# TABLE OF CONTENTS

**CHAPTER 1  INTRODUCTION**
- 1.1 INTRODUCTION ........................................ 4
- 1.2 EMERGENCY PHONE NUMBERS AND SAFETY PERSONNEL CONTACTS ........................................ 5
- 1.3 BIOHAZARDS AND POTENTIALLY INFECTIOUS MATERIALS ........................................ 6

**CHAPTER 2  BIOSAFETY PROGRAM ADMINISTRATION** ........................................ 7
- 2.1 ROLES AND RESPONSIBILITIES ........................................ 7
- 2.2 UNIVERSITY BIOSAFETY POLICY AND BSL-3 POLICY ........................................ 9

**CHAPTER 3  NUS BIOSAFETY REQUIREMENTS** ........................................ 10
- 3.1 WORKPLACE SAFETY AND HEALTH ACT ........................................ 10
- 3.2 WORK INVOLVING BIOHAZARDOUS MATERIAL ........................................ 10
- 3.3 HUMAN PATHOGENS ........................................ 11
- 3.4 RECOMBINANT DNA EXPERIMENTS ........................................ 12
- 3.5 ANIMALS ........................................ 13
- 3.6 HUMAN SUBJECTS/HUMAN TISSUES ........................................ 13
- 3.7 TRAINING ........................................ 13
- 3.8 UNIVERSITY LAB COMMISSIONING/DECOMMISSIONING ........................................ 13
- 3.9 NUS OCCUPATIONAL HEALTH PROGRAMME ........................................ 14
- 3.9 AFTER-HOURS WORK ........................................ 15

**CHAPTER 4  RISK ASSESSMENT AND RISK MANAGEMENT** ........................................ 16
- 4.1 BIOSAFETY RISK ASSESSMENT/RISK MANAGEMENT STRATEGY ........................................ 16
- 4.2 CLASSIFICATION OF BIOLOGICAL AGENTS ........................................ 18
- 4.3 PRINCIPLES OF CONTAINMENT ........................................ 20
- 4.4 BIOSAFETY LEVELS ........................................ 22
- 4.5 VERTEBRATE ANIMAL BIOSAFETY LEVELS ........................................ 27
- 4.6 GUIDELINES FOR DETERMINING BIOSAFETY LEVEL ........................................ 29
- 4.7 RISK ASSESSMENT REVIEW ........................................ 33

**CHAPTER 5  ENGINEERING CONTROLS** ........................................ 35
- 5.1 BIOLOGICAL SAFETY CABINETS ........................................ 35
- 5.2 AUTOCLAVES ........................................ 36
- 5.3 OTHER SAFETY EQUIPMENT ........................................ 36

**CHAPTER 6  ADMINISTRATIVE CONTROLS** ........................................ 37
- 6.1 SIGNS AND LABELS ........................................ 37
- 6.2 MEDICAL SURVEILLANCE ........................................ 38
- 6.3 TRAINING ........................................ 39
- 6.4 INSPECTIONS ........................................ 39
- 6.5 STANDARD OPERATING PROCEDURES (SOPS) ........................................ 40

**CHAPTER 7  GOOD MICROBIOLOGICAL TECHNIQUES** ........................................ 41
- 7.1 PRUDENT PRACTICES AND GOOD TECHNIQUE ........................................ 41
- 7.2 HOUSEKEEPING AND PERSONAL HYGIENE ........................................ 42
- 7.3 RECOMMENDED WORK PRACTICES ........................................ 45
CHAPTER 1  INTRODUCTION

1.1 INTRODUCTION

The purpose of the NUS Laboratory Biorisk Management Manual is to detail the university biological safety program and to provide guidelines for all university personnel for the safe operation of laboratories and performance of experiments involving materials of biological origin. The policies, rules, and procedures set forth in this manual is developed with the purpose of promoting a safe environment for the protection of University of Singapore employees, students, visitors, our community as well as NUS property. The manual also provides guidance on the procedure for risk assessments in a biological setting and the appropriate controls to be adopted in the management of risks. Many of the practices and requirements mentioned are recognized basic codes of practice essential for conducting research with hazardous or potentially hazardous biological materials and are also established with reference to the World health Organization (WHO) Laboratory Biosafety Manual. The codes of practice are also developed to be aligned with recommendations and specific provisions of Singapore regulatory agencies.

Biological laboratories are unique work environments that may pose identifiable infectious disease risks to persons in or near them. Laboratory acquired Infections have been reported in microbiological laboratories worldwide. Biosafety is the application of knowledge, techniques and equipment to prevent personal, laboratory and environmental exposure to potentially infectious agents or biohazards. Everybody working with infectious agents or potentially infected materials must be aware of the potential risks. Microorganisms are classified into different risk groups based on their virulence, mode of transmission and host range of organism, availability of effective preventive measures (e.g., vaccines), availability of effective treatment (e.g., antibiotics) and other factors. It is important to consider how an infection can occur so that appropriate methods to minimize exposure can be established.

For researchers working with animals, chemicals or radioactive materials, separate manuals are currently in development to define the policies and procedures to safeguard NUS personnel and environment from the associated hazards.

The guidelines in this manual should be read before work in the laboratory is initiated. It is essential that laboratory personnel are trained and proficient in the practices and techniques required for handling biohazardous material. Eventually, all personnel working in the laboratories should know how to identify hazards, minimize risks and carry out their laboratory work safely.
1.2 EMERGENCY PHONE NUMBERS AND SAFETY PERSONNEL CONTACTS

Emergency Telephone Numbers
Ambulance/Fire  995
Police  999
Campus Security (24hrs)  x1616 (6874 1616)
General Maintenance/ Breakdown of Services (24 hrs)  x1515 (65161515)

University Health and Wellness Centre (UHWC)

1. YIH Main Clinic
Level 4, Yusof Ishak House
Kent Ridge Crescent
x2880 (65162880)
Consultation Hours:
Monday - Thursday
8.30am to 6.00pm
(Closed 12.30pm to 1.30pm)
Last registration at 5.40pm
Friday
8.30am to 5.30pm
(Closed 12.30pm to 1.30pm)
Last registration at 5.10pm

For enquiries on NUS Occupational Health Programme, contact:
Ms Doris Yek,
Occupational Health Nurse
X7333 (6516 7333)
email: oshyll@nus.edu.sg

2. Bukit Timah Campus (BTC)
Block B, MPA-02-01
(Level 2 MPA block).
Tel: 6467 5492
Consultation Hours
Mondays, Wednesdays & Fridays
8.30am to 10.30am

Office of Safety, Health and Environment (OSHE)

1. OSHE

Office of Safety, Health & Environment
Alumni House, Basement
National University of Singapore
21 Lower Kent Ridge Road
Singapore 119077

General enquiries: 6516 1084
Fax: 67746979
Website: http://www.nus.edu.sg/osh/index.html
2. Faculty/ Department Safety & Health Officers/Coordinators

Contacts for Safety & Health Officers/Coordinators on safety and health issues pertaining to your faculty/department are assessable at:

http://www.nus.edu.sg/osh/aboutus/staff.htm

1.3 BIOHAZARDS AND POTENTIALLY INFECTIOUS MATERIALS

A biological hazard or biohazard is an organism, or substance derived from an organism, that poses a threat to (primarily) human health.

Categories of biohazards or potentially infectious materials include:

1. Human, animal and plant pathogens
   a. Viruses, including oncogenic and defective viruses
   b. Rickettsiae
   c. Chlamydiae
   d. Bacteria, including those with drug resistance plasmids
   e. Fungi
   f. Parasites
   g. Undefined or other infectious agents, such as prions

2. All human blood, blood products, tissues and certain body fluids

3. Cultured cells (all human or certain animal) and potentially infectious agents these may contain.

4. Allergens

5. Toxins (bacterial, fungal, plant, etc.)

6. Certain recombinant nucleic acid products

7. Clinical and diagnostic specimens

8. Infected animals and animal tissues
CHAPTER 2  BIOSAFETY PROGRAM ADMINISTRATION

The Institutional Biosafety Committee (IBC) is the university level committee to oversee the development and implementation of the biosafety programme. The Office of Safety, Health and Environment (OSHE) is the administrator of this programme. The Biosafety Programme consists of the following elements:

2.1 ROLES AND RESPONSIBILITIES

a. NUS President
The President of the National University of Singapore represents the university as the Employer. The final responsibility for safety and health policy and program rests with the President who may delegate the authority and the responsibility needed by the IBC, Deans and Heads of Departments to effectively supervise the occupational safety and health of staff under his or her management. The IBC and OSHE can report any incident or conditions of noncompliance to the President, Provost or Deputy President who are entitled to partially or fully close labs or facilities until all safety issues are addressed.

b. NUS Institutional Biosafety Committee (IBC)
The IBC is appointed by the President. The Terms of Reference for the IBC are:

1. Review the SOPs, Standards and Guidance Documents at university, faculty and departmental level and recommend revisions to the Director of OSHE.

2. Serve in an advisory capacity to OSHE on all Biosafety related matters.

3. Implement and maintain procedures for the registration of biohazardous agents, and review the use of such agents and GMOs as required by the Genetic Modification Advisory Committee (GMAC).

4. Approve all new projects involving biohazardous agents of Risk Group 2 and above through a risk assessment framework that must be completed by the respective Principal Investigators (PIs) before the commencement of a research project or teaching experiment.

5. Review the NUS Biosafety Programme, as well as any audit and inspection findings conducted by OSHE or other independent parties on faculties and departments.

6. Review the NUS Biosafety Policy and recommend to the NUS President on specific action items related to the Biosafety Programme.

7. Advise the University management on BSL 3 policies and programmes.

8. Perform the roles and responsibilities for Institutional Biosafety Committee stipulated in guidelines issued by the Genetic Modification Advisory Committee (GMAC)

The Committee consists of no fewer than five members so selected that they collectively have experience and expertise in biohazardous agents and gene technology and the
capability to assess safe practices for the use of such agents and to identify any potential risks to public health or the environment.

The Committee shall include one faculty member each from the Faculty of Medicine (FOM), Faculty of Science (FOS), Faculty of Dentistry (FOD) and Faculty of Engineering (FOE), and the Office of Life Sciences (OLS). The chair of the Committee shall be appointed by the NUS President for a period not exceeding two terms. The Committee will be assisted by the Occupational Safety and Health Division of OSHE.

c. Principal Investigator

Principal Investigators/researchers who has in their possession agents designated under Risk Group 2 and above must register such agents with the IBC as part of their risk assessment submissions. It is the responsibility of the respective Principal Investigators to ensure safe handling of such substances in his/her lab.

In performing the risk assessment using a common risk assessment framework established under the Biosafety Programme, Principal Investigators will document that protocols and facilities do not jeopardize the health and well being of themselves, their employees, students, the general public, and that all personnel working in laboratories in which Risk Group 2 agents are handled are familiar with the relevant local and university level SOPs and guidance documents, and are appropriately trained and informed of the risks and hazards present in the lab under his/her charge. All risk assessment submissions are to be submitted to the respective Heads of Departments (HODs)/Deans for endorsement prior to their submissions to the IBC.

The Principal Investigator will be accountable for the inventory of Risk Group 2 agents in his/her lab. It is also the responsibility of the Principal Investigator to provide the necessary resources needed to ensure good safety practices and adequate infrastructure for the safe operation of the lab.

d. Deans and Head of Departments (HOD)

All Deans and HODs of respective lab-based faculties and departments will ensure that their respective faculty or departmental biosafety SOPs, standards and guidance documents as well as components of the Biosafety Programme implemented at departmental and faculty level are in order and reviewed periodically. Faculty Safety Officers and personnel appointed to assume safety responsibilities shall be empowered by the respective Deans or HODs to coordinate the NUS Biosafety Programme at the faculty and departmental level.

Respective HODs are responsible for the review of the risk assessment submissions of Principal Investigators before their submissions to the IBC. HODs should verify, where possible, the consistency of the risk assessment submissions.

e. Staff and Students

Under the Ministry of Manpower’s Workplace Safety & Health Act, every person at a workplace is obligated to ensure the safety of their workplace and health of others in the workplace. All staff members and students must comply with all university level SOPs, standards and guidance documents that are applicable to their area of work and ensure that they carry out their work safely.
Support staff such as maintenance service personnel (include NUS operations support staff and external contractors engaged for repair and/or maintenance of structure, facilities and equipment) as well as domestic cleaning service providers are also covered under the act. Support staff should have the knowledge or be informed of the nature of work of the laboratory, and of the safety regulations and procedures of the university.

f. Office of Safety, Health & Environment (OSHE)
OSHE will provide administrative support to the IBC, maintain the University Biosafety Manual, manage all registration and reporting processes for the IBC, maintain appropriate records, and serve as liaison with all faculties, departments and external agencies in the ongoing implementation of the University's Biosafety Programme.
OSHE will also coordinate the provision of biosafety training to relevant staff through the NUS Structured Safety Training System (SSTS). OSHE will arrange periodic biosafety audits and reviews on departments and faculties. OSHE will also be the university body tasked to coordinate any incident or accident investigations as called for by the IBC or the President.

g. University health and wellness center (UHWC)
The UHWC is the medical service provider for the occupational health program of the university.

