

Workplace Safety and Health Guidelines

Laboratories Handling Chemicals



WSHCOUNCIL

Contents

1.	Introduction	3
1.1	Scope and Objective	3
1.2	Laboratory Chemical Life Cycle	4
1.3	Legislation on Hazardous Chemicals	4
1.4	Management of Hazardous Chemicals Programme	7
1.5	Consequences of Poor Chemical Management	8
2.	Risk Management for Laboratories Handling Chemicals	9
2.1	Reducing Risks at Source	10
2.2	Considerations during Procurement of Chemicals	11
2.3	Chemical Inventory Tracking System	12
2.4	Chemical Hazard Communication	13
2.5	Laboratory Risk Assessment	18
2.6	Risk Management and Management of Change	23
3.	Risk Control Measures for Laboratories Handling Chemicals	25
3.1	Chemical Storage	25
3.2	Chemical Transfer	41
3.3	Chemical Usage	44
3.4	Chemical Waste Disposal	57
3.5	Chemical Exposure Monitoring and Medical Surveillance	61
4.	Chemical Incident Emergency Response	65
4.1	Emergency Response Plan	65
4.2	Emergency Evacuation	66
4.3	Chemical Spill Control	67
4.4	Bodily Decontamination	69
4.5	Firefighting	71
4.6	First Aid for Chemical Exposure	75
4.7	Incident Reporting	79
5.	Workplace Safety and Health in Laboratory Design	80
6.	Laboratory WSH Inspection Checklist	88
7.	WSH Planning for New Chemical Experiments	94
8.	References	97

9.	Acknowledgements	99
10.	Annexes	100
	Annex A – List of Incompatible Chemicals	100
	Annex B – Glove Type and Chemical Use	102
	Annex C – List of Toxic Industrial Wastes	105

1. Introduction

1.1 Scope and Objective

This guidelines applies to any basic laboratory where chemicals are handled and is, in particular, dedicated to both the improvement of Workplace Safety and Health (WSH) in company laboratories involved in quality control, as well as teaching laboratories in educational institutions. It supplements the existing *WSH Guidelines on Management of Hazardous Chemicals Programme* by providing more details on the safe storage, transfer, handling and disposal of chemicals in the laboratory context, as well as the recommended measures for laboratories to facilitate effective emergency response to incidents involving chemicals.

In the context of this guidelines, a laboratory is considered basic if the:

- (i) laboratory's activities involve standard or well-documented experimental techniques;
- (ii) laboratory equipment used is readily available in the market; and
- (iii) chemicals being handled are commonly found in standard laboratories or those whose properties are well understood.

In particular, laboratories involved in research and development (R&D) are beyond the scope of this guidelines due to the complex nature of R&D activities, the use of highly specialised equipment and/ or the use of novel chemicals. Those involved in R&D may wish to refer to relevant publications such as, *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards*, published by the National Research Council (United States of America) for specific guidance.

For those involved in setting up a new laboratory or redesigning an existing laboratory, this guidelines provides guidance on WSH aspects to be considered when designing a laboratory where chemicals are used. A chemical laboratory safety inspection checklist is included to help chemical users, laboratory managers* and safety auditors ensure that WSH concerns have been suitably addressed in their laboratories, and necessary control measures properly implemented.

Along with risk assessment (RA), those planning a new laboratory experiment or testing method will also find the list of recommended WSH considerations in this guidelines useful to ensure that all angles are covered before commencing work.

* A laboratory manager is any person who has control over the key aspects of the laboratory environment including the coordination of day-to-day activities, maintenance of equipment, purchasing of supplies, and so on.

1.2 Laboratory Chemical Life Cycle

From a laboratory perspective, the “cradle-to-grave” life cycle of a chemical begins with substance procurement, followed by storage upon delivery, transfer to the laboratory for use, and finally disposal of spent (waste) chemicals (see Figure 1).

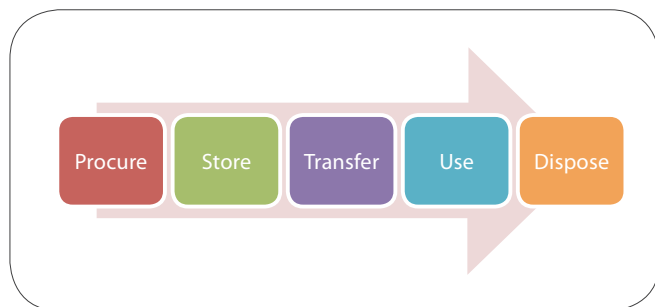


Figure 1: Life cycle of a chemical in a laboratory.

This guidelines provides recommended risk control measures laboratories can implement for handling chemicals at each stage of the chemical life cycle. Readers may wish to refer to relevant sections of this guidelines for specific advice on each of the above stages.

1.3 Legislation on Hazardous Chemicals

Although chemicals can be hazardous (depending on their concentration, toxicity and method of handling), they are used extensively in many workplaces as their use is beneficial to, for example, the processing operation or the end product's quality. Hazardous chemicals can be categorised according to the nature of the hazards they pose, namely: physical hazards (e.g., flammable, explosive, reactive), health hazards (e.g., toxic, corrosive, narcotic, carcinogenic) and/ or environmental hazards (e.g., toxic to aquatic life or the ozone layer).

In Singapore, hazardous chemicals are regulated or licensed by different authorities:

- The Ministry of Manpower (MOM) regulates exposure to chemicals at workplaces through the WSH Act and its subsidiary legislations (elaborated on the next page).
- The National Environment Agency (NEA) licenses the import, storage, use and disposal of environmentally hazardous substances via the Environmental Protection and Management (EPM) Act, the EPM (Hazardous Substances) Regulations and the EPM (Ozone Depleting Substances) Regulations. More information on NEA's control of hazardous substances can be found on NEA's website at www.nea.gov.sg under “Anti-Pollution & Radiation Protection”.

Additionally, NEA controls the handling, transportation, treatment and disposal of Toxic Industrial Waste (TIW) in Singapore under the Environmental Public Health (TIW) Regulations. Refer to Section 3.4 for recommended practices on chemical waste disposal.

- The Singapore Civil Defence Force (SCDF) controls the import, transport and storage of petroleum and flammable substances via the Fire Safety (FS) Act and the FS (Petroleum and Flammable Materials) Regulations. More information on the Fire Safety Licensing scheme for buildings can be found on SCDF's website at www.scdf.gov.sg under “Building Professionals”. In particular, laboratory occupiers are advised to refer to the *SCDF Technical Guidelines on Fire Safety Requirements for Laboratories Handling Chemicals* for guidance on how laboratory work areas can be better designed for fire safety.
- The Singapore Police Force (SPF) regulates the manufacture and storage of explosives and their precursors for national security through the Arms and Explosives (AE) Act and the AE (Explosive Precursors) Rules. The updated list of chemicals (explosive precursors) regulated by SPF and the requirements to hold a license to import or export, manufacture, possess or control, deal in and/ or store any explosive precursors are available on SPF's website at www.spf.gov.sg/licence under “Arms and Explosives”.

Other legislation and licensing requirements affecting chemical users are the:

- Poisons Act regulated by the Health Sciences Authority (HSA) which controls the import, possession and sale of any poison in Singapore;
- Radiation Protection Act regulated by NEA which controls the import, export, sale, transport, possession and use of radioactive materials as well as irradiating apparatus; and
- Chemical Weapons (Prohibition) Act regulated by Singapore Customs to fulfil national obligations under the Chemical Weapons Convention (CWC).

Workplace Safety and Health Act and Subsidiary Legislation

The WSH Act, passed on 1 March 2006, was extended to all workplaces on 1 September 2011. The Act stipulates the WSH obligations to be fulfilled and the responsibilities of every person at work.

Under the Act, the subsidiary legislation applicable to laboratories includes:

- WSH (Risk Management) Regulations;
- WSH (General Provisions) Regulations;
- WSH (Medical Examinations) Regulations;
- WSH (Noise) Regulations;
- WSH (First Aid) Regulations; and
- WSH (Incident Reporting) Regulations.

Together, the WSH Act and its subsidiary legislations spell out the requirements for employers, principals and self-employed persons in all workplaces (including laboratories) to:

- Conduct RAs to identify and control WSH risks;
- Provide safe work facilities and arrangements for workers;
- Ensure safety in machinery, equipment, substances used and work activities carried out;
- Provide adequate instruction, information, training and supervision to workers; and
- Implement risk control measures for dealing with emergencies.

The WSH (General Provisions) Regulations includes provisions for protecting employees against hazardous substances. The list of substances with hazardous properties is listed in the 5th Schedule of the WSH Act (see Table 1).

Hazardous Substances	
• Corrosive substances • Flammable substances • Explosives • Oxidising substances • Pyrophoric substances • Gases under pressure • Organic peroxides • Self-heating substances • Self-reactive substances	• Substances which, in contact with water, emit flammable gases • Toxic substances • Mutagens • Carcinogens • Teratogens • Sensitisers • Irritants • Substances hazardous to the aquatic environment

Table 1: Hazardous substances as per the 5th Schedule of the WSH Act.

Under the WSH (General Provisions) Regulations, it is a requirement that all hazardous substances used in a workplace be placed under the control of a competent person who has adequate knowledge of the substances' properties and dangers. These substances should be stored, handled and disposed of properly, so that they do not pose a risk to the health and safety of any person working in a laboratory. The law also requires hazard communication through the use of warning signs, container labelling and Safety Data Sheets (SDS).

Additionally, to ensure that laboratory users are not exposed to toxic substances above the Permissible Exposure Level (PEL) for more than 600 toxic substances, regular workplace monitoring is required. Under the WSH (Medical Examinations) Regulations, pre-employment and periodic medical examinations are compulsory if laboratory employees are exposed to any of 17 prescribed toxic substances (see Table 2).

Occupations involving the use or handling of or exposure to:	
1. Arsenic or any of its compounds; 2. Cadmium or any of its compounds; 3. Lead or any of its compounds; 4. Manganese or any of its compounds; 5. Mercury or any of its compounds; 6. Benzene; 7. Organophosphates; 8. Perchloroethylene; 9. Trichloroethylene;	10. Vinyl chloride monomer; 11. Tar; 12. Pitch; 13. Bitumen; 14. Creosote; 15. Asbestos; 16. Raw cotton; and/ or 17. Silica.

Table 2: Toxic substances listed under the Schedule of the WSH (Medical Examinations) Regulations for which compulsory medical examination is required.

Equipment (such as centrifuges or other mechanical devices) may generate noise in laboratories. To prevent exposure to excessive noise, the WSH (Noise) Regulations requires the occupier of the workplace and the responsible person (e.g., the employer) to reduce or control machinery or equipment noise in a laboratory. Refer to *WSH Guidelines on Hearing Conservation Programme* for more information on how exposed workers may be protected from the adverse effects of noise.

The WSH (First Aid) Regulations stipulates that every workplace shall have sufficient, adequately equipped first aid boxes. For laboratories, this includes provisions for emergency first aid for exposure to toxic or corrosive substances. Where the eyes or body of any person may come into contact with toxic or corrosive substances in the laboratory, the occupier of the workplace shall provide and properly maintain suitable facilities for quick drenching or flushing of the eyes and body within the work area for emergency use.

Under the WSH (Incident Reporting) Regulations, it is the duty of the employer or occupier to report:

- any workplace accident leading to fatality or injury;
- incidence of occupational disease; and/ or
- any dangerous occurrence to MOM via www.mom.gov.sg/ireport

Details on the WSH Act and its regulatory framework can be found at www.mom.gov.sg/workplace-safety-health/wsh-regulatory-framework/

1.4 Management of Hazardous Chemicals Programme

As a supplement to this guidelines, laboratory occupiers and managers are advised to refer to *WSH Guidelines on Management of Hazardous Chemicals Programme* (MHCP) for guidance on how to set up a comprehensive MHCP for their laboratories (see Figure 2). The elements of MHCP are:

- Policy and strategy;
- Selection and procurement;
- Register and SDS;
- Labelling and warning signs;
- Storage and transportation;
- RA and control;
- Safe Work Procedure (SWP) and Personal Protective Equipment (PPE);
- Workplace monitoring and surveillance;
- Information and training;
- Emergency planning and first aid;
- Waste disposal;
- Contract work; and
- Programme review and audit.

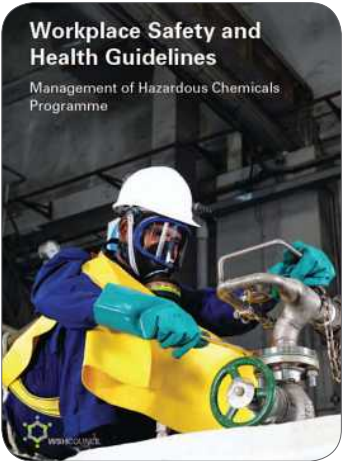


Figure 2: WSH Guidelines on MHCP.

Details on each element of the MHCP can be found in the guidelines which may be downloaded at www.wshc.sg/chemicals

1.5 Consequences of Poor Chemical Management

Poor management of laboratory chemicals may lead to several undesirable consequences such as:

- fires;
- chemical burns;
- explosions;
- occupational diseases;
- chemical poisoning; and/ or
- environmental pollution.

Explosions are particularly dangerous, as they are likely to cause severe bodily injuries to any personnel in the vicinity. People could be injured directly by the explosive force, or hit by flying shrapnel. Laboratory fires (including flash fires) can cause severe burns or deaths, and excessive smoke inhalation can cause severe lung injuries. Both fires and explosions can damage property and equipment, with companies incurring the high cost of cleanup and decontamination, facility restoration, and equipment replacement, not to mention the cost of laboratory operations downtime (see Figures 3 and 4). Extra caution must therefore be exercised when dealing with flammable or explosive substances.

Exposure to chemicals (whether by inhalation, ingestion, injection or skin contact) can result in acute poisoning due to contact with toxic substances or chemical burns due to contact with corrosive substances. Long-term contact may also result in excessive chemical absorption, leading to chronic occupational skin disease and adverse health effects. Consequently, control measures to minimise both short- and long-term exposure to chemicals are important.



Figure 3: Aftermath of a flash fire in a fume cupboard.



Figure 4: A ruptured waste carboy.

Improper chemical disposal (whether of fresh or spent chemicals) can unexpectedly release hazardous substances into the environment. Potential environmental impacts include air, water or land pollution, presenting a significant safety and health risk to downstream workers involved in sanitation and waste management.

Together with an environmental management system, a good chemicals management programme can enhance WSH, minimise chemical exposure and prevent incidence of chemical-related injuries and occupational disease in laboratories.

2. Risk Management for Laboratories Handling Chemicals

Risk management (RM) is a critical instrument for improving WSH.

Under the WSH (RM) Regulations, employers, self-employed persons and principals (including contractors and sub-contractors) have the responsibility to identify safety and health hazards at the workplace and take appropriate actions to eliminate these hazards or reduce the risks associated with them.

The key components of the RM process are: Preparation, Risk Assessment, Implementation and Review, and Record-keeping (see Figure 5).

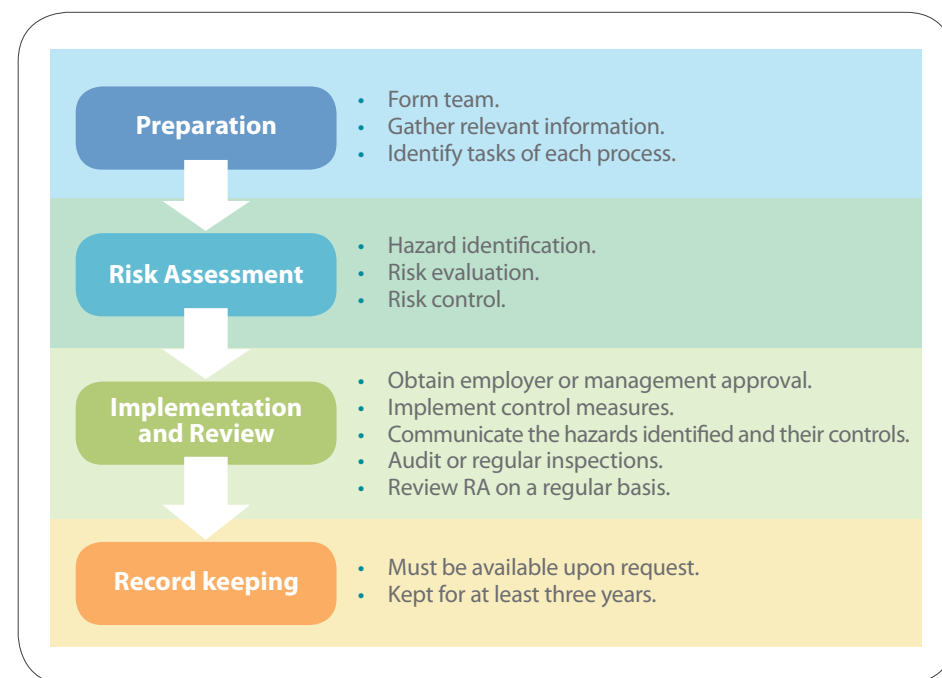


Figure 5: The risk management process.

RM not only involves RA for any work activity or trade, it also includes the on-site implementation of control measures, hazard communication to workers, and regular inspections and audits.

RA is basically a careful examination of the factors that could cause harm to workers' safety or health. The objective of RA is to find ways to mitigate or adequately control the risks posed by hazards as far as is reasonably practicable to do so.

The WSH (Risk Management) Regulations does not expect all risks to be eliminated, but it does require companies to implement risk control measures to protect all persons at work as far as is “reasonably practicable”.

An action is deemed practicable when it can be done. Whether the action is also reasonable takes into account:

- the severity of any injury or harm that may occur;
- the likelihood of the injury or harm occurring;
- how much is known about the hazard and the ways to eliminate, reduce or control it; and
- the availability, suitability and cost of safeguards.

Laboratory managers may use the RM process to foster a proactive accident prevention culture. By carrying out RA before commencing work, laboratory hazards may be identified and risk control measures put in place to minimise risk exposure during laboratory work.

More information on the RM process may be found in the *Code of Practice on Workplace Safety and Health Risk Management* available at www.wshc.sg

2.1 Reducing Risks at Source

The Hierarchy of Control (see Figure 6) applies to the management of chemical risks. The first question that needs to be asked is if the use of a particular hazardous chemical is absolutely necessary. If the chemical is removed, can the laboratory procedure or operating step proceed? Or can the chemical be substituted with something less hazardous?

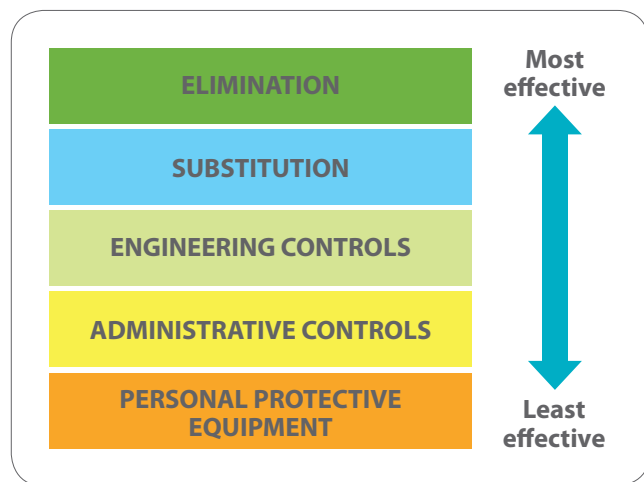


Figure 6: The Hierarchy of Control.

If elimination or substitution is possible without significantly affecting laboratory operations and/ or testing quality, then the priority is to first exercise these options, as reducing the risk at source makes laboratory work inherently safer. Eliminating or substituting the chemical would immediately render the laboratory free from the hazard(s) posed by the chemical in question.

An example of successful hazardous chemical elimination or substitution is in eliminating the use of benzene (a known carcinogen) as a solvent in laboratory operations. Toluene, which has physical properties similar to benzene, is recommended in its place.

If elimination or substitution is not possible (e.g., if the chemical is a critical reagent), then engineering controls (e.g., a cooling water bath for temperature control, a fume cupboard to remove toxic vapours) and/ or administrative controls (e.g., laboratory SWPs, warning signs and proper labelling) should be put in place.

PPE such as a laboratory coat, chemical-resistant apron and gloves, covered non-slip shoes, and/ or safety goggles, is the last line of defence against direct contact with the chemical substance if all above control measures fail and/ or cannot be implemented. Though it is the last line of defence, the use of PPE is still critical as it is difficult to predict what may happen when working in a laboratory. PPE should also be used during laboratory maintenance, repair activities and/ or during emergencies (e.g., cleaning up a chemical spill), or as an additional protective measure against any remaining risks.

2.2 Considerations during Procurement of Chemicals

As bringing a new chemical into the laboratory brings along with it new risks, chemicals to be purchased should be carefully evaluated before transferred into a laboratory, bearing in mind the laboratory chemical life cycle (see Section 1.2) starting with procurement.

Consider the following before ordering a chemical:

- Is a licence or permit required for the purchase, use or storage of the chemical?
- Have you obtained and reviewed the SDS for the chemical?
- Are you aware of all the properties of the chemical and its hazards?
- Have the short- and long-term risks of using the chemical been evaluated?
- Can a safer, less hazardous chemical be used?
- Can smaller quantities of the chemical be used for laboratory operations?
- Is the laboratory equipped with the necessary provisions or facilities to properly store and handle the chemical?
- Is the general ventilation in the laboratory sufficient to minimise worker exposure to the chemical or is local exhaust ventilation (LEV) required?
- Are PPE and safety equipment available for handling the chemical?
- What is the worst case scenario(s) in the event that the substance is mismanaged, spilled, or causes worker injury?
- Are laboratory emergency facilities in place for immediate response to the worst case scenario(s)?
- Are special first aid measures (e.g., antidotes) required?
- Will the chemical (or its end product) require disposal as hazardous waste?
- Is a procedure in place to properly dispose of the chemical (and its end product) legally and safely?

When ordering a chemical, good practice is to:

- purchase the minimum quantity consistent with expected rate of use;
- procure only what would be used within a reasonable time (e.g., a year) or before the expiry date of the chemical; and
- acquire reagents in plastic bottles or plastic-coated glass bottles (instead of ordinary glass bottles) wherever possible to minimise potential breakage, corrosion and rust.

When receiving a chemical, good practice is to:

- inspect the container to make sure it is in good condition;
- obtain and file the latest version of the chemical's SDS;
- date the container with the received date; and
- enter the chemical into a chemical inventory tracking system (see Section 2.3).

Ideally, a centralised purchasing programme is recommended where one person, knowledgeable about the chemicals on hand, does all the purchasing and oversees the chemicals inventory so that excess chemicals in stock can be depleted first before more of the same chemical is acquired.

Prior to the delivery of the chemical, the storage facility should be adequately prepared to meet the specific storage requirements of the incoming chemical (see Section 3.1 on Chemical Storage) and both storeroom and laboratory personnel trained to safely receive the delivery.

Working with Chemical Suppliers or Manufacturers

Where appropriate, laboratory managers are advised to work closely with the chemical manufacturers and/ or suppliers to identify safer and less hazardous chemical substitutes, and better understand the chemicals being procured – the hazards they present, their specific storage requirements, and how the on-site chemicals inventory can be kept small (e.g., through a just-in-time delivery arrangement). Look for suppliers that can sell the smallest amount of the chemical required.

2.3 Chemical Inventory Tracking System

A chemical inventory tracking system is an up-to-date database of chemicals in the laboratory. Laboratories may choose to implement the tracking system as a hard copy-based register of chemicals or as a computer-based system.

The chemical tracking system should be designed to track a chemical from the time it is procured to the time it is used and discarded. A good tracking system will support the chemical RM process and help to eliminate unnecessary purchases, reduce procurement costs, and minimise disposal expenses.

Examples of fields to be included for tracking include:

- chemical name as printed on the chemical container and on the SDS;
- molecular formula and Chemical Abstract Service registry number of the chemical;
- date the chemical was received;
- name of the chemical manufacturer and/ or supplier;
- material of the chemical container;
- chemical hazard classification (for storage, handling and disposal);
- required storage conditions for the chemical;
- designated location for the container (for laboratories with multiple storage locations);
- location of the container within the room (e.g., acid cabinet, shelf number);
- location where the chemicals are to be used;
- expiry or “use-by” date of the chemical;
- amount of chemical in the container;
- name of the person who ordered or requested the chemical; and
- list of persons at risk or liable to chemical exposure.

Once the tracking system is set up, it can be kept up-to-date through regular inventory inspections to verify system data accuracy. As part of laboratory storage space management, inventory inspections may also be used to identify and dispose of expired, no longer needed and/ or deteriorated chemicals.

2.4 Chemical Hazard Communication

Once a chemical is delivered and placed in its designated storage location, the next step is to put in place a system to communicate the risks associated with the hazardous chemical. Hazard communication may be achieved through a combination of written (e.g., a laboratory safety manual), visual (e.g., warning signs) and/ or verbal means (e.g., a safety briefing).

