A Novel Approach for Development and Implementation of an Emergency Response Plan for the BSL-3 Laboratory Service in Singapore

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Introduction

Biosafety Level 3 (BSL-3) laboratory service has been introduced in Singapore in the areas of life sciences and biomedical sciences. The Biological Agents and Toxins Act (BATA) (MOH, 2005a), Singapore's first-ever law on the use of biological agents and toxins, came into force on January 3, 2006 (MOH, 2005b). Experiences, knowledge and information, facilities, equipment, and professional expertise in BSL-3 are in high demand. Every effort counts to promote biosafety and biosecurity. The service sector needs to develop certain standard operating procedures (SOP) which fit the nature of the laboratory and the specific hazards likely to be involved. High-level safety requires all laboratory users to observe correct procedures and practices and to accept their responsibility to protect themselves, their fellow workers, property, and the environment.

In spite of safety programs in a laboratory, accidents still happen. Good safety programs, training, and precautions help reduce the number, frequency, and severity of accidents, but nothing can prevent all accidents. A breakdown in the containment of pathogenic microorganisms may harm people, livestock, agriculture, and/or the environment. For this reason, the BSL-3 administration must establish appropriate plans to respond to potential emergencies that threaten and are ultimately beyond control.

The aim of an emergency response plan (ERP) is to detail various preventive measures and operational actions that need to be undertaken when an emergency occurs at a BSL-3 facility. These procedures include containing any leak or spill and controlling or extinguishing any fire to prevent and reduce injury to personnel and to minimize property damage and loss.

Biosafety and Biosecurity

In the *Laboratory Biosafety Manual*, 3rd edition (WHO, 2004), the WHO defines "Laboratory Biosafety" as the term used to describe the containment principles, technologies, and practices that are implemented to prevent unintentional exposure to pathogens and toxins or their accidental release. The *Laboratory Biosafety Manual* emphasizes the use of good microbiological work practices, appropriate containment equipment, proper facility design, operation and maintenance, and administrative considerations to minimize the risk of worker injury or illness. In following these recommendations, the risk to the environment and surrounding community-at-large is also minimized.

"Laboratory Biosecurity," in the same manual (WHO, 2004) refers to institutional and personal security measures designed to prevent the loss, theft, misuse, diversion, or intentional release of pathogens or toxins. Effective biosafety practices are the very foundation of laboratory biosecurity activities, and it has now become necessary to expand the traditional approach to biosafety through the introduction of laboratory biosecurity measures. Global events in the recent past have highlighted the need to protect laboratories and the high-risk materials they contain from being intentionally compromised.

These preparations are required to face crises or disasters where biosafety and biosecurity measures can be compromised. Institutional efforts may not be sufficient in such situations, and cooperation or help from other organizations or government departments may need to be obtained. However, in such situations BSL-3 administrators should consider the following:

- bringing in outside responders in the event of emergency may constitute a potential security breech;
- safety for all first responders is important; and
- responders must understand all possible risks when confronting an emergency, as well as the policies and practices the facility has adopted for biosafety and biosecurity.

When related agencies know the BSL-3 facility well they can offer safer assistance in emergencies.

Ministry of Health Initiative

The Biosafety Branch, Singapore Ministry of Health (MOH) met with BSL-3 administrators and personnel from government departments and agencies to discuss emergency responses for accidents involving biological agents. These meetings identified possible emergencies in a BSL-3 environment, such as biological spillage, chemical and radioactive spillage, medical emergency, fire, and accidents during transportation of biological agents. Because ERPs and procedures needed to be developed for various scenarios, a core working group was formed to overview potential emergency situations; to identify roles in the laboratory, the health ministry, and other government agencies; to recommend useful and/or required training courses; to specify equipment required by the laboratories; and to develop a generic

procedure for emergency response. Table 1 shows brief descriptions of the roles and responsibilities shared among departments or agencies.

BSL-3 facilities are to establish an institutional emergency response team (ERT) and to develop their own ERP. Each laboratory should have in-house capabilities to handle certain minor emergency situations. Large-scale emergency situations may require assistance from other government agencies such as the Singapore Civil Defense Force (SCDF), the Singapore Police Force (SPF), and the National Environment Agency (NEA).

