

# Developing a Chemical Safety Program for Chulalongkorn University

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## **Abstract**

This project established recommendations for a comprehensive, university-wide chemical safety program at Chulalongkorn University in Bangkok, Thailand, and a strategy for the implementation of the safety program. Improving chemical safety will help to create a safer environment for students, faculty, and staff on the university's campus. Recommendations were based upon research into chemical safety at American universities, interviews with faculty at Chulalongkorn University and King Mongkut University of Technology at Thonburi, Thailand, and surveys of both students and laboratories at Chulalongkorn University.

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## Executive Summary

Chulalongkorn University desires a chemical safety program for the protection of its students, faculty and staff. This Worcester Polytechnic Institute Interdisciplinary Qualifying Project (IQP) addresses the need for a university-wide chemical safety program by a) evaluating the university's current practices, b) establishing the requirements for an effective chemical safety program at Chulalongkorn University, and c) providing recommendations for implementation of a university-wide chemical safety program. If followed, the recommendations will facilitate the implementation of a comprehensive, university-wide chemical safety program to mitigate the risks of performing experiments and research using hazardous chemicals within the campus community.

For the purposes of this research, a model of an ideal university chemical safety program was established based upon United States Occupational Safety and Health Administration (OSHA) standards and the chemical safety programs at prestigious American universities: Massachusetts Institute of Technology, Worcester Polytechnic Institute, and the University of California at Berkeley. An ideal chemical safety program consists of four fundamental elements:

1. a chemical hygiene plan which outlines general procedures, necessary equipment and training, and positions of authority;
2. a hazard communication plan which outlines labeling and listing of materials, and information about each chemical;
3. a chemical waste disposal plan which outlines procedures for the determination, storage, recordkeeping, and disposal of chemicals; and
4. a chemical waste minimization program which outlines methods for reusing and reducing the amount of chemicals in the laboratories (U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Exposure to Hazardous Chemicals in Laboratories, 2006).

In addition, we conducted background research to better understand how to bring about organizational change to establish the components of a chemical safety program. This background research provided ways to aid implementation of the new program through encouragement of participation, enforcement of new policies, and modeling of best practices. Building upon this background research, we used field research to gather both qualitative and quantitative data for the purposes of developing an understanding of the current practices at Chulalongkorn University.

Qualitative data were gathered through semi-structured interviews with members of the Faculty of Science, other administrative personnel from Chulalongkorn University, and the Chemical Safety Officer at King Mongkut University of Technology at Thonburi (KMUTT). These data were analyzed using *grounded theory*, in which understandings are grounded in observation and developed from the data collected through field research. The data were then coded to identify reoccurring thoughts, ideas, and themes. As codes were developed, *constant comparison* was utilized to continue the coding of the interviews and surveys. Constant comparison is the practice of comparing the data obtained from each new interview with all previous interviews to identify any additional persistent thoughts, ideas, or themes that might lead research in a new direction.

Quantitative data were gathered through two structured surveys: the first of seventy-one laboratories within the Faculty of Science and the second of forty-six first-year students from the Department of Chemistry. The survey of laboratories within the Faculty of Science assessed the chemical safety practices of each of the seventy-one laboratories. Its results were analyzed to determine the strengths and weaknesses in laboratories' safety practices. The survey of first-year students from the Department of

Chemistry evaluated their knowledge of chemical safety. Its results were analyzed to establish areas in which chemical safety training could be improved to boost student's knowledge of chemical safety practices. The quantitative data reinforced the qualitative data obtained through the interviews.

During our research, the Faculty of Science, which has already begun to implement a chemical safety program, was used as a case study to better understand issues relevant to broadening a chemical safety program to be university-wide. The chemical safety program of the Faculty of Science currently consists of three basic components: laboratory safety and chemical safety training, chemical inventory management, and chemical waste disposal. On the basis of our empirical research we have identified the strengths and areas for improvement of each of these three components. The strengths of the current program include:

1. training of students,
2. implementation and utilization of a chemical inventory management system,
3. disposal of chemical waste using a third-party removal company,
4. recycling of solvents, and
5. utilization of scale-reduction principles.

Each of these areas represents one part of an ideal chemical safety program. However, for the formation of a comprehensive, university-wide chemical safety program additional chemical safety practices must also be implemented at Chulalongkorn University. What follows are recommendations for the design and implementation of a university-wide chemical safety program based upon the elements of the ideal chemical safety program that have not been addressed so far by the three components of the Faculty of Science's current chemical safety program.

First, we recommend that Chulalongkorn University appoint a Chemical Safety Officer to provide enforcement of the new chemical hygiene plan. This individual should have a bachelor's degree in chemistry, one or more years of supervising experience, knowledge of the regulation for good laboratory practices, and a long-term commitment to the chemical safety program at Chulalongkorn. Without some sort of enforcement structure, there is no way that a chemical safety program can be guaranteed long-term success.

Second, we recommend that the Chemical Safety Officer establish a formal chemical safety program. This program should include all elements of the four parts of an ideal chemical safety program: the chemical hygiene plan, the hazard communication plan, the chemical waste disposal plan, and the waste minimization plan.

The chemical hygiene plan should contain university-wide standards and procedures. KMUTT has already begun to implement some of these procedures, which can be used as a guide for the creation of the plan at Chulalongkorn. The chemical hygiene plan should address the following issues:

- standard operating procedures,
- engineering controls,
- personal protective equipment, and
- strengthening the current training program.

The hazard communication plan should contain practices for maintaining a list of the hazardous materials, standards for labeling chemicals, and requirements for the presence of Material Safety Data Sheets (MSDS).

The chemical waste disposal plan should determine an area for centralized storage of chemical wastes, seek to assess the waste disposal techniques of the waste disposal

company used, develop a contingency plan for proper accident response, and educate professors on categorizing hazardous waste.

The final part of the chemical safety plan, chemical waste minimization, should focus on utilizing ChemTrack (the chemical inventory management program at Chulalongkorn), encouraging chemical exchange, controlling purchase of chemicals, recycling chemicals whenever possible, and applying scale reduction more frequently to minimize the chemicals present on campus.

Third, we recommend the creation of a pilot program within the Faculty of Science. The pilot program should be implemented within the laboratories in each department of the Faculty of Science. After initial implementation, the laboratories should be inspected frequently, and revisions to the chemical safety program should be made to strengthen the program. After the pilot program has been successfully implemented, the program should be expanded throughout the entire faculty.

Fourth, we recommend implementing the program throughout the entire university. Within the other faculties of the university, chemical safety officers should be trained for each faculty by the university-wide Chemical Safety Officer. The chemical safety officer trained for each faculty should be responsible for implementing the chemical safety program within laboratories in their faculty. After the chemical safety program is strengthened in a few laboratories in each faculty the program can be expanded to include all of the laboratories within the faculty.

Finally, we recommend for continual evaluation of chemical safety at Chulalongkorn University. Chemical safety is an ongoing process, needing continual support of the faculty and students at Chulalongkorn University for success. Reevaluation



of the chemical safety program should occur on a regular basis and, if possible, be performed by an outside party.

The recommendations of this report help to provide a foundation for the improvement of chemical safety first within the Faculty of Science, and ultimately throughout campus. However, there are some areas that we did not have sufficient time to explore which warrant additional investigation. For example, we were only able to investigate the Faculty of Science, and had no contact with individuals from other faculties. Although the recommendations made are for a comprehensive chemical safety program, many of the safety elements included are not necessary for other faculties that do not utilize as many harmful chemicals and substances. A mathematics laboratory, for example, has no use for a fume hood because no chemicals are needed to demonstrate mathematical principles. On the other hand, it is important that they are integrated into a comprehensive program because all members of the university community should be informed about chemical safety. Thus, there are several additional areas of research that should be explored to expand upon the findings presented in this report, including:

- effectiveness of chemical safety training because education is an evolving process, and audits should be taken to ensure that the training is effective, with changes made as necessary;
- chemical safety practices within other Faculties because different faculties encounter different hazards, and possess different priorities;
- proper disposal of chemicals by an outside company, because this component is vital for the protection of the environment; and
- opportunities for the treatment of waste from other universities, which can serve as a resource for the perpetuation of good practices and as an economic opportunity.

As the recommendations provided within this report are utilized, first by the Faculty of Science and then by the entire university, chemical safety will be made a

priority at Chulalongkorn, in turn creating a safer campus community. Additionally, the creation and utilization of the university-wide chemical safety plan will correspond with Thailand's national goal to increase chemical safety practices throughout the nation, as established by the second National Master Plan on Chemical Safety (FDA of the Thai Royal Government, 2005). By increasing the standards for chemical safety programming at the university level, the graduates of Chulalongkorn will be trained and prepared to aid in the practice and development of higher standards for safety within industrial settings. This becomes of significant importance as Thailand's economy continues to become more industrialized and a greater number of Thai people's health and well-being depend upon safety practices within the industrial sector.

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## **1. Introduction**

During the past couple decades in Thailand, there has been a shift in the focus of its economic development from agricultural to industrial production. Along with increased industrial activity have come increased risks to workers. As a result, in 1995 there were 216,525 people involved in industrial accidents, with 966 fatalities (SafeWork, 2000). This represents an increase of 200% over the course of only 5 years. Many of these accidents involved individual workers and were not covered by the media. However, a significant number of major accidents also occurred in this period, such as a fire in a Thai factory in 1993 that killed 188 people (SafeWork, 2000). Chemicals serve as a significant cause of accidents in industry. In 2000, the number of occupational injuries due to toxic chemicals was 4,245 (Kogi, 2005). The danger of these industrial accidents, evident in the atrocious number of injuries and fatalities, necessitates an increase in the safety associated with the industrial workplace.

