TABLE OF CONTENTS

1.0 SAFETY POLICY 2

2.0 RESPONSIBILITIES & ACCOUNTABILITIES 3
   2.1 Introduction 3
   2.2 Overall Responsibility 3
   2.3 SPMS Safety Committee 3
   2.4 Supervisors’ / Reporting Officers’ Responsibilities 3
   2.5 Staff and Student Responsibilities (Persons @ Work) 4

3.0 ORGANISATION STRUCTURE (SAFETY) 5

4.0 WORKPLACE SAFETY & HEALTH 6
   4.1 Workplace Safety and Health Act
      (Administered by Ministry of Manpower, Singapore) 6
   4.2 Responsibilities 6
   4.3 Risk Management 7
   4.4 Risk Management Methodology 8
   4.5 Incident Reporting & Investigation 10
      4.5.1 Definition 10
      4.5.2 Incident Reporting and Investigation Form 10
      4.5.3 Purpose of Incident Reporting 11

5.0 EMERGENCY PREPAREDNESS 12
   5.1 Key Personnel Emergency Contact Numbers 13
   5.2 Contacts of Neighbouring Companies 13
   5.3 SPMS Emergency Response Team 14
   5.4 List of Emergency Response Personnel 14
   5.5 Emergency Communication during Outbreak of Fire
      (During Office Hour) 18
   5.6 Emergency Communication during Outbreak of Fire
      (After Office Hours) 19
   5.7 The Assembly Area for SPMS Staff and Students 20
   5.8 Spill Management Procedure 21

6.0 SAFETY INSPECTION 22

7.0 SAFETY TRAINING 23
# TABLE OF CONTENTS (CONT’D)

## 8.0 GENERAL SAFETY  24

8.1 Good Laboratory Practices  24
   8.1.1 Policy  24

8.2 Personal Protective Equipment  25
   8.2.1 Safety Equipment  25
   8.2.2 Eye Protection  25
   8.2.3 Gloves  25
   8.2.4 Laboratory Attire  26
   8.2.5 Respiratory Protection  26
   8.2.6 Personal Hygiene  26
   8.2.7 Housekeeping  27
   8.2.8 Transportation of Chemicals  27

## 9.0 CHEMICAL SAFETY  29

9.1 Safety Data Sheet (SDS)  29
   9.1.1 Introduction  29
   9.1.2 Understanding Chemical Hazard Information in SDS  30

9.2 Labelling  31

9.3 Globally Harmonized System (GHS Label)  33

9.4 Hazardous Substances  35
   9.4.1 Carcinogens  36
   9.4.2 Mutagens  36
   9.4.3 Teratogens  36
   9.4.4 Corrosives  37
   9.4.5 Explosives  38
   9.4.6 Flammable Substances  40
   9.4.7 Water Reactives  41
   9.4.8 Oxidising Substances  42
   9.4.9 Gases Under Pressure  42
   9.4.10 Cryogenics  44
   9.4.11 Allergens/ Sensitizers/ Irritants  46
   9.4.12 Pyrophoric Substances  47
TABLE OF CONTENTS (CONT’D)

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.4.13 Organic Peroxide</td>
<td>48</td>
</tr>
<tr>
<td>9.4.14 Hydrofluoric Acid</td>
<td>52</td>
</tr>
<tr>
<td><strong>10.0 WASTE MANAGEMENT</strong></td>
<td>59</td>
</tr>
<tr>
<td>10.1 General Guidelines</td>
<td>59</td>
</tr>
<tr>
<td>10.2 Categorizing Waste</td>
<td>59</td>
</tr>
<tr>
<td><strong>11.0 BIOSAFETY</strong></td>
<td>61</td>
</tr>
<tr>
<td>11.1 Introduction</td>
<td>61</td>
</tr>
<tr>
<td>11.2 Requirements</td>
<td>61</td>
</tr>
<tr>
<td>11.3 Biological Project Number</td>
<td>61</td>
</tr>
<tr>
<td>11.4 All New Biological Laboratory Users</td>
<td>62</td>
</tr>
<tr>
<td>11.5 Exposure Control</td>
<td>62</td>
</tr>
<tr>
<td>11.6 Biosafety Levels</td>
<td>63</td>
</tr>
<tr>
<td>11.7 General Lab Practices and Techniques</td>
<td>64</td>
</tr>
<tr>
<td>11.8 Biological Safety Cabinets</td>
<td>65</td>
</tr>
<tr>
<td>11.9 Autoclave</td>
<td>65</td>
</tr>
<tr>
<td>11.10 Biological Spills</td>
<td>65</td>
</tr>
<tr>
<td>11.10.1 In Contained Environment</td>
<td>65</td>
</tr>
<tr>
<td>11.10.2 In Uncontained Environment</td>
<td>67</td>
</tr>
<tr>
<td>11.11 Biological Waste Disposal</td>
<td>67</td>
</tr>
<tr>
<td>11.12 Guidelines for Disposal of Biological Wastes</td>
<td>68</td>
</tr>
<tr>
<td><strong>12.0 RADIATION SAFETY</strong></td>
<td>69</td>
</tr>
<tr>
<td><em>(Adapted from NTU Safety Manual for Radiation Works)</em></td>
<td></td>
</tr>
<tr>
<td><em>(Ionising &amp; Non-Ionising) Version 1 2010)</em></td>
<td></td>
</tr>
<tr>
<td>12.1 Introduction</td>
<td>69</td>
</tr>
<tr>
<td>12.2 Definitions &amp; Responsibilities</td>
<td>70</td>
</tr>
<tr>
<td>12.3 Requirement</td>
<td>71</td>
</tr>
<tr>
<td>12.4 Renewal of Licenses</td>
<td>72</td>
</tr>
<tr>
<td>12.5 Requirement for All Persons Involved in Radiation Works</td>
<td>72</td>
</tr>
<tr>
<td>12.6 Reducing Exposure to Ionizing Radiation</td>
<td>72</td>
</tr>
<tr>
<td>12.7 Radiation Hazard Signs and Labels</td>
<td>74</td>
</tr>
<tr>
<td>12.8 General Radioisotopes Safety</td>
<td>75</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS (CONT’D)

12.9 Radiation Survey Meter & Personal Monitoring Device 76  
12.10 Calibration 77  
12.11 Personal Monitoring 77  
12.12 Non-ionizing Radiation Apparatus Safety 77  
12.13 Radiation Emergency Procedures 79  
12.14 Radiation Contamination Clean-up Procedure 80  
12.15 Radiation Materials & Equipment Disposal 81  
12.16 Radiation Safety – Appendix I 83  
12.17 Radiation Safety – Appendix II 87

13.0 LASER SAFETY 88  
13.1 Introduction 88  
13.2 Classification of Lasers 88  
13.3 Laser Safety Precautions 89

14.0 NANOMATERIALS 92  
14.1 Introduction 92  
14.2 Risk Assessment 92  
14.3 Responsibilities 93  
14.4 Engineering Controls 93  
14.5 Work Practices 94

15.0 ELECTRICAL SAFETY 98

16.0 FIRE SAFETY 100  
16.1 Fire Hazards Control 100  
16.2 Classification of Fire and Fire Extinguishers 101  
16.3 Operating a Fire Extinguisher 102  
16.4 Fire Blanket 103

17.0 ACKNOWLEDGEMENT 104
1.0 SAFETY POLICY

The SPMS Occupational Health, Safety and Environment (HSE) Policy illustrates the management’s commitment and approach in providing and maintaining a safe and healthy work environment.

The policy includes:

- A statement, which clearly articulates the safety objectives and goals and the commitment to achieve these objectives and goals;

- A clear description of duties and responsibilities of employees at all levels in promoting and ensuring occupational safety and health in the organization;

- An acknowledgement that employees are an important resource.

The policy is endorsed by the School Chair and demonstrates commitment of the top management.

The policy is aligned to the NTU HSE policy, and the requirements of MOM and the WSH Act. It shall be reviewed and updated when there are major changes.
SPMS Occupational Health, Safety and Environment (HSE) Policy

Policy

Nanyang Technological University (NTU) in recognizing its corporate responsibility commits to take all reasonably practicable means to provide a safe and healthy environment for all staff, partners, students and visitors. NTU further commits to strive for progress with consideration to environmental sustainability.

Objectives (Enablers)

- To comply with Health, Safety and Environment (HSE) legislation in Singapore and adopt or formulate other relevant HSE policies to fulfill the policy;
- To establish, implement, audit and maintain a HSE management system;
- To communicate requirements (as defined in the HSE management system) to staff, students, partners and visitors;
- To identify and manage workplace and environmental risks proactively (risk management) and ensure all partners perform their work in a manner that mitigate HSE risks;
- To measure and evaluate HSE performance regularly so as to achieve continual improvements and to benchmark “best in class” status;
- To provide appropriate HSE training, information and supervision for faculty, staff and students to enable them to work safely and reduce HSE risks at source;
- To report and investigate promptly ALL incidents and accidents to determine the root cause(s) and take appropriate actions to prevent recurrence;
- To improve and continually review facilities and activities to address HSE risks particularly before their commencement;
- To inculcate a sense of shared stewardship of HSE matters among faculty, staff and students; and
- To provide appropriate resources to achieve these objectives.

[Signature]

Assoc Prof Choe Yeow Meng
Chair, School of Physical & Mathematical Sciences
2.0 RESPONSIBILITIES & ACCOUNTABILITIES

2.1 Introduction

A safe and healthy environment at SPMS is a shared responsibility of all staff, students, partners and visitors. Health, Safety and Environment responsibility is a line function beginning with supervisors/reporting officers and progress upwards through the management.

2.2 Overall Responsibility

The Chair for SPMS has the overall responsibility for the health and safety of all personnel in the School and shall ensure the effective implementation of the Workplace Safety and Health (WSH) management system through the SPMS Safety Committee and Assistant Chair (Safety & Infrastructure). The Chair delegates the day-to-day implementation of the WSH management system to the divisional heads within SPMS.

2.3 SPMS Safety Committee

The SPMS Safety Committee has the responsibility to meet and discuss matters relating to the safety and health of persons at work. The Committee has the responsibility to recommend school-wide WSH policies, regulations and programmes. In addition, the Committee will work closely with all divisions on the development and implementation of the WSH management system.

The SPMS Safety committee shall comprise of faculty and staff members who will meet to discuss workplace safety and health issues relating to the School.

2.4 Supervisors’ / Reporting Officers’ Responsibilities

Supervisors/Reporting Officers and Principal Investigators (PIs) have the duty and responsibility of ensuring the workplace health and safety of persons under their supervision (staff, students, contractors and vendors). They shall ensure
that proper risk assessment is carried out and that practicable measures are in place to control the risks so identified. This will include the implementation of school’s safety policy, safe working procedures, proper maintenance of equipment and facilities, and effective communication (including training and supervision) of all persons under their charge.

2.5 Staff and Student Responsibilities (Persons @ Work)

It is the responsibilities of all faculty, staff and students adhere to safety instructions (especially in following safe working procedures and training) for their own safety and health and that of their colleagues and/or fellow students. Unsafe conditions, equipment and practices should be reported immediately to supervisors (PIs)/reporting officers for immediate actions.
3.0 ORGANISATION STRUCTURE (SAFETY)

Chair
- Provide safety leadership and supporting NTU’s HSE policy and objectives
- Ensure all individuals in the School have well defined duties and responsibilities
- Accord the proper authority and resources to implement NTU HSE policy through appropriate SOPs and programmes

Assistant Chair (Safety & Infrastructure)
- Define roles and responsibilities for all individuals in the School
- Implement SOPs and programs for the School
- Lead the safety committee

School Safety Officer
- Ensure compliance and continuous improvement of School’s safety management
- Ensure compliance of statutory requirements
- Advise and assist in the assessment of WSH risks
- Implement School’s emergency response procedure

Division Safety Officer / Representative
- Ensure Division safety compliance
- Ensure that safety procedures and instructions are effectively communicated and implemented across the Division

PIs and Supervisors
- Responsible for workplace health & safety of persons under his/her supervision
- Ensure that proper risk management is carried out and that practical measures are in place to control risks

Safety Leaders
- Report unsafe acts and conditions to PIs/supervisors for remedial actions
- Conduct safety inspections on a regular basis
- Cooperate and work with Division Safety Officer/Representative and School Safety Officer in adhering to safety instructions for their own safety and health and that of their fellow colleague.
4.0 WORKPLACE SAFETY & HEALTH

4.1 Workplace Safety and Health Act
(Administered by Ministry of Manpower, Singapore)

The Workplace Safety and Health Act (WSHA), enacted in 2006, are based on the premise that accidents can only be prevented if all involved in the workplace take personal responsibility for achieving higher safety standards. It is based on 3 principles:

i. Reducing risk at its source by requiring all stakeholders to eliminate or minimize the risks they create at the workplace;

ii. Industries are required to take greater ownership of Safety & Health standards whereby the focus will be shifted from compiling with prescriptive requirements to making employers responsible for developing safe work procedures suited to their particular situations in order to achieve desired safety outcomes;

iii. Preventing accidents through higher penalties for poor safety and health management.

4.2 Responsibilities

The WSHA expands ownership and defines persons who are accountable for safety outcomes:

Principal Investigators, Immediate Supervisors and Reporting Officers must take reasonably practicable measures to protect the safety and health of staff/students who may be affected by their work. Responsibilities include:

- Conducting risk assessments to remove or control risks to your subordinates at the workplace;
• Maintaining safe work facilities and arrangements for the workers at work;

• Ensuring safety in machinery, equipment, substances and work processes at the workplace;

• Developing and implementing control measures for dealing with emergencies;

• Providing employees/ workers with adequate instructions, information, training and supervision.

Everybody can be liable, depending on the duty imposed by the Act.

All staff and students shall exercise their due diligence to prevent accidents to himself and others.

4.3 Risk Management

Risk assessment allows us to identify the hazards at the workplace and implement effective risk control measures before they escalate into accidents and injuries. Having done risk assessment, it is essential that the risks of the work and control measures to be implemented must be communicated to the persons. The Workplace Safety and Health (Risk Management) Regulations, mandates risk communication shall be conducted for all routine and non-routine work undertaken. The Regulations have stipulated that Principal Investigator, Direct Supervisors and Reporting Officers shall conduct Risk Assessment prior to commencing any work.

Risk assessment is a careful examination of what, in the workplace, could cause harm to employees so that the PI/ Direct supervisors can determine whether they have taken enough precautions to migrate the risk or should do more to prevent potential injuries and illnesses.
Responsibilities of Principal / Direct Supervisor/ Lab-In-Charge/ Reporting Officer include:

- Conducting risk assessment to determine the risk of research or lab staff who may be exposed to a hazard thereby causing injury or ill health;

- Taking reasonably practicable steps, such as SOPs or usage of appropriate PPE, to minimize/eliminate any foreseeable risk(s);

- Maintaining record(s) of any risk assessment in a suitable manner for easy retrieval;

- Reviewing the risk assessment at least once every 3 years or upon receipt of new information on safety and health risks surfaces, changes to the area of work or/and after an incident.

### 4.4 Risk Management Methodology

Risk Assessment comprises of 3 steps: Hazard Identification, Risk Evaluation and Risk Controls. NTU adopts the Activity Based – Qualitative Evaluation Methodology using a 5 by 5 risk matrix.