Coordination with the SCDF

The SCDF is a world-class organization that provides fire-fighting, rescue, and emergency ambulance services with professionalism, operational excellence, and quality service. Its mission is to protect and save lives and property to ensure a safe and secure Singapore. The SCDF has developed rescue and evacuation procedures using state-of-the-art technology and expertise and conducts comprehensive training programs. Its mission is to deliver effective services in large-scale emergencies including those at a BSL-3 facility where biosafety and biosecurity are of utmost concern.

BSL-3 facilities must develop their standard operating procedures for various emergency situations according to guidelines (SCDF, 2007). The SOP or ERP is a requirement for the BSL-3 facility to be certified (MOH, 2005a); MOH Biosafety, 2006). The plan should be approved only after it has been tried and validated by the SCDF. Records for emergency drills conducted by the SCDF are reviewed during annual recertification of the BSL-3 facility.

Emergency exercises or drills shall be conducted at least once a year. The facilities should make prior arrangements with the SCDF for emergency drills during annual shutdown of the laboratory for decontamination and certification purposes. A drill exercise has been conducted at the BSL-3 facility at Nanyang Technological University following the facility's response plan and SCDF procedures, even though the facility had never been used. The SCDF fire-fighting team and hazmat team participated in the event. The drill covered the application of SOP to notify personnel, to communicate processes, and to determine actions to be taken; familiarization with equipment and resource management at the facility; laboratory exit procedures; timing for fire-fighting and evacuation of unconscious or injured personnel; and the challenges accompanying the adrenaline-pumping task of saving lives. This rehearsal was followed by reviews and amendments to improve procedures based on the outcomes of the drill analysis.

Emergency Response Plan (ERP)

The ERP provides precise procedures and information that the BSL-3 facilities in Singapore must apply in case of emergency. The plan consists of many parts which provide useful information for all potential emergency situations. Required details include: description of the location and its neighboring areas; access routes from the main roads including diagrams or maps; the nature of applications involving biological agents, chemicals, and reagents along with their hazard and risk assessments; descriptions of all possible emergency scenarios; execution procedures, evacuation procedures, procedures to notify other government agencies; impor-

Table 1

Roles and responsibilities sharing in departments and agencies.

Departments	Activities
Core Working Group	• To identify possible accidents or emergencies in the laboratory environments • To delineate the roles and responsibilities of the laboratories and government agencies • To formulate strategic procedures and set requirements • To recommend training programs required for emergency responses • To recommend equipment and requirements for the laboratory
Government Departments	• The MOH, as a key player, coordinates and communicates with other departments/agencies concerned for emergency responses • The Ministry of Manpower (MOM) participates in training programs • The SCDF contributes rescue and evacuation services; to cooperate ERP development and to conduct emergency drills • The Singapore Police Force (SPF) serves security concerns • The NEA cooperates for environmental issues
BSL-3 Facilities	• To develop and implement generic SOP for emergency responses in accordance with the BATA, regulations, instructions, etc. • To organize own ERT and to get staff trained • To facilitate equipment and resources as recommended • To coordinate/report/notify the MOH and other departments. • To get prepared for possible emergencies such as fire drill, spill exercises, etc.

tant contacts and monitoring procedures; support facilities and aid equipment for detection and protection and a communication flowchart with instructions on how to alert key personnel.

1. Area of Operations

The location of the facility and all possible entrances from main access roads should be clearly stated in the ERP. Neighboring areas, such as highly populated residential or environmentally sensitive locations, are to be identified. A schematic site map is helpful to provide a brief description of the area's layout. In case of emergency, the evacuation assembly area, first aid point, reporting points, and control points must be clearly identified. The ERP requires contact information so that the key personnel in the installation can be notified during and after office hours. In the event the incident escalates beyond the boundaries of the installation, neighboring locations must be informed. All emergency contact numbers are to be provided in the ERP.

Detailed descriptions of the location and the quantity of hazardous products, chemicals, and gasses inside the laboratory, as well as their storage conditions (such as temperature, pressure, etc.) must be clearly indicated on the site plan. A summary of processes, operations, and other activities carried out within each area, and their duration and conditions must be stated. Processes using laboratory equipment or hazardous chemicals can be root causes for some emergencies. Precautions, control measures, and standard process procedures are important information.