Because of this economic move towards industry and the resulting risks to worker health and safety, the Thai government established its first National Master Plan on Chemical Safety in 1997, which has been followed by a second plan in 2001 that is effective until 2006 (FDA of the Royal Thai Government, 2005). One of the main goals of the second National Master Plan on Chemical Safety is to encourage research and development concerning chemicals and chemical safety (FDA of the Royal Thai Government, 2005). The plan focuses on reducing the hazards of chemicals through the improvement of chemical safety at the industrial level.

Chemical safety is also a concern at the university level in Thailand. Many universities work with chemicals within the laboratory setting because of their use in the advancement of industrial products such as plastics, paints, medicines, detergents, and the majority of modern day materials (Royal Society of Chemistry, 2004). However, when chemicals are used within

laboratory settings, the degree of the hazard the chemical poses must always be considered in relation to the benefit of using the chemical. For example, some chemicals may be carcinogenic, toxic, irritants or corrosives (OSHA, 2002), but nevertheless may be beneficial to use under carefully controlled circumstances. In order to reduce the potential hazards of using chemicals, manufacturers specify safety procedures to be followed in their use. Despite the hazards that many chemicals may present, it is often possible to minimize the risks associated with chemicals by creating safety procedures that protect the people using chemicals.

In the United States, federal and state law requires that organizations, such as universities using hazardous chemicals, employ a hazard communication plan to ensure that people using hazardous chemicals understand associated risks (Occupational Safety and Health Administration, 1996). Chemical safety programs within the United States typically consist of:

- a chemical hygiene plan, which outlines general procedures, necessary equipment and training, and position of authority;
- a hazard communication plan, which outlines labeling and listing of materials, and information stored about each chemical;
- a chemical waste disposal plan, which outlines procedures for the determination, storage, recordkeeping, and disposal of chemicals; and
- a chemical waste minimization program, which outlines methods for reusing and reducing the amount of chemicals in the laboratories (U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Exposure to Hazardous Chemicals in Laboratories, 2006).

These four elements comprehensively address all the aspects of working with hazardous chemicals, including proper handling procedures, safe usage, suitable warning signs and labels, contingency plans in the event of an accident, and correct storage and disposal methods.

Chemical safety at universities has not yet been mandated by legislation in Thailand, because institutions of higher learning have not been forced to adopt official chemical safety programs (W. Pongsapich, personal communication, January 19, 2007). Chulalongkorn University in Bangkok, Thailand has expressed interest in the design of a chemical safety



program for the entire university to better protect its students, faculty, and staff. Beyond helping to make the research and teaching environment safer, an additional benefit of a chemical safety program at Chulalongkorn will be training future professionals, since many students go on to work in the industrial sector after graduation. Thus, chemical safety programs in universities can be an important tool to train students for the professional realm.

At Chulalongkorn University, efforts towards developing formal chemical safety programming started in the Department of Chemistry within the Faculty of Science. In 2002, recommendations for the design and implementation of a chemical safety program within the Department of Chemistry were provided by a group of students from Worcester Polytechnic Institute. A new program was not fully implemented according to their recommendations; however, some action has been taken to improve safety throughout the Faculty of Science since their project in 2002. Currently, portions of a chemical safety program focusing on an inventory system, chemical waste disposal, and laboratory safety and training are being implemented within the Faculty of Science at Chulalongkorn University.

This WPI Interdisciplinary Qualifying Project (IQP) a) evaluates the initial phases of the chemical safety program within the Faculty of Science at Chulalongkorn University, b) provides recommendations on how to incorporate additional elements of chemical safety used at other prestigious universities in the US and Thailand into the chemical safety program in the Faculty of Science, and c) utilizes the chemical safety program within the Faculty of Science at Chulalongkorn University as a case study for providing recommendations for integrating chemical safety throughout Chulalongkorn University.

As Thailand begins to make chemical safety a priority, a heightened level of chemical safety will begin to diffuse into industry and society throughout Thailand. This research provides

Chulalongkorn University with the resources to address their chemical safety needs within their institution. We have provided recommendations for the design and implementation of a university-wide chemical safety program for Chulalongkorn University to protect its students, faculty, and staff from the dangers of using hazardous chemicals. The improvement of the chemical safety program at Chulalongkorn University will aid in the national efforts to strengthen chemical safety throughout Thailand.

## **2. Background**

To properly address the improvement of chemical safety at Chulalongkorn University, it was necessary to gain a deeper understanding of existing chemical safety practices, policies, procedures and the ways in which such elements of chemical safety may be effectively implemented within an organization. This chapter first establishes the current chemical safety practices within the Faculty of Science at Chulalongkorn University, and then defines the elements of an ideal chemical safety program by presenting examples of those practices at highly acclaimed universities in the United States, including Worcester Polytechnic Institute, Massachusetts Institute of Technology, and University of California, Berkeley. Additionally, this chapter discusses strategies for implementing change within an organization, which provides insight into how to effectively integrate a comprehensive chemical safety program at Chulalongkorn University. A comparison of the existing chemical safety programs at other universities with the research conducted at Chulalongkorn University has led to recommendations for the expansion of the chemical safety program within the Faculty of Science and the development of a university-wide chemical safety program for Chulalongkorn University.

### **2.1 Previous Chemical Safety Research at Chulalongkorn University**

Since the Faculty of Science at Chulalongkorn University was established in 1916, it has grown from just a few small departments to fourteen full departments, which include Chemistry, Biochemistry, Botany, General Science, Marine Science, Chemical Technology, Food Technology, Materials Science, Photographic Science, and Printing Technology. The total

number of students that are now a part of the Faculty of Science has grown to an enormous 2,800, along with an academic and administrative staff of over 700 (Chulalongkorn University, 2001).

Many of the departments within the Faculty of Science use hazardous chemicals in the laboratory for coursework or research. Both undergraduate and graduate students perform experiments to demonstrate and test many of the concepts learned in classes and through lectures. One of the chemistry laboratories in the science building used for graduate research, for example, has nearly eighty liters of hazardous and non-hazardous chemicals stored inside it for frequent use by the two or three graduate students that use the laboratory. Although these chemicals are quite valuable for education, they are nevertheless dangerous. Thus, it is imperative to adequately manage the risks associated with their use.

Chemical safety at Chulalongkorn University was recognized as a weakness on their campus. In 1996, an IQP team from WPI addressed chemical safety within the Department of Chemistry in the Faculty of Science. Since then, two other IQP teams have completed projects concerning chemical safety at Chulalongkorn University.

The first of these two projects, completed in the year 2000, explored the consequences of the lack of any formal system for keeping an inventory of chemicals within the Faculty of Science. According to our sponsor, Dr. Supawan Tantayanon, many professors and students would not trust each other when it came to the purity of shared chemicals, and as a result most would keep their own stock. Additionally, faculty members would rarely provide a full inventory of their chemicals to the university; thus, the variety and quantity of dangerous chemicals present at Chulalongkorn University was unknown. This would have been particularly dangerous in a situation that requires a specific response for a particular chemical, such as a fire or a spill. In the

end, the IQP team undertaking this project focused on the recommendations for the design of a surplus chemical exchange program and inventory control system for the Faculty of Science. The second IQP, completed in 2002, focused on the design of a comprehensive chemical safety program for the Department of Chemistry within the Faculty of Science. Several areas of needed improvement that were identified by this group included:

- the lack of formal laboratory safety practices and training programs for students, faculty, and staff;
- insufficient communication of hazards within each of the laboratories;
- nonexistent waste disposal procedures;
- inadequate and unsafe storage of both surplus and waste chemicals;
- the absence of any sort of waste minimization or recycling programs; and
- the lack of any official documentation procedure for reporting chemical accidents (Almeida, Fontaine, and Forester, 2002, pp. 57).

As a result, this team came up with recommendations for a chemical safety program, implementation strategy, and implementation timeline for the Department of Chemistry at Chulalongkorn University.

These IQPs were essentially the start of chemical safety-related work at Chulalongkorn University. Since they have been completed, there have been several attempts at improving chemical safety on the university's campus. The Research Methods chapter below describes the ways in which information about the current chemical safety practices at Chulalongkorn will be gathered. The next section in this chapter details the typical elements found in comprehensive chemical safety programs within the United States.

## **2.2 Elements of an Ideal Chemical Safety Program**

Hazardous chemicals are present at schools and universities around the globe. Undergraduate students, graduate students, faculty, and staff conduct experiments and perform

research that often requires the use of hazardous chemicals that may be harmful to human beings, other living organisms, and the environment. Chemical safety programs are designed to protect people and the environment from these hazardous chemicals. Chulalongkorn University in Bangkok, Thailand does not yet have a formal chemical safety program that covers all of its faculties, schools, colleges, and institutes.

Within the United States, the Occupational Safety and Health Administration, or OSHA, maintains standards of health and safety, including those for addressing chemical hazards at universities. Since there is not currently a government organization in Thailand that provides standards for chemical safety at the university level, the chemical safety program OSHA recommends within workplaces that use hazardous chemicals can be used as a model for a chemical safety program for Chulalongkorn University.