2.2 UNIVERSITY BIOSAFETY POLICY AND BSL-3 POLICY

Full description of the policies are available at OSHE’s website:
http://www.nus.edu.sg/osh/policies/biosafety.htm
CHAPTER 3    NUS BIOSAFETY REQUIREMENTS

The following information describes the requirements for all researchers in the National university of Singapore undertaking lab-based research projects involving life sciences. It is the responsibility of each Principal Investigator to ensure the laboratory is in compliance.

3.1 WORKPLACE SAFETY AND HEALTH ACT

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

Under the Act, subsidiary legislations that are applicable to NUS include:
• The Workplace Safety and Health (General Provisions) Regulations 2006
• The Workplace Safety and Health (Incident Reporting) Regulations 2006
• The Workplace Safety and Health (First-Aid) Regulations 2006
• The Workplace Safety and Health (Risk Management) Regulations 2006

The regulations stipulate the requirements for employers, self-employed persons and any person who engages another person/organization to perform work under some arrangement other than a contract of service (including contractors and sub-contractors) of risk assessments in all workplaces in:
• conducting risk assessments to identify and control workplace safety and health risks.
• providing safe work facilities and arrangements for their workers;
• ensuring safety in machinery, equipment, substances and work processes at the workplace;
• providing adequate instruction, information, training and supervision to workers
• implementing control measures for dealing with emergencies

More details about the Workplace Safety and Health Act are available at the Ministry of Manpower’s website:

3.2 WORK INVOLVING BIOHAZARDOUS MATERIAL

All Principal Investigators(PIs) who plan to use biohazardous agents, GMOs, animals and transgenic animals are required to complete and submit a project risk assessment before any new research project or task is implemented (unless exempted under the PI lab certification scheme); or when there are changes that may affect the safety and health aspects of the project / task or as and when required by the University. Details of risk assessment procedures are available through the Office of Safety, Health and Environmental (OSHE) website http://www.nus.edu.sg/osh/manuals/sop.htm#general in the SOP on “Project/ Task Risk Assessment” (OSHE/SOP/U/05). The Risk Assessment Form can also be downloaded from the same web site.
All risk assessment submissions for projects/tasks requiring grant funding are to be submitted to the respective Heads of Departments (HODs)/Deans for endorsement prior to their submissions to the IBC. For projects/tasks that do not require any grant funding (e.g. teaching activities, dissertation projects) risk assessments are approved by the HOD and do not need to be submitted to the IBC for approval.

PIs can only commence work after their risk assessment has been approved.

All PIs are accountable for the inventory of the biohazardous agents in his/her lab and are responsible for ensuring safe operation of the laboratory.

### 3.3 HUMAN PATHOGENS

The possession, use, import, transfer and transportation of biological agents (BAs) and toxins that are known to be hazardous to human health in Singapore is regulated by the Biological Agents and Toxins Act (BATA). Approval is required for the possession, import, handling and transportation of scheduled biological agents and toxins.

#### 3.3.1 Biological Agents and Toxins Act (BATA)

The Biological Agents and Toxins Act (BATA) administered by the Ministry of Health (MOH) came into force on 3 January 2006 in Singapore. (Singapore Statutes online, [http://statutes.agc.gov.sg/](http://statutes.agc.gov.sg/)). The BATA prohibits and otherwise regulates the possession, use, import, transshipment, transfer and transportation of biological agents, inactivated biological agents and toxins that are of public health concern.

Under the BATA, biological agents and toxins are classified into five schedules. The list of agents classified under each of the BATA schedules can be found at: [http://www.nus.edu.sg/osh/_files/legislation/Bata_Schedule_of_Biological_Agents_and_Toxins.doc](http://www.nus.edu.sg/osh/_files/legislation/Bata_Schedule_of_Biological_Agents_and_Toxins.doc)

MOH has also adopted the Laboratory Biosafety Manual, 3rd Edition, by the World Health Organization (WHO) as the national guidelines for biosafety to supplement the BATA.

The Schedules in BATA cover only biological agents capable of causing disease in humans (i.e. human pathogens). Some of the biological agents in the Schedules may similarly cause diseases in animals, and these agents are termed zoonotic pathogens and are jointly controlled by AVA under the Animals and Birds Act and MOH under BATA.

#### 3.3.2 Approvals

a. **Approval for import**

   An import permit is required for biological agents under all schedules. Each permit is valid only for the specific consignment of the biological agent for which the permit has been granted.

b. **Approval to possess**

   Approval to possess biological agents in schedules 1 and 2 and toxins in schedule 5 are agent-specific and granted by the Director of Medical Services. No approval to possess
is required for biological agents in schedules 3 and 4. The approvals to possess agents in schedule 1(part II) and schedule 2 are granted to a certified BSL-3 facility officially recognized as a protected place under the Protected Areas and Protected Places Act. The approval to possess toxins in schedule 5 is granted to a certified or uncertified facility which is officially recognized as a protected place.

c. Zoonotic agents
Some of the biological agents in the Schedules also cause diseases in animals, and are termed zoonotic pathogens. They are jointly controlled by AVA under the Animals and Birds Act and MOH under BATA. To work with zoonotic agents, approval for possession from Agri-Food Veterinary Authority (AVA) of Singapore is required.

d. Genetically modified organisms (GMOs)
For genetically modified organisms (GMOs), approval must be sought from Genetic Modification Advisory Committee (GMAC) before submitting an application for approval and permit to MOH.

e. Applications for Schedule 1, 2 and 5 BAs and toxins must be endorsed by the institutional biosafety committee before submission to MOH. OSHE will work with principal investigators in processing their approvals and permits for submission to MOH.

More information can be found at the MOH website: http://www.moh.gov.sg/biosafety

3.4 RECOMBINANT DNA EXPERIMENTS

For projects which involve genetic manipulation, the guidelines from the Genetic Modification and Advisory Committee (GMAC) are to be adhered to: “The Singapore Guidelines for research on Genetically Modified Organisms (GMOs)”. The full set of guidelines can be found at www.gmac.gov.sg. These guidelines ensure that such experiments are properly regulated and supervised so that they will not pose a threat to public health.

The guidelines cover experiments that involve the construction and/or propagation of all biological entities (cells, organisms, prions, viroids or viruses) which have been made by genetic manipulation and are of a novel genotype and which are unlikely to occur naturally or which could cause public health or environmental hazards. A list of GMAC-approved host/vector system is given in the guidelines.

Notification must be made to GMAC depending on the category of experiments:

Cat A - Regulated experiments with significant risks
Cat B - Notifiable experiments with low risks
Cat C - Experiments with no significant risks

Cat A and B experiments require GMAC notification while Cat C experiments are exempt from GMAC notification. Refer to Section 4 of the guidelines for classes of experiments falling within each category.

PIs must fill out the GMAC ‘Proposal Form for Assessment of Genetic Manipulation Work’ and submit a copy to GMAC via the IBC and obtain the relevant approval before work can be commenced.
3.5 ANIMALS

All research experiments involving animals must be approved by and conducted in accordance with the NUS Institutional Animal Care and Use Committee (IACUC) approved protocol. For more details, refer to IACUC website: http://nus.edu.sg/iacuc/

The IACUC ensures the housing and care of animals are provided in accordance with the National Advisory Committee for Laboratory Animal Research (NACLAR) Guidelines. The national guidelines –“Guidelines on the Care and Use of Animals for Scientific Purposes” was set up for the proper treatment and utilization of animals for scientific purposes in Singapore, taking into consideration the relevant scientific, ethical and legal issues.

3.6 HUMAN SUBJECTS/HUMAN TISSUES

All research projects involving the use of human subjects or human tissues must be submitted for review by the NUS Institutional Review Board (IRB) on the ethical use of human subjects. Refer to the IRB website for guidelines for application: http://www.nus.edu.sg/irb/. For biosafety requirements, please refer to sections 4.4.2 and 4.6 of this manual.

3.7 TRAINING

Under the university’s Structured Safety Training System (SSTS), it is mandatory for all laboratory and technical staff to undergo safety trainings based on their job scope and work hazards. Under the NUS Biosafety policy, all lab officers who are dealing with biological hazards are required to attend the Biological Safety Course. Operations support officers are required to attend the General Lab Safety Course. Courses are also available for chemical and radiological safety programs.

Please contact OSHE for more details or visit the website for more details: http://www.nus.edu.sg/osh/training/safety.htm

For work with vertebrate animals, all personnel are required to undergo the “Responsible Care and Use of Laboratory Animals (RCULA)” Course or the “Responsible Care and Use of Fish (RCUF)” Course. Please contact the Laboratory Animal Centre (Tel: 6516-6654) or visit the website for more details: http://nus.edu.sg/iacuc/animal_use_lac_training_course.shtml

3.8 UNIVERSITY LAB COMMISSIONING/DECOMMISSIONING

3.8.1 Lab commissioning

All lab designs for new or renovated labs in NUS require the approval of the Joint Safety Review Group (JSRG) jointly chaired by OSHE, OED staff, faculty safety officer or safety coordinator. The NUS laboratory standard can be downloaded from: http://www.nus.edu.sg/osh/manuals/lab.htm
A checklist for lab commissioning is also available in the OSHE website:  
https://wws.nus.edu.sg/osh/nus_manuals/sop/labcommchecklist.doc

3.8.2 Lab decommissioning  
All PIs who are decommissioning a lab or lab area prior to leaving the university, relocating to another University laboratory, or renovating their laboratory are required to follow the procedure according to OSHE SOP (OSHE/SOP/U/06) on Laboratory Decommissioning Procedures.

3.9 NUS OCCUPATIONAL HEALTH PROGRAMME

3.9.1 Mandatory health controls

a. For work with animals:
All staff and students are to be administered with a tetanus vaccine prior to working with these animals and a booster shot every 10 years.

b. For work with materials of human origin (human blood, tissues, body fluids, cell lines etc) of both commercial and non-commercial sources:
All staff and student are to be administered with a Hepatitis B vaccine if tested negative for Hepatitis B antibodies. After six months screening of antibody levels should be done. Re-screening should be done 10 years later.

c. For work with materials containing risk group 2 and above agents:
The appropriate medical surveillance, immunization needed must be determined by referring to the MSDS of the infectious agent. The PI must develop an agent specific occupational health programme for research staff and students working in BSL 2 laboratories.

3.9.2 Occupational related disease, illness or infection

In the event of over exposure to hazardous agent resulting in possible infection, disease or illness, the PI/manager shall ensure that:

i. The staff and student are sent for medical assessment at UHWC during office hours and Accident & Emergency Units of Hospitals after office hours.

ii. A report is submitted to OSHE via the online NUS Accident and Incident Reporting System (AIRS) at https://staffweb.nus.edu.sg/oshe/notice.htm

3.9.3 Respiratory protection program

If there’s a requirement for respirator use in the course of work, the staff or/ and student should undergo respirator fit testing and medical assessment.

Application forms and more details of the occupational health programs are available at: http://www.nus.edu.sg/osh/programmes.htm
3.9 AFTER-HOURS WORK

a. If experimental work must be conducted after office hours, the PI or other lab personnel should be informed.

b. Certain types of work may not be undertaken outside of normal working hours, for example, working with highly toxic chemicals or hazardous biological materials. The PI should identify the activities that cannot be performed outside of normal working hours.

c. If experiments are to be run unattended overnight, it should be accompanied with a note containing information of the biological/chemical hazards involved, name of experimenter and contact number in case of an emergency.

d. Carrying out experimental laboratory work alone after hours is strongly discouraged. There should preferably be a “buddy-system” when work is to be carried out during the after-work hours.

e. Final Year Project Students and attachment students should not be allowed to work alone after office hours.

f. It is encouraged to keep an after-hours record of personnel present in the building where possible.
CHAPTER 4  RISK ASSESSMENT AND RISK MANAGEMENT

Responsibility for biosafety exists at all levels and is shared throughout the University. The NUS Biosafety Program was administered to establish procedures for the safe use of biohazards and for compliance with all applicable regulations. The PIs and all lab personnel who perform work with biohazards are the most important component of the biosafety program, as they must incorporate the biosafety requirements and safety precautions into all facets of their work.

The PI is ultimately responsible for safety within the laboratory. An integral part of this responsibility is to conduct a risk assessment of proposed work to identify potential hazards and to adopt appropriate safety procedures before initiation of the experiments (risk management). Properly conducted, risk assessment can help prevent exposure to biohazards and minimize the potential for laboratory acquired infection.

4.1 BIOSAFETY RISK ASSESSMENT/RISK MANAGEMENT STRATEGY

4.1.1 A risk assessment and management strategy should contain the following components:
   i. Identification of hazards
   ii. Assessment of risks and available control measures
   iii. Control of risks though implementation of control measure
   iv. Monitoring of controls to evaluate their effectiveness.

Refer to OSHE’s document -“NUS Occupational health and safety (OH&S) management system standard for laboratories - Part B” for guidelines on performing hazard identification, risk assessment and risk control.

4.1.2 The university has adopted the safety checklist found in the WHO “Laboratory Biosafety Manual, 3rd edition” to the NUS context to assist PIs in assessing microbiological lab safety. A copy of the checklist can be downloaded from: http://www.nus.edu.sg/osh/manuals/checklist.htm

4.1.3 A risk assessment and risk management strategy for a biological laboratory should consider five primary factors or ‘five P’s” in each aspect of laboratory work:

   - Pathogen – hazardous biological agent.
   - Procedures –experimental manipulations and safe work practices.
   - Personnel –training, skills, habits and attitudes
   - Protective equipment – protective clothing and safety equipment.
   - Place – laboratory design.