Protection from chemical risks really begins when workers are aware of the risks and adopt the necessary precautionary measures.

Below are examples of communication channels laboratories may use to raise risk awareness amongst laboratory users.

Register of Chemicals

Risk awareness begins with knowing the range of chemicals available in a particular laboratory. The full list of chemicals that are stored, used or handled in a laboratory should be in the chemicals register. For smaller laboratories with a single storage room, this can be in hard copy format, but larger organisations with multiple laboratories and storage rooms are recommended to use a computer-based inventory tracking system (see Section 2.3). Regardless of implementation approach, it is important that all who are handling or using the chemical have easy access to the chemicals register.

A copy of the chemicals register should also be stored in a location (or accessible from a location) physically separated from the physical stock. This is to allow emergency responders to access the chemicals register even if the storage area where the chemical is kept is affected by a spill or fire.

Chemical SDS

Every chemical on the register must come with its own SDS (see Figure 7).

Under the WSH (General Provisions) Regulations, it is mandatory for the:

- occupier to obtain a SDS for each hazardous substance used, handled or stored in the workplace; and
- seller (or any agent of the seller) to provide the buyer with a SDS for the hazardous substance being procured.

The SDS is an important source of information from the seller (usually the manufacturer or the supplier) to the workplace occupier/ employer who purchases the chemical, and from the employer to employees who handle or use the chemical.

Occupiers are required to assess the SDS, identify the hazards of the substance, take precautionary measures throughout the life cycle of the chemical, and ensure that the correct SDS is available to all persons at work in the laboratory who may be exposed to the substance.

Sellers (or any agent of the seller) play a critical role in ensuring that each SDS contains accurate and adequate information on the hazardous substance and that the SDS format is in conformance with Singapore Standard SS 586: 2008 (2014) – *Specification for hazard communication for hazardous chemicals and dangerous goods – Part 3: Preparation of safety data sheets (SDS)*.

As per SS 586 – 3: 2008 (2014), a SDS should contain 16 sections as follows:

- Section 1: Identification
- Section 2: Hazards identification
- Section 3: Composition/ Information on ingredients
- Section 4: First aid measures
- Section 5: Firefighting measures
- Section 6: Accidental release measures
- Section 7: Handling and storage
- Section 8: Exposure controls/ Personal protection
- Section 9: Physical and chemical properties
- Section 10: Stability and reactivity
- Section 11: Toxicological information
- Section 12: Ecological information
- Section 13: Disposal considerations
- Section 14: Transport information
- Section 15: Regulatory information
- Section 16: Other information

Chemical users are advised to consult the SDS to understand the nature of the substance at hand and confirm that the necessary precautionary measures are in place before commencing laboratory work (see Table 3).



Figure 7: Provide laboratory users with easy access to SDS.

To ensure that SDS information is up-to-date, it is good practice to regularly review the laboratory's SDS collection and replace all SDS that are more than 5 years old (based on the SDS date of issue). If the supplier is unable to provide an updated SDS, an interim measure would be to take reference from the SDS provided by other suppliers of the **same** chemical until the original supplier provides the update.

Substance Information and Hazard Identification	Precautionary Measures	First Aid and Emergency Response	Additional Information
1: Identification 2: Hazards identification 3: Composition/ Information on ingredients 9: Physical and chemical properties	7: Handling and storage 8: Exposure controls/ Personal protection 10: Stability and reactivity	4: First aid measures 5: Firefighting measures 6: Accidental release measures 13: Disposal considerations 14: Transport information	11: Toxicological information 12: Ecological information 13: Disposal considerations 14: Transport information 15: Regulatory information 16: Other information

Table 3: Recommended SDS sections to consult for substance information, precautionary measures, and more.

Chemical Container Labelling

Together with more than 65 countries, Singapore has adopted the Globally Harmonised System (GHS) of Classification and Labelling of Chemicals developed by the United Nations. The GHS is essentially a hazard communication system for chemical hazard classification, container labelling and SDS. GHS not only improves hazard communication across companies and workers from different organisations; it also harmonises and increases risk awareness at an international level (e.g., when importing or exporting chemicals between countries).

More information on GHS in Singapore can be found at www.wshc.sg/ghs

All Singapore chemical manufacturers, suppliers and end users are required to implement GHS for single substance chemicals by end 2012 and for chemical mixtures by mid-2015. Detailed guidance on GHS is given in Singapore Standard SS 586: 2014 – *Specification for hazard communication for hazardous chemicals and dangerous goods – Part 2: Globally harmonised system of classification and labelling of chemicals - Singapore's adaptations*.

Container labelling is an important way to convey hazard information to users at the point of contact with a chemical. Through the use of standard GHS hazard pictograms and a consistent GHS label format, chemical users can be quickly made aware of the hazards at hand and focus on the necessary precautionary measures needed to make work safer. See Figure 8 for GHS hazard pictograms.

Flame over circle	Environment	Exploding bomb
 Oxidisers	 Environmental toxicity	 Explosives/ Organic peroxide/ Self-reactives
Skull and cross bones	Corrosion	Gas Cylinder
 Acute toxicity (severe)	 Corrosives	 Gases under pressure
Health	Flame	Exclamation Mark
 Aspiration toxicity/ Carcinogenicity/ Germ cell mutagenicity/ Target organ toxicity/ Respiratory sensitisation/ Reproductive toxicity	 Emits flammable gas/ Flammable/ Self-heating/ Self-reactive/ Organic peroxide/ Pyrophoric/ Aerosols	 Acute toxicity (harmful)/ Irritant/ Narcotic effects/ Respiratory tract irritation/ Skin sensitisation/ Hazard to Ozone Layer

Figure 8: GHS hazard pictograms.

All chemical containers containing hazardous ingredients should be affixed with a container label.

As outlined in Figure 9, a GHS label must contain these seven information items:

- product name/ identifier
- signal word
- pictogram
- hazard statement
- precautionary statement
- supplementary information
- supplier information

EPICHLOROHYDRIN






DANGER

Flammable liquid and vapour.
Toxic if swallowed.
Toxic in contact with skin.
Fatal if inhaled.
Causes severe skin burns and eye damage.
May cause allergy or asthma symptoms or breathing difficulties if inhaled.
May cause an allergic skin reaction.
Suspected of causing genetic defects.
May cause cancer.
Suspected of damaging fertility or the unborn child.
Causes damage to respiratory organs, liver, kidney.
Causes damage to respiratory organs, kidney, heart, CNS through prolonged or repeated exposure.

Do not handle until all safety precautions have been read and understood.
Wear protective gloves/protective clothing/eye protection/face protection.
Keep away from heat/sparks/open flames/hot surfaces.
No smoking.
Take precautionary measures against static discharge.
Do not breathe dust/fume/gas/mist/vapours/spray.
Use only outdoors or in a well-ventilated area.

Container remains hazardous when empty. Continue to observe all precautions.
For further information on this product, refer to Manufacturer's Safety Data Sheet.

United Nations Chemical Company Ltd.
1-1, Peace Avenue
Jurong Island Annex A, Singapore
Contact Tel: 65 6000 0000

Product Name

Signal Word

Pictograms

Hazard Statements

Label

Precautionary Statements

Precautionary Statements

Supplier Information

Disclaimer: Label is produced not to scale and with the available known data at the point of print.

Source: SCIC Guidebook on the Globally Harmonised System of Classification and Labelling of Chemicals

Figure 9: Sample GHS container label.

Labelling is also required for small chemical storage containers. The minimum information on the label of a small container is the product name and hazard pictogram. More information on reduced workplace labelling for laboratory operations is available in SS 586 – 2: 2014.

In cases where labelling the laboratory container is impractical due to size constraints or its conditions for use, consider providing the information via other means, for example by using a fold-out label, a swing or tie-on tag, affixing the label to a supporting apparatus, or labelling the outer packaging container.

Once the chemical identifier/ product name is known, users may refer to the SDS for more information, including recommended safe storage and handling measures (e.g., chemical safety cabinets, safety gloves), as well as appropriate engineering controls (e.g., fume cupboards) and PPE.

For effective hazard communication, labels should be updated within six months or whenever there is new information from the chemical seller (or agent of the seller) on the label information items.

Chemical User Training

Under the WSH Act, it is the duty of employers to ensure that persons at work (including contract workers) have adequate instruction, information, training and supervision. Training can be achieved through a combination of formal training (e.g., attending a course) and on-the-job training.

Chemical risk awareness is an important component of the training for chemical users and proposed topics include:

- understanding GHS hazard pictograms;
- interpreting the content of SDS;
- performing RA; and
- implementing risk control measures.

Chemical safety and hazard communication should also be clearly documented in key laboratory documents like the laboratory safety manual, equipment operating manuals and experiment instruction sheets. Laboratory supervisors may use safety briefings to highlight/ reinforce key safety messages and bring attention to the risks to laboratory personnel before allowing work to commence.

2.5 Laboratory Risk Assessment

The first two components of the RM process are Preparation and RA.

Prior to conducting RA at a laboratory, Preparation involves establishing the context by gathering relevant information such as:

- lists of laboratory equipment;
- laboratory layout plans;
- summaries of laboratory operations and work activities;
- registers of chemicals/ chemical inventory tracking system;
- SDS and container label information;
- established SWPs;
- details of existing risk control measures and laboratory emergency facilities;
- guidance documents from chemical supplier/ equipment manufacturer;
- technical references (e.g., on process chemistry and substance incompatibility);
- relevant legislation, Codes of Practice and standards;

- WSH inspection records and audit reports;
- occupational hygiene surveys and exposure monitoring reports;
- observations and feedback on WSH-related matters;
- copies of previously completed RA forms;
- records of near misses, past incidents and accidents; and
- medical records of workers.

This is followed by RA which comprises three steps:

Step 1: Hazard identification

Step 2: Risk evaluation

Step 3: Risk control

Key aspects to consider for each step are suggested below.

Step 1: Hazard Identification

Techniques for carrying out hazard identification in a laboratory setting include:

- team brainstorming;
- reviewing past incident and injury records;
- referring to the SDS;
- inspecting the laboratory premises;
- conducting an on-site physical inspection;
- interviewing laboratory employees; and/ or
- carrying out a job safety analysis.

To facilitate more rigorous hazard identification, break down complex laboratory work processes into simpler work activities and analyse each task for specific chemicals that may require closer consideration.

The following steps should be taken during hazard identification:

- Identify all hazardous chemicals in the laboratory (e.g., using the GHS hazard classes as a guide – physical hazards, health hazards and environmental hazards);
- Consider the laboratory chemical life cycle – chemical storage, transfer, usage and disposal;
- Consider possible exposure to toxic, corrosive, reactive and/ or flammable substances;
- Identify both routine and non-routine laboratory work;
- Identify possible unplanned events (e.g., spillage, leakage, splash, failure of control measures);
- Consider fire and explosion hazards (identify fuel and ignition source[s]);
- Consider the hazard of incompatible chemical reactions; and
- Consider the possibility of fugitive emissions and toxic releases.

Step 2: Risk Evaluation

Step 2a - Determine Likelihood

Exposure Estimation

For each identified hazard, consider:

- persons who may be exposed to the hazardous chemical;
- pathways for exposure/ contact with the chemical (e.g., via inhalation, ingestion, skin contact);
- level of exposure by route of entry (e.g., by modelling or direct measurement);
- probability of occurrence of chemical accidents (e.g., fire, explosion, spillage) which may lead to unintended exposure; and
- expected frequency and duration of exposure.

More on exposure estimation may be found in Section 3.5.1 Workplace Exposure Monitoring, and MOM's document entitled "A Semi-Quantitative Method to Assess Occupational Exposure to Harmful Chemicals". Proper exposure measurement is necessary to evaluate the risk of the chemical hazard. See Table 4 for guidance on likelihood level determination.

Level	Likelihood	Description
1	Rare	Not expected to occur but still possible.
2	Remote	Not likely to occur under normal circumstances.
3	Occasional	Possible or known to occur.
4	Frequent	Common occurrence.
5	Almost Certain	Continual or repeating experience.

Table 4: **Guidance for Likelihood Level, L (taking existing risk controls into consideration).**

Step 2b - Determine Severity

Hazard Characterisation

For each identified hazard, relevant information includes:

- the chemical and its physical properties;
- dose-response information;
- toxicological or adverse health effect data; acute/ chronic effect(s) due to exposure;
- exposure standards (e.g., permissible exposure limit and/ or threshold limit value); exposure data (measured or estimated) compared to exposure standards;
- consequence and severity information from past chemical accidents; and
- site-specific severity evaluation criteria.

See Table 5 for guidance on severity level determination.

Level	Severity	Description
5	Catastrophic	Fatality, fatal diseases or multiple major injuries.
4	Major	Serious injuries or life-threatening occupational diseases (includes amputations, major fractures, multiple injuries, occupational cancer, acute poisoning).
3	Moderate	Injury requiring medical treatment or ill-health leading to disability (includes lacerations, burns, sprains, minor fractures, dermatitis, deafness, work-related upper limb disorders).
2	Minor	Injury or ill-health requiring first aid only (includes minor cuts and bruises, irritation, ill-health with temporary discomfort).
1	Negligible	Not likely to cause injury or ill-health.

Table 5: **Guidance for Severity Level, S (taking existing risk controls into consideration).**

Step 2c - Evaluate the Risk

Risk Prioritisation

Risk level may be estimated using the risk matrix below:

Likelihood Severity	Rare (1)	Remote (2)	Occasional (3)	Frequent (4)	Almost Certain (5)
Catastrophic (5)	5	10	15	20	25
Major (4)	4	8	12	16	20
Moderate (3)	3	6	9	12	15
Minor (2)	2	4	6	8	10
Negligible (1)	1	2	3	4	5

Table 6: **Recommended 5 x 5 Risk Matrix with Risk Prioritisation Number ratings (Green Zone = "Low Risk"; Yellow Zone = "Medium Risk"; Red Zone = "High Risk").**

The Risk Prioritisation Number (RPN) rating (or risk level) for each hazard may be easily computed as follows:

$$RPN \text{ Rating} = \text{Severity Level (S)} \times \text{Likelihood Level (L)}$$

The computed RPN rating gives the estimated risk level, with greater RPN rating indicating higher risk:

RPN	Risk Level	Risk Acceptability
$RPN \leq 3$	Low Risk	Acceptable
$4 \leq RPN \leq 12$	Medium Risk	Tolerable
$RPN \geq 15$	High Risk	Not Acceptable

Table 7: **RPN rating, risk level and risk acceptability.**

The RPN obtained will help determine if the risk is acceptable, tolerable or not acceptable.

Step 3: Risk Control

Based on the risk level obtained in Step 2c, the final and most important step is to implement control measures to bring the risk down to an acceptable level.

The following table on risk acceptability and the recommended actions for each risk level is taken from the Code of Practice on WSH Risk Management:

Risk Level	Risk Acceptability	Recommended Action
Low Risk (RPN ≤ 3)	Acceptable	- No additional risk control measures may be needed. - Frequent review and monitoring of hazards is required to ensure that the risk level assigned is accurate and does not increase over time.
Medium Risk (4 ≤ RPN ≤ 12)	Tolerable	- A careful evaluation of the hazards should be carried out to ensure that the risk level is reduced to as low as reasonably practicable within a defined time period. - Interim risk control measures, such as administrative controls or PPE, may be implemented while longer term measures are being established. - Management attention is required.
High Risk (RPN ≥ 15)	Not acceptable	- High Risk level must be reduced to at least Medium Risk before work commences. - There should not be any interim risk control measures. Risk control measures should not be overly dependent on PPE or appliances. - If practicable, the hazard should be eliminated before work commences. - Management review is required before work commences.

Table 8: Recommended action for each risk level.

Hazards with a larger RPN rating (in particular, those that are “High Risk”) must be given first priority and additional control measures put in place to reduce the risk level to “Medium Risk” or “Low Risk” before the laboratory work activity can commence.

Risk control measures should be selected based on the Hierarchy of Control, starting with elimination or substitution wherever possible and ending with the use of PPE only as a last resort:

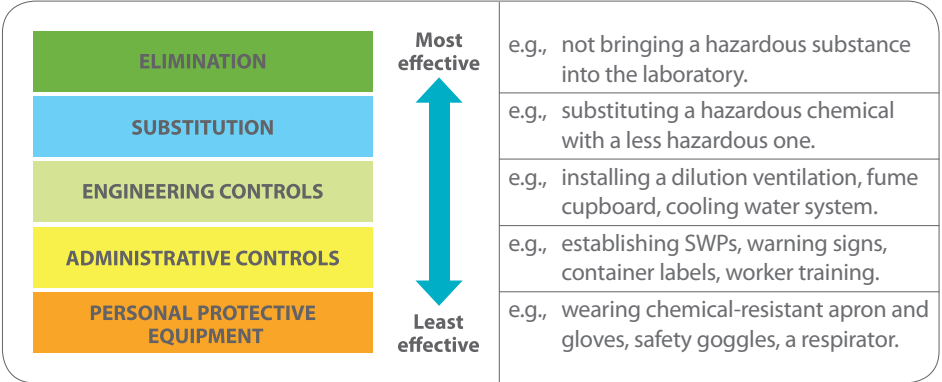


Table 9: Example of risk control measures in a chemical laboratory based on the Hierarchy of Control.

Further Information

- Code of Practice on WSH Risk Management
- WHO Human Health Risk Assessment Toolkit for Chemicals
- ILO Chemical Control Toolkit
- MOM’s “A Semi-Quantitative Method to Assess Occupational Exposure to Harmful Chemicals”

2.6 Risk Management and Management of Change

Risk Management

RA is followed by Implementation and Review, where the risk control measures are physically implemented, communicated to laboratory personnel, audited for conformance, and periodically reviewed to measure their effectiveness. In the event that work-related ill health effects, near misses or accidents occur, an immediate review of the RA is necessary. Otherwise, all RA should be reviewed at least once every three years by default.

RM includes Record-keeping which involves setting up a laboratory risk register (i.e., the collection of RA forms for a laboratory) as well as keeping relevant records of RA training sessions, RM implementation audits and RM process management reviews, for a minimum duration of three years.

Management of Change

As changes may occur after the initial RA is complete, it is important to subject any contemplated changes (whether minor or major, temporary or permanent) to the laboratory facilities or operations to a second RA to fully ascertain the impact of the changes on employee safety and health before they are implemented. Written procedures to manage changes (e.g., new laboratory chemicals, new equipment, new procedures, as well as changes to laboratory facilities) should be established and implemented.

Considerations to be addressed prior to any change include:

- the technical basis for the proposed change;
- the update to hazard communication and operating procedures required as a result of the change;
- the necessary time period for the change to be effected; and
- the authorisation required for the change.

All laboratory personnel whose job tasks will be affected by the change must be made aware of the change and receive the necessary training to handle it before the change is effected.

3. Risk Control Measures for Laboratories Handling Chemicals

Identifying and implementing adequate control measures is an important aspect of RA. This chapter offers practical ideas and suggestions for chemical laboratory owners, managers and/or users to consider when conducting a laboratory RA.

Following the arrival of a chemical onto laboratory premises, the risk control measures suggested in this guidelines are organised according to the flow of the laboratory chemical life cycle, namely: chemical storage, chemical transfer, chemical usage and chemical waste disposal.

3.1 Chemical Storage

As chemicals can be hazardous in different ways (e.g., flammable, corrosive, toxic, unstable), first inspect the chemical's container label and SDS to understand the properties and characteristics of the chemical, and obtain specific storage guidance before determining the best way to store the chemical safely.

Proper storage of chemicals will protect flammable materials from ignition sources, minimise potential exposure to toxic substances and ensure segregation of incompatible chemicals, to prevent accidental mixing due to spillage or human error.

3.1.1 General Chemical Storage

- Do not store chemicals on the floor.
Exits, passageways, areas under tables and laboratory benches should be kept free from chemical containers, especially glass containers. If placed on the floor, the chemical containers risk being walked into, knocked over or hit with a chair or stool.
- Do not store chemicals above eye level.
If a chemical glass container falls and/ or breaks, its contents can splash on one's face and upper body. Storing chemicals below eye level will protect eyes and faces from chemical spills from above. It will also prevent chemicals from being placed out of sight or put out of reach.
- Do not store chemicals on laboratory bench tops.
Laboratory benches are not the right place for storing chemicals (especially pure or concentrated chemicals) as incompatible chemicals may be inadvertently stored next to each other, chemical containers may be easily knocked over, and chemicals are not protected from a laboratory fire. Each chemical should have a proper designated storage location and be returned after use.

- Do not store chemicals in a fume cupboard, except for particularly odorous chemicals that require special ventilation.

Storing items (e.g., chemical containers, storage boxes, laboratory equipment) in a fume cupboard may severely disrupt its airflow, resulting in chemical vapours being drawn back into the laboratory atmosphere. Fume cupboards should be subject to good housekeeping and kept free of unnecessary items at all times.

- Store chemicals away from sources of heat.

Storing chemicals near heat sources (e.g., burners, ovens and steam pipes) will inevitably cause liquid vaporisation rates to increase. This will cause pressure build up in the chemical container, possibly leading to container rupture. To reduce this risk, do not fill the container completely.

In particular, flammable and volatile liquids should be stored in a cool place, away from sunlight or direct heat. If placed next to a heat source, flammable substances can easily ignite, causing a laboratory fire. Storing a chemical in a cool location away from sunlight will also prevent its deterioration and prolong its shelf life.

- Store chemicals by compatibility, then by alphabetical order.

Storing chemicals by alphabetical order may lead to incompatible chemicals being stored next to one another. Instead, first segregate chemicals into inorganics and organics, and then into compatible groups based on their respective GHS hazard class, for example, flammables, oxidisers, reactive substances, corrosives, or toxics. Within the same compatible group, chemicals may be arranged alphabetically to facilitate easy retrieval.

- Only store chemical containers that are properly labelled.

The use of GHS-labelled containers ensures that the chemical can be immediately identified and its hazards communicated to the user at its point of use (see Figure 10). For more information, refer to Section 2.4 on Chemical Hazard Communication and Chemical Container Labelling.

- Store chemicals in proper cabinets.

The use of proper cabinets specially designed for chemical storage is strongly recommended. These cabinets should be clearly labelled to indicate the hazardous nature of their contents (e.g., “flammable” or “corrosive”) together with the corresponding GHS hazard pictograms. In general, these cabinets are lockable and come with chemical resistant spill containment shelving with protective anti-roll edge guards that prevent containers from sliding off. Only authorised persons trained in chemicals handling should be allowed access to the chemicals inside the storage cabinets. No chemicals or equipment should be stored on top of a storage cabinet.



Figure 10: The label on the container facilitates quick identification of its contents.

- Store breakable chemical containers in a secondary container.

A secondary container (e.g., a plastic or metal spill tray or a larger catch basin) will contain the chemical in the event of a spill, leak or container breakage.

- Date all chemical containers once received for storage and when opened.

This is a good practice to identify older chemicals which, when used first, help to reduce the amount of expired or deteriorated chemicals sent for disposal. Note that the expiration date set by the manufacturer indicates the shelf life of the **unopened container**, and does not imply that the chemical is safe for use up to the expiry date **after the container has been opened**.

- Do not store excessive amounts of chemicals.

Always order and store the smallest practical amount of a chemical. Though it may be cheaper (on a per unit cost basis) to buy chemicals in bulk quantities, the disadvantages often outweigh the initial price advantage. More chemicals mean that a larger storage space is required and a greater hazard exists. The cost of disposing unused chemicals can also be higher than their initial purchase cost.

- Equip chemical storage areas with facilities for emergency response.

It is important that any area used for storing chemicals be sufficiently ventilated and equipped with the necessary firefighting, spill control, bodily decontamination and/ or first aid equipment so that in the event of an accident (e.g., a fire or a chemical spill), the laboratory can respond appropriately to the emergency.

Storage of Flammable Chemicals

Flammable chemicals easily catch fire and burn. When heated, flammable liquids become more hazardous as vaporisation rates generally increase with temperature. It is the vapour of the flammable liquid that ignites and burns.

Primary storage concern:

- Protect flammable chemicals from ignition sources.

The following applies when storing flammable chemicals:

- Store flammable liquids in a minimum 1 hr fire-rated storage cabinet designed for flammables away from heat sources or in a cool and well-ventilated area next to or near the laboratory (see Figure 11). The storage cabinet will protect its contents from the heat and flames of an external fire;
- Keep flammable chemicals away from oxidising chemicals and highly sensitive chemicals that liberate heat in reaction to air or moisture;

- Do not store flammable liquids with flash points lower than room temperature in a standard refrigerator meant for household use. Standard refrigerators are not designed to be free of ignition sources. Store flammables only in a laboratory-safe or explosion-proof refrigerator. The refrigerator's temperature needs to be set lower than the flash point of the most readily ignitable substance stored in the refrigerator;
- Minimise the amount of flammable chemicals stored within a laboratory as they pose a serious fire hazard. Storage of flammable chemicals should be kept within the limits stipulated under the Fire Safety (Petroleum and Flammable Materials) Regulations; and
- Firefighting facilities and equipment must be readily available at every storage area with flammables.

