identifier (ORMI) in HMMS has an e-listing of chemicals that are regulated under Petroleum and Flammable Materials List, Environmental Protection and Management Act Scheduled Hazardous Substances List, Singapore Police Force Explosive Precursors List (Explosive List), Health Sciences Authority Poisons Act Chemicals List (Poisons List), Chemical Weapon Convention List (NACWC List) and Misuse Of Drugs List. Please refer to Regulated Chemical Identifier (RCI) for the list of all regulated chemicals.

2. ORMI contains information on regulated chemicals, searchable by Chemical Abstracts Service (CAS) Registry Number (if assigned), regulators, regulator chemical description, harmonized system description & code. It contains information on licence & permit requirements, responsibilities of chemical users and contact person for the licensing matters.

3. Chemical users may refer to ORMI to verify the applicable regulations and licence requirements pertaining to the chemicals. This would help to ensure that regulated chemicals that are to be purchased, possessed and used have the necessary licenses or permits from its regulator. When using ORMI to search for a chemical mixture, users shall perform a search for each component individually to verify the applicable regulations and licence requirements pertaining to the chemical mixture.

4. For a detailed search of NA (CWC) chemicals, please refer to Organisation For The Prohibition of Chemical Weapons

5. Please note that the list provided in ORMI is not a comprehensive list. Chemical users shall contact OSHE for clarification if necessary.

7.4 CHEMICAL INVENTORY

For the purpose of ensuring all chemicals are accounted for, all laboratories shall adopt a chemical inventory system. It is the responsibility of the PI and Laboratory Supervisor to ensure that the use, storage, movements and disposal of all chemicals are recorded. Chemical inventory records for all licensed chemicals such as CWC chemicals, PFM, poisons, hazardous substances, EPs and drugs (see Chapter 3) are mandatory.

7.4.1 Chemical Inventory Record System

1. The chemical inventory system can be implemented at the faculty, departmental, research group or laboratory level.
2. The inventory record system shall contain the following information, where applicable:

   a) Name of chemical (common and scientific names)
   b) Chemical formula/composition
   c) Date of purchase
   d) Date of preparation
   e) Original quantity of the chemical
   f) Location where the chemical is used/kept
   g) Name of owner/person responsible for the chemical
   h) Date of usage
   i) Quantity of usage
   j) Name of person using the chemical
   k) Activity level of the substances (for radioactive source) and date of measurement
   l) Transfer of ownership/location record (if chemical is transferred between laboratories or out of the university)

Additional information field can be created if necessary.

7.4.2 Movement of Chemicals

1. Movement of chemicals across laboratory, departments, institutes or countries may require additional documentation such as permits, consignment notes, etc.
2. The PI shall ensure that such permits, consignment notes, etc are obtained prior to transportation of these materials.
3. The PI shall communicate with the transporting and receiving parties to ensure they have appropriate facilities and licence to transport and store these materials.
4. For CWC Chemicals**,** the PI shall inform OSHE of the transfer of ownership of the scheduled chemicals and the loss of any scheduled chemicals within 24 hours.

7.4.3 Inventory Record

1. The inventory record may be kept in soft copy.
2. All forms of inventory record shall be secured and reliable. Only personnel authorized by the PI/ Laboratory Supervisor shall have access to the inventory record.
3. The chemical inventory record shall be updated periodically.
4. For all regulated chemicals, a full inventory check shall be conducted once every 6 months. Any discrepancies observed during the inventory check exercise shall be reported to the PI/ Laboratory Supervisor. The PI/ Laboratory Supervisor shall conduct investigation for the discrepancy recorded. If the discrepancy is unaccounted for, license or permit holder shall be notified. License or permit holder shall inform OSHE and OSHE will take the necessary actions.
5. Users of EPs shall also maintain a register book detailing each transfer of EPs. The information shall include the name and identification number of the user, the description, quantity and concentration of the EP.
6. The PI/ Lab Supervisor shall keep all inventory records for at least five (5) years.

7.4.4 Update of Inventory

1. In addition to the half yearly inventory check, PIs are required to update their inventory records on a regular basis.
2. As and when necessary, OSHE may request for submission of updated chemical inventory list.

7.5 CHEMICAL TRANSPORT AND TRANSFER

Improper transportation and transferring of chemicals can result in spills and, in some instances, chemical exposures and fire hazards.

Preventive measures shall be put in place when the chemicals are expected to be transported from one location to another via common areas such as lifts and corridors. Where feasible, use freight/goods lift instead of common passenger lift to transport the chemicals. Avoid crowded lift in order to minimize personnel exposure in the event of any chemical spillage/leakage.

Loose chemical bottles or containers shall be placed in a secured and enclosed secondary containment container before it is transported from one location to another location. The chemicals should be packaged in durable, leak-proof container made of compatible material. It should be protected from external forces and secured in an appropriate cart or trolley, when necessary. Carry along an emergency spill kit and the appropriate PPE, if necessary.

Be cautious when transporting/ transferring shock- or impact-sensitive chemicals. Consult the SDS for special precautions to be taken. When transporting and transferring cryogenic liquids, the following precautions must be observed:

- Transportation of cryogenic liquids via elevators should be accomplished by human intervention at each floor level and while elevator is unmanned.
- Transfers or pouring of cryogenic liquids should be done very slowly to minimize boiling and splashing.
- Transfer of liquid nitrogen should be done in a well ventilated area.
- Liquid hydrogen should *NOT* be transferred in an air atmosphere because oxygen from the air can condense in the liquid hydrogen, presenting a possible explosion risk.

7.6 CHEMICAL STORAGE

Proper chemical storage prevents flammables from ignition, minimize the potential of exposure to hazardous materials and segregation of incompatible substances prevent the accidental mixing due to spillage or human error.

7.6.1 General Requirements

The following are the general Dos and Don'ts for chemical storage:

Dos:

- Label all storage locations and each storage location must be accompanied with an inventory list.
- Label every chemical container (see label requirements in Chapter 6, 6.3.1).
- Ensure storage areas are provided with adequate lighting and ventilation.
- Segregate chemicals according to their physical and chemical properties.
- Store chemicals according to their chemical compatibility.
- Licenced chemicals (i.e. CWC chemicals, poisons, explosive precursors and controlled drugs – see Chapter 3) shall be kept under lock and key with proper inventory record. The cabinet key shall be kept by PI or his/her designated senior laboratory officer/ staff or researcher. Only authorized users are allowed to access these licensed chemicals. One suggested controlled mechanism is to have controlled key/card access to the laboratory. If the laboratory is a shared facility, PI has to demonstrate his/her due diligence that within reasonable practicable measures, unauthorized access to regulated chemicals will be strictly prohibited.
- All cyanides must be kept under lock and key. Cyanides are classified as hazardous substances. Dispose of cyanides which are no longer in use.
- Ensure liquid chemicals are provided with a secondary containment to contain leaks and spills. Capacity of secondary containment should be at least 20% of the total volume of chemicals stored within the containment tray.
- Store highly toxic chemicals (e.g. hydrofluoric acid (HF)) in compatible secondary containers prominently labelled with a description of the content.
- Use cork rings to secure/ support round bottom flasks.
- Evaluate the chemicals for safe use periodically (recommended every 6 months). Chemical that is found to be safe shall be permitted to be re-dated and retained for an additional 6-month period.
- Date peroxide formers and other chemicals that degrade over time when received and when opened. Review the label or product information for recommended shelf life and put disposal date on the container as well.
- Store chemicals on shelves that have a raised lip along the outer edge, preferably behind glass door.
- Always consult SDS for compatibility and reactivity information.

Don'ts:

- Do not store chemical in alphabetical order except within “compatible storage group”.
- Do not store chemicals, in particular flammable substances, near heat sources (e.g. oven, direct sunlight).
- As far as reasonably practicable, do *not* store chemicals on shelves above eye level, especially for liquids and corrosive chemicals.

7.6.2 Chemical Compatibility

Incompatible chemicals shall not be stored together. In general:

- Store acid separately from bases.
- Store organic acid separately from inorganic acids (eg. nitric acid).
- Store solvents separately from acids.
- Store oxidizers, including oxidizing acids (e.g. nitric acid and perchloric acids) separately from oxidizable compounds (e.g. acetic acid).
- Store perchloric acid such that it cannot come into contact with organic material.
- Store pyrophoric substances separately in a dry inert atmosphere (e.g. a nitrogen-filled desiccator). Pyrophoric substances are chemicals that will ignite spontaneously, i.e. its auto ignition temperature is below room temperature.
- Chemicals that possess two or more hazardous chemical properties (e.g. acetic acid – corrosive and flammable) shall be stored based on the highest potential threat pose to the personnel working in the lab. In the case of acetic acid, it shall be stored in a flammable safety cabinet, in a separate containment tray or an enclosed secondary container.

Consult SDS for incompatibility and reactivity information. Please refer to Chemical Compatibility Chart. See the following table for some examples of incompatible chemicals.

Table 7.1 Examples of Incompatible Chemicals

Chemicals in List A are incompatible with those in List B

List A	List B
Alkali and alkaline earth Carbides Hydrides Metals Oxides Peroxides	 Water Acids Halogenated organic compounds Oxidizing agents
Azides, inorganic	Acids, heavy metals and their salts, Oxidizing agents
Cyanides, inorganic	Acids, Strong bases
Nitrates, inorganic	Acids, {Reducing agents}
Organic Compounds Organic Acyl halides Organic Anhydrides Organic Halogen Compounds Organic Nitro Compounds	Oxidizing agents Bases, Organic hydroxy and amino compounds Bases, Organic hydroxy and amino compound Group IA and IIA metals, Aluminum Strong bases
Oxidizing agents Chlorates Chromates Chromium trioxide	Reducing agents Ammonia, anhydrous and aqueous Carbon Metals
Dichromates Halogens Halogenating Agents	Metal hydrides Nitrites Organic Compounds

Hydrogen Peroxide Nitric acid Nitrates Perchlorates Peroxides Permanganates Persulfates	Phosphorus Silicon Sulphur
Reducing agents	Oxidizing agents, Arsenates, Arsenites, Phosphorus, Selenites, Selenates, Tellurium salts and oxides
Sulphides, inorganic	Acids

7.6.3 Storage of Flammable & Combustible Chemicals

Flammable and combustible materials are substances that form vapours which can burn or explode. Liquids with low flash point are more flammable than liquids with higher flash point. Flash point is defined as the lowest temperature at which a substance gives off enough vapour to form an ignitable mixture with air.

Flammable liquids have flash points below 37.8 °C and they can cause fire and explosion in the presence of an ignition source, even at room temperature. For substances with flash points above 37.8°C, they are classified as combustible materials and although they do not burn at room temperature, they can be ignited when heated to their flash points.

The three elements that must be present in order for a fire to start are: fuel, oxygen and heat. Pictorially they are also described as the "Fire Triangle" (see Figure 7.3).

Figure 7.3 Fire Triangle

Examples of flammable chemicals include:

all alcohols	acetone	acetaldehyde
acetonitrile	amyl acetate	benzene
cyclohexane	dimethyldichlorosilane	dioxane
ether	ethyl acetate	histoclad
hexane	hydrazine	methyl butane
picolene	piperidine	propanol
pyridine	scintillation liquids	all silanes
tetrahydrofuran	toluene	trimethylamine
xylene		

The primary concern for storage of flammable chemicals is exposure to ignition sources. Ignition sources include open flames, hot surface, oven, furnaces and heating equipment, radiant heat, smoking, static electricity, electrical sparks and frictional heat/ sparks. Some of these ignition sources are commonly present in laboratory; hence, attention should be given on identifying the most suitable locations for storage and usage of flammable chemicals.

Keep the quantity of flammable chemicals in the laboratory to the minimum. Flammable chemicals must be stored in flammable safety cabinet. Flammable safety cabinets are generally not required to be ventilated for fire protection purpose. Additionally, venting a cabinet could compromise the ability of the cabinet to adequately protect its contents from involvement in a fire, because cabinets are not generally tested with any venting. Exhaust ventilation should only be provided when warranted by the materials in the cabinet, for

example for particularly toxic or noxious materials. If provided, the manufacturer's instructions should be followed. The material used for venting system (connections, fittings, etc) should involve small diameter steel duct or pipe leading directly and by the shortest route to the exterior of the building. Exhaust must be taken from the bottom of the cabinet. An approval from the SCDF may be required in the event that the intended fire protection in the laboratory is affected. If not ventilated, storage cabinet vent openings shall be sealed with the bungs supplied with the cabinet.

In NUS, all flammable liquid chemicals are classified as Category I. See ***Appendix A*** for the maximum allowable quantity (MAQ) for flammable substances in laboratory.

Should the chemicals require low temperature storage, store them in a spark-proof or explosion-proof refrigerator. Explosion-proof refrigeration equipment is designed to protect against ignition of flammable vapours both inside and outside the refrigerated storage compartment. This equipment has design features such as thresholds, self-closing doors, friction latches or magnetic door gaskets, and special materials for the inner shell. All of these features are intended to control or limit the damage should an exothermic reaction occur within the storage compartment. The Compressor and its circuits and controls are located at the top of the unit to further reduce the potential for ignition of floor-level vapours.

Ensure all liquid container lids/ caps are closed. Vapour released from open container can accumulate in low areas, which results in having a vapour trail that can be very far from the liquid source. If this vapour trail happen to come into contact with an ignition source (outside the laboratory/ building), fire can flash back to the liquid source in the laboratory.

Ensure that fire extinguisher(s) are readily available and easily accessible in areas where flammable chemicals are stored and used.

Don’ts:

- Do *not* store and handle flammable chemicals near ignition sources.
- Do *not* store flammable chemicals on open shelves.
- Do *not* store flammable chemicals in domestic refrigerator.
- Do *not* store flammables liquid chemicals where they may jeopardize escape pathways in the event of emergency.
- *No* smoking at or near storage area.

As for the storage of chemicals with multiple hazards e.g. acetic acid, it is recommended to store in an enclosed corrosive-resistant container and placed it in the lowest rack of a flammable safety cabinet. Bunsen burner canister should be stored in a flammable safety cabinet or in a fire-resistant cabinet and away from the ignition source.

Please log on to the OSHE portal for the safety video related to Flammables & Explosives in the Laboratory.

7.6.4 Storage of Toxic Chemicals

The toxicity of a chemical is any substance that may cause damage to structure, or disturbance to function, when it is ingested, inhaled or absorbed, or when applied to, injected into or developed within the body. Effects of toxic chemical are related to route of entry into the body, dose and duration of exposure.

Effects of exposure to chemicals may be classified as:

- Acute effect - a short term exposure to usually very high concentration of toxic chemicals resulting in immediate illness, irritation and even death.
- Chronic effect - prolonged or repeated exposure to low concentrations of noxious substances resulting in certain diseases which may take some time to develop.
- Reversible effect - an effect that disappears if exposure to the chemical ceases.
- Irreversible effect - an effect that has a lasting, damaging effect on the body, even if exposure to the chemical ceases.
- Local effect - the chemical causes harm at point of contact or entry.
- Systemic Effect - the chemical enters the body, is absorbed and transported to the various organs of the body where harm is affected.

In general terms, toxic chemicals can be classified into:

Class of Toxic Chemicals	Description	Example
Asphyxiant	A chemical that interferes with the ability of living tissue to absorb oxygen. ➢ Simple asphyxiant- the presence of a gas reduces the oxygen to very low levels ➢ Chemical asphyxiant- interferes with the body's ability to transport and utilize oxygen	Nitrogen, acetylene, carbon dioxide, methane Carbon monoxide, hydrogen cyanide, hydrogen sulphide
Carcinogen	A chemical that causes cancer.	Acrylonitrile, asbestos, arsenic, benzopyrene, vinyl chloride, benzidine, naphthylamine
Corrosive	A chemical that destroys or damages living tissue on contact.	Strong acids and alkalis such as phenols, sulphuric acid, sodium hydroxide
Hepatoxic	A chemical that causes damage to the liver.	Carbon tetrachloride, chloroform, trichloroethylene, vinyl chloride, nitrosamines
Irritant	A chemical that produces local irritation or inflammation of the skin, eyes, nose or tissues of respiratory system.	Nitrogen oxides, sulphur dioxide, chlorine, ammonia, formaldehyde
Mutagen	A chemical that causes permanent damage to DNA in a cell. DNA is deoxyribonucleic acid, a molecule that	Chloroprene

	carries genetic information to control the proper growth and function of cells.	
Narcotic	A chemical that depresses the central nervous system which may lead to coma and death.	Acetone, xylene, chloroform, isopropyl alcohol, ethyl ether
Nephrotoxic	A chemical that causes damage to the kidneys.	Mercury, cadmium, lead, halogenated hydrocarbons
Neurotoxic	A chemical that produces toxic effects on the nervous system.	Manganese, tetraethyl lead, hexane, mercury, carbon disulphide, methyl alcohol
Sensitizer	A chemical that causes or induces an allergic reaction. Effects will depend on individual susceptibility to the chemical itself.	Toluene di-isocyanate, maleic anhydride, nickel or chromium compounds
Teratogen	A chemical that, if present in the blood stream of a woman and transported lo the developing fetus will result in structural or congenital abnormalities in the child.	Lead, methyl mercury, formamides

The primary storage concern for toxic chemical is to prevent the users from exposed to these chemicals via inhalation, ingestion and skin absorption.

Keep the quantity of toxic chemicals in the laboratory to the minimum. Remove or discard the highly toxic chemicals that are not in use. Keep all licensed poisons and hazardous substances (e.g. Hydrofluoric Acid) under lock and key. All volatile toxic chemicals should be stored in the flammable safety cabinet. Liquid poisons in containers larger than 1 litre must be stored below bench level as close to the floor as possible. Smaller container of liquid poison can be stored

above bench level behind sliding doors/ glass panels. Highly toxic chemicals should preferably be stored in double containment prominently labelled with a description of the contents.

Ensure exposure to toxic chemicals does not exceed the permissible exposure levels. Where necessary, conduct industrial hygiene monitoring in the laboratory and arrange for appropriate medical examination to be carried out for pre-placement and at periodic interval thereafter (see Chapter 9 & 10 for more information on industrial hygiene monitoring and medical surveillance).

Where hydrogen fluoride or hydrofluoric acid (HF) is stored or used in the laboratory, ensure HF antidote like calcium gluconate gel is readily available. HF is extremely toxic and may be fatal if not treated immediately.

Ethidium bromide (EtBr) is another toxic chemical commonly stored or used in laboratory. It is a powerful mutagen. Where practicable, the use of EtBr should be substituted with a safer alternative such as SYBR, SYBR Safe™ or SYBR GOLD stains etc. Refer to NUS Biorisk Management Manual for detailed information.

7.6.5 Storage of Corrosive Chemicals

Corrosive materials are substances which, by chemical action or contact, will cause severe damage or irreversible alteration to living tissue. Some chemicals become corrosive when they come into contact with water or moisture.

Corrosives comprise both acids and bases (caustics). Besides attacking living tissues, they also attack many other materials and in the presence of metal, they produce hydrogen which is highly flammable. Some chemical such as nitric acid (HNO_3), hydrochloric acid (HCl), and aqueous ammonia (NH_3) release highly corrosive vapours even at room temperature, when in concentrated form.

Corrosive chemicals can be classified according to:

Group of Corrosive Chemicals	Examples
Acids and anhydrides	Sulphuric acid, hydrochloric acid, nitric acid, acetic acid, acetic anhydride, phosphoric acid, phosphorous trioxide
Alkalis or bases	Potassium hydroxide, sodium hydroxide, organic amines such as ethanolamine
Halogens, halogen salts, organic halides	Chlorine gas, ferric chloride, chlorite solutions, acetyl iodide
Other corrosive substances	Ammonium polysulphide, peroxides, hydrazine

The primary storage concern for corrosive chemicals is to prevent contact and reaction with bases and oxidizer. Some of these chemicals, such as HNO_3, perchloric acid ($HClO_4$), are powerful oxidizing agents, which should be stored as oxidizing agents.

Keep the quantity of corrosive chemicals, in particular concentrated acids and bases, in the laboratory to the minimum. Store organic acid (e.g. acetic acid, formic acid) and inorganic acid separately. Store acid and base separately. Strong acids and bases should be kept in separate cabinets, preferably with catch trays. The main stock of concentrated acids and bases should be stored as near to the floor level as possible.