2. Hazard and Risk Assessment

Hazardous chemicals may be stored and used in the laboratory. Chemicals can be toxic, flammable, evaporative, radioactive, or explosive. Their specific properties provide important information related to the nature of potential hazards. The material safety data sheet (MSDS) must be available for each hazardous chemical.

High-risk biological agents are required to be stored in accordance with local regulations and guidelines. Records for the stored biological agents and their risk group classification must be available onsite and indicated in the ERP.

Procedures to be carried out inside the laboratory should be reviewed carefully. Risk assessments for experimental procedures are very important. Noting possible risks due to the operational steps provides important information to predict emergency scenarios and to generate preventive procedures.

3. Possible Scenarios

All possible scenarios, including the worst cases that could happen in the laboratory, should be identified. Various emergencies such as fire, biological spills, chemical or radiological spills, medical emergencies, chemical and instrumental explosions, and the SOP or control measures for every possibility are to be described (Table 2).

The BATA transportation regulations are to be adhered to when transporting biological agents on public roads. Vehicles used for transport must be affixed with a biohazard label when transporting biological agents or a

Table 2

Descriptions of some possible scenarios.

Emergency Conditions	Scenarios	Control Measures
Biohazard Spill	Spill in BSC Spill in centrifuge Major/minor spill in lab	SOP for centrifuge SOP for BSC Spill kits SOP for spill and clean up
Chemical/Radioactive Spill	Spill during experiments Chemical hazards or toxic	Good laboratory practices SOP for chemical spill SOP for radioactive spill
Explosion	Autoclave Centrifuge Chemical reaction	SOP for autoclave SOP for centrifuge MSDS
Medical Emergencies	Splash to the eyes Cuts and abrasions Thermal burn Injury/life threatening	Use of first aid kit SOP for sharp items SOP for medical emergencies Eye wash station
Fire Emergency	Fire Electrical shocks Flammable chemical	Fire extinguisher Fire alarm and protective equipment Exit procedures SOP for fire and evacuation
Road Traffic Accident	Accident during transportation of biological agent	SOP for packaging BATA requirements Protocol for transportation Notification of departments/agencies

toxic label when transporting toxins. The driver should possess a valid Hazardous Material Transport Driver Permit. A researcher who intends to transport biological agents in his/her own vehicle must be trained to do so and has to possess such a driving permit. The vehicles should be equipped with a breathing apparatus set and biological/chemical spill kits that include absorbent material, disinfectants, disposable gown, gloves, face mask, goggles, tongs/forceps, tape/masking tape, and biohazard bags. The biological agents must be properly packed to meet international and local regulations. The SOP for traffic accidents describes how to cordon off the accident area from the public, who are the responsible personnel to contact, how to alert SCDF for assistance, how to carry out cleaning and decontamination, and procedures for notifying and reporting to the MOH.

4. Execution of Procedures

The emergency operations are to be conducted in phases. Initial response procedures are carried out by institutional ERT. For large-scale emergencies beyond the capabilities of the facility personnel, other organizations or government agencies such as SCDF, SPF, and NEA are to be notified for assistance. The SCDF/SPF responses and actions focus on mitigation, containment, security, cordoning, rescue, and evacuation activities. Upon termination of emergency conditions, clean-up and decontamination procedures are completed and normal operation is resumed.

Detailed descriptions of emergency actions to be carried out by in-house ERT must be developed. The roles and responsibilities of various groups are to be specified. The site main controller (SMC) is the senior management member of the installation. The SMC is in charge of emergency response operations in the installation and is the liaison to senior officials at government agencies. The site incident commander (SIC) is a senior member of the supervisory staff who is in charge of the actual ground response operations. He or she provides assistance and information to the SCDF ground commander during the operation. The ERT members should be trained in basic fire-fighting, first aid and life support, hazmat training, etc. Table 3 shows some locally available training courses recommended by the core working group.

Notification procedures include the initial assessment of the emergency situation, how to alert the SCDF, who is responsible to make contact, what information is required to activate the SCDF; and how to brief on the incident and any actions the ERT has completed before arrival of the SCDF ground commander.

The incident site is divided into HOT, WARM, and COLD zones during an emergency. The hot zone is around the incident area; all personnel entering this area must be fully protected by means of breathing apparatus and proper protective clothing. The warm zone is the area directly outside the hot zone; all personnel in this zone should be equipped with breathing apparatus and, if the situation requires it, full protection against any toxic hazard gas. The cold zone is the non-hazard zone outside the warm zone.