A. Pathogen

Key considerations of risk assessment:
   - Agent risk group classification (See section 4.2)
   - Routes of infection
- Infectious disease process
- Virulence, pathogenicity, quantity, concentration,
- incidence in community
- presence of vectors
- availability of preventative measures and effective treatment
- involvement of genetic manipulation

Key elements of risk management:
- Appropriate biosafety level (section 4.3-4.4)

B. Procedure

Key considerations of risk assessment:
- Aerosol risk: sonication, centrifuging, homogenizing, blending, shaking, etc.
- Percutaneous risk: needles, syringes, glass Pasteur pipettes, scalpels, cryostat blade/knife, etc., animal bites/scratches
- Splash/splatter risk: pipetting, microbial loop, etc.
- Ingestion risk: mouth pipetting, eating, drinking, smoking

Key elements of risk management:
- Written set of standard operating procedures (SOPs) with safety practices incorporated
- Adherence to basic biosafety principles
- Good lab practices.
- Label labs, areas, and equipment housing BL2 or higher agents
- Conduct lab inspections to review practices and containment equipment
- Use trial experiments with non-infectious material to test new procedures/equipment

C. Personnel

Key considerations of risk assessment:
- Susceptibility to disease (Neoplastic disease, Infection, Immunosuppressive therapy, Age, Race, sex, pregnancy, Surgery, preexisting medical conditions)
- Immunization
- Post-exposure prophylaxis
- Attitude toward safety
- Knowledge, skills and experience
- Open wounds, non-intact skin, eczema, dermatitis

Key elements of risk management:
- Safety training
- Prior work experience with biohazards
- Demonstrated proficiency with techniques
- Prompt reporting of all exposure incidents, near misses, as well as signs and symptoms of related disease to PI and OSHE/UHWC
- Investigation/review of incidents/spills, etc. to prevent future occurrence

D. Protective equipment

Key considerations of risk assessment:
- Protection for exposure from Aerosols, Droplets/splatter and Sharps

Key elements of risk management:
- Personal protective equipment (PPE):
  - Respirators – N-95, PAPR etc.
  - Face (eye, nose, mouth) protection – mask and safety glasses, or face shield
  - Solid front gown or lab coat
  - Gloves
- Biological safety cabinets
- Centrifuge safety buckets/rotors
- Training in proper use of PPE

E. Laboratory facility

Key considerations of risk assessment:
- Risk group/biosafety level requirements
- Aerosol risk
- Accidental release of pathogen

Key elements of risk management:
- Basic lab facilities – door, sink, surfaces easily cleaned, eyewash, emergency showers
- Restricted access
- Labels
- Containment laboratory with directional airflow

4.1.4 Different elements of risk management are discussed in detail in chapters 5-10 of this manual. Refer to the relevant sections for considerations of control measures.

4.1.5 It may be useful to break a lab experiment down into specific tasks with distinct objective or equipment usage before attempting to identify the hazards associated with each task within. Use the NUS OH&S Management Standard Risk assessment table for lifescience laboratories attached at end of chapter to assist you in tabulating the risks and controls. The relevant information can then be extracted out for submission of project-based risk assessments (see section 4.7)

4.2 CLASSIFICATION OF BIOLOGICAL AGENTS

Infectious agents are classified into risk groups based on their relative risks in different countries. Risk group classifications are used in the research environment as part of a comprehensive biosafety risk assessment.

4.2.1 WHO risk group classification

WHO recommends that each country classifies the agents in that country by risk group based on pathogenicity, modes of transmission and host range of the organism. These may be influenced by existing levels of immunity, density and movement of host population, presence of appropriate vectors and standards of environmental hygiene.
**Risk Group 1**
(no or low individual and community risk).
A microorganism that is unlikely to cause human disease or animal disease

**Risk Group 2**
(moderate individual risk, low community risk).
A pathogen that can cause human or animal disease but is unlikely to be a serious hazard to laboratory workers, the community, livestock or the environment. Laboratory exposures may cause serious infection, but effective treatment and preventative measures are available and the risk of spread of infection is limited.

**Risk Group 3**
(high individual risk, low community risk).
A pathogen that usually causes serious human or animal disease but does not ordinarily spread from one infected individual to another. Effective treatment and preventive measures are available.

**Risk Group 4**
(high individual and community risk).
A pathogen that usually causes serious human or animal disease and that can be readily transmitted from one individual to another, directly or indirectly. Effective treatment and preventive measures are not usually available.

The risk group classification of infectious agents varies from country to country. An agent classified into Risk Group 2 in one country may be classified as Risk Group 3 in another.

The American Biological Safety Association (ABSA) has a useful online risk group database search function that returns information of the risk grouping of a hazardous agent in various countries: http://www.absa.org/XriskgroupsX/index.html

**4.2.2 Risk groups and BATA schedules**

Under the present BATA, biological agents and toxins are classified into five schedules summarized in the table below. The 5 Schedules in BATA cover a wide spectrum of biological agents and toxins and different levels of controls have been adopted for each Schedule. BATA differentiates between higher risk group and lower risk group biological agents, and also those with potential to be weaponised.
<table>
<thead>
<tr>
<th>Schedule classification</th>
<th>Risk group</th>
<th>Description of schedule</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule 1 (part 1)</td>
<td>3</td>
<td>Potential to cause serious disease which is high risk to individual</td>
</tr>
</tbody>
</table>
| Schedule 1 (part 2)     | 3          | (1) Potential to cause serious disease which is high risk to individual  
                            (2) Potential to be weaponized. |
| Schedule 2              | 4          | (1) Can cause severe/lethal disease, high risk to individual and community  
                            (2) Potential to be weaponized |
| Schedule 3              | 2          | (1) Can infect humans  
                            (2) Need special attention in large scale production |
| Schedule 4              | 2          | Can infect humans |
| Schedule 5              | -          | Microbial toxins with potential to be weaponized |

NB. Schedule 1 is separated into part I and part II based on their potential to be weaponized.

The list of agents classified under each of the BATA schedules (revised July 2007) can be found in the website of the Biosafety section of the Ministry of Health Singapore: http://www.biosafety.moh.gov.sg/bioe/index.do

### 4.3 PRINCIPLES OF CONTAINMENT

#### 4.3.1 Containment

The term "containment" is used in describing safe methods for managing infectious agents in the laboratory environment where they are being handled. Containment is required in order to reduce/eliminate exposure of laboratory workers, persons outside lab and the environment to potentially hazardous agents. It involves the application of a combination of three elements - laboratory practice and procedure, safety equipment and laboratory facilities, when working with potentially infectious microorganisms.

It can be accomplished through:

**Primary Containment** which is the protection of personnel and the immediate laboratory environment through **good microbiological technique (laboratory practice)** and the use of appropriate **safety equipment**.

and

**Secondary Containment**, the protection of the environment external to the laboratory from exposure to infectious materials through a combination of **laboratory facility design and operational practices**.
4.3.2 Laboratory Practices and Techniques

The most important element of containment is strict adherence to standard microbiological practices and techniques.

The use of aseptic techniques and other good microbiological practices achieves three very important objectives:
1. **OCCUPATIONAL HEALTH**: The prevention of illness, disease or injury when working with infectious organisms.
2. **ENVIRONMENTAL SAFETY**: The prevention of contamination of the laboratory by the organisms being handled.
3. **PRODUCT PROTECTION**: The prevention of contamination of the work with organisms from the environment.

The first objective is of prime importance as regards to working safely whereas the second and third are key considerations in relation to the quality of the research.

The Principal Investigator (PI) is responsible for ensuring that all personnel working with infectious agents or potentially infected materials are aware of potential hazards, and are properly trained and proficient in the practices and techniques required to handle such material safely. Chapter 6 describes most of the standard recommended work practices and safe operating procedures common for microbiological laboratories. However, the list of practices is not exhaustive.

Each laboratory should develop safe operating procedures specific to hazards that may be encountered, and which specifies practices and procedures designed to minimize or eliminate risks.

When standard laboratory practices are not sufficient to control the hazard associated with a particular agent or laboratory procedure, additional measures may be needed. Laboratory personnel safety practices and techniques must be supplemented by appropriate facility design and engineering features, safety equipment and management practices.

4.3.3 Safety equipment (primary containment)

Safety equipment includes biological safety cabinets, enclosed containers and other engineering controls designed to remove or minimize exposures to hazardous biological materials. The principal device used for providing containment of infectious splashes or aerosols generated during work with biological material is the biological safety cabinet.

Chapter 8 describes common engineering controls used in the laboratory. Safety equipment also includes items for personal protection such as protective clothing (e.g., gowns, gloves), respirators, face shields, safety glasses or goggles (see Chapter 9). Personal protective equipment (PPE) is often used in combination with other safety equipment when working with biohazardous materials. In some situations, protective clothing may form the primary barrier between personnel and the infectious materials.
4.3.4 Laboratory facility design

The primary function of the laboratory facility is to provide a physical environment in which work activity can be undertaken efficiently and safely. The design and construction of the facility constitute a secondary containment to provide varying degrees of barriers between the laboratory and the outside environment. The function of these barriers is to protect people working inside and outside the laboratory and to prevent the accidental release of micro-organisms into the environment in the event of a failure in a primary containment. Examples of secondary barriers include floors, walls and ceilings, air locks and self-closing doors, differential pressures between spaces (positive pressure and negative pressure designs to ventilation system), exhaust filtration, as well as devices for treating contaminated air, liquids and solids.

The design of a facility is important in providing a barrier to protect people working inside and outside the laboratory, and to protect people or animals in the community from infectious agents which may be accidentally released from the laboratory.

Facility design must be commensurate with the laboratory’s function and the recommended biosafety level for the agent being manipulated.2.

The recommended secondary barrier(s) will depend on the risk of transmission of specific agents. Where there is a low risk of exposure, secondary barriers in these laboratories may include:
- separation of the lab area from public access,
- availability of decontamination facility (e.g., autoclave)
- Hand washing facilities.

Where there is a high risk of exposure to an infectious aerosol, higher levels of primary containment and multiple secondary barriers may be necessary to prevent infectious agents from escaping into the environment. These include:
- specialized ventilation systems for ensuring directional air flow,
- air treatment systems for decontaminating the exhaust air,
- controlled access zones,
- airlocks as laboratory entrances,
- or separate buildings or modules to physically isolate the laboratory.

4.4 BIOSAFETY LEVELS

For each Risk Group of micro-organisms there is a defined minimum set of control measures known as Containment Level or Biosafety Level (BSL) that reduces exposure to an acceptable level for microorganisms of that Risk Group.

There are four biosafety levels (BSL1-4). Each level of containment describes the microbiological practices, safety equipment and facility safeguards appropriate for the corresponding level of risk associated with handling a particular infectious agent. These levels, designated in ascending order, provide increasing levels of protection to personnel and the environment. Detailed descriptions of recommended practices, safety equipment and facility requirements for each BSL can be found in chapter 3-5 of the WHO “Laboratory Biosafety Manual, 3rd edition” which can be downloaded from:

4.4.1 Biosafety Level 1 (BSL1)

Biosafety Level 1 is suitable for work done with well-characterized agents not known to consistently cause disease in healthy adult humans, and is of minimal potential hazard to laboratory personnel and the environment.

a. BSL1 represents a basic level of containment that relies on standard microbiological practices with no special primary or secondary barriers required, other than a sink for hand washing.
b. Work is generally conducted on open bench tops using standard microbiological practices.
c. Laboratory personnel have specific training in the procedures conducted in the laboratory and are supervised by a scientist with general training in microbiology or a related science.

4.4.2 Biosafety Level 2 (BSL2)

Biosafety Level 2 (BSL2) is applicable to work done with agents associated with human disease but is of moderate potential hazard to personnel and the environment. Under NUS requirement, it is also applicable to work involving materials of human origin (human blood, tissues, body fluids, cell lines etc) from both commercial and non-commercial sources.

a. Primary hazards to personnel working with these agents relate to accidental percutaneous or mucous membrane exposures or ingestion of infectious materials.
b. BSL2 builds upon BSL1. Access to the laboratory is limited when work is being conducted.
c. With good microbiological techniques, agents may be used safely on the open bench, provided the potential for producing splashes or aerosols is low.
d. Primary barriers such as splash shields, face protection, gowns and gloves should be used as appropriate. Secondary barriers such as handwash, eyewash and waste decontamination facilities must be available.
e. Extreme precautions are taken with contaminated sharp items
f. Procedures with high aerosol or splash potential must be conducted in primary containment equipment such as biological safety cabinets.
g. Laboratory personnel have specific training in handling pathogenic agents and are directed by competent scientists.

4.4.3 Biosafety Level 3 (BSL3)

Biosafety Level 3 (BSL3) is applicable to work done with indigenous or exotic agents with a potential for respiratory transmission and which may cause serious and potentially lethal infection.
a. Primary hazards to personnel working with these agents include autoinoculation, ingestion and exposure to infectious aerosols.
b. Greater emphasis is placed on primary and secondary barriers to protect personnel in adjoining areas, the community and the environment from exposure to infectious aerosols.
c. All laboratory manipulations are performed in a biological safety cabinet or other approved enclosed equipment; and personnel must wear appropriate personal protective clothing and equipment.
d. Secondary barriers include controlled access to the laboratory and a specialized ventilation system that minimizes the release of infectious aerosols from the laboratory.
e. Laboratory personnel have specific training in handling pathogenic and potentially lethal agents, and are supervised by competent scientists who are experienced in working with these agents.