OSHA defines a hazardous chemical as:

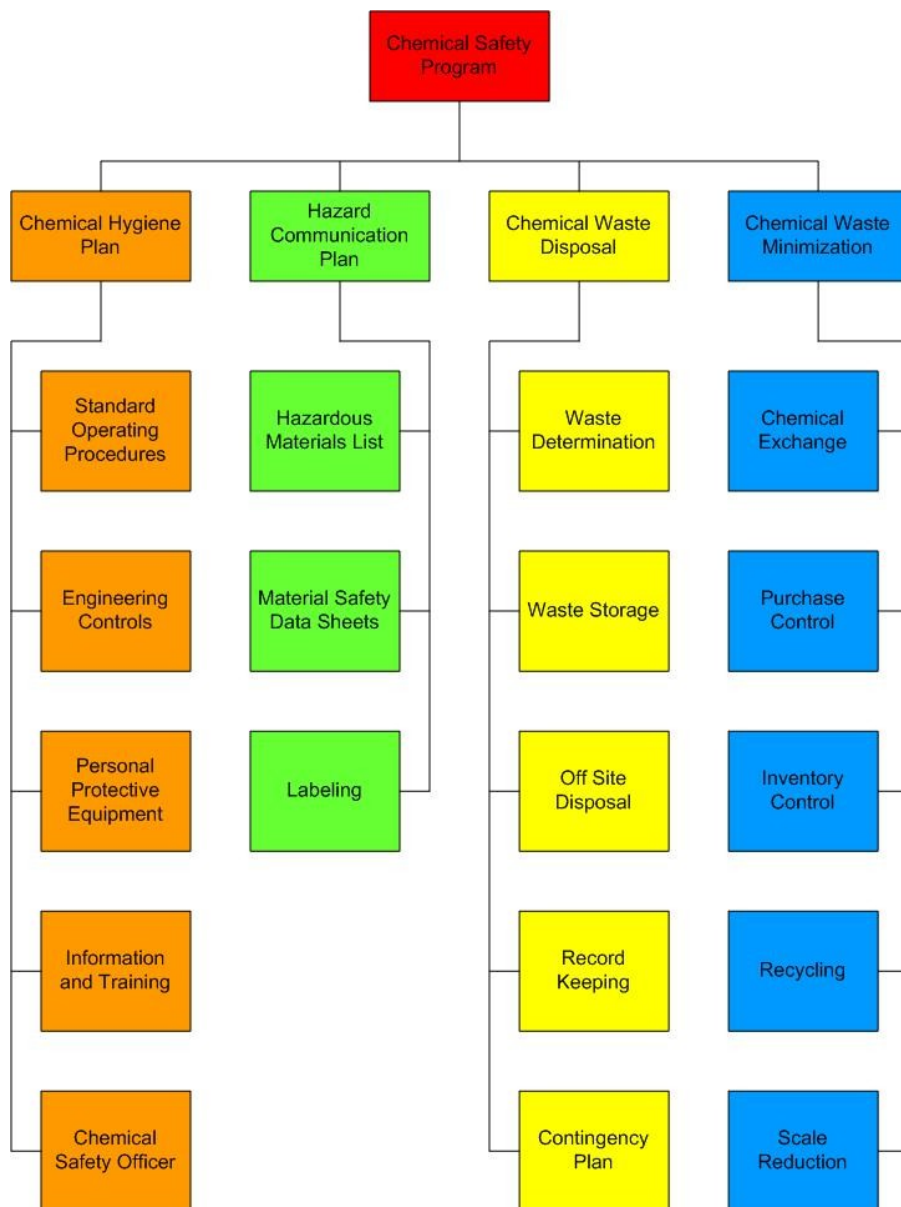
...a chemical for which there is statistically significant evidence based on at least one study conducted in accordance with established scientific principles that acute or chronic health effects may occur in exposed employees (U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Exposure to Hazardous Chemicals in Laboratories, 2006).

Thus, it is necessary when working with such dangerous substances to have some sort of safety program to reduce the risks of hazardous chemicals to people using the chemicals.

Chemical safety programs can provide the protection needed for working with hazardous chemicals. In order to effectively eliminate much of the risk associated with using hazardous chemicals, however, a chemical safety plan must include documentation and procedures that address four main areas, as depicted in Figure 2.2.1. These four main areas are the:

1. Chemical Hygiene Plan,
2. Hazard Communication Plan,
3. Chemical Waste Disposal, and
4. Chemical Waste Minimization.

The following sections briefly describe each area in order to provide a better understanding of a complete chemical safety program.



**Figure 2.2.1:** Elements of a comprehensive chemical safety program  
(The University of Illinois at Urbana-Champaign, 2004)

### **2.2.1 The Chemical Hygiene Plan**

The Chemical Hygiene Plan is the most important part of a chemical safety program. The United States Department of Labor's Occupational Safety and Health Administration, or OSHA, has established regulations requiring the use of a Chemical Hygiene Plan by all laboratories that use hazardous chemicals. These regulations mandate that the following elements, depicted in Figure 2.2.1 must be included in a working Chemical Hygiene Plan:

- a standard set of operating procedures that protect the health and safety of those using hazardous chemicals;
- engineering controls, such as fume hoods (devices used to evacuate harmful vapors from a lab) and vapor detection equipment that provide a safe working environment;
- personal protective equipment, or PPE, such as goggles, gloves, lab coats, etc. that protect an individual from coming into contact with a hazardous chemical;
- a proper training program that informs laboratory staff about the properties of hazardous chemicals, the toxicology of each chemical, the appropriate safety measures for each chemical, and the appropriate emergency response for each chemical; and
- a Chemical Hygiene Officer to oversee the implementation and proper execution of the Chemical Hygiene Plan, and often times the whole chemical safety program (U.S. Department of Labor, Occupational Safety and Health Administration, Occupational Exposure to Hazardous Chemicals in Laboratories, 2006).

Including each of these elements in a Chemical Hygiene plan promotes a clean, organized, and safe working environment for laboratories that use hazardous chemicals. Attention should be paid to each of the elements of the Chemical Hygiene Plan.

### **2.2.2 The Hazard Communication Plan**

The Hazard Communication Plan is another component of a chemical safety program that is required by OSHA for any workplace that uses hazardous chemicals. As shown in Figure 2.2.1, a hazard communication plan, in the United States, must include the following:



- a current list of all hazardous chemicals on site;
- Material Safety Data Sheets (written documents describing the chemical, physical, and hazardous properties of a chemical) for each chemical on the hazardous chemical list; and
- appropriately labeled chemical storage containers marked with both the name of contents and the necessary hazard warnings (U.S. Department of Labor, Occupational Safety and Health Administration, Hazard Communication, 2006).

A Hazard Communication Plan that incorporates these elements seeks to be effective in alerting those using hazardous chemicals about the dangers that may be present. Although a Chemical Hygiene Plan may be quite effective in reducing the risk of an accident in the lab, the information conveyed through the Hazard Communication Plan is just as valuable.

### **2.2.3 Chemical Waste Disposal**

After a hazardous chemical is used in the laboratory, it must be disposed of correctly. A complete chemical safety program should have some sort of protocol for the disposal of chemical waste. Typically, the waste management and disposal process, as shown in Figure 2.2.1, follows several steps:

1. The nature of the waste must be determined. If the waste is non-hazardous, it may be discarded without special regulation. However, if the waste is determined to be hazardous, it must be disposed of at a proper hazardous waste disposal facility.
2. While awaiting disposal, hazardous waste should be stored in a designated area in safe and appropriately labeled containers. Once a certain amount has accumulated, a hazardous waste disposal company must be called to transport the material to an approved off-site disposal facility.
3. Records should be kept to track all hazardous chemical waste from creation to disposal.
4. A contingency plan must exist for contacting the proper authorities if an accident occurs during disposal (Worcester Polytechnic Institute, Hazardous Waste Management Plan, 2006).

If attention is paid to hazardous chemicals after they have been used, hopefully, many possible accidents will be avoided. It is imperative to keep track of all chemical waste to ensure that it is not disposed of in a manner that would harm another individual or the environment.

#### **2.2.4 Chemical Waste Minimization**

Chemical safety programs should include strategies for the reduction of chemical waste, as shown in Figure 2.2.1. The first element of the chemical waste minimization plan, called a *surplus chemical exchange program*, attempts to find uses for surplus chemicals in laboratories other than the one in which the surplus exists. A second method for the minimization of chemical waste, called *purchase control*, is to control the purchase of chemicals such that only the minimum required amount of a chemical can be purchased to prevent the possibility of surplus and the complications of storage. A third way to minimize chemical waste, called *inventory control*, is to remove from storage all of the chemicals that are outdated and have remained unused for a significant period of time. A fourth process to minimize chemical waste, called *recycling*, takes waste that is ready to be disposed of and finds a new use for it. Lead-acid batteries, for example, are a form of chemical waste that can be recycled (Battery Council International, 2006). A final technique is called *scale reduction*. In some experiments, it is possible to replace hazardous waste producing components with non-hazardous waste producing components. This will reduce the amount of hazardous chemicals produced by the experiment and therefore lessen the waste in need of disposal.

### **2.2.5 Summary of the Elements of an Ideal Chemical Safety Program**

The four elements described above should be incorporated into any chemical safety program. The inclusion of each of these elements into a chemical safety program is the ideal goal for chemical safety, but even in countries like the United States where laws and regulations regarding chemical safety programs exist, maintaining these standards is a daunting task. Chulalongkorn will have to work hard to improve its existing chemical safety practices. The next section of this chapter describes comprehensive chemical safety programs at various institutions throughout the United States and highlights the portions of their chemical safety programs that are outlined in Figure 2.2.1.

### **2.3 Programs at Other Universities**

The Occupational Safety and Health Administration (OSHA) clearly defines the legal requirements for chemical safety programs at universities within the United States, as described in Section 2.2. American colleges and universities take the elements of the chemical safety program defined by OSHA and implement these elements within the context of their specific university. The following sections analyze the chemical safety programs at Worcester Polytechnic Institute, Massachusetts Institute of Technology, and University of California, Berkeley. Each university organizes their chemical safety program slightly differently. However, the chemical safety programs of each organization contain a chemical hygiene plan, a hazard communication plan, a chemical waste disposal plan, and a chemical waste minimization plan.