5. Emergency Procedures

Immediate emergency procedures require a general description of how an evacuation will be conducted, containment procedures in place for spillage or leakage of hazardous substances; monitoring procedures for the release of hazardous substances, and fire-fighting and rescue procedures. These must be developed in the ERP.

Emergency shutdown procedures must also be identified. The SMC coordinates with the Incident Manager from an external organization (SCDF) and works closely with him or her to manage the activities. He or she will authorize the shutdown of operations within the installation. After immediately notifying the biosafety committee of any accident that compromises the safety and integrity of the facility, the facility manager will shut down the facility until safe conditions can be sustained.

The facility can resume normal operations if the emergency situation has not compromised biosafety conditions and appropriate clean-up procedures have been carried out. The facility may require decontamination before operations begin again. The decontamination of the laboratory must be carried out in accordance with biosafety guidelines.

Table 3

Some training courses and providers recommended by the core working group.

Training Course	Organizer/Trainers
Basic Cardiac Life Support (BCLS)	Life Support Centre, Singapore General Hospital (SGH)
Advanced Cardiac Life Support Provider (ACLS)	Life Support Centre, SGH
Fundamental Critical Care Support (FCCS)	Life Support Centre, SGH
Occupational First Aid (OFA)	Life Support Centre, SGH
Industrial First Aid	Red Cross/ER Ambulance & Services Pte Ltd.
Community Emergency Preparedness Program (CEPP) and Fire Module	The SCDF
Biosafety and Emergency Responses	Asia-Pacific Biosafety Association (A-PBA)

6. Service Support and Resource Management

Fire detection systems, such as smoke, gas, fire-fighting monitoring and leakage detection systems and their availability and locations, must be identified. The fire extinguishing system, including the fire extinguishers, fire blankets, sprinkler system, hose reel, and fire alarm system, must be indicated with quantities and locations.

Containment equipment, such as a biological spill kit, chemical spill kit, absorbent material, disinfectant, neutralizing reagents, tongs or forceps, and clean-up equipment, must be available in the laboratory.

A basic first aid kit containing sterile cotton wool, gauze, bandages, plaster, etc. is important for minor medical emergencies. Additionally, an eye wash station and safety shower must be available in a BSL-3 laboratory. Appropriate personal protective equipment, breathing apparatus, automatic external defibrillator (AED), resuscitator, and stretcher are also recommended to be kept in the facility.

Figure 1

Organizational chart in ERP at Nanyang Technological University (NTU), School of Biological Sciences BSL3 Facility.

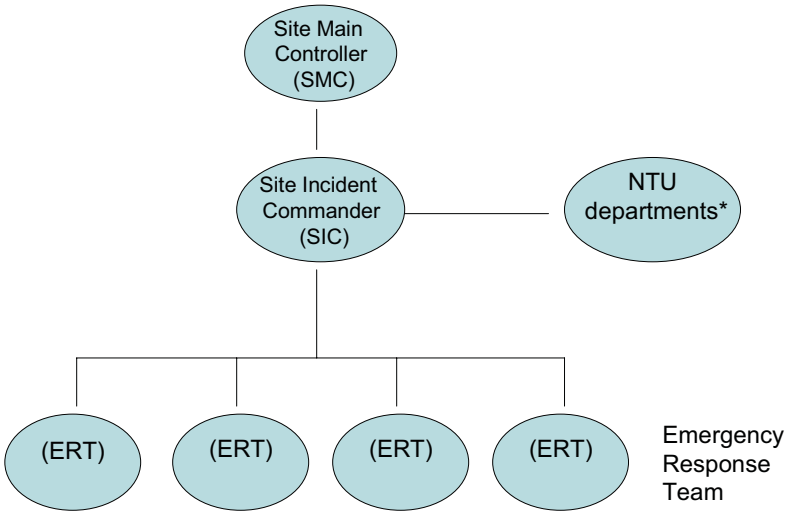
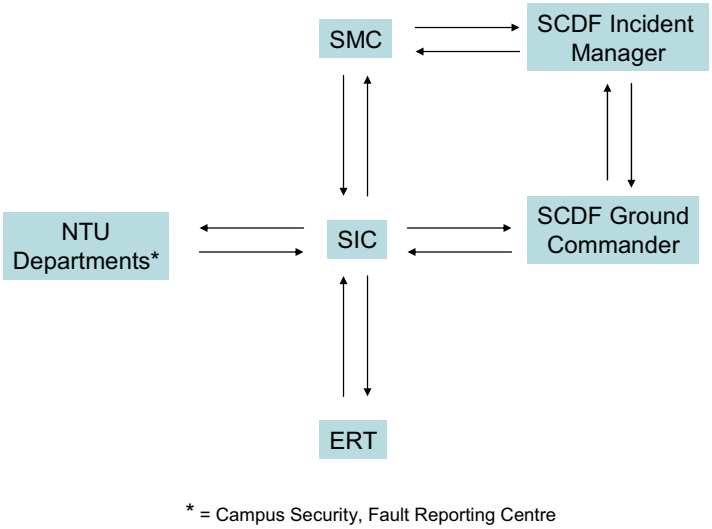