For more details, please refer to:


However, user may also use adopt equipment based or level centred risk methodology.
### Hazard Identification

<table>
<thead>
<tr>
<th>S/N</th>
<th>Work Activity</th>
<th>Hazard</th>
<th>Sub Hazard</th>
<th>Possible Accident / ill health to persons, fire or property loss</th>
<th>Existing Risk Control</th>
<th>Risk Evaluation</th>
<th>Risk Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>1a</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2a.</td>
<td>2b. 2c. 3c.</td>
</tr>
<tr>
<td>1b</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3a.</td>
<td>3b. 3c. 3d. 3e. 3f.</td>
</tr>
</tbody>
</table>

### Risk Evaluation

<table>
<thead>
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<th>2a.</th>
<th>2b.</th>
<th>2c.</th>
<th>3c.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>L</td>
<td>RPN*</td>
<td></td>
</tr>
</tbody>
</table>

### Risk Control

<table>
<thead>
<tr>
<th>3a.</th>
<th>3b.</th>
<th>3c.</th>
<th>3d.</th>
<th>3e.</th>
<th>3f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>L</td>
<td>RPN*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Follow up by</th>
<th>(name) &amp; date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**

- S/N: Sequence number
- Work Activity: Description of the activity
- Hazard: Potential hazard
- Sub Hazard: Additional details
- Possible Accident: Specific accident details
- Existing Risk Control: Control measures already in place
- Risk Evaluation: S = Severe, L = Low, RPN* = Risk Priority Number
- Risk Control: Additional risk control measures
- Follow up by: Responsible person and date
- Remarks: Additional comments or notes.
4.5 Incident Reporting & Investigation

4.5.1 Definition

- **Accident** – is an unplanned occurrence or incident that causes or contributes to personal injury or damage to property.

- **Incident** – is an event that causes or could cause harm (injury, illness or damage) to persons, plant, material or the environment. An incident for the purpose of this procedure will include a ‘near miss’.

- **Near miss** – is any occurrence that might have led to injury or illness to people, danger to health and/or damage to property or the environment.

- **Hazard** – a situation that has the potential to harm a person, the environment or damage to property.

- **Corrective action** – is an action taken after an incident to correct the problem and to reduce the risk of a similar incident occurring.

Any accident and incident must be reported to NTU Office of Health and Safety through the Division and School.

4.5.2 Incident Reporting and Investigation Form

Similar, incident reporting can be done via:


The reporting of all incidents and hazards will assist the School and University to develop and monitor corrective programmes.
4.5.3 Purpose of Incident Reporting

- To establish the root causes of the incident/hazard reported.

- To increase the safety awareness of people and eventually prevent any incident that may result from the hazard.

- To correct the problem in order to prevent a recurrence.

- To allow trends to be measured (through data obtained) and programs implemented to reduce risk.

All incidents reporting and investigation must be documented, filed and made available to management/supervisors to re-conduct risk assessment if necessary.

Please refer to Standard Operating Procedure on Workplace Incident Reporting and Investigation.
5.0 **EMERGENCY PREPAREDNESS**

The objective is to establish a response plan to mitigate consequences arising from potential emergency situations and to familiarise staff and students with the response procedures in the event of an emergency.

The School has established an emergency response plan to:

- Identify emergency situations and assess their impact;
- Implement the emergency response plan at each level of the School, with clear scope, roles and responsibilities;
- Maintain an up-to-date emergency response plan.

The emergency response plan covers at least, but is not limited to, the following areas:

- Fire and explosion;
- Toxic gas release;
- Chemical spill.

An emergency response drill is conducted at least once every 6 months with the participation of all personnel in the School. An evaluation of the drill performance shall be carried out, and the necessary improvement made to the plan.

The School has established training programmes of drills and exercises for individuals and integrated emergency response teams on their roles and responsibilities, as defined in the plan. The programme also assesses the preparedness of the team for prompt and effective response to an emergency situation.
5.1 Key Personnel Emergency Contact Numbers

<table>
<thead>
<tr>
<th>Important Telephone Numbers to Contact During Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fire / Ambulance (Emergency)</td>
</tr>
<tr>
<td>Fault Reporting Centre (FRC) &amp; Campus Security Office (24hrs)</td>
</tr>
<tr>
<td>NTU Medical Centre (Office Hours Only)</td>
</tr>
<tr>
<td>Police</td>
</tr>
<tr>
<td>Ambulance (Non-Emergency)</td>
</tr>
<tr>
<td>SPMS Emergency Contact No (during Office hours)</td>
</tr>
<tr>
<td>SPMS Safety Committee Chairman: Prof Roderick Wayland Bates (during Office hours)</td>
</tr>
<tr>
<td>School Safety Administrator: Tan Can Yu</td>
</tr>
<tr>
<td>First-Aid Team Captain : Dr Li Yongxin (during Office hours)</td>
</tr>
<tr>
<td>Chemical Spill Response Team Captain: Mr Ng Jin Guan (during Office hours)</td>
</tr>
</tbody>
</table>

5.2 Contacts of Neighbouring Companies

To provide contact number of the neighbouring companies within 500m radius, whereby in the event of the incident escalating beyond the boundaries of the installation, the company will have to inform its neighbours.

<table>
<thead>
<tr>
<th>Company Name</th>
<th>Contact No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>School of Electrical and Electronic Engineering (EEE)</td>
<td>6791 1744</td>
</tr>
<tr>
<td>Wee Kim Wee School of Communication and Information (WKWSCI)</td>
<td>6790 6108</td>
</tr>
<tr>
<td>Nanyang Business School (NBS)</td>
<td>6790 6033</td>
</tr>
<tr>
<td>Carpark B (to call Campus Security)</td>
<td>6790 4777</td>
</tr>
</tbody>
</table>
5.3 SPMS Emergency Response Team

- Safety & Infrastructure Chairman
- Liaison Officers
- Emergency Co-ordinator
  - Fire Wardens
  - First Aiders
  - Chemical Spill Response Team
  - SCBA Team

5.4 List of Emergency Response Personnel

List of Liaison Officers (School Level)

<table>
<thead>
<tr>
<th>Name</th>
<th>Role</th>
<th>Tel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assoc Prof Roderick Wayland Bates</td>
<td>Safety &amp; Infrastructure Chairman</td>
<td>6316 8907</td>
</tr>
<tr>
<td>Mr Tan Can Yu</td>
<td>Safety Officer / Emergency Co-ordinator</td>
<td>6513 8447</td>
</tr>
</tbody>
</table>

List of Liaison Officers (Division Level)

<table>
<thead>
<tr>
<th>Name</th>
<th>Division</th>
<th>Tel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asst Prof So Cheuk Wai</td>
<td>CBC</td>
<td>6513 2730</td>
</tr>
<tr>
<td>Asst Prof Fan Hongjin</td>
<td>PAP</td>
<td>6513 7408</td>
</tr>
<tr>
<td>Assoc Prof Wang Li-Lian</td>
<td>MAS</td>
<td>6513 7465</td>
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</table>
## List of Fire Officer / Fire Wardens (CBC)

<table>
<thead>
<tr>
<th>S/N</th>
<th>Location</th>
<th>Salutation</th>
<th>Name</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Level 1</td>
<td>Asst Prof</td>
<td>So Cheuk Wai</td>
<td>Fire Officer</td>
</tr>
<tr>
<td>2</td>
<td>Level 1</td>
<td>Ms</td>
<td>Goh Ee Ling</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>3</td>
<td>Level 1</td>
<td>Dr</td>
<td>Rakesh Ganguly</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>4</td>
<td>Level 2</td>
<td>Ms</td>
<td>Tan Shi Min</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>5</td>
<td>Level 2</td>
<td>Ms</td>
<td>Choo Oi Keng Lynette</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>6</td>
<td>Level 3</td>
<td>Ms</td>
<td>Seow Ai Hua</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>7</td>
<td>Level 3</td>
<td>Ms</td>
<td>Charlene Poo Kean Pyng</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>8</td>
<td>Level 4</td>
<td>Asst Prof</td>
<td>David Webster</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>9</td>
<td>Level 4</td>
<td>Asst Prof</td>
<td>Shao Fangwei</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>10</td>
<td>Level 5</td>
<td>Asst Prof</td>
<td>Motoki Yamane</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>11</td>
<td>Level 5</td>
<td>Asst Prof</td>
<td>Liu Xuewei</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>12</td>
<td>Level 6</td>
<td>Dr</td>
<td>Pullarkat Appukuttan Sumod</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>13</td>
<td>Level 6</td>
<td>Asst Prof</td>
<td>So Cheuk Wai</td>
<td>Asst Fire Warden</td>
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## List of Fire Officer / Fire Wardens (PAP)

<table>
<thead>
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<th>Location</th>
<th>Salutation</th>
<th>Name</th>
<th>Role</th>
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<tbody>
<tr>
<td>1</td>
<td>Nanyang</td>
<td>Asst Prof</td>
<td>Fan Hongjin</td>
<td>Fire Officer</td>
</tr>
<tr>
<td>2</td>
<td>Nanyang</td>
<td>Asst Prof</td>
<td>Xiong Qihua</td>
<td>Fire Officer</td>
</tr>
<tr>
<td>3</td>
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<td>Asst Prof</td>
<td>Tom Wu</td>
<td>Fire Warden</td>
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<tr>
<td>4</td>
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<td>Mr</td>
<td>Kelvin Ong</td>
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</tr>
<tr>
<td>5</td>
<td>Level 2</td>
<td>Ms</td>
<td>Tan Soo Pei Juliet</td>
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<tr>
<td>6</td>
<td>Level 2</td>
<td>Ms</td>
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<tr>
<td>7</td>
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### List of Fire Officer / Fire Wardens (MAS)

<table>
<thead>
<tr>
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<th>Name</th>
<th>Role</th>
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<tr>
<td>1</td>
<td></td>
<td>Asst Prof</td>
<td>Zhao Liangyi</td>
<td>Fire Officer</td>
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<tr>
<td>2</td>
<td></td>
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<td>Wang Li-Lian</td>
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<tr>
<td>3</td>
<td>Level 3</td>
<td>Mr</td>
<td>Peter Lee Choon Seng</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>4</td>
<td>Level 3</td>
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<td>8</td>
<td>Level 5</td>
<td>Dr</td>
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### List of Fire Officer / Fire Wardens (Chair’s Office)

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<td>Mr</td>
<td>Ronald Anthony Lin Linxiong</td>
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</tr>
<tr>
<td>2</td>
<td>Level 4</td>
<td>Ms</td>
<td>Ng Pei Fan, Florence</td>
<td>Asst Fire Warden</td>
</tr>
<tr>
<td>3</td>
<td>Level 5</td>
<td>Ms</td>
<td>Karin Chiong Kai Ying</td>
<td>Fire Warden</td>
</tr>
<tr>
<td>4</td>
<td>Level 5</td>
<td>Ms</td>
<td>Carrie Ang Bee Kah</td>
<td>Asst Fire Warden</td>
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### List of SPMS Certified Occupational First Aiders

<table>
<thead>
<tr>
<th>Names</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Dr Li Yongxin (Captain)</td>
<td>CBC</td>
<td>6316 8843</td>
</tr>
<tr>
<td>Mr Hendra WIDJAYA</td>
<td>CBC</td>
<td>6316 8982</td>
</tr>
<tr>
<td>Mr Ng Jin Guan</td>
<td>CBC</td>
<td>6513 8191</td>
</tr>
<tr>
<td>Ms Zhu Wenwei</td>
<td>CBC</td>
<td>6316 8981</td>
</tr>
<tr>
<td><strong>Ms Lim See Har</strong></td>
<td>PAP</td>
<td>6514 8367</td>
</tr>
<tr>
<td><strong>Ms Moo Aun Mee</strong></td>
<td>PAP</td>
<td>6316 2977</td>
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<tr>
<td><strong>Ms Ng Lai Wah Grace</strong></td>
<td>PAP</td>
<td>6592 7777</td>
</tr>
<tr>
<td><strong>Asst Prof Ng Keng Meng</strong></td>
<td>MAS</td>
<td>6513 8656</td>
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<tr>
<td>Ms Kelly Nguyen</td>
<td>MAS</td>
<td>6592 2491</td>
</tr>
<tr>
<td>Mr Ng JunXie</td>
<td>Chair’s Office</td>
<td>6513 8651</td>
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<tr>
<td>Mr Tan Can Yu</td>
<td>Chair’s Office</td>
<td>6513 8447</td>
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</tbody>
</table>

** Staff will be attending occupational first aider training from Sep 2012 onwards**
### List of SPMS Chemical Spill Response Team

<table>
<thead>
<tr>
<th>Names</th>
<th>Division</th>
<th>Tel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mr Ng Jin Guan (Captain)</td>
<td>CBC</td>
<td>6513 8191</td>
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<tr>
<td>Mr Ang Chee Yong</td>
<td>CBC</td>
<td>6316 8982</td>
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<tr>
<td>Ms Charlene Poo Kean Pyng</td>
<td>CBC</td>
<td>6513 7989</td>
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<tr>
<td>Mr Low Poh Ming Wilson</td>
<td>CBC</td>
<td>6513 8190</td>
</tr>
<tr>
<td>Mr Chan Tau Cherng (Asst Captain)</td>
<td>PAP</td>
<td>6316 2983</td>
</tr>
<tr>
<td>Mr Li Yuanqing</td>
<td>PAP</td>
<td>6513 8485</td>
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</table>

### List of SPMS SCBA Trained Team

<table>
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<tbody>
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<td>Mr Hendra WIDJAYA</td>
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<td>Ng Jin Guan</td>
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<tr>
<td>Mr Chan Tau Cherng</td>
<td>PAP</td>
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<tr>
<td>Mr Li Yuanqing</td>
<td>PAP</td>
<td>6513 8485</td>
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<tr>
<td>Mr Wong Yeow Kheong Joe</td>
<td>Chair’s Office</td>
<td>6513 7433</td>
</tr>
<tr>
<td>Mr Lam Chou Vun Dennis</td>
<td>Chair’s Office</td>
<td>6513 7436</td>
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</table>
5.5 Emergency Communication during Outbreak of Fire (During Office Hour)

Informant
The person who discovers the FIRE during the office hour to inform the Occupier of Workplace

Note:
FRC – Fault Reporting Centre
SCDF – Singapore Civil Defence Force
FCC – Fire command Centre
ERT – Emergency Response Team

Informant & Occupier access the situation

Fire?

Small Fire
Use Fire Extinguisher to put out fire without taking personal risk

Big Fire

Activate the nearest manual call point to trigger 1st Stage Alarm and call NTU FRC Tel 6790 4777 (24hrs) immediately to report the incident, location and contact person name & number

On hearing 1st stage alarm
- Fire wardens to check alarm panel for its location and physically check on site for the location of the fire.
- All building occupants shall stop all instrument and experiment. Lock up important and valuables. Standby for evacuation.

If the fire is confirmed, FRC/ FCC personnel will activate 2nd stage alarm to announce evacuation and SCDF will be informed.

On hearing 2nd stage alarm, Commence total evacuation
- Fire wardens will immediately direct occupants to SPM5 Assembly Area: Near to School of EEE, Blk S2, Carpark P
- First Aiders to set up First Aid point at the Assembly Area.
- ERT to assemble and to take over role and responsibilities.

Submission of Incident Reporting by Occupier with input from Informant
5.6 Emergency Communication during Outbreak of Fire  
(After Office Hours)

Informant  
The person who discovers the FIRE after office hour

Informant assess the situation

Fire?

Small Fire

Use Fire Extinguisher to put out fire without taking personal risk

On hearing 1st stage alarm
- FRC / TC team to check alarm panel for its location and physically check on site for the location of the fire.  
- All building occupants shall stop all instrument and experiment. Lock up important and valuables. Immediately evacuate.

Yes

No

Big Fire

Activate the nearest manual call point to trigger 1st Stage Alarm and call NTU FRC Tel 6790 4777 (24hrs) immediately to report the incident, location and contact person name & number

- FRC to activate 2nd stage alarm if the fire is unable to be suppressed  
- FRC to call SCDF Hotline 995  
- FRC to inform Campus wardens so that can guide Fire Engine from NTU entrance  
- FRC to inform TC Manager/ engineers / OFPM and School Coordinator

Submission of Incident Reporting by FRC with input from Informant to OHS
5.7 The Assembly Area for SPMS Staff and Students

When fire alarm triggers, a PA announcement (“investigation of alarm…..”) will be broadcasted. Staff or students shall remain calm while the alarm is under investigation. The PA will be silenced and reset if the alarm is found to be a false alarm. However, if a fire is confirmed to be in the building, fire alarm will be re-activated and PA announcement (“to evacuate.....”) will be broadcasted. Staff or students shall immediately evacuate from the building through the fire exits (follow the ‘EXIT’ sign and DO NOT use lifts) to the Assembly Area (as shown above). Should there be any query or doubt on the alarm status, users can contact Fault Reporting Centre, FRC @ 6790 4777 which is 24 hours in service.
5.8 Spill Management Procedure

**SPILL**

**QUIK ASSESSMENT**

- Anyone hurt?