These schools were chosen because they represent both small institutions (WPI) and large institutions (MIT, University of California, Berkeley) that practice strong chemical safety practices. The first university reviewed, Worcester Polytechnic Institute, was chosen because its

reputation as one of the best small engineering schools in the country, and because of its size, which is very similar to that of the Faculty of Science at Chulalongkorn University. This similarity in population helped to demonstrate how a chemical safety program for the Faculty of Science might initially be structured. The other two schools, Massachusetts Institute of Technology and University of California, Berkeley, were chosen by our team as well-known and highly acclaimed institutions in collaboration with our sponsor, Dr. Supawan. These programs were used as models to help develop recommendations for the improvement of the existing chemical safety program within the Faculty of Science at Chulalongkorn University into a program that will be suitable for the entire university.

### **2.3.1 Worcester Polytechnic Institute (WPI)**

Worcester Polytechnic Institute (WPI) was established in 1865 in the city of Worcester, Massachusetts, and was one of the first technological schools in the United States. Of the three institutions we have reviewed, WPI is the smallest with a total combined graduate and undergraduate population of about 4,000 students (Worcester Polytechnic Institute, Just the Facts, 2006). The university is made up of eighteen different departments and offers more than fifty undergraduate and graduate degree programs, ranging from engineering to management to professional writing. Considered by many one of the best small engineering schools in the country, WPI was ranked by *U.S. News & World Report* as 64th among “America’s Best Colleges 2007” (*U.S. News and World Report*, 2007).

The use of WPI is important in establishing a contrast between its practices and those of larger institutions like Massachusetts Institute of Technology and University of California, Berkeley. Additionally, the extensive chemical safety program at WPI helps to demonstrate how

a chemical safety program specifically for the Faculty of Science might be initially structured, because the population of WPI is similar to that of the Faculty of Science, more so than MIT or University of California, Berkeley.

WPI conducts research that involves the use of hazardous chemicals in many fields, including biology, physics, chemistry, nuclear physics, and engineering. As a result, WPI has implemented an extensive chemical safety program that includes all elements of the model chemical safety program described in Section 2.2 above: the chemical hygiene plan, the hazard communication plan, the hazardous waste disposal plan, and the chemical waste minimization plan.

WPI's Chemical Hygiene Plan is comprised of sections that dictate general rules and guidelines, requirements for personal protective equipment, and standards for maintenance and inspections, as shown in Table 2.3.1.1. The general rules and guidelines outline general housekeeping policies and basic response procedures. The section on personal protective equipment contains ways to reduce exposure to hazardous chemicals through the use of proper safety equipment. The portion on maintenance and expectations explains how the constant upkeep of equipment sustains the proper level of safety, and how inspections discover lapses in chemical safety.

Topic	Purpose
General Rules and Guidelines	General Housekeeping, Basic Response Procedures
Personal Protective Equipment (PPE): proper dress, use of lab coats, gloves, and goggles	Reduction of exposure through use of equipment
Maintenance and Inspections	Continuous upkeep of equipment helps to sustain proper level of safety, inspections discover anomalies and gaps in safety

**Table 2.3.1.1:** Chemical hygiene plan outline  
(Worcester Polytechnic Institute, Chemical Hygiene Plan, 2006)

Two very important elements of any successful safety program, as stated in Section 2.2, are proper training procedures and knowledgeable staff. WPI’s training program is both extensive and effective. New laboratory workers must learn “the measures [they] can use to protect themselves from these hazards, including specific procedures such as appropriate work practices, personal protective equipment to be used and emergency procedures” (Worcester Polytechnic Institute, Chemical Hygiene Plan, 2006). Having this knowledge promotes a safer environment, as preemptive safety measures would be utilized and in the event of an accident the proper course of action will be taken to minimize damages.

As required by the Office of Environmental and Occupational Safety, WPI employs an enforcement framework for chemical safety practices on its campus. Dave Messier holds the position of Chemical Hygiene Officer (CHO), an administrative member that is experienced and

has been trained to provide guidance in developing and implementing the Chemical Hygiene Plan (CHP) and other elements of the chemical safety program.

The CHO is an extremely important position, as he or she directly affects what steps are taken to maximize chemical safety at the institution. He or she is responsible for determining work practices and procedures and any required personal protective equipment or other equipment needed to protect the health and safety of laboratory staff (Worcester Polytechnic Institute, Chemical Hygiene Plan, 2006). More importantly, however, the chemical hygiene officer is responsible for the verification and implementation of new aspects of the program. Only the CHO has the power to approve any new hazardous material that enters the campus. Without such a power structure, there is a high likelihood that hazardous substances may be unknowingly brought on campus without verification that someone is available with the skills and knowledge to properly use the substance.

Additionally, the CHO is responsible for ensuring that a proper hazard communication plan, chemical waste disposal plan, and chemical waste minimization plan are present. The officer must ensure that all of the information on these plans is available to the entire student body and that the appropriate people, such as laboratory staff and faculty members, are aware of and follow the institute's policies and procedures. Without a CHO, there is essentially no way to properly enforce any chemical safety program.

Because the WPI CHO has so much responsibility in terms of chemical safety, it is necessary to delegate some of the responsibility to laboratory supervisors. According to the WPI Chemical Hygiene Plan, "Each laboratory supervisor has the responsibility of giving all the necessary safety instructions to his or her workers prior to the beginning of any laboratory work involving hazardous chemicals" (Worcester Polytechnic Institute, Chemical Hygiene Plan,

2006). The supervisor assumes responsibility for the tasks to be carried out instead of the CHO, creating a hierarchy within the chemical safety plan itself. This structure of responsibilities provides a very high level of safety oversight because there are many people working towards the same goal.

According to Dave Messier, the Hazardous Waste Management Plan at WPI is thorough, and its design is largely a result of federal and state regulations. Individuals who produce hazardous waste are required to take annual training on how to manage the waste they create. The chemical inventory at WPI is fully updated once every couple years, but large purchases are generally covered through personal communication with the CHO. Dave Messier noted that keeping a precise inventory of exactly how much of a chemical remains in each container is unnecessary. The important elements of an inventory are the chemicals present and the maximum amount of any given chemical that could be present (D. Messier, personal communication, January 30, 2007).

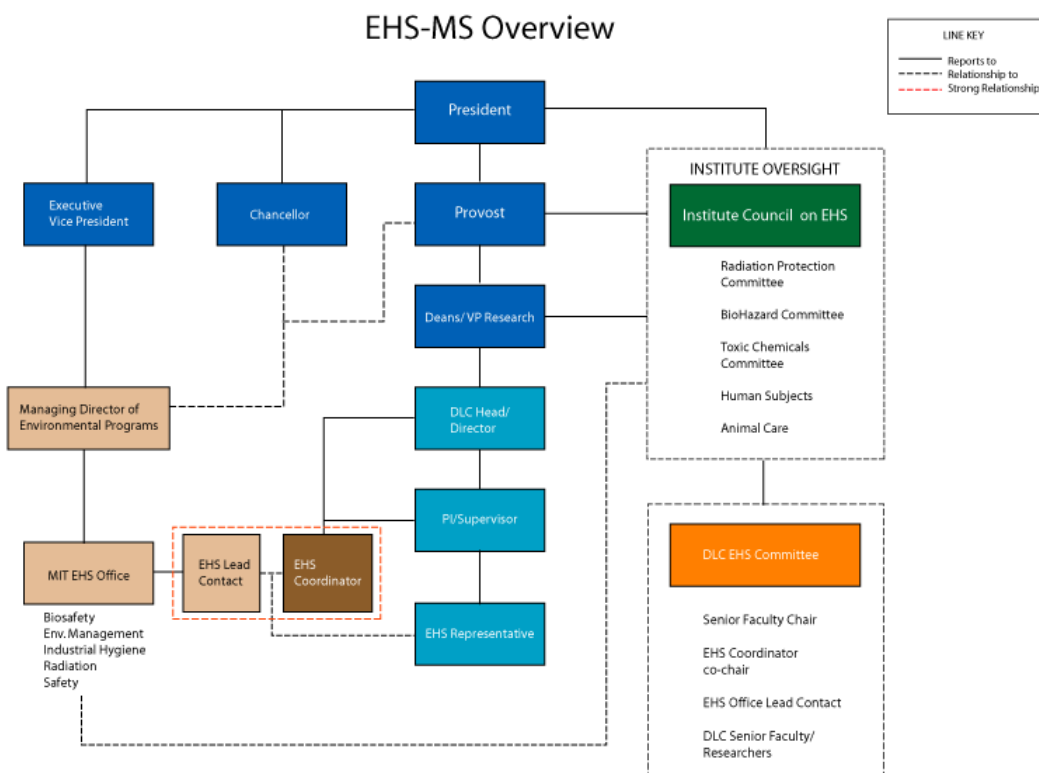
The Chemical Hygiene Plan at Worcester Polytechnic Institute is a set of guidelines that serves as a solid foundation for chemical safety. The CHP charges one to maintain good hygiene while in the laboratory and reinforces the importance of PPE. Inspections of engineering controls, such as fume hoods, help to sustain a high level of safety by regularly reducing potential exposure to harmful chemicals. Knowledgeable staff members help to prevent or lessen the impact of accidents by knowing how to respond. Finally, the organizational structure dictated by the Chemical Hygiene Plan provides security and enforcement to avoid uncontrollable situations within the laboratory setting.



### **2.3.2 Massachusetts Institute of Technology (MIT)**

Massachusetts Institute of Technology (MIT), located in Cambridge, Massachusetts, is a much larger school than Worcester Polytechnic Institute with over 10,000 undergraduate and graduate students (Massachusetts Institute of Technology, Frequently Asked Questions, 2007). MIT consists of six different schools made up of over thirty degree programs ranging from engineering to political science. The university was ranked by *U.S. News and World Report* as the number one undergraduate engineering school in the country in 2007 (*U.S. News and World Report*, 2007). Because of its excellent program in engineering, our sponsor, Dr. Supawan Tantayanon, recommended that we include MIT in our research of chemical safety at institutions within the United States.