The recommended features to look out for when acquiring a cabinet for the storage of flammable liquid chemicals are:

- cabinet (usually yellow) with a large warning label reading "Flammable";
- double-wall construction with an air space for improved fire resistance;
- ventilation ports with flash arrestors to prevent build-up of flammable vapours;
- structurally reinforced all-welded construction;
- adjustable corrosion-resistant powder-coated steel shelving;
- self-latching non-sparking lockable doors;
- leak-proof cabinet bottom sill; and
- adjustable levelling legs.

As stated in the SCDF Guidelines on Fire Safety Requirements for Laboratories, the amount of flammable chemicals kept outside of the flammables storage cabinet (e.g., on the work benches) should not be more than 10% of the Maximum Allowable Quantity (MAQ) for each flammable chemical in the laboratory.



Figure 11: Storage cabinet for flammable chemicals with cabinet doors closed (top) and open (below).

Storage of Corrosive Chemicals

In general, a corrosive chemical is any substance that has either a very low pH (e.g., ≤ 2.0) or a very high pH (e.g., ≥ 11.5), and this includes many strong acids and alkalis (bases). Corrosive chemicals can destroy or irreversibly alter living tissue, and are particularly damaging to the skin and eyes. Also, as some chemicals become corrosive upon contact with water or moisture, inhaling a corrosive vapour or mist can cause severe irritation or damage to the respiratory tract.

Primary storage concerns:

- Prevent workers from inhaling chemicals, and/ or their eyes or skin from coming into contact with chemicals; and
- Prevent chemicals from coming into contact with incompatible substances (e.g., acids from coming into contact with alkalis).

The following applies when storing corrosive chemicals:

- Corrosive liquids should be stored in a storage cabinet designed for corrosives;
- Always store corrosives on a low shelf (the lower the better) and never above eye level. This will minimise the spread/ extent of the splash or spill should a container fall from the shelf. In particular, concentrated acids and bases should be stored as near the floor as possible;
- Corrosives should be stored in unbreakable plastic containers or in special safety-coated glass containers, preferably placed on a chemical resistant catch tray. These special glass containers are lined with a protective plastic coat that can prevent the glass from shattering and contain the corrosive substance in its original container long enough for proper disposal;
- Separate acids from alkalis as these can react violently when mixed. Store acids in a dedicated acid cabinet. Also, keep acids away from flammables as many acids are also strong oxidisers;
- Nitric acid (HNO_3) should be stored in a dedicated secondary container (e.g., a plastic tub or basin) in the storage cabinet as it is incompatible with most other chemicals;
- Ensure that a spill control kit (equipped with acid and base neutralising agents) is readily available at each location where corrosive chemicals are stored; and
- Bodily decontamination facilities (e.g., an eyewash station and emergency shower) must be located near to or inside storage areas for immediate use upon accidental exposure (especially skin contact or contact with the eyes) to a corrosive chemical.

Hydrofluoric (HF) acid is extremely hazardous and needs special mention. HF acid is very corrosive – it readily penetrates the skin and damages underlying tissue and bones. When exposed to air, concentrated solutions of HF acid and anhydrous HF produce pungent fumes which, when inhaled, damage the respiratory system.

Further Information

- SCDF Guidelines on Fire Safety Requirements for Laboratories
- SS 532: 2007 Code of Practice for the Storage of Flammable Liquids

When storing HF acid, remember the following:

- Do not store HF acid in a glass container as it is incompatible with glass. Because of its high reactivity toward glass and moderate reactivity toward many metals, HF acid is usually stored in a plastic container; and
- Store HF acid separately from the other corrosives and keep only the minimum amount required for use in the laboratory. While HF acid may be stored with other acids in the same storage cabinet, it should be kept separate from other acids, for example, by storing it in a dedicated storage compartment or in a dedicated secondary container.

The recommended features to look out for when acquiring a cabinet for the storage of corrosive chemicals (including corrosives that are flammable) are:

- cabinet (usually blue) with a large warning label reading “Corrosive”;
- double-wall construction with an air space for improved fire resistance;
- ventilation ports with flash arrestors to prevent the build-up of flammable vapours;
- structurally reinforced all-welded construction OR non-metallic 100% plastic construction for storing sulphuric, hydrochloric and nitric acid;
- adjustable corrosion-resistant powder-coated steel shelving with plastic trays on each shelf OR 100% plastic shelving;
- self-latching non-sparking lockable doors;
- leakproof cabinet bottom sill with plastic tray; and
- adjustable levelling legs.

See Figure 12 for an example storage cabinet.



Figure 12: Storage cabinet for corrosive chemicals with cabinet doors closed (left) and open (right).

Storage of Highly Toxic Chemicals

A toxic substance is any chemical that is harmful to human health (e.g., causing severe illness, organ damage, impairment of the central nervous system, or death) if inhaled, ingested, injected or absorbed through the skin or eyes. The adverse health effects of exposure to a toxic chemical will depend on its route of entry into the body, the exposure dose and the duration of exposure.

Primary storage concern:

- Prevent workers from inhaling chemicals, or their eyes or skin from coming into contact with chemicals.

The following applies when storing toxic chemicals:

- Store highly toxic chemicals (including carcinogens, mutagens, teratogens) in a dedicated poisons cabinet labelled “Toxic” or “Poison”;
- Highly toxic chemicals must be kept under lock and key to prevent unauthorised access;
- Store chemicals of moderate to high toxicity in unbreakable containers placed in chemical resistant secondary containers;
- Containers for toxic chemicals must be well-sealed to avoid vaporisation and spills. Container caps made of plastic wrap, aluminium foil, and glass or cork stoppers do not adequately prevent toxic vapours from being released directly into the atmosphere;
- Toxic chemicals in volumes larger than one litre should be stored as close to the floor as possible; and
- Bodily decontamination facilities (e.g., an eyewash station and emergency shower) must be located near to or inside storage areas for immediate use upon accidental exposure (especially skin contact or contact with the eyes) to a toxic chemical.

Storage of Oxidising Chemicals

Oxidising chemicals readily yield oxygen or its equivalent, stimulating combustion. As such, oxidising chemicals present a greater fire and explosion hazard. Oxidisers, while not necessarily combustible themselves, may cause spontaneous ignition or increase the burning rate of the combustible material they come into contact with.

Primary storage concern:

- Keep oxidising chemicals away from flammables and reducing agents.

Strong oxidising agents (e.g., chromic acid) should be stored in an inert, preferably unbreakable, container (e.g., glass or plastic), and capped tightly to prevent leaks.

Perchloric acid (as a solution) needs special mention as it is a very strong oxidising agent at higher concentrations or when heated. Perchloric acid should be substituted with a less hazardous chemical wherever possible. Also, never use perchloric acid in its anhydrous form, as it is unstable at room temperature and can spontaneously decompose resulting in a severe explosion. Anhydrous perchloric acid can also explode upon contact with wood or other organic materials.

The following applies if the use of perchloric acid is necessary:

- Procure only the minimum amount of perchloric acid needed for the laboratory work and store perchloric acid by itself;
- Store perchloric acid bottles in glass or ceramic trays in a metal cabinet away from organic or flammable materials. Alternatively, perchloric acid can be stored in a fume cupboard specially designed to handle perchloric acid; and
- Keep perchloric acid away from strong dehydrating agents like sulphuric acid as the dehydration of perchloric acid can lead to a fire and/ or explosion.

Storage of Reactive Chemicals

Reactive chemicals sometimes used in chemical laboratories can be water-reactive, air-reactive (i.e., pyrophoric substances), or peroxide-forming.

In general, reactive chemicals are highly unstable. They readily react with air or moisture to form new hazardous substances that may be flammable, toxic or corrosive. Peroxide-forming chemicals are particularly hazardous as they can react to form organic peroxide compounds, which are extremely sensitive and may violently decompose if exposed to sparks, heat, friction, impact or light.

Primary storage concerns:

- Prevent reactive chemicals from coming into contact with incompatible substances; and
- Protect reactive chemicals from unfavourable environmental conditions (e.g., temperature changes).

The following applies when storing reactive chemicals:

- Store reactive chemicals in an isolated part of the laboratory that is cool, dry, away from direct sunlight, open flames and hot surfaces, and protected from rapid temperature changes;
- Store containers of reactive chemicals in individual chemical resistant secondary containers large enough to hold the contents of a full spill;
- The storage environment should protect reactive chemicals from unfavourable conditions such as shock, friction, light, and so on; and
- Chemicals which readily absorb moisture or react violently with air must be kept in a tightly-sealed dry box with desiccators or a nitrogen-purged box under positive pressure.

Water-reactive Chemicals

- Store water-reactive chemicals in a watertight and/ or humidity-controlled dry cabinet away from any water source (e.g., a sink, an emergency shower, a water sprinkler, a refrigerator, an air conditioner, or an open window where rain may enter). Label the cabinet "Water-Reactive Chemicals – No Water".

Air-reactive (Pyrophoric) Chemicals

- As air-reactive chemicals can burst into flames once their container seals are broken, store them separately from flammables and other heat sensitive chemicals.
- Store air-reactive chemicals in an inert atmosphere (e.g., under a nitrogen blanket or an inert liquid) at all times.

Peroxide-forming Chemicals

- Store peroxide-forming chemicals away from heat sources and sources of ignition as organic peroxides are highly flammable.
- Do not store peroxide-forming chemicals in a clear glass container as doing so exposes them to light, which accelerates organic peroxides formation.
- Tightly secure the lids and caps of each peroxide-forming chemical container to discourage evaporation and unintended concentration.
- Do not store peroxide-forming chemicals in a glass container with a screw cap lid or a glass stopper. Friction from unscrewing the cap lid or grinding from removing the glass stopper may be sufficient to trigger an explosion.
- Date all peroxide-forming chemical containers with their received date, opened date and expected shelf life.
- Test for peroxides regularly. If the presence of organic peroxides is suspected (e.g., if crystals can be observed forming in the container or around its cap), do not open or move the storage container. Call a chemical disposal specialist for assistance with immediate disposal.

Storage of Gaseous Chemicals

Chemical gases are typically stored in a compressed gas cylinder. Common gases used in a laboratory include: air, oxygen, nitrogen, carbon dioxide, nitrous oxide, chlorine, ammonia, methane, acetylene, and helium.

Compressed gas cylinders pose both a chemical and physical hazard. As each cylinder contains large amounts of stored energy and may contain a highly flammable/ toxic substance, compressed gases can potentially create a hazardous environment. If the valve of a gas cylinder were to break off, not only will the chemical gas escape, but the force of its quick expansion could propel the cylinder a few metres away from its original location.

Primary storage concerns:

- Keep gas cylinders away from heat sources, physical damage and tampering; and
- Keep chemical gases away from incompatible gases.

The following applies when storing gas cylinders:

- Keep stocks of gas cylinders to a minimum and within SCDF guidelines;
- Ensure that each gas cylinder is clearly labelled to indicate its contents prior to storage. It is also good practice to label each cylinder as "FULL", "IN USE" or "EMPTY";
- Good practice is to store gas cylinders in an upright position on a floor rack or in a locked cage (to prevent unauthorised access and tampering) placed outside the laboratory in a cool and well-ventilated area, away from direct sunlight, heat sources and corrosive substances (see Figure 13). The required gases can be piped into the laboratory work area when necessary;



Figure 13: Gas cylinders secured in an upright position and stored in a cool, well-ventilated area.

- Secure all gas cylinders (whether empty or full) to prevent them from falling over and damaging the valve (or falling on a person). Gas cylinders can be secured in an upright position by chaining or fastening them to a wall bracket or other fixed support;
- Store cylinders by gas type, separating incompatible gases from one another (e.g., separate oxygen/ oxidising agents from flammable gases). Separation can be achieved either through safety distance or using a fire wall;
- Ensure each gas cylinder's main valve is easily accessible, so that the gas supply can be shut off immediately in an emergency;
- Wherever practicable, install a water sprinkler system over the storage area for gas cylinders so that the water spray will keep the cylinders cool in a fire. A system that automatically releases a suitable extinguishing agent over the cylinders may also be deployed where feasible;
- If a gas cylinder is no longer in use, shut its main valve, remove the pressure regulator and put its safety cap back in place to protect the valve prior to storage; and
- Mark all gas cylinders that are empty and store them separately from cylinders that are full or still in use.

Below is a summary of SCDF's requirements on the storage of gas cylinders in a laboratory:

- Flammable Gases
 - MAQ (L) = 170 L (for LWA ≤ 50 m²)
 - MAQ (L) = 3.4 × LWA (for LWA > 50 m²)
- Oxidising Gases
 - MAQ (L) = 170 L (for LWA ≤ 50 m²)
 - MAQ (L) = 3.4 × LWA (for LWA > 50 m²)
- Liquefied Flammable Gases
 - MAQ (L) = 30 L (for LWA ≤ 50 m²)
 - MAQ (L) = 0.6 × LWA (for LWA > 50 m²)
- Toxic Gases
 - MAQ (L) = 8 L (for LWA ≤ 50 m²)
 - MAQ (L) = 0.16 × LWA (for LWA > 50 m²)

Note:

- MAQ = Maximum Allowable Quantity; LWA = Laboratory Work Area
- A LWA is a space within a laboratory unit for testing, analysis, research or similar activities involving the use of chemicals. A laboratory unit is any enclosed space used for experiments or tests and this may include ancillary offices, restrooms, and contain one or more separate LWAs. A laboratory unit should be housed in a 2 hr fire rated enclosure for non-sprinkler protected premises or a 1 hr fire rated enclosure in sprinkler protected premises.
- The capacity in litres (L) refers to the internal volume (water capacity) of the cylinder.

- The above MAQ is for laboratories protected by a water sprinkler system. For items 1 to 3, the MAQ needs to be halved if there is no sprinkler system.
- For laboratories protected by a water sprinkler system, minimum separation distance of 3m must be applied between each group of gases (6m for laboratories without a sprinkler system).

Further Information

- NFPA 55: 2013 *Compressed Gases and Cryogenic Fluids Code*
- NFPA 58: 2011 *Liquefied Petroleum Gas Code*

3.1.2 Chemical Compatibility

Chemicals should not be simply stored in alphabetical order. For example, acetic acid would be next to acetaldehyde if stored in alphabetical order, but the two chemicals are an incompatible pair and an adverse reaction will occur if they come into contact with each other.

The following are examples of hazards which could arise due to incompatible chemical reactions:

- Heat generation – for example, concentrated acid and water;
- Fire – for example, hydrogen sulphide and calcium hypochlorite;
- Explosion – for example, picric acid and sodium hydroxide;
- Toxic gas/ Vapour production – for example, sulphuric acid and plastic;
- Flammable gas/ Vapour production – for example, acids and metals;
- Formation of a substance with greater toxicity than reactants – for example, chlorine and ammonia;
- Formation of shock- or friction-sensitive compounds;
- Solubilisation of toxic substances – for example, hydrochloric acid and chromium; and
- Violent polymerisation – for example, ammonia and acrylonitrile.

To avoid creating incompatible combinations, first separate chemicals into their organic and inorganic families, and then into compatible groups, before finally storing alphabetically within a compatible group (see Section 3.1.3 for a listing of compatible groups).

Keep in mind that safe storage must address both the chemicals' hazardous nature (flammable, corrosive, toxic, unstable) and the issue of chemical compatibility. Always consult the chemical's SDS to understand its properties and characteristics, and obtain specific guidance on its storage requirements. Specific information on chemical compatibility can be found in Section 10 (Stability and Reactivity) of a SDS.

In general, the following chemical groups need to be stored separately from one another:

- flammable chemicals;
- corrosive chemicals;
 - acids are to be separated from alkalis (bases);
 - acids are to be further separated into inorganic acids and organic acids;

- toxic chemicals;
- oxidising chemicals;
 - oxidising agents to be separated from reducing agents;
- unstable chemicals including:
 - water-reactive chemicals;
 - air-reactive (pyrophoric) chemicals;
 - peroxide-forming materials;
 - chemicals which can react with themselves (e.g., through polymerisation);
 - potentially explosive chemicals; and
- incompatible chemicals.

Within the same storage cabinet, incompatible groups can be separated from one another by a physical barrier (e.g., a different cabinet compartment, a different leak proof shelf, or via the use of secondary containment such as a plastic tray or bin) to maximise cabinet space for chemical storage.

Examples of incompatible chemicals are given in Annex A.

For more details on chemical compatibility, refer to the chemical compatibility matrix given in Table C.3 (Annex C) of Singapore Standard *CP 100: 2004 Code of Practice on Hazardous Waste Management*.

Container Compatibility

Other than compatibility between chemicals, the material of a chemical's primary container is also critical, as it must be able to withstand long-term exposure to the chemical without deteriorating. Chemical containers are typically constructed from glass and plastic as they are generally non-reactive and can be used for long-term storage of a wide variety of chemical substances. See Figure 14 for examples of chemical containers.

Glass is an excellent media as it is clear and transparent (allowing chemicals to be easily identified, for example, by their colour), chemically inert, rigid and hard-wearing. It is also easily fabricated into bottles, relatively inexpensive and readily recyclable. For storage of light-sensitive chemicals, amber-tinted glass bottles are typically used. Glass, however, is easily breakable.

Plastic containers are the next best choice as they are light, not easily breakable, generally non-toxic and chemical-resistant. Plastic containers may be opaque, translucent or clear depending on the type of polymer used and/ or their method of construction. Plastic, however, may degrade after extended contact with a particular chemical.



Figure 14: A variety of container types are available for use in a laboratory. Select one that is compatible with the chemical being stored.

A container material compatibility chart for commonly used polymer types is provided below as a general reference for key chemical family groups:

Plastic Material:	Teflon®	HDPE	LDPE	PC	PETG	PP	PVC
Chemical Family							
Acids (diluted/ weak)	E	E	E	E	G	E	E
Acids* (strong/ concentrated)	E	G	G	G	N	G	G
Alcohols (aliphatic)	E	E	E	G	G	E	G
Aldehydes	E	G	G	G	G	G	G
Alkalis (bases)	E	E	E	N	N	E	E
Esters	E	G	G	N	G	G	N
Hydrocarbons (aliphatic)	E	G	F	G	G	G	G
Hydrocarbons (aromatic)	E	N	N	N	N	N	N
Hydrocarbons (halogenated)	E	N	N	N	N	N	N
Ketones (aromatic)	E	N	N	N	N	N	F
Oxidising Agents (strong)	E	F	F	F	F	F	G

* for oxidising acids, see Oxidising Agents (strong)

Compatibility		HDPE	High Density Polyethylene
E	Excellent. 30 days of constant exposure caused no damage. Plastic may tolerate the chemical for years.	LDPE	Low Density Polyethylene
G	Good. Little or no damage after 30 days of constant exposure to the chemical.	PC	Polycarbonate
F	Fair. Some effect after seven days of constant exposure to the reagent. Effects include crazing, cracking, loss of strength or discolouration.	PETG	Polyethylene Terephthalate Copolyester
N	Not recommended. Immediate damage may occur. Depending on the plastic, the effect may be crazing, cracking, loss of strength, discolouration, deformation, dissolution or permeation loss.	PP	Polypropylene
		PVC	Polyvinyl Chloride

Table 10: Container compatibility chart for chemical families versus commonly used polymers.

Chemical containers can also be made of steel. To conveniently store, carry and dispense of flammable liquid or fuel, galvanised steel or stainless steel safety cans are often used as they come with special provisions to minimise flammable vapour emissions.

Laboratory managers and chemical users are advised to check the chemical SDS and work closely with chemical container suppliers to determine the right container material for the long-term storage of each chemical in a laboratory.

3.1.3 Suggested Shelf Storage Pattern

The following arrangement of compatible chemical families for the shelves of a chemical storage cabinet is based on the Suggested Chemical Storage Pattern in the *Flinn Scientific Catalog/ Reference Manual*:

Step 1 Sort chemicals into inorganic chemicals and organic chemicals.

Step 2 Separate chemicals into the following compatible storage groups:

Inorganic Chemicals	Organic Chemicals
- Metals, hydrides - Acetates, halides, halogens, iodides, oleates, oxalates, phthalates, phosphates, sulfates, sulfites, thiosulfates - Amides, azides, nitrates (EXCEPT ammonium nitrate), nitrites - Carbon, carbonates, hydroxides, oxides, silicates - Carbides, nitrides, phosphides, selenides, sulfides - Bromates, chlorates, chlorites, hydrogen peroxide, hypochlorites, iodates, perchlorates, perchloric acid, peroxides - Arsenates, cyanates, cyanides - Borates, chromates, manganates, molybdates, permanganates, vanadates - Inorganic acids (EXCEPT nitric acid – nitric acid should be isolated and stored by itself) - Arsenic, phosphorous, phosphorous pentoxide, sulphur - Inorganic miscellaneous	- Organic acids, amino acids, anhydrides, peracids - Alcohols, amides, amines, glycols, imides, imines, sugars - Aldehydes, esters, hydrocarbons, oils - Ethers, polyethylene oxide, halogenated hydrocarbons, ketenes, ketones - Epoxy compounds, isocyanates - Azides, hydroperoxides, peroxides - Nitriles, polysulfides, sulfides, sulfoxides - Cresols, phenols - Dyes, stains, indicators - Organic miscellaneous

Step 3 Store chemicals according to the following suggested shelf storage pattern:

INORGANIC CHEMICALS	
TOP SHELF	
Arsenic, phosphorous, phosphorous pentoxide, sulphur	Arsenates, cyanates, cyanides Caution: Store away from water.
Acetates, halides, halogens, iodides, oleates, oxalates, phthalates, phosphates, sulfates, sulfites, thiosulfates	Carbides, nitrides, phosphides, selenides, sulfides
Amides, azides, nitrates, nitrites EXCEPT Ammonium nitrate Caution: Store ammonium nitrate away from all other substances.	Borates, chromates, manganates, molybdates, permanganates, vanadates
Metals, hydrides Caution: Store away from water. Store flammable solids in flammables cabinet.	Bromates, chlorates, chlorites, hydrogen peroxide, hypochlorites, iodates, perchlorates, perchloric acid, peroxides
Carbon, carbonates, hydroxides, oxides, silicates	Inorganic miscellaneous
BOTTOM SHELF	

Acid Storage Cabinet

Acids (EXCEPT Nitric acid)

Caution:
Store inorganic acids separately from organic acids. Inorganic acids can only be stored in the same cabinet as organic acids if placed in separate secondary storage containers or secondary containment trays.

Store nitric acid separately as it is incompatible with most other chemicals. Nitric acid must be stored away from other acids unless the acid storage cabinet provides a dedicated compartment for nitric acid.

ORGANIC CHEMICALS

TOP SHELF

Alcohols, amides, amines, glycols, imides, imines, sugars

Caution:
Store flammables in a dedicated cabinet.

Cresols, phenols

Aldehydes, esters, hydrocarbons, oils

Caution:
Store flammables in a dedicated cabinet.

Azides, hydroperoxides, peroxides

Ethers, polyethylene oxide, halogenated hydrocarbons, ketenes, ketones

Caution:
Store flammables in a dedicated cabinet.

Organic acids, amino acids, anhydrides, peracids

Caution:
Some organic acids need to be stored in an acid cabinet.

Epoxy compounds, isocyanates

Dyes, stains, indicators

Caution:
Store alcohol-based solutions in the flammables cabinet.

Nitriles, polysulfides, sulfides, sulfoxides

Organic miscellaneous

BOTTOM SHELF

Flammables Storage Cabinet

Inorganics: Metals, hydrides
Organics: Alcohols, amides, amines, glycols, imides, imines
Organics: Aldehydes, esters, hydrocarbons
Organics: Ethers, polyethylene oxide, halogenated hydrocarbons, ketenes, ketones
Organics: Alcohol-based indicators

Caution:
Store flammable solids separately from flammable liquids.
Also separate organic flammables from inorganic flammables.

Poisons Storage Cabinet

All moderately to highly toxic chemicals are to be stored in a locked cabinet.

3.2 Chemical Transfer

Chemicals may need to be transferred from the storage container to a smaller receiving container as they are moved from where they are stored to where they will be used (e.g., from the storage room to the laboratory). As the transfer may involve using a lift and/ or passing through a corridor, some planning is needed to ensure the transferral can be accomplished safely.

Things needed in preparation for chemical transfer are:

- chemical SDS;
- primary receiving container;
- PPE (e.g., safety goggles);
- LEV (e.g., a fume cupboard); and
- secondary container and chemical utility cart.