Store acid away from active metals (e.g. potassium, sodium), oxidizers and flammable substances. Hydrofluoric acid (HF) is a highly toxic chemical, which must be kept separately under lock and key.

Dilute acid/ base with care. Always add acid/ base to the water, and not the other way round.

Ensure safety showers and emergency eye wash stations are available, functional and easily accessible in areas where corrosive chemicals are stored or used.

7.6.6 Storage of Oxidizing Chemicals

Oxidizing materials are substances that readily yield oxygen or its equivalent to stimulate the combustion (oxidation) of organic matter. Chromic acid and (Di)chromates, Nitric acid and Nitrates, Perchloric acid and Perchlorates, Permanganates, Peroxides and Bleach (hypochlorite) are all examples of oxidizing reagents.

Oxidizers are incompatible with reducing agents (which usually contain hydrogen), such as hydrides, Bisulphites and Thiosulfates, and with flammable and combustible materials such as solvents, Varsol and Acetic acid.

Nitric acid (HNO_3) and Perchloric acids ($HClO_4$) are both strongly oxidizing acids. They will act rapidly on exposed skin by a denaturing mechanism. They will also react explosively with organic compounds and reducing agents.

All organic peroxides are highly flammable and should be protected from ignition sources. Most peroxides are heat-, shock, and friction sensitive. Be mindful that there is always a risk of explosion for peroxide-containing material, in particular when it is heated or concentrated.

Store all peroxide forming chemicals away from heat and light (which catalyse the peroxidation reaction). Store such compounds in sealed, opaque, airtight containers with tight-fitting caps. DO NOT store these chemicals in open, partially empty, or transparent containers since these conditions promote peroxide formation.

Certain peroxide forming chemicals require to store under nitrogen or other inert gas or in an inert atmosphere chamber. Note: Some inhibitors actually need small amounts of oxygen to prevent peroxide formation and it is recommended that inhibited chemicals are not stored under an inert atmosphere. Follow the manufacturer’s recommendations.

Followings are some examples of common laboratory chemicals that may form peroxides on exposure to air:

Organic structures	Inorganic structures
• Ethers and acetals with alpha hydrogen atoms • Olefins with allylic hydrogen atoms • Chloroolefins and fluoroolefins • Vinyl halides, esters and ethers • Dienes • Vinylacetylenes with alpha hydrogen atoms • Alkylacetylenes with alpha hydrogen atoms • Alkylarenes that contain tertiary hydrogen atoms • Alkanes and cycloalkanes that contain tertiary hydrogen atoms • Acrylates and methacrylates • Secondary alcohols • Ketones that contain alpha hydrogen atoms • Aldehydes • Urea, amides and lactams that have a H atom linked to a C attached to a N	• Alkali metals, especially potassium, rubidium and cesium • Metal amides • Organometallic compounds with a metal atom bonded to carbon • Metal alkoxides

The lists are not exhaustive and analogous compounds that have any of the structural features given in the following table should be tested for the presence of peroxides before being used as solvents or distilled. The recommended retention times begin with the date of synthesis or of opening the original container.

Severe peroxide hazard on storage with exposure to air: Discard within 3 months	
• Diisopropyl ether • Divinylacetylene[a] • Potassium metal	• Sodium amide (sodamide) • Vinylidene chloride (1,1-dichloroethylene)[a] • Potassium amide
Peroxide hazard on concentration: do not distil or evaporate without first testing for the presence of peroxides: Discard or test for peroxide after 6 months	
• Acetaldehyde diethyl acetal (Acetal) • Cumene (isopropylbenzene) • Cyclohexene • Cyclopentene • Decalin (decahydronaphthalene) • Diacetylene • Dicyclopentadiene • Diethyl ether • Diethylene glycol dimethyl ether (diglyme) • Dioxan / Dioxolan	• Ethylene glycol dimethyl ether (glyme) • Ethylene glycol ether acetates • Ethylene glycol monoethers (cellosolves) • Furan • Methylacetylene • Methyl cyclopentane • Methyl isobutyl ketone • Tetrahydrofuran (THF) • Tetralin (tetrahydronaphthalene) • Vinyl ethers[a]
Hazard of rapid polymerization initiated by internally formed peroxides[a]	
List A. Normal liquids: Discard or test for peroxides after 6 months[b]	
• Chloroprene (2-chloro-1,3-butadiene)[c] • Styrene	• Vinyl acetate • Vinylpyridine
List B. Normal gases: discard after 12 months	
• Butadiene[c] • Tetrafluoroethylene[c]	• Vinylacetylene[c] • Vinyl chloride

[a] *Monomer may polymerize and should be stored with a polymerization inhibitor from which the monomer can be separated by distillation just before use.*

[b] *Although common acrylic monomers such as acrylonitrile, acrylic acid, ethyl acrylate and methyl methacrylate can form peroxides, they have not been reported to develop hazardous levels in normal use and storage.*

[c] *The hazard from peroxide formation in these compounds is substantially greater when they are stored in the liquid phase. If store in this form, without an inhibitor, they should be included in List A.*

Source: Chemical Safety Matters, International Union of Pure and Applied Chemistry and International Programme on Chemical Safety.

Hydrogen peroxide shall be stored in spark proof refrigerator and if it is not available and user required to source for alternate storage facilities. User has to consider the potential threat posed by the chemical during the decomposition process. In the case of hydrogen peroxide, oxygen will be released during decomposition process and it will pose potential fire threat. It shall then be kept in an enclosed container and stored in corrosive safety cabinet.

The typical storage period for most peroxide-containing chemical is 12 months. For those that may form explosive peroxides upon exposure to air (e.g. isopropyl ether), the recommended storage is 3 months. Chemicals that readily absorb moisture or react violently with air must be kept in tightly sealed containers or desiccators. Always date the chemical upon receipt in the laboratory and upon opening the chemical. Evaluate and test the chemical for safe use when the storage period expires (regardless whether it is unopened or it is in use).

7.6.7 Storage of Cryogenic Liquids

Cryogenic liquids are materials that are characterized by their extremely low temperature (-60°C to -270°C). In addition to their extremely cold temperature, cryogenic liquids have high expansion ratio. Should there be an accidental release to the atmosphere, it could results an oxygen-deficient atmosphere in a confined space (for liquid nitrogen, liquid argon, liquid helium), or an oxygen-rich/ hydrogen-rich atmosphere presenting fire and explosion hazard (for liquid oxygen and liquid hydrogen respectively).

Store cryogenic liquids in well-ventilated areas. Cryogenic liquids and dry ice used as refrigerant baths should be open to the atmosphere. They should never be in a closed system where they may develop uncontrolled or dangerously high pressure. Cryogenic liquids should be handled and stored in containers that are designed for the pressure and temperature to which they may be subjected. The most common container for cryogenic liquids is a double-walled, evacuated container known as a Dewar flask.

Dewar flask should not be filled more than 80% of capacity, to protect against possible thermal expansion of the contents and bursting of the vessel by hydrostatic pressure. If the possibility exists that the temperature of the cylinder may increase to above 30^{o}C (86^{o}F), a lower percentage (i.e. 60 percent capacity) should be the fill limit.

Containers and systems containing cryogenic liquids should have pressure relief mechanisms. Dewar flasks should be shielded with tape or wire mesh to minimize flying glass and fragments should an implosion occur. It should be labelled with the full cryogenic liquid name and hazard warning information.

All precautions should be taken to keep liquid oxygen from organic materials; spills on oxidizable surfaces can be hazardous.

Liquid nitrogen containing equipment or containers should be stored in a well-ventilated area with tiled flooring instead of vinyl flooring to prevent damage to the floor.

7.6.8 Storage and handling of pyrophoric chemicals

Pyrophoric chemicals are substances that ignite spontaneously upon exposure to air. They can also be water-reactive, where heat and hydrogen (a flammable gas) are produced. Examples of pyrophoric materials include metal hydrides, finely divided metal powders, nonmetal hydride and alkyl compounds, white phosphorus, alloy of reactive materials, organometallic compounds, including alkyllithiums and silane. Improper use of these materials may result in labs being shut-down to deal with the after effects of fire, equipment damage, injury and even potential fatality. The increased level of risk presented by pyrophoric chemicals will require safe storage and handling and personnel should be familiar when handling pyrophoric chemicals:

1) Always perform a risk assessment for any activity involving pyrophoric chemicals **prior** to the commencement of that activity. Risk assessment should also include the waste generated and the apparatus/materials contaminated with pyrophoric chemicals.
2) Ensure **all** the possible hazards have been identified for the activity and for each hazard determine the risk involved and the appropriate risk control measures.
3) Ensure all risk control measures have been identified, documented and communicated to all users.
    - Store and handle pyrophoric/moisture-sensitive chemicals under inert atmosphere at all times. Pyrophoric chemicals will ignite spontaneously on contact with oxygen or moisture.
    - Use glassware which have been oven-dried and are free from moisture and

contamination. Pyrophoric chemicals are water reactive and can create hydrogen (flammable gas) when in contact with water.

- Do not crush pyrophoric chemicals as the friction could lead to the overheating of such materials.
- Use a plastic/glass spatula, instead of a metal spatula to take out the sample, so as to prevent the generation of sparks.
- Do not use paper for weighing the pyrophoric chemicals; use a glass or plastic container instead.
- Please click here for more information on handling of pyrophoric chemicals.
- Check the integrity of the chemicals before use, especially if they have been stored for long period of time.
- Wear the appropriate PPE (nitrile gloves, eye protection wear, lab coat, covered shoes, etc.) as stipulated in the manufacturer's technical sheet and safety data sheet, when handling pyrophoric chemicals.
- Where possible, work in pairs when handling pyrophoric chemicals.

4) Develop procedures for the safe handling and storage of waste material and equipment contaminated with pyrophoric chemicals.
5) Refer to the safety data sheet, technical specifications and lessons learned from prior accidents to identify risk controls.
6) Ensure emergency situations and procedures have been identified, including quenching procedures. Ensure the appropriate fire extinguishing medium is present. For pyrophoric chemicals, a Class D fire extinguisher or a bucket of sand must be readily available for use during a fire emergency.

   For more information on the handling of pyrophoric chemicals, please refer to the University of Minnesota's Pyrophoric Chemical Guide:
   http://www.dehs.umn.edu/PDFs/Pyrophoric_Chemicals_Guide.pdf

7.7 CHEMICAL WASTE DISPOSAL

Hazardous waste is produced as a result of chemicals left over from, or the products of, an experiment. Chemical wastes may be classified as liquids, sludge, solids or mixed waste. They are either incinerated, send to landfill or undergo a physical and chemical transformation, such

as neutralization and separation or even biological treatment. If the chemical wastes are not handled appropriately, it can cause pollution and endanger the health and safety of the staff, students, waste collectors and the general public who are exposed to it.

7.7.1 Management of hazardous wastes

1. Heads & Directors shall conduct risk assessments to determine the appropriate controls to be implemented for wastes and wastes storage areas in common facilities. These controls should include:
    - Access control
    - Characterizing the compatibility nature of the wastes
    - Adequate segregation of the non-compatible wastes
    - Adequate labelling of the wastes which includes hazard warning label for waste

2. Heads & Directors shall ensure risk assessments are conducted for transportation of wastes in common and public areas and the appropriate controls are defined. These controls should address:
    - Segregation of the waste bottles
    - Minimizing exposure to public in common areas
    - Prohibition of personnel accompanying waste trolleys in the lifts
    - Type of personal protection equipment used during transportation
    - Responding & mitigating accidental releases

3. PIs shall implement the waste management policies issued by Heads & Directors.

4. PIs shall ensure risk assessments are conducted for waste management activities in areas under their supervision and ensure the appropriate controls are defined. Controls should include:
    - Characterizing the compatibility nature of the wastes
    - Chemical compatibility of the waste with the waste container
    - Adequate segregation of the wastes
    - Adequate labelling of the wastes
    - Defining the storage duration of the wastes in the laboratory

- Communicating the risks of the wastes to all relevant laboratory members and the safety coordinator
- Type of personal protection equipment used during transportation
- Responding & mitigating accidental releases

Chemical bottles should not be re-used for waste storage. Departments should use chemical containers supplied by licensed waste collectors. Plastic containers should be used when appropriate. Please refer to EPA's Chemical Compatibility Chart for determining the compatibility of chemical mixtures.

7.7.2 Identification, Classification and Labelling

Containers of hazardous waste and those suspected to be hazardous should be clearly identified, classified and labelled accordingly. In general, wastes shall be classified as follows:

Table 7.2 Classification of Waste

Waste Classification	Examples
Toxic Industrial Waste (TIW) – hazardous wastes that are toxic as defined in the schedule of the Environmental Public Health (Toxic Industrial Waste) Regulations.	Acids, bases, solvents, cytotoxic wastes, toxic chemical wastes from chemical analysis, obsolete laboratory chemicals
Radioactive Waste	Radioactive isotopes, radiation-contaminated materials. Refer to the NUS Radiation Safety Manual for more information.
Biohazardous Waste	Infectious waste, pathological waste. Refer to the NUS Biorisk Management Manual for more information
General Waste	Rubbish, food waste, etc

Cytotoxic waste shall be bagged in purple colour bags (see ***Appendix C***) with appropriate labelling. Sharps used for cytotoxic drugs shall be discarded into the sharps bin and subsequently disposed in a cytotoxic-labelled waste bag.

If the waste is classified as CWC chemical waste, refer to Chapter 7, 7.7.5

Waste container/ bag shall be labelled legibly. The waste label should indicate the following information:

i. chemical name or formula of the content in the container,
ii. generator's name,
iii. date of waste generated/ collected,
iv. approximate quantity/ volume, and
v. affixed with the appropriate caution labels indicating the hazard classification and class of waste.

The blue Hazardous Waste Labels (see ***Appendix C***) can be obtained from the Faculty Safety & Health Officer or OSHE.

7.7.3 Segregation and Storage

Ensure all wastes are segregated and stored at the designated storage areas. Waste storage locations are to be confirmed with the assistance of Faculty Safety & Health Officer. Hazardous wastes and TIWs are to be stored in appropriate containers with secondary containment and appropriate labelling. Incompatible wastes shall *NOT* be stored in the same container.

The PI and Laboratory Supervisor shall be responsible to ensure good housekeeping for all wastes stored in the common area under their jurisdiction.

7.7.4 Transportation of chemical waste

All wastes shall be segregated based on their chemical compatibility and put in a chemical trolley for transportation to waste collection point. The chemical waste trolley should be designed for safe transportation and it shall meet the following criteria:

a. be made of chemical resistant material
b. have wheels with 360^{o}C mobility that supports manoeuvring
c. have lockable wheels to prevent “runaway’ incidents

d. have handles to provide for ergonomic steering
e. have compartments to capture and contain chemical spills
f. have storage space for chemical inventory lists and safety data sheets
g. house (enclosed) the chemical bottles so as to minimize splashes during transportation

During the waste transportation, hazard signage shall be affixed to warn and prevent others from entering the lift. No personnel shall be in the lift during waste transportation.

7.7.5 Licensed Waste Collector

Prior to entering into or renewing any contract with a waste collector, the Faculty Safety & Health Officer shall ensure that the waste collector has a valid license for the type of waste to be collected from NUS. List of Toxic industrial waste collectors/PVC collectors can be found in NEA website.

A consignment note shall be completed for all hazardous waste and TIW collected. For TIW, a consignment note shall be submitted to the NEA-Pollution Control Department (PCD) through e-tracking or mail. Transport approval from PCD is required for consignment of TIW exceeding the prescribed quantity under Environmental Public Health (TIW) Regulations.

The PI/ Laboratory Supervisor or his/her designate shall maintain copies of all consignment notes. All consignment notes shall be kept for at least one (1) year.

7.7.6 Disposal of CWC Chemical Wastes

Before arrangement is made to remove CWC chemical wastes, the PI must complete and submit to OSHE the form 'Notification of Disposal of Scheduled Chemicals Listed under the Chemical Weapons (Prohibition) Act' (OSHE/F/CS/02) (see ***Appendix F***) available in the website

After the disposal, the PI must provide OSHE a copy of the consignment note from the TIW collector.

7.8 CHEMICAL DECONTAMINATION OF EQUIPMENT AND LABS

Prior to removal or recycling laboratory equipment, any chemicals inside the equipment shall be removed and disposed of accordingly. Following are some generic guidelines for handling and decontamination of equipment and labs, that contain or in contact with chemicals:

- Using knowledge of historic usage of lab and equipment, the chemicals that have been used must be identified. Appropriate personal protective equipment like safety glasses, protective clothing, gloves, and (if there is risk of aerosol) a respirator (use of respirator requires fit testing and training) must be worn.
- All loose materials must be removed from the area/equipment
- A disposable cleaning pad/cloth and an appropriate cleaning liquid must be used for cleaning.
- Areas contaminated with inorganic materials can be cleaned with mild acid (eg. 10% nitric acid). Areas contaminated with organic materials can be cleaned with a solvent (eg. Ethanol or acetone). If all contaminants are non-hazardous, or there is no obvious contamination or signs of spills, a mild soap solution can be used.
- Certain equipment may be sensitive to chemicals and water. The manufacturer/vendor or manuals must be consulted for recommended decontamination solutions.
- The decontamination and cleaning must be performed from the outside of the contaminated area and towards the middle to prevent spreading the contamination.
- Brushes or abrasive materials can be used to remove hard stains.
- After decontamination, all labels and signs that indicate the chemical hazard must be removed

Please log on to the OSHE portal for the safety video related to “Preventing Contamination in the Laboratory”.

7.9 SAFETY GUIDELINES FOR BENCH-WORK IN SHARED LABORATORIES

There is an increasing trend of research laboratories being designed in an “open” concept, instead of individual laboratory suites. This layout provides greater opportunities for collaboration and for monitoring of safety practices. As there might be different research groups in these laboratories, there is a need for each group to communicate their hazards and risks to the other research groups.

The guidelines are applicable to all NUS students, staff, collaborators and visitors who perform laboratory based research activities in “open” benches in shared laboratories.

7.9.1 Safety Guidelines

1. The Principal Investigator (PI) shall conduct a risk assessment of the activities and determine if the activities can be conducted in the open bench.
2. The PI shall ensure that the controls for ensuring the health and safety of the other researchers in the laboratory are in place. This should include:
    a. Relevant hazard warning signs shall be posted to communicate the hazards to other occupiers of the shared laboratory. For example, if research activity involving animals are performed in a shared lab, a warning sign stating “Animals may be used in labs” shall be posted on the entrance to the laboratory door.
    b. The PI shall identify possible emergency situations in the shared laboratory that may arise from the research activities conducted by their respective group. PI shall also ensure appropriate emergency response procedures are developed for such situations and these are communicated to other occupiers in the shared laboratory.
    c. Determining if researchers in the neighbouring benches require specific risk controls such as Occupational Health monitoring or specialized Personal Protective Equipment. This should be determined based on the level and duration of exposure of the hazard to the researchers working in neighbouring benches.

7.10 SAFETY GUIDELINES FOR ACTIVITIES INVOLVING USE OF CYTOTOXIC DRUGS

Cytotoxic drugs are used for treatment of various diseases as they have the ability to inhibit the growth and proliferation of cells. It is also this very nature of cytotoxic drugs that makes them harmful to healthy cells. These drugs have the potential of causing hazardous effects

like organotoxicity, cancers, reproductive risks and other acute or chronic damage. Researchers using cytotoxic drugs in their research activities must practice safety best practices to eliminate or minimize exposure to these drugs. The purpose of this document is to provide guidelines on safe usage of these drugs.

Appendix G provides a list of some common cytotoxic drugs referenced from the National Institute of Occupational Safety and Health (NIOSH) and International Agency of Research on Cancer (IARC). The drugs listed in Appendix G are not exhaustive. For drugs not included in Appendix G, or drugs that are derivatives/analogs of drugs in Appendix G, the PI shall review the published literature on the possible safety and health effects, and exercise their professional judgment to designate the drugs as cytotoxic.