- Attend to injured first.
- Seek medical help if necessary.

Any primary hazards? (Airborne) Note (1)

- FIRE: Highly flammable substance
- BIOLOGICAL: (High risk group) 3 or 4
- TOXIC: Highly toxic

**STOP SPILL** (Only when it is safe to do so)

- Remove all ignition sources within 3m
- Evacuate spill area immediately
- Ventilate area

**INFORM** (Others of spill)

- Call for help (ERT or trained laboratory staff)

Can you handle spill?

- Cordon Off (Large > 5ℓ liquids / 5kg solids)

**PPE** (Put on appropriate)

- SHARPS (Remove sharps with tools, decontaminate & dispose off)

Small < 5ℓ Note (2)
Large > 5ℓ Note (3)

**CLEAN UP** (Note 4)

**DISPOSE** (Absorbed spill)

DECONTAMINATE AREA

- Remove cordon
- Stop ventilation

DECONTAMINATE SELF (Clean up) (Dispose of gloves)

Check self if hurt

- Seek medical help

**ADMINISTRATION** (Incident report to OHS) (Disposal by licensed)
6.0 SAFETY INSPECTION

The objective is to establish an effective programme to conduct random inspection in order to identify unsafe acts/practices and conditions for remedial actions. Surprise spot-checks and unscheduled inspections (including weekends) may be carried out.

The School shall adopt inspection practices and protocols established by the NTU Office of Health & Safety (OHS) (Workplace Safety Inspection Checklist). The checklists shall be used to assist the inspection team in identifying and classifying potential hazards. Checklists shall be reviewed to ensure their relevance.

Safety inspections at all levels of the School shall be conducted by appointed safety personnel (safety chairman, safety officer, division safety representative, safety committee members and safety leaders).

The inspection programme shall include safety observation and safety sampling of the unsafe behaviours at work. This is for the purpose of inculcating positive safety attitudes and behaviours amongst staff. The inspection programme shall encourage staff and students’ participation in their daily routine checking of their work areas and workstations.
7.0 SAFETY TRAINING

The objective of safety trainings is to provide and equip all staff in SPMS with the required skills, knowledge, and safety related information associated with the operations, work processes and maintenance of facilities and equipment to enable them to carry out their work safely.

A safety training programme shall be established in SPMS based on OHS’s SOP on safety training.

The programme shall include:

- **Level 1:** Generic Safety Courses to inculcate a culture of safety and good safety discipline for all staff (e.g. safety induction for new staff, fire safety awareness)

- **Level 2:** Specific Safety Courses that are needed as a result of risk assessments of processes, equipment and/or materials and their associated hazards (e.g. chemical spill handling, use of PPE)

- **Level 3:** Specialised Safety Courses that are mandated by law (e.g. Occupational First Aider, Laser Safety)

Training analysis shall be performed using a training matrix that defines the safety training that a person-at-work will require in order to accomplish work safely. The completion of the identified training need shall be bound to specified time limits, and conditional to the access of facility and/or use of equipment, and/or handling of hazardous substances.
8.0 GENERAL SAFETY

8.1 Good Laboratory Practices

8.1.1 Policy

In order to be authorized access to work in the laboratory it is mandatory for all staff/students to attend a Safety Induction course as well as any additional courses mandated by the School or Division.

If experiments are running overnight, a notice should be posted at a visible location. The notice shall contain information about the experiment & user’s contact information.

Staff/students are not allowed to work alone in a laboratory at anytime.

The penultimate person to leave the laboratory has the responsibility to inform the remaining person that he/she is leaving. No one should unexpectedly find himself/herself alone in the laboratory.

The last person(s) to leave the laboratory shall:

- Walk through the laboratory and inspect for any unsafe conditions;

- Turn off power supply of any equipment or instruments which are not in use;

- Ensure that all fume hood sashes are lowered;

- Turn off the lights if no experiments are running overnight;

- Close and lock laboratory doors;
• All taps are turned off, unless needed for experiments.

8.2 Personal Protective Equipment

8.2.1 Safety Equipment

Know the operation of, as well as the locations of nearby eye wash stations, safety showers, fire extinguishers, fire blankets, fire alarm, first aid box & emergency exits. Maintain unobstructed access to these locations.

Ensure that the eye wash stations are allowed to run for 2 minutes weekly and safety showers, monthly. Division safety reps are responsible for this.

8.2.2 Eye Protection

Eye protection must be worn at all times by all persons in the laboratory because of hazards of splashing chemicals and corrosive vapours. This includes faculty, researchers, cleaning staff, administrators and visitors.

Appropriate eye protection should be used depending on the type of substance(s) to be handled. Appropriate eye protection consists of safety glasses, goggles, a full face shield or even laser goggles.

8.2.3 Gloves

Gloves that are resistant to the substances being worked with must be worn for protection from incidental contact with hazardous materials. All gloves should be inspected for holes, tears and discoloration before use.

Gloves should be removed before leaving the lab and should not be worn when answering a phone call, touching a door handle or typing on a keyboard.
Cut resistance gloves should be worn when working with blades or when adding/removing tubing from glassware.

To protect from skin burns, cryo-gloves should be used when handling cryogenic liquids and dry ice.

8.2.4 Laboratory Attire

Laboratory coats MUST be worn for protection against chemical spills, vapours /dust. Laboratory coats are to be velco or press studs types.

Shorts and skirts are not proper laboratory attires and should NOT be worn when working with chemicals. Long pants should be worn to protect against possible flash fires.

Covered-toe shoes MUST be worn for protection against chemical spills or broken glass. Slippers / sandals/ shoes exposing any part of the feet/toes are not allowed.

8.2.5 Respiratory Protection

Disposal dust masks can be used for protection from airborne or fine dust. However these are not suitable for protection against hazardous vapours and gases.

Respiratory mask with chemical cartridges are used for protection against hazardous vapours and gases.

8.2.6 Personal Hygiene

Consumption and storing of food stuffs are strictly prohibited in the lab at all times. Any food stuff used for laboratory testing must be clearly labelled.
Laboratory refrigerators, desiccators and ovens should NOT be used for food storage. Ice taken from the lab ice maker should not be consumed.

Confine long hair and loose clothing when in the laboratory to keep them from dipping into chemicals, entangled in moving machinery or catching fire.

Lab coats and gloves should be removed before leaving the laboratory to prevent contamination of other areas.

Hands should be washed before leaving the laboratory.

8.2.7 Housekeeping

Work areas/benches should be kept clean and organised.

All containers including wash bottles, solvent bottles as well as waste disposal containers must be clearly labelled.

Chemical wastes must be disposed of into proper waste containers. No chemicals should be discharged into the sink.

Work areas should be cleaned up following the completion or any operation or at the end of the day and kept free from obstructions.

Chemicals or solvent bottles must NOT be placed on the floor as they can be kicked over.

Avoid keeping empty cardboard boxes in the lab.

8.2.8 Transportation of Chemicals

Secondary contentment shall be implemented.
The passengers’ lift must **NOT** be used for the transportation of chemicals.

Gloves should be removed before transportation to avoid possible contamination on door handles and other objects.

Proper risk assessments should be conducted.
9.0 CHEMICAL SAFETY

9.1 Safety Data Sheet (SDS)

9.1.1 Introduction

In our laboratories, hundreds of chemicals are in use on any given day. Many chemicals will cause poisoning if breathed in, contacted with skin or ingested. Inappropriate handling may lead to fire or even an explosion. Hence it is vital for all lab users to be familiar with the hazards and control procedures of the chemicals before use so as to minimize possible adverse impact.

SDS is a form of data that contains information pertaining to the characteristics and properties of that substance. The SDS provides workers and safety representatives with information to safety handle/manage the risk(s) from hazardous substance exposure. It is therefore important for all at the workplace to be able interpret a SDS.

SDS format varies from source to source depending on manufacturers/suppliers. It contains information such as emergency and first aid handling procedures, melting point, boiling point, flash point, toxicology, reactivity, stability, storage, disposal considerations, transport and regulatory information, spill handling procedures and protective equipment to be used.

- All chemicals purchased must come with the SDS.

- All lab users should know how and where they can access manufacturer/supplier specific SDS for the chemical they work with.

- All lab users MUST READ THE SDS and understand the characteristics of the chemical/substance BEFORE USE.
9.1.2 Understanding Chemical Hazard Information in SDS

**Flash Point** is the lowest temperature at which a liquid gives off enough flammable vapour to ignite in the presence of a source of ignition. A lower flash point would mean greater fire risks. Many common laboratory solvents (e.g. acetone, methanol, benzene) have flash points that are below room temperature.

**Auto ignition temperature** or ignition temperature is the temperature at which a material will ignite even in the absence of an ignition course; a spark is not necessary for ignition when a flammable vapour reaches its auto ignition temperature. The ignition temperature is inversely proportional to a fire risk.

**Exposure Limit** is the maximum limit of exposure to an air contaminant. The threshold limit value (TLV) or permissible exposure limit (PEL) can be expressed as the following:

- **Short-term exposure limit (STEL),** is the maximum average concentration to which most workers can be exposed over a 15 minute period, day after day, without adverse effects;

- **Ceiling (C)** defines a concentration that must never be exceeded; and is applied to many chemicals with acute toxic effects.

**Fire Point** is the temperature at which a substance (e.g. lubricating oil), will give off a vapour that will burn continuously after ignition.

**Flammable Limits or Explosive Limits** defines the range of concentrations of a material in air that will burn or explode in the presence of an ignition source such as a spark or flame. The lower the explosive limit (LEL) or lower flammable limit (LFL) is the lowest vapour concentration that will burn or explode if ignited. Below this limit, the concentration of fuel is “lean” for ignition. The upper
explosive limit (UEL) or upper flammable limit (UFL) is the highest vapour concentration that will ignite. Above this limit, the mixture is “rich” for ignition.

**LD$_{50}$ or Lethal Dose 50** is defined as a single dose of a substance which causes the death of 50% of an animal population when exposed to the substance by any route other than inhalation. $LD_{50}$ is usually expressed as milligrams or grams or material per kilogram of animal weight (mg/kg or g/kg). The animal species and means of administering the dose (oral, intravenous etc.) should also be stated.

**LC$_{50}$**, also known as Lethal Concentration$_{50}$ is the concentration in air of a toxic substance that will kill 50% of an exposed animal population. $LC_{50}$ is expressed as parts of test substance per million parts of air (PPM) for gases and vapours, or as milligrams per litre or cubic meter of air (mg/L or mg/m$^3$) for dusts, mists and fumes. It is important to note that a lower $LD_{50}$ or $LC_{50}$ value is more toxic than those with higher values.

### 9.2 Labelling

Labelling is a form of hazard communication to all who need to access a particular chemical/item. Some common chemical labelling information includes combustibility, flammability, corrosivity, toxicity and irritancy. Correct labelling of all chemicals is therefore critical to workplace safety.

**Understand the different hazard labels**

- Carcinogen
- Respiratory Sensitizer
- Reproductive Toxicity
- Target Organ Toxicity
- Mutagenicity
- Aspiration Toxicity
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tbody>
<tr>
<td>![Irritant]</td>
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<tr>
<td>![Dermal Sensitizer]</td>
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<tr>
<td>![Acute toxicity (harmful)]</td>
<td>Acute toxicity (harmful)</td>
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<td>![Skin corrosion]</td>
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<tr>
<td>![Serious eye damage]</td>
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<td>![Acute toxicity (severe)]</td>
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</tbody>
</table>
Currently, there are several systems and standards for labelling chemicals to communicate their hazards. A number of organizations have each developed her regulations for labels & safety data sheets (SDS) to be transmitted to chemicals users, resulting in varying labels/SDS for the same product. Hence, an internationally harmonized classification and labelling approach, known as GHS, has been developed.

GHS is an acronym for the Globally Harmonized System of Classification and Labelling of Chemicals. This system which is globally agreed upon has been set to replace the various classification and labeling standards used in different countries. Hazard classification, labels and Safety Data Sheets will be harmonized under GHS.

9.3 Globally Harmonized System (GHS Label)

<table>
<thead>
<tr>
<th></th>
<th><strong>Product Identifier</strong></th>
<th>Identity of the chemical</th>
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<tbody>
<tr>
<td>2</td>
<td><strong>Pictogram</strong></td>
<td>Assigned to a GHS hazard class and category</td>
</tr>
<tr>
<td>3</td>
<td><strong>Signal words</strong></td>
<td>Indicate the relative hazard severity and alert readers to a potential hazard. DANGER &gt; WARNING</td>
</tr>
<tr>
<td>4</td>
<td><strong>Hazard statements</strong></td>
<td>Phrases describing the nature &amp; the degree of hazard of a chemical</td>
</tr>
<tr>
<td>5</td>
<td><strong>Precautionary statements</strong></td>
<td>Describe the recommended measures that should be taken to minimize or prevent adverse effects resulting from exposure, or improper storage or handling of a hazardous chemical</td>
</tr>
<tr>
<td>6</td>
<td><strong>Supplier information</strong></td>
<td>Name, address &amp; telephone number of the manufacturer or supplier</td>
</tr>
<tr>
<td>7</td>
<td><strong>Supplementary information</strong></td>
<td>Provided by the supplier to include additional useful information on the chemical at its discretion</td>
</tr>
</tbody>
</table>
An example of GHS Label:

<table>
<thead>
<tr>
<th>EPICHLOHYDRIN (1-Chloro-2,3-epoxypropane)</th>
<th>Product Identifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAS No. 106-89-8</td>
<td>Hazard Pictogram</td>
</tr>
<tr>
<td>UN No. 2023</td>
<td>Signal Word</td>
</tr>
<tr>
<td></td>
<td>Precautionary Statement</td>
</tr>
<tr>
<td></td>
<td>Supplemental Information</td>
</tr>
</tbody>
</table>

DANGER

- Flammable liquid
- Toxic if swallowed
- Toxic in contact with skin
- Fatal if inhaled
- May cause an allergic skin reaction
- May cause genetic defects
- May cause cancer
- Cause severe skin burns & eye damage
- Causes serious eye irritation
- Toxic to aquatic life

Precautions:
Avoid exposure - obtain special instructions before use. In case of accident or if you feel unwell, seek medical advice immediately
Supplier:
ABC Company
Address: 123 abc street Fr 12-34, Country S
Tel: +xx-yyyy-zzzzzz Fax: + yy-xxx-zzzzzs

For more information, please refer to SDS

<table>
<thead>
<tr>
<th>Dimension of GHS Label:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity of Container</td>
</tr>
<tr>
<td>Not exceeding 3 litres</td>
</tr>
<tr>
<td>Greater than 3 litres but not exceeding 50 litres</td>
</tr>
<tr>
<td>Greater than 50 litres but not exceeding 500 litres</td>
</tr>
<tr>
<td>Greater than 500 litres</td>
</tr>
</tbody>
</table>

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 & Chemical properties
10. Stability & reactivity
11. Toxicological information
12. Ecological information
13. Disposal considerations
14. Transport information
15. Regulatory information
16. Other information
We need to:

- Prepare ourselves for the labeling, starting from single substance.
- Educating/Training lab users on the new GHS labeling system.
- Update our SDS database and GHS label when change(s) made.

For more information, please visit:
http://www.unece.org/trans/danger/publi/ghs/ghs_rev02/02files_e.html

9.4 Hazardous Substances

Many substances which we encounter in the laboratory are known to be toxic, corrosive or combination of both. We may also frequently encounter new and untested substances that maybe hazardous to us. Chemicals that are flammable and/or explosive pose another significant hazard. Therefore, it is essential that all laboratory users understand the types of toxicity and are familiar with the major hazard classes of chemicals. It would be important to treat all compounds as potentially harmful, especially new and unfamiliar materials, and work with them under conditions to minimize exposure by skin contact and inhalation.