Transferring to a Smaller Receiving Container

1. As part of RA, the first step is to find out about the specific chemical to be transferred. Obtain the SDS for the chemical you intend to transfer. Note the specific hazards associated with the chemical (e.g., if the chemical is flammable, corrosive, toxic, reactive) and determine the list of materials and substances with which it is incompatible. Refer to Section 2.4 on Chemical SDS. Specifically, see Section 7 of a SDS for guidance on the safe handling of the chemical to be transferred.
2. Choose a receiving container made of a compatible material. Hydrochloric acid, for example, will rapidly react with some metal containers to form explosive hydrogen gas, so a glass container should be used for hydrochloric acid. Hydrofluoric acid, however, reacts with glass, so a durable plastic container needs to be used instead. Refer to Section 3.1.2 on Container Compatibility. Figure 15 shows the transfer of a chemical into a small receiving container.
3. Confirm the receiving container is clean and completely free from any residue, especially incompatible residue (e.g., from other chemicals it might have held), or any water left from cleaning operations. In the case of air-reactive chemicals, the container will need to be purged with an inert gas (e.g., nitrogen) before the chemical can be transferred. Refer to Section 3.1.2 on Chemical Compatibility.
4. Check that the receiving container is sufficiently large to hold the volume of chemical to be transferred. To minimise risk of spillage, fill each container only up to $\frac{3}{4}$ of its volume so that each container will have some air space after the transfer.
5. Ensure that the receiving container can be properly closed or sealed after the transfer. More volatile chemicals will produce vapours (especially at higher temperatures) and the container must be able to withstand the increase in pressure that may be generated as a result. Fit the container with an overpressure venting device if necessary.



Figure 15: Carry out transfers in a fume cupboard to minimise exposure to chemical vapours.

- Label the receiving container before the transfer to clearly identify the chemical and communicate its hazards. Refer to Section 2.4 on Chemical Container Labelling.
- Use the required PPE as recommended by the SDS. These may include safety goggles, respirator, covered shoes, chemical-resistant gloves and/ or an apron. If necessary, perform the transfer under LEV to remove vapours that may be generated during the transfer. Refer to Section 3.3.3 on Personal Protective Equipment and LEV.
- If there is a chance of ignition due to electrostatic discharge, bond the storage and receiving container with a metal wire and connect both to an electrical ground point with a grounding strap. In cases where the chemical is highly sensitive to electrostatic discharge, it may also be necessary for the person carrying out the transfer to be grounded as well.
- Place the receiving container in a stable position and place a funnel in the mouth of the receiving container to assist in the transfer. Position the receiving container at a suitable height to make the transfer ergonomically safe.
- Pour (or siphon) the chemical from the storage container into the receiving container. Pour slowly and keep the storage container close to the receiving container to minimise fall distance and/ or splashing. Use guide rods to facilitate the transfer if necessary.
- Once the transfer is complete, remove the funnel and cap (or seal) the receiving container. If the storage container is empty, either dispose of it or clean it in accordance with the manufacturer's instructions for that chemical. If the storage container contains leftover chemical, return it to its designated storage location.

Moving a Receiving Container to a New Location

- Carry out a RA and plan the route of movement to ensure that the proposed route is safe and free of hazards that can cause a slip, trip or fall. The route of movement should avoid any location where many people are located (e.g., the general office or the cafeteria). Familiarise yourself with the uneven surfaces, ramps, and blind corners along the chosen route. When moving a chemical, use the freight lift rather than the stairs if possible. If the building only has a passenger lift, wait until it is empty before using it to transfer a hazardous chemical. Refer to your company's in-house lift policy for specific instructions.
- Place the receiving container in a durable break-resistant secondary container (e.g., a plastic or metal container with carrying handle) so that any leakage will be contained by the secondary container (see Figure 16). This will prevent chemical spills along the route and allow for the chemical to be brought to the nearest fume cupboard in the event of a leak. Note the material of the secondary container must be compatible with the contents of the receiving container. Refer to Section 3.1.2 on Container Compatibility.



Figure 16: Use a secondary container to transfer a receiving container to its new location.

- For the transfer of larger and heavier chemical quantities (e.g., a few containers of different chemicals), first group the chemicals by hazard class to ensure chemical compatibility. Refer to Section 3.1.2 on Chemical Compatibility. Make a separate move for each hazard class.

Using a chemical utility cart or trolley (with guard rails to prevent containers from slipping off and leak-resistant edge protection) together with secondary containers is recommended. Heavier containers should be placed on the bottom rack of the utility cart. Do not overload the cart, but make as many trips as necessary.

See Figure 17 for an example of a chemical utility cart.

- Wear the necessary PPE and stay with the chemical containers at all times while they are being transported. Never let them out of your sight or leave them unsupervised during the move (unless you are using a designated unmanned cargo lift for transportation of chemicals). Be aware of your surroundings. Watch for doors opening in your way. Consider working in pairs with a colleague walking in front of the utility cart/ chemical container to ensure the path is clear and to warn others of the hazard.
- Have a chemical spill kit as well as emergency contact numbers on standby in the event there is a spill during the transfer.

Moving a Gas Cylinder

- Do not move any gas cylinder with a pressure regulator attached. Remove the regulator from the gas cylinder and replace the valve safety cap before making the move.
- Always use a cylinder cart (see Figure 18) to move gas cylinders. Ensure that the cylinder is securely chained or strapped to the cart. Never roll, slide or drag a gas cylinder as this may not only physically damage the cylinder, but may also result in the cylinder being dropped due to loss of control.
- When moving the gas cylinder, keep it as upright as possible. Never lay a gas cylinder on its side as this can cause condensed liquids to enter the cylinder valve. When the valve is opened, this condensed liquid will rapidly volatilise and expand, creating a potentially explosive condition.



Figure 17: A chemical utility cart with 12 separate compartments for moving chemical containers.



Figure 18: A cylinder cart specially designed for moving gas cylinders.

Further Information

- CP 75 : 1998 Code of Practice for Gas Cylinders – Procedures for Change of Gas Services
- SS 281: 1984 Pressure Regulators for Liquefied Petroleum Gases
- SS 447: 1998 Gas Cylinders – Terminology

3.3 Chemical Usage

Chemicals are transferred into a laboratory so that they can be used. To protect the safety and health of workers, employers can put in place risk control measures to reduce possible worker exposure to chemical substances during laboratory work.

3.3.1 Exposure to Chemicals

Chemicals may enter our bodies via four key routes, namely:

- inhalation;
- ingestion;
- absorption through the skin or eyes; and/ or
- injection.

Inhalation

- Chemicals, in the form of gas, vapour, fumes or dust, can easily enter the body through inhalation.
- The total amount of a toxic compound absorbed depends mainly on the concentration of airborne chemicals and the duration of exposure.
- Excessive exposure through inhalation may cause direct irritation or local damage to the respiratory system, as well as injure bodily tissues as a result of absorption from the lungs into the circulatory system.

Ingestion

- Toxic materials may be injected as a result of poor personal hygiene, for example, eating with contaminated hands or taking meals in a laboratory.
- Ingested chemicals may be absorbed into the bloodstream through the small intestine. The contaminated blood then travels to various parts of the body, injuring specific organs.

Absorption through the Skin

- Skin contact with chemicals may result in severe irritation or a sensitisation reaction similar to an allergic response.
- Certain chemicals (e.g., organic solvents) are readily absorbed via the skin. The chemical would be absorbed into the body even more readily if the skin is broken or damaged by a cut or abrasion. Once the chemical enters the bloodstream, its toxicity may affect one or more target organs within the body.

Absorption through the Eyes

- The eyes can readily absorb chemicals when splashed with a liquid chemical. Chemical irritants (in the form of gases, vapours, fumes or dusts) may also adhere to the surface of the liquid covering the eye.

- Contact lenses should not be worn when working in a chemicals laboratory as they diminish the natural rinsing effect of tears, resulting in less efficient removal of the chemical irritant. This may cause the irritant to concentrate in the eye, intensifying the chemical's effect.

Injection

- Injections occur when a sharp object (e.g., a needle) punctures the skin, injecting a chemical directly into the bloodstream.
- The use of tongs or other tools to pick up sharp objects can help lower the exposure to injection.

The objective of implementing risk control measures is to prevent or minimise potential chemical exposure via all possible entry routes while handling chemicals in the laboratory.

3.3.2 Permissible Exposure Level

As chemicals are easily inhaled, it is important to put in place the necessary controls to minimise the risk of chemical exposure while handling them in a laboratory.

The WSH (General Provisions) Regulations states that it is the legal duty of the occupier of a workplace (including laboratories) to implement reasonably practicable measures to ensure that no person at work is exposed to toxic substances in excess of the PEL specified in the First Schedule of the Regulations.

PEL is the maximum time-weighted average concentration in the air of a toxic substance to which persons may be exposed without suffering any adverse health effects.

There are two types of PELs specified in the First Schedule:

- **PEL (Long Term)** is the PEL over an eight hour working day and a 40 hour working week; and
- **PEL (Short Term)** is the PEL over a 15 min period during any working day.

See Table 11 for the PEL values of some common toxic substances.

Toxic Substance	Permissible Exposure Level			
	PEL (Long Term)		PEL (Short Term)	
	ppm ⁺	mg/m ³	ppm	mg/m ³
Ammonia	25	17	35	24
Chlorine	0.5	1.5	1	2.9
Methanol	200	262	250	328
Pentane	600	1770	750	2210
Sulphur dioxide	2	5.2	5	13

Table 11: Selected PEL values from the First Schedule of WSH (General Provisions) Regulations.

⁺ Where ppm is the parts of toxic substance per million parts of contaminated air by volume and mg/m³ is the milligrammes of toxic substance per cubic metre of contaminated air.

To assess the risk of over-exposure to toxic contaminants, first the air in the laboratory is sampled to determine the atmospheric concentration of each chemical contaminant. The measured result is then compared with its PEL value to confirm that exposure is below the permissible level.

For substances that do not have a PEL (Short Term), the PEL (Short Term) of the substance is deemed to be exceeded if the measured result over a 15 min period during any working day exceeds 5 times the PEL (Long Term) of that substance.

In the event there is exposure to more than one toxic substance at the same time and the substances have similar harmful effects, the PEL is deemed to be exceeded if the sum of the ratios between the time-weighted average concentration and the PEL of each substance exceeds one.

For substances not listed in the First Schedule of WSH (General Provisions) Regulations, an alternative reference and equivalent for PEL is the Threshold Limit Value (TLV®) published by the American Conference of Governmental Industrial Hygienists (ACGIH®).

Note that both PEL and TLV® serve as guidelines or recommendations to assist in the evaluation and control of potential workplace health hazards. They are by no means a relative index for toxicity and do not represent the line between safe and dangerous exposure concentrations.

3.3.3 Controlling Exposure

Dilution ventilation, local exhaust ventilation and personal protective equipment may be used to reduce one's exposure to chemical substances while working in a laboratory environment.

Dilution Ventilation

Mechanical ventilation controls the flow of air into and out of a work area so that there is always fresh air in the working environment. From a WSH perspective, general or dilution ventilation (effected through mechanical ventilation) serves an important function – it controls inhalation exposure to low toxicity gases and vapours by diluting airborne contaminants to within the permissible level.

In the laboratory context, dilution ventilation is most useful when the:

- toxicity of the contaminant is low to moderate (i.e., relatively high PEL);
- contaminant source is not well localised or there are multiple contaminant sources;
- generation rate and velocity of the contaminant is low to moderate; and
- contaminant emission source(s) is/ are not near the breathing zone of any worker.

For dilution ventilation to be effective, there is a need to:

- mix contaminated air with a large volume of fresh air;
- create air movement at all locations within the laboratory; and
- have sufficient air changes per hour to prevent contaminant build-up.

More details on dilution ventilation requirements and the formulas for determination of dilution ventilation rate can be found in *SS 567: 2011 Code of Practice for Factory Layout – Safety, Health and Welfare Considerations*.

The ideal dilution ventilation rate will depend on various factors (e.g., laboratory layout and occupant loading) and should be determined according to the risk level of the laboratory and the required ventilation performance. An important reference for designers of laboratory ventilation systems is *NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals*. SCDF's Fire Safety and Shelter Department (FSSD) may be consulted for technical assistance in this area.

Local Exhaust Ventilation

A LEV device is designed to capture and remove high toxicity airborne contaminants at or very near their sources of emission. The most common LEV device used in a laboratory is the chemical fume cupboard, also referred to as a chemical fumehood. Depending on the nature of work and the laboratory setup, flexible arm capture hoods may also be used (see Figure 19). LEV devices prevent the transmission of gaseous or vapour contaminants from source to worker, significantly reducing inhalation exposure.



Figure 19: A flexible arm capture hood can be positioned close to the contaminant source.

In the laboratory context, LEV is most useful when the:

- toxicity of the contaminant is high (i.e., relatively low PEL);
- contaminant is emitted from a fixed location or from a specific container;
- generation rate and velocity of the contaminant is high; and
- worker's breathing zone is in the immediate vicinity of the contaminant emission source.

For LEV to be effective, there is a need for the:

- hood to either enclose the contaminant source or be positioned as close to it as possible;
- capture velocity to be high enough to draw the contaminant into the hood from the furthest point where it is likely to be present; and
- direction of air movement to be designed such that contaminants are carried away from the worker's breathing zone.

More details on LEV requirements, the range of desired capture velocities for different contaminant dispersion scenarios, and the recommended duct velocities for proper conveyance through the exhaust system can be found in *SS 567: 2011 Code of Practice for Factory Layout – Safety, Health and Welfare Considerations*.

I. Using a Laboratory Fume Cupboard

The standard fume cupboard consists of a vertically sliding sash, rear baffle(s), an exhaust fan and ductwork that connects the hood to the exhaust stack (see Figure 20 for an example of a laboratory fume cupboard).

Two main types of fume cupboards exist, ducted and recirculating (i.e., ductless). Both types operate on the same principle – air is drawn in from the front (or open) side of the cabinet, across the work surface, through the rear baffles and either expelled outside the building via the exhaust stack or made safe through filtration and fed back into the laboratory.

The exhaust fan will draw air through the face of the hood at a certain capture velocity. For conventional fume cupboards, this velocity typically varies according to the position of the sash, for example, the capture velocity through the fume cupboard opening increases as the sash is lowered. However, as an energy saving feature for Variable Air Volume (VAV) fume cupboards, the total amount of air exhausted is reduced to keep the capture velocity constant even as the sash is lowered.

Fume Cupboard Dos and Don'ts:

- Laboratory equipment and glassware should be placed at least 15cm behind the sash opening. This reduces exposure to any chemical vapour that may escape from inside the fume cupboard back into the laboratory due to air turbulence.
- Do not use the ventilated area of the fume cupboard as a storage cabinet for chemicals. Storing chemical containers or other items in the ventilated area disrupts the air flow within the fume cupboard. Nothing should be allowed to block the airflow through the rear baffles or through the baffle exhaust slots as most of the air is exhausted from them.
- Do not keep loose papers or paper towels inside the fume cupboard as they can get drawn into the exhaust fan and adversely affect its performance.
- Do not allow your head to enter the plane of the hood opening. For example, for vertical rising sashes, keep the sash below your face at all times when using the fume cupboard. The sash will provide protection against fires, explosions or chemical splashes in the fume cupboard.

When the fume cupboard is not in use, pull the sash all the way down. While working in front of the fume cupboard, pull down the sash as low as possible. In general, except for VAV fume cupboards, a smaller sash opening increases the capture velocity of the fume cupboard.

- If large equipment (e.g., a centrifuge) is to be used inside a fume cupboard, elevate it 3cm to 5cm off the work surface to allow air to flow underneath the equipment. This dramatically reduces turbulence within the fume cupboard and helps increase its capture efficiency.



Figure 20: A fume cupboard with a base cabinet specially designed for storage of flammables.

- Do not place objects directly in front of a fume cupboard (e.g., hanging a lab coat on the fume cupboard controls) as this may disrupt the air intake/ airflow and draw contaminants out of the fume cupboard.
- Do not store chemicals in the base cabinet of a fume cupboard unless the base cabinet in question was specially designed for the safe storage of flammables or corrosives (see Section 3.1 on Chemical Storage).

Note that fume cupboards are not designed for work with microorganisms. Biosafety cabinets must be used for work with hazardous microorganisms.

II. Fume Cupboard Inspection and Maintenance

The best designed and engineered installation will cease to perform effectively if not maintained regularly. Fume cupboards are no exception – their performance should be tested periodically and their internal working mechanisms (e.g., controls, pressure gauges, alarms, exhaust fan) subject to equipment maintenance at least once every year.

Daily Inspection

The fume hood area should be visually inspected for unauthorised equipment storage, materials and other visible blockages that could disrupt the air intake or airflow of the fume cupboard.

Periodic Testing

The performance of a fume cupboard should be tested periodically, for example, once every three to six months. A key indicator of fume cupboard performance is its capture velocity, measured using a velometer or anemometer. Use a minimum of six readings (at different locations) to determine average capture velocity. A smoke test can be used to simulate contaminants and visually confirm the direction of air movement and fume cupboard capture effectiveness.

Hoods for most common chemicals should have an average capture velocity of 30 m per minute at sash opening of 46 cm or higher.

Annual Maintenance

The fume cupboard should undergo regular maintenance. This includes maintenance of the fume cupboard controls, alarm system and exhaust fan (e.g., lubrication of moving parts, belt tension, fan impeller replacement). The ductwork should also be inspected annually and cleaned as necessary. Maintenance should be conducted in accordance with the manufacturer's recommendation.

At minimum, the following maintenance checks are recommended at least once a year:

- Inspect sash mechanism for corrosion and damage;
- Check proper function of sash stop;
- Check condition of worktop seals;
- Check condition of utility services and controls including alarms;

- Inspect exhaust fan, motors, drives and bearings to check if they are running correctly:
 - Check exhaust fan motors for worn bearings and excessive noise;
 - Check if exhaust fan belt pulleys are taut and correctly aligned; and
 - Check exhaust fan impellers for wear and corrosion;
- Check fire damper and release mechanism;
- Check the built-in water sprinkler system (if installed);
- Check the water wash system in fume cupboard (if installed);
- Check the condition of flexible connections;
- Inspect the condition of the exhaust ducting and ductwork joints (e.g., bends and elbows);
- Check the need for cleaning and repair inside the ductwork; and
- Check the stability and condition of discharge stack.

All periodic inspections, performance tests and maintenance activities should be duly recorded. It is good practice to display the certificate of inspection and the inspection record on the fume cupboard itself, together with the results of each inspection. To protect workers' health, any fume cupboard which failed an inspection or was not inspected on schedule should be taken out of service and tagged accordingly until repairs are completed.

Personal Protective Equipment

PPE aims to protect a worker from being exposed to chemicals via the main routes of entry into a person's body, namely, through the:

- nose (inhalation);
- mouth (ingestion); and
- eyes or skin (absorption).

In the laboratory context, PPE includes items of protective clothing such as a laboratory coat (fitted with easy-to-remove fastenings, e.g., through the use of Velcro or studs; and to be worn with long pants), chemical resistant gloves and aprons, and protective items such as covered non-slip shoes, safety eyewear and respirators (e.g., for use in the event of a chemical spill).

As the use of PPE does not eliminate or reduce the hazard, the user is likely to be exposed to laboratory hazards should the PPE fail. Given that PPE is the last line of defence, a PPE programme is recommended to ensure that workers are indeed protected when PPE is used. See Figure 21 for standard PPE used in a laboratory environment.



Figure 21: Standard PPE for a laboratory environment includes a laboratory coat, chemical resistant gloves and safety eyewear.

Key elements of a comprehensive PPE programme include:

- PPE selection;
- PPE fitting;
- PPE maintenance and storage; and
- PPE user education and training.

PPE Selection

Once the chemical hazard(s) has/ have been identified, a useful approach is to think through from "head-to-toe" on the protection needed to prevent the worker from being exposed to chemical hazards. Selection of PPE should be based on the types of chemicals being handled and the SDS is a good source of information in this regard.

For protection against direct skin contact with chemicals, it is important that the material of the PPE be carefully selected for its ability to resist chemical penetration and/ or permeation, particularly if chemicals are toxic or corrosive. For improved body protection, the use of chemical resistant aprons is recommended. For situations where a higher level of body protection is required (e.g., during an emergency response to a major chemical spill), the use of chemical protective clothing is required.

PPE Fitting

To ensure effective protection, PPE needs to be correctly (and comfortably) fitted to its user, for example, through a fit test for respirators, properly fitted laboratory coat and gloves, and so on.

PPE Maintenance and Storage

To keep PPE (e.g., gloves) in good condition and ready for use, they need to be stored properly (e.g., in a cool environment away from direct sunlight) to prevent material deterioration. PPE should also be subject to regular maintenance and checked (e.g., through a leak test on gloves and respirators) before each use. Finally, it is important that PPE be replaced periodically (especially gloves), depending on the frequency of use, permeability to the chemical(s) being handled, and lifespan of the material.

PPE User Education and Training

As part of a comprehensive PPE programme, users will need to receive training on the selection of PPE as well as proper use of respirators in order to prevent or minimise exposure to chemical hazards.

I. Skin Protection

As chemicals can enter the skin upon contact, a laboratory coat, apron and hand gloves are necessary to reduce worker exposure to chemicals when working in a laboratory.

Chemical resistant gloves available in the market may be made of various materials such as rubber, polyvinyl chloride, polyvinyl alcohol, neoprene, nitrile or butyl. These materials serve as an impermeable barrier and can protect hands from chemicals, oils and solvents.

The following table lists the common types of glove materials along with the chemicals they can be used against:

Type	Advantages	Disadvantages	Use Against
Natural rubber	Low cost, good physical properties, dexterity.	Poor vs oils, greases, organics. May be of poor quality.	Bases, alcohols, dilute water solutions; fair vs aldehydes, ketones.
Natural rubber blends	Low cost, dexterity, better chemical resistance than natural rubber vs some chemicals.	Physical properties frequently inferior to natural rubber.	Bases, alcohols, dilute water solutions; fair vs aldehydes, ketones.
Polyvinyl chloride (PVC)	Low cost, very good physical properties, medium cost, medium chemical resistance.	Plasticisers 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	Oxidising acids, anilines, phenol, glycol ethers.
Nitrile	Low cost, excellent physical properties, dexterity.	Poor vs benzene, methylene chloride, trichloroethylene, many ketones.	Oils, greases, aliphatic chemicals, xylene, perchloroethylene, trichloroethane; fair vs toluene.
Butyl	Speciality gloves, polar organics.	Expensive, poor vs hydrocarbons, chlorinated solvents.	Glycol ethers, ketones, esters.
Polyvinyl alcohol (PVA)	Specialty glove, resists a very broad range of organics, good physical properties.	Very expensive, water sensitive, poor vs light alcohols.	Aliphatics, aromatics, chlorinated solvents, ketones (except acetone), esters, ethers.
Fluoro-elastomer	Specialty glove, organic solvents.	Extremely expensive, poor physical properties, poor vs some ketones, esters, amines.	Aromatics, chlorinated solvents, also aliphatics and alcohols.
Norfoil (Silver Shield)	Excellent chemical resistance.	Poor fit, easily punctures, poor grip, stiff.	Use for HAZMAT work.

Table 12: Advantages and disadvantages of different glove types for use against chemicals.

Annex B provides recommendations on suitable glove types for various chemicals typically encountered in many workplaces including chemical laboratories.

Further Information

- *SS EN 420: 2003 Protective Gloves - General Requirements and Test Methods Annex E: Glove Material Selection Guide*

General Tips on Glove Selection and Use

- Only select gloves which are resistant to the chemicals being used. Consult the relevant SDS and obtain the manufacturers' specific recommendations when selecting chemical resistant gloves, especially if the gloved hand will be immersed in the chemical.
- Select gloves of the correct size and fit as gloves that are too small are uncomfortable and may tear, whereas gloves that are too large may interfere with hand or finger movement. In some cases, such as when using hydrofluoric (HF) acid, it is advisable to select gloves that can be removed very quickly in an emergency.
- Before use, it is good practice to check gloves (even new ones) for physical damage such as tears or pin holes and for previous chemical damage. This is especially important when dealing with dangerous materials such as HF acid.
- When working with a hazardous chemical, it is advisable to frequently wash the external surface of the gloves with clean water.
- Some gloves, especially lightweight disposables, may be made of flammable material. If wearing these gloves, it is important to keep one's hands away from naked flames or other high temperature heat sources.
- Gloves should be removed in a way that prevents the skin from coming into contact with the glove's contaminated exterior. Once the gloves are removed, wash hands thoroughly.
- Gloves that have been contaminated must be properly disposed of or sent for special cleaning. Do not attempt to reuse disposable gloves. Never wear possibly contaminated gloves outside of the laboratory or to handle office equipment like telephones or computer keyboards.

II. Eye and Face Protection

When working in a laboratory, examples of eye and face protection include safety glasses, safety goggles and face shields to protect against chemical splashes, chemical dusts, mists, fumes and other foreign objects.

In general, safety goggles offer greater protection than safety glasses against chemical splashes. However, when there is a high probability of eye and face injury, a face shield (see Figure 22) should be used with a pair of safety goggles. Note that ordinary prescription spectacles do not provide adequate protection against eye injury.

See Table 13 for a general guide on safety glasses, safety goggles and face shields.



Figure 22: Face shields should be used when handling large quantities of chemicals as well as cryogenic materials.