7.10.1 Risk Assessment

The degree of risk associated with working with cytotoxic drugs is dependent on factors such as inherent toxic properties of the drug, as well as the extent of exposure. Users shall perform a thorough evaluation of risks associated with all activities that involve the handling of cytotoxic drugs in their projects and identify and implement controls to minimize such risks. An activity-based risk assessment shall be performed and the following shall be taken into account:

- Potential safety and health impact to surrounding area or other parties nearby
- Worst possible incident scenario that may occur while handling such drugs
- Published literature available through portals like PUBMED to determine the possible safety and health effects.

The risk assessment shall be performed using the 3x3 Risk Assessment template commonly used in NUS for all risk assessment activities. The risk assessment methodology can be found in ***Appendix H***, and the process flow for the Cytotoxic Drugs Risk Assessment can be found in ***Appendix I***.

7.10.2 Safety Control Measures

The selection and implementation of safety control measures shall be prioritized according to

the hierarchy of control. The table below indicates examples of safety control measures that can be implemented to reduce the likelihood of exposure to cytotoxic drugs. The PI and the research group must determine any applicable/appropriate safety measures based on potential exposure levels and likelihood of exposure, that need to be implemented to reduce risk levels to as low as reasonably practicable.

Hierarchy of Control	Examples
Elimination	• Purchase cytotoxic drugs in ready-to-use concentrations, to eliminate preparation • Establish supply arrangements with a company or healthcare institution that specializes in the preparation of cytotoxic drugs.
Substitution	• Purchase single-dose preparations • Purchase cytotoxic drugs in a liquid form rather than in a powder form • Use a more dilute form of cytotoxic drug where possible • Incorporate handling techniques that minimize aerosol generation • Purchase drugs in vials, not ampoules • Purchase drugs in plastic vials, or vials reinforced with plastic casings.
Engineering Controls	• Adopt closed-system operations • Handling cytotoxic drugs in an enclosed area, such as a properly operational cleanroom with appropriate ventilated cabinet (eg. Class II – Type B2 or equivalent) • Using high efficiency particulate air (HEPA) filters which supply filtered air to the cleanroom and anteroom. Secondary containment is provided by maintaining the cleanroom at a pressure lower than that of the anteroom • Drug packaging features in-built breakage prevention systems • Use wide-bore needles to transfer liquids from containers • Using needle-less drug administration systems or retractable needles • Incorporate secure storage facilities.
Administrative Controls	• Provide appropriate information, education and training to employees • Drugs are stored in dedicated clearly marked storage areas, including refrigeration • Correct labelling of decanted solutions (same label as purchased product) • SDS are available at site of storage and use • Designate an area for handling of cytotoxic drug, which only permits entry to authorized people. • Allocate responsibilities for health and safety • Reduce the number of employees who work with cytotoxic drugs • Clean work areas regularly • Keep containers of cytotoxic drugs secure and tightly lidded when not in use • Prohibit eating, drinking and smoking in work areas • Develop and implement standard operating procedures for all work activities • Providing suitable washing facilities • Providing first aid facilities • Use cytotoxic signs and labels to clearly identify all cytotoxic drugs

Hierarchy of Control	Examples
	• Store cytotoxic waste in specific, clearly identified areas, separate from other waste • Develop emergency procedures to deal with spills. • Effective management of contaminated laundry
Personal Protective Equipment	• Coveralls • Gowns • Head covering • Closed footwear • Overshoes • Gloves of appropriate material and thickness • Safety glasses • Respiratory protective devices.

7.10.3 Medical Examination

Personnel performing activities involving cytotoxic drugs that are classified as HIGH risk (based on risk calculated to be 6 or 9 in the 3x3 risk assessment matrix) shall be enrolled into the University Occupational Health Program. These personnel may be subjected to targeted medical examination and investigations depending on the type of drugs used, their medical conditions and applicable international standards and practices.

All personnel handling cytotoxic drugs are to seek medical attention in the event of accidental exposures and in the event of change of personnel's medical status such as pregnancy or immunosuppression status. The personnel are to review the risk assessment with the supervisor and determine if additional risk controls is required.

7.10.4 Cytotoxic Waste

Cytotoxic waste shall be managed as per Chemical Safety Manual section 7.7: "Chemical Waste Disposal". It shall be bagged in purple colour bags with appropriate labelling (See Chemical Safety Manual ***Appendix C***).

8 ENGINEERED NANOMATERIALS

Nanotechnology is define as the manipulation of matter at the atomic, macromolecular levels, in the length scale of approximately 1-100 nm range to produce new materials, structures, and devices with unique properties and functions because of its small size.

Current information about the potential adverse health effects of engineered nanomaterials, exposure assessment, and exposure control is limited. Research has shown that the physicochemical characteristics of particles can influence their effects in biological systems.

Nanomaterials have the greatest potential to enter the body through the respiratory system if they are airborne and in the form of respirable-sized particles (nanoparticles). They may also come into contact with the skin or be ingested.

Risk assessment shall be conducted prior to the commencement of projects involving nanomaterials. Issues to consider when working with engineered nanoparticles but not limited to are size & size distribution, shape, mass, concentration & numbers, process, properties and location of work.

Engineering control techniques such as source enclosure and local exhaust ventilation systems should be effective for capturing airborne nanoparticles. High-efficiency particulate air (HEPA) filter should effectively remove nanoparticles.

Currently, there are no specific exposure limits for airborne exposure to engineering nanoparticles and little information about the effectiveness of available PPE against exposure to nanomaterials. Until more is known about the hazards, following general safe work practices would be a prudent approach to minimize the risk level of nanoparticles.

Preliminary data shows that standard respirators such as N95 are sufficient for particulates as small as 2.5nm. It is recommended to use N, P or R95 (HEPA) particulate respirators for protection against inhalation exposure.

All nanomaterial wastes must be disposed of as chemical waste.

9 INDUSTRIAL HYGIENE MONITORING

Industrial hygiene is the science devoted to the anticipation, recognition, evaluation, prevention, and control of those occupational factors or stresses arising in or from the workplace which may cause sickness, impaired health and well-being, or significant discomfort among workers or citizens of the community.

Industrial hygiene monitoring guidelines apply to all activities performed by NUS staff in laboratories and workshops. Where certain toxic substances are used or emitted in the laboratory, the PI shall arrange for industrial hygiene monitoring to be carried out to ensure that the staff/ student's exposure to these chemicals does not exceed the permissible exposure levels (PEL).

A PEL is the maximum amount or concentration of a chemical that a worker may be exposed to. In Singapore, the Ministry of Manpower (MOM) defines PEL into two categories:

- PEL (Long Term) – means the permissible exposure level over an 8-hour working day and a 40-hour work week

- PEL (Short Term) – means the permissible exposure level over a 15-minute period during any working day

The list of toxic chemicals and their corresponding PEL values can be found in ***Appendix D***.

Threshold limit value (TLV) is recommended guidelines for occupational exposure to airborne contaminants published by the American Conference of Governmental Industrial Hygienists (ACGIH). TLVs represent the average concentration for an eight-hour workday and a 40-hour workweek to which nearly all workers may be repeatedly exposed without adverse effect.

Industrial hygiene monitoring helps to reveal personnel's levels of health hazard exposure to toxic substances and aids in the assessment of possible health risks that may result. It also helps to gauge the need for and/ or effectiveness of hazard control measures.

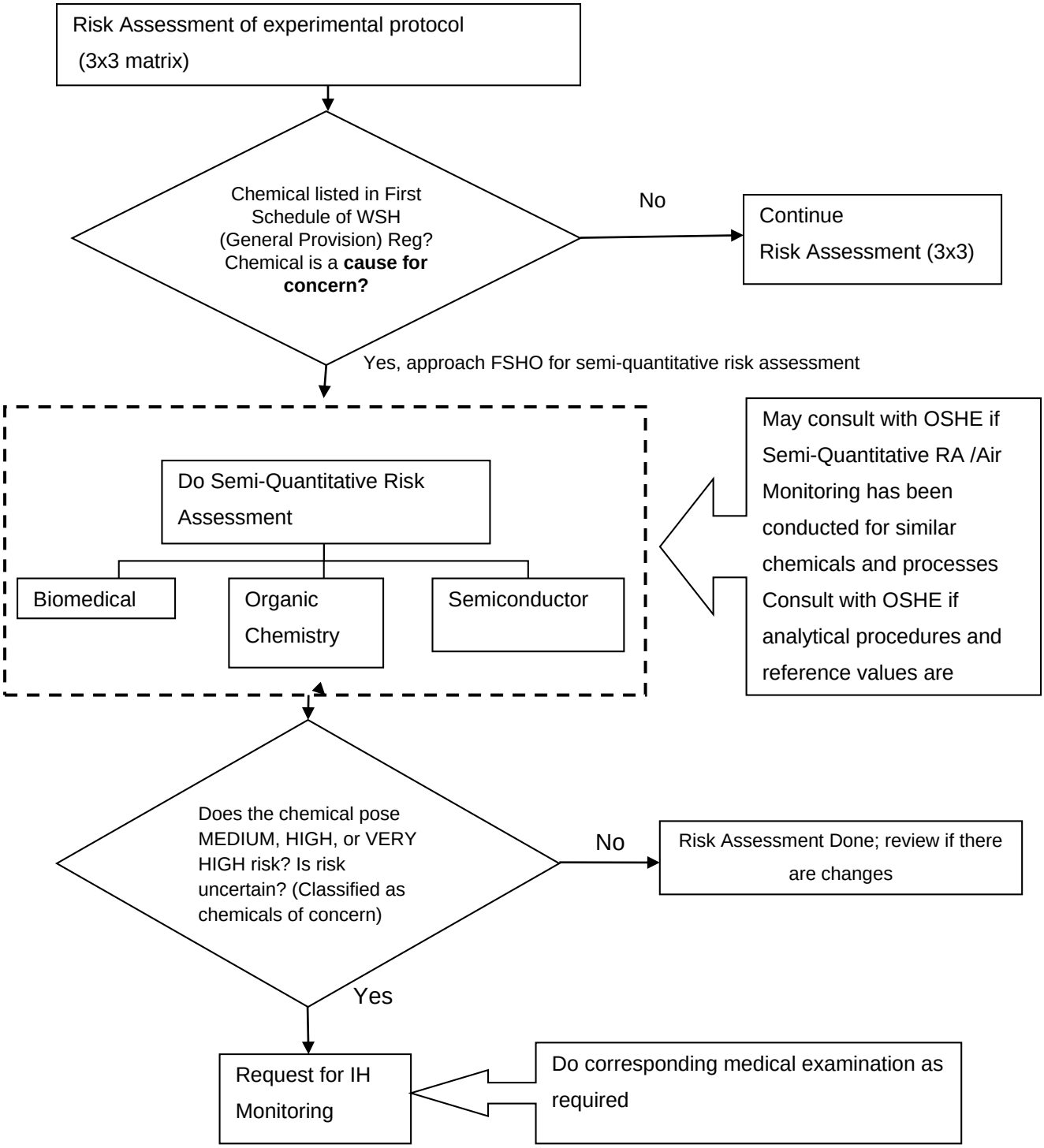
For a start, all laboratories with extensive use of toxic chemicals should have a monitoring done for the purpose of recording the baseline data. Baseline measurements may be used to determine the adequacy of existing control measures for a new or modified facility, practice, procedure, or piece of equipment by comparing the exposure levels with the PELs and TLVs.

Once levels under existing controls have been examined, it may or may not be necessary to modify or add new controls.

Depending on the first monitoring result, periodic monitoring may be required thereafter. Industrial hygiene monitoring may also be required in the event that there is a change in experimental procedure or a change in type, quantity and concentration of toxic substances used. A monitoring should also be conducted where there is credible complaint from staff/ students with regards to smell, deteriorating health status or other valid concerns.

NUS adopt a risk-based approach in industrial hygiene monitoring. Lab members should conduct a semi-quantitative risk assessment (SQRA) based on the chemicals used in the labs and in the instance where the SQRA shows negligible or low risk from the chemical hazards, then there is no requirement to have the statutory industrial hygiene monitoring. This is consistent with the Ministry of Manpower policies where exemption is given upon evidence of very low environmental exposures.

The industrial hygiene monitoring is arranged and funded by OSHE. The NUS's exposure assessment process is depicted by the following flow chart.



Certain air contaminants are to be monitored periodically as required by the Ministry of Manpower as stated in the Workplace Safety and Health (General Provisions) Regulations. Once the exposure is initially quantified, follow-up monitoring may be required as outlined in the

following table.

Percentage of PEL	Industrial Hygiene Monitoring Frequency
Greater than 100%	At least once every three (3) months until the exposure is reduced to below the PEL
Between 50%–100%	At least once every six month
Between 10%-50%	At least once a year
Less than 10%	No monitoring required Until a change in the work environment / process or worker concern suggests that monitoring is required

A department or laboratory user may request air monitoring for other chemicals of concerns not included in the schedule under the WSH (General Provisions). Staff / students at NUS should discuss industrial hygiene concerns with their supervisors / Faculty Safety and Health Officer. The supervisor / FSHO will evaluate the need to request for industrial hygiene air monitoring using the semi-quantitative risk assessment method.

To determine the need for industrial hygiene air monitoring, please refer to ***Appendix J*** – *"Determining Need For Industrial Hygiene Air Monitoring For Laboratories Through Semi-Quantitative Risk Assessment"*

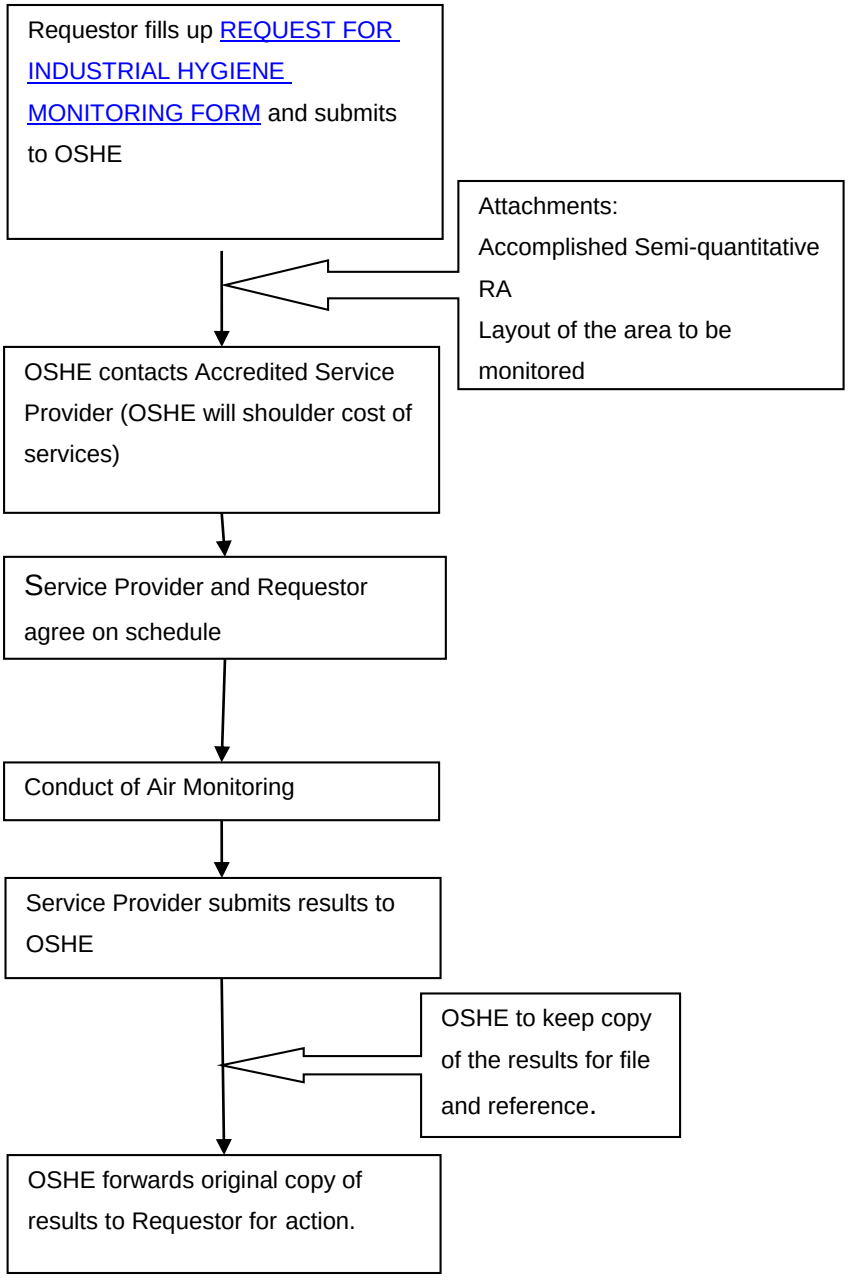
The main outcome of the risk assessment is to assign a risk rating to different work tasks involving exposure hazards. The hazard scenarios are then ranked and the ranking is used for prioritizing actions to address the hazards and to reduce the risk.

If the semi-quantitative assessment indicates a negligible (Risk Rating = 1) or low risk (Risk Rating = 2) of exposure, no further action (such as quantitative monitoring or the implementation of additional control measures) is required. For unacceptable exposure risk (Risk Rating > 2), or if exposure risk is uncertain, a quantitative exposure assessment is required.

Risk Rating	Risk Level	Action
1	Negligible	No need for air monitoring
2	Low	No need for air monitoring
3	Medium	Request for air monitoring
4	High	Request for air monitoring
5	Very High	Request for air monitoring
	Uncertain	Request for air monitoring

In addition to air monitoring, if the assessment shows that there is a significant risk to health, the additional control measures appropriate should be taken to reduce the risk.

To request for industrial hygiene air monitoring, the requester shall fill up the form "*Request for Industrial Hygiene Monitoring"* (***Appendix K***) and send to OSHE by hand, email or fax. A schematic layout of the area to be monitored and the results of the Semi-Quantitative Risk Assessment should be included in the request.



The request form can be downloaded from NUS Forms-Chemical Safety.

Once the request is received, OSHE will arrange with the Accredited Service Provider and the Requestor for the conduct of industrial hygiene surveys to assess potential exposures to hazardous materials and contaminants in the workplace.

There are two types of monitoring, i.e. personal and area sampling. Personal sampling will be used to measure personnel exposure to airborne contaminants. Workplace air is sampled over an eight-hour period (or for the full work shift) and is representative of the individual's breathing zone. The industrial hygienist also observes and records general information about personnel work processes.

For area sampling, air sampling will define the extent of contamination or to measure the effectiveness of engineering controls. The air sampler is placed in a fixed location in the work area or near the suspected source of the hazard.

The PI shall review the monitoring results, taking into consideration of the PEL values. Where necessary, the PI may need to arrange for medical examination for his/her staff and student (see Chapter 9 for more information), suspend the personnel from working with certain chemicals until further notice, or take other measures to safeguard the health of the personnel. All staff and student should be informed of the results of industrial hygiene monitoring.

10 MEDICAL SURVEILLANCE

Medical surveillance is an important system of monitoring the health status of laboratory personnel, to determine departures from normal health and to take the necessary corrective actions early. It is thus applicable to all NUS staff and students.

Biological monitoring is a component of medical surveillance and involves the determination of the concentration of the chemical or its metabolites or the metabolic effects they produce from analysis of biological specimens like blood, urine, saliva, hair nails or expired air. It provides information on the internal dose of the substance or the effects of exposure to the substance, thus providing a better picture of the exposure risk of the individuals. Not everyone needs to undergo biological monitoring. Personnel who have "significant exposure" to certain toxic substances should undergo medical assessments conducted by the OSHE Occupational Health Physician. "Significant exposure" will depend on:

- the outcome of risk assessment
- expected or suspected exposure to toxic chemicals at levels especially beyond their 10% environmental permissible exposure limits (applicable only to substances where inhalation is the only route of exposure)
- referral from PI or Faculty Safety & Health Officer

Types of Medical Surveillance Examinations in NUS:

1. Statutory Medical Examinations

Under the WSHA (Medical Examinations) regulations, staff who are exposed to the specified chemical hazards are required to undergo mandatory specific preplacement and periodic medical examinations called statutory medical examinations.