Hazardous Substances with Toxic Effects on Specific Organs

<table>
<thead>
<tr>
<th>Category</th>
<th>Effects on organs</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hepatotoxins</td>
<td>Liver damage</td>
<td>Nitrosamines, Carbon Tetrachloride</td>
</tr>
<tr>
<td>Nephrotoxins</td>
<td>Kidneys damage</td>
<td>Certain halogenated hydrocarbons</td>
</tr>
<tr>
<td>Neurotoxins</td>
<td>Nervous system</td>
<td>Mercury, Acrylamide, Carbon Disulfide</td>
</tr>
<tr>
<td>-</td>
<td>Decrease haemoglobin function &amp; deprive body tissues of oxygen</td>
<td>Carbon monoxide and Cyanides</td>
</tr>
<tr>
<td>-</td>
<td>Damage of Lung tissue</td>
<td>Asbestos and Silica</td>
</tr>
</tbody>
</table>
General Safety practices when handling Hazardous Substances:

- Read the SDS for all materials used in your work. The SDSs are a starting point for drawing up an emergency plan. If the directions in each SDS section are unclear or incomplete, contact supplier for help;

- Conducting risk assessment to determine the likelihood that you/your lab mates may be exposed to an injury arising from the work undertaken;

- Taking reasonably practicable steps to minimize/eliminate any foreseeable risk(s), such as SOPs or usage of appropriate PPE.

The following are classified as hazardous substances under the Workplace Safety and Health Act:

9.4.2 Carcinogens

Carcinogens are chemical of physical agents that cause cancer. They are generally chronically toxic substances i.e. they cause damage after repeated or prolong exposure. These agents may have pose immediate or apparent harmful effects but they are insidious.

9.4.2 Mutagens

Mutagen is an agent that can induce a genetic mutation if inhaled or ingested.

9.4.3 Teratogens

Teratogens are substances which if inhaled or ingested or penetrated into the skin of a pregnant woman, may induce deformation in the foetus.
9.4.4 Corrosives

Corrosives are substances which erode or irreversibly change living tissue and are particular damaging to the eyes. Respiratory damage by means of severe bronchial irritation occurs from the inhalation of vapors or mists of these types of chemicals.

Some corrosives such as sulphuric, nitric and perchloric acids are also oxidizers, therefore they are not compatible with flammable or combustible materials. They may liberate heat with mixed with water and release toxic/explosive products when reacted with other chemicals.

There are 3 general categories:

- **Strong acids:**
  Hydrochloric, nitric, phosphoric and sulfuric acids;

- **Strong bases:**
  Ammonia, potassium hydroxide and sodium hydroxide;

- **Dehydrating agents:**
  Concentrated sulfuric acid, sodium hydroxide, phosphoric pentoxide and calcium oxide.

When handling corrosives:

- Wear appropriate skin and eye protection.

- Handle concentrated corrosive liquids only in a chemical fume hood.

- Dilution should be carried out slowly.

- Always dilute by adding acids to water.
• Store liquid corrosives below eye level.

• Acids are to be stored separately from gases.

**When handling corrosives spill:**

Acids and bases require different types of spill control materials. Appropriate cleaning up materials can be determined by referring to the Safety Data sheet and should be done prior the use of any corrosive chemical. These materials neutralize the hazardous nature of the spilled material.

**9.4.5 Explosives**

Explosives are substances that cause a sudden, almost instantaneous release of energy, pressure, gas and heat when subjected to sudden shock, vibration, pressure or high temperature. Some will become increasingly shock sensitive with age. Picric acid is one that becomes shock sensitive and explosive if it dries out.

**When Handling Explosives substances:**

• Refer to the label & SDS to determine if a chemical is explosive.

• Wear appropriate PPE and perform experiments behind face shield.

• Work must be carried out within a fume hood.

• Indicate the dates received and opened on all the explosive /shock sensitive chemical containers.

• Work with smallest quantity possible.
- For exothermic reactions, reagents should be added dropwise with rapid stirring. Overcooling must be avoided as a dangerous buildup of unreacted reagents may occur.

- Inspect all such containers every month.

- Keep picric acid solutions wet i.e. 30% or more water. Some substances can be set off by the action of their own crystal formation and hence should not be allowed to become “dry”.

15 precursors that are widely used for industrial & research purposes have been identified for control under the Arms and Explosives Act by the Singapore Police Force (SPF). They include:

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Exclusions</th>
<th>Some Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonium Nitrate</td>
<td>a) Aqueous solutions containing &lt; 60% Weight in weight* of ammonium nitrate</td>
<td>Fertilizers, matches, explosives, pyrotechnics, oxidizer in solid rock propellants</td>
</tr>
<tr>
<td></td>
<td>b) Any moisture, including a fertilizer, which contains ammonium nitrate &amp; in which any part of the nitrogen content having a chemically determined ammonium equivalent constitutes, together with that equivalent, &lt; 28%, by weight of the said mixture</td>
<td></td>
</tr>
<tr>
<td>Ammonium Peroxide</td>
<td></td>
<td>Propellants, explosives &amp; pyrotechnics</td>
</tr>
<tr>
<td>Barium Nitrate</td>
<td>Preparations &amp; solutions containing &lt; 10%, weight in weight, of barium nitrate</td>
<td>Glass, ceramics, pyrotechnics for green fire, green signal light</td>
</tr>
<tr>
<td>Guanidine Nitrate</td>
<td>-</td>
<td>Disinfectants, photographic chemicals</td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Preparations &amp; solutions containing not &gt; 20%, weight in weight, of</td>
<td>Antiseptic, disinfectant, bleaching,</td>
</tr>
<tr>
<td>Chemical</td>
<td>Usage</td>
<td></td>
</tr>
<tr>
<td>--------------------------</td>
<td>----------------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Hydrogen peroxide</td>
<td>Electroplating, refining &amp; cleaning metals</td>
<td></td>
</tr>
<tr>
<td>Potassium chlorate</td>
<td>Bleaching, dyes, explosives, pyrotechnics, fireworks &amp; matches</td>
<td></td>
</tr>
<tr>
<td>Potassium nitrate</td>
<td>Preparations &amp; solutions containing &lt; 5%, weight in weight, of potassium nitrate or a combination of both potassium nitrate &amp; sodium nitrate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Preservatives, matches, fertilizer, pyrotechnics, fireworks &amp; toothpastes</td>
<td></td>
</tr>
<tr>
<td>Potassium perchlorate</td>
<td>Photography, explosives &amp; pyrotechnics</td>
<td></td>
</tr>
<tr>
<td>Sodium chlorate</td>
<td>Herbicides, weed killer, explosives, matches</td>
<td></td>
</tr>
<tr>
<td>Sodium nitrate</td>
<td>Preparations &amp; solutions containing &lt; 5%, weight in weight, of sodium nitrate or a combination of both sodium nitrate &amp; potassium nitrate</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fertilizer, refrigerant, matches, pharmaceuticals, dyes, preservatives</td>
<td></td>
</tr>
<tr>
<td>Sodium nitrite</td>
<td>Aqueous solutions containing &lt; 5% weight in weight, of sodium nitrite</td>
<td>Rubber accelerators, medicine, preservatives, photography</td>
</tr>
<tr>
<td>Sodium perchlorate</td>
<td>Explosives, matches</td>
<td></td>
</tr>
<tr>
<td>Perchloric acid</td>
<td>Electroplating, explosives</td>
<td></td>
</tr>
<tr>
<td>Tetranitromethane</td>
<td>Petrochemicals, explosives, propellants</td>
<td></td>
</tr>
</tbody>
</table>

*Weight in weight: The concentration levels of the controlled chemicals cannot exceed the stipulated threshold limit*

### 9.4.6 Flammable Substances

Flammable substances, solids, liquids or gases, will ignite when exposed to heat, sparks or flame. They have a **flash point** of less than 37.8 °C or 100 °F. When these substances/chemicals reach their individual flash point, the vapors given off will readily catch fire and burn in air.
Common flammable liquids are ethanol, methanol, acetone, ether & toluene.

When handling flammable substances:

- Appropriate PPE must be worn.
- Keep all sources of ignition, high heat and combustion from storage and dispensing areas.
- Always keep most organic solvents away from accidental contact with oxidizers.
- Store and use in the small amounts possible so that any spillage can be cleaned up before it can cause a large fire.
- Do not store flammable liquids on the floor.

9.4.7 Water Reactives

These substances react with water or moisture in the air and release heat/flammable/toxic gases. Examples include alkali metals, alkaline earth metals, carbides, hydrides, phosphorus and sulfur chlorides, phosphorus pentoxide, nitrides, peroxides and phosphides.

When handling water reactives:

- Appropriate PPE should be worn;
- Water-reactives should be stored under mineral oil in a cool, dry place and be isolated from other chemicals;
- These should not be stored near water, alcohols and other compounds containing acidic OH;
• Appropriate fire extinguishers (Type “D”) should be available in areas where water-reactives are used.

9.4.8 Oxidising Substances

Oxidising substances are capable of igniting flammable and combustible material even in an oxygen-deficient atmosphere. This type of substance decomposes and liberates toxic gases when heated. They can burn or irritate skin, eyes, breathing passages and other tissues.

Examples include:

• Chlorates, chromates, bromates, iodates, nitrates, nitrites, perborates, perchlorates, permanganates, peroxides, percarbonates and persulfates.

9.4.9 Gases Under Pressure

Many laboratory operations require the usage of compressed gases. Cylinders contain gases with varying chemical properties from inert and harmless to toxic and explosive. Gases under high pressure present significant mechanical and chemical hazards.

Compressed gases are hazardous due to the high pressure inside cylinders. Knocking over an unsecured, uncapped cylinder of compressed gas can break the cylinder valve; the resulting rapid escape of high pressure can propel the cylinder like an unguided rocket, causing serious injury and damage. Poorly controlled release of compressed gas in the laboratory can burst reaction vessels, cause leaks in equipment and hoses or result in runaway chemical reactions. Compressed gases may also have flammable, oxidizing, dangerously reactive, corrosive or toxic properties. Inert gases such as nitrogen, argon, helium and neon can displace air, reducing oxygen levels in poorly ventilated areas and causing asphyxiations.
Generally, gas cylinders, full or empty, have to be securely restrained at all times to prevent them from falling over. Cylinders may be strapped to a bench top, chained individually to the wall, placed in a holding cage or placed on a cylinder trolley. If the chain/belt is too low or too high, it will not be able to hold the cylinder securely. The chain should not be around the neck of the cylinder, since the cylinder could slide under the chain. The chain should not hang below the midpoint of a cylinder, since it could topple over the chain.

**Transportation of gas cylinders**

- Caps shall be kept on at all times except when cylinders are physically connected to a regulator, manifold or distribution apparatus.

- Cylinders can also be protected by a collar. Do not lift it by the cap or collar.

- Cylinders shall not be dropped or permitted to strike against each other or other surfaces violently.

- Cylinders shall be transported by suitable hand trucks (preferable on a stable three or four wheeled trolley, or rolled on the bottom edge for short distances only.

- Cylinders cannot be rolled when conditions are unsafe such as when surfaces are wet or a slope.

- Cylinders shall not be rolled over any electrical cables.

- No cylinders shall be rolled horizontally on the ground nor be transported horizontally on a push cart.
Cylinders shall not be transported in any passenger lifts with any occupants.

**Storage of gas cylinders**

- **Oxygen Cylinders**, full or empty, shall not be stored in the same vicinity as flammable gases

- **Cylinders containing flammable gases** (e.g. Hydrogen /acetylene), shall not be stored in close proximity to open flames, areas where electrical sparks are generated, or where other sources of ignition may be present. They should be stored in a well-ventilated area.

- **Acetylene Cylinders** shall NEVER be stored on their side. An open flame should never be used to detect leaks of flammable gases.

- **Hydrogen Cylinders** shall be stored away from noble metals such as Ni, Pd and Pt to eliminate possible fire hazards.

For more information, please refer to Guideline on Compressed Gas Cylinder Safety.

### 9.4.10 Cryogenics

Cryogenics are materials with very low temperature (below −150 °C) such as liquefied nitrogen, helium, argon, neon and dry ice (solid CO$_2$). A number of hazards may be present from the use of cryogenic liquids in the laboratory; hence staff and students should be properly trained prior use.

When handling cryogenics:
- Watches, rings, bracelets or other jewellery that could trap fluids against should not be worn when handling cryogenic liquids as these could freeze to your skin.

- Proper PPE such as gloves (provide high level of thermal protection from direct contact with cold objects) and eye protection must be worn at all times.

- Avoid skin contact with cryogenic liquid as it this will cause severe frostbites/thermal burns. Prolong contact could lead to blood clots.

- Substances may become brittle upon contact with liquid nitrogen and shatter, sending broken pieces flying.

- Use materials which are resistant to embrittlement (e.g. latex rubber tubing).

- Liquid nitrogen and helium should not be used to cool flammable mixtures because oxygen (present in the air) will condense on the surface and lead to potentially explosive hazard.

- Cryogenic liquids can freeze water very rapidly. Careless use of water can lead to heavy icing, which may block pressure relief valves.

**Transportation of cryogens in cargo/ fireman Lifts**

Liquid nitrogen should **not** be transported in the lift with accompanying passengers. This is due to the asphyxiation risk involved when liquid N2 is transported in a confined space with inadequate ventilation. 1 litre of liquid nitrogen will product 682L of nitrogen gas. In the event of a spill or prolonged breakdown of the lift, the boiling off of liquid Nitrogen will very quickly create an oxygen-deficient atmosphere that is fatal.

The following should be strictly complied with when transporting liquid nitrogen through lifts:
1. There should be no passengers in the lift which is used to transport liquid nitrogen.

2. Two persons must work together in order to safely transport the dewar of liquid nitrogen up to the designated level.

3. The first person must be stationed at the designated level to which the liquid nitrogen is to be transported.

4. The second person will place the liquid nitrogen dewar in the center of the lift. The hazard warning sign will be placed just behind the lift door and in front of the dewar such that it is prominent and prevents personnel from entering the lift at intermediate levels. The person then selects the destination level and exits.

5. When the lift arrives at the designated level, the first person will remove the dewar and the hazard warning sign from the lift.

6. The hazard warning sign must be returned immediately to the liquid nitrogen storage area for subsequent usage. Hazard warning sign reads, “DO NOT ENTER - Liquid Nitrogen In Transit”

**9.4.11 Allergens/ Sensitizers/ Irritants**

These are substances that may produce skin or lung hypersensitivity. Examples include:

- Formaldehyde, isocyanates, certain phenols, dichromates and nickel containing compounds.

When handling allergens/ sensitzers / irritants:
- Consult and follow the recommendations contained in SDS for specific precautions;

- Wear appropriate PPE, gloves, dust mask as recommended on SDS;

- Keep minimum contact.

### 9.4.12 Pyrophoric Substances

A pyrophoric substance is one that will ignite spontaneously upon exposure to oxygen, moisture or both. These materials must be stored in inert gas atmosphere or under kerosene.

Extreme Pyrophoric liquids include:

- $t$-butyllithium, $sec$-butyllithium, borane, THF, diethylzinc, neat Trialkyl aluminums (e.g. Me$_3$Al) and other substances of comparable properties.

Pyrophoric liquids include:

- Alkylaluminums in solution, $n$-butyllithium, diisobutylaluminum hydride (DIBAL-H), Grignard reagents and other substances of comparable properties.

Pyrophoric solids include:

- Alkali metals (Na, K, Rb, Cs), metal hydrides (KH, NaH, LiAlH$_4$, CaH$_2$), Raney nickel and other substances of comparable properties.

When Handling Pyrophoric Reagents:

- Appropriate PPE must be worn;
• A Class D fire extinguisher must be placed at a nearby location before the use of pyrophoric reagents begins;

• Your lab mates must be informed of what you are working with and you must review emergency procedures with them in the event of a spill or a fire;

• All work with pyrophoric materials should take place in fume hood or glove box;

• All reagent bottles and reaction flasks must be firmly clamped in place so that there is no chance of them being knocked over.