The primary organization in charge of safety at MIT is the Institute Council on Environment, Health, and Safety (EHS), and is another example of a well-structured, organized, and effective chemical safety program. The structure of EHS very clearly establishes the hierarchy of power within the organization. As shown in Figure 2.3.2.1, the EHS contains an Institute Council that reports directly to the President, the Provost, the Deans, and the Vice President of Research. The Institute Council also contains an EHS Committee comprised of the Senior Faculty Chair, the EHS Coordinator Chair, the EHS Office Lead Contact, and the Departments, Laboratories, and Centers (DLC) Senior Faculty/Researchers. Thus, there are specific individuals throughout the university responsible for continually overseeing and improving the chemical safety program at MIT.



**Figure 2.3.2.1: MIT EHS-MS structure**  
(Massachusetts Institute of Technology, 2006)<sup>1</sup>

This web of relationships between the different personnel involved in chemical safety programming stresses the importance of communication, as the relationships are very complex, not just within a single department, but throughout the system as a whole. This type of structure also allows for more effective enforcement of practices, because there are several checks and balances within the system. Inspections, often on a weekly basis, serve as a deterrent to

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carelessness in the laboratory and are performed by safety inspectors with various levels of authority. It is the responsibility of each individual to abide by the policies set forth by the EHS, and failure to do so results in appropriate actions taken by the school against the individual according to disciplinary policy. EHS does not enforce policy strictly through punishment, but provides a system of incentives for the exhibition of good practices ranging from simple thank you notes to gift certificates and financial rewards (Massachusetts Institute of Technology, 2006).

Training is one of the most important aspects stressed by EHS. All lab workers must undergo general chemical hygiene training and must read and understand the chemical hygiene plan. In addition, workers must take training in the areas specific to hazards they intend to encounter (B. Edwards, personal communication, November 14, 2006), as shown in Table 2.3.2.1.

<b>Regulated Activity</b>	<b>Required Training Course</b>	<b>Retraining</b>
Working with chemicals in a laboratory	General Chemical Hygiene	Initial Only
	Lab-Specific Chemical Hygiene	Annual
	Managing Hazardous Waste	Annual
Working with Class 3b or 4 lasers	Laser Safety Training	Initial Only
Working with radioactive materials	Radioactive Materials Safety Training	Biennial
Handling human materials	Blood Borne Pathogen Training	Annual

**Table 2.3.2.1:** MIT training outline for lab workers  
(Massachusetts Institute of Technology, 2006)

The EHS manual serves as an excellent reference for programs already in place, but also dictates policy for the implementation of chemical safety plans for new programs within the institute. First, it must be established that the new program requires the creation of a chemical hygiene plan. If one is needed, then the new program only needs to add the appropriate

information into the standard chemical hygiene plan template, which the school provides. The EHS office then reviews the proposed plan, and if it is acceptable to both the EHS and the Chemical Hygiene Officer, it is approved. The new program, similar to all other current programs, will undergo review on an annual basis. (B. Edwards, personal communication, November 14, 2006)

Like WPI, MIT's chemical safety program incorporates a chemical hygiene plan, a hazard communication plan, a chemical waste disposal plan, and a chemical waste reduction plan. Also like WPI, most of the elements of the a hazard communication plan, a chemical waste disposal plan, and a chemical waste reduction plan are contained within the chemical hygiene plan and are the responsibility of the Chemical Hygiene Officer. Some of the major categories included in MIT's Chemical Hygiene Plan are:

- roles and responsibilities,
- training,
- standard operating procedures,
- safety equipment,
- waste management,
- exposure assessment,
- Chemical Hygiene Officer,
- security, and
- recordkeeping.

Each program at MIT has its own Chemical Hygiene Plan, so there is great variability in terms of the specific details. Because each program is based upon the same template, they all cover the appropriate areas of chemical safety. The power structure that exists within the administration, faculty, and staff at MIT provides an excellent environment for an effective chemical safety program. No single person can act alone, and inspections allow for constant surveillance and strict enforcement of chemical safety. Required training of laboratory workers, especially in the hazards of their area of practice, is essential to maximizing safety. Lastly, a sound process exists

for the creation and implementation of new programs through the use of the template. EHS makes all of this possible and is ultimately responsible for the safety of the campus.

### **2.3.3 University of California at Berkeley (UCB)**

The University of California at Berkeley, located in Berkeley, California, is the largest of the institutions reviewed in this chapter with almost 34,000 undergraduate and graduate students (University of California at Berkeley, Office of Planning and Analysis, 2006). In 2007, 97% of the University of California at Berkeley's graduate programs made the National Research Council's list of the top ten programs in each field. This included the chemistry program, which was ranked first among all chemistry programs in the nation (University of California at Berkeley, Honors and Awards, 2007). This institution was chosen for review because of its similarity in population to Chulalongkorn University and its high reputation.

UCB has a chemical safety plan that is broken down into the following sections:

- Emergency Procedures,
  - Responsibilities and Contacts,
  - Information on Chemical Hazards,
  - Standard Operating Procedures,
  - Controlling Exposures,
  - Campus Safety Resources, and
  - Training Documentation
- (University of California at Berkeley, 2006).

While this safety plan encompasses all of the elements of the model chemical safety plan described in Section 2.2 above, it has no official structure; thus the plan does not exactly mirror the programs at the two other institutes that were examined.

The first section of the plan contains emergency procedures outlining each of the actions that should be taken if different accidents occur, such as a hazardous chemical spill or a fire. This

section standardizes each of these responses so that the proper actions will be taken to alleviate the situation. The Responsibilities and Contacts portion of the plan lists who is in charge in certain instances and gives the phone numbers of people to call to obtain consent for new projects. In the plan, the institution extends the simple format to the chemical hazards section, which lists in a table the specific classifications of chemicals, the hazard that the chemical poses, and what protective measure can be taken to either prevent or treat an undesired occurrence (University of California at Berkeley, 2006). The Standard Operating Procedures section details the procedure that should be used in the lab when conducting experiments and when storing and disposing hazardous wastes. The Controlling Exposures section outlines the types of protection that should be used for each hazardous chemical found in the laboratory, and the Campus Safety Resources section lists the names and phone numbers of people to contact in case of an emergency. The only training that the CHP requires is for each student, faculty, and staff member to read and understand the Chemical Hygiene Plan. The training section contains extra documentation on what responsibilities lay with each person, and how each person should go about properly assuming their responsibility. However, this section is not necessarily a requirement and is considered an extra accomplishment if undertaken (University of California at Berkeley, 2006).

When a new program requires the creation of a new chemical hygiene plan, the UCB chemical safety plan allows for the implementation of new safety measures in a fashion that is very similar to that of MIT. A laboratory-specific hygiene plan can be developed by checking boxes on the template that apply to the laboratory. Next to these checkboxes are links to the appropriate standard operating procedures for that choice (University of California at Berkeley,

2006). These operating procedures are designed to reduce exposure to chemicals and are reinforced by practices suggested in the Controlling Exposures section of the plan.

The University of California at Berkeley also utilizes a chemical exchange program seeking to reduce excess hazardous waste on campus. With this program, unwanted and unclaimed chemicals are gathered and entered into a database called CHEX. Employees can search through this database for a chemical that they need and make a request for that chemical. Credits equal to the amount of the chemical's disposal cost are awarded to a Hazardous Waste Recharge Account for the department that donated it (University of California at Berkeley, 2000). This program is an excellent example of how to recycle unneeded chemicals on a university campus.

In contrast to the plans of WPI and MIT described above, this plan places less emphasis on both enforcement and structure. Despite this, the chemical safety plan at UCB is simple and complete. The Office of Environment, Health, and Safety, which oversees all laboratories and all safety practices on the campus (such as fire protection and matters of disposal), assumes much of the responsibility of a typical chemical hygiene officer. At the University of California at Berkeley, all of the necessary elements of a chemical safety program are presented in an easy to understand manner, allowing for increased compliance and remembrance of its contents, making it a very effective program.

#### **2.3.4 Relevance of Programs at Other Universities**

During our research of chemical safety programs at universities within the United States, we found that the three examined each had a significantly different structure; however, all included every single one of the elements of the ideal chemical safety plan described in Section

2.2. Therefore this research accomplishes two things. First, the structure of each program provided examples of chemical safety practices to follow and ideas on chemical safety programming to include within the recommendations for a university-wide chemical safety program at Chulalongkorn University. Second, the consistent inclusion of all of the elements of chemical safety described in Section 2.2 reinforces their importance as part of a comprehensive chemical safety program. The next section details exactly how to bring about changes within an organization, which will be of help when determining recommendations for a new chemical safety program at Chulalongkorn University. More importantly, it outlines strategies to successfully implement a new program within an institution.

#### **2.4 Transforming Organizations**

After proposing a design for a university-wide chemical safety program, there are a number of methods of organizational change that can be used to implement the changes into any university, such as Chulalongkorn. Strategies of organizational change may also be useful for refining the chemical safety program within the Faculty of Science. This section outlines strategies for organizational change, and then proposes potential methods for the utilization of these strategies for the continued improvement of the chemical safety program within the Faculty of Science and for integration of the recommendations for the development of a comprehensive chemical safety program at Chulalongkorn University.