Safety Glasses	Safety Goggles	Face Shield and Safety Goggles
Required when: Working with low hazard chemicals*, or when a low splash probability exists.	Required when: Working with smaller amounts of corrosive or injurious chemicals* and a moderate splash probability exists.	Required when: Working with larger quantities of corrosive or injurious chemicals* and/ or a high probability of eye and face injury exists.
Examples: • Handling a closed bottle of chemical. • Opening centrifuge tubes. • Pipetting. • Mixing solutions.	Examples: • Pouring acid out of a 500 ml bottle. • Pouring a chemical from a 1 litre bottle. • Working with liquids under pressure.	Examples: • Working with an acid bath. • Pouring 4 litres of acid into a container. • Handling highly reactive chemicals that may splatter.

Table 13: General guide on the use of safety glasses, safety goggles and face shield.

Further Information

- SS 473: 2011 Part 1: Specification for Personal Eye-Protectors – General Requirements
- SS 473: 2011 Part 2: Specification for Personal Eye-Protectors – Selection, Use & Maintenance

III. Respiratory Protection

To protect workers from injuries due to inhalation of chemicals, all laboratory work involving toxic, corrosive or highly volatile substances should be carried out under LEV, for example, in a chemical fume cupboard.

* Refer to the relevant SDS for information on the hazard(s) posed by the chemical being handled.

In cases where LEV is not available or ineffective (e.g., an emergency situation involving a hazardous chemical spill), personal respirators are essential to protect the worker (or team of workers) carrying out spill control or clean up.

There are two basic types of respirators:

- air-purifying respirators; and
- air-supplied respirators.

Air-purifying respirators clean the air by filtering or absorbing contaminants before they enter the respiratory system. An air-purifying respirator contains either a filter for removing particulates from the air (e.g., for handling silica), or a chemical cartridge for absorbing gases, vapours, fumes and mists. As air-purifying respirators only clean the air, it is critical that workers use these respirators only in atmospheres that are not oxygen-deficient.

The type of filter or cartridge to be used depends on the type of contaminant(s) present. It is essential to obtain advice from the supplier of the respirator on the correct filter or cartridge type for a specific contaminant. Unfortunately, there is no single filter or cartridge that can protect a worker from all hazardous chemicals.

If the gaseous contaminant is unknown or if the atmosphere is oxygen deficient, an air-supplied respirator should be used as it provides a continuous supply of uncontaminated air and offers the highest level of respiratory protection. During a laboratory emergency, a portable small cylinder containing compressed or liquid air or oxygen may be used as the breathing air supply to the air-supplied respirator.

Respirators may come as half-face masks (covering the mouth, nose and chin) or full-face masks (covering the face including the eyes). To ensure effective use, workers must be trained and educated in the proper use, care and maintenance of respirators. Wearing an improperly maintained or poorly fitted respirator can be more dangerous than not wearing one at all, as workers may think they are protected while they are not.

Further Information

- SS 548: 2009 Code of Practice for Selection, Use and Maintenance of Respiratory Protective Devices

Other Administrative Controls

Administrative measures to ensure safe laboratory work include:

- restricting entry to high risk laboratories to a small number of trained personnel;
- posting signs at prominent locations to warn workers of hazardous areas and to clearly indicate that PPE is required;
- developing SWPs for all work activities carried out in the laboratory;
- providing WSH training to all workers handling or exposed to chemicals;

- shortening the duration of worker exposure to hazardous chemicals (e.g., through limiting the number of workers exposed or by worker rotation);
- isolating susceptible or allergic workers from certain chemicals;
- banning smoking and prohibiting the consumption of food and drink in any laboratory;
- implementing the Permit-to-Work system for all potentially hazardous work (e.g., for maintenance employees and contractors requiring access to high risk laboratories); and
- conducting frequent laboratory checks and inspections to ensure that workers (including contractors) observe all SWPs and laboratory rules and regulations.

3.3.4 Good Laboratory Housekeeping

Good housekeeping is reflected in the cleanliness and tidiness of a laboratory. Good housekeeping is important because a clean and tidy laboratory can reduce WSH risks and keep workers safe (see Figure 23).

Poor housekeeping is one of the many contributing factors to past laboratory accidents and fires. To create a safe and healthy workplace, good housekeeping practices are necessary to prevent accidents and injuries. Maintaining a high standard of housekeeping will also improve work efficiency and convey a sense of professionalism to those working or visiting the laboratory.

Good housekeeping also plays an important role in contaminant control. Chemical spills (liquid or fine powder) and other contaminants that fall and settle onto the work surface or floor can become airborne by evaporation or convection air currents, exposing workers to harm. Good housekeeping through frequent wet washing or vacuum cleaning is necessary to keep the laboratory free from contaminants.



Figure 23: Example of a laboratory with good housekeeping.

General Housekeeping Guide for Laboratories

- Keep the laboratory neat and free of clutter at all times:
 - Remove unnecessary items from the floor, from under work benches, and from bench tops;
 - Laboratory bench tops and work surfaces should be kept clean and free of infrequently used chemicals, glassware and equipment;
 - Aisles and corridors should be kept free of tripping hazards such as laboratory stools, power extension cords, computer cables, and so on; and
 - Access routes to corridors and stairways, electrical panels, wash basins, eyewash stations, emergency showers, spill kits, first aid kits, fire extinguishers and fire exits must not be blocked.
- Chemical reagents and solutions must be clearly labelled as per GHS requirements so that they can be readily identified and correctly stored.

- Store all laboratory chemicals in proper chemical storage cabinets (e.g., separate storage cabinets for flammables, acids and poisons). In general, do not store chemicals or other laboratory equipment in fume cupboards. Designate a cupboard or room for storage of laboratory equipment.
- Each chemical should be returned to its rightful location after use.
- Chemical waste (including spent, expired and unwanted chemicals) should be properly managed and stored prior to collection by the toxic waste collector.
- Compressed gas cylinders should be stored upright and properly secured.
- Laboratory personnel using work benches, laboratory equipment and common facilities should be responsible for cleaning up after use. In particular, contaminated chemical containers and glassware should be washed as soon as possible after use.
- Keep the laboratory floor clean, dry, and in good condition. In particular, any chemical spillage and/ or broken glass should be cleaned up immediately.
- Use only chairs or stools that can be easily cleaned. Fabric-covered chairs or stools should not be used in a laboratory.
- Pay attention to electrical safety:
 - Do not overload electrical circuits;
 - Electrical devices must carry the SAFETY mark;
 - Equipment must be properly grounded;
 - Electrical devices kept away from wet or damp areas; and
 - Frayed cords must be promptly replaced and loose cords properly coiled up.
- Use secondary containment (e.g., a suitable plastic container with carrying handle or a chemical utility pushcart) to transfer chemicals from one location to another in order to minimise spillage.
- Personal belongings are best kept in lockers outside the laboratory and not left where they can be contaminated or cause obstruction.
- Workers are to observe good hygiene, such as washing their hands thoroughly before leaving the laboratory so they do not contaminate outside areas (e.g., one's office, car and home).

3.4 Chemical Waste Disposal

Waste refers to any substance or object that needs to be discarded. Chemicals that are spent, expired or no longer wanted need to be safely disposed of as chemical waste. Chemical waste may come in the form of liquids, solids, sludge or mixed waste.

Chemical waste is classified as hazardous waste if it exhibits one or more of the following characteristics:

- flammable or combustible;
- corrosive;
- toxic; and/ or
- reactive.

Improper handling of hazardous chemical waste may cause environmental pollution and endanger WSH, especially for workers handling the waste. Also, as disposal costs can sometimes exceed the original chemical purchase price, strategies to minimise waste should be considered.

3.4.1 Strategies to Minimise Waste

All laboratories that use chemicals will inevitably produce chemical waste. It is important to minimise both the amount and the toxicity of the chemical waste generated.

A key strategy in waste minimisation is source reduction. Source reduction refers to any activity that reduces or eliminates the generation of waste at its source. The best way to limit or eliminate the need for and cost of waste disposal is to review all laboratory processes and limit or eliminate those that generate waste.

If the elimination of key waste-generating processes is not possible, then consider the following to minimise the waste generated, reduce hazards and control costs:

- Plan laboratory processes with risk and waste minimisation in mind by:
 - substituting hazardous substances with safer alternatives wherever possible;
 - conducting micro-scale experiments that require less chemicals;
 - recycling chemicals by performing cyclic experiments where the product (or by-product) of a reaction becomes the starting material for the next experiment;
 - acquiring laboratory equipment or modifying procedures to reduce waste generation; and
 - including waste neutralisation or detoxification in the operating procedure;
- Set up a waste register to track the type and amount of waste generated. The waste register will provide valuable information for planning waste minimisation initiatives;
- Buy chemicals wisely and in the smallest quantity needed;
- Check the existing chemical inventory for a needed chemical before buying a fresh bottle;
- Monitor the chemical inventory to avoid expired chemicals;
- Store chemicals properly to prevent deterioration or ageing;
- Develop procedures for waste segregation and containerisation so that disposal options are clearer and more cost effective; and
- Prepare for chemical spills as spill cleanup can generate a lot of waste. Minimise the likelihood of spills through the use of secondary containers. Acquire the right kind of spill control materials to minimise the amount of resulting debris or waste.

3.4.2 Waste Segregation and Storage

In a laboratory, chemical wastes are usually segregated on-site into appropriate waste bottles or carboys, before collection by a licensed TIW collector. Proper segregation of waste will allow for maximum treatment and recovery by the TIW collector.

Recommended Practice for Segregating Laboratory Waste

- Separate chemical wastes into different types, for example, waste organic solvents, aqueous waste, wastes that are incompatible with one another.
- Further separate waste organic solvents (i.e., hydrocarbon-based) into halogenated and non-halogenated solvent waste. Non-halogenated organic solvent waste can either be recycled or burnt for energy recovery, while halogenated solvent organic waste must be specially incinerated to minimise the formation and release of dioxins.
- Separate aqueous waste containing toxic compounds from waste organic solvent. Only innocuous aqueous waste (such as sodium chloride solution) may be poured down the wash basin.
- Segregate the following and package separately:
 - strong oxidisers from organics;
 - acids from bases;
 - heavy metal solutions from salts;
 - chemical carcinogens;
 - cyanide-containing materials;
 - peroxide-forming chemical from combustible materials and mineral acids; and
 - water-reactive chemicals from moisture, water and other chemicals.
- Collect waste elemental mercury separately for reclamation.
- Collect chemically contaminated solid waste and broken glass in plastic containers or plastic-lined cardboard. Broken glass that is contaminated with chemicals is usually not suitable for recycling.

Recommended Practice for Storage and Handling of Chemical Waste

- Ensure that chemical reactions are complete before discarding the chemical waste. This is because incomplete reactions may continue inside the waste container, leading to pressure build-up within the container.
- Store all chemical waste in durable, leak-proof containers (usually bottles or carboys) that are in good condition and compatible with their contents. Chemical waste in containers that are bulging, rusted, cracked, and/ or have improper or missing caps must be transferred to an appropriate container in good condition for storage. Refer to Section 3.1.2 for general guidance on Container Compatibility. Table C.1 (Annex C) of Singapore Standard *CP 100: 2004 Code of Practice on Hazardous Waste Management* provides further details on the chemical compatibility of common containers with different hazardous waste types.
- Establish and implement SWPs for all chemical waste handling work.
- Work under LEV when transferring chemical waste into a container.
- Use the appropriate PPE when handling chemical waste, for example, impervious gloves, face shield, safety goggles, chemical-resistant apron and safety boots. Refer to Section 3.3.3 on Personal Protective Equipment.

- Label each waste container so that its contents can be easily identified, and label it “HAZARDOUS WASTE” if the contents are flammable, corrosive, toxic or reactive. At minimum, the label should state the:
 - waste type;
 - volume of the waste;
 - its key chemical constituents;
 - purity of the waste (if available);
 - date of disposal;
 - associated safety and health hazards; and
 - the recommended PPE if necessary.
- If the waste container is already partially filled, conduct a RA and check for chemical compatibility before pouring in more waste. Never mix one waste with another waste in the same container unless the constituents in both waste sources are known. If necessary, conduct laboratory testing to ascertain the hazardous substances in each source before combining waste from different sources. Refer to Section 3.1.2 on Chemical Compatibility and in particular the chemical compatibility matrix given in Table C.3 (Annex C) of Singapore Standard *CP 100: 2004 Code of Practice on Hazardous Waste Management*.
- Do not fill waste containers to their brims – fill up to three-quarters of the container’s maximum capacity. This leaves sufficient headspace at the top of each waste container to cater for temperature changes, increased vaporisation and potential pressure build-up.
- Cap all waste containers prior to storage. Keep all waste containers closed except when adding to or removing from the container.
- Store chemical waste in a designated area away from normal laboratory operations. Never place waste containers in common areas like hallways or corridors, or near wash basins and floor drainage points.
- Ideally, store chemical waste in a dedicated chemical storage cabinet (see Figure 24). Incompatible wastes should be properly segregated to prevent inadvertent mixing, which can result in undesirable chemical reactions. Use a physical barrier (e.g., a separate cabinet compartment, a different leak proof shelf, or secondary containment such as a plastic container or tray) to separate incompatible wastes. Lock the storage cabinet to prevent unauthorised access.
- If waste is stored in a central storage room, the room should be provided with appropriate ventilation, fire suppression facilities or equipment (e.g., an automatic water sprinkler system and fire extinguishers), emergency equipment (e.g., a respirator and spill kit) as well as containment dikes to avoid sewer contamination in the event of spills.



Figure 24: A dedicated cabinet for the storage of chemical waste.

3.4.3 Waste Disposal

The laboratory officer in charge of chemical waste disposal is responsible for engaging a licensed TIW collector and communicating relevant waste disposal requirements to contractors. The updated list of TIW contractors licensed by the National Environment Agency (NEA) under the Environmental Public Health (TIW) Regulations may be found at NEA’s website (www.nea.gov.sg) under Anti-Pollution & Radiation Protection > Chemical Pollution > Toxic Industrial Waste.

Recommended Practice for Disposing of Chemical Waste

- Never pour liquid chemical waste down the drain or throw solid chemical waste into the trash bin unless the waste is innocuous and safe for disposal as normal refuse.
- Do not treat hazardous waste on-site unless the laboratory has special facilities to do so.
- Seek the services of a licensed TIW collector who can assist with and ensure proper treatment and disposal of hazardous chemical waste.
- Containers used for the storage of chemicals are to be regarded as TIW.
- Return all gas cylinders to the industrial gas supplier/ distributor/ vendor.
- Use appropriate mechanical lifting or handling devices to aid in the transfer of heavy waste containers and gas cylinders.
- Record the details of the waste disposal (e.g., description of the waste, characterisation analyses where applicable, volume or weight of the waste, date of disposal, TIW contractor responsible for the disposal) in the waste register.

Note that chemical waste (whether in solid or liquid form) or any materials contaminated by chemical waste should never be deposited into bins meant for general waste as this may lead to uncontrolled reactions and/ or severely injure the janitor/ cleaner in-charge of clearing the general waste.

The list of chemical substances classified as TIW can be found in Annex C of this guide.

Further Information

- *CP 100: 2004 Code of Practice for Hazardous Waste Management*

3.5 Chemical Exposure Monitoring and Medical Surveillance

3.5.1 Workplace Exposure Monitoring

The WSH (General Provisions) Regulations requires regular exposure monitoring in workplaces where toxic substances are used or emitted. Workplace monitoring reveals the workers’ level of health hazard exposure and helps assess possible health risks. Additionally, exposure monitoring helps assess the effectiveness and adequacy of hazard control measures already in place and determines compliance with PELs. See Table 14 for the required frequency of exposure monitoring.

The method of sampling (to be carried out by a competent person) depends on the chemical being monitored. Common air sampling methods include air sample bags, sorbent tubes, impingers, filters or badges. Also available are direct reading instruments (e.g., electrochemical sensors, solid state detectors, photo-ionisers, and infrared analysers) for measuring gases, vapours and aerosols in the air. The advantage of direct reading instruments is that some allow for continuous monitoring of contaminant levels and/ or include data logging features or alarms to warn users of hazardous conditions.

Sampling strategy considerations include:

- the location of sampling (e.g., fixed location or attached onto the worker);
- duration and volume of sampling;
- frequency of sampling; and
- the number of samples required to accurately represent worker exposure or workplace environmental condition.

Exposure Level	Monitoring Frequency
Exposure < 10% of PEL	Not required unless there is a change in the process
10% of PEL ≤ Exposure < 50% of PEL	At least once a year
50% of PEL ≤ Exposure ≤ 100% of PEL	At least once every 6 months
Exposure ≥ PEL	At least once every 3 months until the exposure is reduced to < PEL by appropriate control measures

Table 14: Required frequency of exposure monitoring depends on the exposure level.

Under the WSH (Noise) Regulations, regular noise monitoring (at least once every three years) is also required for workplaces where ten or more persons are exposed to excessive noise. Noise monitoring must be carried out within three years if any change in machinery, equipment, process, operation, work, control or other condition is likely to cause increased exposure to excessive noise. Monitoring of noise must be done by a competent person using an appropriate sound level meter.

Upon completion of the monitoring exercise, soft copies of the Toxic Substances Monitoring Report Form (along with the corresponding workplace layout map with sampling points indicated) and the Noise Monitoring Report Form (along with the corresponding Noise Map) should be submitted to the MOM either by the company’s WSH Officer or the HR Officer.

Finally, the results of workplace monitoring should be evaluated and the necessary measures taken to safeguard worker health. Employees should also be informed of the monitoring results so they are aware of the hazards, use the necessary PPE and actively participate in the development and implementation of engineering control measures to address the hazards.

3.5.2 Statutory Medical Surveillance

Medical surveillance is a system of monitoring the health status of workers to determine departures from normal health and to take corrective action(s) early (see Figure 25).

Under the WSH (Medical Examinations) Regulations 2011, workers must undergo pre-employment and periodic medical examinations if they are employed in any occupation involving exposure to:

- benzene;
- vinyl chloride;
- organophosphates;
- tar;
- pitch;
- bitumen;
- creosote;
- silica;
- asbestos;
- trichloroethylene;
- perchloroethylene;
- raw cotton;
- lead;
- mercury;
- manganese;
- cadmium; and/ or
- arsenic or their compounds.

Pre-employment and periodic audiometric examinations are also required for workers employed in occupations involving exposure to excessive noise.

Companies are advised to consult an occupational hygienist on the need for medical surveillance for exposure to substances not listed under the WSH (Medical Examinations) Regulations 2011.

The objective of medical examinations is to detect the early symptoms of occupational diseases and to ensure workers remain medically fit for work.

The type of medical examination, the clinical test(s) required and the frequency of such examinations will depend on the type of hazard involved, the substance the worker was exposed to, and the degree of that exposure. The results of medical monitoring reflect the adequacy of control measures put in place to safeguard the health of the employee.



Figure 25: Periodic medical examinations allow occupational disease to be detected early.

The employer is duty bound to arrange and pay for the medical examinations which must be carried out by a Designated Workplace Doctor (DWD) registered with the Commissioner for WSH. The list of DWDs can be found on MOM's website (www.mom.gov.sg) under Workplace Safety & Health > Monitoring and Surveillance > Medical Monitoring.

The following are good practices for employers:

- **Pre-employment Medical Examination**

For effective medical surveillance, it is useful to start from the time a worker begins his/her exposure to a particular substance. The pre-employment examination should be conducted within three months of employment and its results used as the baseline against which subsequent changes can be compared.

For example, workers exposed to lead are required to undergo a haemoglobin test and blood lead estimation pre-employment. If a worker is found to have a low haemoglobin level (anaemic), he should not be engaged in work involving lead exposure as he would be at greater risk of developing lead poisoning. An increase in blood lead levels in subsequent examinations compared to the baseline would suggest that lead has entered the worker's body. If left unchecked, the worker may eventually be poisoned.

- **Periodic Medical Examinations**

These are used to detect early signs of disease (e.g., through a chest X-ray, a liver function test, or an audiogram test) and the levels of a chemical or its metabolite (e.g., blood lead, urinary phenol) in a worker's body.

These examinations are useful when detecting groups of workers for whom corrective action may be taken before they develop the disease. For example, workers with high lead levels should no longer be exposed to the chemical. In this way, overt poisoning can be prevented.

Employers are required to keep a record of all medical examinations conducted. Information on worker exposure should be kept for at least five years from the date of the examination. The register of workers exposed to a hazard and the summary report of examinations should be submitted to the MOM either by the DWD or the company representative.

Find out more on workplace monitoring and surveillance at the MOM website (www.mom.gov.sg) under Workplace Safety & Health > Monitoring and Surveillance.

Further Information

- *WSH Guidelines on Statutory Medical Examinations*

4. Chemical Incident Emergency Response

Accidents involving hazardous chemicals all have one thing in common – they are often uncontrolled, involving fires, explosions or release of hazardous chemicals. They may result in death or injury of a large number of persons inside or outside the laboratory, or cause extensive damage to equipment, property and the environment. To minimise injury and mitigate damage, laboratories should put in place an emergency response plan (ERP).

4.1 Emergency Response Plan

The first step when preparing for an emergency is to prepare for it in advance. Every laboratory worker who comes into contact with hazardous chemicals must not only be aware of preventive measures but also be trained in emergency procedures prior to commencing work.

At the individual level, key emergency procedures each laboratory worker needs to be familiar with include:

- spill control procedure;
- decontamination procedure;
- first aid measures;
- fire-extinguishing technique; and
- evacuation plan.

Each laboratory should establish its own ERP. An ERP is essentially a backup to the risk control measures for the management of laboratory hazards. The ERP should be formulated according to the hazard(s) associated with the chemicals being used and the nature of the laboratory operation.

At minimum, a good ERP should make clear the following aspects:

- Duties and responsibilities of in-house emergency response personnel, for example, employees trained in firefighting for small fires, fire wardens, first aiders;
- Location, use and maintenance of emergency equipment in the laboratory including:
 - spill control equipment, for example, spill kits, absorbents, floor drain covers, PPE;
 - first aid equipment, for example, emergency showers, eyewash stations, first aid kits, stretchers; and
 - fire-fighting equipment, for example, fire hose reels, fire extinguishers, sprinkler systems;
- Evacuation procedure for workers, including details such as the location of emergency exits, the alarm system for initiating evacuation and the system of accounting for all workers at a safe assembly area outside the building. The evacuation plan should detail procedures for the immediate evacuation of workers who may need assistance (e.g., disabled workers, pregnant women) in getting to the emergency exits;

- Procedure to call for external help, in particular the SCDF for assistance in fire-fighting, first aid, rescue and spill clean-up; and
- ERP training for workers including the schedule for emergency drills. Emergency drills help verify the ERP's effectiveness, familiarise workers with emergency procedures, and reinforce the need to be prepared at all times.

In many cases of laboratory mishaps, appropriate action in the first few seconds of an emergency situation can prevent a relatively minor incident from escalating to a serious one. Therefore, every worker should have sufficient training in basic emergency procedures to react promptly should a chemical incident occur.

As with preventive measures, the key to appropriate emergency response lies with sound knowledge of the chemicals used and quick access to the relevant safety information. The first place one can look for specific information on first aid measures, fire-fighting techniques and spill control procedures is the chemical's SDS. The label on the chemical container may also offer valuable information during an emergency.

To facilitate quick notification for external assistance, it is good practice to post the list of emergency response contact numbers (including those of the Laboratory Supervisor, Safety Officer and SCDF) near the exit of the laboratory and on every telephone.

Further Information

- *SCDF Guidelines for Emergency Response Plan*

4.2 Emergency Evacuation

In the event of a serious emergency involving a fire, explosion or release of hazardous chemical, the laboratory must be evacuated. This not only protects those in the laboratory from the hazard, but clears the way for in-house emergency response teams and/ or SCDF to handle the emergency.

General Guide to Laboratory Evacuation

- Laboratory evacuation may be necessary if there is a chemical release, fire or explosion.
- Be aware of the marked exits from the laboratory and the building evacuation route.
- The evacuation alarm is usually a loud continuous siren or horn.
- To activate the building alarm system, proceed to the nearest emergency call point and press the emergency alarm button (break the protective sheet as necessary).
- Walk quickly to the nearest exit and guide others to do the same.
- Once outside, proceed to the designated assembly point or to a clear area that is at least 50m from the affected building.
- Do not return into the building until the emergency situation has been rectified and the building cleared for re-entry.

4.3 Chemical Spill Control

For a spill or leak that releases a hazardous chemical, emergency procedures need to be established so that the source of the release can be promptly rectified, and the contaminated area contained and properly decontaminated.

When developing an ERP, consider all possible spill scenarios and the magnitude of the spill that can create or complicate an emergency situation:

- What chemical(s) might be spilled? Are the chemicals toxic, flammable, corrosive or highly reactive? Are they compatible with one another?
- What is the magnitude of the spill? Are more materials stored in the laboratory than necessary?
- Where are the potential spill locations? Can these locations be consolidated or moved to a safer area of the laboratory?
- What PPE are required for spill clean-up? Are the PPE readily available? Are laboratory employees trained in proper PPE use?