Currently, chemical hazards that require statutory medical examinations are:

i. Fumes, dust or vapour for Arsenic and its compounds
ii. Asbestos dust
iii. Benzene fumes/vapour
iv. Cadmium and its compounds
v. Cotton dust
vi. Fumes, dust or vapour for Lead and its compounds
vii. Fumes, dust or vapour for Manganese and its compounds

viii. Fumes, dust or vapour for Mercury and its compounds
ix. Organophosphates fumes/vapour
x. Perchloroethylene fumes/vapour
xi. Silica dust
xii. Tar, pitch, bitumen and creosote
xiii. Trichloroethylene fumes/vapour
xiv. Vinyl chloride monomer fumes/vapour

Where a staff is planning to work with one of the hazards listed above, he shall be referred to OSHE Occupational Health Clinic to obtain a baseline assessment and a Certificate of Fitness prior to starting work. This is known as the pre-placement medical examination. The staff shall also undergo a periodic medical examination (which is usually annually, but may be half-yearly or 3 yearly, as defined by the WSHA).

For workplaces or research projects involving only students, there is no legal requirement to do statutory medical examinations. However, as NUS has the ethical duty and corporate social responsibility to safeguard the safety and well-being of students, an internal application would still be required to exempt from the statutory medical examinations. Refer to Appendix N for the exemption workflow.

2. Toxic Chemical Medical Examinations

These medical examinations apply to those chemicals which do not fall within the statutory list of chemicals, and apply to toxic chemicals. The toxic chemicals could include:

Neurotoxic chemicals – MPTP (which causes Parkinsonism),
Carcinogens – which causes cancer of various organ systems such as formaldehyde
Solvents – which causes systemic toxicity of the nerves, liver, skin and reproductive system such as toluene, xylene
Respiratory sensitizers – which causes occupational asthma

A risk assessment is required to evaluate whether the risk to the individual is significant. The individual is then referred to OSHE Occupational Health Clinic for evaluation as part of the pre-placement and periodic medical examinations.

3. Occupational Health Evaluations

Occupational Health medical evaluations are available whenever there are unexpected workplace exposures (e.g. spills, leakages) or when the individual develops a medical condition (e.g. pregnancy, immunosuppression) that may be aggravated by exposure to the chemicals being used. They can be referred to the OSHE Occupational Health Clinic by the department or as a self-referral.

4. Respirator Use Medical Examinations

For individuals who need to use particulate or purifying respirators at work, they will be required to undergo a Respirator Use Medical Examination. It will comprise of completing a medical questionnaire, fit-testing, lung function testing and a physical examination.

Administration of the Medical Surveillance Programme

Request for medical examination can be made to Occupational Health Clinic using the form 'Application form for Occupational Health Services' (***Appendix L***) The form will be put up by the individual's supervisor or the Principal Investigator, and submitted to the Faculty Safety and Health Officer for approval. The individual will then make an appointment with the OSHE Occupational Health Clinic.

A Certificate of Fitness will be issued by the attending physician with a validity of 1 year (6 months for work with lead). The Certificate will be given to the respective staff/student upon completion of the medical review, together with recommendations or work restrictions.

The PI/ Supervisor shall review the certification and where necessary, to implement the recommendations/work restrictions. He/ she is also responsible for monitoring follow up medical programmes for his/her staff and students.

For more information on medical examinations, refer to Occupational Health Programme.

11 EMERGENCY PREPAREDNESS & RESPONSE

An emergency plan should be formulated based on the particular hazards associated with the chemicals used or processes involved. The plan should include an assessment of the nature and size of the events, actions to be taken on site, which may include first aid arrangement, fire fighting procedures, rescue and evacuation arrangements and decontamination procedures.

Please log on to the OSHE portal for the safety video related to "Planning for Laboratory Emergencies".

11.1 CHEMICAL SPILL RESPONSE PLAN

Every faculty or department must develop a response and mitigation plan to respond to chemical spills/ releases. The complexity and details of the plan will depend on the physical characteristics, volume of material being handled and the potential toxicity level.

The emergency plans should contain the following elements:

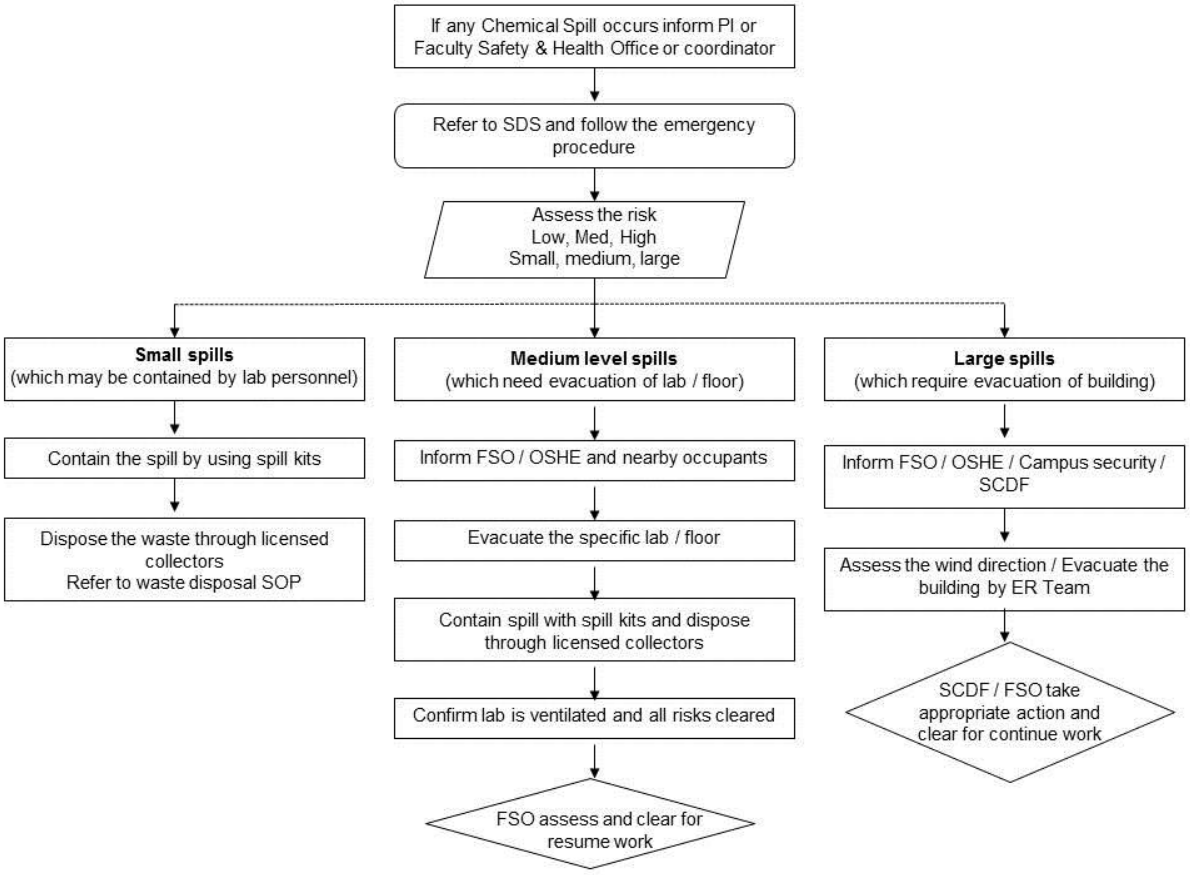
i. How to contain the chemical spill/ release, including using the appropriate absorbent material for liquids and ventilation methods for vapours.
ii. The type of response in relation to the spill (see Figure 10.1)
iii. Activation of emergency response team, if available.
iv. Provision of adequate and appropriate type of PPE.
v. How to give first aid for injuries resulting from exposure to chemicals.
vi. Provisions of signage and barrier taps to warn others of the hazards and to prevent entry to affected area.
vii. Means to raise alarm to alert others in the vicinity.
viii. Notification to PI, departmental staff, Faculty Safety & Health Officer, OSHE and external agencies, if necessary.
ix. Evacuation procedures.
x. Reporting and investigation procedures
xi. Storage of absorbents and other materials (e.g. PPE) used in the spill.
xii. Means for proper disposal of contaminated absorbents and other cleanup materials.
xiii. Decontamination of PPE, if necessary.

xiv. Decontamination of the affected area following the clean up.

xv. Verification of the affected area safe for re-entry or re-occupation.

xvi. Training and drills.

Figure 11.1 Flowchart for Chemical Spill Response



11.2 SPILL RESPONSE KIT

To effectively contain any spilled chemicals, each laboratory should purchase and maintain suitable spill kits. The contents of the spill kit should contain, at minimal, the following:

i. Appropriate absorbent to soak up the chemical.
ii. Appropriate PPE such as gloves, boots, face shield, etc. If a respirator is required, the user must undergo fit test and medical examination (see Chapter 6, 6.4.3).
iii. Waste disposal bags.
iv. Signage and labels.
v. Tongs to put up sharps such as glass pieces.

11.3 FIRST AID PROCEDURE

The standard emergency treatment for victims involved in chemical accidents is described as follows. For critical injury/ illness, contact UHC for medical assessment during opening hours or proceed to the Accident & Emergency Units of the nearest hospital after office hours.

- Splashes on the skin

  Remove contaminated clothing and flush with water for at least 10 minutes. Get medical help.

- Splashes in the eye

  Flush the eyes with water for several minutes. Seek medical treatment.

- Inhalation of gases or vapours

  Remove casualty to a safe area. Apply cardiac pulmonary resuscitation (CPR) if breathing has stopped. Send for medical aid immediately.

- Ingestion of poisonous chemicals

  Wash the mouth with water. Do not induce vomiting. Seek medical treatment immediately.

- Contact with cryogenic liquid
  - Warm the affected area of the body rapidly by immersion in water not to exceed 40ºC,

with body heat, or by exposure to warm air. In the event of massive exposure, the emergency shower should be used to warm the body. All clothing must be removed prior to showering. Maintain the affected area of the victim at normal body temperature until medical help arrives.

- Calm the victim and prevent aggravation of the injury. People with frostbitten feet should not walk on them. Do not rub or massage the affected parts of the body. Prevent infection; use a mild soap to clean the affected area. Dressings need to be applied if the skin is intact.
- Flush eyes, if affected, with warm water for 15 minutes.

12 ACCIDENT/ INCIDENT REPORTING AND INVESTIGATION

All accidents, known exposures and near misses (which does not result in injury) shall report to OSHE via the online Accident/ Incident Reporting System (AIRS). All injuries requiring first aid treatment shall be recorded in the First Aid Log Book.

Reporting must be done within twenty-four (24) hours. It can be submitted by the informant, injured staff/ student, PI, Laboratory Supervisor or other representative if the staff/ student is unfit or unable to do the initial report.

All accidents and incidents must be investigated in order to identify the root cause(s) and contributing factor(s). The investigation team may comprise of representatives from OSHE, the Departmental Safety and Health Committee, the Faculty Safety & Health Officer, PI, Laboratory Supervisor or other members if required.

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22. American Chemical Society Video on Safety in the Academic Chemistry Laboratory: Eye Protection
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14 List of Appendices

Appendix A: Requirement for Storage of Flammable Materials in Laboratory

Storage limits of petroleum & flammable materials in NUS laboratories

Liquid in Laboratory						
Lab Unit Hazard Class	**Requirement set by**	**Liquid Category**	**Excluding Qty in Cabinet**		**Including Qty in Cabinet**	
			Max Qty liters per sq m	**Max Qty litres per lab unit**	**Max Qty litres per sq m**	**Max Qty litres per lab unit**
Laboratory other lab in hospital & health care occupancy	SCDF	I, II	0.8	250 (350)	1.6	500 (750)
		I, II, III	1.6	350 (500)	3.2	750 (1000)
	NUS	I, II, III	0.8	250 (350)	1.6	500 (750)

(*) = Maximum Allowable Quantity (MAQ) for sprinkler protected lab

Liquid category – Cat I : Flash point < 23°C
Cat II : Flash point ≥ 23°C ≤ 60°C
Cat III : Flash point > 60°C ≤ 93°C

Note:

1) Each lab unit shall be a fire compartment with floor area not more than 1000m^2. The minimum fire rating (including fire door) shall be 2 hours including the walls abutting the smoke-stop lobby and fire-fighting lobby.
2) Not more than 250L of flammable liquid shall be stored in any individual safety cabinet (UL, FM or PSB listed product)
3) NUS adopts a more stringent limits for flammable liquids in laboratories. All

flammable liquids are classified as Class 1

4) Laboratory operators are strongly advised and encouraged to minimize their amount of flammable liquids on benches by returning them to chemical store or safety cabinets when the liquid are not needed for the day. The quantity of these liquid placed on benches and fume cupboards shall not exceed 10% of total MAQ within the lab unit. Liquid used for running and operating lab instruments or other work-in-progress which may require some quantities of solvents to operate are exempted from the 10% limit.

5) The above-mentioned MAQ shall include waste. The quantity of each package/container shall be limited to 20L.

MAXIMUM ALLOWABLE QUNATITY FOR GASES PER LAB UNIT (WITH SPRINKLER SYSTEM)

1. Flammable gases

170 L for 50 sq meters and less
Y (L) = 3.4 x Lab Unit for > 50 sq meters

2. Oxidising gases

170 L for 50 sq meters and less
Y (L) = 3.4 x Lab Unit for > 50 sq meters

3. Liquefied flammable gases

30 L for 50 sq meters and less
Y (L) = 0.6 x Lab Unit for > 50 sq meters

4. Toxic gases

8 L for 50 sq meters and less
Y (L) = 0.16 x Lab Unit for > 50 sq meters

Note:

(1) For 1 to 3, the MAQ shall be halved if the lab is without any sprinkler system

(2) Spacing of 3m (6m for lab w/o sprinkler system) apart for each group

(3) For LPG cylinders, only 2 x 4.5kg cylinders are allow for each lab unit.

Appendix B: Glove Type and Chemical Use

Source: Ministry of Manpower (MOM), Guidelines on Prevention and Control of Chemical Hazard (Page No.83)

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile Latex
*Acetaldehyde	VG	G	VG	G
Acetic acid	VG	VG	VG	VG
*Acetone	G	VG	VG	P
Ammonium hydroxide	VG	VG	VG	VG
*Amyl acetate	F	P	F	P
Aniline	G	F	F	P
*Benzaldehyde	F	F	G	G
*Benzene	F	F	F	P
Butyl acetate	G	F	F	P
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	P	P	G
Castor oil	F	P	F	VG
*Chlorobenzene	F	P	F	P
*Chloroform	G	P	P	P
Chloronaphthalene	F	P	F	F
Chromic Acid (50%)	F	P	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	F	G	VG
*Dibutyl phthalate	G	P	G	G
Diesel fuel	G	P	P	VG
Diisobutyl ketone	P	F	G	P
Dimethylformamide	F	F	G	G
Dioctyl phthalate	G	P	F	VG
Dioxane	VG	G	G	G
Epoxy resins, dry	VG	VG	VG	VG
*Ethyl acetate	G	F	G	F
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether	VG	G	VG	G
*Ethylene dichloride	F	P	F	P
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	P	F	G
Freon 12	G	P	F	G
Freon 21	G	P	F	G

Freon 22	G	P	F	G
*Furfural	G	G	G	G
Gasoline, leaded	G	P	F	VG
Gasoline, unleaded	G	P	F	VG
Glycerine	VG	VG	VG	VG
Hexane	F	P	P	G
Hydrochloric acid	VG	G	G	G
Hydrofluoric acid (48%)	VG	G	G	G
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	F
Isooctane	F	P	P	VG
Isopropyl alcohol	VG	VG	VG	VG
Kerosene	VG	F	F	VG
Ketones	G	VG	VG	P
Lacquer thinners	G	F	F	P
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	F	VG	VG
Lineoleic acid	VG	P	F	G
Linseed oil	VG	P	F	VG
Maleic acid	VG	VG	VG	VG
Methyl alcohol	VG	VG	VG	VG
Methylamine	F	F	G	G
Methyl bromide	G	F	G	F
*Methyl chloride	P	P	P	P
*Methyl ethyl ketone	G	G	VG	P
*Methyl isobutyl ketone	F	F	VG	P
Methyl methacrylate	G	G	VG	F
Monoethanolamine	VG	G	VG	VG
Morpholine	VG	VG	VG	G
Naphthalene	G	F	F	G
Naphthas, aliphatic	VG	F	F	VG
Naphthas, aromatic	G	P	P	G
*Nitric acid	G	F	F	F
Nitromethane (95.5%)	F	P	F	F
Nitropropane (95.5%)	F	P	F	F
Octyl alcohol	VG	VG	VG	VG
Oleic acid	VG	F	G	VG
Oxalic acid	VG	VG	VG	VG
Palmitic acid	VG	VG	VG	VG
Perchloric acid (60%)	VG	F	G	G
Perchloroethylene	F	P	P	G
Petroleum distillates (naphtha)	G	P	P	VG
Phenol	VG	F	G	F
Phosphoric acid	VG	G	VG	VG
Potassium hydroxide	VG	VG	VG	VG
Propyl acetate	G	F	G	F
Propyl alcohol	VG	VG	VG	VG

Propyl alcohol	VG	VG	VG	VG
Propyl alcohol (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Stryene (100%)	P	P	P	F
Sulfuric acid	G	G	G	G
Tannic acid (65%)	VG	VG	VG	VG
Tetrahydrofuran	P	F	F	F
*Toluene	F	P	P	F
Toluene diisocyanate	F	G	G	F
*Trichloroethylene	F	F	P	G
Triethanolamine	VG	G	G	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG
*Xylene	P	P	P	F

*denotes limited service

VG	very good
G	good
F	fair
P	Poor (not recommended)

Appendix C: Hazardous Waste Disposal Bag/Label

a) Cytotoxic Disposal Bag

b) Hazardous Waste Label

NUS National University of Singapore

HAZARDOUS WASTE LABEL

Name of PI:	**Phone:**
Department/School:	**Date of Waste Generated:**
Container Serial No:	**Total volume/weight in waste container:**
Chemical (include all constituents) Total should = 100%, No Abbreviations)	**Approximate Concentration (%/ kg)**

Please "✓" type of waste

- ☐ Poison
- ☐ Flammable Solvent
- ☐ Flammable Solid
- ☐ Carcinogen
- ☐ Oxidizer
- ☐ Acid
- ☐ Alkali
- ☐ Irritant
- ☐ Reactive
- ☐ Others, please specify: _____

HANDLE WITH CARE! CONTAINS HAZARDOUS OR TOXIC WASTES.