### 2.4.1 Strategies for Bringing about Change in an Organization

For a university-wide chemical safety program to be effective, changes within the organization of the university must be implemented. There are seven strategies for changing an organization (Nervis, Lancourt, & Vassallo, 1996): participation, coercion, making it difficult to make mistakes, expectancy, persuasion, modeling and selective reinforcement, as shown in Table 2.4.1.1. For continued success of a program within an organization a combination of the seven steps should be applied; however, one need not address these steps sequentially. The following subsections explain each of the seven strategies of organizational change and give examples of how each strategy could be useful for the successful expansion of the chemical safety programming at Chulalongkorn University.

<b>Seven Strategies for Bringing About Change in an Institution</b>
<ul style="list-style-type: none"><li>• <b>Participation</b> – Involvement of those affected, allowing for more input</li><li>• <b>Coercion</b> – Establishment of a method of enforcement</li><li>• <b>Make It Difficult to Make Mistakes</b> – Simplification of procedures and manuals for easy comprehension</li><li>• <b>Expectancy</b> – Setting of high expectations in appropriate areas</li><li>• <b>Persuasion</b> – Use of visual devices to convey need for caution</li><li>• <b>Modeling</b> – Use of good role models to convey proper practices to others</li><li>• <b>Selective Reinforcement</b> – Connection of people to the problem by rewarding good behavior</li></ul>

**Table 2.4.1.1:** Seven Strategies for Bringing About Change

### *Participation*

Of the seven methods of implementing change within an organization, the most important aspect of bringing about change in an organization is participation (Nervis, Lancourt, & Vassallo, 1996). In general, the more input individuals have in a new program, the more they are committed to executing the program. Therefore, the more students and faculty members involved in developing and implementing the chemical safety program within the university, the more successful the program should be.

One problem with participation as a strategy for organizational change is that it takes a significant amount of time to get the members of an organization to accept the program (Nervis, Lancourt, & Vassallo, 1996). Thus, some form of motivation or *coercion* is usually necessary to facilitate as much participation as possible. Individuals should be encouraged to participate by their superiors while at the same time reassuring that their authority in the matter has remained unchanged. In this respect, participation takes on an important role when expanding the chemical safety program to the entire university.

### *Coercion by establishing enforcement*

When accidents occur within universities, coercion, the enforcement of penalties, becomes necessary. For every expectation set by a chemical safety program, a penalty for not meeting that expectation should exist. Additionally, someone must have the power to punish individuals, if the expected chemical safety practices are not followed. There should also be barriers to prevent people from ignoring the punishment. For example, if someone fails to properly label a chemical, some kind of penalty should exist for that failure.

Coercion at universities in the United States frequently occurs through governmental laws and regulations, at both the state and federal level. Unfortunately, while there are some occupational health and safety laws set by Thailand's national government that apply to chemical safety, they are somewhat deficient due to the limited scope of these regulations and the separation of Occupational Health and Safety (OSH) among several departments within the government (Kogi, 2001). Therefore, at this time, Thai governmental regulations cannot play a prominent role in coercion within the Faculty of Science or within the university as a whole.

Identification of the positions of power within Chulalongkorn University, with regard to chemical safety, will be helpful for effective enforcement of a new chemical safety program. However, enforcement may be difficult in Thailand, because of cultural preferences toward avoiding confrontation.

#### *Make it difficult to make mistakes*

An additional step for successfully bringing about change in a program is to make it difficult to do the wrong thing. Procedures and manuals for the university-wide chemical safety program should be easy to understand and thoroughly address chemical safety in a comprehensive, but succinct manner. Straightforward manuals should ease the learning of new practices and procedures leading to easier adoption. It should, therefore, make it more difficult for workers to make a mistake since the proper safety procedures can be easily understood.

#### *Set clear expectations*

Expectancy sets the standards for the chemical safety program. The expectations of a comprehensive chemical safety program must be set as high as possible in all areas, because a

comprehensive program can only improve conditions to the level of expectations that it sets (Nervis, Lancourt, & Vassallo, 1996). If expectations are set too low and are too easy to achieve, then there will be very little change with respect to the original state. If, however, the expectations for the chemical safety program are set high, then the university-wide chemical safety program can achieve great success, but with the condition that expectations are not set so high that they are unachievable for the participants in the program. Higher expectations may be more difficult to achieve and require more work from the individuals responsible for carrying out the chemical safety plan, but in the end they will be beneficial to the chemical safety program.

In one example, there may be a set of standard training expectations for all of the university as well as variable levels of additional expectations for some specific faculties, schools, colleges, and institutes. Massachusetts Institute of Technology (MIT) utilizes a system where all laboratory workers are required to undergo general chemical hygiene training, in addition to reading and understanding the MIT Chemical Hygiene Plan (B. Edwards, personal communication, November 14, 2006). Also, extra training may be required depending on the hazards of a given laboratory. Furthermore, any concerns that faculty or students may have should be considered when determining expectations. These concerns have been noted in our research within the Faculty of Science, which is a case study upon which to base recommendations for a comprehensive chemical safety program. As the university-wide chemical safety program is integrated into the university, expectancy should set the tone of the university's response to the program.

### *Persuasion*

Persuasion is also used to facilitate organizational change. Persuasive measures often utilize signs or warnings to convey a message, but these measures are limited because people need to be inspired to follow the warnings and signs (Nervis, Lancourt, & Vassallo, 1996). For example, signs may be posted within a laboratory stating “Wash your hands before leaving,” but individuals may still neglect to wash their hands before leaving the laboratory. Additionally, individuals with credibility within the organization should be the personnel responsible for implementing persuasive strategies. Persuasion is necessary, but it is not sufficient by itself.

### *Modeling appropriate behaviors*

Modeling desired behaviors can have a significant impact on the actions individuals take (Nervis, Lancourt, & Vassallo, 1996). This step can also be thought of as “Building the guiding team,” where the individual implementing change must “get the right people in place with the right emotional commitment, and the right mix of skills and levels” (Chapman, ©2006). The changes should be modeled by respected faculty members who exhibit good chemical safety practices. If other faculty members and students follow the good practices of the model faculty members, then the safety of the entire facility should increase. Therefore, respected faculty members must serve as good role models so that the university-wide chemical safety program will be taken seriously. If someone does not take the chemical safety program seriously, other members of the community may think that a comprehensive chemical safety program is not important.

### *Positive reinforcement*

As a chemical safety program is implemented, selective and positive reinforcement of proper behavior should occur (Nervis, Lancourt, & Vassallo, 1996). For example, signs saying “Congratulations there have been no accidents at Chulalongkorn University for the past 90 days!” would be encouraging, and rewarding to the faculty and students involved in the chemical safety program. Selective reinforcement can allow people to feel more connected to the problem that is being resolved. Programs should “...reward and recognize progress and achievements” to “empower actions” (Chapman, ©2006) within the organization. However, when practicing selective reinforcement, the right behaviors must be rewarded.

To effectively implement a university-wide chemical safety program, a combination of all of these methods for organizational change should be used. Additionally, it should be noted that the strategies listed above are ongoing and must continue until the change is complete. These strategies should be used when implementing the recommendations for expanding the chemical safety program within the Faculty of Science, and for developing a university-wide chemical safety program for Chulalongkorn University.

## **2.5 Conclusion**

Each of the areas addressed by the background chapter has a critical bearing on the questions asked as part of the research into Chulalongkorn University. The organization of the university and the Faculty of Science was important because it helped our team determine who we should interview in our methodology. The history of chemical safety at Chulalongkorn University and the Faculty of Science was important because it is vital in providing a baseline for comparison to current practices, which was determined in our field research. It was important to

establish the components of an ideal chemical safety program so that a comparison could be made between the program and the expectations of the faculty and staff at the university. The chemical safety programs of WPI, MIT, and UCB were analyzed to provide examples of how an ideal chemical safety program can be adapted to overcome the specific problems of a particular institution. The challenges to implementing a chemical safety program at Chulalongkorn University will be established by our research, as described in the next chapter. Finally, the seven steps towards changing organizations were established so that with the research into the motivation of Chulalongkorn University an effective strategy for implementing a chemical safety program at Chulalongkorn University could be determined.

### 3. Research Methods

To make recommendations for an effective and comprehensive chemical safety program at Chulalongkorn, our team developed a research methodology that would help establish an understanding of the policies, procedures, and expectations for chemical safety at Chulalongkorn. Currently, policies and procedures regarding chemical safety are found mainly within the Faculty of Science. Thus, the Faculty of Science served as a case study for evaluating chemical safety practices that might be extended throughout the university. The expectations of professors within the Faculty of Science were of particular importance because these individuals are responsible for promoting chemical safety. Additionally, we assessed the aspects of Thai culture that might affect how well a chemical safety program may function.

To obtain information on these topics and ultimately create recommendations for the design of a complete chemical safety program, the following questions were researched at Chulalongkorn University:

- How extensive is the current knowledge of students, faculty, and staff about chemical safety?
- What are the expectations of individual faculty and staff for a chemical safety program?
- What organizational structure exists for the enforcement of a chemical safety program?
- What are the potential barriers to new chemical safety policies?
- What are the motivations to change current chemical safety practices?

This chapter discusses the aforementioned issues and questions and describes the research methods used to gather and analyze the data needed to make these recommendations.



### 3.1 Overview of Research Methods

Field research methods have been used to gather both qualitative and quantitative data on current chemical safety practices at Chulalongkorn University; these methods are described within this section.

#### *Qualitative Field Research*

Some of the data used to answer research questions came from observations of attitudes and behaviors of students and faculty at Chulalongkorn, rather than from statistically representative samples. This type of research is defined as qualitative observational field research. In *The Practice of Social Research*, Earl Babbie writes, “Field research more typically yields qualitative data: observations not easily reduced to numbers. Thus, for example, a field researcher may note the ‘paternalistic demeanor’ of leaders at a political rally or the ‘defensive evasions’ of a public official at a public hearing without being able to express either the paternalism or the defensiveness as numerical quantities or degrees” (Babbie, 1989, p. 261). Using the qualitative data, we systematically drew conclusions about chemical safety within the Faculty of Science and Chulalongkorn University as a whole.