**Biosafety Level 2+ (BSL2+)**

In certain circumstances, experiments with BSL2 agents are approved only at BSL2+ containment. The means that work can be done in an ordinary BL-2 laboratory but BSL3 work practices must be utilized.

In other circumstances, some existing facilities may not have features recommended for BSL3 (i.e., double-door access zone and sealed penetrations). An acceptable level of safety for the conduct of routine procedures, (e.g., diagnostic procedures involving the propagation of an agent for identification, typing, susceptibility testing, etc.) may be achieved in a Biosafety Level 2 facility, provided that:

1) exhaust air from the laboratory room is discharged to the outdoors,

2) directional airflow into the laboratory is ensured.

3) there is controlled access to the laboratory when work is in progress, and

4) recommended BSL3 work practices are rigorously followed.

However, the implementation of such modification of Biosafety Level 3 should strictly be made upon recommendation of the IBC.

**4.4.4 Biosafety Level 4 (BSL4)**

BSL4 is applicable for work with dangerous and exotic agents which pose a high individual risk of aerosol-transmitted laboratory infections and life-threatening disease. Agents with close or identical antigenic relationship to Biosafety Level 4 agents should also be handled at this level.

a. All manipulations of potentially infected materials and isolates pose a high risk of exposure and infection to personnel, the community and the environment.
b. Primary hazards to personnel include respiratory exposure to infectious aerosols, mucous membrane exposure to infectious droplets and autoinoculation.
c. Isolation of aerosolized infectious materials is accomplished primarily by working in a Class III biological safety cabinet or a full-body, or Class II biological safety cabinet with an air-supplied positive pressure personnel suit.

d. Access to the laboratory is strictly controlled.

e. The facility is generally a separate building or a completely isolated zone within a complex with specialized ventilation and waste management systems to prevent release of viable agents to the environment.

f. Laboratory personnel have specific and thorough training in handling extremely hazardous infectious agents and understand the primary and secondary containment functions of the standard and special practices, the containment equipment, and the laboratory design characteristics. They are supervised by competent scientists who are trained and experienced in working with these agents.

A summary of requirements pertaining to each of the biosafety levels (BSLs) for activities involving infectious materials is presented in the table below (adapted from WHO “Laboratory Biosafety Manual, 3rd edition”)

<table>
<thead>
<tr>
<th>Risk group</th>
<th>Biosafety Level</th>
<th>Laboratory type</th>
<th>Laboratory Practices</th>
<th>Safety Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BSL 1</td>
<td>Basic teaching, Research</td>
<td>General Microbiological Techniques</td>
<td>None; open bench work</td>
</tr>
<tr>
<td>2</td>
<td>BSL 2</td>
<td>Primary health services; diagnostic services, research</td>
<td>General Microbiological Techniques plus protective clothing, biohazard sign</td>
<td>Open bench plus BSC for potential aerosol</td>
</tr>
<tr>
<td>3</td>
<td>BSL 3</td>
<td>Special diagnostic services, research</td>
<td>As level 2 plus special clothing, controlled access, directional airflow</td>
<td>BSC and/or other primary devices for all activities</td>
</tr>
<tr>
<td>4</td>
<td>BSL 4</td>
<td>Dangerous pathogen units</td>
<td>As level 3 plus airlock entry, shower exit, special waste disposal</td>
<td>Class III BSC, or positive pressure suits in conjunction with Class II BSCs, double-ended autoclave(through the wall), filtered air</td>
</tr>
</tbody>
</table>

4.4.5 Risk groups and BSL handling requirements

Generally, the direct relationship between the Risk Group of a micro-organism and the minimum level of containment under which it can be handled can be followed eg. Containment Level 2 for Risk Group 2. However, depending on the characteristics of the micro-organism, the nature of the work and features of the exposed individuals, additional precautions may be required. Examples include:

i. Handling requirements of risk group 1 agents may be adjusted to BSL2 for high concentrations, increased pathogenic potential or aerosolization during handling.

ii. Some Risk Group 3 micro-organisms where the risk of airborne transmission is low can, in some circumstances, be handled under less stringent conditions than BSL3.
iii. BSL2+ containment rather than BSL-2 should be considered for work involving co-cultivation, virus replication studies, or manipulations involving concentrated virus or increased quantities of virus while virus production activities, including virus concentrations, require a BSL-3 facility and use of BSL-3 practices and procedures. E.g. Routine diagnostic work with BSL 2 agents such as Hepatitis B Virus, Human Immunodeficiency Virus (HIV) or Lentivirus can be done safely at BSL2 but may require a higher level of containment if large volumes or high risk procedures are used.

The assignment of an agent to a biosafety level for laboratory work must thus be based on a thorough risk assessment.

A summary of Risk Group (RG) and BSL handling requirements is presented in the table below as a general guide. (adapted from NIH Guidelines-" NIH Guidelines For Research Involving Recombinant DNA Molecules").

### Table 3 Risk groups and Biosafety levels pertaining to various agents and lab activities.

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Classification</th>
<th>Examples of Agents, Tissues and Procedures in this Risk Group (RG)</th>
<th>Handling Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Agents not associated with disease in healthy adult humans</td>
<td>Agents: <em>Escherichia coli</em>-K12, asporogenic <em>Bacillus subtilis</em>, <em>Saccharomyces cerevisiae</em>, bacteriophages, low-risk oncogenic viruses (e.g., SV 40, mouse mammary tumor virus), adeno-associated virus types 1 through 4 Tissues: Tissues from animals infected with RG1 agents Procedure: Most routine laboratory procedures involving well-characterized agents not known to cause disease in man</td>
<td>Generally, BSL1 but may be adjusted to BSL2 for high concentrations, increased pathogenic potential, or aerosolization during handling.</td>
</tr>
<tr>
<td>2</td>
<td>Agents associated with human disease which is rarely serious and for which preventive or therapeutic interventions are often available</td>
<td>Agents: <em>Salmonella</em> and <em>Legionella</em> species, enteropathogenic <em>E. coli</em>, <em>Cryptococcus neoformans</em>, adeno-viruses (including replication-defective strains), hepatitis viruses, all polioviruses, rabies virus; amphotropic and xenotropic murine and avian retroviruses Tissues: Human or other primate blood, body fluids and tissues; cell cultures of human origin Procedure: Minimum level for Category A and B recombinant DNA experiments as defined by GMAC; eg. Introducing recombinant DNA (rDNA) into RG2 agents, or DNA from RG2 or RG3 agent into nonpathogenic prokaryote or lower eukaryote; working with replication-defective RG2 virus in presence or absence of helper virus</td>
<td>Generally, Biosafety Level 2 (BSL2) but may be adjusted up or down depending upon specific conditions of use.</td>
</tr>
</tbody>
</table>
### 3. Risk Group Classification

<table>
<thead>
<tr>
<th>Risk Group</th>
<th>Classification</th>
<th>Examples of Agents, Tissues and Procedures in this Risk Group (RG)</th>
<th>Handling Requirements</th>
</tr>
</thead>
</table>
| 3          | Agents associated with serious or lethal human disease for which preventive or therapeutic interventions may be available (high individual risk but low community risk) | **Agents:** *Mycobacterium tuberculosis*, *Coxiella burnetii*, *Yersinia pestis*, *Histoplasma capsulatum*, prions, HIV, HTLV, and most arboviruses  
**Tissues:** Placental tissues from sheep infected with *C.burnetii*  
**Procedure:** Introducing rDNA into RG3 agents | Generally, **Biosafety Level 3 (BSL3)** but may be adjusted up or down depending upon specific conditions of use. |

| 4          | Agents that are likely to cause serious or lethal human disease for which preventive or therapeutic interventions are not usually available (high individual risk and high community risk) | **Agents:** Only viruses, including Lassa, Junin, Machupo, Ebola and Marburg viruses and *Herpesvirus simiae*  
**Tissues:** Specimen from any individual infected with any RG4 agent  
**Procedure:** Introducing DNA from a RG4 agent into a nonpathogenic prokaryote or lower eukaryote without demonstrating that a totally and irreversibly defective fraction of the agent’s genome is present in the recombinant | **Biosafety Level 4 (BSL4).** |

Further details can be found in:
1. WHO “Laboratory Biosafety Manual, 3rd edition”
2. GMAC guidelines: “The Singapore Guidelines for research on Genetically Modified Organisms (GMOs) “.

## 4.5 VERTEBRATE ANIMAL BIOSAFETY LEVELS

There are four animal biosafety levels, designated Animal Biosafety Level (ABSL) 1 through 4, for work with infectious agents in mammals. The levels are combinations of work practices, safety equipment and facilities for experiments on animals infected with agents which produce or may produce human infection. In general, the biosafety level recommended for working with an infectious agent in vivo and in vitro is comparable.

**Only ABSL1 and ABSL2 facilities are available in the university.**

### A. Animal Biosafety Level 1 (ABSL1)

Animal Biosafety Level 1 (ABSL-1) is suitable for work involving little or no known potential hazard to animal handling personnel and the environment.

- Work is conducted on the open bench top.
- Special containment equipment, such as a biosafety cabinet, is generally not required.
- Lab coats or gowns are worn in the animal facility.
- Bedding materials are removed in such a manner to minimize aerosol generation.
- Cages are cleaned and disinfected on a regular basis.
B. Animal Biosafety Level 2 (ABSL2)

Animal Biosafety Level 2 (ABSL2) is suitable for animal work involving inoculation of agents of moderate potential hazard to personnel and the environment. Under NUS requirement, it is also applicable to work with animals inoculated with materials of human origin (human cell lines, tissues, body fluids etc) from both commercial and non-commercial sources. Animal Biosafety Level 2 (ABSL-2) is similar to ABSL-1, but biosafety cabinets are required whenever aerosol generating procedures are conducted.

- Access to the facility is limited while the experiment is in progress.
- All personnel must receive appropriate training on the hazards associated with the research.
- All biohazardous agents used in the animal facility must be transported in a manner to minimize leakage. Agents must be transported using double containment in a labeled container.
- Medical surveillance appropriate to the animal species used shall be offered to workers prior to the initiation of the experiment.
- Protective clothing worn in the animal use areas shall not be worn outside the room.
- Work areas are disinfected at the conclusion of the experiment.
- A sink should be available for hand-washing.
- Animals must be housed in individually ventilated cages with HEPA-filtered tops.
- Procedures with high aerosol or splash potential such as inoculations and vortexing animal specimens must be conducted in a biological safety cabinet.
- Animal cages and infected animal bedding should be autoclaved or incinerated prior to disposal.
- Administration of biological agents to animals must be performed within a biosafety cabinet.

C. Animal Biosafety Level 3 (ABSL3)

Animal Biosafety Level 3 (ABSL3) is suitable for work involving BL-3 agents may cause serious or lethal disease by the inhalation route.

- All ABSL3 procedures are conducted within a biosafety cabinet and the workers may also be required to wear personal protective equipment such as a respirator.
- The lab has special engineering features to prevent a release of the BL-3 agent to the environment.
- All wastes from the ABSL-3 animal room are autoclaved before disposal.
- All pathological waste from the animal room shall be transported in a leak-proof container before disposal and eventual incineration.
- Appropriate face and respiratory protection is worn by personnel entering non-human primate housing areas.
- All experimental procedures shall be performed in such a manner so as to minimize aerosol generation.
D. Animal Biosafety Level 4 (ABSL4)

Animal Biosafety Level 4 (ABSL4) is required for all work with dangerous and exotic agents which pose a high individual risk of aerosol transmitted laboratory infections and life threatening disease.

4.6 GUIDELINES FOR DETERMINING BIOSAFETY LEVEL

The appropriate Biosafety Level (BSL) must be assigned for each research project and the associated biological agent(s). Good references for assigning BSLs can be obtained from:


2. Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition; National Institutes of Health, Department of Health and Human Services, USA. (Section II on risk assessment).


5. Biological agents: Managing the risks in laboratories and healthcare premises; (2003) Advisory Committee on Dangerous Pathogens, Department of Health, United Kingdom
4.6.1 First, identify the risk group of the biological agent and determine the BSL or ABSL assigned for the biological agent as shown in the flowcharts below. (NB. The BMBL publication and the Public Health Safety of Canada MSDS section are useful references which provides agent summary statements for some agents and information on the associated hazards and recommended precautions.)

**Flowchart to determine biosafety level**

- Does project involved live, viable cells/cell lines/bacteria/viruses/fungi/parasites?
  - Yes: Is agent classed as BSL-2 or higher by ATCC or manufacturer? (Risk group is a suitable analogue for BSL)
    - Yes: BSL-2 or higher containment required
    - No: Is material of human origin involved?
      - Yes: BSL-2
      - No: BSL-1
  - No: No live, viable material involved. Project may involve pure DNA/RNA as the sole biological agent.
    - BSL-1
4.6.2 The BSLs assigned to a particular agent assume activities typically associated with the growth and manipulations of the quantities and concentrations of infectious agents required to accomplish identification or typing. However, if the protocol requires higher concentrations, larger volumes, or practices likely to endanger personnel, the BSL assignment must be increased.

