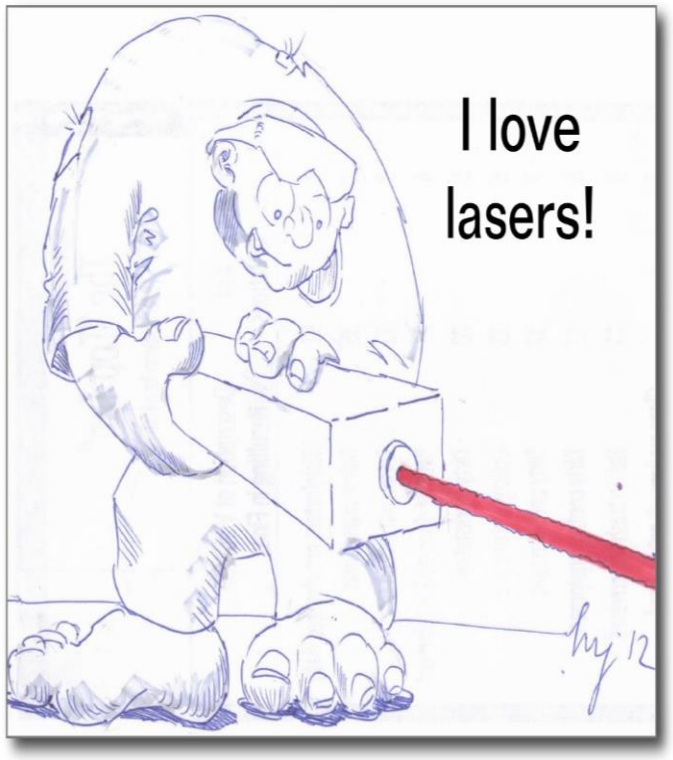


Laboratory Safety

Liquid N2 burn

Acid burn

Third degree burn

Electrical fires

Eye injury (laser)

Why the need for workplace safety?

Humane - An employee should not have to expect that by coming to work they are risking life or limb, and nor should others affected by their undertaking.

Economic - legal fees, fines, compensatory damages, investigation time, lost production, lost goodwill from the workforce, and lost goodwill from customers.

Legal - We have a duty under the law to ensure, so far as is reasonably practicable, the health, safety and welfare at work of all our employees.

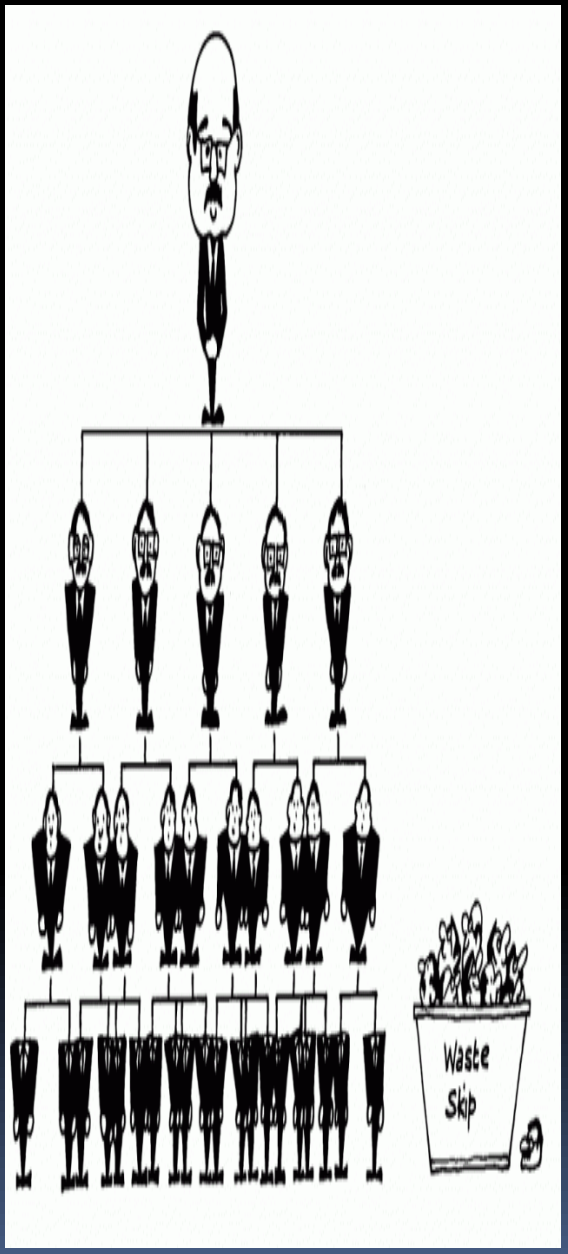
HSE Responsibilities

A safe and healthy environment at NTU

- a shared responsibility of all staff, students, partners and visitors to the University.

HSE responsibility is a line function

Line function begins with managers and supervisors at all levels and progress upwards through the management.



PRESIDENT of NTU

- Overall responsibility

Senior Management (Deans, Chairs, Directors and HoDs)

- Provide leadership
- Ensure all have well defined safety duties and responsibilities
- Implement NTU HSE policy through appropriate SOPS and programmes.

Supervisors (PI and Managers)

- Responsible for occupational health & safety of all persons.
- Do risk management & to control risks
- Implementation of NTU HSE policy, objectives, SOPs,
- Carry out proper maintenance of equipment and facilities,
- Provide effective communication (i.e. training & supervision) of all parties.

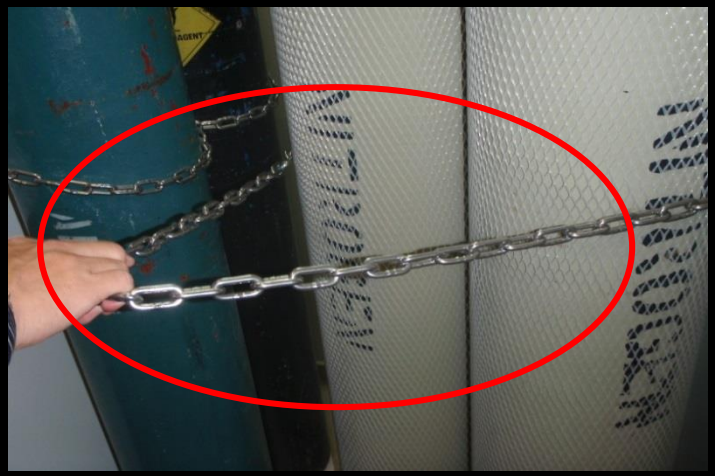
Faculty, Staff and Students

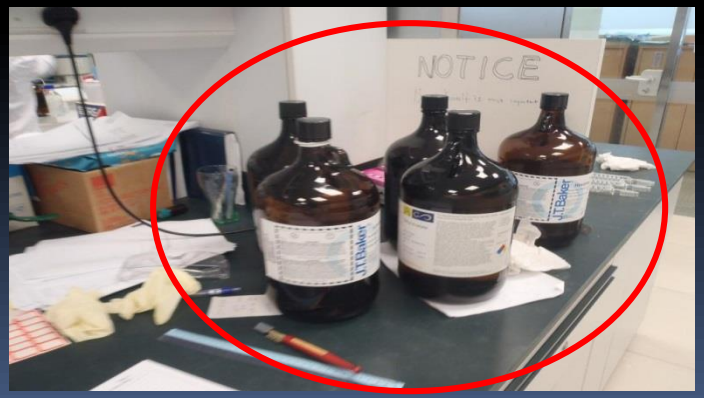
- Cooperate with NTU management
- Adhering to HSE instructions for their own safety and health
- Report unsafe conditions, equipment and practices

Office of Health and Safety

Unsafe Acts

Unsafe Conditions





NTU Emergency Management

Our Greatest Risk

FIRE!!!

NTU Emergency Management

A fire accident can be due to unsafe practices in handling chemical and electrical issue and housekeeping

These can be avoided - Overloading Circuits

Also in Office

These can be avoided - Poor Housekeeping

Office Equipment on Fire

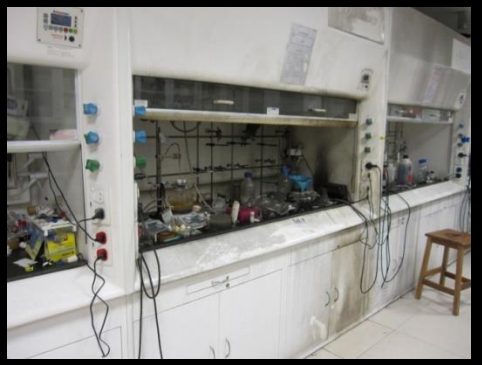
Air-Con Unit Burnt

These can be avoided - Fire

Laboratory Fire

RECAP OF FIRE ACCIDENT

• Fire occurred when researcher was preparing to quench residue of a chemical reagent with an alcohol.



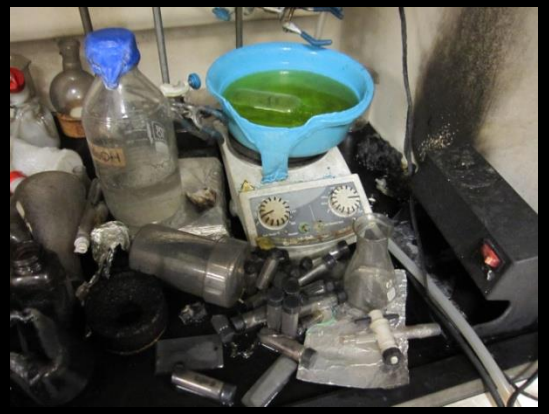
• The mixture heated up rapidly when the alcohol was added to the residue reagent in the conical flask.

RECAP OF FIRE ACCIDENT

• A flash fire developed, accompanied by a loud sound.

• The ignited alcohol gushed from the flask and splashed onto the staff, setting his coat alight

• The fire spread from the solvent spilled from the container. The fire caused extensive to the furniture in the lab.



These can be avoided - Fire

Fire at NUS Engineering School, Aug 10, 2012 ~7:25pm

Projector burst into flame at NUS LT 7A of Engineering Block, Oct 22, 2012 ~12:00pm
~260 people were evacuated

Office Fire at Singapore Polytechnic, Teaching Block 2, Level 5, July 16, 2013 ~7:25pm

Fire in Singapore Polytechnic, Food Court 3, July 18, 2013 ~7:40pm
1 injured

Fire at SPMS Laboratory,
Apr 2013 ~7:30pm

Fire in NTU LT, Sept 2012
~1:00am

Fire

If you discover a fire

Raise the fire alarm **by breaking the Fire Call Point**. You can activate the fire call point by breaking the glass using either:

A sharp object

Your fingers

This is NOT the fire call point

✓ This IS

At the same time…

Inform NTU Campus Security @ **6790 5200**

Inform SCDF @ 995

Primary Protective Equipment – Fire Extinguisher

Observe the following equipment when you first enter a laboratory facility

- Research laboratory has fire extinguisher

Fire Extinguisher Use:

- Pull safety pin
- Aim nozzle at base of fire
- Squeeze lever
- Sweep – sweeping action at base of fire

OPERATING A FIRE EXTINGUISHER

Operating a fire extinguisher using the **P.A.S.S.** technique:

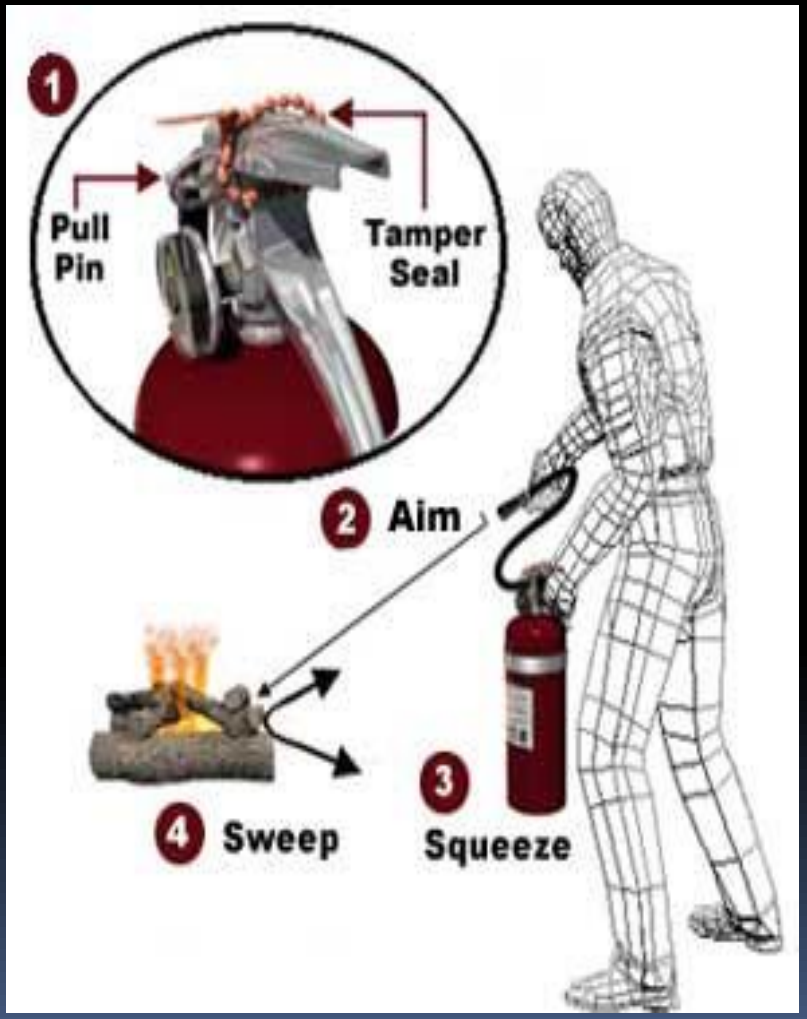
1.PULL … Pull the pin. This action will also break the tamper seal.

2.AIM… Aim low, pointing the nozzle/horn/hose of the extinguisher at the base of the fire.

3. SQUEEZE… Squeeze the handle of the extinguisher to release the extinguishing agent.

4. **SWEEP**…Sweep from side to side at the base of the fire until the fire appears to be out.

If the fire re-ignites, repeat steps 2-4



IMPORTANT

DO NOT attempt to fight a fire if it gets out of control or you are not confident to do so !!

Evacuate immediately via the nearest exits

Fire Alarm & Evacuation

Fire Bell and Announcement

1st alarm with Announcement with short Bell ring: "Investigation of alarm..."

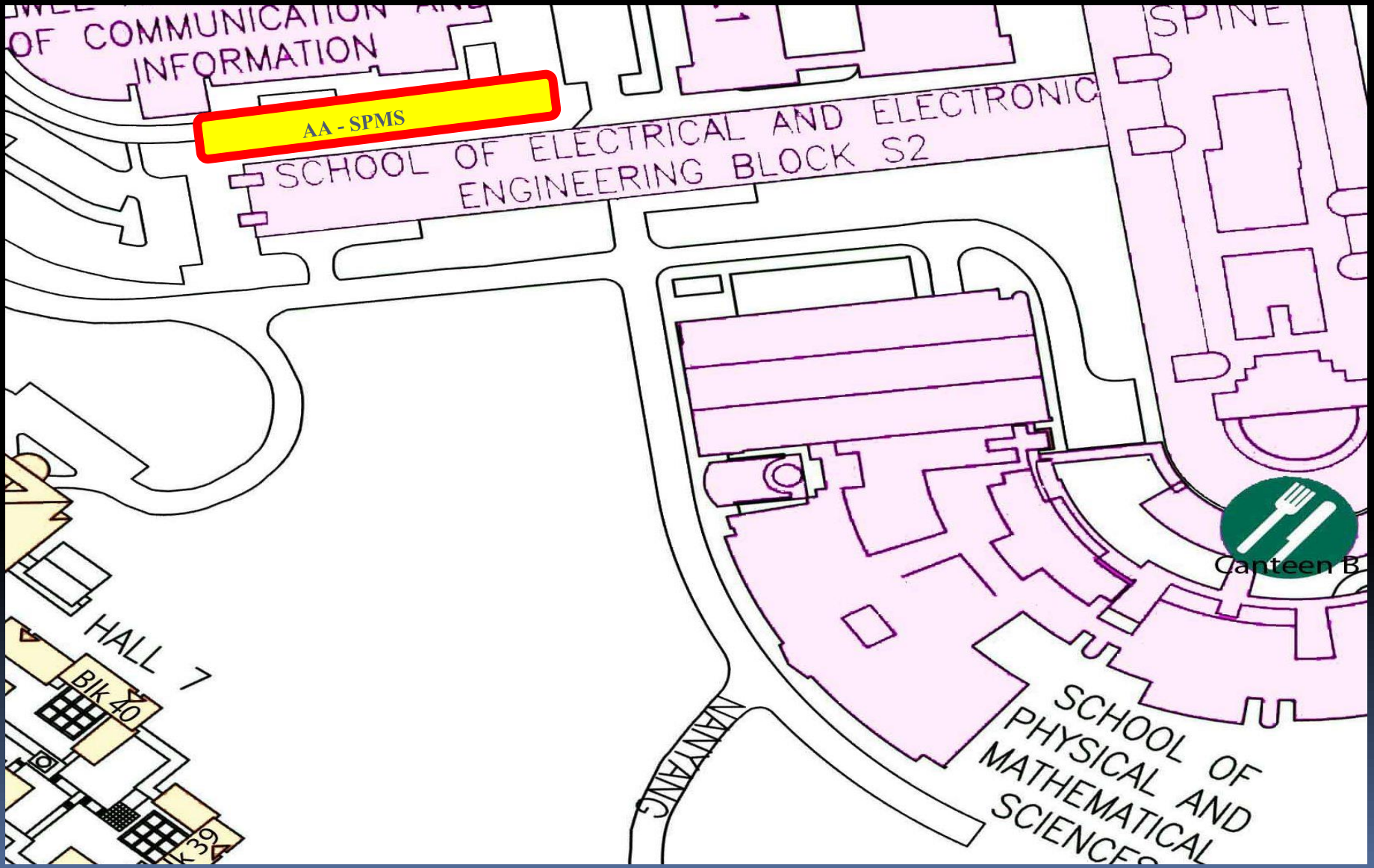
- Stop all instrument and experiments
- Get ready for evacuation

2nd alarm with Announcement & Continuous Bell ring: "To evacuate ..."

- Evacuate to the assembly area in an orderly manner
- Follow the EXIT sign. Do not use Lifts
- Follow the instructions of fire wardens or other emergency response personnel

If in doubt of the alarm status, please call Fault Reporting Centre @ 6790 5200.

SPMS Fire Assembly Area




LOADING
AND
UNLOADING
ONLY

Primary Protective Equipment

Observe the following equipment when you first enter a laboratory facility

Fire Blanket

- If fire on body spread blanket over body

First Aid Kit

- Apply first Aid when minor injury occurs.
- Report to your supervisor

Using fire blanket on a person on fire

APPROACH :

For smouldering a person on fire, shield yourself and cover below the neck line of casualty and wrap like a shawl completely.

Wrap the person firmly but not too tight as choking him.

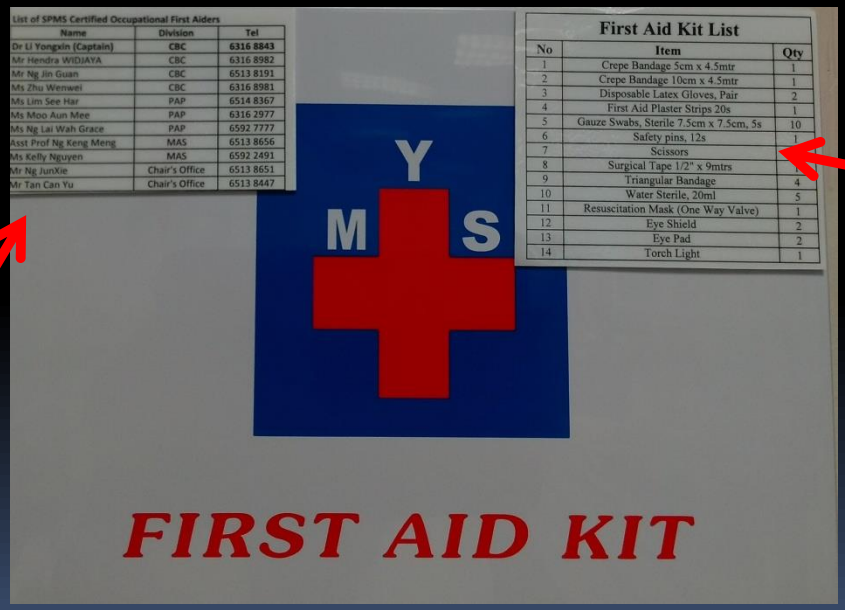
Ensure that there are no openings or pockets to re-ignite the fire.

If possible, use the “stop, drop and roll” technique if you are alone.

First Aid Box

First Aid Box is located in every laboratories in SPMS

Overview of first aid box



List of First Aiders

Items in First Aid Box

First Aid Box

The first aid box shall

- Be easily accessible
- Be checked regularly
- Bear the list of appointed First Aiders

First Aid

First Aid

Items in the first aid box:

Individually wrapped sterile adhesive dressings
Crepe Bandage 5 cm
Crepe Bandage 10 cm
Absorbent Gauze (Pack of 10 pieces)
Hypoallergenic Tape
Triangular Bandages
Scissors *(optional)*
Safety Pins
Disposable Gloves (pairs)
Eye Shield
Eye Pad
Resuscitation Mask (One-way)
Sterile Water or Saline in 100 ml disposable containers
Torch Light *(optional)*

•No OTC Medication allowed

NTU Medical Centre

The NTU Medical Centre is located at the University Health Service Building, beside Student Services Centre

Emergency numbers:

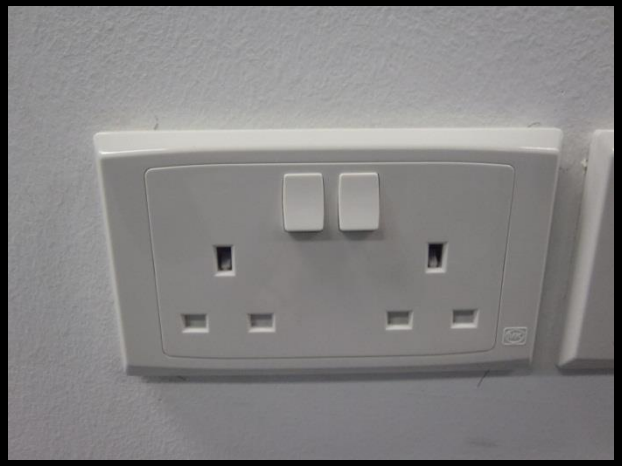
6790-5200
Boss's Telephone number
995
999
More information is available on the division and SPMS website:

Electrical Safety

Listed products that have Safety Marks can be used in NTU.