Appendix D: Permissible Exposure Limits of Toxic Substances

Source: First Schedule, Workplace Safety and Health (General Provisions) Regulations 2006

FIRST SCHEDULE

Regulations 2 and 40

PERMISSIBLE EXPOSURE LIMITS OF TOXIC SUBSTANCES

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Acetaldehyde	—	—	25	45
Acetic acid	10	25	15	37
Acetic anhydride	5	21	—	—
Acetone	750	1780	1000	2380
Acetone cyanohydrin	—	—	4.7	5
Acetonitrile	40	67	60	101
Acetophenone	10	49	—	—
Acetylene tetrabromide	1	14	—	—
Acrolein	0.1	0.23	0.3	0.69
Acrylamide	—	0.03	—	—
Acrylic acid	2	5.9	—	—
Acrylonitrile (Vinyl cyanide)	2	4.3	—	—
Adipic acid	—	5	—	—
Adiponitrile	2	8.8	—	—
Aldrin	—	0.25	—	—
Allyl alcohol	2	4.8	4	9.5
Allyl chloride	1	3	2	6
Allyl glycidyl ether (AGE)	5	23	10	47
Allyl propyl disulfide	2	12	3	18
Aluminium				
Metal dust	—	10	—	—
Pyro powders, as Al	—	5	—	—
Welding fumes, as Al	—	5	—	—
Soluble salts, as Al	—	2	—	—
Alkyls, as Al	—	2	—	—
Aluminium oxide	—	10	—	—
2-Aminopyridine	0.5	1.9	—	—
Amitrole	—	0.2	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Ammonia	25	17	35	24
Ammonium chloride fume	—	10	—	20
Ammonium perfluorooctanoate	—	0.01	—	—
Ammonium sulfamate	—	10	—	—
n-Amyl acetate	100	532	—	—
sec-Amyl acetate	125	665	—	—
Aniline	2	7.6	—	—
Anisidine	0.1	0.5	—	—
Antimony and compounds, as Sb	—	0.5	—	—
Antimony trioxide, as Sb	—	0.5	—	—
Arsenic, elemental and inorganic compounds, as As	—	0.01	—	—
Arsine	0.05	0.16	—	—
Asbestos (all forms)	—	0.1 (fibre/cc)	—	—
Asphalt (petroleum) fumes	—	5	—	—
Atrazine	—	5	—	—
Azinphos-methyl	—	0.2	—	—
Barium, soluble compounds, as Ba	—	0.5	—	—
Barium sulfate	—	10	—	—
Benomyl	0.84	10	—	—
Benzene	1	3.18	—	—
Benzoyl peroxide	—	5	—	—
Benzyl chloride	1	5.2	—	—
Beryllium and compounds, as Be	—	0.002	—	—
Biphenyl	0.2	1.3	—	—
Bismuth telluride,				
Undoped	—	10	—	—
Se-doped	—	5	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Borates, tetra sodium salts				
Anhydrous	—	1	—	—
Decahydrate	—	5	—	—
Pentahydrate	—	1	—	—
Boron oxide	—	10	—	—
Boron tribromide	—	—	1	10
Boron trifluoride	—	—	1	2.8
Bromacil	—	10	—	—
Bromine	0.1	0.66	0.2	1.3
Bromine pentafluoride	0.1	0.72	—	—
Bromoform	0.5	5.2	—	—
1,3-Butadiene	2	4.4	—	—
Butane	800	1900	—	—
n-Butanol	—	—	50	152
sec-Butanol	100	303	—	—
tert-Butanol	100	303	—	—
2-Butoxyethanol (EGBE)	25	121	—	—
n-Butyl acetate	150	713	200	950
sec-Butyl acetate	200	950	—	—
tert-Butyl acetate	200	950	—	—
n-Butyl acrylate	10	52	—	—
n-Butylamine	—	—	5	15
tert-Butyl chromate, as CrO_3	—	—	—	0.1
n-Butyl glycidyl ether (BGE)	25	133	—	0.1
n-Butyl lactate	5	30	—	—
Butyl mercaptan (Butanethiol)	0.5	1.8	—	—
o-sec-Butylphenol	5	31	—	—
p-tert-Butyl toluene	1	6.1	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Cadmium, as Cd				
Elemental	—	0.01	—	—
Compounds	—	0.002	—	—
Calcium carbonate (Limestone, Marble)	—	10	—	—
Calcium chromate, as Cr	—	0.001	—	—
Calcium cyanamide	—	0.5	—	—
Calcium cyanide	—	—	—	5
Calcium hydroxide	—	5	—	—
Calcium oxide	—	2	—	—
Calcium silicate	—	10	—	—
Calcium sulfate	—	10	—	—
Camphor	2	12	3	19
Caprolactam				
Dust	—	1	—	3
Vapour	5	23	10	46
Captafol	—	0.1	—	—
Captan	—	5	—	—
Carbaryl	—	5	—	—
Carbofuran	—	0.1	—	—
Carbon black	—	3.5	—	—
Carbon dioxide	5000	9000	30,000	54,000
Carbon disulfide	10	31	—	—
Carbon monoxide	25	29	—	—
Carbon tetrabromide	0.1	1.4	0.3	4.1
Carbon tetrachloride (Tetrachloromethane)	5	31	10	63
Carbonyl fluoride	2	5.4	5	13
Catechol (Pyrocatechol)	5	23	—	—
Cellulose	—	10	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Cesium hydroxide	—	2	—	—
Chlordane	—	0.5	—	—
Chlorinated camphene (Toxaphene)	—	0.5	—	—
Chlorinated diphenyl oxide	—	0.5	—	—
Chlorine	0.5	1.5	1	2.9
Chlorine dioxide	0.1	0.28	0.3	0.83
Chlorine trifluoride	—	—	0.1	0.38
Chloroacetaldehyde	—	—	1	3.2
Chloroacetone	—	—	1	3.8
2-Chloroacetophenone (Phenacyl chloride)	0.05	0.32	—	—
Chloroacetyl chloride	0.05	0.23	0.15	0.69
Chlorobenzene (Monochlorobenzene)	10	46	—	—
o-Chlorobenzylidene malononitrile	—	—	0.05	0.39
Chlorobromomethane (Bromochloromethane)	200	1060	—	—
Chlorodifluoromethane	1000	3540	—	—
Chlorodiphenyl (42% chlorine)	—	1	—	—
Chlorodiphenyl (54% chlorine)	—	0.5	—	—
Chloroform (Trichloromethane)	10	49	—	—
bis (Chloromethyl) ether	0.001	0.0047	—	—
1-Chloro-1-nitropropane	2	10	—	—
Chloropentafluoroethane	1000	6320	—	—
Chloropicrin (Trichloronitromethane)	0.1	0.67	—	—
β-Chloroprene (2-Chloro-1,3-butadiene)	10	36	—	—
2-Chloropropionic acid	0.1	0.44	—	—
o-Chlorostyrene	50	283	75	425
o-Chlorotoluene	50	259	—	—
Chlorpyrifos	—	0.2	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Chromium, metal and inorganic compounds, as Cr				
Metal and Cr III compounds	—	0.5	—	—
Water-soluble Cr VI compounds	—	0.05	—	—
Insoluble Cr VI compounds	—	0.01	—	—
Chromyl chloride	0.025	0.16	—	—
Clopidol	—	10	—	—
Coal, respirable dust	—	2	—	—
Coal tar pitch volatiles (Polycylic aromatic hydrocarbons), as benzene solubles	—	0.2	—	—
Cobalt, elemental and inorganic compounds, as Co	—	0.02	—	—
Cobalt carbonyl, as Co	—	0.1	—	—
Cobalt hydrocarbonyl, as Co	—	0.1	—	—
Copper				
Fume	—	0.2	—	—
Dusts and mists, as Cu	—	1	—	—
Cotton dust, raw	—	0.2	—	—
Cresol	5	22	—	—
Crotonaldehyde	2	5.7	—	—
Crufomate	—	5	—	—
Cumene	50	246	—	—
Cyanamide	—	2	—	—
Cyanogen	10	21	—	—
Cyanogen chloride	—	—	0.3	0.75
Cyclohexane	300	1030	—	—
Cyclohexanol	50	206	—	—
Cyclohexanone	25	100	—	—
Cyclohexene	300	1010	—	—
Cyclohexylamine	10	41	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Cyclonite	—	1.5	—	—
Cyclopentadiene	75	203	—	—
Cyclopentane	600	1720	—	—
Cyhexatin (Tricyclo hexyltin)	—	5	—	—
DDT (Dichlorodiphenyltrichloroethane)	—	1	—	—
Decaborane	0.05	0.25	0.15	0.75
Demeton	0.01	0.11	—	—
Diacetone alcohol (4-Hydroxy-4-methyl-2-pentanone)	50	238	—	—
Diazinon	—	0.1	—	—
Diazomethane	0.2	0.34	—	—
Diborane	0.1	0.11	—	—
2-N-Dibutylaminoethanol	0.5	3.5	—	—
Dibutyl phenyl phosphate	0.3	3.5	—	—
Dibutyl phosphate	1	8.6	2	17
Dibutyl phthalate	—	5	—	—
Dichloroacetylene	—	—	0.1	0.39
o-Dichlorobenzene	25	150	50	301
p-Dichlorobenzene	10	60	—	—
1,4-Dichloro-2-butene	0.005	0.025	—	—
Dichlorodifluoromethane	1000	4950	—	—
1,3-Dichloro-5,5-dimethyl hydantoin	—	0.2	—	0.4
1,1-Dichloroethane (Ethylidene chloride)	100	405	—	—
1,2-Dichloroethylene (Acetylene dichloride)	200	793	—	—
Dichloroethyl ether	5	29	10	58
Dichlorofluoromethane	10	42	—	—
1,1-Dichloro-1-nitroethane	2	12	—	—
1,3-Dichloropropene	1	4.5	—	—
2,2-Dichloropropionic acid	1	5.8	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Dichlorotetrafluoroethane	1000	6990	—	—
Dichlorvos	0.1	0.90	—	—
Dicrotophos	—	0.25	—	—
Dicyclopentadiene	5	27	—	—
Dicyclopentadienyl iron	—	10	—	—
Dieldrin	—	0.25	—	—
Diethanolamine	0.46	2	—	—
Diethylamine	5	15	15	45
2-Diethylaminoethanol	2	9.6	—	—
Diethylene triamine	1	4.2	—	—
Diethyl ketone	200	705	—	—
Diethyl phthalate	—	5	—	—
Difluorodibromomethane	100	858	—	—
Diglycidyl ether (DGE)	0.1	0.53	—	—
Diisobutyl ketone (2,6-Dimethyl-4-heptanone)	25	145	—	—
Diisopropylamine	5	21	—	—
N,N-Dimethyl acetamide	10	36	—	—
Dimethylamine	5	9.2	15	27.6
Dimethylaniline (N,N-Dimethylaniline)	5	25	10	50
Dimethylformamide	10	30	—	—
1,1-Dimethylhydrazine	0.5	1.2	—	—
Dimethylphthalate	—	5	—	—
Dimethyl sulfate	0.1	0.52	—	—
Dinitolmide (3,5-Dinitro-o-toluamide)	—	5	—	—
Dinitrobenzene	0.15	1.0	—	—
Dinitro-o-cresol	—	0.2	—	—
Dinitrotoluene	—	0.15	—	—
Dioxane	25	90	—	—
Dioxathion	—	0.2	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Dichlorotetrafluoroethane	1000	6990	—	—
Dichlorvos	0.1	0.90	—	—
Dicrotophos	—	0.25	—	—
Dicyclopentadiene	5	27	—	—
Dicyclopentadienyl iron	—	10	—	—
Dieldrin	—	0.25	—	—
Diethanolamine	0.46	2	—	—
Diethylamine	5	15	15	45
2-Diethylaminoethanol	2	9.6	—	—
Diethylene triamine	1	4.2	—	—
Diethyl ketone	200	705	—	—
Diethyl phthalate	—	5	—	—
Difluorodibromomethane	100	858	—	—
Diglycidyl ether (DGE)	0.1	0.53	—	—
Diisobutyl ketone (2,6-Dimethyl-4-heptanone)	25	145	—	—
Diisopropylamine	5	21	—	—
N,N-Dimethyl acetamide	10	36	—	—
Dimethylamine	5	9.2	15	27.6
Dimethylaniline (N,N-Dimethylaniline)	5	25	10	50
Dimethylformamide	10	30	—	—
1,1-Dimethylhydrazine	0.5	1.2	—	—
Dimethylphthalate	—	5	—	—
Dimethyl sulfate	0.1	0.52	—	—
Dinitolmide (3,5-Dinitro-o-toluamide)	—	5	—	—
Dinitrobenzene	0.15	1.0	—	—
Dinitro-o-cresol	—	0.2	—	—
Dinitrotoluene	—	0.15	—	—
Dioxane	25	90	—	—
Dioxathion	—	0.2	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Diphenylamine	—	10	—	—
Dipropylene glycol methyl ether	100	606	150	909
Dipropyl ketone	50	233	—	—
Diquat				
Total dust	—	0.5	—	—
Respirable dust	—	0.1	—	—
Di-sec-octyl phthalate (Di (-2-ethylhexyl) phthalate)	—	5	—	10
Disulfiram	—	2	—	—
Disulfoton	—	0.1	—	—
2,6-Di-tert-butyl-p-cresol	—	10	—	—
Diuron	—	10	—	—
Divinyl benzene	10	53	—	—
Emery	—	10	—	—
Endosulfan	—	0.1	—	—
Endrin	—	0.1	—	—
Enflurane	75	566	—	—
Epichlorohydrin (1-Chloro-2, 3-epoxypropane)	2	7.6	—	—
EPN	—	0.1	—	—
Ethanol (Ethyl alcohol)	1000	1880	—	—
Ethanolamine	3	7.5	6	15
Ethion	—	0.4	—	—
2-Ethoxyethanol (EGEE)	5	18	—	—
2-Ethoxyethyl acetate (EGEEA)	5	27	—	—
Ethyl acetate	400	1440	—	—
Ethyl acrylate	5	20	15	61
Ethylamine	5	9.2	15	27.6
Ethyl amyl ketone (5-Methyl-3-heptanone)	25	131	—	—
Ethyl benzene	100	434	125	543

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Ethyl bromide	5	22	—	—
Ethyl butyl ketone (3-Heptanone)	50	234	—	—
Ethyl chloride	1000	2640	—	—
Ethylene chlorohydrin	—	—	1	3.3
Ethylenediamine (1,2-Diaminoethane)	10	25	—	—
Ethylene dichloride (1,2-Dichloroethane)	10	40	—	—
Ethylene glycol	—	—	50	127
Ethylene glycol dinitrate	0.05	0.31	—	—
Ethylene oxide	1	1.8	—	—
Ethylenimine	0.5	0.88	—	—
Ethyl ether (Diethyl ether)	400	1210	500	1520
Ethyl formate	100	303	—	—
Ethylidene norbornene	—	—	5	25
Ethyl mercaptan (Ethanethiol)	0.5	1.3	—	—
N-Ethylmorpholine	5	24	—	—
Ethyl silicate	10	85	—	—
Fenamiphos	—	0.1	—	—
Fensulfothion	—	0.1	—	—
Fenthion	—	0.2	—	—
Ferbam	—	10	—	—
Ferrovanadium dust	—	1	—	3
Fibrous glass dust	—	10	—	—
Fluorides, as F	—	2.5	—	—
Fluorine	1	1.6	2	3.1
Fonofos	—	0.1	—	—
Formaldehyde	—	—	0.3	0.37
Formamide	10	18	—	—
Formic acid	5	9.4	10	19
Furfural	2	7.9	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Furfuryl alcohol	10	40	15	60
Gasoline	300	890	500	1480
Germanium tetrahydride	0.2	0.63	—	—
Glutaraldehyde	—	—	0.2	0.82
Glycerin mist	—	10	—	—
Glycidol (2,3-Epoxy-1-propanol)	25	76	—	—
Grain dust (oat, wheat, barley)	—	4	—	—
Graphite, respirable dust	—	2	—	—
Hafnium	—	0.5	—	—
Halothane	50	404	—	—
Heptachlor and Heptachlor epoxide	—	0.05	—	—
Heptane	400	1640	500	2050
Hexachlorobenzene	—	0.025	—	—
Hexachlorobutadiene	0.02	0.21	—	—
Hexachlorocyclopentadiene	0.01	0.11	—	—
Hexachloroethane	1	9.7	—	—
Hexachloronaphthalene	—	0.2	—	—
Hexafluoroacetone	0.1	0.68	—	—
Hexamethylene diisocyanate	0.005	0.034	—	—
1,6-Hexanediamine	0.5	2.3	—	—
Hexane (n-Hexane)	50	176	—	—
Other isomers	500	1760	1000	3500
sec-Hexyl acetate	50	295	—	—
Hexylene glycol	—	—	25	121
Hydrazine	0.1	0.13	—	—
Hydrogenated terphenyls	0.5	4.9	—	—
Hydrogen bromide	—	—	3	9.9
Hydrogen chloride	—	—	5	7.5
Hydrogen cyanide	—	—	4.7	5

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Hydrogen fluoride	—	—	3	2.6
Hydrogen peroxide	1	1.4	—	—
Hydrogen selenide	0.05	0.16	—	—
Hydrogen sulfide	10	14	15	21
Hydroquinone (Dihydroxy benzene)	—	2	—	—
2-Hydroxypropyl acrylate	0.5	2.8	—	—
Indene	10	48	—	—
Indium and compounds, as In	—	0.1	—	—
Iodine	—	—	0.1	1.0
Iodoform	0.6	10	—	—
Iron oxide dust and fume, as Fe	—	5	—	—
Iron pentacarbonyl, as Fe	0.1	0.23	0.2	0.45
Iron salts, soluble, as Fe	—	1	—	—
Isoamyl acetate	100	532	—	—
Isoamyl alcohol	100	361	125	452
Isobutyl acetate	150	713	—	—
Isobutyl alcohol	50	152	—	—
Isooctyl alcohol	50	266	—	—
Isophorone	—	—	5	28
Isophorone diisocyanate	0.005	0.045	—	—
Isoproproxyethanol	25	106	—	—
Isopropyl acetate	250	1040	310	1290
Isopropyl alcohol	400	983	500	1230
Isopropylamine	5	12	10	24
N-Isopropylaniline	2	11	—	—
Isopropyl ether	250	1040	310	1300
Isopropyl glycidyl ether (IGE)	50	238	75	356
Kaolin, respirable dust	—	2	—	—
Ketene	0.5	0.86	1.5	2.6

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Lead, inorganic dusts and fumes, as Pb	—	0.15	—	—
Lead arsenate	—	0.15	—	—
Lead chromate				
as Pb	—	0.05	—	—
as Cr	—	0.012	—	—
Lindane	—	0.5	—	—
Lithium hydride	—	0.025	—	—
L.P.G. (Liquified petroleum gas)	1000	1800	—	—
Magnesite	—	10	—	—
Magnesium oxide fume	—	10	—	—
Malathion	—	10	—	—
Maleic anhydride	0.25	1.0	—	—
Manganese, as Mn				
Dust and compounds	—	1	—	—
Fume	—	1	—	3
Manganese cyclopentadienyl tricarbonyl, as Mn	—	0.1	—	—
Mercury				
Alkyl compounds	—	0.01	—	0.03
Aryl compounds	—	0.1	—	—
Inorganic forms including metallic mercury	—	0.025	—	—
Mesityl oxide	15	60	25	100
Methacrylic acid	20	70	—	—
Methanol (Methyl alcohol)	200	262	250	328
Methomyl	—	2.5	—	—
Methoxychlor	—	10	—	—
2-Methyoxyethanol (EGME)	5	16	—	—
2-Methoxyethyl acetate (Ethylene glycol methyl ethyl acetate, EGMEA)	5	24	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
4-Methoxyphenol	—	5	—	—
Methyl acetate	200	606	250	757
Methyl acetylene (Propyne)	1000	1640	—	—
Methyl acetylene-propadiene mixture (MAPP)	1000	1640	1250	2050
Methyl acrylate	10	35	—	—
Methylacrylonitrile	1	2.7	—	—
Methylal (Dimethoxymethane)	1000	3110	—	—
Methylamine	5	6.4	15	19
Methyl n-amyl ketone (2-Heptanone)	50	233	—	—
N-Methyl aniline	0.5	2.2	—	—
Methyl bromide	5	19	—	—
Methyl-tert butyl ether	40	144	—	—
Methyl n-butyl ketone (2-Hexanone)	5	20	—	—
Methyl chloride	50	103	100	207
Methyl 2-cyanoacrylate	2	9.1	4	18
Methylcyclohexane	400	1610	—	—
Methylcyclohexanol	50	234	—	—
0-Methylcyclohexanone	50	229	75	344
2-Methylcyclopentadienyl manganese tricarbonyl, as Mn	—	0.2	—	—
Methyl demeton	—	0.5	—	—
Methylene bisphenyl isocyanate (MDI, Diphenyl methane diisocyanate)	0.005	0.051	—	—
Methylene chloride (Dichloromethane)	50	174	—	—
4,4'-methylene bis (2-chloroaniline) [MOCA]	0.01	0.11	—	—
Methylene bis (4-cyclo-hexylisocyanate)	0.005	0.054	—	—
4,4'-Methylene dianiline	0.1	0.81	—	—
Methyl ethyl ketone (MEK, 2-Butanone)	200	590	300	885