A risk assessment strategy that may be used to determine if changes in an assigned BSL are required is shown below. At each stage in the assessment, a subjective evaluation considering the infective potency of the agent involved and the gravity of the infection must be made.

BSL IDENTIFIED FOR AGENT?

- **YES**
  - STARTING BSL
    - DOES EXPERIMENT PROCEDURE INCREASE EXPOSURE POTENTIAL (ie aerosol generation)?
      - **YES**
        - INCREASE BSL
      - **NO**
        - DOES EXPERIMENT PROCEDURE USE LARGE VOLUMES (>10L) OR HIGH CONCENTRATIONS OF AGENT?
          - **YES**
            - INCREASE BSL
          - **NO**
            - SAFE / CONTAINMENT EQUIPMENT ADEQUATE?

- **NO**
4.6.3 If the BSL assignments of a biological agent is not known or there is insufficient information eg. unknown agent that may be present in a diagnostic specimen, make a preliminary determination of the biosafety level that best correlates with the initial risk assessment based on the identification and evaluation of the agent hazards. It would be prudent to assume the specimen contains an agent presenting the hazardous classification that correlates with BSL-2 unless additional information suggests the presence of an agent of higher risk. Consider routes of agent transmission and the infective potential of the agent. The strategy shown below could be adopted. At each stage, assess the best available information to make an evaluation.

```
BSL IDENTIFIED FOR AGENT?
  NO
  IS AGENT INFECTIVE TO HUMANS
    NO → BSL 1
    YES
      IS POTENTIAL FOR INFECTION HIGH?
        NO → BSL 2
        YES
          ARE THE CONSEQUENCES OF INFECTION GRAVE?
            NO → BSL 3
            YES → BSL 4
```

4.6.4 If experiments involving genetic manipulation or recombinant DNA are to be carried out, BSL assignment follows the same guidelines as the wild-type biological agent with additional considerations of possible risk associated with changes in the agent’s pathogenicity or susceptibility to current treatments as a result of the modification. For experiments involving recombinant viral vectors, BSLs assignment is dependent on the ability of the virus to infect humans.

The following sources of information are useful references that can be used to assist in assessing risk and establishing appropriate biosafety level for work involving recombinant DNA molecules:

i. GMAC guidelines: “The Singapore Guidelines for research on Genetically Modified Organisms (GMOs) “

ii. NIH Guidelines for Research Involving Recombinant DNA Molecules, National Institutes of Health, Department of Health and Human Services, USA.

4.6.5 The final selection of the appropriate biosafety level and the selection of any additional laboratory precautions would require a comprehensive understanding of the practices, safety equipment, and facility safeguards.
4.7 RISK ASSESSMENT REVIEW

All staff undertaking new lab-based research projects must carry out a project-based risk assessment and submit to the IBC for review. The form can be downloaded from OSHE website: http://www.nus.edu.sg/osh/manuals/ra_note.htm

OSHE will conduct a preliminary review of the risk assessment on behalf of the IBC. For higher risk projects or projects whereby OSHE does not have the expertise or competency to evaluate the risk assessments will be reviewed by the IBC or government agencies.

Refer to OSHE SOP (OSHE/SOP/GL/05) - Project/Task Risk Assessment for instructions on when and how to submit the risk assessments.
### NUS OH&S Management Standard Risk assessment form for lifescience laboratories

<table>
<thead>
<tr>
<th>No</th>
<th>Description/Details of Steps in Activity</th>
<th>Equipment Used</th>
<th>Hazardous Agents/ Materials used</th>
<th>Hazards &amp; Possible Accident / Ill Health &amp; Person-at-Risk</th>
<th>Existing Risk Control</th>
<th>Severity</th>
<th>Likelihood (Probability)</th>
<th>Risk</th>
<th>Additional Risk Control</th>
<th>Person Responsible</th>
<th>By (Date)</th>
<th>Additional resources needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
CHAPTER 5 ENGINEERING CONTROLS

Engineering controls are tools or equipment that provide protection to the operator and the environment when used correctly. Examples include biological safety cabinets, autoclaves, sharps containers, personal protective equipment (PPE). Correct usage is critical. Engineering controls should never be used in place of protective behavior or administrative controls.

5.1 BIOLOGICAL SAFETY CABINETS

Biological safety cabinets, also known as tissue culture hoods, are one of the most important engineering controls at NUS. Proper use provides a high level of containment that protects the operator from exposure while providing some protection from contamination of the material being handled within the work volume.

Biological safety cabinets are designed to contain aerosols generated through the use of laminar air flow and high efficiency particulate air (HEPA) filtration. Three types of biological safety cabinets (Class I, II and III) are used in laboratories. Open-fronted Class I and Class II biological safety cabinets are partial containment devices which provide a primary barrier offering significant levels of protection to laboratory personnel and to the environment when used in combination with good laboratory technique.

The **Class I biological safety cabinet** is suitable for work involving low to moderate risk agents, where there is a need for containment, but not for product protection. It provides protection to personnel and the environment from contaminants within the cabinet but does not protect the work within the cabinet from "dirty" room air.

The **Class II biological safety cabinet** protects the material being manipulated inside the cabinet (e.g., cell cultures, microbiological stocks) from external contamination. It meets requirements to protect personnel, the environment and the product. There are three basic types of Class II biological safety cabinets: Type A, Type B and 100% Exhaust. The major differences between the three types may be found in the percent of air that is exhausted or recirculated, and the manner in which exhaust air is removed from the work area.

The gas-tight **Class III biological safety cabinet**, or glove box, provides the highest attainable level of protection to personnel, the environment and the product. It is the only unit which provides a total physical barrier between the product and personnel. It is for use with high risk biological agents and is used when absolute containment of highly infectious or hazardous material is required.

It is important to note that horizontal laminar flow benches must not be utilized for work with biohazardous or chemically hazardous agents. These units provide product protection by ensuring that the product is exposed only to HEPA-filtered air. They do not provide protection to personnel or the ambient environment.

Proper operation and maintenance of a biological safety cabinet is essential for effective protection to be provided. Refer to OSHE SOP (OSHE/SOP/BS/04) “Safe Operation of Biological Safety Cabinets” for more information.
Biological safety cabinets must be certified annually by a qualified vendor.

5.2 AUTOCLAVES

Autoclaves are pressurized equipment used for heat sterilization. The autoclaving process commonly use steam heated to 121°C, at 15 psi above atmospheric pressure. Autoclaves are generally used to sterilize instruments, media and glassware, and to decontaminate biohazardous wastes prior to disposal.

As an autoclave uses saturated steam under high pressure to achieve sterilizing temperatures, proper use is important to ensure operator safety. Appropriate personal protective equipment must be worn when operating autoclaves and when handling potentially infectious materials to be autoclaved. Refer to OSHE SOP (OSHE/SOP/BS/03) “Operation of Autoclaves” for more information.

Preventative maintenance and quality control checks should be done to ensure proper performance of the equipment. All autoclaves must also be inspected by MOM authorized boiler inspectors yearly or bi-yearly depending on the capacity of the autoclave.

5.3 OTHER SAFETY EQUIPMENT

a. PPE such as gloves, coats, gowns, shoe covers, boots, respirators, face shields, safety glasses or goggles provide protection from different modes of exposure. (Refer to chapter 9).

b. Safety centrifuge cups and safety blenders are enclosed containers designed to prevent aerosols from being released during centrifugation or homogenization of infectious material.

c. Sharps containers or devices with engineered sharps injury prevention features are engineering controls used for safe handling of sharps for prevention of percutaneous injuries.
CHAPTER 6  ADMINISTRATIVE CONTROLS

Administrative controls are important in laboratory safety because they stipulate behaviors and actions that apply to and protect all members of the laboratory staff. They are also an important means of evaluating compliance with regulatory requirements.

Administrative controls include:
- placement of proper signs and labels in and about the laboratory
- medical surveillance programs,
- performance of training and
- laboratory inspections,
- development of standard operating procedures and the establishment of sound safety attitudes.

6.1 SIGNS AND LABELS

6.1.1 Biohazard Warning Sign

a. A biohazard label is required for all areas or equipment which contain biohazardous or toxic agents. The appropriate place for posting the label is at the main entrance door(s) to laboratories and animal rooms, on equipment like refrigerators, incubators, transport containers, and/or lab benches. Follow OSHE SOP (OSHE/SOP/GL/01) “Lab sign Posting and Labelling” for guidelines on labeling. Labels can be obtained from OSHE or generated using the Standard Lab Signposting Generator software posted on OSHE’s website: https://wws.nus.edu.sg/osh/labsign/default.aspx

6.1.2 Door signs

a. Each laboratory must have a sign at the entrance of the room that provides safety information to visitors and service personnel.

b. Entrance to laboratories that handle BL2 materials, human blood or other potentially infectious materials must be posted with a BL2 biohazard sign that contains the universal biohazard symbol, the legend “Biohazard” and the term BL2.

6.1.3 Internal Lab signs

a. Room signs must contain information on all laboratory hazards in use within the laboratory (carcinogens, acutely toxic agents, biohazards, radioactive materials etc.),
specific personal protective equipment (PPE) needed in the lab as well as the name and phone numbers of the principal investigator or other responsible person.

b. Biological hazard warning labels must be used to identify infectious waste containers, containers for storage of infectious materials as well as refrigerators, incubators and/or freezers where biohazards are stored. Large pieces of equipment for handling such materials (e.g., centrifuges, biological safety cabinets) must be similarly labeled.

c. Certain areas and pieces of equipment within a laboratory may also require signs. Refrigerators, freezers, cabinets and other storage facilities require the biohazard symbol whenever used to store infectious agents of Risk Group 2 or higher or human blood or blood products, unfixed tissues, cell or organ cultures, body fluids or excreta.

6.2 MEDICAL SURVEILLANCE

Medical assessment programs are provided through the University Health and Wellness Centre (UHWC) for personnel who are at risk of occupational exposure to human pathogens.

6.2.1 Immunizations

The program includes vaccinations for hepatitis B, tetanus and other agent specific immunization as deemed necessary (see section 3.9), post-exposure evaluation, treatment and follow-up.

Application forms and more details of the occupational health programs are available at: http://www.nus.edu.sg/osh/programmes/occup_health/elements.htm

6.2.2 Pregnancy

Exposure to certain infectious agents may adversely affect a fetus during pregnancy if the mother is infected with the agent. Therefore, if pregnancy is possible while you are working in an infectious disease laboratory or laboratory engaged in work with infectious agents you should consult your Principal Investigator. Women that are pregnant or become pregnant are encouraged to inform their supervisors or Principal Investigators. All staff are urged to discuss exposure issues with their principal investigators regarding associated risks of research being conducted and pregnancy. UHWC will give advice about precautions that might be necessary. Please contact medical health services at UHWC for a list of reproductive and fetal pathogens.

6.2.3 BSL-3 work

All staff and students working in BSL 3 facilities must be put on a comprehensive medical surveillance programme. The details of the programme shall be defined by the Principal Investigator in consultation with an occupational health consultant that has been appointed by the University. Medical assessments shall be done by University-appointed Health Physicians. The details of the medical surveillance programme must be submitted to the Institutional Biosafety Committee for approval.
6.3 TRAINING

Good microbiological and laboratory practices are essential for a safe work environment. The purpose of training is to provide the understanding, technical knowledge and tools to the laboratory personnel to improve his or her daily laboratory safety practices.

Under the university’s Structured Safety Training System (SSTS), it is mandatory for all staff working in labs to undergo safety trainings based on their job scope and work hazards. All lab personnel who are dealing with biological hazards are required to attend the Biological Safety Course conducted by OSHE. OSHE also provides courses for chemical and radiological safety programs. For work with vertebrate animals, all personnel are required to undergo the “Responsible Care and Use of Laboratory Animals (RCULA)” Course or the “Responsible Care and Use of Fish (RCUF)” Course.

At the minimum, all personnel working with biological materials should be trained in the following areas prior to the start of their experiments:

- Knowledge of the NUS Biological Safety Manual and SOPs
- Experimental procedures to be used
- Decontamination and spill clean up procedures
- Safe handling methods for any infectious agent and/or recombinant DNA (rDNA) they might be handling
- Proper methods for transporting infectious agents and other biohazardous materials

In addition, they should receive adequate laboratory specific training from the Principal Investigator (PI) on:

- good laboratory and animal practices as applicable
- site specific information on risks, hazards and procedures
- laboratory or environment specific BSL-2 or 3 procedures as applicable

The PI is responsible for ensuring that lab personnel in his/her laboratory receive proper training in the biohazards and controls specific to his or her laboratory and the safe conduct of the experimental procedures to be used.

6.4 INSPECTIONS

PIs should develop a system for internal audit to ensure that they have an appropriate safety management system in place for a safe laboratory working environment.

Useful inspection checklists can be found in OSHE’s website: http://www.nus.edu.sg/osh/manuals/checklist.htm

1. OSHE’s generic checklist: “NUS Self-Help Safety + Health Starters’ Checklist - Part 1”

2. Checklist based on WHO “Laboratory Biosafety Manual, 3rd edition”. This checklist has been adapted to the NUS context and is intended to assist in assessments of microbiological laboratory safety.
Inspections and audits are also carried out periodically at the levels of the Faculty Safety Officer, Departmental Safety Committee, Faculty Safety Committee or OSHE.