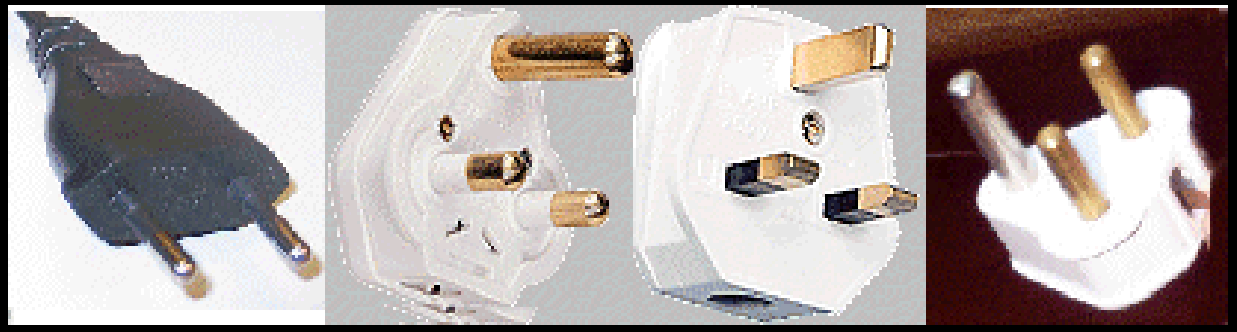
The Singapore Safety Mark is the approval mark under the Consumer Protection (Safety Requirements) Registration.

Electrical Safety



What's the current rating?

Electrical Safety



Permitted Plugs

Not Permitted Plugs

Electrical Safety

Unapproved adaptor

Unauthorized Power Socket Outlet (PSO)

Electrical Safety

Unsafe Practices

Use of not permitted plugs

Daisy chaining of extensions

Plug used to supply 2 appliances

Damaged insulation of an electrical cord

Exposed wiring of an electrical cord

Accidents

- Report all accidents, no matter how small, to your supervisor or lab safety leader (Include chemical spillages)
- Avoid getting any chemicals on your skin. If a chemical does come into contact with your skin, rinse it with cold water for at least 2-5 minutes. Soap is unnecessary

Incident Reporting

What to report?

- Accident
- Incident
- Occupational diseases

Why report?

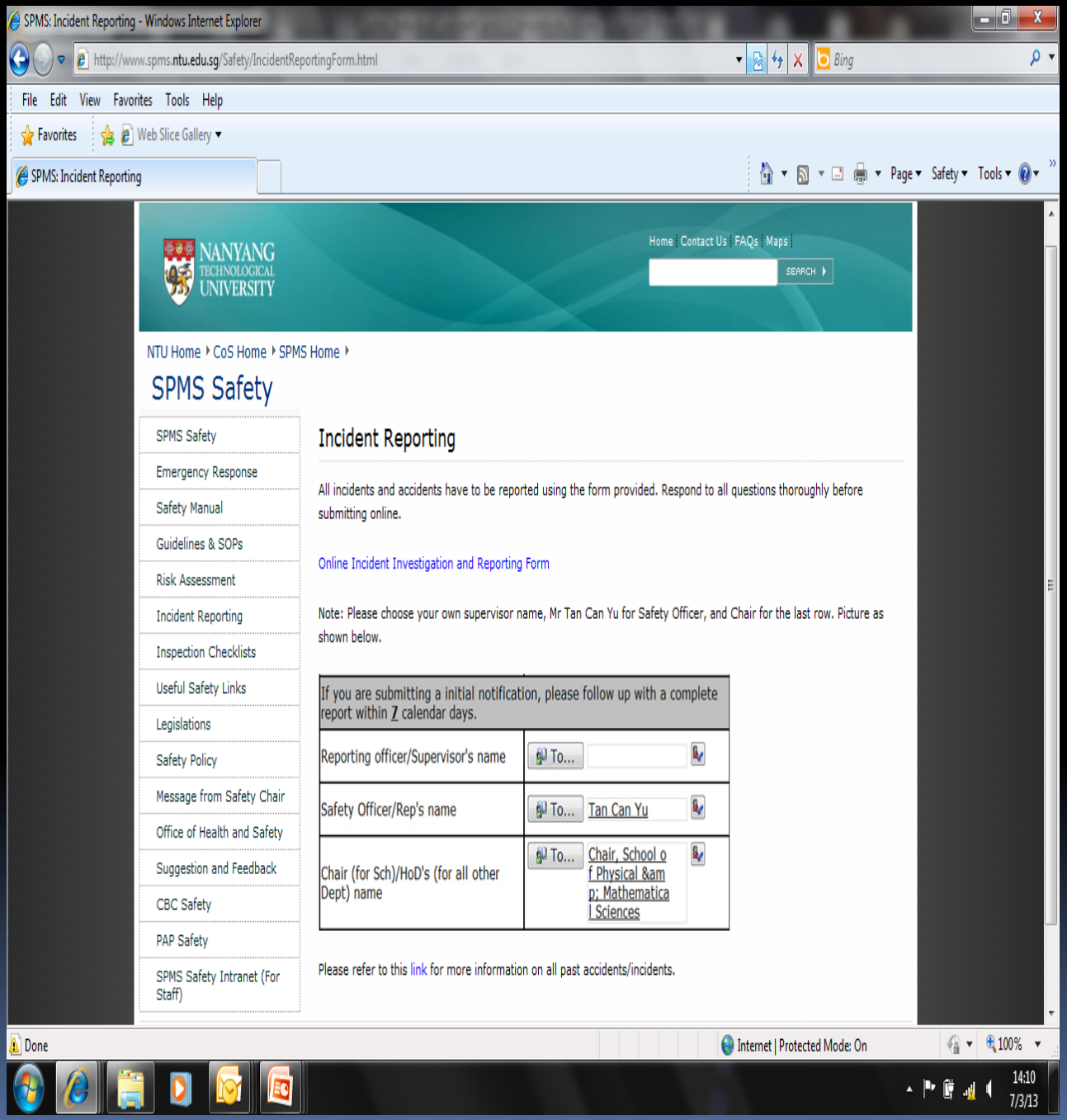
- Determine both the immediate and the root cause(s) of the accident / incident.
- Communicate with all others of the case.
- Ensure this does not happen again (hopefully) - by applying elimination. substitution, engineering, administrative or PPE.
- Review of Risk is risk management.
- WSH (Incident Reporting) Regulation.

Incident Reporting

Report all accidents, no matter how small, to your supervisor or lab safety leader (Include chemical spillages)

Drop an email to School Safety in charge

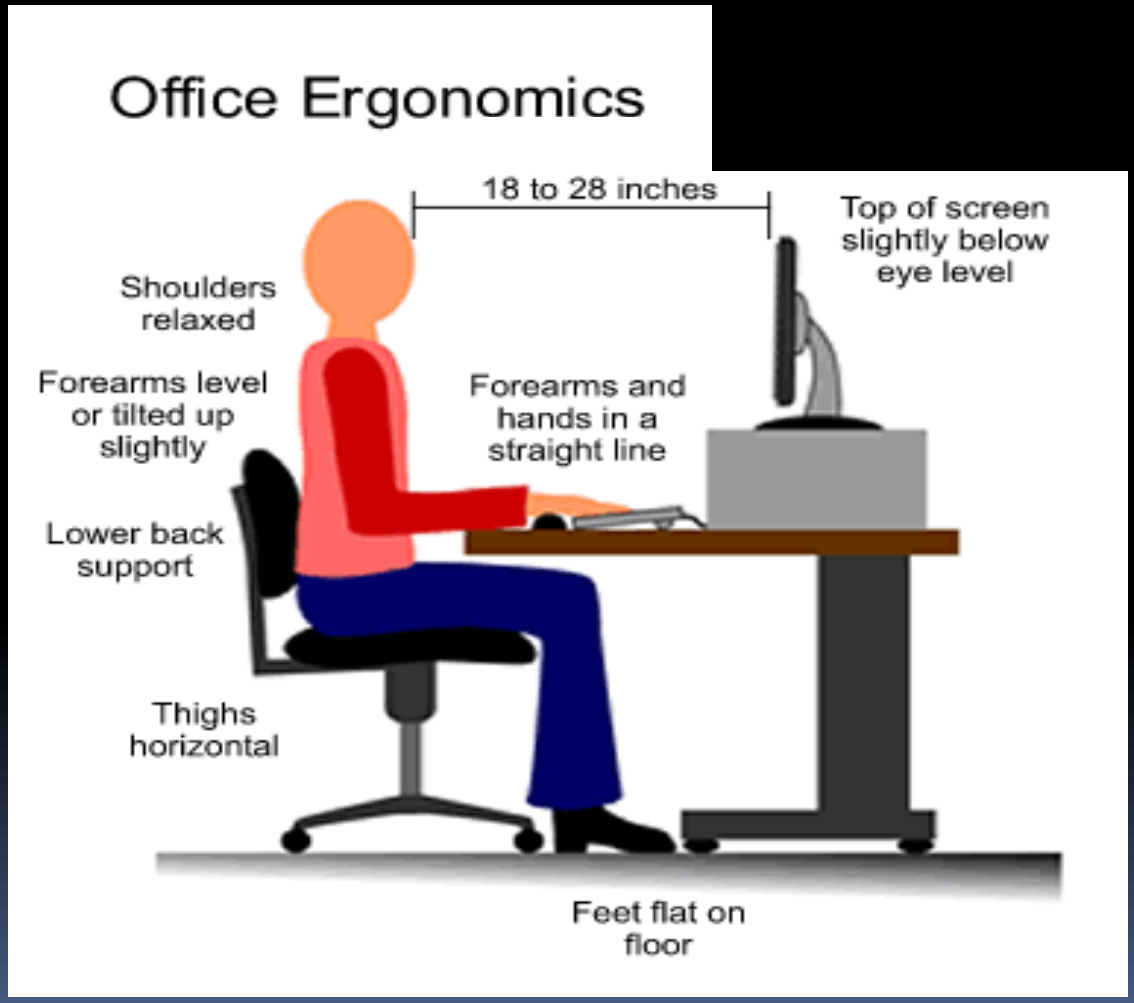
Fill up online incident reporting form



Office of Health & Safety - Incident Investigation & Reporting Form	
IIRF Number (For OHS Use Only)	
Please choose one	
Reporter's Particulars	
Name *	
Staff/Student Card No. *	
School/Dept *	
Designation *	
Contact No *	
Email	yypoon@ntu.edu.sg
Reporting Officer/Supervisor Name	
Injured's Particulars	
Name	
Staff/Student Card No.	