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Methyl ethyl ketone peroxide	—	—	0.2	1.5
Methyl formate	100	246	150	368
Methyl hydrazine	—	—	0.2	0.38
Methyl iodide	2	12	—	—
Methyl isoamyl ketone	50	234	—	—
Methyl isobutyl carbinol (Methyl amyl alcohol)	25	104	40	167
Methyl isobutyl ketone (Hexone)	50	205	75	307
Methyl isocyanate	0.02	0.047	—	—
Methyl isopropyl ketone	200	705	—	—
Methyl mercaptan (Methanethiol)	0.5	0.98	—	—
Methyl methacrylate	100	410	—	—
Methyl parathion	—	0.2	—	—
Methyl propyl ketone (2-Pentanone)	200	705	250	881
Methyl silicate	1	6	—	—
αMethyl styrene	50	242	100	483
Metribuzin	—	5	—	—
Mevinphos (Phosdrin)	0.01	0.092	0.03	0.27
Mica, respirable dust	—	3	—	—
Mineral wool fiber	—	10	—	—
Molybdenum, as Mo				
Soluble compounds	—	5	—	—
Insoluble compounds	—	10	—	—
Monocrotophos	—	0.25	—	—
Morpholine	20	71	—	—
Naled (Dimethyl-1,2-dibromo-2,2 dichloroethyl phosphate)	—	3	—	—
Naphtha	300	1370	—	—
Naphthalene	10	52	15	79

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Nickel				
Metal	—	1	—	—
Insoluble compounds, as Ni	—	1	—	—
Soluble compounds, as Ni	—	0.1	—	—
Nickel carbonyl, as Ni	0.05	0.12	—	—
Nickel sulfide, as Ni	—	1	—	—
Nicotine	—	0.5	—	—
Nitrapyrin (2-Chloro-6-(trichloromethyl) pyridine)	—	10	—	20
Nitric acid	2	5.2	4	10
Nitric oxide	25	31	—	—
p-Nitroaniline	—	3	—	—
Nitrobenzene	1	5	—	—
p-Nitrochlorobenzene	0.1	0.64	—	—
Nitroethane	100	307	—	—
Nitrogen dioxide	3	5.6	5	9.4
Nitrogen trifluoride	10	29	—	—
Nitroglycerin (NG)	0.05	0.46	—	—
Nitromethane	20	50	—	—
1-Nitropropane	25	91	—	—
2-Nitropropane	10	36	—	—
Nitrotoluene	2	11	—	—
Nitrous oxide	50	90	—	—
Nonane	200	1050	—	—
Nuisance particulates	—	10	—	—
Octachloronaphthalene	—	0.1	—	0.3
Octane	300	1400	375	1750
Oil Mist, mineral	—	5	—	10
Osmium tetroxide, as Os	0.0002	0.0016	0.0006	0.0047
Oxalic acid	—	1	—	2

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Oxygen difluoride	—	—	0.05	0.11
Ozone	—	—	0.1	0.20
Paraffin wax fume	—	2	—	—
Paraquat				
Total dust	—	0.5	—	—
Respirable dust	—	0.1	—	—
Parathion	—	0.1	—	—
Pentaborane	0.005	0.013	0.015	0.039
Pentachloronaphthalene	—	0.5	—	—
Pentachloronitrobenzene	—	0.5	—	—
Pentachlorophenol	—	0.5	—	—
Pentaerythritol	—	10	—	—
Pentane	600	1770	750	2210
Perchloroethylene (Tetrachloroethylene)	25	170	100	685
Perchloromethyl mercaptan	0.1	0.76	—	—
Perchloryl fluoride	3	13	6	25
Perfluoroisobutylene	—	—	0.01	0.082
Perlite	—	10	—	—
Phenol	5	19	—	—
Phenothiazine	—	5	—	—
Phenylenediamine	—	0.1	—	—
Phenyl ether	1	7	2	14
Phenyl glycidyl ether (PGE)	0.1	0.6	—	—
Phenylhydrazine	0.1	0.44	—	—
Phenyl mercaptan	0.5	2.3	—	—
Phenylphosphine	—	—	0.05	0.23
Phorate	—	0.05	—	0.2
Phosgene	0.1	0.40	—	—
Phosphine	0.3	0.42	1	1.4

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Phosphoric acid	—	1	—	3
Phosphorus	0.02	0.1	—	—
Phosphorus oxychloride	0.1	0.63	—	—
Phosphorus pentachloride	0.1	0.85	—	—
Phosphorus pentasulfide	—	1	—	3
Phosphorus trichloride	0.2	1.1	0.5	2.8
Phthalic anhydride	1	6.1	—	—
m-Phthalodinitrile	—	5	—	—
Picloram	—	10	—	—
Picric acid (2,4,6-Trinitrophenol)	—	0.1	—	—
Pindone (2-Pivalyl-1,3-indandione)	—	0.1	—	—
Piperazine dihydrochloride	—	5	—	—
Platinum				
Metal	—	1	—	—
Soluble salts, as Pt	—	0.002	—	—
Portland cement	—	10	—	—
Potassium cyanide	—	—	—	5
Potassium hydroxide	—	—	—	2
Propargyl alcohol	1	2.3	—	—
β-Propiolactone	0.5	1.5	—	—
Propionic acid	10	30	—	—
Propoxur	—	0.5	—	—
n-Propyl acetate	200	835	250	1040
n-Propyl alcohol	200	492	250	614
Propylene dichloride (1,2-Dichloropropane)	75	347	110	508
Propylene glycol dinitrate	0.05	0.34	—	—
Propylene glycol monomethyl ether	100	369	150	553
Propylene imine	2	4.7	—	—
Propylene oxide (1,2-Epoxypropane)	20	48	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
n-Propyl nitrate	25	107	40	172
Pyrethrum	—	5	—	—
Pyridine	5	16	—	—
Quinone	0.1	0.44	—	—
Resorcinol	10	45	20	90
Rhodium				
Metal	—	1	—	—
Insoluble compounds, as Rh	—	1	—	—
Soluble compounds, as Rh	—	0.01	—	—
Ronnel	—	10	—	—
Rotenone	—	5	—	—
Rouge	—	10	—	—
Selenium and compounds, as Se	—	0.2	—	—
Selenium hexafluoride	0.05	0.16	—	—
Sesone	—	10	—	—
Silica-Amorphous				
Diatomaceous earth (uncalcined)	—	10	—	—
Precipitated silica	—	10	—	—
Silica, fume, respirable dust	—	2	—	—
Silica, fused, respirable dust	—	0.1	—	—
Silica gel	—	10	—	—
Silica-Crystalline				
Cristobalite, respirable dust	—	0.05	—	—
Quartz, respirable dust	—	0.1	—	—
Tridymite, respirable dust	—	0.05	—	—
Tripoli, respirable dust	—	0.1	—	—
Silicon	—	10	—	—
Silicon carbide	—	10	—	—
Silicon tetrahydride	5	6.6	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Silver				
Metal	—	0.1	—	—
Soluble compounds, as Ag	—	0.01	—	—
Soapstone				
Respirable dust	—	3	—	—
Total dust	—	6	—	—
Sodium azide as Hydrazoic acid	—	—	—	0.29
vapour	—	—	0.11	—
Sodium bisulfite	—	5	—	—
Sodium cyanide	—	—	—	5
Sodium fluoroacetate	—	0.05	—	—
Sodium hydroxide	—	—	—	2
Sodium metabisulfite	—	5	—	—
Starch	—	10	—	—
Stearates	—	10	—	—
Stibine	0.1	0.51	—	—
Stoddard solvent	100	525	—	—
Strontium chromate	—	0.0005	—	—
Strychnine	—	0.15	—	—
Styrene, monomer (Phenylethylene, vinyl benzene)	50	213	100	426
Subtilisins	—	—	—	0.00006
Sucrose	—	10	—	—
Sulfometuron methyl	—	5	—	—
Sulfotep	—	0.2	—	—
Sulfur dioxide	2	5.2	5	13
Sulfur hexafluoride	1000	5970	—	—
Sulfuric acid	—	1	—	3
Sulfur monochloride	—	—	1	5.5

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Sulfur pentafluoride	—	—	0.01	0.10
Sulfur tetrafluoride	—	—	0.1	0.44
Sulfuryl fluoride	5	21	10	42
Sulprofos	—	1	—	—
Talc	—	2	—	—
Tantalum, metal and oxide, as Ta	—	5	—	—
Tellurium and compounds, as Te	—	0.1	—	—
Tellurium hexafluoride	0.02	0.10	—	—
Temephos	—	10	—	—
Terephthalic acid	—	10	—	—
TEPP	0.004	0.047	—	—
Terphenyls	—	—	0.53	5
1,1,1,2-Tetrachloro-2,2-difluoroethane	500	4170	—	—
1,1,2,2-Tetrachloro-1,2-difluoroethane	500	4170	—	—
1,1,2,2-Tetrachloroethane	1	6.9	—	—
Tetrachloronaphthalene	—	2	—	—
Tetraethyl lead, as Pb	—	0.1	—	—
Tetrahydrofuran	200	590	250	737
Tetramethyl lead, as Pb	—	0.15	—	—
Tetramethyl succinonitrile	0.5	2.8	—	—
Tetranitromethane	0.005	0.04	—	—
Tetrasodium pyrophosphate	—	5	—	—
Tetryl (2,4,6-Trinitrophenyl methylnitramine)	—	1.5	—	—
Thallium, elemental and soluble compounds, as Ti	—	0.1	—	—
4,4'-Thiobis (6-tert-butyl-m-cresol)	—	10	—	—
Thioglycolic acid	1	3.8	—	—
Thioyl chloride	—	—	1	4.9
Thiram	—	1	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Tin				
Metal	—	2	—	—
Oxide inorganic compounds, as Sn	—	2	—	—
Organic compounds, as Sn	—	0.1	—	0.2
Titanium dioxide	—	10	—	—
Toluene (Toluol)	50	188	—	—
Toluene-2,4-diisocyanate (TDI)	0.005	0.036	0.02	0.14
Toluidine	2	8.8	—	—
Tributyl phosphate	0.2	2.2	—	—
Trichloroacetic acid	1	6.7	—	—
1,2,4-Trichlorobenzene	—	—	5	37
1,1,1-Trichloroethane (Methyl chloroform)	350	1910	450	2460
1,1,2-Trichloroethane	10	55	—	—
Trichloroethylene	50	269	100	537
Trichlorofluoromethane	—	—	1000	5620
Trichloronaphthalene	—	5	—	—
1,2,3-Trichloropropane	10	60	—	—
1,1,2-Trichloro-1,2,2-trifluoroethane	1000	7670	1250	9590
Triethanolamine	—	5	—	—
Triethylamine	1	4.1	5	20.7
Trifluorobromomethane	1000	6090	—	—
Trimellitic anhydride	—	—	—	0.04
Trimethylamine	5	12	15	36
Trimethyl benzene	25	123	—	—
Trimethyl phosphite	2	10	—	—
2,4,6-Trinitrotoluene (TNT)	—	0.5	—	—
Triorthocresyl phosphate	—	0.1	—	—
Triphenyl amine	—	5	—	—
Triphenyl phosphate	—	3	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3
Tungsten, as W				
Insoluble compounds	—	5	—	10
Soluble compounds	—	1	—	3
Turpentine	100	566	—	—
Uranium				
Soluble & Insoluble compounds, as U	—	0.2	—	0.6
n-Valeraldehyde	50	176	—	—
Vanadium pentoxide Respirable dust or fume	—	0.05	—	—
Vegetable oil mists	—	10	—	—
Vinyl acetate	10	35	15	53
Vinyl bromide	5	22	—	—
Vinyl chloride (Chloroethylene)	5	13	—	—
4-Vinyl cyclohexene	0.1	0.4	—	—
Vinyl cyclohexene dioxide	10	57	—	—
Vinylidene chloride (1,1-Dichloroethylene)	5	20	20	79
Vinyl toluene	50	242	100	483
Warfarin	—	0.1	—	—
Welding fumes	—	5	—	—
Wood dust				
Hard wood	—	1	—	—
Soft wood	—	5	—	10
Xylene	100	434	150	651
m-Xylene α, α1-diamine	—	—	—	0.1
Xylidine (dimethylaminobenzene)	0.5	2.5	—	—
Yttrium metal and compounds, as Y	—	1	—	—
Zinc chloride fume	—	1	—	2
Zinc chromates, as Cr	—	0.01	—	—

FIRST SCHEDULE — *continued*

Toxic Substance	*Permissible Exposure Level (PEL)*			
	PEL (Long Term)		*PEL (Short Term)*	
	ppm[a]	mg/m^3 [b]	ppm[a]	mg/m^3 [b]
Zinc oxide				
Fume	—	5	—	10
Dust	—	10	—	—
Zirconium and compounds, as Zr	—	5	—	10

Notes:

(*a*) ppm means parts of the substance per million parts of contaminated air by volume; and

(*b*) mg/m^3 means milligrammes of the substance per cubic metre of contaminated air.

Appendix E: Request for Licence/ Purchase of Scheduled Chemicals Listed under the Chemicals Weapon Prohibition Act

(OSHE/F/CS/01)

Office of Safety, Health and Environment

REQUEST FOR LICENCE / PURCHASE OF SCHEDULE CHEMICALS LISTED UNDER THE CHEMICAL WEAPON PROBITION (ACT)

Part I - To be completed by Principal Investigator

A. Requestor's Details

Name (Mr/Mdm/Ms/Dr/Assoc. Prof/Prof)	Faculty	Department
Email	Contact	Location (where NACWC is kept)

B. Details of Chemicals (Please attach Safety Data Sheet)

IUPAC Name / Common Trade name	CAS No	Purity (%)	Schedule 1A/1B/2A/2B/2C/3A/3B/ Unscheduled DOCs

Purpose (pls select one)

☐ Production ☐ Importing
☐ Consumption (and/or storage) ☐ Exporting (and/or local transfer)
☐ Processing

Quantities

_____ ug for schedule 1
_____ kg for schedule 2
_____ tne for schedule 3 & unscheduled DOCs

C. Chemical structure

D. Principal Investigator Acknowledgment

Conditions of use

1. All subsequent purchases have to notified to OSHE
2. Any changes, variations to the use, storage and disposal
3. Validation - this must be renewed on a yearly basis

I confirm that the information provided above is accurate and the risks of handling these chemical(s) have been duly communicated to the people handling it.

_____ PI's signature

_____ Date

Part II - For Official Use

NACWC License No.	OSHE Official stamp
Date:	

OSHE/F/CS/01

Note: Please click here to download the form

Appendix F: Notification of Disposal of Scheduled Chemicals Listed under the Chemical Weapons (Prohibition) Act

(OSHE/F/CS/02)

Office of Safety, Health & Environment

OSHE/F/CS/02

NOTIFICATION OF DISPOSAL OF SCHEDULED CHEMICALS LISTED UNDER THE CHEMICAL WEAPONS (PROBIHITION) ACT

Part I – To be Completed by Principal Investigator					
A. Requester's Details					
Name (Mr/ Mdm/ Ms/ Dr / Assoc. Prof / Prof)		Faculty		Department	
Contact		Email		Building & Unit Number	
B. Chemical Weapon Details					
Schedule	**IUPAC Name and Common Trade Name**	**CAS No.**	**Purity (%)**	**Amount (Kg)**	**Chemical Structure**
C. Disposal Details					
Toxic Waste Collector Name and Contact:					
Date:	Time:		Place:		
H. Acknowledgement by Head of Department					
Name (Mr/ Mdm/ Ms/ Dr / Assoc. Prof / Prof)		Signature		Contact	
Department		Email		Date	

PLEASE PASTE A PHOTOCOPY OF THE CONSIGNMENT NOTE HERE

Note: Please click here to download the form

Appendix G: List of Some Common Cytotoxic Drugs

S/N	Generic Name of Drugs	Source**
1	Aldesleukin	NIOSH
2	Altretamine	NIOSH
3	Amsacrine	NIOSH
4	Anastrozole	NIOSH
5	Arsenic trioxide	NIOSH
6	Asparaginase	NIOSH
7	Azacitidine	NIOSH
8	Azathioprine	IARC Group 1
9	Bendamustine Hydrochloride	NIOSH
10	Bexarotene	NIOSH
11	Bicalutamide	NIOSH
12	Bleomycin	NIOSH, IARC Group 2B
13	Bortezomib	NIOSH
14	Busulfan	NIOSH
15	Capecitabine	NIOSH
16	Carboplatin	NIOSH
17	Carmustine	NIOSH, IARC Group 2A
18	Chlorambucil	NIOSH
19	Chlornaphazine	IARC Group 1
20	Chlorozotocin	IARC Group 2A
21	Cisplatin	NIOSH
22	Cladribine	NIOSH
23	Clofarabine	NIOSH
24	Cyclophosphamide	NIOSH
25	Cytarabine	NIOSH
26	Dacarbazine	NIOSH
27	Dactinomycin	NIOSH
28	Dasatinib	NIOSH
29	Daunorubicin Hydrochloride	NIOSH, IARC Group 2B
30	Decitibine	NIOSH
31	Degarelix	NIOSH
32	Denileukin Diftitox	NIOSH
33	Diethylstilbestrol	IARC Group 1
34	Docetaxel	NIOSH
35	Doxorubicin Hydrochloride	NIOSH
36	Epirubicin	NIOSH
37	Estramustine phosphate	NIOSH
38	Etoposide	NIOSH
39	Everolimus	NIOSH

S/N	Generic Name of Drugs	Source**
40	Exemestane	NIOSH
41	Floxuridine	NIOSH
42	Fludarabine	NIOSH
43	Fluorouracil	NIOSH
44	Flutamide	NIOSH
45	Fulvestrant	NIOSH
46	Gemcitabine	NIOSH
47	Gemtuzumab ozogamicin	NIOSH
48	Goserelin	NIOSH
49	Hydroxycarbamide or Hydroxyurea	NIOSH
50	Idarubicin	NIOSH
51	Ifosfamide	NIOSH
52	Imatinib mesylate	NIOSH
53	Irinotecan Hydrochloride	NIOSH
54	Ixabepilone	NIOSH
55	Letrozole	NIOSH
56	Leuprolide acetate	NIOSH
57	Lomustine	NIOSH, IARC Group 2A
58	Mechlorethamine Hydrochloride	NIOSH
59	Medroxyprogesterone acetate	IARC Group 2B
60	Megestrol	NIOSH
61	Melphalan	NIOSH
62	Mercaptopurine	NIOSH
63	Methotrexate	NIOSH
64	Methoxsalen	IARC Group 2A
65	Mitomycin C	NIOSH
66	Mitotane	NIOSH
67	Mitoxantrone Hydrochloride	NIOSH
68	Nelarabine	NIOSH
69	Nilotinib	NIOSH
70	Nilutamide	NIOSH
71	Nitrogen mustard, n-oxide	IARC Group 2B
72	Oxaliplatin	NIOSH
73	Paclitaxel	NIOSH
74	Pazopanib Hydrochloride	NIOSH
75	Pegaspargase	NIOSH
76	Pemetrexed	NIOSH
77	Pentostatin	NIOSH
78	Pipobroman	NIOSH
79	Pralatrexate	NIOSH
80	Procarbazine	NIOSH
81	Romidepsin	NIOSH
82	Semustine	IARC Group 1
83	Sorafenib	NIOSH

S/N	Generic Name of Drugs	Source**
84	Streptozocin	NIOSH
85	Sunitinib malate	NIOSH
86	Tamoxifen	NIOSH
87	Temozolomide	NIOSH
88	Temsirolimus	NIOSH
89	Teniposide	NIOSH
90	Testolactone	NIOSH
91	Thioguanine	NIOSH
92	Thiotepa	NIOSH
93	Topotecan	NIOSH
94	Toremifene citrate	NIOSH
95	Treosulfan	IARC Group 1
96	Trichlormethine (Trimustine Hydrochloride)	IARC Group 2B
97	Triptorelin	NIOSH
98	Uracil mustard	NIOSH, IARC Group 2B
99	Valrubicin	NIOSH
100	Vinblastine sulfate	NIOSH
101	Vincristine sulfate	NIOSH
102	Vinorelbine tartrate	NIOSH
103	Vorinostat	NIOSH

**References:

(a) NIOSH: Agents listed as “Antineoplastic agents” in the “NIOSH list of antineoplastic and other hazardous Drugs in Health care Settings” (http://www.cdc.gov/niosh/docs/2012-150/)

(b) IARC: Cytotoxic drugs classified by the International Agency for Research on Cancer - IARC (http://www.lrws.gov.sk.ca/cytotoxic-drugs)

Appendix H: Cytotoxic Drugs Risk Assessment Methodology

Evaluation of Severity:

The severity for exposure to cytotoxic drugs shall be evaluated based on the potential health effects that may result from exposure in respective laboratory work settings of the research group. Users shall take into consideration the information available in any available published literature sources (such as published books, research papers, safety data sheets, etc) and also the quantity of cytotoxic drug being used in the work activity to evaluate the potential health effects. Thus, the inclusion of a cytotoxic in **Appendix G** does not automatically qualify the agent to be in the 'High' severity category, since the quantity being used may be very small, and below the amounts documented to cause life-threatening diseases or serious injuries. The severity level shall then be determined according to the following table:

Severity	Guidelines
Low	No injury, injury or ill-health requiring basic medical treatment only - includes ill-health with temporary discomfort
Medium	Injury requiring medical treatment or ill-health leading to disability, includes rashes, dermatitis, deafness, work-related upper limb disorders
High	Fatal, serious injury or life-threatening occupational disease, includes occupational cancer, acute poisoning and fatal diseases

**Table referenced from NUS Activity-based Risk Assessment Risk Ranking Guide.*

Evaluation of Likelihood:*

The likelihood of exposure refers to the possible occurrence of accidental exposure *after* appropriate Safety Control Measures (see Section 3 below) have been put in place. The following table can be used as a general guideline for evaluating the likelihood:

Likelihood	Guidelines
Unlikely	Exposure will possibly recur; could occur at some time in 2 to 5 years
Possible	Exposure will probably recur; might occur at some time (yearly)
Very Likely	Exposure will probably occur in most circumstances (daily/weekly/monthly)

**Table referenced from "Safe Handling of Cytotoxic Drugs and Related Wastes: Guidelines for South Australian Health Services 2012", SA Health, Government of South Australia.*

Determination of Risk Level and Action Required

After determining the severity rating and the likelihood rating, the risk rating can be determined by multiplying the two together:

Risk Rating = Severity Rating x Likelihood Rating

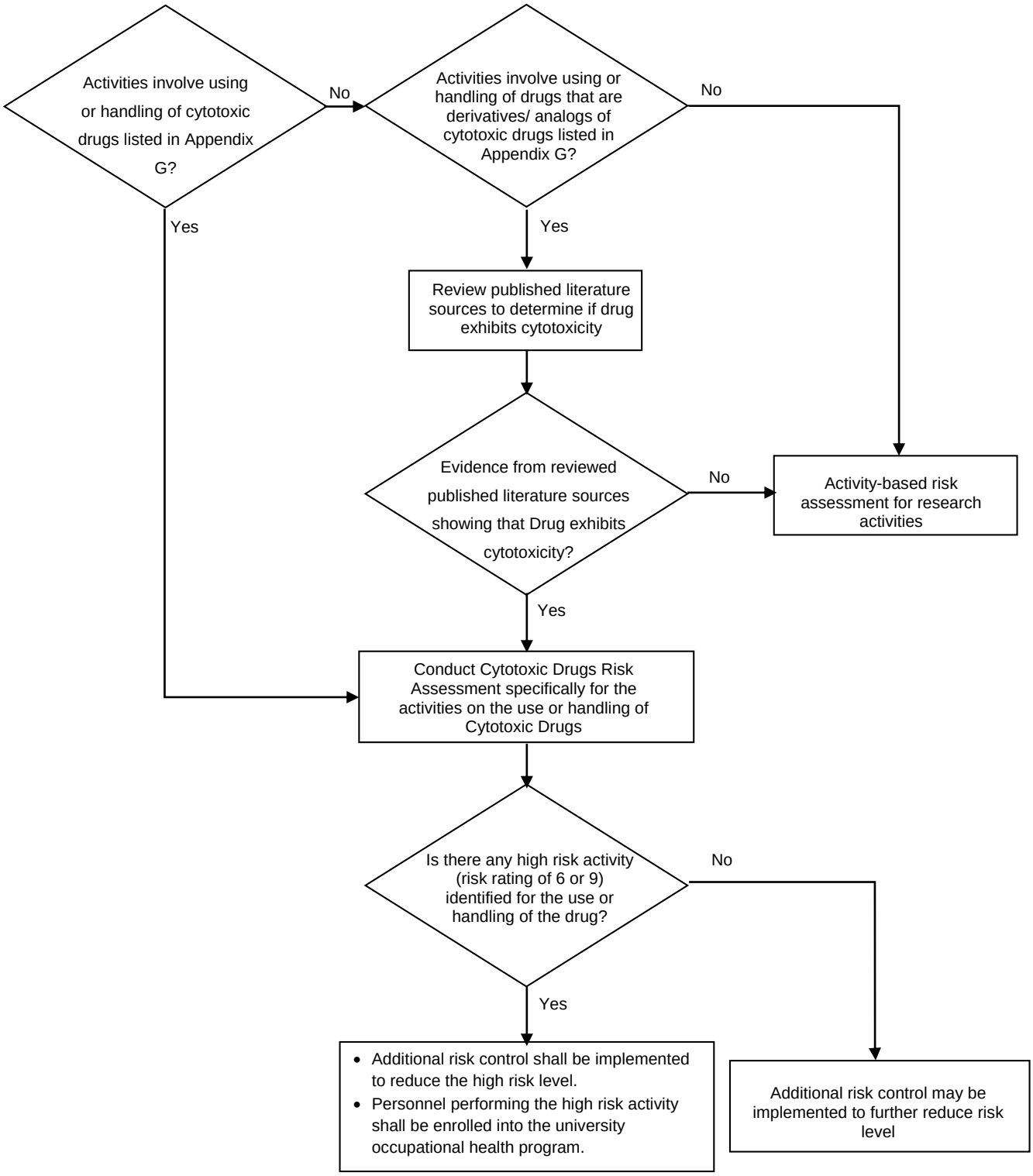
The various possible values of the risk are provided in the table below:

		LIKELIHOOD		
		Very Likely	Possible	Unlikely
SEVERITY	Low	3	2	1
	Med	6	4	2
	High	9	6	3

The next step would be to evaluate whether the risk is acceptable and whether any additional safety control measures need to considered or implemented. The following table can be used as a guide:

RISK RATING	DECISION PROCESS
1 or 2	**RISK ACCEPTABLE**
3 or 4	**CONSIDER ADDITIONAL SAFETY CONTROL MEASURES**
6 or 9	**ADDITIONAL SAFETY CONTROL MEASURES REQUIRED**

Appendix I: Cytotoxic Drugs Risk Assessment Methodology



Appendix J: Determining Need for Industrial Hygiene Air Monitoring For Laboratories through Semi-Quantitative Risk Assessment (SQRA)

Adapted from "*A Semi quantitative Method to Assess Occupational Exposure to Harmful Chemicals"* published by Ministry of Manpower

NOTE: Alternatively, a pre-filled-up template can be downloaded from OSHE website.

STEP 1: IDENTIFY CHEMICALS

Identify all the chemicals (as listed in the WSH (General Provisions) Regulations or from the selection list in OSHE's SQRA template) that are used or produced, e.g. raw materials, intermediates, main products and secondary products. A chemical might be in the form of a solid, liquid, gas, vapour, dust, mist or fume. All chemicals must be included regardless of any control that may be in place.

The presence of chemicals may be identified by:

- looking at the stock lists, inventories, registers, safety data sheets (SDS) and container labels
- inspecting all locations where chemicals are stored or used
- considering the substances that may be produced during any work process as intermediates,
- by-products, finished products or given off as wastes, residues or fugitive emissions
- considering all substances that are used, or may arise from work such as maintenance and repair, cleaning or testing.

For each work process or task identified, list the chemical(s) involved using pre-filled up template "GP Listed Chemical Worksheet".

STEP 2: DETERMINATION OF HAZARD RATING

Having identified the chemicals used or present, the next step is to determine if they are toxic or harmful to health. The hazard of a chemical depends on its toxicity, routes of exposure and other factors.

The hazard rating can be determined from the toxic or harmful effects of the chemical (Table 1). Alternatively, the rating can be determined from the acute toxicity of the chemical in terms of lethal dose (LD50) and lethal concentration (LC50) – Table 1A. Information on the toxic effects of a chemical, its LD50 and LC50 can be obtained from the SDS.

Table 1 : Hazard Rating		
	Description of Effects/Hazard Category	**Example of chemicals**
1	− No known adverse health effects − ACGIH* A5 carcinogens − −Not classified as toxic or harmful	sodium chloride, butane, butyl acetate, calcium carbonate
2	− Reversible effects to the skin, eyes or mucous membranes, not severe enough to cause serious health impairment − ACGIH A4 carcinogens − Skin sensitisers and skin irritants	acetone, butane, acetic acid (10% concentration), barium salts, aluminium dust
3	− Possible human or animal carcinogens or mutagens, but for which data is inadequate − ACGIH A3 carcinogens − IARC* Group 2B − Corrosive (pH 3 to 5 or 9 to 11) , respiratory sensitizers, harmful chemicals	toluene, xylene, ammonia, butanol, acetaldehyde, acetic anhydride, aniline, antimony
4	− Probable human carcinogens, mutagens or teratogens based on animal studies − ACGIH A2 carcinogens − NTP* Group B − IARC Group 2A − Very corrosive (pH 0 to 2 or 11.5 to 14) − Toxic chemicals,	formaldehyde, cadmium, methylene chloride, ethylene oxide, acrylonitrile, 1, 3butadiene
5	− Known human carcinogens, mutagens or teratogens − ACGIH A1 carcinogens − NTP Group A − IARC Group 1 − Very toxic chemicals	benzene, benzidine, lead, arsenic, beryllium, bromine, vinyl chloride, mercury, crystalline silica

Table 1A – Hazard Rating by Acute Toxicity				
	LD50 absorbed orally in rat mg/kg body weight	**LD50 dermal absorption in rat or rabbit mg/kg body weight**	**LC50 absorbed by inhalation in rat, mg/litre per 4 h Gases and Vapours**	**LC50 absorbed by inhalation In rat, mg/litre per 4 h Aerosols and particulates**
2	> 2000	> 2000	> 20	> 5
3	> 200 to ≤ 2000	> 400 to ≤ 2000	> 2.0 to ≤ 20	> 1 to ≤ 5
4	> 25 to ≤ 200	> 50 to ≤ 400	> 0.5 to ≤ 2.0	> 0.25 to ≤ 1
5	≤ 25	≤ 50	≤ 0.5	≤ 0.25

Determine the hazard rating (HR) of each chemical identified and record it in pre-filled up template “GP Listed Chemical Worksheet” .

STEP 3 CONDUCTING WORK INSPECTION AND INTERVIEWS

Conduct a 'walk-through' inspection according to the work tasks listed in pre-filled up template and interview the staff.

The aim of the interview is to find out if all the tasks are listed and whether all the staff groups are accounted for. In order to assess whether the staff are exposed to toxic or harmful chemicals, it is important to talk to the employees regarding their work practices and procedures.

If a new job, process or work unit is being planned but not yet in operation, evaluation of the relevant work process, plan or design is required, and it should be included in the pre-filled up template.

STEP 4 DETERMINE FREQUENCY AND DURATION OF EXPOSURE

For staff who are or might be exposed to toxic or harmful chemicals, estimate the degree of exposure, taking into account the level, frequency and duration of exposure, as well as the different routes of exposure.

There are five factors that determine the exposure rating. These are:

1) vapour pressure or particle size
2) detectable odour/permissible exposure level ratio
3) existing hazard control measures
4) amount of chemical used and,
5) duration of work per week.

However, *not all the factors will be utilized in a risk assessment*, depending on whether the parameters are available.

The **EXPOSURE RATING (ER)** can be determined from the **EXPOSURE INDEX (EI)** using the following equation:

$$ER = \lceil EI_1 \ x \ EI_2 \ \ldots\ldots x \ EI_n \rceil^{\frac{1}{n}}$$

Where, n is the number of exposure factors used.

The exposure indexes are rated on a five-scale rating from 1 to 5 in an increasing order of magnitude i.e. 1 means very low, 5 means very high and 3 is medium.

Table 3: Exposure Factors and Index

Exposure Index / Exposure Factor	1	2	3	4	5
Vapour pressure or particle size (aerodynamic diameter)	< 0.1 mmHg	0.1 to 1 mmHg	>1 to 10 mmHg	> 10 to 100 mmHg	>100 mmHg
	Coarse, bulk or wet material	coarse and dry material	dry and small particle size > 100 µm	dry and fine material 10 to 100 µm	dry and fine powdered material < 10 µm
Ratio of *OT/PEL (TLV)	<0.1	0.1 to 0.5	> 0.5 to 1	>1 to 2	≥2
Hazard control measure	Adequate control with regular maintenance	Adequate control with irregular maintenance	Adequate control without maintenance ; moderately dusty	Inadequate control; dusty	No control at all; very dusty
Amount used per week	Almost negligible amount used (< 1 kg or l)	Little amount used (1 to <10 kg or l)	Medium amount used, workers are trained on handling the chemical (10 to < 100 kg or l)	Large amount used, workers are trained on handling the chemical (100 to 1000 kg or l)	Large amount used, workers are not trained on handling the chemical (> 1000 kg or l)
Duration of work per week	<8 hrs	8 to 16 hrs	16 to 24 hrs	24 to 32 hrs	32 to 40 hrs

* Odour threshold (OT) divided by the permissible exposure level (PEL) or Threshold Limit Value (TLV). Refer to ***Annex A*** , ***Appendix D*** (for PEL) and SDS (for TLV)

For liquids:

In the first row of the above Table, when the chemical is a liquid at room temperature, its exposure hazard depends on its vapour pressure which can be obtained from the SDS. Vapour pressure depends on temperature. When the liquid is at a different temperature from the one stated in the SDS, its vapour pressure can be determined using the Antoine equation.

$$\log_{10} P = A - \frac{B}{C + T}$$

where p is the vapour pressure, T is temperature and A, B and C are component-specific constants.

For solids:

When the chemical is a solid, its inhalation hazard depends on the size of the solid particles. This might require an onsite judgment. The particle size refers to its aerodynamic diameter, and is given by this formula:

$$Da = Dp\sqrt{sg}$$

where
Da = aerodynamic diameter
Dp = diameter of the particle
sg = specific gravity of the bulk chemical

The exposure rating depends on the permissible exposure level and the detectable odour threshold (second row) of the specific chemical. They can be found in ***Annex A*** and ***Appendix D*** respectively.

The likelihood of exposure to a chemical is largely determined by the presence of engineering control measures and their effectiveness. A properly designed and well-constructed local exhaust system will greatly reduce the exposure risk, whereas an open process or poorly designed and maintained system can result in high exposures. The differences are reflected in the hazard control measure ratings (third row of Table 3). Examples of adequate control measures are process containment or enclosure with no direct contact, no visible contaminant release or emission, adequate capture velocity. ***NOTE: The provision of personal protective equipment is not a form of control in this context.***

The degree of exposure to a chemical also depends on the amount of chemical used and the duration of work or exposure. These are shown in the fourth and fifth rows of Table 3 respectively. A weekly work shift (usually 40 hours) is used as the basis for assigning exposure rating as the PEL values are based on 40-hour exposures.

Example, fine powdered silica dust (EI = 5) is generated during weighing and this task takes 1 hour per day or 7 hours per week (EI = 1). There is moderate dust by visual inspection (EI = 3). The amount used is little (EI = 2).

ER =(5 x 3 x 2 x 1)1/4 = 2.3

STEP 5: EVALUATION OF RISK

The risk can be expressed in the following form:

$$Risk = \sqrt{(HR\ x\ ER)}$$

where

HR = hazard rating on the scale of 1 to 5 (see Table 1)

ER = exposure rating on the scale of 1 to 5

The square root is to limit the risk value within the scale of 1 to 5. When the risk rating is not a whole number, it should be rounded up to the nearest whole number.

Example. HR = 4, ER = 3

$$Risk = \sqrt{(4\ x\ 3)} = 3.5\ (round\ up\ to\ 4)$$

Determine the risk of each task and rank it in accordance with the following Table:

Risk Level	
1	Negligible Risk
2	Low Risk
3	Medium Risk
4	High Risk
5	Very High Risk

Alternatively, the matrix below can be used to determine the risk level.

ER \ HR	1	2	3	4	5
1	1 .4	1.4	1. 7	2	2.2
2	1. 4	2	2. 4	2. 8	3.2
3	1. 7	2. 4	3	3. 5	3.9
4	2	8	3. 5	4	4. 5
5	2. 2	3.	3.	4. 5	5

Negligible Risk
Low Risk
Medium Risk
High Risk
Very High Risk

The risk rating scaling of 1 to 5 is in increasing order of magnitude. Rating of 1 implies negligible risk and a rating of 5 implies very high risk. Record the risk rating and rank it.

This ranking will enable a prioritization of action plans to reduce the risk of exposure. The Risk Levels should be recorded in pre-filled-up template.

STEP 6: DETERMINE NEED FOR AIR MONITORING

If the semi-quantitative assessment indicates a negligible (Risk Rating = 1) or low risk (Risk Rating = 2) of exposure, no further action (such as quantitative monitoring or the implementation of additional control measures) is required.

For unacceptable exposure risk (Risk Rating > 2), or if exposure risk is uncertain, a quantitative exposure assessment is required.

	Risk Level	
1	Negligible	No need for air monitoring
2	Low	No need for air monitoring
3	Medium	Request for air monitoring
4	High	Request for air monitoring
5	Very High	Request for air monitoring
	Uncertain	Request for air monitoring

In addition to air monitoring, if the assessment shows that there is a significant risk to health, the additional control measures appropriate should be taken to reduce the risk.

Instructions for pre-filled Semi-Quantitative Risk Assessment (SQRA) template of occupational exposure to harmful chemicals.

NOTE: Not all the exposure factors will be utilized in a risk assessment, depending on whether the parameters are available.

1. For Chemicals listed in the WSH (General Provisions) Regulations, please use GP LISTED CHEMICALS Worksheet
    a. Fill in the Department, Location and Process the chemical is used
    b. Under the Chemical column, please select the chemical name from the drop-down list
        b.1) The Hazard Rating will be automatically filled-up
        b.2) For Liquids or Gases, the Vapour Pressure Index will be automatically filled-up, if available
        b.3) For SOLIDS, please select particle size from the drop-down list; the Particle Size Index will be filled-up.
        b.4) The Odour Threshold/Permissible Exposure Limit Index will be automatically filled-up, if available

c. Select EXISTING CONTROL MEASURES from the drop down menu

d. Select DURATION OF EXPOSURE PER WEEK from the drop down menu

e. Select AMOUNT USED PER WEEK from the drop down menu

f. The Risk Level will be automatically computed.

2. For Other Chemicals of Concern not listed in the WSH (General Provisions) Regulations, please use CHEMICALS OF CONCERN Worksheet

   NOTE: Refer to the Safety Data Sheet for chemical information or visit the International Occupational Safety and Health Information Centre for International Chemical Safety Cards (ICSC) or US CDC NIOSH Pocket Guide to Chemical Hazards (NPG)

   a. Fill in the Department, Location and Process the chemical is used
   b. Fill in the Chemical Name
   c. Select HAZARD DESCRIPTION from the drop-down list; The Hazard Rating will be automatically filled-up
   d. Select VAPOUR PRESSURE (for liquids/gases) or PARTICLES SIZE (for solids) from the drop down menu; the Vapour Pressure/Particle Size Index will be automatically filled-up
   e. If available, select ODOUR THRESHOLD / THRESHOLD LIMIT VALUE RATION from the drop-down list. The Odour Threshold/Permissible Exposure Limit Index will be automatically filled-up.
   f. Select EXISTING CONTROL MEASURES from the drop down menu; the Hazard Control Index will be automatically filled-up.
   g. Select DURATION OF EXPOSURE PER WEEK from the drop down menu; the Duration of Exposure Index will be automatically filled-up.
   h. Select AMOUNT USED PER WEEK from the drop down menu; The Amount Used Index will be automatically filled-up.
   i. The Risk Level will be automatically computed.