Spill Control Equipment

Equipment and supplies (see Figure 26) for handling a chemical spill include:

- neutralisers for acid and alkali spills;
- universal inert absorbents (e.g., absorbent booms, pads, pillows);
- adsorbents for solvent and hydrocarbon spills;
- drain covers and caution tape;
- PPE (e.g., chemical protective clothing, chemical-resistant gloves, safety goggles, respirator, safety boots);
- whisk broom or handheld brush, plastic/ metal scoops and dust pan;
- leak-proof disposal bags to hold the spilled material and contaminated absorbents;
- sealable impervious disposal container(s); and
- mercury spill kit (for laboratories where mercury is used).



Figure 26: Supplies for chemical spill control.

Responding to a Minor Laboratory Spill

Before cleaning up a chemical spill, one should know the hazards associated with the spilled substance. Consult the chemical's SDS as necessary. A minor spill is one which laboratory employees are capable of handling safely, without the assistance of emergency personnel. Minor (or simple) spills involve chemicals with low toxicity where there is little risk of fire or incompatible reactions.

The steps involved in responding to a minor spill include:

- Turn the container (from which the spill originated) upright if it is safe to do so;
- Notify all persons in the immediate vicinity and evacuate them as appropriate;
- Ventilate the area by opening the windows and doors, and turn on the ventilation system (e.g., switching on the fans and establishing LEV);
- Cover all nearby drainage points;
- Cordon off the contaminated area with caution tape;
- Put on the appropriate PPE. Respirators are generally not required for minor spills of chemicals with low toxicity;
- For liquid spills, contain the spill by first surrounding it, then covering it completely with compatible absorbent/ adsorbent materials;
- For a powder spill, cover it with wet paper towels (if compatible) to avoid dispersion;
- Use a plastic scoop to collect the residual chemical and contaminated cleanup materials into disposal bags/ disposal container for disposal as hazardous chemical waste. Arrange for removal by a licensed TIW collector; and
- Wash the affected area with soap and water and mop dry.

Responding to a Major Laboratory Spill

All other chemical spills that are not minor should be regarded as major spills. Major spills require immediate evacuation of the laboratory, and should only be contained and cleaned up by a specially trained and equipped emergency response team (e.g., the SCDF HAZMAT Team). Also, the SCDF should be notified immediately.

A spill is considered major (or complicated) if:

- A person is injured;
- The identity of the spilled chemical is unknown;
- Multiple chemicals are involved;
- The chemical is highly toxic, highly flammable or highly reactive;
- The spill involves a large quantity of chemicals;
- The spill occurred in a public space such as the corridor;
- The spill has the potential to spread to other parts of the building through the ventilation system, floor drainage points, or some other means;
- Appropriate cleanup procedures are not known or appropriate cleanup materials are not available;
- The cleanup requires a respirator to be worn and no personnel have been fit tested or trained to use a respirator; and/ or
- The spill may endanger the environment as it may contaminate a neighbouring waterway or the ground outside.

The steps involved in responding to a major spill include the following:

- Evacuate all persons from the laboratory and activate the fire alarm as necessary;
- If the spilled chemical is flammable, turn off all ignition sources if this can be done safely;

- Attend to injured or contaminated co-workers if it is safe to reach them. Use the emergency shower or eyewash as necessary. Move them outside the laboratory as quickly as possible;
- The last person to evacuate should close all windows and doors on exiting (to slow down the spread of odours), leaving the doors unlocked;
- Isolate the area with warning signs and caution tape, so that no one will re-enter the laboratory; and
- Contact the emergency response team, and remain stationed near the laboratory (but at a safe distance) to provide information to the responders once they arrive.

4.4 Bodily Decontamination

For direct contact with a hazardous chemical (for example, from a chemical splash on the skin or in the eyes), an on-site easily accessible safety shower and emergency eyewash is essential for immediate decontamination as part of first aid prior to medical treatment (see Figure 27).

Fast access to safety showers and emergency eyewashes is critical to mitigate the consequences of chemical exposure. Decontamination can be achieved through *dilution* (i.e., diluting the chemicals that are on the skin or in the eyes to a non-harmful level) and/ or *irrigation* (i.e., flushing the chemicals out of the eyes or off the skin) with potable water.

As a rule of thumb, safety showers and emergency eyewash stations should be located close to potential hazard sites and in places that allow an injured person to access them within ten seconds along an unobstructed path. This is so the injured person can reach the decontamination point in the shortest possible time before the effects of chemical contamination set in. An unobstructed path is crucial as the person can avoid wasting precious time getting to the safety shower and/ or eyewash during an emergency.

A good practice is to mark the location of all safety showers and eyewash stations with the appropriate sign so that laboratory users will be able to quickly identify their locations.

Facilities with safety shower and eyewash stations need to ensure the water released is clean (in particular, free from any impurities that may have accumulated in the water pipeline). This can be achieved by establishing a procedure for each station to be activated regularly for a few minutes (e.g., once a week) so as to flush the water supply and test for proper operation.



Figure 27: Emergency eyewash with flexible hose located next to a wash basin.

For chemical eye injuries, a soft stream of aerated potable water is recommended as it provides a gentle scrubbing action to remove contaminants efficiently and safely.

Keep the area around a safety shower free from live electrical equipment and power outlets as these present an electrocution hazard. Also, never tie or secure the pull rod (or handle) of the safety shower as this will interfere with shower operation.

After the injured person has been decontaminated, first aiders are advised to:

1. Quickly identify the chemical(s) involved;
2. Obtain the SDS of the chemical;
3. Render first aid for the chemical exposure; and
4. Pass the SDS to the doctor or emergency medical personnel for specific follow-up treatment.

General Guide on using a Safety Shower

- Remove all clothing, jewellery and shoes under the shower – if not removed, these items may hold chemicals against the skin and increase the damage.
- Remain under the shower for at least 15 mins, then seek medical attention immediately.
- When using the shower, exercise caution as wet floors are slippery.

See Figure 28 for an example of a safety shower.

General Guide on using an Emergency Eyewash

- Flush your eyes immediately if chemicals are splashed on them as a delay of a few seconds could cause severe eye damage or blindness.
- Move the eye up, down and sideways to wash thoroughly behind the eyeball where chemicals could be trapped. The injured worker should not rub his/ her eyes.
- If chemicals are splashed into the eye, hold the eyelids open and flush with water continuously for at least 15 mins, and then seek medical attention immediately.

Continuous flow eyewash setups are preferred to standalone self-contained portable eyewash stations due to their ready access to large volumes of clean water.

The advantage of portable eyewash stations is that they are compact and easily deployed at work sites where a potable water source is not available or without plumbing capabilities. However, these portable stations contain a limited supply of water, and the water may become contaminated with microorganisms if kept under unfavourable conditions.



Figure 28: Safety shower with integrated eyewash and hand/ foot controls.

Moreover, the portable units often come with squeeze bottles that one has to hold to operate, meaning the user will not be able to manually hold his/ her eyelids open while washing them.

Portable eyewash stations are most useful for immediate response when the work location is not fixed. Thus, they are commonly carried by drivers transporting dangerous substances as well as fire and emergency teams. In a laboratory, the portable eyewash may be used to provide the initial flush until the injured worker reaches a plumbed eyewash station.

4.5 Firefighting

As the chemicals used in a laboratory may be flammable, the possibility of a fire (or flash fire) is always present. It is therefore important to equip each laboratory with the necessary firefighting facilities and equipment to handle a (small) fire outbreak should it occur.

Taking reference from the fire triangle (see Figure 29), three components must be in place before a fire can start – fuel, oxygen source, and ignition or heat source.

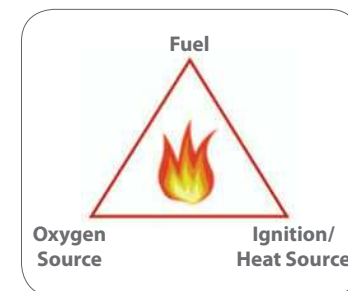


Figure 29: The fire triangle.

Some common fuels, oxygen and ignition sources found in a laboratory:

Components of a Fire Triangle	Common Sources
Fuel	Solids Wood, paper, plastic, polymer dust, metal particles. Liquids Alcohols, ethers, esters, ketones, solvents, petroleum liquids. Gases Acetylene, hydrogen, methane, propane, butane.
Oxygen	Air, oxygen, hydrogen peroxide, metal peroxide, organic peroxide, sodium chlorate, ammonium nitrate.
Ignition / Heat	Open flames, hot surfaces, frictional sparks, static electricity.

Table 15: Common sources of each component of the fire triangle.

Once started, for a fire to remain in existence and spread, all three components must remain present:

- fuel for the fire to burn;
- oxygen for the fire to “breathe”; and
- heat for the fire to continue burning.

Fire extinguishment is about finding ways to remove one or more components of the fire triangle:

Method of Fire Extinguishment	Targeted Fire Triangle Component
Cooling	Removal of the “Heat” component, for example, by using water.
Suffocation	Removal of the “Oxygen” component, for example, by using a fire blanket, foam or inert gas like CO ₂ .
Starving	Removal of the “Fuel” component, for example, by physically removing the fuel.

Table 16: [Methods of extinguishment and their corresponding impact on a fire.](#)

Firefighting facilities and equipment found in many laboratories include overhead water sprinkler systems, special hazard non-water extinguishing systems, fire alarm systems, nearby firewater hose reels, flame-retardant fire blankets and portable fire extinguishers.

Fire Classification and Fire Extinguishers

Fires are classified into five categories which take into account the nature of the fuel and the means of extinguishment.

Class A

Class A fires are fires involving ordinary combustible materials (usually of an organic nature) like wood, paper, cloth, furnishing, plastics, rubber, and so on, in which combustion normally takes place with the formation of glowing embers. Their most effective extinguishing agent is water (either as a spray or jet) which works by cooling the glowing embers which propagate the fire.

Class B

Class B fires are fires involving flammable liquids, solvents, oils, paints, thinner or liquefiable solids, where oxygen exclusion or a flame-interrupting property of the extinguishing agent is required.

Class C

Class C fires involve flammable gases.

Class D

Class D fires involve combustible metals such as potassium, magnesium, titanium, sodium, lithium and zirconium, where a material specific extinguishing agent is required. Special dry powders such as graphite, talc, soda ash, limestone and dry sand can be used to smother the fire. Normal extinguishing agents (e.g., water) should not be used for Class D fires.

Class F

Fires involving cooking media (vegetable or animal oils and fats) in cooking appliances.

Portable fire extinguishers can be very effective for the control of small laboratory fires. The four common types of fire extinguishers used in Singapore are dry powder fire extinguishers (most common), carbon dioxide fire extinguishers, foam fire extinguishers and pressurised water fire extinguishers (least common due to the widespread adoption of other on-site water dispensing firefighting facilities such as water sprinkler systems and firewater hose reels).

Extinguisher Type	Action
Dry Chemical	Suffocation and interference with the combustion process.
Carbon Dioxide (CO ₂)	Mainly suffocation and some cooling.
Foam	Mainly suffocation and some cooling.
Water	Cooling.

Table 17: [List of common fire extinguisher types and their action on fire.](#)

Extinguisher Type	Suitable for:	Remarks
Dry Chemical (Multi-purpose)	Class A, B, C and electrical fires	Most versatile with wide applicability. However, residue is corrosive and sticky and may cause damage to delicate electrical equipment.
Carbon Dioxide (CO ₂)	Class B, C and electrical fires	Very clean leaving behind no residue. Excellent for use on electrical equipment. Must be applied very close to the fire as spraying range is short.
Foam	Class A, B fires	Not to be applied on electrical equipment as foam contains water. Good for application on oil fires.
Water	Class A fires only	Inexpensive to refill and maintain. Limited applicability. Not to be applied on electrical equipment as water is a conductor of electricity and will severely damage the equipment. Not to be used on oil fires as oil will, in general, float on water.

Table 18: [List of common fire extinguisher types and their applicability by fire class.](#)

Most laboratories are mainly equipped with ABC dry chemical fire extinguishers placed strategically around the premises, with CO₂ fire extinguishers stationed near electrical equipment.

In general, the dry chemical fire extinguisher can be used on chemical, paper or electrical fires. The CO₂ extinguisher can be used on chemical, flammable liquid/ gas or electrical fires as it is the extinguisher of choice for fires involving electrical equipment.

Water as an extinguishing agent should only be used on fires involving combustible materials such as wood, paper, cloth and plastics. Should a person be on fire, rush the person to the nearest safety shower or wrap him/ her tightly in a fire blanket and roll him/ her on the ground to smother the fire. The use of a dry chemical or CO₂ on a person is not recommended due to possible complications.

Good practice is to call for a replacement immediately once any fire extinguisher is found to be used, damaged, vandalised or if the indicator on its pressure gauge is in the red zone. The extinguishers should also be regularly serviced in accordance to the timeline stipulated by the supplier.

General Guide on the Use of a Fire Extinguisher

Only attempt to extinguish small fires with a portable fire extinguisher (see Figure 30), and always fight a fire from a location that allows escape.

To use a fire extinguisher:

- Pull out the safety pin;
- Aim the fire extinguisher nozzle at the base of the fire;
- Squeeze the handle of the fire extinguisher to release the extinguishing media; and
- Sweep the nozzle from side to side and aim the discharge at the base of the fire starting from the front and working towards the rear until the fire goes out.

If the fire cannot be extinguished, quickly evacuate the laboratory and close doors as you leave (to limit fire spread). The building fire alarm system should be activated and SCDF (dial 995) notified as soon as possible.



Figure 30: ABC dry chemical fire extinguisher.

Further Information

- SCDF Fire Code 2013
- CP 10: 2005 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems
- CP 52: 2004 Code of Practice for Automatic Fire Sprinkler System
- SS EN 3: 2012 Portable Fire Extinguishers (EN 3 Series)
- SS 575: 2012 Code of Practice for Fire Hydrant, Rising Mains and Hose Reel Systems
- SS 578: 2012 Code of Practice for Use and Maintenance of Portable Fire Extinguishers
- NFPA 45: 2011 Standard on Fire Protection for Laboratories Using Chemicals

4.6 First Aid for Chemical Exposure

Occupational first aid refers to the immediate assistance and initial care rendered to an injured worker during an emergency before professional medical help is available. First aid is a critical aspect of emergency response as correct immediate action can minimise bodily injury and/ or help the injured worker stay alive.

Under the WSH (First Aid) Regulations, all workplaces employing more than 25 persons are required to appoint at least one competent first aider for every 100 persons employed. Additionally, all workplace occupiers are to have a first aid room in any location where there are more than 500 persons at work. A sufficient number of first aid boxes must be provided and all first aid boxes must be adequately equipped, properly maintained and made easily available. These requirements apply to all workplaces and industry sectors except for hospitals and medical clinics.

Items typically found in a first aid box include plasters, dressings, bandages, gauze, surgical tape, scissors, safety pins, disposable latex gloves, eye shield, eye pad, resuscitation mask (one-way), saline solution or sterile water, a torch light, and so on (see Figure 31).



Figure 31: First aid kit (left) with contents shown (right).

Laboratories where chemicals are used should establish a first aid programme so that measures are in place for emergency treatment of victims of chemical poisoning or excessive exposure to toxic chemicals. In general, the programme should cover:

- first aid facilities (e.g., safety shower and emergency eyewash station) and equipment;
- first aid personnel; and
- the appropriate first aid procedures specific to the set of chemicals used in each laboratory.

For specific guidance on the relevant first aid for a particular chemical substance, consult the SDS (section on First Aid Measures) of the chemical prior to rendering the aid. If further medical attention at a hospital is required, call SCDF (dial 995).

General Guide to First Aid Procedures for Chemical Exposure

Chemical Splash on the Skin

- For a major splash covering a large surface area of the body, rush the injured worker to the nearest safety shower. For a minor splash, involving, for example, only the lower arm, the nearest tap with potable water will do. To minimise injury, it is critical that water flushing start immediately following skin contact with the chemical.
- Remove any jewellery, clothing and footwear that has been contaminated by the chemical while flushing with running water. Persons assisting the injured worker should don the appropriate PPE (e.g., safety goggles and gloves) prior to rendering assistance.
- Continue flushing the contaminated skin surface with water for at least 15 mins.
- Do not apply burn ointment or spray anything on the affected area(s).
- Seek medical attention immediately.

Chemical Splash in the Eye

- Rush the injured worker to the nearest emergency eyewash station. If a fixed eyewash station is not available, either bring a portable eyewash station to the worker or rush him to the nearest tap with potable water.
- Flush the eyes with running water for at least 15 mins while holding the eyelids open. Irrigate the eye outwards (towards the ear) to avoid flushing material into the other eye. The worker should move his/ her eye up, down and sideways to thoroughly wash behind the eyelid and the sides of the eyeball. To minimise injury, it is critical that water flushing start immediately following eye contact with the chemical.
- Cover the victim's eyes with sterile gauze and seek medical attention immediately.

Inhalation of Chemical Gas or Vapour

- Quickly move the injured worker to a safe location with fresh air.
- If the worker has stopped breathing, perform cardiac pulmonary resuscitation (CPR) and use an automated external defibrillator (AED) (see Figure 32) if necessary.
- Seek medical attention immediately.

Ingestion of Poisonous Chemical

- Rush the worker to the nearest tap with potable water or bring many glasses of water to the worker.
- Get the worker to spit everything out and quickly rinse his/ her mouth with plenty of water. Repeat the rinsing process until the mouth is clear of the chemical.



Figure 32: An AED station.

- Do not induce vomiting following the ingestion of a chemical as there is a risk of the chemical causing severe burns to the throat a second time as it exits.
- Send the injured worker to the hospital for stomach cleansing and medical attention as soon as possible.

Neither the first aider nor the injured worker should be put at further risk during the provision of first aid. In particular, if an injured worker is grossly contaminated, the first aider will need to take precautions so that he/ she does not become a victim as well. This can be achieved by, for example, having the first aider don the appropriate PPE (e.g., safety goggles, gloves, impervious aprons) prior to rendering assistance.

First Aid for Exposure to Hydrofluoric Acid

Liquid hydrofluoric (HF) acid is a highly corrosive and poisonous acid that can penetrate the skin and cause severe chemical burns. In some cases, exposure can lead to hypocalcemia. First aid treatment requires irrigating the exposed skin with large amounts of water, followed by the application of 2.5% calcium gluconate gel (see Figure 33).

If the eyes are involved, open the eyelids gently and irrigate with large amounts of water for at least 15 mins, especially the area under the eyelids. Do not apply any eye drops, ointment or calcium gluconate gel.

If HF acid is ingested, give the injured worker water, milk, antacids or any calcium-containing compounds. Do not induce vomiting or give activated charcoal.

If HF acid is inhaled, monitor for breathing difficulties and perform CPR and/ or use the AED if breathing has stopped.

For severe HF acid burns, immediately send the injured person to the Burns Centre at Singapore General Hospital (SGH).

First Aid for Cyanide Poisoning

Cyanides are highly toxic and can be rapidly absorbed through the skin. The commonly used antidote for cyanide poisoning is *amyl nitrite* ($\text{CH}_3(\text{CH}_2)_4\text{ONO}_2$) via inhalation. Companies with cyanide on their premises may consider acquiring this antidote and having it available on-site for emergency use. Amyl nitrite comes in small glass ampoules wrapped in protective gauze (see Figure 34) and is typically available as part of a cyanide antidote kit containing amyl nitrite, sodium nitrate and sodium thiosulphate.



Figure 33: Calcium gluconate gel used for exposure to hydrofluoric acid.

The first aid procedure for cyanide poisoning is as follows:

1. Move the injured worker away from the source of cyanide poisoning to an area where there is fresh air;
2. Remove contaminated clothing and immediately wash contaminated parts of the body with large amounts of water;
3. The first aider puts on gloves before breaking the amyl nitrite ampoule within the gauze (see Figure 35); and
4. Allow the injured worker to inhale the amyl nitrite vapour for 15 to 30 seconds every minute by holding the ampoule close to the worker's nose and mouth. A new ampoule should be used until the casualty recovers. Carefully follow the instructions in the cyanide antidote kit for administration of the sodium nitrate and sodium thiosulphate.

Amyl nitrite works to reduce the negative effects of cyanide poisoning by inducing the body to produce methaemoglobin (a specialised haemoglobin) which will bind the cyanide in the bloodstream and convert it into a relatively non-toxic form. Amyl nitrite, however, must be administered carefully and only by a medical professional trained in its use. An overdose will lead to side effects such as a severe drop in blood pressure, elevated heart rate, vomiting and cold sweat.



Figure 34: Amyl nitrite ampoule with gauze.



Figure 35: Gloves should be worn when breaking an amyl nitrite ampoule.

Further Information

- *Occupational First Aid Manual, National First Aid Council and MOM*
- *WSH Council's Worker's Safety Handbook on Working with Hazardous Materials*
- *MOM's Circular on Management of Workers accidentally exposed to Hydrofluoric Acid*

4.7 Incident Reporting

Under the WSH (Incident Reporting) Regulations, employers and occupiers are required to report workplace accidents (including laboratory accidents), dangerous occurrences and occupational diseases to MOM at www.mom.gov.sg/ireport

This helps the Occupational Safety and Health Division (OSHD) of MOM monitor national WSH trends, identify where the risks are and channel resources in partnership with the relevant stakeholders to prevent the recurrence of similar accidents and reduce workplace injuries and diseases. Reporting also facilitates insurance claims and claims under the Work Injury Compensation Act.

For accidents resulting in a fire, SCDF is to be notified to conduct fire investigation. Findings from the fire investigation would help prevent future occurrence of a similar accident.

Employers are required to report to MOM if any of these incidents happen:

- An employee died in a work accident;
- An employee sustained a work-related injury or contracted a disease due to work exposure to a chemical/ biological agent and is:
 - hospitalised for at least 24 hrs; and/ or
 - given a medical certificate (MC) for more than 3 days (consecutive or otherwise).
- An employee contracted an occupational disease; and/ or
(see list of occupational diseases for reporting at MOM's website (www.mom.gov.sg) under Workplace Safety & Health > Incident Reporting)
- A dangerous occurrence at the workplace where no one was injured or killed.
(see list of dangerous occurrences for reporting at MOM's website [www.mom.gov.sg] under Workplace Safety & Health > Incident Reporting)

In the laboratory context, all incidents and injuries should be immediately reported to the Laboratory Supervisor and/ or Laboratory Safety Officer who will determine if the incident is reportable to MOM.

Incident reporting will facilitate the identification of laboratory hazards and specific areas of laboratory management that need to be addressed. Once the hazards and problem areas are identified, corrective action can be taken to prevent recurrences. If the risk control measures and/ or the necessary changes to the laboratory management system are implemented in time, the lessons learnt from the minor laboratory incident would have served to prevent a major accident from happening.

5. Workplace Safety and Health in Laboratory Design

A key objective in laboratory design is to provide a safe and conducive environment for laboratory personnel to carry out their work. To achieve this, hazards must be identified and risks carefully assessed so that WSH measures can be incorporated into the design of a laboratory.

When designing a laboratory, consider the following to build WSH aspects into the design:

	WSH Design Considerations
Walls	The laboratory must be enclosed (i.e., bounded by four walls) and separated from outside areas. An enclosed laboratory will help contain spills and keep unauthorised personnel from entering areas where hazardous chemical operations are performed. As per NFPA 45*, the enclosing walls of a laboratory should be designed to have a minimum fire rating of one hour (for sprinkler protected laboratories) and two hours (for a non-sprinkler protected laboratories). In general, laboratories should be fire compartmented from each other and non-laboratory areas, so that a fire can be contained to the room of origin should it occur. It is also important that enclosing walls are made of a material that does not cause rapid fire spread or result in heavy smoke generation. Walls should be painted with durable, easy-to-clean, impervious paints that are resistant to common laboratory reagents. Wooden and wood finish walls are not appropriate as they can absorb hazardous liquids, making decontamination difficult.
Floors	Laboratory floors need to be impervious to chemical spills. This can be achieved through the use of specialty adhesives, vinyl flooring, epoxy-coated concrete slabs, and so on. The floor should also be easy-to-clean, slip-resistant and non-sparking should an object fall or slide on it. Also, the floor of a laboratory should be covered up the wall to ensure that spills do not go under the floor. Small floor tiles and wooden planks are not suitable for laboratory floors as liquids can easily seep through the small gaps between pieces.
Door	Laboratory doors should be side-hinged, swinging-type, outward opening (in the direction of exit travel), self-closing, lockable and designed to be fire resistant. To facilitate emergency egress, the door must be easy to open without a key. Draw bolts and hooks should not be installed on a laboratory door.

* NFPA 45: 2011 Standard on Fire Protection for Laboratories Using Chemicals.