9.4.13 Organic Peroxide

Introduction

An organic peroxide is any organic (carbon-containing) compound having two oxygen atoms joined together (\(-O-O-\)). This chemical group is called a "peroxy" group which is chemically unstable. It can easily decompose, give off heat at a rate that increase as temperature increases. Many organic peroxides, when decompose, give off flammable vapor which can catch fire easily. They are hazardous due to their extreme sensitivity to shock, sparks or other forms of mild ignition. They are also sensitive to heat, friction, impact and light as well as to strong oxidizing and reducing agents.

• Ethers such as THF, ethyl ether, diisopropyl ether (not containing stabilizers or inhibitors of auto oxidation) can generate high concentrations of peroxides within a short period of time when exposed to air.

• Diisopropyl ether forms a bis-peroxide crystalline that explodes with deadly force.
• Exposure of peroxidizable solvents to peroxides or other oxidants, especially in air, may also generate hazardous levels of peroxides.

• All substances with weak C-H bonds should be considered potentially peroxidizable and hazardous.

Compounds known to auto oxidize upon exposure to atmospheric oxygen & light:

• Aldehydes;

• Ketones, especially cyclic ketones;

• Ethers, especially cyclic ethers & those containing \(1^0\) and \(2^0\) alkyl groups;

• Compounds with benzylic hydrogens;

• Compounds with allylic hydrogens (C=C-CH), including most alkenes, vinyl & vinylidene compounds;

• Compounds containing a \(3^0\) C-H group.

When Handling Organic Peroxides:

• If possible, try to choose the least hazardous materials that can do the job effectively and safely;

• Consult the safety data sheet (SDS) pertaining to the organic peroxide you will be working with. The SDS has information on the health, fire, corrosivity, chemical reactivity as well as special storage requirements;

• Inspect all incoming containers to ensure they are properly labeled and undamaged. Do not accept delivery of defective containers;
- Avoid skin contact and protect your eyes and face by wearing suitable PPE. The SDS provides information on suitable PPE;

- Ensure that areas where organic peroxides are used are clean and free from ignition sources, combustible and incompatible materials;

- Diluting organic peroxides should be done strictly according to chemical supplier’s advice. Using an incorrect solvent or contaminated solvent could result in an explosion. E.g., methyl ethyl ketone peroxide and cyclohexanone peroxide may explode when mixed with acetone, a common solvent. Using reclaimed solvents of uncertain composition can be also be hazardous as they may contain dangerous contaminants which are not compatible with the organic peroxide;

- Organic peroxides should be stored in containers which the chemical supplier recommends. Generally, these are the same containers in which material was shipped. Repackaging can be dangerous especially when incompatible or contaminated containers are used;

- Ensure containers are clearly labeled. Information such as recommended storage temperature range should be marked on the label. It is a good practice to mark the date that the container was received and date in which container was opened;

- Some liquid organic peroxides such as methyl ethyl ketone peroxide gradually decompose giving off gas. These peroxides are shipped in containers with specially vented caps. Use no other type of cap for containers of these organic peroxides. The vent caps are meant to relieve normal gas pressure buildup. Vent caps should be checked regularly to ensure they are working properly. Always keep vented containers in an upright position. NEVER stack vented containers;
Organic peroxides should be stored away from incompatible materials such as strong acids, strong bases, oxidizing materials, flammable or combustible liquids and materials that can be oxidized (often called reducing agents). Such containers should be stored at eye level, a convenient height for handling.

**Peroxide testing/monitoring for all peroxide forming solvents**

1. All peroxide forming solvents* should have labels (available from CBC Store) that indicate:
   
   a. the date received;
   b. the date first opened;
   c. the dates tested (quarterly).

   ![Peroxide Test Table]

   2. All peroxide-forming solvents should be checked for the presence of any peroxides prior to distillation or evaporation.

   3. Peroxide test strips are available at the CBC Store.

   4. Solvents that have peroxide concentration values above 100ppm must be discarded.
5. If peroxide forming solvents have unusual viscosity or crystal formation, do not move/open the container. Seek help from Safety personnel immediately.

6. **Peroxide forming solvents**

- Peroxide test for solvents, Class A

  (Explosive without concentration)

<table>
<thead>
<tr>
<th>Butadiene</th>
<th>Chloroprene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Divinylacetylene</td>
<td>Isopropyl ether</td>
</tr>
<tr>
<td>Tetrafluoroethylene</td>
<td>(Not a comprehensive list)</td>
</tr>
<tr>
<td>Vinylidene chloride</td>
<td></td>
</tr>
</tbody>
</table>

- Peroxide test for solvents, Class B

| Acetal, Acetaldehyde, Benzyl Alcohol, 2-Butanol Dioxanes, Chlorofluoroethylene, Cumene(isopropylbenzene), Cyclohexene, 2-Cyclohexen-1-ol, Cyclopentene, Decahydronaphthalene(decalin), Diacetylene(butadiyne), Dicyclopentadiene, Diglyme, Diethyl ether, Ethylene glycol ether acetates | Furan, 4-Heptanol, 2-Hexanol, Methyl Acetylene, 3-Methyl-1-butanol, Methyl-isobutyl ketone, 4-Methyl-2-pentanol, 2-Pentanol, 4-Penten-1-ol, 1-Phenylethanol, Tetrahydrofuran, Tetrahydronaphthalene, Vinyl Ethers, Sec. Alcohols, (Not a comprehensive list) |

9.4.14 **Hydrofluoric Acid**

**Introduction**

Hydrofluoric acid (HF) is a particularly hazardous and highly corrosive substance. HF has added dangers that make it especially dangerous to work with. Therefore it should be handled with extreme care. HF penetrates the skin deeply; its burns affect deep tissue layers which are extremely excruciating and disfiguring. Due to the ability of HF to penetrate tissue, poisoning can occur readily through exposure of skin or
eyes, inhaled or swallowed. Symptoms of exposure may be delayed for up to 24 hours, even with dilute solutions. The highly reactive fluoride ion circulates throughout the body and can cause multiple organ toxicity, including heart arrhythmias and death, if not treated. Any suspected exposure to HF should be immediately flooded with water, decontaminated with calcium gluconate gel, and treated.

Handling Hydrofluoric Acid Safely

- All persons who will be using hydrofluoric acid must be made aware of its properties and trained in proper procedures for use and disposal.

- Reference should be made to an up-to-date Safety Data Sheet.

- Risk Assessment shall be conducted (according to Risk Management SOP) and all appropriate control measure shall be implemented before usage/storage.

- Procedures for using HF must never be attempted out of normal working hours and lunch period when trained First Aiders may not be available.

- When working with HF, work in a fume hood with the sash as low as possible. Specific PPE are required at all times. Hands and body protection must be of impervious material such as Neoprene or Nitrile (22mil) gloves or other HF resistant gloves. Double gloves are highly recommended. Gloves should be checked for leaks. A chemical resistant apron (Neoprene has a 60min breakthrough time) is also recommended.

- All lab personnel, not just those who will be using HF, should be informed of the dangers of this chemical and the emergency
procedures necessary in case of an accident. A sign must be posted to alert people that “Work with HF is in progress”.

- All laboratories using HF must have unexpired calcium gluconate decontamination gel on hand. Calcium gluconate gel is a topical antidote for HF skin exposure. Calcium gluconate works by combining the HF to form insoluble calcium fluoride, thus preventing the extraction of calcium from tissues and bones.

- Before beginning any procedure involving HF, make sure the access to the emergency shower and eyewash is unobstructed. A supply of calcium carbonate or calcium hydroxide for spills and calcium gluconate gel must be available near the fume hood where the work will be conducted.

**HF Storage**

All HF must be stored in compatible containers (e.g. polyethylene or Teflon). Glass, metal and ceramic containers are **NOT** compatible with HF.

Never store HF with incompatible chemicals (ammonia or other alkaline materials).

Always place HF on low levels of protected shelf where it will not be accidentally spilled/knocked over.

**Transporting HF**

If an HF containing solution is to be transported from one lab area to another:
• Secondary containment shall be implemented for the transportation of HF. HF in any open containers shall NOT be moved outside the laboratory work area.

• To avoid possible chemical contamination on door handles and other objects, gloves should be removed before transporting the container.

• You may consider putting on a single clean glove with which to carry the container, leaving any un-gloved hand to open doors and handling other objects.

• You may also consider asking a lab mate to open doors and handle objects on your behalf during transportation.

HF Waste

All HF should be dilute or neutralised with powdered calcium carbonate before disposal. This is to make sure that the free fluoride will not cause harm to any persons or to the environment.

HF waste should be placed in chemically compatible containers (e.g. Polyethylene or Teflon) with a sealed lid and clearly labelled and a disposal pickup should be requested.

HF Spills

Ensure you are well protected against any skin surface contact when cleaning up such spill. HF shall be treated before disposal with either Calcium Chloride or Calcium Carbonate powder. Laboratories having HF MUST have the powder as part of their spill kit near HF:

• Attend to any person that has been exposed to HF such as shower & eyewash.
• Alert all other personnel who may be affected by the spill.

• Contain the spill.

• Starting from the outer edge of the spill, sprinkle powder liberally on the spill till excess powder is seen.

• Allow 1 hour to react.

• Keep fume hoods operating so as to remove vapour.

• Sweep up powder, slurry or liquids. Avoid direct surface contact with spilled material.

• After the cleanup, contaminated materials are to be classified as hazardous waste and waste pick up to be requested.

HF Spill Kits should include the following items:

<table>
<thead>
<tr>
<th>Items</th>
<th>Purpose</th>
<th>Quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium Chloride/ Carbonate powder</td>
<td>Neutralising HF spills</td>
<td>A few packs of 0.5 to 1 kg</td>
</tr>
<tr>
<td>Shoe covers</td>
<td>Shoes protection</td>
<td>2 or more pairs</td>
</tr>
<tr>
<td>Spill Scoop &amp; Brush</td>
<td>For cleaning up purposes</td>
<td>1 set</td>
</tr>
<tr>
<td>Hazardous waste container &amp; tag</td>
<td>For containing items used for spillage clean up</td>
<td>1 set</td>
</tr>
</tbody>
</table>

Emergency Procedures for HF

(Adapted from 1st Aid for unique acid HF by Eileen B Segal, Chemical Health Safety, Jan 2000 pp 18-23)

Skin Contact

• Use safety shower IMMEDIATELY and open value fully.
• Remove contaminated clothing whilst in shower, remove gloves first & eye protection last.

• Drench continuously for FIVE minutes. Cover victim with blanket to keep warm.

• Persons assisting are to put on gloves (recommended nitrile gloves) & eye protection.

• Dry contaminated skin area by dabbing, NOT rubbing

• Apply unexpired 2.5% calcium gluconate gel or cream generously. Gently massage into affected area. Excessive rubbing will cause affected burnt area to have further tissue damage and infection.

• Apply around burns if burns area evident.

• Do not administer pain killers as relieve of pain is not an indication of successful treatment.

• Transfer victim to hospital as soon as possible. Treatment should be continued until the victim is attended by medical professionals at the hospital.

**Eye Contact**

• Use emergency eye station immediately.

• Persons assisting are to put on gloves (recommended nitrile gloves) & eye protection.

• Hold both eyes open in the drenching solution.
• Use 1% sterile calcium gluconate solution. DO NOT apply calcium gluconate gel to eye.

• Patch eye and transfer to hospital as soon as possible.

**Inhalation**

• Bring victim to fresh air (if victim does not have other visible exposure e.g. skin contact).

• Apply 100% oxygen using an oxygen mask.

• Keep victim warm and quiet. Place victim in recovery position.

• Look out for shocks (CPR if necessary).

**Ingestion**

• Rinse mouth with large amount of water quickly.

• Drink large amount of water or milk. Do not induce vomiting. Vomiting is possible.

• Keep victim warm and quiet. Place victim in recovery position. Look out for shocks (CPR if necessary).
10.0 WASTE MANAGEMENT

10.1 General Guidelines

- DO NOT mix chemicals of different categories, an explosion may result!

- DO NOT discharge hazardous waste into the sink.

- Chemical users must have sufficient knowledge of safety handling and disposal.

- Chemical users must read Safety Data sheets or consult trained personal when in doubt.

- All waste bottles must be clearly labelled.

10.2 Categorizing Waste

Chemical wastes in the labs are divided into the following categories:

**Nonhalogenated Waste**

All organic materials that are liquid which:

- Do not contain halogens or sulphur;

- Will dissolve in organic solvents;

- Do not contain water.

These include such common substances as THF, alcohols, acetone, ether, DMF, hexanes and toluene. When in doubt, check with your supervisor.
Halogenated Waste

All sulfur and halogen containing organic materials which include tetrahydrothiophene, chloroform, chloroform-dichloromethane, carbon tetrachloride, thiophene, thiols, dimethyl sulphide and chlorobenzene.

Hazardous Waste

These include used solvents, strong acids and bases or are otherwise unstable, contaminated rags and wipes. Do not simply pour corrosive and/or reactive molecules into any waste bottle. Dispose of in HALOGENATED WASTE bottles.

Hazardous wastes are prohibited from sink/drain disposal. A substance is deemed a hazardous waste if it exhibits any one of these characteristics:

- **Ignitability** = Flashpoint < 60°C and < 24% by volume alcohol;

- **Corrosivity** = pH < 2 or > 12.5 or both corrosive solutions with pH in the range of (2.0 < pH < 5.5) and (12.0 < pH < 12.5) must be neutralised before disposal;

- **Reactivity** = contains cyanides or sulfides or may emit toxic vapour when mixed with water
11.0 BIOSAFETY

11.1 Introduction

Biosafety aims to minimise potential risks that may arise from the use of biotechnology. Biosafety promotes safe laboratory practices, proper use of containment equipment, facilities as well as proper handling of biological agents by laboratory staff/students in a biomedical environment so as to prevent infectious organisms from being released to the environment. Therefore, Biosafety regulations and precautions are essential to eliminate the risks of such exposure.

11.2 Requirements

With effect from 1st January 2011, all workplaces in NTU (Schools/ Research Centres, etc) shall keep a register of biological works (grant awarded projects) conducted within their premises. The register shall follow the format provided by the Biological Safety Committee (BSC). The updated register shall be submitted to the BSC.

Records of final year projects and biological works carried out by attachment students, school or research centre must be maintained. The school/ research centre may, but not necessarily, use the format provided by the BSC. Quarterly submission of this record is not required.

11.3 Biological Project Number

Besides the quarterly updates, details of all new projects are to be submitted to BSC for obtaining the NTU Biological Project Number (BPN). Project without this number is deemed unauthorized work in NTU.
11.4 All New Biological Laboratory Users

With effect from 1st April 2011, all laboratory users performing biological works are to register for training within 2 weeks from the date of work commencement. Supervisors/ PIs can request for waiver for the user if he/she is able to prove his/her competency on safe handling of biological works and have understood the regulatory requirements stipulated in the Singapore Acts and Regulations related to biological works.

11.5 Exposure Control

Containment defines safe methods for handling infectious agents in the laboratory environment. Three elements of containment include:

i. Laboratory Practice and Techniques

Strict adherence to standard microbiological practices and techniques is an important element of containment. Persons working with infectious agents/materials must be aware of the hazards; trained and proficient in the practices and techniques required for handling such materials safely.

ii. Safety Equipment

These include enclosed containers, biosafety cabinets as well as other engineering controls designed to rid or reduce exposures to hazardous biological materials. The Biosafety cabinet is the principal device used to provide containment of infectious splashes or aerosols generated by microbiological procedures. Basic Personal Protective Equipment such as lab coats, respirators, safety glasses and appropriate gloves has to be put on to provide primary barrier between laboratory personnel and the infectious materials.
iii. Facility Design

The design of a facility is deemed as a secondary barrier to protect those working inside and outside the laboratory from any form of accidentally release from the laboratory. Secondary barriers include separation of laboratory work area from public access as well as decontamination facility (e.g. autoclave). Facilities have to be designed in accordance to the laboratory’s function and the recommended biosafety level for the biological agent being handled.