Figure 2

Communication during operation between SMC, SIC, ERT members, university departments, and external organization (SCDF).



7. Manpower/In-House ERT

The key personnel in emergency situations are the SMC, SIC, ERT members, and security personnel. The roles and responsibilities of each must be specified in detail, and the organizational chart for ERP must be identified (Figure 1). Emergency exercises should be conducted regularly. ERT members must understand all emergency procedures well and acquire relevant knowledge or experience for emergency situations through training and education. It is recommended that they should have attended first aid, life-saving, and fire-fighting training. They must be competent since they are part of the official response to a crisis.

8. Communication

Communicating in a crisis is unique. How people understand or act on information they receive in an emergency may be different from actions in a non-emergency situation. Affected people may interpret information differently and behave differently when they are in a state of panic. Correct and precise information and proper timing help minimize confusion and lead to the right actions. A well-prepared organization has communication plans and resources in place to maximize the success of any disaster response operation.

Communication among the SMC, SIC, ERT, and SCDF commander and other external organizations is very important during an emergency operation. The communication flowchart should show details of these linkages (Figure 2). What are the communication means or devices between each party? All these things must be stated in the ERP.

Conclusion

Crisis leading to the compromise of biosafety and biosecurity will result in a lot of uncertainty. People hate uncertainty. The magnitude of the problem will be unknown. Early in such crisis situations there will be more questions than answers. We spend a lot of time working to reduce uncertainty. If you are responsible for fixing the problem, a great danger is to promise an outcome outside your control. Preparedness in advance certainly helps reduce unpredictable outcomes. Planning for emergency situations in the BSL-3 environment is an absolute necessity. The ERP is an enforced practice to promote biosafety and biosecurity.

The plan should provide precise and correct information about what to do; who to contact; what equipment is available; what steps to follow; and how safe evacuations take place during particular emergency situations. It should be easily understandable and as simple as possible. The plan needs regular review, and new procedures or amendments and modifications to meet specific needs are to be adopted.

Biosafety and biosecurity are main concerns in BSL-3 environments. Safety must be your highest priority if you work in a high-risk situation. The standard operating procedures will provide only basic information that can be used as a guideline and reference. It is your responsibility to work safely in a laboratory, and how well you carry out your responsibilities provides the key to maximum safety. Your attitude towards safety counts because you are doing the work.

References

Ministry of Health (MOH). (2005a). Biological Agents and Toxins Act. Available at: www.biosafety.moh.gov.sg/bioe/ui/pages/links/abt_bata.htm

Ministry of Health (MOH). (2005b). *Commencement of Biological Agents and Toxins Act*. Singapore: *MOH Circular, 70* (13/15-0026).

Ministry of Health (MOH) Biosafety. (2006). *Public information*. Available at: www.biosafety.moh.gov.sg/bioe/index.do

Singapore Civil Defense Force (SCDF). (2007). *Guidelines for company emergency response plan*. Available at: www.scdf.gov.sg

Singapore Statutes Online. (2006). *Biological Agents and Toxins Act 2005, Act 36 of 2005*. Available at: http://statutes.agc.gov.sg

World Health Organization (WHO). (2004). *Laboratory biosafety manual* (3rd ed.). Geneva, Switzerland. Available at: www.who.int/csr/resources/publications/biosafety/WHO_CDS_CSR-LYO-2004_11/en