6.5 STANDARD OPERATING PROCEDURES (SOPS)

Standard Operating Procedures, or SOPs, are developed to establish a consistent, repeatable method for performing common, repetitive tasks. Such tasks have been performed many times and most of the common errors and unsafe practices have been discovered and corrected. The set approach and methods presented in the SOP ultimately enhance both the efficiency and the safety of the procedure.

SOPs should be kept updated. Laboratory personnel should be alert for ways to improve the SOPs in use and to ensure that demonstrated improvements are incorporated into the documents.
CHAPTER 7 GOOD MICROBIOLOGICAL TECHNIQUES

Human error, poor laboratory techniques and misuse of equipment cause the majority of laboratory injuries and work-related infections. This chapter provides a compendium of methods, practices and technical SOPs that are designed to avoid or minimize the most commonly reported hazards.

7.1 PRUDENT PRACTICES AND GOOD TECHNIQUE

a. Human factors and attitudes are important elements for considerations of biosafety in the laboratory. Factors compromising safety include:

   – The lack of accident perception
   – Inflexibility of work habits, that tend to preclude preventative action when an accident situation is recognized
   – Working at an abnormal rate of speed
   – Intentional violations of regulations
   – Performance of routine procedures such as diluting and plating cultures is the most frequent task being performed at the time of laboratory accidents.
   – Working when one is very tired
   – Working at a disorganized and crowded laboratory bench

b. Each employee working with biohazardous agents must be aware of the importance of the proper attitude in preventing accidents in the laboratory.

c. Prudent practices and good technique are of primary importance in laboratory safety. Both are based on sound technical knowledge, experience, common sense and an attitude of courtesy and consideration for others. They are spelled out in detail in section 7.3 Recommended work practices.

d. At a minimum, the Seven Basic Rules of Biosafety should be the basis of any personal laboratory work ethic:

   • Do not mouth pipette.
   • Manipulate infectious fluids carefully to avoid spills and aerosol production.
   • Use needles, syringes and other "sharps" carefully to avoid self-inoculation; and dispose of sharps in puncture-resistant and leak-proof containers.
   • Use personal protective equipment such as laboratory coats, gloves and eye protection.
   • Wash hands following all laboratory activities, following the removal of gloves, and immediately following contact with infectious materials.
   • Decontaminate work surfaces before and after use and immediately after spills.
   • Do not eat, drink, store food, apply cosmetics or smoke in the laboratory.
7.2 HOUSEKEEPING AND PERSONAL HYGIENE

Well-defined housekeeping procedures and schedules are essential in reducing the risks associated with working with pathogenic agents and leads to safe accomplishment of the research program.

Injuries and exposures are more likely to occur in poorly maintained, disorderly work areas than in neat, well-kept spaces. For those with the luxury of unshared work space, personal safety is greatly enhanced by keeping that space neat, clean and orderly. More often than not, work space is shared with others and good personal housekeeping in the laboratory becomes a cardinal rule. Leaving behind a jumbled mess after work exposes others to risks of which they may have little or no knowledge. In shared spaces, consideration for others and cleaning up after oneself is essential for maintaining a safe working environment.

7.2.1 Objectives of Housekeeping
a. To provide an orderly work area conducive to the accomplishment of the research program
b. To get rid of physical clutter that could interfere with the activities of laboratory personnel at a critical moment in a potentially hazardous procedure
c. To provide a work area that is free of physical hazards injury or background contamination
d. To prevent the accumulation of materials from current and past experiments that constitutes a hazard to laboratory personnel.
e. To ensure that locations of various hazards will be known
f. To prevent the creation of aerosols of hazardous materials
g. To prevent the accumulation of organic debris that may:
   - harbor microorganisms that are potentially threats
   - enhance the survival of microorganisms inadvertently released in experimental procedures.
   - retard penetration of decontaminates.
   - be transferable from one area to another on clothing and shoes.
   - With sufficient buildup, become a biohazard as a consequence of secondary aerosolization by personnel and air movement
   - cause allergenic sensitization of personnel (e.g., to animal dander).

7.2.2 Housekeeping procedure
a. Housekeeping tasks should be carried out by lab personnel on an individual basis for their immediate work areas and on a cooperative basis for areas of common usage.

b. Housekeeping chores, both individual and cooperative, should be performed on a periodic basis. Routine housekeeping will provide a work area free of significant sources of background contamination.

c. Areas for which housekeeping should be carried out include but are not limited to:
   ◆ Corridors ◆ Lab Entrances and Exits ◆ Aisles ◆ Work Benches ◆ Floors ◆ Lab Equipment Cleanup ◆ Biological Safety Cabinets ◆ Lab reagents storage areas ◆ Refrigerators ◆ Cold Rooms ◆ Deep Freezers ◆ Incubators ◆ Waste Storage areas ◆ Cryogenic tanks ◆ Work Surfaces ◆ Lab SOPs
d. Housekeeping tasks should be assigned to personnel who are knowledgeable of the lab environment.

e. Keeping a housekeeping tasks schedule helps to ensure that work in the lab will not be interrupted.

f. PIs should carry out periodic inspections of the lab to assure compliance.

7.2.3 Good housekeeping practices

a. All areas of the laboratory must be kept clean and orderly. Keep the area as clean as the work allows throughout the day and all working surfaces should be decontaminated and cleaned at the end of each work day.

b. Stock solutions of disinfectants e.g. 70% ethanol, 10% bleach should be maintained at each bench top and biological safety cabinet work area.

c. Shared workbenches or lab space should be cleaned prior to leaving it for the next user as a common courtesy.

d. Keep floors clean and free of tripping hazards or clutter.

e. Keep stairways, hallways, passageways/aisles and access to emergency exits dry and free of obstruction.

f. Store items so they do not block access to the fire extinguisher(s), safety equipment, electric panel boxes, or other emergency items such as an eyewash or safety shower.

g. Do not allow combustible material such as paper, cardboard boxes, or pallets to accumulate. Do not place these materials in hallways.

h. Minimize extraneous supplies and equipment. To the extent possible, restrict all work areas to only those items needed for the immediate experimental procedure.

i. Do not clutter fume hoods or biosafety cabinets with unnecessary items. The safety of these workspaces and the ventilation provided is compromised when excessive items and equipment are kept in this space.

j. Label all personal materials clearly for ease of identification.

k. Do not let materials accumulate. Dispose of materials, chemicals, and equipment that are no longer needed.

l. Store chemicals in designated locations- Store flammable liquids in a flammable liquids cabinet. Do not store acids above shoulder height or in unprotected metal cabinets. Store water reactive materials away from water sources, such as sprinkler systems and sinks. Chemical products should be returned to their proper place after use.
m. Maintain a chemical inventory. Store only the amount of material reasonably needed. Do not over-purchase. Replace chemicals that have reached their expiration date.

n. Do not store frequently used or heavy items on top shelves. Locate supplies used daily close to the work area and place items used periodically in nearby storage areas.

o. Shelves should be equipped with doors or lips to prevent items from falling.

p. Keep an adequately stocked spill kit in the work area. Clean up all small spills immediately. Know what to do in the event of a hazardous material spill and take appropriate action immediately.

q. Always restrain compressed gas cylinders.

r. Dispose of all laboratory wastes (e.g., radioactive, chemical, biohazardous and sharps wastes) properly. Ensure waste containers are placed near the point of use and are adequate of size. Do not over fill the collection containers.

s. Decontaminate all infectious materials, contaminated plasticware/glassware, and contaminated waste prior to washing or disposal.

t. Periodic inspections should be carried out by the PI

7.2.4 Personal hygiene

a. Personal hygiene is an important means to enhance personal protection in the laboratory.

b. Personal protective equipment such as lab coats and gloves must be worn in the laboratory work areas and removed prior to leaving the laboratory after lab activities. Do not wear contaminated or potentially contaminated lab coats outside the laboratory.

c. All lab coats should be laundered regularly by sending to a lab coat laundering service. Do not bring lab coats home to wash!

d. Wash hands with antiseptic soap immediately after removing gloves or on contact with infectious agents. This ensures that contamination of the hand by glove micropuncture or prior exposure is neutralized before being spread.

e. Do not eat, drink or smoke in the lab. Do not store food or drinks in laboratory areas such as cold rooms or lab refrigerators.

f. Do not perform personal cosmetic tasks such as applying makeup, manipulating contact lenses, trimming fingernails, or combing hair. These activities provide opportunities for exposure to infectious agents.
7.3 RECOMMENDED WORK PRACTICES

Recommended work practices detailed in the following standard operation procedures (SOPs) are aimed at providing guidance for the use and manipulation of biohazards commonly found in laboratories where biological work is performed are [http://www.nus.edu.sg/osh/manuals/sop.htm#biological](http://www.nus.edu.sg/osh/manuals/sop.htm#biological)

a. Safe handling of cryogenic liquids
   OSHE SOP (OSHE/SOP/GL/09)

b. Transport and transfer of biological agents
   OSHE SOP (OSHE/SOP/BS/02)

c. Safe handling of sharps
   OSHE SOP (OSHE/SOP/BS/07)

d. Safe handling of mammalian cell cultures
   OSHE SOP (OSHE/SOP/BS/08)

e. Safe handling of ethidium bromide
   OSHE SOP (OSHE/SOP/BS/09)

f. Safe handling of biological materials.
   OSHE SOP (OSHE/SOP/BS/10)

g. Safe use of laboratory equipment
   OSHE SOP (OSHE/SOP/BS/11)
CHAPTER 8 DECONTAMINATION AND DISPOSAL

Materials containing infectious agents must be decontaminated prior to reuse or disposal. The aim of decontamination is to as to reduce or eliminate the potential of infectious agents to cause disease.

Decontamination is a process that removes and/or kills microorganisms. It can be achieved by sterilization or disinfection. These terms are used synonymously but are distinct from one another:

Sterilization is the process that kills and/or removes all classes of microorganisms and spores.

Disinfection is a physical/chemical means of killing microorganisms, but not necessarily spores.

A disinfectant is a chemical or mixture of chemicals used to kill microorganisms, but not necessarily spores and is usually applied to inanimate surfaces or objects.

An antiseptic is a substance that inhibits growth and development of microorganisms without necessarily killing them and is usually applied to body surfaces.

8.1 METHODS OF DECONTAMINATION

8.1.1 Heat sterilization
a. The application of heat, either moist or dry, is recommended as the most effective method of sterilization.

b. Dry heat at 160°C to 170°C for periods of two to four hours is suitable for destruction of viable agents on an impermeable non-organic material such as glass, but is not reliable in even shallow layers of organic or inorganic material that can act as insulation.

c. Incineration is another use of heat for decontamination. Incineration will burn any organism to ash. It serves as an efficient means of disposal for human and animal pathological wastes.

d. A widely-used method for heat sterilization is the autoclave. Autoclaves commonly use steam heated to 121°C, at 15 psi above atmospheric pressure. Autoclaving is the most convenient method of rapidly achieving sterility under ordinary circumstances as moist heat causes the denaturation of proteins at lower temperatures and shorter times than dry heat.

Autoclaves can sterilize all items that are heat stable. Proper autoclave treatment will inactivate all fungi, bacteria, viruses and also bacterial spores, which can be quite resistant. Solid surfaces are effectively sterilized when heated to 121°C, at 15 psi for at least 15 minutes. Liquids and instruments packed in layers of cloth require a much longer time to reach a sterilizing temperature.
Position the items in the autoclave in a manner that allows steam to penetrate into all the items. Materials in tightly sealed or stoppered containers may not be effectively decontaminated and may become dangerously pressurized causing injury when removed from the autoclave. Items containing chemicals such as phenol or chloroform should not be placed in an autoclave. Caution must also be exercised when handling hot solids and liquids. Laboratory personnel should be aware of the safe and proper operation of autoclaves. See OSHE SOP (OSHE/SOP/BS/03) – “Operation of autoclave”.

### 8.1.2 Liquid decontaminants

a. Although heating provides the most reliable way to rid objects of all infectious agents, it is not always appropriate, because it will damage heat-sensitive materials such as biological materials.

b. Liquid chemical decontaminants can be used for surface decontamination and, at sufficient concentration, as decontaminants of liquid wastes for final disposal in sanitary sewer systems. However, proper consideration must be given to such factors as temperature, contact time, pH, the presence and state of dispersion, penetrability and reactivity of organic material at the site of application in order for decontamination to be effective.

c. Most chemical decontaminants are not sterilizers and should not be relied on to destroy all organisms on a surface or piece of equipment. Simple wiping of the surface to be decontaminated with a liquid disinfectant does not kill all the organisms present.

d. Liquid decontaminants can be categorized as halogens, acids and alkalis, heavy metal salts, quaternary ammonium compounds, phenols, aldehydes, ketones, alcohols, and amines and are commonly available in a variety of trade names.

e. Alcohols such as ethanol or isopropyl alcohol in concentrations of 70-90% are good as general use disinfectants. They are effective against bacteria and lipoviruses, less active against nonlipid viruses and not effective against bacterial spores. However, they are not significantly harmful to personnel using them.

f. Halogens: Chlorine-containing solutions commonly available as household bleach are active against bacteria, fungi and viruses. At higher concentrations and extended contact times, chlorine can inactivate bacteria spores as well. However, they are corrosive to metals and tissues. Iodophors, which are iodine containing formulations, are active against vegetative forms of bacteria, fungi and viruses. There are non-toxic to humans and are generally used as antiseptics and in surgical soaps.

g. Phenolic-based compounds are effective decontaminants against some viruses, fungi, and vegetative bacteria, including rickettsiae. Phenolics are not effective in ordinary use against bacterial spores. A common phenolic disinfectant is Lysol™.

h. Quaternary Ammonium Compounds are cationic detergents that are strongly surface-active. They are only effective against vegetative bacteria and lipid-
containing viruses. They are easily inactivated by the presence of excess organic material.