	WSH Design Considerations
	If two doors are to be placed in series, as might be the case of an isolation airlock where the separation of a facility from a corridor needs to be maintained, the doors should be sufficiently separated to prevent both doors from being opened simultaneously.
Security and Access Control	Laboratory doors need to be locked when the laboratory is not in use. Only authorised personnel should be allowed to enter and carry out work in the laboratory. Consider the use of cardkey access for entry into laboratory and chemical storage areas. Additionally, all hazardous substances must be kept under lock and key at all times. Storage cabinets and laboratory refrigerators, whether housing flammables, corrosives, poisons or highly reactive substances, should be physically locked to prevent unauthorised access.
Furniture	Laboratory bench tops must be sturdy and able to withstand moderate heat. Work surfaces must be both impervious and chemically resistant to reagents used. Epoxy and epoxy-impregnated sandstone are recommended for use with acids and solvents. Chemical-resistant laminated plastic may also be considered as it provides an acceptable work surface for many laboratory tasks at much less initial cost. Keep bench top seams and crevices to a minimum to facilitate easy cleaning. A light coloured work surface is preferred to reduce colour contrasts and eye fatigue. Bench tops made of unfinished wood are not recommended as they absorb liquids. Note that wood will burn a fire.
Furniture Layout and Exit Paths	High hazard laboratories with an occupant load greater than 25 persons at any one time must have at least two well-separated exits*. Laboratory benches must not impede emergency access to an exit. This also applies to other laboratory furniture and appliances such as refrigerators, fume cupboards, and so on. In general, aisles used for emergency egress should have clearance of at least one metre, after taking into account the presence of miscellaneous items like laboratory stools. Clear aisles and exits are necessary to facilitate quick departure in the event of an emergency. General work not involving laboratory operations (e.g., record maintenance, calculations, discussions) should be performed at a desk area separate from the active laboratory work area. Desk areas (e.g., comprising a few tables) should be located such that they do not create a barrier to emergency egress. Ideally, desk areas should be located near exits and in the path of fresh air. This will ensure that, in the event of an emergency, employees do not have to pass through more hazardous areas to exit the laboratory.

+ SCDF Fire code 2013.

	WSH Design Considerations
General Ventilation	Air-conditioned laboratories should have a mechanically-generated supply and exhaust air. This is so that the air balance of the room can be adjusted. In general, laboratories should be continuously maintained under negative pressure in relation to the corridor or other less hazardous areas. Negative pressure will ensure airflow from areas of low hazard (e.g., administrative or service areas), unless the laboratory is a clean or sterile room. To effectively dilute airborne contaminants, active laboratory areas should be provided with single pass 100% fresh air. Laboratory air should not be re-circulated as this can result in contaminant accumulation within the laboratory and/ or distribution of contaminants from the laboratory throughout the building. For more effective dilution ventilation, air exhaust points should be located as near as possible to expected contaminant sources. Additionally, air supply points should be located such that the airflow directs contaminant emissions away from a worker's face and towards exhaust point(s). Note that work involving strong vapour emissions should be carried out under LEV. Windows should not be opened in an air-conditioned laboratory since the room air balance will be affected. Cabinets, boxes, equipment or other structures need to be placed such that they do not block the air supply or exhaust points. The ideal general ventilation rate depends on various factors (e.g., laboratory layout and occupant loading) and should be determined according to a risk- and performance-based approach guided by NFPA 45 Standard on Fire Protection for Laboratories Using Chemicals.
LEV	Fume cupboards should be located away from activities or facilities which produce air currents or turbulence. Ideally, fume cupboards should be located away from doors and high traffic areas as air turbulence affects a fume cupboard's ability to effectively exhaust contaminated air. In particular, do not locate a fume cupboard next to an emergency exit as a fire or chemical release incident may originate from a fume cupboard, making the exit impassable during an emergency. Where practicable, fume cupboard exhaust fans should be connected to an uninterruptible power supply so that hazardous chemicals will continue to be exhausted in the event of a power failure. Exhaust fans should be designed to automatically resume once power is restored.

	WSH Design Considerations
	Fume cupboard exhaust should be channelled to a stack extended beyond the roof of a building. It is important to locate the stack exhaust point away from air intake points to prevent contaminants from being circulated back into the building. Depending on the chemicals used in the fume cupboard, the exhaust may have to be treated (e.g., filtered, adsorbed by activated charcoal or scrubbed) before being sent to the stack. As fires have been known to originate from fume cupboards, consider acquiring one with a built-in fire suppression system. Additionally, the interior of the fume cupboard and exhaust duct should be selected for chemical resistance, and both the interior lighting and exhaust fan certified explosion proof.
Room Temperature and Humidity	It is important to provide laboratory workers with a comfortable working environment. Under very humid conditions, laboratory workers will be less inclined to use their PPE. If the room temperature and/ or humidity are not within a comfortable range, workers are likely to be less productive and more prone to make mistakes, both of which are not acceptable in a laboratory environment. Note that certain electrical appliances (e.g., a heater or a refrigerator) exhaust heat, raising a laboratory's temperature. Consider providing air-conditioned laboratories with manual room temperature control so that the room temperature can be easily adjusted as required.
Lighting	A laboratory needs appropriate lighting so that work can be carried out comfortably. Generally, it is ideal to have a majority of the light in a laboratory come from natural illumination from windows. Indoor illumination should be without glare. Position the light source to ensure that laboratory workers do not work in their own shadows.
Liquid Chemical Storage	Storage of flammable liquids must be kept within the Maximum Allowable Quantity (MAQ) stipulated in the SCDF Guidelines*. The MAQ will depend on whether the laboratory is protected with a water sprinkler system. Sufficient space (e.g., a separate store room) or facilities (e.g., storage cabinets with internal partitions) should be provided so that incompatible chemicals can be physically separated. Storage cabinets need to be of liquidtight construction to contain a spill should one arise. If chemicals are kept separately in a store room, consider storing them in a dike to achieve secondary containment. The chemical storage room should also be designed to be liquidtight where the floor meets the walls. Storage shelves should come with a safety lip at the front edge to prevent containers from falling off shelf.

* SCDF Guidelines and Fire Safety Requirements for Laboratories Handling Chemicals.

	WSH Design Considerations
	Storage cabinets for flammable substances should be placed away from exit paths so that in the event of a fire outbreak (from the cabinet or otherwise), escaping persons will not be obstructed. A clearance of at least 3m between a flammables storage cabinet and any source of ignition and combustible materials is recommended. There should be no storage shelves above a wash basin, as any spillage or breakage will send the chemical directly into the sewer system. In general, storing flammable substances under a fume cupboard is not recommended, as fires have been known to originate from under fume cupboards. Space must also be provided for the storage of chemical waste. Laboratories should be designed to conveniently and safely accommodate temporary storage of chemical waste based on laboratory use projections.
Gaseous Chemical Storage	Where feasible, gas cylinders should be placed outside the laboratory and piped in to minimise the quantity of gas in a laboratory, especially during a fire incident or toxic release. It is recommended that the gas piping system be made of stainless steel and feature double-walls if highly toxic and flammable gases are being used. As the laboratory may not be safe to enter during an emergency, valves for gas lines should be located outside the laboratory so that gas supplies can be safely shut off from the outside. For storage of gas cylinders, NFPA 55* recommends a minimum separation of 6.1m between incompatible compressed gases. This separation distance may be reduced if separating walls of at least 1.5m high are provided or if gases are stored in a gas cabinet. For laboratories protected by a water sprinkler system, SCDF⁺ requires a minimum separation distance of 3m between the following groups of gases: flammable gases, oxidising gases, liquefied flammable gases, and toxic gases. The minimum separation distance needs to be raised to 6m for laboratories without a sprinkler system. For outdoor storage of compressed gases, NFPA 55* recommends a minimum of 7.6m from sources of ignition and a minimum of 3m from combustible materials. For indoor storage, a minimum of 6m from flammable liquids and combustible materials is recommended.

	WSH Design Considerations
	As per NFPA 58* and SCDF guidelines⁺, liquefied petroleum gases (LPG) should be stored at ground level (outdoors or in a recessed area) a minimum of 3m from sources of ignition, parked vehicles, the fire engine access way, and the premise boundary limit. If the LPG cylinders are placed next to an exit door, a minimum clearance of 3m to the exit door (if there is only one exit) or 1.5m (if there is more than one exit) is recommended. For use of toxic or flammable gas within a laboratory, a gas leak detection system should be provided which can detect the leak, sound the alarm, and shut off the gas supply automatically.
Electrical	Laboratories should be fitted with a sufficient number of electrical outlets to accommodate the electrical power requirements of equipment used. Equipment and/ or laboratory design must take into consideration the expected electrical demand prior to occupancy to avoid power outages due to overloading. Critical equipment (e.g., fume cupboards, refrigerators) and vital safety systems (e.g., emergency and egress lighting, fire detection and protection systems) need to be connected to an uninterruptible power supply to ensure continued operation in the event of electrical interruption. Electrical outlets on laboratory bench tops may be protected from water and chemical spills by means of a suitable plastic cover. Use only electrical appliances and devices that carry the SAFETY mark. As the laboratory may be unsafe to enter during an emergency, the circuit breakers and master disconnect switch should be located outside the laboratory so that key electrical appliances can be safely shut off from the outside. Electrical circuits should be clearly identified to correlate with the labels in the circuit breaker panel.
Noise	Certain laboratory equipment, especially those incorporating the use of pumps (e.g., in pilot-scale process experiments), compressors (e.g., in refrigeration units) or internal moving parts (e.g., a centrifuge), will raise the noise level. Implement suitable noise control measures (e.g., by replacing noisy machines with quieter alternatives, using sound enclosures, through staggered usage of noise generating equipment) to ensure that laboratory personnel are not exposed to continuous noise emissions above the permissible exposure limits stipulated under The Schedule of the WSH (Noise) Regulations.

* NFPA 55: 2013 Compressed Gases and Cryogenic Fluids Code.

⁺ SCDF Guidelines and Fire Safety Requirements for Laboratories Handling Chemicals.

* NFPA 58: 2011 Liquefied Petroleum Gas Code.

⁺ SCDF Fire Safety Requirements for Liquefied Petroleum Gas (LPG) Cylinder Installations.

	WSH Design Considerations
Wash Basins	Each laboratory should have at least one basin for hand washing. The trap of the basin should be made of corrosion-resistant material. Plumbing will need to be sized to accommodate the safety shower and emergency eyewash. As exposure to chemical substances can easily occur via hand-to-mouth transmission, it is important for employees to maintain personal hygiene and wash their hands before leaving the laboratory. Because of this, it is a good idea to locate a wash basin close to the exit of the laboratory.
Emergency Eyewash and Safety Shower	Emergency eyewash stations and safety showers should be installed in any work area (including chemical storage rooms) where a worker's body or eyes may come into contact with a substance that is corrosive, severely irritating to the skin or toxic when absorbed by the skin. As a general guide, there should be at least one eyewash station and one safety shower in each laboratory where chemicals are used or stored. It is good practice to install eyewash stations and safety showers in an accessible location, defined as a location an injured person can reach in ten seconds along an unobstructed pathway. In particular, as work involving hazardous chemicals tends to be carried out in fume cupboards, an eyewash and shower should be installed within ten seconds from where fume cupboards are located. Note that there should be no live electrical equipment or power outlets located near an eyewash station or a safety shower as these will present an electrocution hazard.
Fire Detection and Suppression	The potential for fires is higher in a chemical laboratory than in a typical building. As such, depending on floor area, it is recommended for each laboratory and chemical store room to: • be equipped with a ceiling-mounted water sprinkler with automatic fire detection and/ or alarm system; • have at least one manual fire alarm call point; • have at least one ABC dry chemical fire extinguisher inside the laboratory or chemical store room and another mounted outside along the corridor; • be within reach of at least one firewater hose reel; and • have at least one fire blanket available for use in emergencies. A water sprinkler system should also be installed over a storage area for gas cylinders so that the water spray can be used to keep the cylinders cool in the event of a fire. When water cannot be used for fire suppression, for example, because of a large amount of water-reactive or flammable substances, other options for consideration include the use of inert gas (to be applied only when all personnel have evacuated) or total flooding with a dry chemical.

	WSH Design Considerations
Recommended Practice	The location of the following items need to be determined during the laboratory design stage: • chemical storage cabinets; • compressed gas cylinders; • manual alarm call point; • fire extinguishers; • fire hose reels; • safety shower; • eyewash station; • spill control kit; • first aid kit; • resuscitation equipment; • escape breathing equipment; • exit and directional exit signs; • evacuation routes; • gas shut off valves; • electrical circuit breaker; and • master disconnect switch. Good practice is to mark the items on the laboratory floor plan for posting at suitable location(s) within the laboratory and include them in the laboratory safety manual.

Further Information

- *SS 332: 2007 Specification for Fire Doors*
- *SS 531: 2006 Part 1: Code of Practice for Lighting of Work Places – Indoor*
- *SS 532: 2007 Code of Practice for the Storage of Flammable Liquids*
- *SS 553: 2009 Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings*
- *SS 563: 2010 Code of Practice for the Design, Installation and Maintenance of Emergency Lighting and Power Supply Systems in Buildings*
- *SS 567: 2011 Code of Practice for Factory Layout – Safety, Health and Welfare Considerations*

6. Laboratory WSH Inspection Checklist

Laboratory inspections play a critical role in preventing accidents and injuries by providing the opportunity to identify hazards on-site and confirm that risk control measures are indeed in place and effectively implemented. It is recommended that laboratory managers and their employee teams or WSH personnel conduct routine inspections of their work areas on a frequent basis (e.g., fortnightly or monthly) so that unsafe conditions may be readily identified and promptly remedied.

The use of a checklist can help bring focus to a laboratory inspection and ensure that key WSH aspects are examined. A generic WSH inspection checklist for any laboratory where chemicals are used is provided below. The checklist provided is non-exhaustive and laboratory managers are encouraged to insert new entries and customise the checklist as necessary to fit the specific circumstances of each laboratory to be inspected.

Generic WSH Inspection Checklist for Chemical Laboratories			
Laboratory Documentation		Yes	No
1	Laboratory safety manual is available.		
2	Equipment operating manuals are available.		
3	Register of chemicals is available for each laboratory.		
4	SDS are available for each chemical in the laboratory.		
5	SDS are up-to-date (i.e., less than five years old).		
6	Risk register (i.e., a compilation of completed RA forms) is available.		
7	Chemical inventory tracking system is in place.		
8	Inventory inspection records are available.		
9	Fume cupboard certificate of inspection and inspection records are available.		
10	SWPs are available for each laboratory work activity.		
11	Toxic substances monitoring report is available.		
12	Noise monitoring report is available.		
13	Summary report on medical examinations is available.		
14	Chemical waste register is available.		
15	WSH training records are available.		
16	Emergency response plan (including the evacuation plan) is available.		
Laboratory Housekeeping		Yes	No
1	Food and drink are not allowed in the laboratory.		
2	Laboratory benches, sinks, fume cupboards and storage areas are kept clean and tidy.		

Generic WSH Inspection Checklist for Chemical Laboratories			
Laboratory Housekeeping		Yes	No
3	Laboratory floor is slip resistant and kept clean and dry.		
4	There are no tripping hazards (e.g., due to extension cords, cables, hoses).		
5	Electrical plugs, cords and outlets are in good condition.		
6	Laboratory aisles and corridors are unobstructed.		
7	Laboratory exits (including the fire exits) are unobstructed.		
8	Access routes to emergency equipment and facilities (e.g., safety shower, fire extinguishers, and first aid kits) are unobstructed.		
9	No chemicals are stored on the floor.		
10	Fume cupboards are not used for storage.		
11	Tops of cabinets and cupboards not used for storage.		
12	At least one basin is provided for washing.		
13	Chemical containers and glassware are washed and properly stored after use.		
14	Waste chemicals are stored appropriately.		
Risk Assessment		Yes	No
1	RA is carried out prior to work commencement.		
2	Laboratory users/ Chemical users are involved in the RA.		
3	Non-routine laboratory work (e.g., carried out by contractors) is covered in the RA.		
4	Proposed control measures are implemented within a reasonable time.		
5	Laboratory work that is determined to be High Risk is first reduced to Medium or Low Risk before the work is allowed to begin.		
6	Implemented control measures are effective in reducing the level of risk.		
7	Completed RA forms are compiled into a risk register.		
8	Changes to laboratory facilities and/ or operations are subject to RA before implementation.		
Risk Communication		Yes	No
1	Laboratory users have been briefed on the laboratory rules and regulations.		
2	Laboratory users are given a copy of the laboratory safety manual.		
3	Hazard warning signs are in place and consistent with the hazards present.		
4	Chemical containers are labelled according to GHS standards.		
5	Container labels are updated when there is new information for the chemical.		
6	Laboratory users have ready access to SDS and the risk register.		
7	Laboratory users have received the necessary training to perform their work safely.		
8	Risk communication includes contractors and anyone exposed to the risk.		

Generic WSH Inspection Checklist for Chemical Laboratories

Chemical Procurement		Yes	No
1	Chemicals are evaluated for short- and long-term risks prior to procurement.		
2	Less hazardous chemicals are procured whenever safer alternatives exist.		
3	Checks are made to ensure existing stock is depleted before more is acquired.		
4	Minimum quantity is procured in line with expected rate of use.		
5	Laboratory is equipped with facilities to properly store the incoming chemical.		
6	SDS are obtained for each arriving chemical.		
7	Chemical deliveries are promptly recorded into the inventory tracking system.		
8	Employees are trained to safely receive the chemicals being delivered.		
Chemical Storage		Yes	No
1	Chemicals are stored by compatibility, then by alphabetical order.		
2	Chemical containers are compatible with their contents.		
3	Chemicals are stored properly, for example, in fire-rated storage cabinets or in dedicated storage rooms.		
4	Quantity of chemicals stored is within the MAQ stipulated in SCDF Guidelines on Fire Safety Requirements for Laboratories.		
5	Labels on each chemical container are readable and as per GHS standard.		
6	Chemical containers are kept securely closed except during chemical transfers.		
7	Storage shelves come with anti-roll edge guards to prevent containers from sliding off.		
8	Larger or heavier chemical containers are stored on the lower shelves.		
9	Chemical storage areas are equipped with facilities for emergency response.		
10	Flammable chemicals are stored away from oxidisers, heat and other ignition sources.		
11	Flammable liquids with flash points lower than room temperature are stored in a laboratory-safe refrigerator.		
12	Flammable substances are not stored under a fume cupboard.		
13	Corrosive chemicals are stored in unbreakable containers or safety-coated glass containers.		
14	Containers holding corrosive chemicals are placed in secondary containment or in chemical-resistant catch trays.		
15	Containers holding corrosive chemicals are stored on low shelves (the lower the better) and not above eye level.		
16	Toxic chemicals are stored in containers that are well-sealed.		
17	Highly toxic chemicals are locked up to prevent unauthorised access.		
18	Oxidising chemicals are stored away from flammables and reducing agents.		
19	Water-reactive chemicals are stored away from any water source.		
20	Air-reactive chemicals are stored under an inert atmosphere.		

Generic WSH Inspection Checklist for Chemical Laboratories

Chemical Storage		Yes	No
21	Peroxide-forming chemicals are stored away from sources of ignition, light and/or impact.		
22	Incompatible chemicals are segregated from one another by a physical barrier (e.g., a different storage compartment or via the use of a secondary container) when stored within the same storage cabinet or shelf.		
23	Gas cylinders are stored upright and properly secured to prevent from falling over.		
24	Gas cylinders are stored in a cool and well-ventilated area away from direct sunlight, heat sources and corrosive substances.		
25	Gas cylinders are fitted with a pressure regulator when in use and capped with a protective safety cap when not in use.		
26	Incompatible gases (e.g., flammable gases and oxygen gas) are segregated from one another (e.g., by safety distance or a fire wall).		
27	Chemical containers and compressed gas cylinders are in good condition (not damaged) and not leaking.		
Chemical Transfer		Yes	No
1	Receiving containers are compatible with the chemical being transferred.		
2	Receiving containers are labelled to identify their contents and associated hazards.		
3	Chemicals are moved from one location to another by hazard class to ensure compatibility. A separate move is made for each hazard class.		
4	When moving a chemical, the route is planned to ensure it is safe and avoids crowded areas.		
5	When moving a chemical between floors, the lift (preferably a freight lift) is used, and not the stairs.		
6	Secondary containers are used when moving chemicals from one location to another.		
7	A utility cart or trolley is used when moving larger and heavier quantities of chemicals.		
8	Before moving a gas cylinder, pressure regulators are removed and replaced with a protective safety cap.		
9	A cylinder cart is used for moving gas cylinders. Gas cylinders are strapped securely to the cart before being moved.		
Chemical Usage		Yes	No
1	Dilution ventilation rate adheres to SCDF Guidelines on Fire Safety Requirements for Laboratories Handling Chemicals.		
2	LEV (e.g., a fume cupboard) is used when handling toxic chemicals.		
3	Maximum operable sash height is indicated on the fume cupboard and when working at a fume cupboard, sash is lowered as far as is practical.		
4	Fume cupboard performance is tested periodically (e.g., once every two to three months).		

Generic WSH Inspection Checklist for Chemical Laboratories

Chemical Usage		Yes	No
5	Fume cupboard is subject to equipment maintenance at least once a year.		
6	Laboratory users are equipped with and use PPE (e.g., safety goggles, safety gloves, laboratory apron, non-slip shoes) appropriate for the task.		
7	Material of the PPE is resistant to the chemical(s) at hand.		
8	PPE has been placed under a PPE programme.		
Chemical Waste Disposal		Yes	No
1	Laboratory processes are planned with waste minimisation in mind.		
2	Chemical wastes are segregated into different waste types based on compatibility.		
3	Unwanted and expired chemicals are properly disposed of.		
4	No liquid waste (except innocuous aqueous waste) is poured down the basins or allowed to enter the sewer (e.g., via floor drain points).		
5	Chemical waste is stored in durable leak-proof containers compatible with their contents.		
6	Waste containers are labelled to indicate waste type, key constituents, associated hazards and recommended PPE prior to storage.		
7	Chemical waste is stored in a designated area away from normal laboratory operations.		
8	All waste containers are kept securely closed except during waste transfer.		
9	Secondary containment is used to facilitate safe storage of hazardous waste.		
10	Waste handling procedure highlights the need to check for compatibility before waste from different sources are mixed.		
11	Chemical waste is collected by a licensed TIW collector.		
12	Chemical gas cylinders are returned to the gas supplier or vendor.		
13	Details of chemical waste disposal are recorded into the waste register.		
Exposure Monitoring and Medical Surveillance		Yes	No
1	Exposure monitoring is in place where toxic substances are used or emitted.		
2	Exposure monitoring is in place in areas where excessive noise is generated.		
3	Exposed persons are informed of exposure monitoring results.		
4	Persons exposed to any of the substances listed under The Schedule of WSH (Medical Examinations) Regulations are sent for pre-employment and periodic medical examinations.		
Emergency Response		Yes	No
1	Laboratory users have been briefed on the emergency response plan, including the evacuation plan.		
2	Emergency evacuation route is clearly posted and easily visible.		
3	Emergency exit lights are working and clear of obstruction.		
4	List of emergency contact numbers is posted near the exit of the laboratory and on every telephone.		

Generic WSH Inspection Checklist for Chemical Laboratories

Emergency Response		Yes	No
5	Chemical spill control equipment is regularly replenished and available.		
6	At least one safety shower and at least one emergency eyewash station is installed in the laboratory as well as in the chemical storage area.		
7	The locations of safety shower and emergency eyewash stations are clearly marked with appropriate signs.		
8	Safety shower and emergency eyewash stations are located in an area free from live electrical equipment and power outlets.		
9	Safety shower and emergency eyewash stations are tested regularly (e.g., once a week) to flush the water supply and test for proper operation.		
10	Fire extinguishers are appropriate for the specific hazard(s) in the laboratory. At least one multi-purpose portable dry powder fire extinguisher is available for use against Class A, B, C and electrical fires.		
11	Firefighting equipment and facilities (e.g., water sprinkler system, fire extinguishers) are functional and ready for activation.		
12	There is at least one manual fire alarm call point in the laboratory.		
13	Fire doors are self-closing.		
14	At least one first aid box is available and adequately equipped.		
15	All dangerous occurrences, occupational disease incidences and laboratory accidents resulting in injury or fatality are reported to MOM.		
Laboratory Design		Yes	No
1	Laboratory furniture and appliances do not impede emergency access to an exit.		
2	Aisles for emergency egress are at least 1m wide.		
3	Safety shower and emergency eyewash stations are located within ten seconds of potential hazard sites in the laboratory along an unobstructed path.		
4	Flammable storage cabinets are placed away from exit paths.		
5	Clearance of 3m is provided between flammable storage cabinets and sources of ignition/ combustible materials.		
6	Fume cupboards are located away from doors and high traffic areas.		
7	Critical equipment (e.g., fume cupboard exhaust fans, refrigerators) and vital safety systems (e.g., emergency and egress lighting, fire detection and protection systems) are connected to an uninterruptible power supply.		
8	Circuit breaker and master disconnect switch are located outside the laboratory.		
9	Gas cylinders are placed outside the laboratory wherever possible.		
10	Master shut off valves for gas pipelines are located outside the laboratory.		
11	Incompatible gases are separated by a distance of at least 6.1m unless separating walls are provided or if stored in a gas cylinder cabinet.		
12	LPG is stored on the ground floor (outdoors or in a recessed area).		
13	For LPG cylinders placed next to an exit door on the ground floor, a minimum clearance of 3m to the door is provided if there is one exit (1.5m if there is more than one exit).		