11.6 Biosafety Levels

A Biosafety level is the level of bio-containment precautions required to isolate hazardous biological agents within an enclosed facility. There are four levels of Biosafety and the levels of containment range from the lowest biosafety level 1 (BSL 1) to the highest at level 4 (BSL 4).

- **BSL 1** – Applies to agents that do not ordinarily cause human disease; applies to basic teaching and research laboratories where good microbiological techniques (GMT) are in place.

- **BSL 2** – Appropriate for agents that can cause human disease but the potential for transmission is limited. Research laboratories with GMT plus PPE, biohazard sign, controlled laboratory access and biological safety cabinet. Most research laboratories in NTU are classified as BSL2.

- **BSL 3** – Applies to agents that may be transmitted by the respiratory route which can cause serious infection. Containment laboratory with practices as level 2 plus special clothing, strict controlled access, directional air flow, biological safety cabinets and other primary devices for all activities.
• BSL 4 – Currently, BSL4 is not available in NTU. It applies to agents which pose high risk of serious disease/infection or even death, therefore maximum containment required.

11.7 General Lab Practices and Techniques

• Appropriate PPE (gloves, goggles, lab coats, face shield etc) has to be worn when handling infectious materials/agents or contacting contaminated surfaces.

• Eating, drinking, handling of contact lenses or application of cosmetics in the laboratory is prohibited. Storage of any foodstuff, medications or cosmetics is also prohibited.

• Standard microbiological practices and techniques have to be adhered to.

• Laboratory personnel must be aware of hazards associated with infectious agents and must be trained in practices and techniques required for handling of hazards associated with agents involved; the necessary precautions to prevent exposures and exposure evaluation procedures.

• Work areas should be clean and uncluttered.

• Knowledge of locations of nearby fire extinguishers, eye washers and showers.

• Laboratory technical staff and supervisors have to be informed immediately in the event of an accident, injury, illness or obvious exposure associated with laboratory activities.

• All containers must be clearly labelled with chemical name, concentration and hazardous warning(s).
• Storage of chemicals and materials in the safety cabinets / on the floor is strongly discouraged.

11.8 Biological Safety Cabinets

A Biological Safety cabinet (BSC) is an enclosed, ventilated workspace designed to provide protection and a clean work environment for personnel working with biological hazards. BSCs effectively contain and capture microbial contaminants and infectious agents using High Efficiency Particulate Air (or HEPA) filters to clean the air which exits the biosafety cabinet, removing harmful bacteria/ viruses. The HEPA filter removes airborne particulates from the air, but does not remove chemical fumes.

Biological Safety Cabinets are classified as Class I, Class II or Class III cabinets. For more information on BSCs, you may refer to this Biological Matters and Biosafety links from OHS.

11.9 Autoclave

All materials and equipment which have been contaminated with or containing potential infectious agents should be decontaminated. Autoclaving is the most widely used sterilizing process that eradicates micro-organisms by using pressurized steam to cause thermal stress. A sufficient kill rate can be achieved by raising the temperature such that the most thermo-tolerant become inactivated, hence the classic 125°C for 15 minutes.

11.10 Biological Spills

11.10.1 In Contained Environment

Spills that are contained (e.g. in BSC or centrifuges) are not as dangerous since they are already confined to a small area. Nevertheless, care must be taken to ensure the spill remains confined and that equipment is not contaminated. The possibility of aerosol
generation must also be evaluated as this will impact the risk of exposure and degree of contamination resulting from the setting or aerosols or droplets.

**Spills within a Biological Safety Cabinet (BSC)**

- Leave ventilation on.
- All items within the cabinet should be disinfected (walls & surfaces wiped down, equipment wiped down and/or autoclaved before disposal).
- Cover the spill area with paper towels.
- Pick up with paper towels (with gloved hands or using thongs).
- All waste has to be autoclaved.
- Ventilation should run for 10-15 minutes.
- Spill area must be cleaned with appropriate disinfectant (i.e. 10% clorax or 70% IPA/Water).

**Spills within Centrifuge**

- Ensure centrifuge is turned off.
- Lid is to be left closed. Allow aerosols to settle for at least ½ hour.
- Notify others (via warning signs) in the laboratory not to use the centrifuge, inform lab manager or PI.
• If possible, move the centrifuge (or at least the rotors and buckets) to a BSC.

• Disinfect the centrifuge or rotors and buckets using appropriate disinfectant, allowing at least 30 minutes of contact time.

• Carefully retrieve broken glass form inside the centrifuge suing forceps/tweeters and place in a sharps container.

11.10.2 In Uncontained Environment

If spillage has happened in an uncontained area, treat as normal chemical spill. The area shall be disinfected using 10% household chlorine bleach (10% sodium hypochlorite solution or chlorine bleach is corrosive, refer to MSDS before use) or 70% alcohol/ water mixture (treat as flammable). All materials shall be suitably autoclaved before disposal. Mops used must NOT be used in any other general areas to avoid contamination.

11.11 Biological Waste Disposal

Wastes associated with biological materials must be regarded as bio-hazardous wastes due to the possibility of being contaminated with infectious organisms or agents. These potentially infectious or bio-hazardous materials or wastes include:

• All sharps (e.g. needles syringes, blades etc) coming from facilities using infectious materials.

• Biologically-cultured stocks and plates, human blood or tissues.
11.12 Guidelines for Disposal of Biological Wastes

- All users must have sufficient knowledge on handling and disposal of the biological agents/chemicals they used. They should read the SDS and always consult trained personnel when in doubt.

- Sterilize or disinfect all waste materials associated with bacterial, viral or other infectious agents via autoclave or chemical treatment equivalent to 1:10 bleach solution.

- All biological samples treated with antibiotics should be autoclaved due to possible environmental impact.

- All bio-hazardous wastes (except for sharps) should be placed directly into appropriate bio-waste bag.

- Place all sharps into the sharps containers; filled sharps containers should be placed in bio-waste bag.

- All waste bags must be clearly labelled.
12.0 RADIATION SAFETY

(Adapted from NTU Safety Manual For Radiation Works
(Ionising & Non-Ionising) Version 1 2010)

12.1 Introduction

Hazards associated with using radioactive materials and radiation apparatus have been well documented. Exposure to these radiation works without appropriate protection may pose safety and health risks to users and workers nearby. Radiation exposure can cause damage to living tissue, high doses result in mutation, cancer and even death.

Non-ionizing radiation refers to any type of electromagnetic radiation that does not carry enough energy to completely remove an electron from an atom or molecule. Instead of producing charged ions when passing through matter, the electromagnetic radiation has sufficient energy only for excitation, the movement of an electron to a higher energy state. Nevertheless, different biological effects are observed for different types of non-ionizing radiation. Examples of non-ionizing radiation include Sunlamps, Ultrasound Apparatus, Magnetic Resonance Imaging Apparatus, Lasers, Microwave Ovens.

Ionizing radiation consists of particles or electromagnetic waves that are sufficiently energetic to detach electrons from atoms or molecules, thus ionizing them. Direct ionization from the effects of single particles or single photons produces free radicals (unpaired electrons) which tend to be especially chemically reactive due to their electronic structure. Examples of ionizing particles are alpha particles, beta particles, cosmic rays and neutrons. The frequency determines the ability of an electromagnetic wave to ionize and atom or molecule.

To ensure proper management of radioactive materials and radiation apparatus, the NTU Radiation Safety Committee has developed a “Safety Manual For Radiation Works (Ionizing and Non-Ionizing)” which include the following information:
12.2 Definitions & Responsibilities

**Reporting Officer** is a person whom the radiation worker reports to for work. In the scenario of a research staff and students working in a school, the Reporting Officer is usually the Project Supervisor. The Reporting Officer shall take all reasonable practicable means to ensure the safety of the radiation workers. Reasonably practicable means include, but not limit to, conduct risk assessment, construct proper shielding, use calibrated survey meter, provide appropriate personal protective equipment, ensure wearing of personal monitoring device and establish safety protocols using all necessary documents including Regulations.

**Radiation Worker** may also refer to as a licensee, is the person performing any radiation works holding a L5, L6, N3 and R1 license issued by NEA. Persons exempted from possessing a radiation license (See Appendix I) but allowed to perform radiation works shall also be termed as a radiation worker. The radiation worker shall receive trainings or briefings on radiation safety before commencement of any radiation works. The trainings/ briefings received shall be documented and maintained by the respective schools or research centres/ institutes.

**School Safety Officer/ Safety Representative** is the person employed or appointed by the school or research centres to ensure safety practices are carried out all the time at their respective workplaces. The School Safety Officer or Safety Representative are required to have general safety knowledge on radiation works and know the types of radiation works carried out in their respective workplaces. They are also required to maintain a register of the radioactive materials, radiation apparatus, and all licenses required under the Regulations. This register shall be updated quarterly and sent to the Radiation Safety Committee. Format of resister will be provided by the Committee.

**The Office of Health And Safety (OHS)** acts on behalf of the Radiation Safety Committee to execute audits, routine inspections and unscheduled checks for any radiation work performed within NTU. OHS will also carry out an
investigation if there is any incident/accident occurred. This is to ensure that the process of management for radiation safety, stipulated by the Radiation Safety Committee (e.g. risk assessment), is accurately reflected in the workplaces.

12.3 Requirement

All persons involved in radiation work are to check with their School Safety Representative or Safety Officer for application for these licenses. The Radiation Protection (Ionizing Radiation) Regulations Part (II) - (See Appendix I) should be read and check for license exemption. If a license is needed, application can be done via the NEA license website. The different types of licenses for radiation works are shown below:

For Ionizing Radiation – Radioisotopes, Irradiating Apparatus (X-rays)

The types of license offered by NEA are as follows:

<table>
<thead>
<tr>
<th>License</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1-</td>
<td>To manufacture, possess for sale or deal in irradiating apparatus</td>
</tr>
<tr>
<td>L2-</td>
<td>To manufacture, possess for sale or deal in radioactive materials</td>
</tr>
<tr>
<td>L3-</td>
<td>To keep or possess an irradiating apparatus for use (other than sale)</td>
</tr>
<tr>
<td>L4-</td>
<td>To keep or possess radioactive materials for use (other than sale)</td>
</tr>
<tr>
<td>L5-</td>
<td>To use irradiating apparatus (other than sale)</td>
</tr>
<tr>
<td>L6-</td>
<td>To use, handle and transport radioactive materials (other than sale)</td>
</tr>
<tr>
<td>R-</td>
<td>Anyone working partly or wholly on ionizing radiation works</td>
</tr>
</tbody>
</table>

For Non-Ionizing Radiation

The types of license offered by NEA are as follows:

<table>
<thead>
<tr>
<th>License</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1-</td>
<td>To manufacture or deal with any of the irradiating apparatus specified in Parts I, II, III of the First Schedule</td>
</tr>
</tbody>
</table>
12.4 Renewal of Licenses

All persons registered with NEA for these licenses are known as licensees. Licensees who wish to renew their license are to apply one month BEFORE expiry of the current license.

12.5 Requirement for All Persons Involved in Radiation Works

Applicants for L5, L6, R1 licenses are required to go for a Medical Examination. The Medical Certificate form is to be attached to the application form. Applicants for L5 and L6 licenses must be knowledgeable on radiation safety by documentary proof or sit for a test set by CRPNS.

With effect from 1st September 2010, all schools and research centres within NTU must update the Radiation Safety Committee every quarterly on the renewing and withdrawal of any radiation licenses.

When not using any radiation apparatus or materials, a “lock” procedure, e.g. Lockout-Tagout (LOTO) must be applied.

Please refer to Standard Operating Procedure on Workplace Lockout-Tagout System

12.6 Reducing Exposure to Ionizing Radiation

ALARA (As Low As Reasonably Achievable) shall be applied to all ionizing radiation works. For Ionizing Radiation, shielding (S), Time (T) and distance (D) are 3 factors to be considered. Appropriate shielding means less exposure.
(A) **Shielding Requirements for Ionizing Radiation**

<table>
<thead>
<tr>
<th>Emitters</th>
<th>Shielding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Emitters Radioisotopes ((^{238}\text{U}, , ^{230}\text{TH}, , ^{241}\text{Am}, , ^{222}\text{Rn}))</td>
<td>Paper</td>
</tr>
<tr>
<td>Low Energy Beta Emitters ((^{3}\text{H}, , ^{14}\text{C}, , ^{35}\text{S}, , ^{33}\text{P}))</td>
<td>Thicker paper</td>
</tr>
<tr>
<td>Medium/ High Energy Beta Emitters ((^{32}\text{P}))</td>
<td>Plastic, Glass, Perspex (approx 10 mm)</td>
</tr>
<tr>
<td>X-ray, Gamma Ray Emitters ((^{125}\text{I}, , ^{51}\text{Cr}, , ^{60}\text{Co}, , ^{137}\text{Cs}))</td>
<td>Lead, Concrete, Steel</td>
</tr>
</tbody>
</table>

(B) **Time Exposure Calculation in Ionizing Radiation**

Reducing exposure time is a practical method to radiation protection. The dose of radiation receive (DR) is equivalent to exposure rate (ER) x time (T). If ER is 10mSv/hr, and the working time is 15 minutes, then DR = (10mSv/hr) x 0.25 hr = 2.5mSv. **Shorter Time = Less Exposure.**

(C) **Distance**

The dose received is inversely proportional to the square of the distance from the source.

Inverse Square Law \(I_1(d_1)^2 = I_2(d_2)^2\)

Where I = Intensity, D = Distance

The radiation intensity from a radiation source is 20mSv/hr at a distance of 1 metre. The intensity is greatly reduced to 5 mSv/hr when the distance is 2 meters instead of 1. **Greater Distance = Less Exposure**
The radiation level limit at our workplace shall be:

<table>
<thead>
<tr>
<th>Source</th>
<th>Limit Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>XRD equipment</td>
<td>No more than 10 microsieverts per hour (µSv/hr)</td>
</tr>
<tr>
<td>Storage of radio-isotopes</td>
<td>No more than 0.5 microsieverts per hour (µSv/hr)</td>
</tr>
<tr>
<td>Use of radio-isotopes</td>
<td>No more than 10 microsieverts per hour (µSv/hr)</td>
</tr>
</tbody>
</table>

12.7 Radiation Hazard Signs and Labels

<table>
<thead>
<tr>
<th>Radiation Hazard Signs &amp; Labels</th>
<th>Radiation Apparatus</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Radiation icon]</td>
<td>X-ray, Radioactive Materials</td>
</tr>
<tr>
<td>![Laser icon]</td>
<td>Laser</td>
</tr>
<tr>
<td>“WARNING – ULTRAVIOLET RADIATION”</td>
<td>FOLLOW INSTRUCTIONS – FAILURE TO USE PROTECTIVE EYEWARE MAY RESULT IN SEVERE BURNS OR OTHER EYE INJURY. IF DISCOMFORT DEVELOPS, DISCONTINUE USE AND CONSULT A PHYSICIAN</td>
</tr>
<tr>
<td>CAUTION – MICROWAVES</td>
<td>Microwaves</td>
</tr>
<tr>
<td>CAUTION – ULTRASOUND</td>
<td>Ultrasound Apparatus</td>
</tr>
<tr>
<td>CAUTION – HAZARDOUS LASER AND ELECTROMAGNETIC RADIATION WHEN OPENED AND INTERLOCK DEFEATED</td>
<td>Entertainment Lasers</td>
</tr>
</tbody>
</table>

These signs and labels showed above are required to be displayed on the radiation apparatus and doors to warn users and public of the presence of
radiation materials or work. These signs are to be displayed clearly when a radiation material is being used or work is being carried out. For details of these signs, please refer to the Radiation Protection (Ionizing Radiation) Regulations 2001 and Radiation Protection (Non-Ionizing) Regulations 2001.

12.8 General Radioisotopes Safety

- Any workplace using unsealed radioisotopes shall maintain a register to document processes such as storage, usage, monitoring and disposal.