Ergonomics / Manual Handling

Workstation Ergonomics In The Modern Office

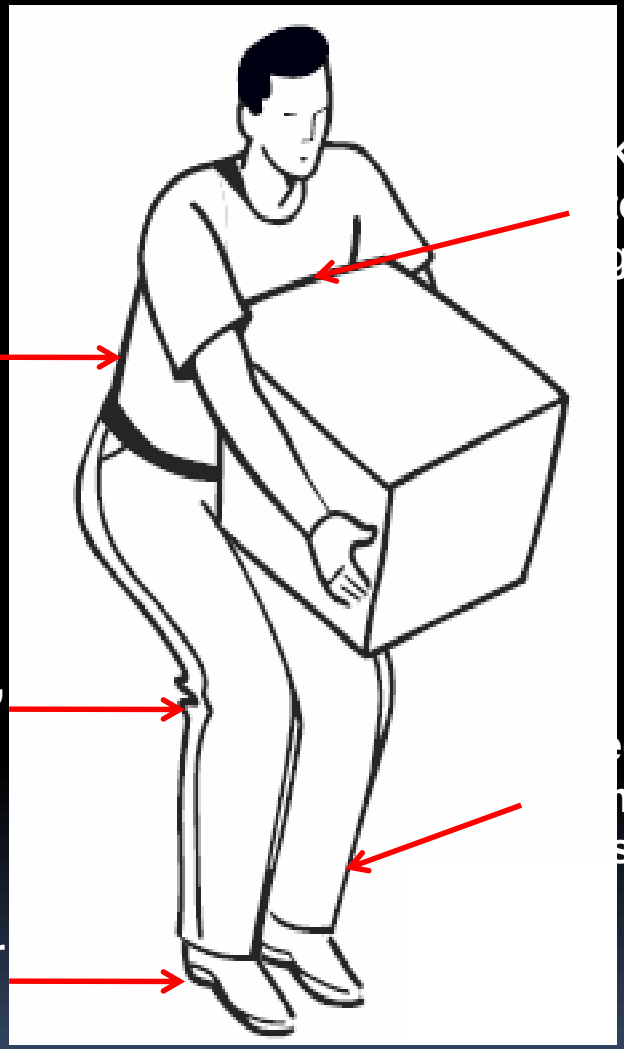


AVOID tight elbow angle

AVOID wrist bent upward

AVOID pressure on elbow or wrist

Proper Manual Handling



Keep your back straight

Bend your knees, not your back

Turn using your feet, not your back

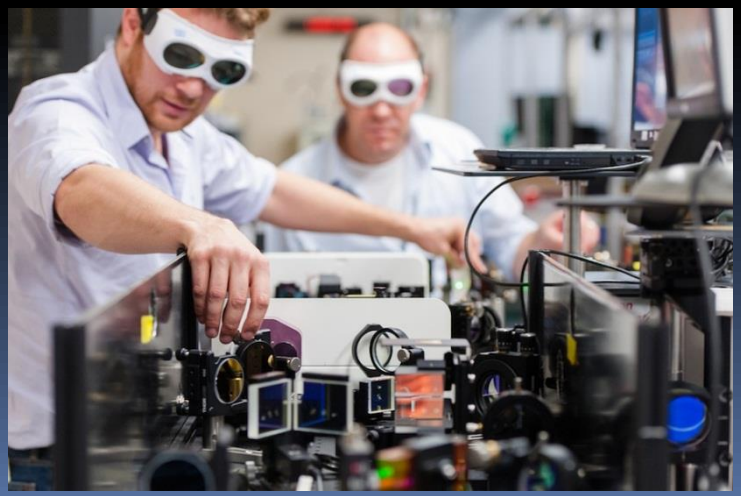
Keep object close to body and keep a good grip

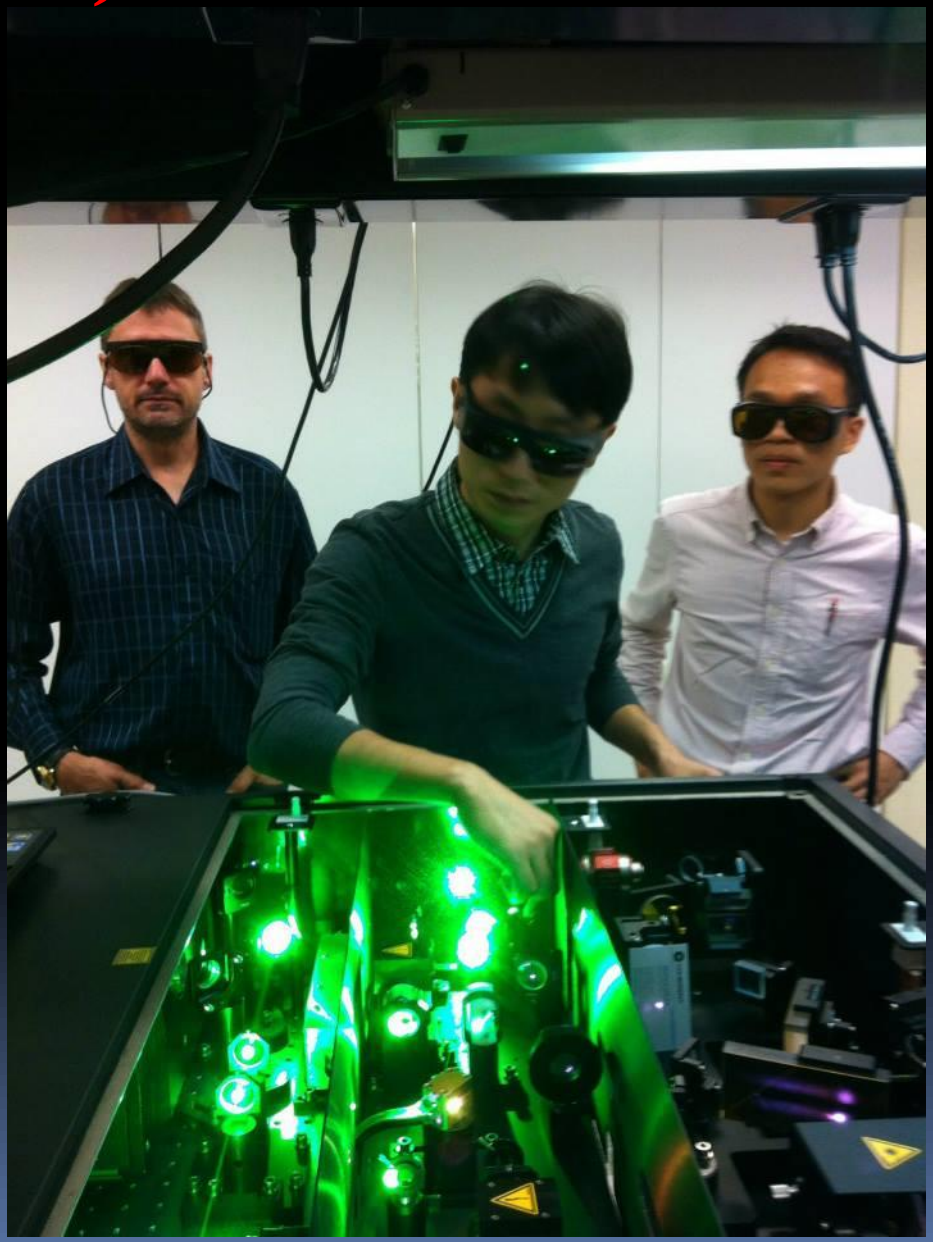
ep your feet mfortably apart stabilize load

Laser Safety

Laser Safety (Cont'd)

Eyewear Requirements:
Protective eyewear is required for all individuals who are exposed to Class 3B and Class 4 laser radiation. The eyewear must be labeled with the wavelength to be attenuated and the optical density (OD) for each wavelength.





Laser Safety

- **Laser users must be aware of the risks involved (Check with your supervisor)**

- **Risk assessment has to be conducted prior to operating lasers and has to be documented**

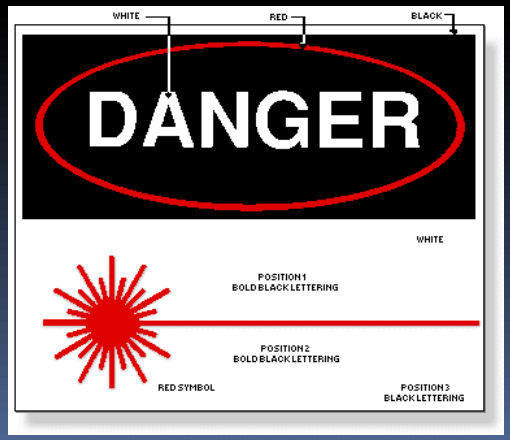
- **All high power laser users are to go through online LAMS laser safety training in NTULearn**

Note: Research lasers are not always in visible wavelengths so the beam is not obvious

Laser Safety

- **All operators must receive training on safe and proper handling of lasers by the PI (or a person designated by the PI) before he/she is allowed to operate a laser**

- **Laser users must put on appropriate laser-specific eye protection**



Laser Safety

Contacts for license application if you will be handling high power lasers:

Ms HOANG Do Quyen (PAP)

Phone: (65) 6513 8481
Office: SPMS-PAP-01-06A
E-mail: dqhoang@ntu.edu.sg

Mr Tan Can Yu (CBC)

Phone: (65) 6513 8447
Office: SPMS-Chair Office-04-01
E-mail: TANCY@ntu.edu.sg

Safety in Wet Chemistry Labs

Wearing proper PPE (Personal Protective Equipment)

Familiarize yourself:
where FIRE EXTINGUISHERES /FIRE BLANKETS are located
where SAFETY SHOWERS are located
where EYE WASHES are located

We do not want accidents to happen to any of you!!

Personal Protective Equipment (PPE)

PPE

1. Eyewear
2. Laboratory Coat
3. Safety Gloves When Doing Experiment

Dress code

1. Covered shoes
2. Long pants (no shorts or bermudas)
3. Long hair tied up

These are mandatory!

Goggles

- Goggles must have a lip on the top so as to prevent liquid from spilling into your eyes from the top

- Safety goggles **must be worn at all times** while in the laboratory. This rule must be followed whether you are actually working on an experiment or simply writing in your lab notebook

- Contact lenses are not allowed. Even when worn under safety goggles, various fumes may accumulate under the lens and cause serious injuries or blindness.

Laboratory coat

Velcro-type coats

Don’t wash your lab coat using a washing machine at home

Get new ones from CBC Chemical Store

Closed toe shoes and long pants must be worn in the lab. Sandals and shorts are not allowed.

Leggings, pants with holes, shorts, and Tank tops ARE NOT permitted

Long Hair must be tied up

N.Y. / REGION

Yale Student Killed as Hair Gets Caught in Lathe

By LISA W. FODERARO APRIL 13, 2011

As a Yale undergraduate majoring in astronomy and physics, Michele Dufault was used to extreme physical environments. She worked on underwater robotic vehicles last summer as a fellow at the Woods Hole Oceanographic Institution in Massachusetts. She also traveled to Houston as part of a team of undergraduates chosen by NASA to perform a plasma physics experiment in reduced gravity.

But it was a rudimentary machine — a lathe in a campus laboratory — that erased what everyone imagined to be a brilliant future for Ms. Dufault, who also found time to mentor girls interested in science and to play saxophone in Yale's precision marching band.

On Tuesday, just weeks from graduating, she toiled late at night inside a machine shop in a chemistry lab, as she had for weeks while working on her senior thesis: investigating the possible use of liquid helium for detecting dark matter particles. Ms. Dufault, 22, was killed when her hair became caught in the lathe, whose rotating axis is used to hold materials like wood or metal being shaped.

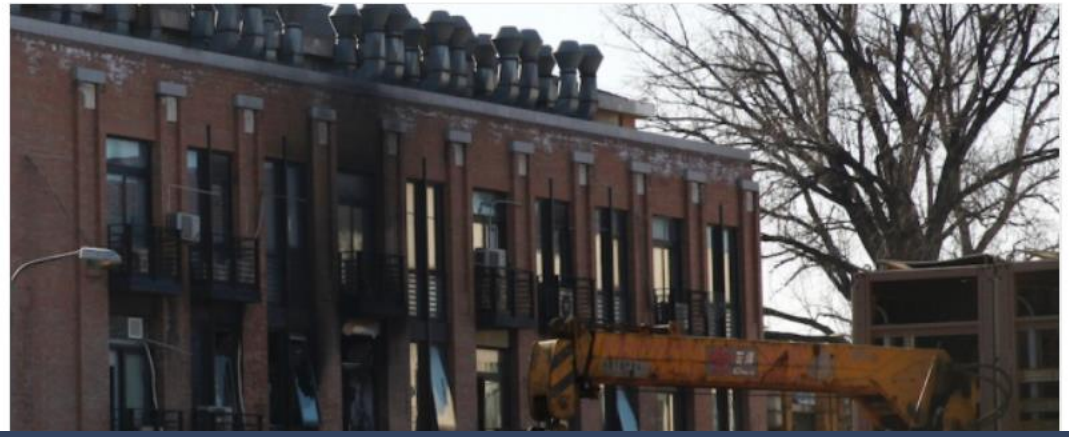
NATURE | NEWS

Postdoc dies in lab fire at Tsinghua University

Explosion occurred in chemistry building on Beijing campus.