### 8.1.3 Vapors and Gases

a. Chemical decontaminants that are gaseous at room temperature are useful as space-penetrating decontaminants. When employed in a closed system and under controlled conditions of temperature and humidity, excellent decontamination can result. The most common ones are formaldehyde and ethylene oxide.

b. Vapor and gas decontaminants are primarily useful in decontaminating biological safety cabinets, bulky or stationary equipment that resists penetration by liquid surface decontaminants; instruments and optics that may be damaged by other decontamination methods; rooms, buildings and associated air-handling systems and air filters.

c. **Formaldehyde** as a gaseous sterilizing agent is prepared by heating of solid paraformaldehyde. Formaldehyde in solution form as formalin is used as a fixatives and liquid sterilizing agents, provided that the immersion time is sufficiently long. Formaldehyde is effective against all bacteria, viruses and bacterial spores and is commonly used for the decontamination of BSCs. However, it is toxic and potentially carcinogenic so personnel exposure must be limited and considerable care is required when handling, storing and using formaldehyde.

d. **Ethylene oxide** use is very limited and is generally used in surgical and clinical areas and for sterilizing disposable medical devices. Ethylene oxide however is highly flammable and is mutagenic. It requires a longer time to sterilize than any heat treatment and the process also requires time for aeration post sterilization to remove toxic residues.

e. Avoid inhalation of vapors of formaldehyde and ethylene oxide. Stock containers of these products should be air-tight and kept in properly ventilated chemical storage areas.

### 8.1.4 Radiation

a. Sterilization can be achieved using radiation such as gamma rays, X-rays or ultra-violet (UV) radiation.

b. **Gamma rays** and **X-rays** are ionizing radiation active against bacteria, viruses and spores and are commonly used for sterilization of prepackaged disposable medical devices, such as syringes, needles. Gamma rays are very penetrating and require bulky shielding operator safety. X-rays are less penetrating but require less shielding. Ionizing radiation is not a practical tool for the lab.

c. Ultraviolet light irradiation is useful only for sterilization of surfaces and some transparent objects. UV irradiation is routinely used to sterilize the interiors of biological safety cabinets but has been overrated as an effective decontamination method. UV has very low penetration and is ineffective in shaded areas, including areas under dirt. In addition, due to its damaging and harmful effects, the use of UV for decontamination is increasingly discouraged.
8.2 SELECTING CHEMICAL DISINFECTANTS

a. Microorganisms exhibit a wide range of resistance to inactivating agents. Most vegetative bacteria, fungi and lipid-containing viruses are relatively susceptible to chemical decontamination whereas non-lipid containing viruses and bacteria with a waxy coating e.g. tubercle bacillus have mid-range resistance. Spores are most resistant to inactivation.

b. No single chemical disinfectant or method is effective for decontamination in all situations. The choice of chemical disinfectants should be made after consideration of the following factors:
- Target organism
- Highest concentration of organisms
- Amount of extraneous organic material present
- The material to be decontaminated
- Potential toxicity of disinfectant
- Activity of disinfectant

8.3 GUIDELINES FOR USE OF COMMON DECONTAMINANTS

Decontaminants/ disinfectants should be used in accordance with manufacturer’s directions in order for effective decontamination to occur.

A decontaminant selected on the basis of its effectiveness against organisms on any range of the resistance scale will be effective against organisms lower on the scale ie. disinfectants that effectively control spore forms can be assumed to inactivate any other organism.

High titers of microorganisms or presence of large amounts of organic materials such as agar, proteinaceous nutrients, and cellular materials can effectively retard or chemically bind the active moieties of chemical disinfectants. Such interference with the desired action of disinfectants may require higher concentrations and longer contact times.

Ineffectiveness of a decontaminant can also occur as a result of failure of the decontaminant to contact the microorganisms. Microorganisms under spots of grease, rust, dirt or dry areas of tiny bubbles on the surface of the item will not be contacted by the decontaminant.

The more active the disinfectant, the more likely it will possess undesirable characteristics such as corrosiveness. Particular care should be observed when handling concentrated stock solutions of disinfectants. Personnel should be aware of safety precautions to follow and appropriate personal protective equipment to use when handling them.

**Alcohol**

a. Ethanol or isopropanol should be used at concentrations of around 70 % (v/v) in water. They have less effective germicidal properties at higher or lower concentrations.
b. A contact time of ten minutes is generally employed in efficacy tests with disinfectants. Due to the high evaporation rate of alcohols, repeated applications may be required to achieve the required ten minute contact time for decontamination.

c. Isopropyl alcohol is generally more effective against vegetative bacteria; ethyl alcohol is a more virucidal agent.

d. 70% ethanol can be used on skin, for disinfecting work surfaces and for swabbing/soaking small pieces of equipment.

e. Alcohols denature proteins and are somewhat slow in germicidal action.

f. Alcohols are not very caustic and are not significantly harmful to personnel using them.

i. As alcohols are flammable, do not use them near open flames.

j. They should be stored in proper containers to prevent evaporation as they are volatile.

**Bleach**

a. Bleach is a broad spectrum disinfectant used in many labs here. It is active against bacteria, fungi and viruses. At higher concentrations and extended contact times, bleach can inactivate bacteria spores as well.

b. Guidelines for use:
Liquid wastes can be decontaminated with 1:10 dilution of household bleach (ie. one part bleach to 9 parts liquid) for 30 minutes. After decontamination, liquid waste can be disposed of in the public sewer with copious amount of water provided no other hazardous materials are present (e.g., chemicals and/or radioactive materials).

c. Effective working concentrations of bleach for disinfection are:

   “Dirty” conditions (e.g. presence of large amounts of organic matter) - Sodium hypochlorite solution containing 0.5% available chlorine. (Also equivalent to 5 g/litre or 5000 parts per million)

   “Clean” conditions (e.g. for disinfecting surfaces, rinsing protective clothing) - Sodium hypochlorite solution containing 0.1% available chlorine. (or 1 g/litre or 1000 parts per million)

Domestic household bleach is typically made of 5.25% (52,500 ppm). Sodium Hypochlorite but can range from 3-6%. Industrial bleach solutions have a higher concentration (10-15% Sodium Hypochlorite). They have to be diluted accordingly to obtain the working concentration.
d. The efficacy of a bleach solution to act as a disinfectant is considerably reduced:
   – by presence of organic material (e.g. Serum and protein in blood);
   – with storage;
   – by exposures to high temperature, oxygen and sunlight

e. Hypochlorite concentrations drop over time due to relative instability of the active chlorine component. As a general guide, solutions with high levels of organic matter should be changed at least daily, while those with less frequent use may last for as long as a week.

f. Chlorine solutions can also be made from:

   *Bleach powder* - Chlorine compounds available in powder form (e.g. calcium hypochlorite or chlorinated lime) or

   *Chlorine-releasing tablets*-(Sodium dichloroisocyanurate, or commercial preparations e.g. “Presept” or “Haz-Tab” tablets)

   Solutions can be made fresh for use when required. Follow the manufacturer's instructions for preparation and usage of working solutions.

g. Many by-products of chlorine can be harmful to humans. Avoid indiscriminate use of chlorine-based disinfectants and follow safety precautions when using bleach:
   – Chlorine gas is highly toxic. Store and use bleach in a well-ventilated area.
   – Household bleaches containing 5% sodium hypochlorite is an irritant. More concentrated bleaches contain 10-15% sodium hypochlorite is corrosive. Avoid direct contact with skin and eyes. Skin contact will produce caustic irritation or burns. Splash goggles/face shield and protective gloves are recommended PPE.
   – Hypochlorite and other chlorine-releasing disinfectants may cause corrosion of metals and this must be taken into account when decontaminating equipment.
   – Do not mix bleach with other chemicals. For example, bleach mixed with acids or ammonium-containing materials rapidly generates the toxic chlorine and chloramine gas respectively. Check the incompatibility chart of bleach.

**8.4 BIOLOGICAL WASTE DECONTAMINATION AND DISPOSAL**

Depending on the category, biohazardous wastes in the university is either sterilized and disposed off as regular wastes, or collected by licensed biowaste collectors.

The decontamination and disposal procedure of different categories of biohazardous wastes is detailed in OSHE SOP (OSHE/SOP/BS/01) on “Biological Waste disposal”.

51
CHAPTER 9 PERSONAL PROTECTIVE EQUIPMENT

Personal Protective Equipment (PPE) are often used in combination with biological safety cabinets and other containment equipment to protect personnel from contact with biohazardous materials, animals, other materials such as toxic and corrosive chemicals, heat, cold, fire and other physical hazards. Appropriate PPE may also protect the experiment from contamination.

The extent and kind of clothing and equipment to be selected for any particular activity depends upon the research operations and levels of risk associated with the research. It should be understood that while PPE serves as a second line of defense. Good laboratory techniques, procedures and appropriate laboratory equipment are the primary barriers against potential exposure to hazardous agents.

9.1 LABORATORY CLOTHING

9.1.1 Laboratory Clothing

a. Laboratory clothing includes laboratory coats, scrub suits, and gowns.
b. The clothing should be durable and provide protection of the skin from exposure to harmful agents.
c. Long sleeved garments should be used to minimize the contamination of skin or street clothes and to reduce shedding of microorganisms from the arms. If proper precautions are not taken, contaminated clothing may carry infectious materials outside the laboratory and into other work areas, cafeterias, or the home.
d. In procedures where splashes may occur, the lab clothing must be resistant to liquid penetration to protect clothing from contamination.
e. If the lab clothing is not disposable, it must be capable of withstanding sterilization, in the event it becomes contaminated.
f. Change the lab clothing as soon as feasible whenever it is contaminated, soiled or torn. Upon overt exposure to agents at all level of risk, immediately decontaminate the lab clothing and change into a clean piece.
g. Remove protective clothing and leave it in the laboratory before leaving for non-laboratory areas. Protective clothing worn within the laboratory should not be worn outside the facility to the library, cafeteria, or other places accessible to the public.
h. Do not take protective clothing home to launder. They should be discarded in the laboratory, disinfected or laundered by laundry services engaged by the department. All contaminated clothing should be decontaminated before being sent to the laundry or discarded. Treat contaminated areas with an appropriate disinfectant. Lab coats with extensive contamination may be placed in a biohazard bag and autoclaved.
i. Provisions should be made for PPE to be provided to visitors and maintenance or security personnel, if applicable.
9.1.2 Shoes

a. Shoes worn in the laboratory must be closed-toe. Do not wear sandals. Protective shoes are required for certain work activities.

b. When working with infectious agents it is advisable to wear shoe covers, which can be decontaminated (autoclaved) before disposal, over street shoes.

c. For work in tissue culture laboratories it may be necessary to change from street shoes to specific laboratory shoes for protection of cultures from contamination.

d. In certain animal facilities personnel are required to wear overshoes or shoe covers to protect the animals in containment areas. Similarly, people who work with animals and do cage washing are required to wear protective shoes.

9.1.3 Gloves

a. Gloves must be worn when working with biohazardous and/or toxic materials and physically hazardous agents. Breaks in the skin barrier of the hand (damaged cuticles, scrapes, micro-cuts, dermatitis, etc.) are common. Disposable (single use) gloves provide a barrier between infectious agents and the skin.

b. Gloves should be comfortable and of sufficient length to prevent exposure of the wrist and/or forearm. When working with hazardous materials, the lower sleeve and the cuff of the laboratory garment should be overlapped by the glove. A long sleeved glove or disposable arm-shield may be worn for further protection of the garment.

c. Gloves may be fabricated of cloth, leather, natural and synthetic rubbers, or plastics depending on the hazards involved and the activities to be conducted. Consult the MSDS of materials handled to select the appropriate type of glove.

d. Check gloves for visible tears before use.

e. Disposable gloves must not be washed or reused.

f. Change gloves periodically and when soiled. Gloves must be disposed of when contaminated, removed when work with infectious materials is completed. Always wash hands after removing gloves.

g. Gloves must never be worn outside the laboratory. Gloves shall be removed and hands washed before exiting the laboratory.

h. Do not touch door handles, elevator buttons, telephones, computers or other clean surfaces or items with gloved hands.

i. Use the one glove method, or an appropriate secondary container, when transporting materials through common use areas.

j. Normal disposable gloves will not prevent needle sticks or other percutaneous injuries.

k. Surgical grade Kevlar gloves and stainless steel mesh gloves can provide protection against slices, scratches or cuts, but will not prevent direct puncture or needlestick injuries. Neoprene and other abrasive resistant gloves are cut resistant, but significantly reduce dexterity.
l. Temperature-resistant gloves must be worn when handling hot material, dry ice or materials being removed from cryogenic storage devices.

m. Chemical resistant gloves such as nitrile gloves must be worn when handling corrosive chemicals.

n. In some instances double gloving may be appropriate e.g. Work with highly infectious agents or cleaning-up of spills.