We supplemented qualitative observational field research with survey field research to add both depth and validity to our findings. As Babbie writes, “In part, field research is a matter of going where the action is and simply watching and listening. You can learn a lot merely by being attentive to what’s going on. At the same time... field research can involve more active inquiry. Sometimes it’s appropriate to ask people questions and record their answers” (Babbie, 1989, p. 269). In the case of this project, simply observing chemical safety practices at

Chulalongkorn did not provide enough data to make sound conclusions and generalizations. Survey research provided more data and added legitimacy to this project.

This project employed two methods of survey research: interviews and questionnaires. The data obtained from the interviews were qualitative, whereas the data from the questionnaires were quantitative. Questionnaires will be discussed further in the quantitative field research subsection, but there are some common features for the formatting of both interviews and questionnaires that need to be discussed first.

There are three different types of interviews and questionnaires: structured, semi-structured, and lightly structured (Knight, 2002, p.63). Structured interviews and questionnaires have fixed responses and are quick to do; thus, they usually give straightforward answers and require a large group of respondents to obtain a complete data set. In contrast, semi-structured and lightly-structured interviews and questionnaires elicit more open-ended responses, thus taking more time than structured interviews and questionnaires in both research and analysis because the information gained needs to be coded and interpreted. The main difference between semi-structured and lightly-structured survey methods is that semi-structured methods have a combination of fixed-response questions and open-response questions, whereas lightly-structured interviews and questionnaires contain some prompts and questions but have a flexible sequence. Neither semi-structured nor lightly-structured interviews nor questionnaires require a large group of respondents, because “interpretive research tends not to see sample size as a key indicator of research quality” (Knight, 2002, p.63).

Because of limited time and resources, the interviews we conducted were lightly-structured. This type of interview allowed us to utilize a relatively small sample of respondents

and enabled a more in-depth exploration of the topics addressed within each interview. See Appendix A for a complete list of interview questions.

### *Quantitative Field Research*

In addition to the qualitative field research, quantitative research was conducted using two questionnaires: one on safety practices within laboratories in the Faculty of Science and the other within a class of students from the Department of Chemistry.

The goal of the first questionnaire was to assess the chemical safety practices in seventy-one laboratories within the Faculty of Science. The questionnaires for these laboratories were structured, and designed by two graduate students within the Department of Chemistry at Chulalongkorn University. Using structured questionnaires is ideal when gathering information from large samples in a limited amount of time, as described in the Qualitative Field Research section; because data were obtained from seventy-one laboratories within the Faculty of Science, structured questionnaires were used when surveying these laboratories. For each questionnaire, the graduate students assessed the state of chemical safety within each laboratory based on the fixed responses contained within the questionnaires. See Appendix B for a list of survey questions and possible responses.

The second questionnaire aimed to develop an understanding of the knowledge students have on chemical safety. These questionnaires were semi-structured by design allowing for both closed and open-ended questions to be asked of the forty-six students surveyed. Quantitative analysis of the data was performed to determine the percentages of students with similar responses to questions. Examining these percentages allowed for recognition of any trends which existed in the data. See Appendix D for the in class questionnaire and a summary of the results.

Quantitative statistical analysis of the data obtained through these two questionnaires added another dimension to our research, validity to our conclusions and, ultimately, validity to our recommendations for a university-wide chemical safety program.

## **3.2 Analysis**

This section describes the ways in which both types of data—qualitative and quantitative—have been analyzed in order to make valid generalizations and conclusions for the recommendations for a university-wide chemical safety program at Chulalongkorn University.

### **3.2.1 Analysis of Qualitative Data Using Grounded Theory**

The primary method we used for the analysis of qualitative data relating to chemical safety is *grounded theory*. Grounded theory was developed by Barney Glaser and Anselm Strauss in the 1960s as a means to provide a clear, systematic method for analyzing qualitative data (Glaser and Strauss, 1967). Fundamentally, grounded theory revolves around the coding of qualitative data—in this case interview transcripts—so that data can be extracted in a way that minimizes its volume while still maintaining the validity of the interpretations.

Coding is done by looking carefully at what was said in an interview to name and categorize data by searching for key ideas, or “codes,” that evolve from interview responses. Codes are thoughts, ideas, or themes that are consistently present throughout the obtained results. To analyze interview transcripts, for example, the researcher scans the document and search for words, phrases, and key points (codes) that are relevant or important to his or her research. These codes may then be grouped together by theme, and conclusions may be drawn by observing the

relationships that exist between the groups of codes (Gibbs and Taylor, 2006). For example, if individuals who are interviewed discuss their feelings about the general safety of a laboratory, some individuals may feel safe and some may feel unsafe, but their responses could all be grouped in a code for the general feelings about chemical safety at the university.

During the coding process, the researcher should rescan the previously coded data to see if any of the newly coded data is relevant. This process is called *constant comparison*, and allows for continuous development of the relationships between groups of codes. Constant comparison also provides the opportunity to take research into new directions that may be beneficial to the outcome of the project through uncovering relationships between groups of new and previously coded data (Gibbs and Taylor, 2006).

Grounded theory is used to establish a clear understanding of the ideas being expressed by the individuals who are interviewed. By coding and grouping the codes based on similar themes or ideas and then examining the relationships between them, it was possible to form an accurate understanding of the following:

1. the existing chemical safety practices at Chulalongkorn University;
2. the education and general knowledge of the university's students, faculty, and staff about chemical safety;
3. the expectations of the university's students, faculty, and staff concerning a new chemical safety program;
4. the university's policies and procedures for chemical safety; and
5. the cultural elements of Thai society that affect chemical safety.

The codes that evolved and the conclusions that were drawn from them are covered in the Findings and Discussion chapter. Once we gained an understanding of current levels of chemical safety at Chulalongkorn, this knowledge was compared to the information gathered from the Background chapter detailing the key elements of an all-encompassing chemical safety program.

The areas in which Chulalongkorn University's chemical safety could be strengthened were noted and recommendations were made for improvement.

### **3.2.2 Analysis of Quantitative Data**

Quantitative data from the questionnaires distributed in laboratories by two graduate students within the Department of Chemistry and the questionnaires given to first-year chemistry students were analyzed in a different manner.

For fixed response questions, the percentages of each response were determined. Then trends within the results were identified. From these trends, conclusions were drawn. For the survey conducted within the laboratories, seventy-four of the eighty-seven questions in the survey were multiple-choice and had between two and four possible responses. Each possible response was assigned a numeric value between one and four using a Likert scale, with four being very good, three being good, two being average, and one being below average. Some questions, such as questions that could only be responded with a yes or no, allowed for fewer than four possible responses. In this instance, yes might be assigned a value of four and no a value of one. For the survey conducted within the classroom of first-year students, common responses to questions were grouped together, and the percentages of students with common responses were calculated. These numerical data were utilized to support the findings determined through qualitative analysis. See Appendix C for a summary of the results from the laboratory survey.

The next section describes the research methods used to collect both qualitative and quantitative data on the current level of chemical safety practiced within the Faculty of Science at Chulalongkorn University.

### **3.3 Current State of Chemical Safety at Chulalongkorn University**

To inform the development of recommendations for a comprehensive chemical safety program both within the Faculty of Science and at the university level, the current level of safety practiced at Chulalongkorn University was assessed. Relevant information gathered about the university included:

- Standard operating procedures;
- Safety equipment;
- Training requirements;
- Enforcement structure;
- Hazard communication methods;
- Waste storage and disposal practices; and
- Waste minimization practices.

By obtaining as much knowledge on each of these subjects as possible, we established the current status of safety practices and then used qualitative data analysis to compare this with the model chemical safety program developed in the Background chapter. See Section 3.2 for further information on the analysis of data gathered using the methods described below.

In order to gather a sufficient amount of information to develop recommendations for a university-wide safety program, we conducted interviews with five individuals at Chulalongkorn University (Table 3.3.1). Each interview was conducted in a lightly-structured fashion, meaning that there was a flexible sequence for responses, and questions were used as a guide for the interviews. Each interview was led by one team member, but other team members also asked additional questions as the interview was occurring. For each interview, all members of the project team recorded notes, which were compiled following the interview to obtain a complete record.

<b>Name</b>	<b>Chemical Safety Specialty</b>
Dr. Soottiporn Chittmittrapap	Overall Program
Dr. Sarowarux Fuangwasdi	Chemical Safety Training
Dr. Lursuang Mekasut	Chemical Inventory Program
Dr. Prasert Reubroycharoen	Chemical Waste Disposal
Dr. Wasant Pongsapich	Hazardous Waste Management

**Table 3.3.1:** Individuals Interviewed at Chulalongkorn University

The first interview that we conducted was with Dr. Prasert Reubroycharoen, one of the assistants for the school's chemical waste disposal program in charge of coordinating waste disposal for the entire university. He has knowledge about hazard communication, waste storage and disposal, and waste minimization practices at Chulalongkorn. For this interview, we used semi-structured questions that were open-ended and allowed for detailed explanation of the inner workings of the university's policies and procedures on hazardous waste and its removal from campus (see Appendix A).

The second interview conducted was with Dr. Sarowarux Fuangwasdi, an integral member of the chemical safety training and management program at Chulalongkorn University. She has extensive knowledge about chemical safety training and education. Again, we used semi-structured, open-ended questions during this interview to understand the education and training received by students, faculty, and staff (see Appendix A).