David Cyranoski

18 December 2015 | Updated: 24 December 2015



UC system, UCLA professor charged in lab fire that killed staffer [Updated]

DECEMBER 27, 2011 | 4:35 PM

Health/ Personal Hygiene

- Keep your hands away from your face, eyes, mouth, and body while using chemicals.
- Food and drink, open or closed, should never be brought into the laboratory or chemical storage area.
- Never use laboratory glassware for hot pot, eating or drinking purposes.
- Do not apply cosmetics while in the laboratory.
- Wash hands with soap after removing gloves, and before leaving the laboratory. (especially before you pee!!)
- Remove any protective equipment (i.e., gloves, lab coat or apron, chemical splash goggles) before leaving the laboratory.

- Remove your gloves when you are touching door handles, lift buttons, keyboards...., toilets....

Health/ Personal Hygiene

- Eating and drinking, even water is not allowed in the laboratory. Also, do not chew gum.
- Smoking is not permitted in the laboratory

Pregnancy

- Men/Women: If you are pregnant, please inform your supervisor. Stop doing research!

Student Area

- Do not wear lab coats in the student area (CBC) designated writing area (PAP) or toilet

Personal Safety

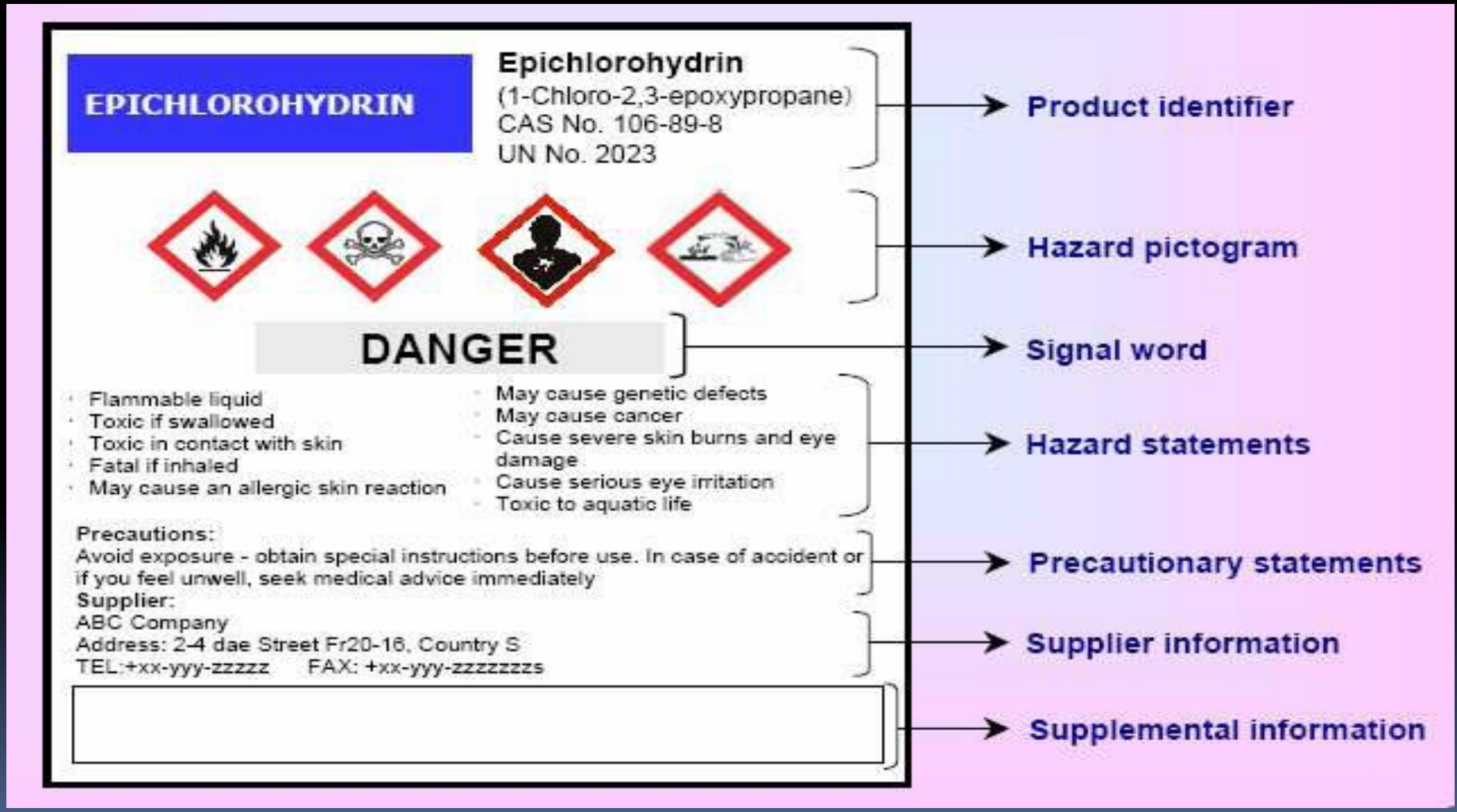
- Consider **all** chemicals to be hazardous unless you are instructed otherwise.
- Safety Data Sheets (SDS) are available in lab for all chemicals in use. These will inform you of any hazards and precautions of which you should be aware.

Safety Data Sheet (SDS)

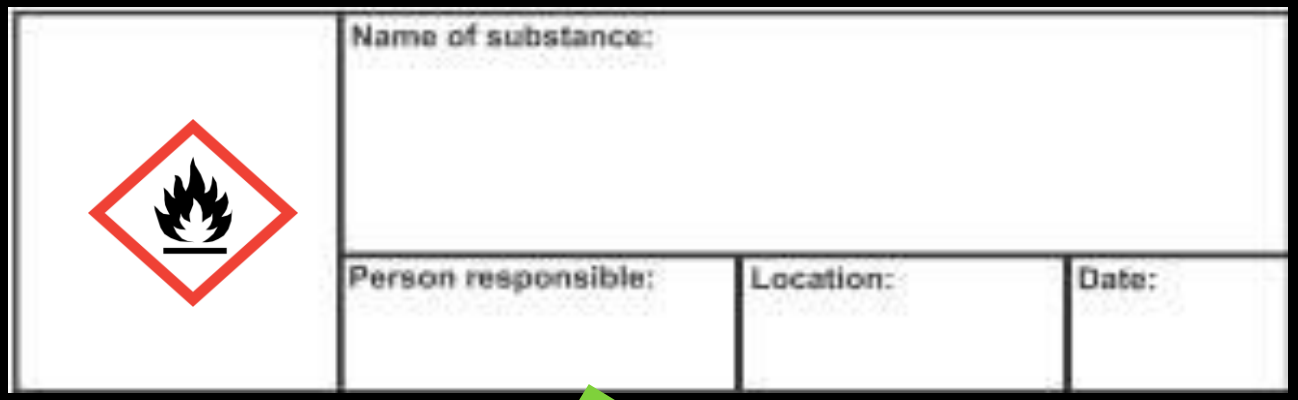
1. Identification
2. Hazards Identification
3. Composition /information on ingredients
4. First-aid measures
5. Fire-fighting measures
6. Accidental release measures
7. Handling and storage
8. Exposure controls/ personal protection
9. Physical and chemical properties
10. Stability and reactivity
11.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

To show sample SDS

GHS Label - example



GHS Label - SPMS



Proper Handling of Chemicals and Equipment

1.Know what chemicals you are using. Carefully read the label *twice* before taking anything from a bottle.

2.Excess reagents are **never** to be returned to stock bottles. If you take too much, dispose of the excess.

3.Many common reagents, for example, alcohols and acetone, are highly flammable. **Do not use them anywhere near open flames and heat gun.**

4. Never point a test tube or any glassware that you are heating at yourself or your neighbor--it may erupt like a geyser..

5.Clean up all broken glassware immediately and dispose off the broken glass properly.

TABLE WHICH SHOWS COMPATIBILITY MATRIX

	Inorganic acids	Oxidizing acids	Organic acids	Bases	Oxidersers	Toxic (Inorganic)	Toxic (Organic)	Water Reactive	Organic Solvents*
Inorganic acids			X	X		X	X	X	X
Oxidizing acids			X	X		X	X	X	X
Organic acids	X	X		X	X	X	X	X	
Bases	X	X	X				X	X	X
Oxidersers[1]			X				X	X	X
Toxic (Inorganic)[2]	X	X	X				X	X	X
Toxic (Organic)	X	X	X	X	X	X			
Water Reactive	X	X	X	X	X	X			
Organic Solvents[3]	X	X		X	X	X			

X = Not compatible—do not store together

http://www.spms.ntu.edu.sg/cbc/Safety/documents/2013/Safety%20Fact%20Sheet-Incompatible%20Chemicals%20(240113).pdf

Hazardous Materials Safety Management

Need to establish and implement workplace safety practices and procedures in the handling of hazardous materials.

1)Risk Assessment

2) Purchasing of Hazardous Materials

3)Transportation of Hazardous Materials

4)Storage of Hazardous Materials

5)Use of Hazardous Materials

6) Disposal of Hazardous Wastes

http://intranet.ntu.edu.sg/ohs/Shared%20Documents/Directives/NTU%20Hazardous%20Materials%20Safety%20Directive%20(120809).pdf

SPMS Chemical Management

Procedure

- Licence & compliance
- SPMS Safety Manual and Guidelines

Transport

- Wet/dry corridor system
- Secondary containment

Storage

- Compatibility
- Safety Data Sheets

Use

- GHS label
- RA/SWP/Guidelines
- Safety training

Disposal

- Proper disposal of waste
- Transport of waste

Primary Protective Equipment

Observe the following equipment when you first enter a laboratory facility

Eye Wash

In the event that chemicals get into the eyes:

- Hold face over the eye wash.
- Keep eyes open or blink while spraying water.
- Wash eyes continuously for at least **15 minutes**.

Press handle to activate

Push flap to activate

Flush eyes and eyelids with water or eye solution for a **<u>minimum</u>** of 15 minutes. “Roll” eyes around to ensure full rinsing.

When Splashed

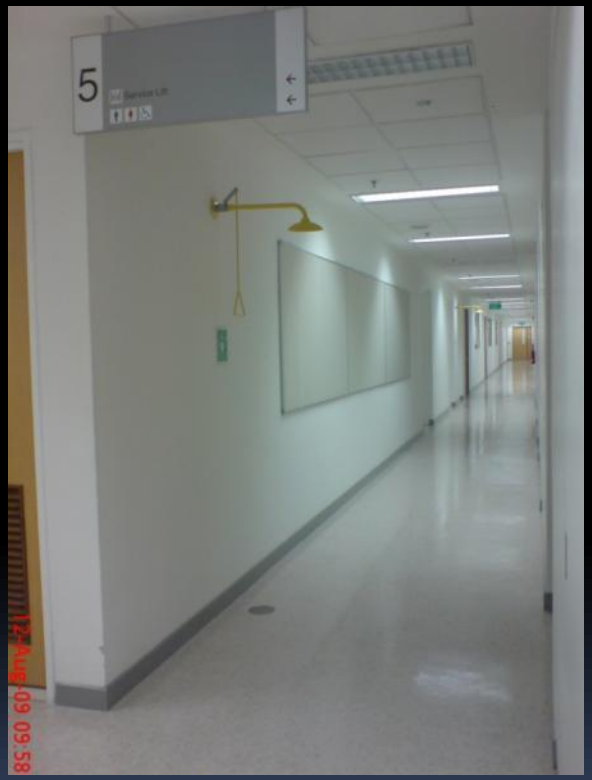
- Keep Calm, Do not touch or rub the eyes.
- Bring Casualty to the eye wash.
- Activate station.
- Rinse hand (for 5 seconds).*
- Lower head; Remove safety spec, goggles or spectacles.
- Do not remove contact lenses immediately, flush it out.