9.2 FACE AND EYE PROTECTION

a. Face protection are required for preventing splashes, sprays or splatters of infectious or other hazardous materials to the face.

b. Face protection devices includes goggles or safety glasses with solid side shields in combination with masks, chin length face shields or other splatter guards.

c. Shields should cover the entire face, permit tilting back to clean the face if desired, and be easily removed in the event of an accident.

d. Contact lenses do not provide eye protection. It is recommended that contact lenses not be worn when working around chemicals, fumes, and other hazardous material and dust particles since these items may become trapped in the space between the contact lens and the cornea. When contact lenses are worn, eye protection, such as tight fitting goggles, must be worn.

9.3 RESPIRATORS

a. Infection via the respiratory system can occur by inhalation of respirable-sized aerosols of less than 5um.

b. HEPA filtered respirators (air purifying or powered air purifying) are worn to prevent exposure to potentially infectious aerosols. However, engineering controls, such as the use of biological safety cabinets, should always be considered as a first line of defense against respiratory infection when working with infectious organisms. Respirators should only be considered as a second line of defense after feasible engineering controls have been put into place and additional controls are still needed.

c. Personnel who require respiratory protection must enroll in the NUS Respiratory Protection Program before using a respirator. Contact the Faculty Safety Officers for assistance in selection of equipment and proper usage.

d. The use of respirators requires medical clearance and fit-testing by UHWC. Please submit the form for “Request for occupational health related medical assessment” to OSHE available on OSHE website: http://www.nus.edu.sg/osh/forms.htm
CHAPTER 10 EMERGENCY RESPONSE TO EXPOSURE

10.1 EXPOSURE MANAGEMENT

An "exposure incident" is a contact with potentially infectious materials via eye, mouth, other mucous membrane, respiratory tract via inhalation, non-intact skin, or parenteral contact.

If a known or potential exposure incident has occurred, remove gloves and treat the affected area immediately. General actions to take following exposure incidents are as follows:

10.1.1 Percutaneous Injury

a. Percutaneous injuries include puncture wounds, needlestick injuries, cuts, abrasions, animal bites/scratches.

b. For cuts and abrasions, wash area with soap and water for 1–2 minutes.

   For injuries with contaminated sharps and needlesticks, wash the affected area with antiseptic soap and warm water for 15 minutes. Apply an appropriate skin disinfectant.

c. Cover injured area with clean gauze.

d. Obtain medical attention as necessary for cuts and abrasions. Obtain prompt medical attention if injuries involve contaminated sharps and needlestick exposures to human material (blood, body fluids, tissues); as well as animal bites and scratches.

e. Report injury to your supervisor and complete accident/incident report (Section 10.4). Report cause of injury and organisms involved (if any).

f. Keep all medical records and accident/incident reports properly.

10.1.2 Splash to Face/Eye

a. Flush affected area in an emergency eyewash for 15 minutes.

b. Forcibly hold eyes open to ensure effective wash behind both eyelids.

c. Obtain prompt medical attention. Bring along safety data sheets or other source of contaminant information to the physician’s office.

d. Report injury to your supervisor and complete accident/incident report (Section 10.4)

e. Keep all medical records and accident/incident reports properly.

10.1.3 Contact on skin

a. Remove any contaminated clothing, jewelry, etc.
b. Wash skin thoroughly with water using a drench hose, emergency shower or faucet.

c. Take care not to break the skin.

d. Flush mucous membranes with soap and water.

e. Obtain medical attention if necessary. Bring along safety data sheets or other source of contaminant information to the physician's office.

f. Report injury to your supervisor and complete accident/incident report (Section 10.4).

g. Keep all medical records and accident/incident reports properly.

10.1.4 Ingestion of potentially infectious material

a. Remove protective clothing if any.

b. Seek medical attention. Provide information of material ingested and circumstances of the incident.

c. Report injury to your supervisor and complete accident/incident report (Section 10.4).

d. Keep all medical records and accident/incident reports properly.

10.1.5 Aerosol Exposure

a. Hold your breath and immediately vacate the area.

b. Remove Personal Protective Equipment (PPE) carefully. When removing PPE make sure to turn the exposed areas inward. Wash hands well with soap and water.

c. Inform the PI and biosafety officer immediately.

d. Post spill sign on lab entrance and evacuate the lab for at least 30 minutes to allow aerosols to settle.

e. Carry out appropriate decontamination procedure (see section 8.3) after the appropriate time. The lab must be cleared for reentry by the PI, biosafety officer or OSHE depending on the extent of decontamination.

f. Seek medical attention. Provide information of material inhaled and circumstances of the incident.

f. Report injury to your supervisor and complete accident/incident report (Section 10.4).

g. Keep all medical records and accident/incident reports properly.
10.2 MEDICAL ASSISTANCE

FOR EMERGENCY CARE DIAL 995 FOR AN AMBULANCE

In the event of exposure to biological materials/infectious agents resulting in possible infection, disease or illness, please call at the University Health and Wellness Center (UHWC) for a medical assessment during opening hours or proceed to the Accident & Emergency Units of Hospitals after office hours.

University Health and Wellness Centre locations:

1. YIH Main Clinic, NUS
   Level 4, Yusof Ishak House
   Kent Ridge Crescent
   Tel: x2880 (65162880)

   Consultation Hours:
   Monday - Thursday
   8.30am to 6.00pm
   (Closed 12.30pm to 1.30pm)
   Last registration at 5.40pm

   Friday
   8.30am to 5.30pm
   (Closed 12.30pm to 1.30pm)
   Last registration at 5.10pm

   For enquiries on NUS Occupational Health Programme, contact:
   Ms Doris Yek,
   Occupational Health Nurse
   X7333 (6516 7333)
   email: oshyll@nus.edu.sg

2. Bukit Timah Campus (BTC)
   Block B, MPA-02-01
   (level 2 MPA block).
   Tel : 6467 5492

   Consultation Hours
   Mondays, Wednesdays & Fridays
   8.30am to 10.30am

The nearest hospital in the vicinity of the university is:

National University Hospital
5 Lower Kent Ridge Road
Singapore 119074

Main Line (24hr General Enquiries) Tel: (65) 6779 5555
Emergency Tel: (65) 6772 5000
10.2.1 Medical Emergencies

If an injury is a medical emergency the lab personnel should be taken to the National University Hospital Accident and Emergency Department where initial assessment and emergency treatment will be provided.

a. CALL 995 for an ambulance in any life-threatening situation requiring immediate medical attention.
b. Provide the following information:
   - Type of emergency and any injuries;
   - Injured person’s location, if applicable;
   - Your name, location and telephone number;
c. Remain on line until the dispatcher disconnects the call.
d. Check for hazards before entering location where emergency occurred.
e. Initiate lifesaving measures if required and only if you are trained to do so.
f. Do not move injured persons unless there is an immediate danger of further harm.
g. Keep injured person warm.
h. Remain with victim until medical assistance arrives.

10.2.2 Laboratory-acquired illness

If a laboratory personnel who work or handle infectious materials sustain a laboratory acquired illness:

a. Seek medical assistance immediately. Provide information on the infectious agent or material used in the laboratory.
b. Report the illness to the Principal Investigator.
c. Submit a report to OSHE via the online NUS Accident and Incident Reporting System (AIRS).
d. Consult with the medical care provider before to returning to work.

PIs should also assess the risk of exposure posed to fellow lab workers and other persons encountered by the affected personnel and determine whether medical assessments are appropriate.

10.2.3 Non-Emergency Medical Treatment

If non-emergency medical treatment is required following exposure,

a. The medical treatment for the injury should be obtained as soon as possible following the injury.
b. Bring along with you any safety data sheets or information of any contaminant you were exposed to. If an incident report had been made prior, present it to the attending doctor.
10.3 SPILL RESPONSE

10.3.1 Spill response plan

In any spill scenario, the priority of actions should follow the order of People-Environment-Property. The highest priority is to provide aid to injured personnel and prevent spill area access to others. Following that, action should be taken to prevent environmental damage if it can be done without endangering personnel. An example would be to prevent a biomaterial from spreading by placing an absorbent in the flow path. Finally, action to prevent property damage should be taken if it can be done safely.

The basic rules for responding to a spill are:

a. Immediately report all spills and injuries.

b. Tend to the injury/ injured - Seek immediate medical assistance.

c. Isolate the spill - evacuate the immediate spill area or the entire room in the case of an aerosolizing (splashing or spraying) spill or a spill of volatile material; prevent others from entering the spill area with barricades or, if necessary, a sentry.

d. Contain the spill - place absorbent material around, on or in the flow path of the spilled material only if it can be done safely.

e. Proceed with cleanup – only if trained and properly equipped with personal protective equipment to clean up and disinfect spill safely. Otherwise, wait for assistance of trained spill clean-up personnel / spill response teams.

10.3.2 Biological Spill Kit

A biological spill kit is an essential safety item for labs working with infectious or potentially infectious agents classified at Biosafety Level 2 or higher and for groups working with large volumes (> 1 liter) of Biosafety Level 1 material.

A basic spill kit should include:

a. Concentrated disinfectant appropriate for the infectious agent handled in the lab e.g. household bleach.

b. Spray bottle for making dilutions of disinfectant

c. Forceps, autoclavable broom and dust pan, or other mechanical device for handling sharps

d. Paper towels or other suitable absorbent

e. Biohazard autoclave bags for contaminated items

f. Utility gloves and medical examination gloves

g. Face protection (eye wear and mask, or full face shield)

Each spill kit should be tailored to meet the specific needs of each lab. It is the responsibility of the PI to ensure a well thought out spill kit is readily available and maintained.
One-time-use spill kits are also available from several safety supply sources. These kits contain everything needed for cleaning up and disposing of biohazard spills.

Laboratories should have a supply of biological spill kits and trained laboratory staff that knows how to use them.

The spill kits should be strategically located close to the work areas so that they are easily accessible.

10.3.3 Spill response procedure

Refer to OSHE SOP (OSHE/BS/05) for procedure on “Biological Spill response”

10.4 ACCIDENTS AND INCIDENTS REPORTING

10.4.1 Laboratory events that might create hazards, exposures, or accidents requiring reporting include:

- Accidents during work with biohazardous materials that result in physical injury, cuts, burns, abrasions, or fractures. The injured site could be contaminated with the biohazardous agent in use.

- Incidents occurring during the handling of biohazardous agents, infected specimens, or animals that could allow the undesired transfer of the agent to the lab personnel or release of the agent to the environment e.g. biological spills, exposure to aerosols and penetration of agents through the unbroken skin.

All accidents, known exposures, and potential hazards should be identified and reported in order to control the biohazards and contain the organisms involved as well as devise necessary measures to prevent such accidents from happening in the future.

10.4.2 All incidents or accidents have to be notified by the Reporting Person to OSHE via the online NUS Accident and Incident Reporting System (AIRS). (https://staffweb.nus.edu.sg/oshe/notice.htm). More information on reporting can be found in OSHE SOP (OSHE/SOP/GL/02) - “Incident/Accident Reporting and Investigation”

10.4.3 In general, the reporting person is the PI of the lab. However, the reporting responsibility begins with the individual involved in an accident, exposure, or suspected hazardous situation. The individual should report as soon as practical to the PI and/ or the Faculty safety and health officer in order to begin the reporting process.

10.4.4 OSHE or/and the Faculty Safety and Health officers Officer in cooperation with the PI and his/her staff, will conduct the necessary investigation of any laboratory accident. The goal of the investigation is to prevent similar accidents as well as to assess the circumstances and number of personnel who may have been exposed to the agent in question
10.5 EMERGENCY RESPONSE PLANS

10.5.1 Departments are encouraged to develop an emergency response plan which covers contingencies which may arise in the event of an accidental exposure.

10.5.2 The fundamental rule in dealing with a biological spill is to be prepared. Establish an emergency spill response plan. It should consist of a step-by-step procedure to follow if a spill occurs. Spill kit materials should be present in proximity to the area where biohazardous materials are handled.

10.5.3 Identify the biohazard risks involved on the site and the types of potential spills or emergencies which can occur.

10.5.4 The emergency response plan should carry the following information:

1. The type of ventilation system serving the lab, corridors and the building in order to enable you to know how aerosols or airborne particles would move;
2. Where the fume hoods and biological safety cabinet exhaust ducting goes after leaving the lab area;
3. Where the biohazard work areas and storage areas of biohazardous materials in order to assess what hazard could result in the event of a fire, flood, or explosion.
4. Evacuation routes and procedures to be used in the event of an emergency with biohazardous materials;
5. Established procedures for safe handling, storage and disposal of biohazardous materials to minimize accidental release and to avoid conditions which might lead to an accidental spill;
6. Procedures for dealing with exposure to biohazardous materials;
7. Any agent-specific post exposure treatment protocol; and
8. Procedures for reporting
REFERENCES

1. Advisory Committee on Dangerous Pathogens, Department of Health, United Kingdom, (2003). *Biological agents: Managing the risks in laboratories and healthcare premises.*


5. Genetic Modification and Advisory Committee (GMAC), 2006. *The Singapore Biosafety Guidelines for research on Genetically Modified Organisms*


12. National Institutes of Health, Department of Health and Human Services, USA, 2007. *Biosafety in Microbiological and Biomedical Laboratories (BMBL), 5th edition*


18. University of Nebraska-Lincoln. *Office of Environmental Health & Safety Safe Operating Procedures*