Appendix K: Request for Industrial Hygiene Monitoring Form

(OSHE/F/EM/01)

Office of Safety, Health & Environment
OSHE/F/EM/01
REQUEST FOR INDUSTRIAL HYGIENE AIR MONITORING FORM

To be Completed by Requester			
A. Requester's Details			
Name (Mr/ Mdm/ Ms/ Dr)	Faculty	Department	
Contact	Email	Building & Unit Number	
B. Purposes of Request			
☐Baseline Data	☐ Scheduled Periodic Monitoring	☐Chemicals of concern (please provide details on a separate sheet)	☐Others (please specify):

C. Sampling Point Details ***(Please attach Semi-Quantitative Risk Assessment Results and layout of area(s) to be monitored)***

No.	Dept	Location to be monitored	Process, work aor operation	Substances to be monitored	Total number of people exposed	Date of assessment (depend on availability of process)	Remarks
1.							
2.							
3.							

D. Acknowledgement by Principal Investigator			
Name (Mr/ Mdm/ Ms/ Dr)	Signature	Contact	
Department	Email	Date	

Note: Please click here to download the form

Appendix L: Application form for Occupational Health Services

Section B: Reviewed by Faculty/Institute/Department* Safety and Health Officer
(Optional as required by PI or Lab Supervisor)

The request for the above medical assessment/management is

☐ Approved

☐ Not Approved

Name of Safety & Health Officer	Signature	Date
_____	_____	_____

Section C: Approval by PI or Supervisor
(PI endorsement is not needed for work-related injury or illness)

Name:	**Department/Program:**
Contact no: **NUS Email Address:**	**Invoice Mailing Address:**

The request for the above medical assessment/management is

☐ Approved

☐ Not Approved

We agree to undertake payment for the above medical assessment/management.

Signature of PI or Supervisor	**Date**
_____	_____

BILLING PARTICULARS
(Please fill in particulars of the staff for which invoice is to be sent to – if different from PI or Lab Supervisor)

Name: _____ **NUS Email Address:** _____

Tel: _____ **Invoice Mailing Address:** _____

Note: Please click here to download the form

Appendix M: Guidelines on the Selection of Laboratory Coats

Personal Protective Equipment (PPE) is the last line of defense against laboratory hazards. Risk assessment has to be conducted to identify the hazards associated and to determine the type of control measures required including the type of PPE. Whenever feasible, hazards must be eliminated through engineering, and/or administrative controls, prior to resorting to the use of PPE.

In general protective clothing such as lab coats, prevents skin and street clothing from incidental contact with hazardous substances and from physical hazards such as fire. It prevents the spread of contamination outside the lab and also serves as a removal barrier in case of spill or splash of hazardous substances.

Different activity requires different level of protective clothing. It is essential to choose the right protective clothing based on the hazards identified by conducting risk assessment. Some of the key factors to consider while choosing laboratory coats are as follows:

1. **Sleeves**

   Loose fitting sleeves should be avoided as they can knock over chemical containers, catch fire easily and forearms are easily exposed to hazardous substances. Properly fitted cuffed sleeves will ensure that sleeves stay in place and forearms are covered at all times, preventing direct contact with hazardous substances. Cuffs may by either knitted or elastic.

Fig 1: Short lab coat sleeve exposing forearms

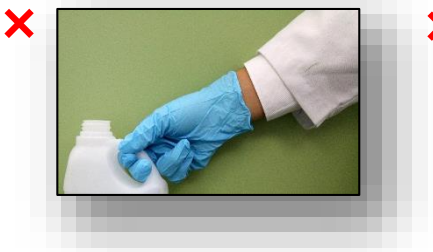


Fig 2: Loose lab coat sleeve knocking chemical container

Fig 3: Knitted lab coat sleeve

Fig 4: Elastic cuff sleeve

2. Fastening

Fully buttoned type of fastening are commonly used in lab coats. However, this type of lab coat cannot be removed quickly. For easy removal of lab coats in case of contamination or fire, fastening such as snap closure or Velcro may be used. Do note that Velcro may degrade over time.

3. Appropriate material

Lab coats are available in various fabrics and the choice of lab coat depends on the hazards identified in the activity.

One lab coat may not be sufficient for all activities in the lab. For example, a basic cotton/polyester blend lab coats may be generally used in lab, however for activities involving pyrophoric materials or highly flammable chemicals or open flame, fire resistant lab coat will be required. Chemical resistant apron has to be worn over lab coat, if there is possibility of chemical splash.

Below table provides information on some of the fabrics available and their limitations. You may use the table as a guide to determine the best fabric for your activity.

Fabric type	Features	Limitations
Cotton/Polyester blend. (Includes 100% polyester, 80/20 or 65/35)	Commonly used. Offers better splash resistance than cotton.	i. When exposed to a flame, or contaminated with pyrophoric substances, due to polyester content they burn very readily, melt and stick to the body, causing severe burns.
100 % Cotton	Commonly used. Comfortable.	i. When exposed to a flame, or contaminated with pyrophoric substances, burns easily. ii. Readily absorbs fluids
Flame Resistant Fabrics		
Flame resistant treated	Appropriate for labs where	i. The flame retardant properties may

cotton *(Cotton fabric treated with cotton coats are available that are treated with a fire-resistant material)* *E.x Bulwark Excel FR* 	there may be a significant fire hazard, with an understanding of the limitations of the testing criteria for flame resistance.**	dissipate after repeated laundering. ii. May not be fluid resistant, not generally tested for chemical resistance.
Dupont Nomex *Nomex (IIIA) Flame resistant lab coats* 	Highly fire- resistant providing inert barrier between the fire and skin, protecting the wearer from direct exposure. Self-extinguish when exposed to a flame of short duration during testing. Inherent thermal protection that cannot be washed away. Durable and resistant to abrasion, tears, and chemicals. Appropriate for use with pyrophoric liquids and large quantities of flammable liquids where risk of fire is present.	No specific testing information on chemical resistance could be found.
Kimberly-Clark Professional™ KleenGuard	Designed for use in areas where exposure to sparks	Disposable lab coats, usually suitable for one

A65 	or flame is possible. Comfortable, breathable and durable fabric resist tearing.	time use.
Dupont Tychem Thermopro 	Offers triple hazard protection • Chemicals • Flash fire • Electric arc	Available only in coveralls, apron, jacket overalls type of garment design.
Splash resistant fabrics		
Splash resistant fabrics *Example: Neoprene*  *Example: Nitrile* 	Resistant to solvents and corrosive chemicals.	If chemical resistant aprons are used, it shall be worn over lab coat.

* Please contact manufacturer for detailed information.

** The term “flame resistant” refers to the characteristic of a fabric that causes it not to burn in air. The testing criteria involves applying an open flame to the bottom edge of a strip of fabric in a test chamber for 12 seconds and then looking at char length, after

flame, and after glow, testing the self-extinguishing properties of the fabric. The flame resistance test criteria were intended to simulate circumstances of a flash fire, or electric arc flash, not a chemical fire.

Some of the vendors supplying different types of lab coat in Singapore:

- **Sigma-Aldrich Pte Ltd**
  Tel **:** (65) 6779 1200
  Fax : (65) 6779 1822
  E-mail : sapl@sial.com

- **Fischer Scientific Pte Ltd**
  Tel **:** (65) 6873 6006
  Fax **:** (65) 6873 5005
  Email : Enquiry.sg@thermofisher.com

- **PDS International Pte Ltd**
  Tel **:** (65) 6776 6200
  Fax **:** (65) 6776 6882
  E-mail **:** pds@safety.com.sg

- **Flemings Safety Pte Ltd**
  Tel : (65) 6442 7383
  Fax : (65) 6442 0872
  Email : sales@flemings-safety.com

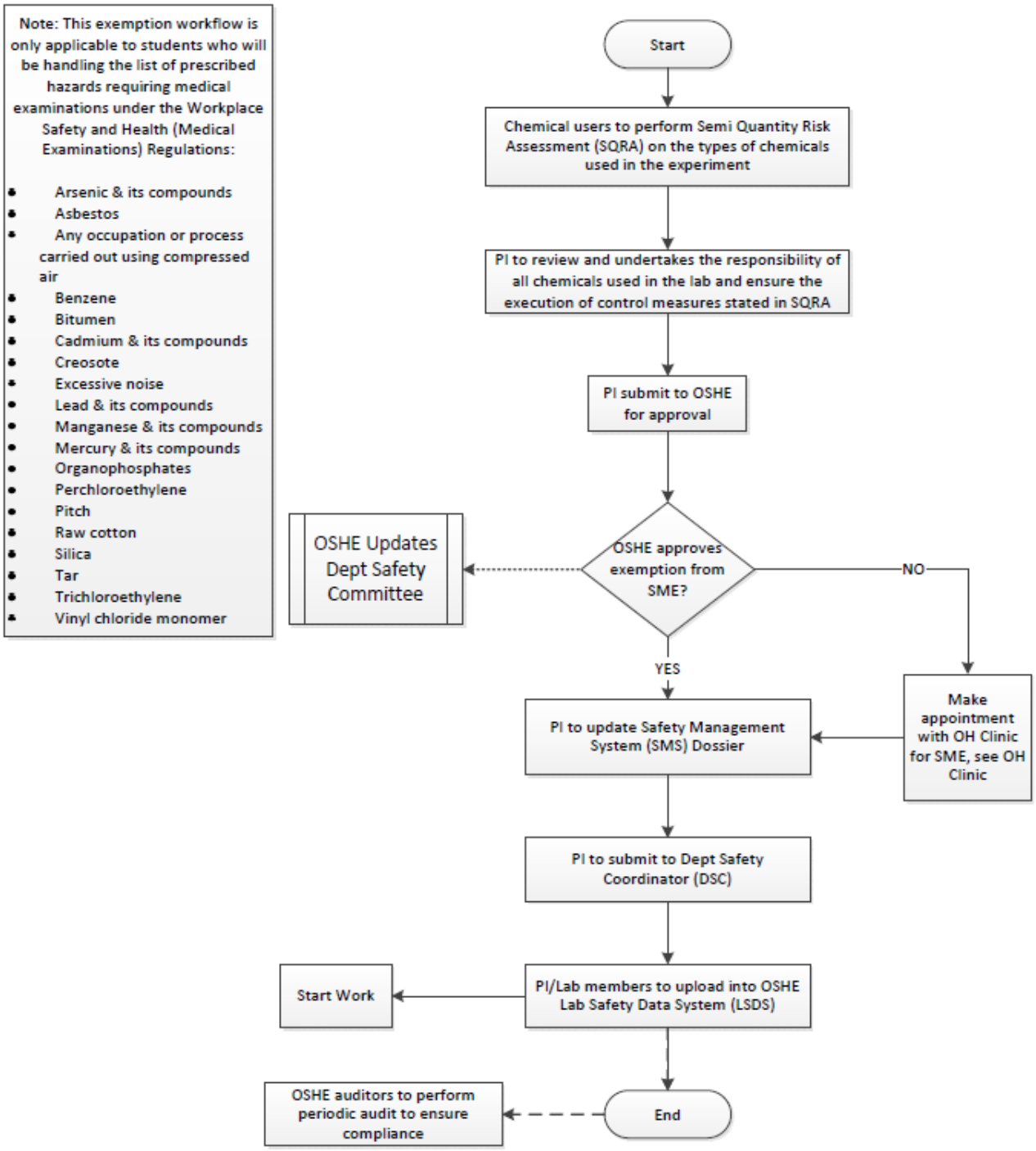
- **NUS CO-OP** (Note: Custom ordering needs to be placed including requesting the specific type of fabric).
  Person in-charge: Mrs. Lee
  Tel : (65) 6776 6145
  Fax : (65) 6779 6816
  Email :Copfos1@nus.edu.sg

4. Fit

Proper fit is essential for adequate body protection and comfort. No one size fits all, custom tailoring may be required in order to ensure that lab coat

(a) length is below knee level
(b) sleeves length covers the entire forearm and
(c) lapel should close to collar to provide optimal protection.

Appendix N: Workflow for Exemption from Statutory Medical Examinations for Students



References:

1. *Massachusetts Institute of Technology, Environmental Health & Safety, Lab Coat Selection, Use, and Care Guide*
2. *University of California, Los Angeles, Office of Environmental Health & Safety, PPE Selection Guide*
3. *University of Pennsylvania, Environmental Health & Safety, Personal Protective Equipment (PPE) Program*
4. *Harvard University, Environmental Health & Safety, PPE Selection Guide by Task*
5. *National Institutes of Health, United States, Division of Occupational Health and Safety, Chemical Hygiene Plan*
6. *Yale University, Environmental Health & Safety, Personal Protective Equipment Policy*
7. *Duke University, Environmental Health & Safety, General Health & Safety, PPE Selection Guidelines and Quick Reference Guide*
8. *Stony Brook University, Environmental Health & Safety, Laboratory Safety, Personal Protective Equipment Selection Guide*
9. *Dupont, Protective Clothing Selector Tool*
10. *DuPont™ Thermo-Man® Demonstration*

11. *Dupont - Flame Resistant Clothing Made with Nomex®*
12. *Dupont Personal Protection – Thermal technical Bulletin*

15 LIST OF ANNEXES

Annex A: Odour Thresholds and Irritation Concentration of Chemicals

Odour Thresholds and Irritation Concentrations of Chemicals

Chemical Compound	Low Odour mg/m3	High Odour mg/m3	Description of Odour	Irritating Concentration mg/m3
Acetaldehyde	0.0002	4	Green, sweet, fruity	90
Acetic acid	2.5	250	Sour, vinegar-like	25
Acetic anhydride	0.6	1.5	Sharp odour, sour acid	20
Acetone	48	1,614	Minty chemical, sweet	475
Acetonitrile	70	70	Ether-like	875
Acrolein	0.05	38	Burnt, sweet	1.3
Acrylic acid	0.3	3	Rancid, sweet	-
Acrylonitrile	8	79	Onion-garlic pungency	-
Allyl alcohol	2	5	Pungent, mustard	13
Allyl chloride	1.4	75	Green, garlic, onion	75
Allyl glycidyl ether	44	44	Sweet	1,144
Ammonia	0.03	40	Pungent, irritating	72
Aniline	0.0002	350	Pungent, amine-like	-
Arsine	0.8	2	Garlic-like	-
Benzene	4.5	270	Sweet, solventy	9,000
Boron trifluoride	4.5	4.5	Pungent, irritating	-
Bromine	0.3	25	Bleachy, penetrating	2
1,3-Butadiene	0.4	3	**Mild,aromatic**	
n-Butyl acetate	33	95	Fruity	473
n-Butyl alcohol	0.4	150	Sweet	75
Butyl cellosolve	0.5	288	Sweet, ester	-
Butyl cellosolve acetate	0.7	1.3	Sweet, ester	-
Carbon disulfide	0.02	23	Disagreeable, sweet	-
Carbon tetrachloride	60	128	Sweet, pungent	-
Cellosolve	2	185	**Sweet, pleasant**	-
Cellosolve acetate	0.3	270	Sweet, musty	-
Chlordane	0.008	0.04	**Pungent, chlorine-like**	-
Chlorine	0.03	15	Bleachy, pungent	9
Chlorine dioxide	0.3	0.3	Sharp, pungent	15
Chlorobenzene	1	280	Sweet, almond-like	933
Chloroform	250	1,000	**Sweet,pleasant**	20,480
Cresol	0.001	22	Sweet, creosote, tar	-
Cumene	0.04	6	Sharp, aromatic	23
Cyclohexane	1.4	1.4	Sweet, aromatic	1,050
Cyclohexanol	400	400	Camphor-like	200
Cyclohexanone	0.5	400	Sweet, peppermity	100

Diborane	2	4	Repulsively sweet	-
o-Dichlorobenzene	12	300	**Pleasant,aromatic**	150
p-Dichlorobenzene	90	180	Mothballs	240
Dichloroethane	446	810	Chloroform-like	-
Diethylamine	0.06	114	Fishy, ammonical	150
Diisobutyl ketone	0.7	2	Sweet, ester	150
Dimethyl formamide	300	300	**Fishy,unpleasant**	-
1,1-Dimethylhydrazine	12	20	Ammonical, amine-like	-
1,4-Dioxane	0.01	612	Ethyl-like	792
Epichlorohydrin	50	80	Chloroform-like	325
Ethanolamine	5	11	Ammonia	13
Ethyl acetate	0.02	665	Fruity, pleasant	350
Ethyl alcohol	0.3	9,690	Sweet, alcoholic	9,500
Ethyl amine	0.5	396	Sharp, ammonical	180
Ethyl benzene	9	870	aromatic	870
Ethyl ether	1	3	Sweet, ether-like	300
Ethyl mercaptan	3×10^{-5}	0.09	Garlic	-
Ethylene diamine	2.5	28	Ammonical, musty	250
Ethylene dibromide	77	77	Mild, sweet	-
Ethylene dichloride	24	440	sweet	-
Ethylene glycol	63	63	sweet	-
Ethylene oxide	520	1,400	Sweet, olefinic	-
Fluorine	6	6	**Pungent, irritating**	50
Formaldehyde	1.5	74	Pungent, hay	1.5
Formic acid	0.05	38	Pungent, penetrating	27
Furfural	0.02	20	Almonds	48
Hydrazine	3	4	Ammonical, fishy	-
Hydrochloric acid	7	49	Irritating, pungent	49
Hydrofluoric acid	0.03	0.1	Strong, irritating	4
Hydrogen bromide	7	7	Sharp, irritating	10
Hydrogen cyanide	0.9	5	Bitter almond	-
Hydrogen sulfide	0.0007	0.01	Rotten eggs	14
Iodine	9	9	**Irritating**	2
Isophorone	1	50	Sharp, objectionable	50
Isopropyl alcohol	8	490	pleasant	490
Maleic anhydride	1.8	2	Acrid	6
Methyl acetate	610	915	Fragrant, fruity	30,496
Methyl acrylate	70	70	Sharp, sweet, fruity	263

Methyl alcohol	13	26,840	Sweet	22,875
Methyl bromide	80	4,000	Sweetish	
Methyl cellosolve	0.3	288	Mild, non-residual	368
Methyl cellosolve acetate	1.6	240	Sweet, ester	-
Methyl chloroform	543	3800	Chloroform-like	5,429
Methyl ethyl ketone	0.7	148	Sweet, acetone-like	590
Methyl isobutyl ketone	0.4	193	Sweet, sharp	410
Methyl mercaptan	4×10^{-5}	0.08	Sulfidy	-
Methyl amine	0.03	12	Fishy, pungent	-
Methylene chloride	540	2,160	Sweet	8,280
Mineral spirits	157	787	**Kerosene-like**	-
Naphthalene	1.5	125	Mothball, tar-like	75
Nickel carbonyl	0.2	21	Musty	-
Nitric acid	0.8	2.5	**Acrid, choking**	155
Nitric oxide	0.4	1.2	-	-
Nitrobenzene	0.02	9.5	Shoe polish, pungent	230
Nitroethane	620	620	Mild, fruity	310
Nitrogen dioxide	2	10	Sweetish, acrid	20
Nitromethane	250	250	Mild, fruity	360
1-Nitropropane	1080	1,080	Mild. fruity	360
2-Nitropropane	18	1,029	**Fruity**	-
Octane	725	1,208	Gasoline-like	1,450
Ozone	0.001	1	Pleasant, clover-like	2
Pentane	7	3,000	Gasoline-like	-
Perchloroethylene	31	469	Mildy sweet	1,340
Phenol	0.2	22	Medicinal, sweet	182
Phosgene	2	4	Musty hay, green corn	8
Phosphine	0.03	3.6	Decaying fish	11
n-Propyl alcohol	0.08	150	Sweet, alcohol	-
Propyl alcohol	75	500	Sharp, musty	13,750
Propylene	40	116	Aromatic	-
Propylene oxide	25	500	Sweet, alcoholic	1,125

Pyridine	0.009	15	Burnt, sickening	90
Stoddard solvent	5	156	Kerosene-like	2,100
Styrene	0.2	860	Solvently, rubbery	430
Sulfur dioxide	1.2	12.5	Pungent, irritating	5
Sulfuric acid	1	1	-	1.1
Tetrachloroethane	21	35	Sickly sweet	1,302
Tetrahydrofuran	7	177	Ether-like	-
Toluene	8	150	Rubbery, mothballs	750
Toluene 2,4-diisocyanate	3	17	Sweet, fruity, acrid	4
Trichloroethylene	1	2,160	Etheral, chloroform like	864
Turpentine	560	1,120	**Pine-like**	560
Vinyl acetate	0.4	1.7	Sour, sharp	-
Naphtha	4	4	-	435
Xylene	0.4	174	Sweet	435