* *Also to clear first few seconds of stagnant water*

- Allow casualty to remove contact lenses if possible. DO NOT FORCE.
- Remove contact lenses as soon as possible. Reduce chemicals being trapped behind the lenses.
- If contact lenses is “stuck” keep rinsing till ambulance arrives. Use eye patch; transport.
- Hold eyelids open using the thumb and index finger.
- Eyelids must be held open.

Primary Protective Equipment

Observe the following equipment when you first enter a laboratory facility



Emergency Shower

In the even that large volume of chemicals are spilled on clothes or any part of body.

- Pull lever to activate the shower.
- Flush for at least 10 minutes.

Remember to remove all affected clothing!

When Splashed

- Remain Calm.
- Bring casualty immediately to the shower.
- One quick tug, pull the lever to activate flush.
- If possible, remove contaminated clothing under shower.
- Stay for 15 minutes.
- Seek medical treatment fast, especially for corrosive liquids/solids.

laboratory safety practices

Safe Behavior

- Do not wear lab coats in the student area or toilet
- Do not eat or drink inside any laboratory
- Always ask when in doubt

Student Area

Primary Protective Equipment

- Keep ALL doors (labs, corridors or lift lobby) closed at all times
  - Fire safety (for fire doors)
  - Security

Working Alone

It is not permitted to do laboratory work alone. This means that there must be another person present in the laboratory. This is to say that the second person must be in the same room.

Further, for undergraduate researchers, the second person present must be of higher status. i.e. not another undergraduate, but a graduate student, postdoc, RA or faculty member.

Primary Protective Equipment

Fume Hoods

•All experiments are to be carried out here

Features

•Double laminated glass that will not crack into small pieces when explode

•Capture and contain fumes generated during research process

•Fire suppression system (CO_2)

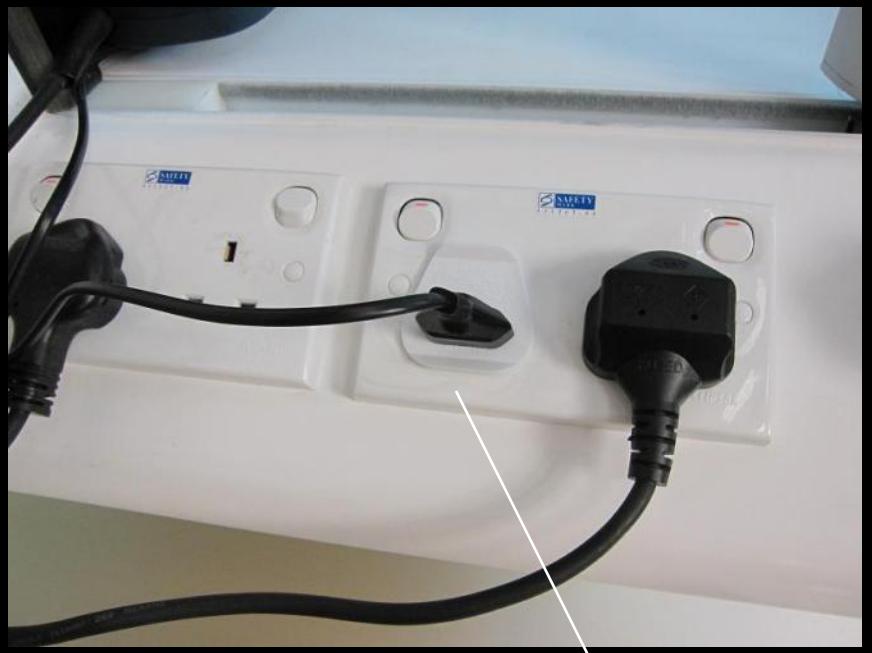
For Best Performance

- Work in the middle of the bench space (10 cm gap).
- Minimise the amount of items in the fume cupboard. Do not place storage items behind - this effects air flow.
- Avoid using fume cupboard as a storage for flammable solvents.
- Avoid sticking your head into the fume cupboard when the hazardous material is inside. (As a rule do not stick your head in!)

- Avoid release of a large amount of gases and flammable vapour, especially near the front. < 10% LEL.
- Keep sash clean and do not use abrasive materials (Sash is not a drawing board).
- Always pull the sash down to a position to reduce aperture space.
- Any heating apparatus e.g. hot plate or heating mantle should be at least 5 cm from the sides of the fume cupboard.
- Do not use naked flames as they will have a serious adverse effect on the air flow.

Electrical practices

Do not use multi-adapter



Better Practice

Chemical Transportation

• Requirement to use secondary containment while transporting chemicals outside of the lab (from one lab to another or via Chemical Store). Any breakage will contain spill within the container.

Even you use a trolley to transport chemical, you also need a secondary container to hold your chemicals.

- There was an incident in which one student , Mr. XXXX, was transporting goods without second container from the store through the level 1 corridor. A 4L bottle of diethyl ether fell off the trolley and smashed.
- Investigation showed that the cause was overloading of the trolley.
- Result: the student is not permitted to enter the CBC building for two weeks; his security access has been removed.

Chemical spillage

- Use provided Chemical Spill Response Pack to contain spill instead of tissue paper!!!!
- Why? Tissue paper will get burnt in contact with a lot of chemicals like nBuLi, LiAlH4, azide, etc etc
  - If the spill is flammable , ensure all ignition sources are removed
  - Wear proper PPE (gloves, lab coat, safety specs)
  - Use mini booms to prevent further spreading of the liquid, adsorbent pads to soak up liquid
  - Report spill to supervisor or Safety Leader

Waste Disposal

- Regular trash and uncontaminated lab debris (gloves, paper towels, etc) goes in the trash can.
- Broken glass goes in the cardboard box designated for broken glass.
- Sharps (blades) and needles are disposed of in the red/yellow SHARPS container.
  - Separate the needle from the syringes. The syringe bodies can go in the regular trash.
  - Needles even if covered go in the SHARPS container

Glass and SHARPS boxes

Waste Disposal Containers

Solid Waste
Silica Waste

Halogenated waste
Non-Halogenated waste
Aqueous Waste
Waste Oil

Empty Containers

Sharp container

Broken Glass

Day	Waste
Monday	Non-halogenated waste solvent Halogenated waste solvent Empty Glass/ Plastic Containers Solid waste Silica Waste
Tuesday	Non-halogenated waste solvent Halogenated waste solvent Empty Glass/ Plastic Containers Solid waste Silica Waste Aqueous waste
Wednesday	Non-halogenated waste solvent Halogenated waste solvent Empty Glass/ Plastic Containers Solid waste Silica Waste
Thursday	Non-halogenated waste solvent Halogenated waste solvent Empty Glass/ Plastic Containers Solid waste Silica Waste Yellow Sharp Bins
Friday	Non-halogenated waste solvent Halogenated waste solvent Empty Glass/ Plastic Containers Solid waste Silica Waste Broken Glass Bins

- Never put acids, bases, or oxidizing agents into the organic solvent waste containers. They may catalyze (possibly violent) chemical reactions resulting in the evolution of heat and fumes.

- Organic acid, mineral (inorganic) acids, Chromic acid, bases waste should be neutralized in advance.

- Waste inorganic bases → be thoroughly diluted

- Bases containing heavy metals (Hg, Pb, Cr, etc..) should be placed separately in containers and appropriately labeled.

- Follow your boss's instructions.

- waste solvents are poured into the appropriately labeled waste-solvent containers. Two waste-solvent containers are provided. One container is for general organic solvents; the other is for halogenated organic solvents and carcinogenic substances (including methylene chloride, chloroform, carbon tetrachloride, benzene).

- Never put acids, bases, or oxidizing agents into the waste-solvent containers. They may catalyze (possibly violent) chemical reactions resulting in the evolution of heat and fumes.

- Waste mineral acids should be placed in the appropriate waste container provided.

- Chromic acid waste should be kept in a separate, appropriately labeled container.

- Organic acid waste also should be dealt with separately,

- Waste inorganic bases should be thoroughly diluted and placed into appropriate waste containers.
- Bases containing heavy metals should be placed in containers and appropriately labeled.

- Waste organic bases should be dealt with separately, according to your boss's instructions.

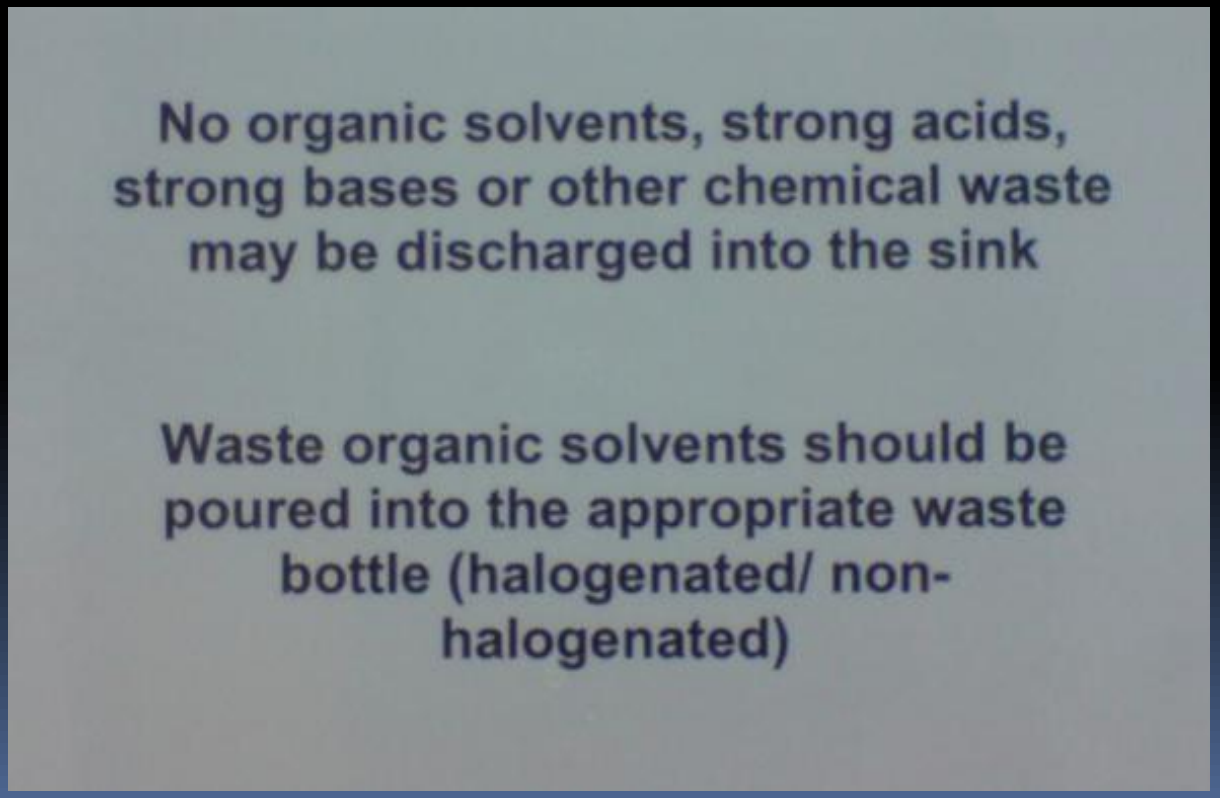
- Chemical waste, solid or liquid, containing heavy metals such a mercury, lead, and chromium should be placed in individual waste jars and appropriately labeled.

- Spills of mercury metal should be reported to your supervisor immediately.

- Never put any chemical waste into the garbage can unless so instructed. All waste containers must be labeled, identifying contents, the principal investigator and lab room number.