- All licensees and exempted persons shall put on gloves when dealing with the materials and wash his/her hands thoroughly after each operation and before exiting the workplace.

- Working areas shall be provided with disposal paper towels and foot operated waste bins which are lined with removable PE bags.

- Work area surfaces are to be lined with polythene sheets and surfaces shall be non porous.

- Eating, drinking, application of cosmetics and smoking are prohibited.

- Appropriate shielding must be provided when there is a chance of producing aerosols.

- All of radiation work must be accompanied by a calibrated survey meter and/or personal monitoring devices.

- All contaminated items due to radioisotope work (e.g. swaps, sharps, towels, gloves, tubes etc), shall be separated from the biohazard and chemical wastes. These items are to be disposed as radioactive wastes. These wastes shall be cleared as soon as possible from work area and disposed at the
respective radioactive waste room for “delaying and decaying” until most radioactivity of the particular radioisotope is minimal.

- When the radioactivity is minimal (e.g. GM counter readings at less than or equals to 1 cps or survey meter readings less than 0.5 microsieverts per hour), the waste has to be disposed according to the requirement by National Environment Agency (please refer to NEA Website for details or see Appendix II)

- When transporting radionuclides, a secondary container shall be used to contain possible spillage. Absorbent materials should also be used to retain the isotope in case of breakage/spillage. All containers should be able to provide sufficient shielding and must bear the radioactive label, indicating isotope and activity.

12.9 Radiation Survey Meter & Personal Monitoring Device

Types of Radiation Survey Meter

| Ionisation chamber survey meters are used to measure radiation exposure rate from gamma & X-rays | GM counter rate meters are used principally to detect gamma rays, X-rays & beta particles |

In our workplace, the use of survey meter measured in µSv/h is strongly recommended. Schools or research centres / institutes may use any other survey meters like Geiger Muller Counters or Scintillation Counters, but are required to possess at least one calibrated survey meter measuring radiation in µSv/h.
12.10 Calibration

Under the Radiation Protection (Ionizing Radiation) Regulations 2001, any radiation monitor used in connection with any radiation work e.g. survey meters, direct reading personal dosimeters etc. must be calibrated once every 12 months by a person approved by Director CRPNS.

12.11 Personal Monitoring

The thermoluminescent dosimeter (TLD) consists essentially of two parts - a TLD card and a plastic holder.

The radiation dose received by an individual exposed to radiation is expressed in the unit called "mSv". Under the Radiation Protection (Ionizing Radiation) Regulations 2001, the effective dose limit to the whole body for occupationally exposed individuals is 20 mSv a year, averaged over defined periods of 5 years and with the further provision that the effective dose shall not exceed 50 mSv in any single year.

12.12 Non-ionizing Radiation Apparatus Safety

The following apparatus have been categorized by NEA as non-ionizing radiation apparatus: Sunlamps, Microwave Ovens, Ultrasound Equipment, Magnetic Resonance Imaging Apparatus, Entertainment Lasers and High Power Lasers. Below are some examples of the safety practices for non-ionizing radiation apparatus:
<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Examples of Safety Requirement / Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunlamps</td>
<td>On-Off Switch, Timer, Maximum No of People That Can Be Exposed To, Protective Eyewear, Hazard Label</td>
</tr>
<tr>
<td>Microwave Ovens</td>
<td>Indication of Operation, Clear Display Of The Level Of Power, Door Unable To Open When In Operation, Unable To Operate When Door Is Opened,</td>
</tr>
<tr>
<td>Ultrasound Equipment</td>
<td>Power Indicator, Timer, Clear Indication of Wave Produced, Equipment labelled As “CAUTION-ULTRASOUND”,</td>
</tr>
<tr>
<td>Magnetic Resonance Imaging Apparatus</td>
<td>Currently Not Available At The Moment</td>
</tr>
<tr>
<td>High Power Lasers (Class 3b onwards)</td>
<td>Protective Housing, Safety Interlock, Key-actuated Master Control, Emission Indicator, Protective Eyewear, Operated by N3 Licensee, On-Off Switch, Stable Mounting, Hazard Sign Displayed.</td>
</tr>
</tbody>
</table>

For details of the safety requirement, please refer to the Radiation Protection (Non-ionizing) Regulations 2001, the equipment instruction manual any other relevant materials.
12.13 Radiation Emergency Procedures

When any radiation accident occurs, the licensee of the area at the time shall:

(a) Inform the Reporting Officer, School Safety Officer or Safety Representative immediately and evacuate all individuals from the affected area, if necessary;

(b) Block off (by the emergency response team or ERT) the affected area (including all locations where the radiation level exceeds 25μSv/hr), and post warning signs at all its entrances;

(c) Refer affected individuals for medical observation and treatment;

(d) Inform the Office of Health & Safety (92351327);

(e) Make arrangements to provide temporary shielding, monitoring and decontamination of any affected individual and the area and take all other actions necessary, to return the situation to normal;

(f) Ensure that any contaminated items are removed from the person before the individual leaves the premises; and

(g) Ensure that any personal clothing or other private property which is contaminated by radioactive materials is not taken from the premises or released for disposal until the radioactivity is minimal (refer to page 11).

A written investigation report has to be submitted to the Office of Health and Safety within 24 hours after the accident. The person reporting shall use the Office of Health & Safety Incident Investigation Reporting Form (See Appendix II) when conducting the reporting. This preliminary written report shall contain details of:
the time, place and nature of the accident, the number of individuals affected and the manner in which they were affected and the period during which there was loss of control of radiation apparatus or radioactive material;

the area over which any radioactive substance may have been dispersed and the degree of contamination;

After the preliminary reporting, an additional detail report, if necessary, shall be submitted to the Office of Health & Safety. This report shall include:

the actions taken to rectify the accident situation and to minimize the possibility of any future recurrence;

any individual who may have suffered radiation exposure and the assessment of the effective dose received by the individual; and

the results of medical examinations carried out on affected individuals, and in the case of any internal exposure of individuals, the results of biological monitoring.

12.14 Radiation Contamination Clean-up Procedure

Use a survey meter to monitor all potentially-contaminated equipment, gloves, clothing and work area (including bench, walls and floor).

Place all affected items in the waste bag and ensured fully shielded.

If the spill is liquid, use an absorbent material to reduce the spread. Dispose the absorbent material in the waste bag and ensured fully shielded.

Dilute De-con 90 (detergent solution – see manufacturer label for dilution factor), and wipe the surface contaminated (outside in to prevent
spreading).

- Re-wipe to ensure fully removal of contamination.
- Where appropriate, soak contaminated equipment, glassware, pipettes in detergent. Dispose of detergent as radioactive liquid waste.
- Use the survey meter to monitor the work area, equipment and yourself one last time after cleaning up.

12.15 Radiation Materials & Equipment Disposal

<table>
<thead>
<tr>
<th>Procedure For Disposal of Radioactive Waste (Unsealed Source)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1: Ensure all radioisotopes are completely decayed. Check using a calibrated Survey Meter</td>
</tr>
<tr>
<td>Step 2: Record the type of radioisotopes and the amount to be disposed.</td>
</tr>
<tr>
<td>Step 3: Fill in the form as prescribed by NEA and obtain the approval and date for disposal.</td>
</tr>
<tr>
<td>Step 4: Send the approved form to Sembcorp to arrange for disposal.</td>
</tr>
</tbody>
</table>

(A sample of the NEA form is shown on Appendix II)

Any disposal of school asset are to follow the protocol (Board of Survey, BOS) given by the University. The following procedures only applied when BOS final approval is granted by NTU. When in doubt, please check with your school safety representatives.
**Procedure For Disposal of X-Ray Unit & Sealed Source**

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Permanently disable the power connection to the X-ray generator.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>Remove the X-ray tube from the equipment.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Contact vendor of the equipment to remove the X-ray tube from the equipment and collect it with any hazardous substances that is attached to the tube and / or apparatus for proper disposal.</td>
</tr>
<tr>
<td>Step 4</td>
<td>Take photographs of the X-Ray unit before and after destruction (in particular the serial nos.) for submission of license termination to NEA-CRPNS.</td>
</tr>
<tr>
<td>Step 5</td>
<td>Remove / obliterate any radiation hazard sign or label prior disposal.</td>
</tr>
</tbody>
</table>

**Procedure For Disposal of Non-ionization Radiation (Laser) Equipment**

<table>
<thead>
<tr>
<th>Step 1</th>
<th>Permanently disable the power connection to the laser.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 2</td>
<td>Remove the laser tube from the equipment.</td>
</tr>
<tr>
<td>Step 3</td>
<td>Contact vendor of the equipment to remove the tube from the equipment and collect it with any hazardous substances that is attached to the tube and / or apparatus for proper disposal.</td>
</tr>
<tr>
<td>Step 4</td>
<td>Take photographs of the laser unit before and after destruction (in particular the serial nos.) for submission of license termination to NEA-CRPNS.</td>
</tr>
<tr>
<td>Step 5</td>
<td>Remove / obliterate any radiation hazard sign or label prior disposal.</td>
</tr>
</tbody>
</table>
12.16 Radiation Safety – Appendix 1

Exemptions

(1) The provisions of the Act shall not apply to any import, export, possession, manufacture, transport, use, disposal, sale of or other dealing in the following radioactive substances:

   a. A natural radioactive substance of any equivalent specific radioactivity not exceeding that of natural potassium and

   b. A radioactive substance having an activity or activity concentration not exceeding that prescribed in the 1st Schedule with respect to the particular radionuclide unless it is used for medical purposes, is intentionally added to foodstuff, fertilisers, pharmaceutical goods, cosmetics or toys, or is to be disposed of as radioactive waste.

(2) Any educational institution which has in its possession or under its control any radioactive substance, being a sealed source, not exceeding 100 times the activity or activity concentration prescribed in the 1st Schedule with respect to that particular radioactive substance, and any teacher designated under this paragraph, shall be exempted from sections 5(1) (b) and (d) and 6 of the Act if:

   a. The radioactive substance is used or to be used solely for demonstration, teaching or research purposes in the education institution;

   b. The radioactive substance is under the control of a competent teacher designated by the principal in the case of a secondary school, or by the head of department, in the case of a university, polytechnic or college, to take full responsibility for the safe storage and use of such radioactive substance and for the compliance with the relevant provisions of these Regulations relating to a sealed source; and
c. The name of the teacher designated in accordance with sub-paragraph (b) and the complete details of the radioactive substance are submitted to the Chief Executive.

(3) Any person who has in his possession or under his control not more than 3 sealed sources, each of which contains any radioactive substance not exceeding 175 kBq, for the sole purpose of checking or calibrating a particular radiation survey or monitoring instrument shall be exempted from sections 5 (1) (b) and (d) and 6 of the Act if completed details of the radioactive substance are submitted to the Chief Executive, except that the person shall be responsible for the safe storage and use of the radioactive substance and for compliance with the relevant provisions of these Regulations relating to a sealed source.

(4) The Act and all regulations there under (except Parts XIII and XV of these Regulations) shall not apply to

a. Any radioactive substance which is implanted or has been internally administered to an individual for medical purposes; and

b. Any such implant of a permanent nature which has been notified to the Chief Executive with such other information as he may require.

(5) Any person having the control or management of a single station or non-single station ionization chamber smoke detector containing a sealed source shall be exempted from sections 5 (1) (b) and (d) and 6 of the Act, and from regulations 26 and 29 if the ionization chamber smoke detector complies with the recommendations of the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development or any other equivalent international standards and recommendations.

(6) Section 6 of the Act shall not apply to any registered or enrolled student of an education institution, who, in the course of his studies, performs any experiment or carries out any research involving the handling or use of any
irradiating apparatus or radioactive materials under the direct supervision of a licensee authorised to conduct such experiment or research.

(7) The provisions of the Act shall not apply to the import, export, possession, use or sale of or other dealing in the following articles or irradiating apparatus:

a. Any timepiece, instrument, or device containing self-luminous elements, except during the manufacture or repair of the self-luminous elements themselves and providing the timepiece, instrument or device contains no more that:

- 35 kBq of radium-226, 105 kBq of americium-241, 70 MBq of promethium-147 or 3.5 GBq of tritium, where the luminescent substance is substantially insoluble in water and is in the form of glass, vitreous enamel or similar substance or in the form of a paint or film which adheres to the timepiece, instrument or device during normal use; or

- 70 GBq of tritium or 9 GBq of krypton-85 in the form of radioactive gas.

b. Any electrical equipment, other than equipment referred to in paragraph (c), which is not primarily intended to produce ionizing radiation (such as cathode ray tubes, transmitting valves, rectifying valves, image converters and television tubes) and which does not produce a radiation level of more than 5 µSv per hour at a distance of 5 centimetres from any accessible surface; or

c. Any Video Display Unit or domestic type television set or television equipment used for projection purposes, closed circuit applications and the like which conforms to the standards of the International Commission on Radiological Protection or any other equivalent international standards or recommendations.
d. Notwithstanding sub-paragraphs (b) and (c) of paragraph (7), the provisions of the Act shall apply to the testing or servicing, in the course of production, of the equipment specified in those sub-paragraphs.

(*The exemptions are directly extracted from the Radiation Protection (Ionizing Radiation) Regulations 2001 Part II and may be subjected to amendment from time to time. Licences and Radiation Workers may wish to view the latest copy of the Regulations from national Environment Agency Website).
12.17 Radiation Safety – Appendix II

(Granted Permission For Use By Mr Tin Tun, Safety Manager of SBS)
13.0 LASER SAFETY

13.1 Introduction

LASER is the acronym that stands for Light Amplification by Stimulated Emission of Radiation. The energy generated by the laser is in or near the optical portion of the electromagnetic spectrum. Lasers have become increasingly important tools in many areas of Sciences. If improperly handled or controlled, lasers can cause injuries to operators and other personnel.

Laser radiation predominantly causes injury via thermal effects. Moderately powered lasers can cause injury to the eye. High power lasers can cause considerable damage to the skin. Some lasers are so powerful that even the diffuse reflection from a surface can be damaging to the eyes. Injury can be permanent and serious which may lead to blindness.

13.2 Classification of Lasers

A laser’s classification is based on several factors including its wavelength, power output, accessible emission level, and emission duration. The level of hazard associated with each class of lasers is listed below.

CLASS 1

Lasers in this class are considered to be incapable producing damaging radiation levels, hence, exempted from most control measures. E.g. Laser printers & compact disc players

CLASS 2

Lasers under this class emit radiation in the visible portion of the spectrum, which are only capable of producing eye damage if the beam is stared at directly for longer than the normal human aversion response time to bright light (0.25 second). This means that the human eye will blink within 0.25 seconds when
exposed to class 2 laser light. This blink reflex provides sufficient protection. However this can be a hazard if a person stares into the beam and refuses to blink or turn away. E.g. Laser pointers, bar-code readers

**CLASS 3A**

These lasers normally would not produce injury if viewed momentarily with unaided eye unless the person views directly at the beam and refuses to blink or turn away (<0.25s). Hazard may be present if views using collection optics e.g. telescopes, microscopes or binoculars. E.g. HeNe laser above 1 mW but not exceeding 5 mW radiant power or some pocket laser pointers.

**CLASS 3B**

Class 3b lasers will cause eye damage instantly from both direct and specular reflected beams. These are visible, ultraviolet and infrared lasers with powers in the 5 to 500 mW range. E.g. Bio-simulation and therapeutic.

**CLASS 4**

Class 4 lasers are lasers with power levels greater than 500mW. These lasers pose skin hazards, eye hazards and even fire hazards. Flammable or combustible materials may ignite if exposed to the beam directly. Laser warning signs must be posted for all Class 4 lasers. All control measures must be implemented. E.g. Entertainment lasers, welding and industrial cutting.

### 13.3 Laser Safety Precautions

Laser users must be aware of the risks involved. Risk Assessment has to be conducted prior to operating the laser. All Risk Assessment conducted has to be documented.
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. All training has to be recorded and documented.

Optical experiments should be conducted on an optical table with all laser beams travelling in horizontal plane only. All beams should be stopped at the edges of the optical table. Users should never place their eyes at same level as the horizontal plane where the beams are; this is to prevent any case of reflected beams leaving the table.