7. WSH Planning for New Chemical Experiments

Regardless of whether laboratory work is carried out in a research, commercial or academic setting, planning and preparation for safety must be done upfront. Once a test or experiment has started it may be too late to stop what is going to happen. Good preparation for laboratory work requires anticipating potential hazards and planning for emergency action should things go wrong.

Planning chemical experiments is essential to laboratory safety. Experiment planning involves the comprehensive review of laboratory operations and the potential hazards associated with a particular experiment or set of experiments. The planning process is also an opportunity to build in waste minimisation initiatives, achieve upfront alignment to legislative requirements and identify ways to realise operational cost savings.

When designing a new experiment, it is important to first carry out a laboratory RA (see Section 2.5). Start by looking for potential hazards in each of the following:

- SDS of the chemical(s) to be used;
- proposed experimental procedure; and/ or
- laboratory equipment operating manual.

Once potential hazards are identified, evaluate the risk presented by each identified hazard by estimating the likelihood of an accident resulting from it and the severity of its expected consequence. If the estimated risk level obtained is unacceptable, then control measures to drive the risk down to an acceptable level must be put in place before the experiment may proceed.

For the RA to be holistic and effective, also consider action plans for foreseeable but “not normal” scenarios such as sudden equipment break downs, electrical outages, if the cooling water supply is cut off, a fire occurs, a chemical leaks, and so on.

WSH planning requires critical thinking not only about what the new experiment is attempting to accomplish but also how the experiment can be designed to prevent a WSH incident. A good way to jumpstart the WSH planning process would be to consult a safety officer, researcher or colleague who has had prior experience with the chemicals for the new experiment or laboratory test method.

WSH Considerations for Safety Planning of New Chemical Experiments

Chemical Procurement and Storage

- Is the use of hazardous chemicals really necessary for the new experiment? Can it/ they be eliminated or substituted with something safer and less hazardous?
- Is the quantity of the raw chemical to be procured within the limits allowed by legislation? Is the amount to be brought in the minimum quantity required? Is there existing stock of the needed chemical in the laboratory inventory?
- Is there a need for toxic or flammable gases to be used in the experiment? Is a compressed gas cylinder required?
- Is the laboratory or storage room equipped with proper facilities to safely store liquid and gaseous chemicals? Is the laboratory or storage room sufficiently ventilated to prevent build-up of chemical gas or vapour should there be a small leak?
- Are the chemicals stored by compatibility? Is the material of the chemical storage container compatible with its contents?
- Are SDS available for each chemical to be acquired? Will each chemical container be labelled according to GHS standards prior to storage?

Chemical Transfer

- Does the hazardous chemical have to be stored away from the laboratory? Can the distance between point of storage and point of use be minimised? If no, is the proposed route of movement safe and away from areas where many people are located?
- Will a chemical utility cart and secondary container be provided to facilitate safe transfer?

Chemical and Equipment Usage

- Are the chemicals to be used or generated toxic, corrosive or flammable? Are the chemicals air- or water-reactive? What substance(s) is/ are the chemicals incompatible with?
- How will the hazards posed by each chemical be communicated to the chemical user?
- Will the experiment be run at temperatures and/ or pressures higher or lower than normal room conditions? Can the experiment be run at lower temperature or pressure conditions?
- Can new chemical reactions be tested out on a micro-scale before moving on to a full-scale experiment?
- Is the laboratory equipment (e.g., pumps, tubing, glassware, heat generators) appropriate for the experiment?
- Have users been trained in the safe use and operation of the laboratory equipment?
- Will alarms, equipment safety guards and/ or interlocks be installed to ensure safe operation?
- Have equipment parts that present potentially dangerous man-machine interactions (e.g., moving parts, doors, sharp objects, hot surfaces) been identified? Can these interactions be minimised, for example, by experiment design or automation?
- Are there other hazards to be aware of such as noise, electrical, radiation or biological hazards?
- Is there a risk of exposure to chemicals via inhalation, ingestion or skin/ eye contact? Is the expected exposure below the permissible exposure limit of the chemical?

- Can laboratory equipment be fitted with emission control devices or the experiment procedure redesigned to minimise exposure risk?
- Should the experiment be conducted under LEV (e.g., a fume cupboard)? Will the fume cupboard be periodically inspected and maintained?
- Are there further engineering and/ or administrative risk control measures that can be put in place to protect the safety and health of chemical users?
- Will chemical users be provided with the necessary PPE (e.g., safety goggles, chemical resistant aprons, safety gloves, personal respirators)?

Chemical Disposal

- Has the experiment been planned with waste minimisation as an objective?
- Must the leftover reagent or end product be disposed of as hazardous waste?
- Is the laboratory equipped with facilities for storage of hazardous waste prior to disposal?
- Will the waste containers be labelled prior to storage?
- Is there a plan for proper segregation of chemical waste prior to collection by a licensed TIW collector? Is incompatible waste properly segregated? Is the material of the waste storage container compatible with its contents?
- Is there a procedure to check for chemical compatibility before combining waste from different sources?
- Will a waste register be set up to record the details of waste disposal activities?

Chemical Incident Emergency Response

- Has an emergency response plan been developed?
- Are emergency and first aid equipment and facilities (e.g., fire extinguishers, safety shower, emergency eyewash, spill control equipment, first aid kit) available in the event of accidental exposure, fire outbreak or chemical release?
- Will laboratory users be provided with training on first aid procedures and use of the emergency equipment and facilities?

8. References

Workplace Safety and Health Act

- Workplace Safety and Health (Risk Management) Regulations
- Workplace Safety and Health (General Provisions) Regulations
- Workplace Safety and Health (Medical Examinations) Regulations
- Workplace Safety and Health (Noise) Regulation
- Workplace Safety and Health (First-Aid) Regulations
- Workplace Safety and Health (Incident Reporting) Regulations

Environmental Protection and Management Act

- Environmental Protection and Management (Hazardous Substances) Regulations
- Environmental Protection and Management (Ozone Depleting Substances)

Environmental Public Health Act

- Environmental Public Health (Toxic Industrial Waste) Regulations

Fire Safety Act

- Fire Safety (Petroleum and Flammable Materials) Regulations

Arms and Explosives Act

- Arms and Explosives (Explosive Precursors) Rules

Others

- Code of Practice on Workplace Safety and Health Risk Management
- CP 10: 2005 Code of Practice for Installation and Servicing of Electrical Fire Alarm Systems
- CP 52: 2004 Code of Practice for Automatic Fire Sprinkler System
- CP 75: 1998 Code of Practice for Gas Cylinders – Procedures for Change of Gas Services
- CP 100: 2004 Code of Practice for Hazardous Waste Management
- Flinn Science Catalog/ Reference Manual
- Globally Harmonised System of Classification and Labelling of Chemicals (GHS) at www.wshc.sg/ghs
- International Labour Organization (ILO) Chemical Control Toolkit
- ISO 14001: 2004 Environmental Management System – Requirements with Guidance for Use
- Ministry of Education (MOE) School Science Laboratory Safety Regulations 2006
- Ministry of Manpower (MOM) Guidelines on the Prevention and Control of Chemical Hazards
- Ministry of Manpower (MOM) "A Semi-Quantitative Method to Assess Occupational Exposure to Harmful Chemicals"

- Ministry of Manpower (MOM) Circular on Management of Workers accidentally exposed to Hydrofluoric Acid
- NFPA 45: 2011 Standard on Fire Protection for Laboratories Using Chemicals
- NFPA 55: 2013 Compressed Gases and Cryogenic Fluids Code
- NFPA 58: 2011 Liquefied Petroleum Gas Code
- Occupational First Aid Manual, National First Aid Council and Ministry of Manpower
- SCDF Fire Code 2013 (also known as the Code of Practice for Fire Precautions in Buildings)
- SCDF Fire Safety Requirements for Liquefied Petroleum Gas (LPG) Cylinder Installations
- SCDF Guidelines on Fire Safety Requirements for Laboratories Handling Chemicals
- SCDF Guidelines for Emergency Response Plan
- Singapore Chemical Industry Council's (SCIC) Guidebook on the Globally Harmonised System of Classification and Labelling of Chemicals
- SS EN 3: 2012 Portable Fire Extinguishers (EN 3 Series)
- SS EN 420: 2003 Protective Gloves – General Requirements and Test Methods
- SS 281: 1984 Pressure Regulators for Liquefied Petroleum Gases
- SS 332: 2007 Specification for Fire Doors
- SS 447: 1998 Gas Cylinders – Terminology
- SS 473: 2011 Part 1: Specification for Personal Eye-Protectors – General Requirements
- SS 473: 2011 Part 2: Specification for Personal Eye-Protectors – Selection, Use and Maintenance
- SS 531: 2006 Part 1: Code of Practice for Lighting of Work Places – Indoor
- SS 532: 2007 Code of Practice for the Storage of Flammable Liquids
- SS 548: 2009 Code of Practice for Selection, Use and Maintenance of Respiratory Protective Devices
- SS 553: 2009 Code of Practice for Air-Conditioning and Mechanical Ventilation in Buildings
- SS 563: 2010 Code of Practice for the Design, Installation and Maintenance of Emergency Lighting and Power Supply Systems in Buildings
- SS 567: 2011 Code of Practice for Factory Layout – Safety, Health and Welfare Considerations
- SS 575: 2012 Code of Practice for Fire Hydrant, Rising Mains and Hose Reel Systems
- SS 578: 2012 Code of Practice for Use and Maintenance of Portable Fire Extinguishers
- SS 586: 2014 – Specification for hazard communication for hazardous chemicals and dangerous goods – Part 2: Globally harmonised system of classification and labelling of chemicals
- SS 586: 2008 (2014) – Specification for hazard communication for hazardous chemicals and dangerous goods – Part 3: Preparation of safety data sheets.
- Workplace Safety and Health Guidelines on Management of Hazardous Chemicals Programme
- Workplace Safety and Health Guidelines on Statutory Medical Examinations
- Workplace Safety and Health Guidelines on Hearing Conservation Programme
- World Health Organization Human (WHO) Health Risk Assessment Toolkit for Chemicals
- WSH Council's Worker's Safety Handbook on Working with Hazardous Materials

9. Acknowledgements

The Workplace Safety and Health (WSH) Council and Ministry of Manpower would like to thank the National University of Singapore (NUS) for the images used in this publication.

10. Annexes

Annex A: List of Incompatible Chemicals

The following table contains examples of chemicals that are incompatible with one another.

Chemical	Keep out of contact with:
Acetic acid	Chromic acid, nitric acid, hydroxide compounds, perchloric acid, peroxides, permanganates and other oxidizers
Acetone	Concentrated nitric and sulphuric acid mixtures, and strong bases
Acetylene	Chlorine, bromine, copper, fluorine, silver, mercury
Alkali metals	Water, carbon tetrachloride or other chlorinated hydrocarbons, carbon dioxide, halogens
Ammonia, anhydrous	Mercury, chlorine, calcium hypochlorite, iodine, bromine, hydrofluoric acid
Ammonium nitrate	Acids, metal powders, flammable liquids, chlorates, nitrites, sulphur, finely divided organic or combustible materials
Aniline	Nitric acid, hydrogen peroxide, bromine, ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Bromine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Calcium oxide	Water
Carbon, activated	Calcium hypochlorite, all oxidizing agents
Carbon tetrachloride	Sodium
Chlorates	Ammonium salts, acids, metal powders, sulphur, finely divided organic or combustible materials
Chromic acid and chromium trioxide	Acetic acid, naphthalene, camphor, glycerol, glycerin, turpentine, alcohol, flammable liquids in general
Chlorine	Ammonia, acetylene, butadiene, butane, methane, propane (or other petroleum gases), hydrogen, sodium carbide, turpentine, benzene, finely divided metals
Chlorine dioxide	Ammonia, methane, phosphine, hydrogen sulphide
Copper	Acetylene, hydrogen peroxide
Cumene hydroperoxide	Acids, organic or inorganic
Cyanides	Acids
Flammable liquids	Ammonium nitrate, chromic acid, hydrogen peroxide, nitric acid, sodium peroxide, halogens
Hydrocarbons	Fluorine, chlorine, bromine, chromic acid, sodium peroxide
Hydrocyanic acid	Nitric acid, alkali

Chemical	Keep out of contact with:
Hydrofluoric acid	Ammonia (aqueous or anhydrous), bases and silica
Hydrogen peroxide	Copper, chromium, iron, most metals or their salts, alcohols, acetone, organic materials, aniline, nitromethane, flammable liquids, oxidising gases
Hydrogen sulphide	Fuming nitric acid, other acids, oxidising gases, acetylene, ammonia (aqueous or anhydrous), hydrogen
Hypochlorites	Acids, activated carbon
Iodine	Acetylene, ammonia (aqueous or anhydrous), hydrogen
Mercury	Acetylene, ammonia, fulminic acid
Nitrates	Sulphuric acid
Nitric acid	Acetic acid, aniline, chromic acid, hydrocyanic acid, hydrogen sulphide, flammable liquids, flammable gases, copper, brass, any heavy metals
Nitrites	Acids
Oxalic acid	Silver, mercury
Oxygen	Oils, grease, hydrogen; flammable liquids, solids or gases
Perchloric acid	Acetic anhydride, bismuth and its alloys, alcohols, paper, wood, grease and oils
Peroxides, organic	Acids (organic or mineral), avoid friction, store cold
Phosphorous (white)	Air, oxygen, alkalis, reducing agents
Phosphorous pentoxide	Water
Potassium	Carbon tetrachloride, carbon dioxide, water
Potassium chlorate and perchlorate	Sulphuric and other acids, alkali metals, magnesium and calcium
Potassium permanganate	Glycerin, ethylene glycol, benzaldehyde, sulphuric acid
Silver	Acetylene, oxalic acid, tartaric acid, ammonium compounds, fulminic acid
Sodium	Carbon tetrachloride, carbon dioxide, water
Sodium nitrite	Ammonium nitrate and other ammonium salts
Sodium peroxide	Ethyl or methyl alcohol, glacial acetic acid, acetic anhydride, benzaldehyde, carbon disulfide, glycerin, ethylene glycol, ethyl acetate, methyl acetate, furfural
Sulphides	Acids
Sulphuric acid	Potassium chlorate, potassium perchlorate, potassium permanganate (or compounds with similar light metals, such as sodium, lithium, etc.)

Note

The above is not an exhaustive list of incompatible chemicals. Always consult the SDS of the chemical(s) you are working with to determine specific incompatibilities.

Annex B: Glove Type and Chemical Use

The table below provides glove type recommendations by chemical.

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile
*Acetaldehyde	VG	VG	VG	VG
Acetic acid	VG	VG	VG	VG
*Acetone	G	G	G	G
Ammonium hydroxide	VG	VG	VG	VG
*Amyl acetate	F	F	F	F
Aniline	G	G	G	G
*Benzaldehyde	F	F	F	F
*Benzene	F	F	F	F
Butyl acetate	G	G	G	G
Butyl alcohol	VG	VG	VG	VG
Carbon disulfide	F	F	F	F
*Carbon tetrachloride	F	F	F	F
Castor oil	F	F	F	F
*Chlorobenzene	F	F	F	F
*Chloroform	G	G	G	G
Chloronaphthalene	F	F	F	F
Chromic Acid (50%)	F	F	F	F
Citric acid (10%)	VG	VG	VG	VG
Cyclohexanol	G	G	G	G
*Dibutyl phthalate	G	G	G	G
Diesel fuel	G	G	G	G
Diisobutyl ketone	P	P	P	P
Dimethylformamide	F	F	F	F
Diocetyl phthalate	G	G	G	G
Dioxane	VG	VG	VG	VG
Epoxy resins, dry	VG	VG	VG	VG
*Ethyl acetate	G	G	G	G
Ethyl alcohol	VG	VG	VG	VG
Ethyl ether	VG	VG	VG	VG
*Ethylene dichloride	F	F	F	F
Ethylene glycol	VG	VG	VG	VG
Formaldehyde	VG	VG	VG	VG
Formic acid	VG	VG	VG	VG
Freon 11	G	G	G	G
Freon 12	G	G	G	G
Freon 21	G	G	G	G
Freon 22	G	G	G	G
*Furfural	G	G	G	G
Gasoline, leaded	G	G	G	G
Gasoline, unleaded	G	G	G	G
Glycerine	VG	VG	VG	VG
Hexane	F	F	F	F

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile
Hydrochloric acid	VG	VG	VG	VG
Hydrofluoric acid (48%)	VG	VG	VG	VG
Hydrogen peroxide (30%)	G	G	G	G
Hydroquinone	G	G	G	G
Isooctane	F	F	F	F
Isopropyl alcohol	VG	VG	VG	VG
Kerosene	VG	VG	VG	VG
Ketones	G	G	G	G
Lacquer thinners	G	G	G	G
Lactic acid (85%)	VG	VG	VG	VG
Lauric acid (36%)	VG	VG	VG	VG
Lineoleic acid	VG	VG	VG	VG
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 (iso)	VG	VG	VG	VG
Sodium hydroxide	VG	VG	VG	VG
Styrene	P	P	P	F
Stryene (100%)	P	P	P	F

Chemical	Neoprene	Natural Latex or Rubber	Butyl	Nitrile
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	V	V	VG
Tung oil	VG	P	F	VG
Turpentine	G	F	F	VG
*Xylene	P	P	P	F

* denotes limited service

where VG = Very Good
 G = Good
 F = Fair
 P = Poor (i.e. not recommended)

Reproduced from *MOM Guidelines on the Prevention and Control of Chemical Hazards*.

Annex C: List of Toxic Industrial Wastes

Acids

- Spent inorganic acids, e.g., hydrochloric acid, sulphuric acid, nitric acid, phosphoric acid, hydrofluoric acid, boric acid and pickling acid
- Spent organic acids, e.g., acetic acid, formic acid, benzoic acid and sulphononic acid

Alkalies

- Spent alkaline solutions
- Spent ammoniacal solutions
- Metal hydroxide sludges and oxide sludges

Antimony and its Compounds

- Spent antimony potassium tartrate

Arsenic and its Compounds

- Timber preservative residues containing arsenic
- Wastes containing gallium arsenide

Asbestos

- Asbestos wastes from asbestos/ cement manufacturing processes
- Empty sacks/ bags which contain loose asbestos fibre
- Asbestos wastes generated from industrial activity, demolition, renovation and delagging works and/ or ship repairing

Cadmium and its Compounds

- Plating effluents and residues containing cadmium
- Wastes containing cadmium from Ni/ Cd battery manufacturing

Chromium Compounds

- Plating effluents and residues containing chromium
- Timber preservative residues containing chromium
- Spent and aqueous solutions containing chromic compounds
- Tannery effluents and residues containing chromium

Copper Compounds

- Plating effluents and residues containing copper
- Spent etching solutions containing copper from printed circuit board manufacturing
- Timber preservative residues containing copper

Cyanides

- Plating effluents and residues containing cyanides
- Heat treatment residues containing cyanides
- Spent quenching oils containing cyanides
- Spent processing solutions containing cyanides from photographic processing

Fluoride Compounds

- Timber preservative residues containing fluorides
- Spent ammonium bi-fluoride

Isocyanates

- Spent di-isocyanates, e.g., toluene di-isocyanate (TDI) and methylene di-isocyanate (MDI) from polyurethane foam-making process

Laboratory Wastes

- Obsolete laboratory chemicals
- Toxic chemical wastes from chemical analysis

Lead Compounds

- Ash, residues and sludges containing lead and lead compounds
- Spent organo-lead compounds, e.g., tetraethyllead (TEL) and tetramethyllead (TML)
- Waste lead-acid batteries, whole or crushed

Mercury and its Compounds

- Effluents, residues or sludges containing mercury from chlor-alkali industry
- Wastes containing mercury from equipment manufacturing involving the use of metal mercury
- Spent catalysts from chemical processes containing mercury
- Spent organo-mercury compounds

Metal Catalysts

- Spent metal catalysts from chemical processes and petroleum refining, e.g., catalysts containing chromium and cobalt

Nickel Compounds

- Plating effluents and residues containing nickel

Organic Compounds containing Halogen

- Spent halogenated organic solvents, e.g., trichloroethylene, 111-trichloroethane, perchloroethylene, methylene chloride, tetra-chloromethane and 112-trichloro-122-trifluoroethane
- Residues from recovery of halogenated organic solvents
- Packaging materials or residues containing chlorobenzenes and/or chlorophenals and their salts

Organic Compounds not containing Halogen

- Spent non-halogenated organic solvents, e.g., benzene, toluene, xylene, turpentine, petroleum, thinner, kerosene, methanol, ethanol, isobutanol, isopropanol, methyl ethyl ketone, methyl isobutyl ketone, isopropyl ether, diethyl ether, hexane, dimethyl sulphide and dimethyl sulphoxide
- Residue from recovery of non-halogenated organic solvents

Organotin Compounds

- Sludges, residues, effluents and spent blasting grit generated from removal of paints containing organotin compounds

Other Wastes

- Obsolete/ Abandoned chemicals and pesticides from storage, manufacturing and trading activities
- Used containers, bags and process equipment contaminated by chemicals and pesticides from storage, manufacturing and trading activities
- Wastes/ Residues containing unreacted monomers, e.g., vinyl chloride and styrene monomers, from polymer manufacturing processes
- Tar residues from distilling and tarry materials from refining
- Wastes from toxic waste treatment processes, e.g., wastes and residues from solidification, fixation and incineration processes
- Wastes from toxic chemical drums and tank cleaning activities
- Chemical and oil slops from ship tankers
- Waste from the production, formulation and use of resins, latex, plasticisers, glues/ adhesives containing solvents and other contaminants
- Wastes from the production, formulation and use of inks, dyes, pigments, paints, lacquers, varnish containing organic solvents, heavy metals or biocides
- Solid wastes and sludges or obsolete/ off specification materials not categorised elsewhere in the Schedule and failing the NEA's landfill disposal criteria

Pathogenic Wastes

- Pathogenic wastes from hospitals
- Pathogenic wastes from healthcare and research institutions, clinics and laboratories

Pharmaceutical Wastes

- Pharmaceutical wastes comprising antineoplastic agents, antibiotics, vaccines and other immunological products, controlled drugs under the Misuse of Drugs Act (Cap. 185) and pharmaceutical wastes containing arsenics, cyanides and heavy metals and their salts

Phenolic Compounds

- Sludges/residues from paint stripping using chemicals containing phenols
- Residues containing unreacted phenol and formaldehyde from adhesive industry

Polychlorinated Bi-phenyl (PCB) Including Poly-chlorinated Ter-phenyl (PCT)

- Spent transformer oil containing PCB and/ or PCT
- Retrofilled transformer contaminated with PCB and/ or PCT
- Electrical equipment and parts containing or contaminated with PCB and/ or PCT, e.g., capacitors and transformers
- Containers and all waste materials contaminated with PCB and/ or PCT

Polyvinyl Chloride (PVC)

- All waste materials containing PVC, e.g., PVC insulated wires, PVC pipes and trunking, PVC parts, PVC upholstery and PVC resins

Silver Compounds

- Spent processing solutions containing silver from photographic processing

Used, Contaminated Oil

- Used mineral, lubricating and hydraulic oil from machine cylinders, turbines, switch gears and transformers

- Spent motor oils from petrol and diesel engines
- Spent quenching oil from metal hardening
- Oil recovered from solvent degreasers
- Spent oil water emulsions, e.g., spent coolants from metal working industries
- Oil water mixtures (mainly oil), e.g., oily ballast water from ship tankers
- Oil and sludge from oil interceptors
- Tanker sludges and oil sludges/ residues from storage tanks
- Oil sludges containing acid from recovery and recycling of used oil

Zinc Compounds

- Plating effluents and residues containing zinc

Reproduced from *The Schedule of Environmental Public Health (TIW) Regulations*.

Published in July 2014 by the Workplace Safety and Health Council in collaboration with the Ministry of Manpower.

All rights reserved. This publication may not be reproduced or transmitted in any form or by any means, in whole or in part, without prior written permission. The information provided in this publication is accurate as at time of printing. All cases shared in this publication are meant for learning purposes only. The learning points for each case are not exhaustive and should not be taken to encapsulate all the responsibilities and obligations of the user of this publication under the law. The Workplace Safety and Health Council does not accept any liability or responsibility to any party for losses or damage arising from following this publication.

This publication is available on the
Workplace Safety and Health Council
Website: www.wshc.sg
Email: contact@wshc.sg