Waste Management

- NEVER pour any solvents or chemicals down the sink.
- Spot checking are conducted periodically.



Introduction to Compressed Gas

- **Compressed Gas**
  - A gas, other than in solution, that is in a packaging under charged pressure and is entirely gaseous at a temperature of 20°C (293K)

- **Compressed Gas Cylinder**
  - Designed to contain gases such as Oxygen, Carbon Dioxide, Nitrogen, Argon, Helium, Hydrogen etc.
  - Heavy, normally **weighing about 80kg**
  - Gas is released through a valve which regulates its discharge

Before Handling Compressed Gas Cylinders

- Conduct Risk Assessment
- Understand the Properties & Hazards of the gas
- Attend SPMS Safety Training

Types of Compressed Gases

- **Liquefied gases**
  - Gases which become liquids at room temperature when compressed at high pressure inside cylinders
  - Example: **Carbon Dioxide, Anhydrous ammonia, Chlorine** etc.
- **Non-liquefied gases**
  - Also known as compressed, pressurized or permanent gases
  - Gases do not become liquid at room temperature even when compressed at high pressure
  - Example: **Oxygen, Nitrogen, Helium, Hydrogen, Argon** etc.
- **Dissolved gases**
  - A commonly known dissolved gas is **Acetylene**
  - It is chemically unstable and can explode at atmospheric pressure
  - Acetylene gas is added into the cylinder and the gas is dissolved in volatile solvent (acetone) to stablize

Why is Compressed Gas Cylinder Dangerous?

Hazards Associated with Compressed Gas Cylinders

- **Chemical Hazards**
  - **Sub-Hazards include:** Toxic
    Asphyxiating
    Flammable
    Explosive
    Oxidizing
- **Physical Hazards**
  - **Sub-Hazards include:** **<u>Tipping and Falling (Most common)</u>**
    Valve leakage
    Fire and explosion
    High pressure

Chemical Hazards

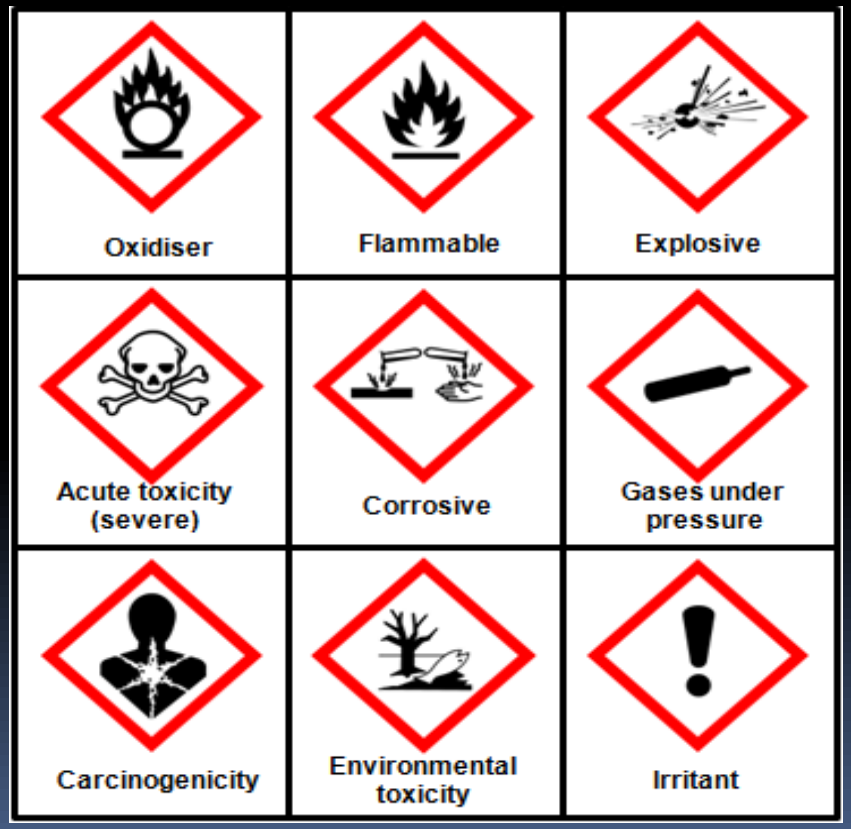
- Contained gas may be toxic, asphyxiating or flammable

Examples of types of compressed gases	Hazard
Oxygen	supports combustion
Nitrogen, Argon, Helium and Carbon Dioxide	cause asphyxiation and death in confined and poorly ventilated areas
Hydrogen	Hydrogen– A flammable gas. When mixed with oxygen or air in a confined area, can result in an explosion if ignited by spark, flame or any ignition source
Acetylene	A flammable gas. A mixture of acetylene and oxygen or air in a confined area can result in explosion when brought in contact with an ignition source

- Always read the Safety Data Sheet (provided by supplier)

Chemical Hazards

- **Nature of Gas** - The gas shall be defined as per classification under GHS system.



Sample of Gas Cylinder Safety Data Sheet

	SAFETY DATA SHEET	Page : 1 Revised edition no : 0 Date : 28 / 12 / 2010 Supersedes : 0 / 0 / 0
Hydrogen		2010489

2.1 : flammable gas.

Danger

1 Identification of the substance/mixture and of the company/undertaking

Product identifier

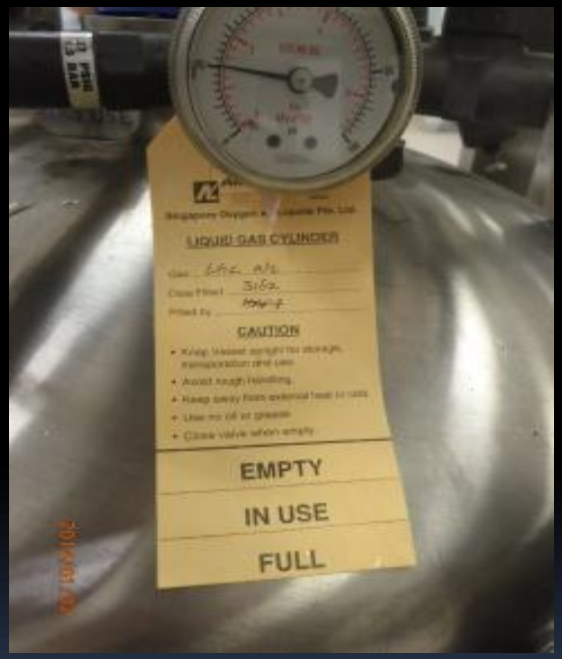
Trade name	: Hydrogen
SDS Nr	: 2010489
Chemical description	: Hydrogen CAS No :001333-74-0 EC No :215-605-7 Index No :001-001-00-9
Chemical formula	: H2
Use	: Industrial and professional. Perform risk assessment prior to use.
Company identification	:
Emergency telephone number	:

Physical Hazards

- Tipping and falling (Most Common)
  - Compressed gas cylinders are heavy and awkward to handle
  - Required special care and equipment to handle and secure to prevent tipping and falling
- Valve leakage
  - Poorly maintained cylinder valve can result in leakage of gas content
- Fire and explosion
  - All compressed gas will expand when heated resulting in explosion
  - Fire ball may form if compressed gas is flammable

Things to Do

- Always monitor the usage of cylinder by indicating on the tag



Full Cylinder

Cylinder in Use

Safe Practices for Transportation

- Always keep Cylinder Caps on at all times except when cylinders are physically connected to a regulator, manifold or distribution apparatus

- Transport cylinders using suitable hand truck

- Never lift cylinders by the cap or collar

Safe Practices for Transportation

- Rolling compressed gas cylinders on the bottom edge for short distances is acceptable (generally not more than 2 metres), for example, moving the cylinder from a cart to the final resting place.

(Note: The cylinder is heavy and it may be necessary to have two persons to assist in the manipulation of cylinders.)

Safety Video on handling compressed gas cylinder

- Do not roll cylinders down drop-down step

Safe Practices for Storage

- Compressed and liquefied gases in portable cylinders shall be stored in accordance with guidelines given by SCDF (for flammable gases) and code of practice.
- Total quantities stored and used shall not be more than the quantity specified by the P&FM license.
- Where different types of gas cylinders are stored at the same location, the cylinders shall be grouped by types and their compatibility.
- Cylinders shall not be:

  (a) stored near flammable or combustible substances;

  (b) exposed to sparks or flames; and

  (c) located where they could become part of an electrical circuit i.e. possibility of contact with a live wire

Safe Practices for Storage

- Cylinders should be secured at all times.
  - This can be done with wall mounted brackets (provided that the wall is strong enough)
  - With bench brackets. The brackets should be fitted with strong chains or fabric straps.
  - An upright storage box or cage with individual cells designed to hold several cylinders at one time
  - No more than two cylinders may be secured by one chain. Wherever possible, one chain should be used for one cylinder. If installation of a bracket is not possible, a cylinder stand can be used.

Examples of Compressed Gas Cylinders Storage

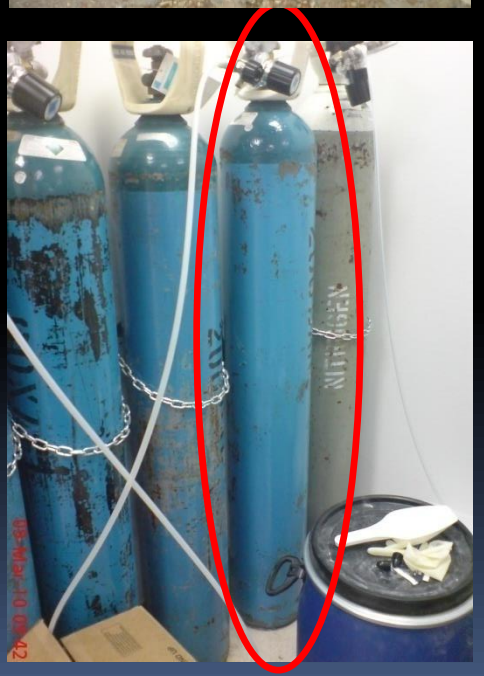
			 right  wrong
bench bracket	wall bracket - correct	wall bracket – incorrect (one chain – many	brackets can be installed at heights suitable for small cylinders. A lab stool is **not** a suitable restraint.

Cylinder Safety

- Gas cylinders must be secured to prevent the risk of toppling over
- A rupture gas cylinder is a missile.

✓

✓



X

Introduction to Cryogenic Liquids

- Cryogenic liquids are liquefied gases that are kept in their liquid state at very low temperatures
- All cryogenic liquids are extremely cold. Cryogenic liquids have boiling points below -150°C (123k)
- One of the most common cryogenic liquid is liquid nitrogen with boiling point below -196°C
- All cryogenic liquids are gases at normal temperatures and pressures. These gases must be cooled below room temperature before an increase in pressure can liquefy them

Before Handling Cryogenic Liquids

Conduct **Risk Assessment**

Understand the **Properties** & **Hazards** of the Cryogenic liquids

Attend **SPMS Safety Training**

Protect Yourself

Laboratory coat

Face shield

Cryogenic apron

Cyrogenic gloves

Covered shoes

Protect Yourself

Hazards Associated with Cryogenic liquid

Hazards	Effects
Extreme Temperature	• Severe cold burns upon contact with skin; skin will freeze to cold metal surfaces • Materials become brittle and can shatter or crack easily • Liquid oxygen may condense in containers of cryogenic liquid below -182.9 deg C → result in explosive hazard
Vapour	• Closed vessels containing cryogenic liquids (if it is not designed for the purpose) may explode because of the build-up in pressure caused by the evaporation • In poorly ventilated rooms, air will be displaced by the expanding gases, leading to an oxygen-deficient atmosphere and death by asphyxiation. If cryogenic liquid is oxygen, it will lead to oxygen enriched atmosphere and will fuel a fire or explode
Topple and fall	• Large liquid N2 tanks can weigh >200kg. May result in severe injuries

- **Always read the Safety Data Sheet (provided by supplier)**

Handling Of Cyrogens

Freeze Burns

- Wear cryogenic gloves
- Wear proper PPE (safety specs, lab coat, covered shoes)
- Avoid direct contact with cryogen and objects at low temperature

Pressure build-up

•Ensure containers used to store/transport cryogens are checked regularly. Vents are not blocked to prevent pressure build-up.