Never look directly at any laser beam and never direct a beam at anyone. Avoid placing the unprotected eye along or near the beam axis. The probability of a hazardous specular reflection is greatest in this area.

Laser users must put on appropriate laser-specific eye protection. Protective eyewear is specific to the types of laser radiation in the lab. Eyewear should be examined prior to each use and discarded if there is damage which could reduce its effectiveness. Protective eyewear generally will not provide adequate protection against viewing the direct beam of a high-powered laser. Wearing protective eyewear should not be used as an excuse for performing an unsafe procedure.

Always engage minimum laser radiation required for the application. Operate a laser at the minimum power necessary for any operation. Beam shutters and filters can be used to reduce the beam power. Use a lower power laser whenever possible during alignment procedures.

Entrances to Class 3b and 4 laser facilities must be posted with appropriate warning signage. Each laser must be labelled where each label indicates the classification of the laser and identification of laser beam emission.

Class 4 laser facilities where the beam is not fully enclosed should have a visible warning device (e.g. a laser in operation sign) at the outside of the entrance, which indicates when a laser is in operation.
Reflective jewellery should not be worn when working with Class 3b and 4 lasers; Metallic jewellery increases electrocution hazards.

Class 4 lasers pose potential fire hazard precautions has to be taken against possible fire.

Except for fully enclosed and interlocked systems, an authorized user must be present or the room kept locked during laser operations.

Many laser systems have interlocked protective housings which prevent access to high-voltage components or laser radiation levels higher than those accessible through the aperture. These interlocks should not be bypassed without the specific authorization of the PI. Additional control measures must be taken to prevent exposure to the higher radiation levels or high voltage while the interlock is bypassed.

Servicing and maintenance of a laser can only be performed by a competent person who has been authorized by the PI. For work involving accessing an embedded laser of a higher class, appropriate control measures applicable to the higher class must be practiced.

Any laser, which is significantly modified, must be re-evaluated to determine its classification.

In the event of an accident or unusual incident involving a laser:

- **TURN OFF THE LASER.**

- Report **immediately** to the laboratory supervisor or PI.
14.0 NANOMATERIALS

14.1 Introduction

Nanomaterials are defined as materials consisting of particles with two or three dimensions that are less than 100 nanometers. A nanometer, or nm, is equivalent to $1 \times 10^{-9}$ meters. They are made up of many different base materials such as carbon, silicon and metals (e.g. gold, cadmium & selenium). Nanomaterials generally exhibit very different properties from their bulk materials.

Nanomaterials are used in electronic, biomedical, cosmetic, pharmaceutical, magnetic, catalytic and materials applications and processes.

The toxicity of most nanomaterials is currently not known. Preliminary toxicity testing has indicated that some nanoparticles may be more toxic than the corresponding micron sized particle due to their greater surface area and reactivity.

As the exposure standards have not been established for nanomaterials due to relatively new introduction, it is therefore necessary to assume that nanomaterials are toxic until more health data are published.

14.2 Risk Assessment

Risk Assessment is now requirement under Workplace Safety and Heath (Risk Management) Regulation.

Researchers/students planning to work with nanomaterials shall implement risk assessment together with a combination of engineering controls, work practices and personal protective equipment to minimise potential exposures to themselves and others. A high concentration of nanomaterials is a fire hazard and may cause an explosion. Special considerations should be given to the high
reactivity of some nanomaterial powders with regard to potential fire and explosion.

14.3 Responsibilities

PI is responsible for:

- Approval of the risk assessment and that the controls have risks as low as reasonably practicable.

- Approval of Standard Operating Procedures (SOPs) for processes and experiments involving nanomaterials.

- Inspection of laboratory to ensure controls stated in the risk assessment had been followed.

Researcher(s) is/are responsible for:

- Conducting risk assessment and establishing control measures to reduce risk as low as reasonably practicable especially for operations with higher risk of exposure such as manipulation of nanomaterials in gas stream, working with dry dispersible nanomaterials.

- Reviewing risk assessment and control measures as a basis for formulating Standard Operating Procedures (SOPs).

- Following work practices, including good laboratory practices and the correct use of personal protective equipment as described in your risk assessment.

14.4 Engineering Controls

Use fume hoods, glove boxes or other vented enclosures when there is a potential for aerosolization, such as:
• Handling powders

• Creating nanoparticles in the gas phase

• Pouring or mixing liquid media which involves a high degree of agitation.

DO NOT use horizontal laminar flow hoods as these devices direct the air flow towards the worker.

Use fume hoods or other local exhaust devices to exhaust tube furnaces and/or chemical reaction vessels in suspended nanomaterials directly to the environment and dispersed well. If possible, the exhaust should be HEPA filtered. Exhaust must not be directed into the room. Ductless type fume cupboards shall not be used for handling nanomaterials.

For fume hoods, a variable air volume fume hood is preferred, especially for dry or easily aerosolised nanomaterials.

Perform any maintenance activities, such as repair to equipment used to create nanomaterials or cleaning/replacement of dust collection systems, in fume hoods or under appropriate local exhaust.

14.5 Work Practices

Personal Protective Equipment

- Gloves, lab coats, safety goggles, long pants, closed-toe shoes and face shields should be worn as appropriate dependent on the nature of the materials and procedure. If possible, wear disposable hair net.

- Use double gloves as nanomaterial powder may permeate through single layer gloves. (Gloves are often not uniform in thickness and some areas which are thin, are likely to promote permeation).
- If work cannot be carried out in a fume hood or other ventilated enclosure, alternative respiratory protection with other controls should be used to minimize airborne nanomaterials. It is recommended to use NIOSH certified respiratory protection such as at least with P2 or P3 filter efficiency with determination from the risk assessment to use the type of respirators, such as half or full face mask.

- Fitting test shall be performed for persons that need to use the respiratory protective equipment and it shall be conducted by competent person.

Nanomaterials Selection

- Whenever possible, handle nanomaterials in solutions or attached to substrates to minimize airborne release.

- Consult Safety Data Sheet (SDS) or other appropriate references prior to using Nanomaterials especially one which you are unfamiliar with. Note: SDS may be based on the bulk material which may not be appropriate.

- The best place to keep up to date is the International Council on Nanomaterials (ICON) database which collects toxicity and environmental information by nanoparticle type.

Safety Equipment

- Know the location and proper use of emergency equipment such as safety showers, fire extinguishers and fire alarms.

Hygiene

- Do not consume or store food and beverages, or apply cosmetics where chemicals or nanomaterials are used or stored since their practice increases the likelihood of exposure by ingestion.
- Wash hands frequently to minimize potential exposure through ingestion and dermal contact, especially when leaving the laboratory.

- Remove gloves when leaving the laboratory, so as not to contaminate doorknobs, phones computers, etc.

- Avoid touching any parts of the body during or after handling of nanomaterials until you have washed your hands.

- Lab coats shall not be brought into areas that are considered non-operational zone, such as melting rooms, offices, etc.

- Clean up (Wet clean) work area often, including equipment and apparatus.

- Never store or place clean PPE with nanomaterials.

- Avoid raising dust.

**Labeling and Signage**

- Store in a well-sealed container, preferable one that can be opened with minimal agitation of the contents. Avoid over tightening lid as users will tend to use excessive force to open stuck containers resulting in spills.

- Label all containers with the identity of the contents. Avoid abbreviations/ acronyms. Include the term “nano” in descriptor (e.g. “nano-zinc oxide particles” rather than just “zinc oxide”) Hazard warning and chemical concentration information should also be included, if known.

- Use judgement when leaving operations unattended:

  1. Post signs to communicate appropriate warnings and precautions.

  2. Anticipate potential equipment and facility failures.
3. Provide appropriate containment for accidental release of hazardous chemicals.

**Cleaning**

- Wet wipe and/or HEPA-vacuum work surfaces regularly.

- Spills should be dealt with immediately.

**Disposal**

- Disposable tissues and towels after cleaning and bench top paper lining should be placed in a plastic bag and tied before disposing into municipal waste.

- Collect and store waste materials in a tightly closed container. Include information describing the nanomaterials on the waste tag.

**Spill Response**

- Wear personal protective equipment (PPE).

- DO NOT sweep or use conventional vacuum cleaners.

- Use wet cleanup methods (only if the material is not reactive to water) or vacuum cleaners equipped with HEPA-filters.

- Collect spill cleanup materials in a tightly closed container with proper labelling.

- The cleaned up waste should be categorised as hazardous waste.
15.0 ELECTRICAL SAFETY

Electrical hazards can lead to electrical shock, fire, burns or even explosion. Electrical accidents are often due to ignorance, lack of maintenance and usage of unsafe equipment. To safeguard ourselves against such hazards, it is important to observe the following practices:

- Only licensed electricians (from OFPM) are permitted to work on electrical systems and equipment that use or control electrical power.

- The wiring of equipment should be inspected prior use. Engage licensed electricians to replace damaged or frayed electrical cords soonest possible.

- Electrical cords on equipment must be in good condition, not frayed or cracked. Damaged cords must be removed or repaired, not taped over.

- Cables used must be appropriate to their loading. They must not be overloaded, otherwise they will overheat and the insulation will be damaged.

- Proper maintenance of the equipment is necessary. Disconnect the power source before servicing or repairing electrical equipment.

- One of the most important safety precautions when building or repairing equipment is to ensure that it is sufficiently grounded. Wires are to be connected according to the current Singapore Standard:
  
  Brown = Live  
  Blue = Neutral  
  Green with yellow = Earth

- Put up “Danger” signage when handling high voltage appliances/equipment.

- Do not operate electrical tools or equipment in wet areas.
- Report hazards (damaged equipment, exposed wires etc.) to the building manager, Safety officer or supervisor immediately.

- Remove any combustible materials such as paper and wood from the area. Ensure that flammable liquids and gases are secured from areas where appliance is in use.

- Avoid wearing jewellery. Jewellery provides a good conductive path to your body.

- Do not run electrical cords along the floor where they will become a tripping hazard and be subjected to wear.

- Ensure hands are dry. Wear nonconductive gloves and shoes with insulated soles when handling equipment that is plugged in.

- If it is safe to do so, work with only one hand. This precaution reduces the likelihood of accidents that may result in current passing through the chest cavity.

- If water or a chemical is spilled onto equipment, shut off power at the main switch and unplug the equipment.

- In the event of flooding, researchers should turn off all power sources before cleaning/ drying the affected areas.

- Cleaners shall NOT be allowed to clean up wet areas.

- After the affected areas have been dried, a licensed electrician should be engaged to certify that all affected electrical cords, sockets & equipment are safe for use.

Please also refer to Guidelines on Using Electrical Appliances in NTU
16.0 FIRE SAFETY

Laboratory fires can be caused by electrical heating units, bunsen burners, heat guns, overloading of electrical circuits or faulty equipment. Therefore fire prevention is an important aspect in laboratory safety.

16.1 Fire Hazards Control

- Good housekeeping, keeping premises clear of combustible items/waste.

- Emergency exits and walkways must be free from obstruction.

- Know the locations of the fire extinguishers, fire blankets near your work area.

- Familiarize yourself with the laboratory layout plan and fire escape route(s).

- Do not overload electrical systems.

- Do not leave containers with flammable liquids opened and unattended.

- Use and store flammable liquids and gases in well ventilated areas. Use a fume hood when working with products that release flammable vapours.

- Store flammable chemicals that require refrigeration in explosion safe laboratory refrigerators.

- Minimize or eliminate the use of open flames (e.g. Bunsen burners).

- Gas cylinders should be secured and pressure vessels must be checked and properly maintained.
- Beware of sparking sources in the laboratory. Avoid using heat guns in the vicinity of flammables.

- Ovens must be elevated from the floor to minimize the risk of fire should there be a solvent spill.

- Minimize the volume of flammable solvent on hand at any one time. Placing solvent order in smaller quantities more frequency would be a preferred over placing solvent order in large quantities.

- Minimize the amount of solvent waste in the laboratory.

- Ensure disposal of waste chemical according to its compatibility group.

- Clean flammable liquids spills promptly.

16.2 Classification of Fire and Fire Extinguishers

It is important to use the correct type of fire extinguisher for the type of fire. Fire is classified according to the type of fuel:

<table>
<thead>
<tr>
<th>Classes of Fire</th>
<th>Types of materials</th>
<th>Examples of such materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Combustible materials</td>
<td>Paper, plastic, cloths, rubber, wood</td>
</tr>
<tr>
<td>Class B</td>
<td>Flammable liquids</td>
<td>Solvents, oil, paint, gas</td>
</tr>
<tr>
<td>Class C</td>
<td>Electrical Equipment</td>
<td>Wiring, fuse boxes, motor</td>
</tr>
<tr>
<td>Class D</td>
<td>Combustible metals</td>
<td>Sodium, Magnesium, Potassium</td>
</tr>
</tbody>
</table>

Familiarize yourself with the fire class ratings of the fire extinguishers in your work area so that you will know the types of fire you can attempt to extinguish with them. E.g. If you are working with sodium metal, Class D fire extinguisher is one of the control measures to be included in your Risk Assessment.
The correct type of extinguisher should be used for the respective hazard and you cannot use all types of extinguishers safely on all types of fires.

<table>
<thead>
<tr>
<th>Types of Portable Fire Extinguisher</th>
<th>Classes of Fire</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon dioxide (no gauge)</td>
<td>B,C</td>
</tr>
<tr>
<td>Dry chemical (with gauge)</td>
<td>A,B,C</td>
</tr>
<tr>
<td>Metal –X powder</td>
<td>D</td>
</tr>
</tbody>
</table>

**16.3 Operating a Fire Extinguisher**

Attempt to put out small fires only and only if there is an escape route behind you. If you are unable to put out a fire within 30 seconds, you should stop and get out of the building.

Remember to have the extinguisher recharged after use. Ensure also that your fire extinguishers are serviced annually.

Adopt the “P-A-S-S” procedure:

<table>
<thead>
<tr>
<th>Image</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="P - Pull" /></td>
<td>P – <strong>Pull</strong> and twist the pin at the top of the extinguisher, breaking the seal.</td>
</tr>
<tr>
<td><img src="image" alt="A - Aim" /></td>
<td>A – <strong>Aim</strong> the extinguisher hose/nozzle at the base of the fire.</td>
</tr>
<tr>
<td><img src="image" alt="S - Squeeze" /></td>
<td>S – <strong>Squeeze</strong> the top of the handle to release extinguishing agent.</td>
</tr>
</tbody>
</table>
### 16.4 Fire Blanket

A Fire Blanket is a fire safety apparatus made of fibreglass/aramid fibres coated with a fire retardant material. It cuts off oxygen supply to a fire thus smothering it.

Fire Blanket is used to put up small fire (e.g. kitchen fire, clothing fire).

DO NOT use for large fires.

#### For small fire:
- Protect yourself, Raise opened blanket to shield your face & hands as you go near fire.
- Gentle cover/drop blanket over the fire completely.
- Do NOT lift fire blanket for 20 to 30 minutes. Stay around in case fire reignite.

#### For Clothing Fire:
- Protect yourself.
- Wrap blanket firmly neck down (but not too tightly) over casualty (like a shawl).
- No opening to prevent fire reigniting.
17.0 ACKNOWLEDGEMENT

I, ____________________________________________________________. NRIC/FIN ____________________________ do hereby acknowledge that I have read the SPMS Safety Manual. I understand and appreciate fully the risks, hazards and dangers involved when working in the laboratory. I am also aware of additional safety rules of the Division.

I am fully aware that I am responsible for my personal safety as well as those around me. I am to conduct operations in an acceptable manner, in accordance to the Safety guidelines and Standard Operating Procedures to minimize hazards to self and others.

<table>
<thead>
<tr>
<th>Signature of Researcher / Student:</th>
<th>Date:</th>
</tr>
</thead>
</table>

Division: CBC / MAS / PAP
(Please circle)

Name of PI : _______________________

Date : _______________________

Please neatly tear off this page and return to your Division Safety Representative after you and your PI have signed.