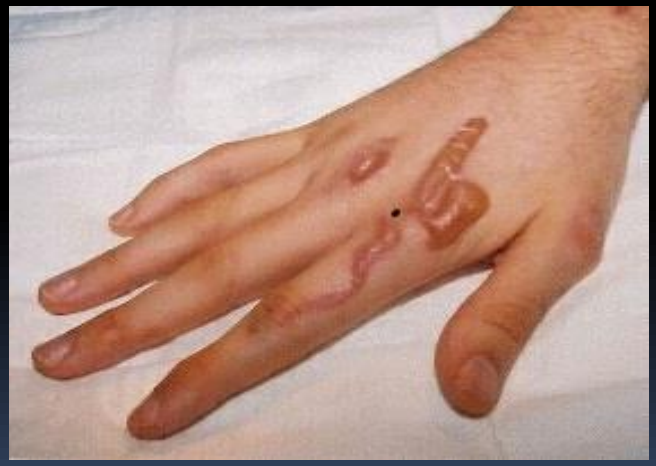
Fire/Explosion

•Use cryogens to cool evacuated systems only.
Cooling non-evacuated systems will cause formation of liquid O_2 inside the system.

- When warmed, liquid O_2 will boil off and create a dangerous rise in pressure.

•Liquid O_2 may also burn/explode when in contact with flammable materials/ignition sources.

Liquid Nitrogen Burn



Handling Of Cyrogens

Transport Of Cryogens in Lifts

- There should be **no passengers** in the lift used to transport liquid N_2.
- **Two persons must work together** to safely transport the dewar of liquid N_2
- The first person must be stationed at the designated level to which the liquid N_2 is to be transported.
- The second person will place the liquid nitrogen dewar/container in the center of the lift. **Install barrier chain across the lift door** preventing personnel from entering the lift at intermediate levels. The person then selects the destination level and exits.
- When the lift arrives at the designated level, the **first person removes the dewar**/container and returns the chain to its original position.

Risk Assessment

What is Risk Assessment?

Risk Assessment Header

Risk Assessment Details ID: RA_SPMS_2019 Approval ID: 0 Revision ID: 1			
User's School/ Department:	School of Physical & Mathematical Sciences	**Project Title:**	Risk Assessment Sample - Organic Synthesis
Workplace:	School of Physical & Mathematical Sciences	**Other workplace:**	-
Location:	CBC-05-08	**Conducted By:**	Tan Can Yu(TANCY)
Approved By:	Roderick Wayland Bates (RODERICK@NTU.EDU.SG)	**Submitted Date:**	24-Jul-13
Approved Date:	-	**Next Review Date:**	-
Status:	Pending	**Comments:**	-

Hazard Identification

1. Hazard Identification				
1a.	1b.	1c.	1d.	1e.
No.	Work Activity	Hazard	Sub Hazard	Possible Accident/Ill Health & Person-at-Risk
5	Solvent distillation	Chemical	Flammable	Burns/ scalds

Workplace Hazards (Main Cause)

	Chemical*	Acute and Chronic
	Biological*	Acute and Chronic
	Radiation	
	Physical*	
	Mechanical*	
	Electrical	
	Ergonomics	

Sub Hazards (Agent)

Chemical	
	Corrosive
	Flammable
	Health - MTC
	Toxic
	Oxidising
	Asphyxia
	Reaction/ combustion

Physical	
	Temperature (+/-)
	Pressure (+/-)
	Size/shape
	Density/weight
	Odour
	Radiation, Ionisation
	Slip, Trip, Fall

Risk Evaluation

2. Risk Evaluation			
2a.	**2b.**	**2c.**	**2d.**
Existing Risk Control (If any)	**S**	**L**	**R**
Top up the still only when the solvent is not boiling; ensure there are no sources of ignition (e.g. heat gun) nearby; ensure that the solvent has cooled before collection; regularly check the water flow indicator; ensure that the fire extinguisher is within reach; check indicator for FC fire suppression system.	3	1	3

Severity Table

SEVERITY INDEX	SEVERITY DESCRIPTION	WORKPLACE SAFETY	WORKPLACE HEALTH	ENVIRONMENT	FIRE DAMAGE	DOWNTIME INCURRED
5	CRITICAL	Fatality, single or multiple	Acute Poisoning, Failure of major Bodily Function	Spills to outside campus	More than $10 million damages	More than 1 year for full re-instatement
		Permanent Body Injury or Loss of Use	Infection with no known cure	Infection outside confines of campus		
4	VERY SERIOUS	Injury requiring 30 days of hospitalization and/ or medical leave	Moderate exposure, Reversible Injury to Bodily functions on prolong recovery	Spills to outside building	More than $1 million damages	More than 3 months for full re-instatement
		Temporary Body Injury or Loss of Use	Infection with known cure but extensive treatment	Infection outside confines of building affecting neighboring buildings but within campus		
3	SERIOUS	Injury requiring 10 days of hospitalization and/ or medical leave	Mild Exposure, Reversible injury to Bodily Functions with less than 1 month recovery	Spills to outside laboratory room	More than $100K damages	More than 1 month for full re-instatement
		Temporary Body Injury or Loss Use	Infection with known cure but extensive treatment	Infection outside confines of workplace but within laboratory only		

Severity Table

2	MARGINAL	Injury Requiring maximum of 3 days of medical leave only	Very mild exposure, reversible injury to bodily functions with less than 3 days recovery	Spills to outside workplace but within laboratory	More than $10K damages	More than 5 days for full re-instatement
		Temporary Body Injury or Loss of Use	Infection with known cure but treatment needed	Infection outside confines of laboratory but within building only		
1	NEGLIGIBLE	First aid treatment only	Very mild exposure, reversible injury to Bodily functions with less than 3 days recovery	Spills within workplace only	Less than $10k damages	No significant
		No or superficial injury	No Exposure	No Infection or infection with no effects		

Likelihood Table

Likelihood Index	Likelihood Description	Likelihood of Occurrence / Exposure Criteria
5	Frequent	Likely to occur many times per year
4	Moderate	Likely to occur once per year
3	Occasional	Might occur once in three years
2	Remote	Might occur once in five years
1	Unlikely	Might occur once in ten years

5X5 Risk Matrix

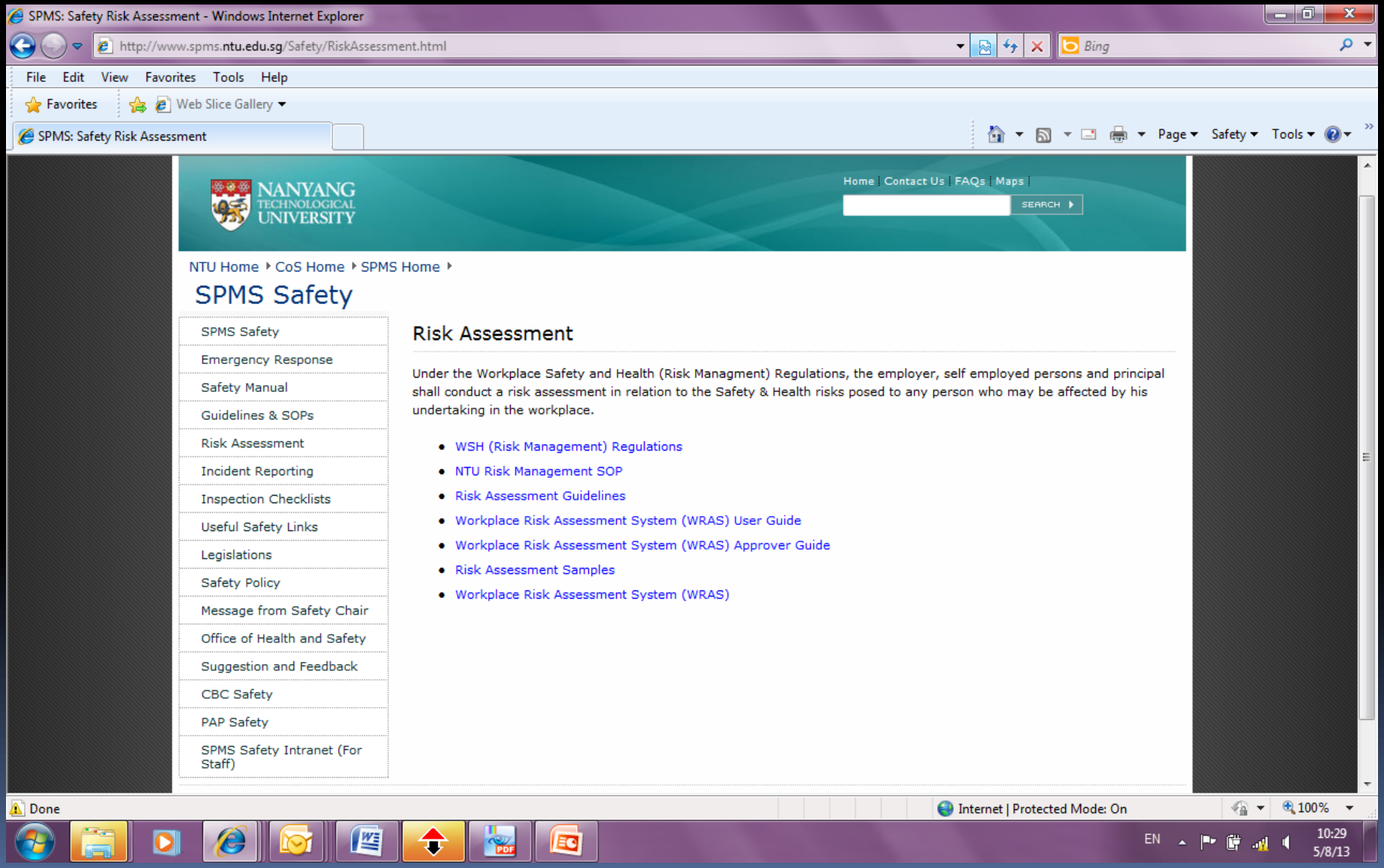
Risk Evaluation (using the 5x5 risk matrix)

Severity / Likelihood	Critical (5)	Very Serious (4)	Serious (3)	Marginal (2)	Negligible (1)
Frequent (5)	25 Operation not permissible	20 Operation not permissible	15 High priority	10 Review at appropriate time	5 Risk acceptable:
Moderate (4)	20 Operation not permissible	16 Operation not permissible	12 High priority	8 Review at appropriate time	4 Risk acceptable:
Occasional (3)	15 High priority	12 High priority	9 Review at appropriate time	6 Risk acceptable:	3 Risk acceptable:
Remote (2)	10 Review at appropriate time	8 Review at appropriate time	6 Risk acceptable:	4 Risk acceptable	2 Risk acceptable:
Unlikely (1)	5 Risk acceptable:	4 Risk acceptable:	3 Risk acceptable:	2 Risk acceptable:	1 Risk acceptable:

Risk Control

Risk Control					
3a	3 b	3c	3d	3e	3f
Additional Risk Control Measures	S	L	RP N°	Follow up by (name) & date	Remarks

Access to WRAS



More information is available on the division and SPMS website:

THANK YOU