The third interview was with Dr. Lursuang Mekasut, the person in charge of the chemical inventory management program at Chulalongkorn University, to obtain more knowledge on waste storage and disposal as well as waste minimization. Similar to the first two interviews, we used semi-structured, open-ended questions to learn about the cycle of each chemical through the university and the steps taken to reduce the amount of chemicals on campus (see Appendix A).



The fourth interview at Chulalongkorn was with Dr. Soottiporn Chittmittrapap, the Vice President of Research and International Affairs, who is in charge of chemical safety for managing chemical safety for entire university. Once again, semi-structured interviews with open-ended questions were used to learn about the process for implementing programs within the university and the Vice President's goals for the Chemical Safety Program.

The final interview was with Dr. Wasant Pongsapich, who is in charge of Hazardous Waste Management at Chulalongkorn University. The interview was semi-structured, and open-ended questions were asked to determine the current hazardous waste management practices at the university as well as his goals for the expansion of the management program.

Although the interviews with faculty members provided us with information on many chemical safety practices at Chulalongkorn, there were still aspects of the program that needed to be explored further. Therefore, to supplement the information gained through interviews, we utilized existing research on chemical safety that had been performed by Jib and Liew, two of Dr. Supawan's graduate students within the Department of Chemistry. These students conducted surveys of seventy-one laboratories on campus to assess the variety of safety procedures and equipment used in each location (see Appendix C). These data were statistically analyzed, as described in Section 3.2.2, to evaluate the level of safety practiced within the laboratories.

The final method utilized to gather information on the chemical safety practices present consisted of personal observation of a laboratory. We observed a laboratory in the Faculty of Science by conducting one of the questionnaires from the graduate students' study. As the questionnaire was filled out, photos of the areas the questionnaire posed questions about were taken. The visual inspections of chemicals, chemical safety equipment, and chemical safety procedures supplemented the information contained in the surveys conducted by the graduate

students and established the validity of the survey process. The information provided by observation is qualitative, not quantitative, and was analyzed as such; additional information on the methods of analysis is found above in Section 3.2.1.

### **3.4 Chemical Safety Education and Knowledge at Chulalongkorn University**

For a chemical safety program at the university level to be successful, all students and faculty in the university who deal with chemicals should be educated in chemical safety practices. To develop recommendations on expanding the educational programming on chemical safety, we researched the current safety training practices through an interview with Dr. Sarowarux Fuangwasdi, who is responsible for chemical safety training within the Faculty of Science.

This interview consisted of questions, located in Appendix A, relating to the extent of formal chemical safety training for students and faculty of all levels. For example, we asked questions like what kind of chemical safety training is required of undergraduate students within the Faculty of Science and is there any additional chemical safety training required for graduate students working with specific hazardous chemicals. Additionally, we asked what training existed for students and faculty dealing with chemicals outside the Faculty of Science. In accordance with grounded theory, outlined in Section 3.2.1., the information obtained about knowledge of chemical safety was coded following the interview.

### **3.5 Expectations for the Expansion of the Chemical Safety Program**

An understanding of the expectations of the individuals who will play a key role in implementing a university-wide chemical safety program is important when establishing recommendations for the future.

Interviews with Dr. Soottiporn Chittmitrapap, the Vice President of Chulalongkorn University, Dr. Prasert Reubroycharoen, chairman of chemical management and hazardous waste disposal, Dr. Lursuang Mekasut, head of developing a chemical inventory program for Chulalongkorn University, and Dr. Sarowarux Fuangswasdi, head of chemical safety training within the Faculty of Science, contained questions to establish the expectations of a chemical safety program for the university as a whole. The latter three individuals were identified by the sponsor of this project, Dr. Supawan Tantayanon, as faculty members who currently have a prominent role in implementing the improved chemical safety program within the Faculty of Science.

Interview questions on expectations were conducted in a lightly structured manner, which differs from semi-structured in that the questions presented are open-ended, allowing for a wider variety of responses and no limit to the length of response (Knight, 2002). The questions brought to the interview were used as a guide, but the individual being interviewed was allowed to provide information that was not necessarily directly tied to the specific question being asked. These interview questions were asked and recorded in the same manner described in Section 3.3.

By establishing the expectations of faculty for a chemical safety program, recommendations for the improvement of the program within the Faculty of Science and the expansion of the program to the university level could be made with the goals of the faculty in mind.

### **3.6 Policy and Structure at Chulalongkorn University**

When a formal program is implemented within a university, the policies and procedures designed to integrate the program into the structure of the university must be followed. An understanding of the organizational structure at the administrative level of the university is important to determine who should be responsible for integrating different phases of a program into the university.

The Vice President of Chulalongkorn University, Dr. Soottiporn Chittmitrapap, provided us with an understanding of the policies and procedures for bringing about change and the current structure that exists within the institution. This interview was conducted in semi-structured format to provide further insight into understanding the policies and administrative structure of the university.

With knowledge of the methods Chulalongkorn University uses to bring about institutional change, recommendations for the expansion of the chemical safety program within the Faculty of Science to the university level were designed specifically to conform to the university's own policies and procedures.

### **3.7 Impact of Thai Culture on Chemical Safety Programs**

King Mongkut University of Technology at Thonburi (KMUTT) is a university in Thailand that has a formal chemical safety program. We studied the impact of Thai culture on a chemical safety program at the university level by evaluating the program at KMUTT, and then comparing our findings to the ideal chemical safety program outlined within the Background chapter. This section of our research provided information on any cultural differences that may

exist when implementing a chemical safety program in Thailand as opposed to within the United States.

At KMUTT, we interviewed Assistant Professor Suchada Chaisawadi, who is their Chemical Safety Officer. This interview was done in a semi-structured format using open-ended questions to allow for extensive discussion of the chemical safety program at the university. The interview was conducted in the same manner as interviews with Chulalongkorn faculty. The analysis of this data is described in Section 3.2.1.

From this interview, we learned the methods used to implement a chemical safety program within a Thai university as well as the areas where their program is particularly strong. The coded data from this interview was compared with the coded data from the interviews at Chulalongkorn using constant comparison, as described in Section 3.2, to identify any similarities or differences between the two programs. This comparative analysis highlighted elements in the chemical safety program present at King Mongkut University of Technology at Thonburi that may be successful at Chulalongkorn.

### **3.8. Motivation for a Safer Working Environment at Chulalongkorn University**

A chemical safety program is designed to minimize the risk of an accident when working with hazardous chemicals, and provide a contingency plan for instances when accidents occur. To be effective, faculty, students, and staff must abide by the rules of the chemical safety program. Graduate students conducting research with hazardous chemicals, for example, have the responsibility to be aware of the requirements, restrictions, policies, procedures, and other aspects of the chemical safety program pertaining to the work they are doing. It is also their responsibility to make sure that their actions reflect what they know about the chemical safety

program and that they comply with its every requirement. By doing so, the risk associated with the hazardous chemicals being used for necessary research will be minimized.

In some situations, those working under the jurisdiction of a chemical safety plan may not follow the policies and procedures set forth by the safety program. Students not thoroughly educated in lab safety, for example, may be unaware of certain hazards and may not use appropriate safety techniques. More educated graduate students, as another example, may not be very careful in a laboratory if they feel overly confident in themselves, their knowledge and abilities, and have never had any sort of accident. In these instances and others, the risks the chemical safety program aims to minimize or eliminate can grow and the essential purpose of the chemical safety program is defeated. Thus, motivation for the adoption of and adherence to a chemical safety program becomes essential.

In our research, we have utilized a method for measuring motivation for a university-wide chemical safety program at Chulalongkorn University. Motivation was measured through interviews with Dr. Sarowarux Fuangswasdi, head of chemical safety training, Dr. Prasert Reubroycharoen, head of the development of the new chemical inventory program, and Dr. Lursuang Mekasut, the head of the chemical waste minimization program. One additional interview was conducted through convenience sampling with Jib, a graduate student within the Department of Chemistry at Chulalongkorn University.

In these lightly-structured interviews, we asked questions about the aspects of a chemical safety program present within each individual's area of chemical safety, and their goals for the chemical safety program in the future. Questions asked during these interviews included whether or not people expressed interest in improving chemical safety and if an improved program were adopted how people might react. To evaluate the data we used *grounded theory*, as outlined in

Section 3.2.1. From this evaluation, we were able to create recommendations regarding the overall level of motivation for improving chemical safety. This allowed for identification of the characteristics of an improved program that would be embraced by the community and in turn be successful throughout the university.

### **3.9. Relevance of Research Methods**

The information that was gathered through the methods outlined above provided the necessary foundation for determining recommendations for the expansion of the current chemical safety program within the Faculty of Science at Chulalongkorn University to encompass the entire university. The Faculty of Science was used as a case study to determine what chemical safety practices had already been instituted and what areas of chemical safety needed to be improved. The expectations and motivation of faculty members and students towards the improvement of chemical safety provided a better understanding of Chulalongkorn University's vision of a successful chemical safety program and the areas of the chemical safety program that have not been addressed at Chulalongkorn. The comparison of the organizational structure of Chulalongkorn University and King Mongkut University of Technology at Thonburi allowed for identification of Thai cultural and organizational influences on a comprehensive chemical safety program. In-depth understanding of these key topics led to the development of recommendations for continued improvement of the chemical safety program within the Faculty of Science, and a chemical safety program specifically for Chulalongkorn University. The next chapter of this report highlights the findings obtained with these research methods, and a discussion of these findings.

## **4. Findings and Discussion**

To make recommendations for the improvement of chemical safety at Chulalongkorn University, it was first important to pull the relevant information from the data that was gathered through the research methods described above. This chapter discusses our findings pertaining to chemical safety at both Chulalongkorn University and King Mongkut University of Technology at Thonburi (KMUTT).

### **4.1 Chemical Safety at Chulalongkorn University**

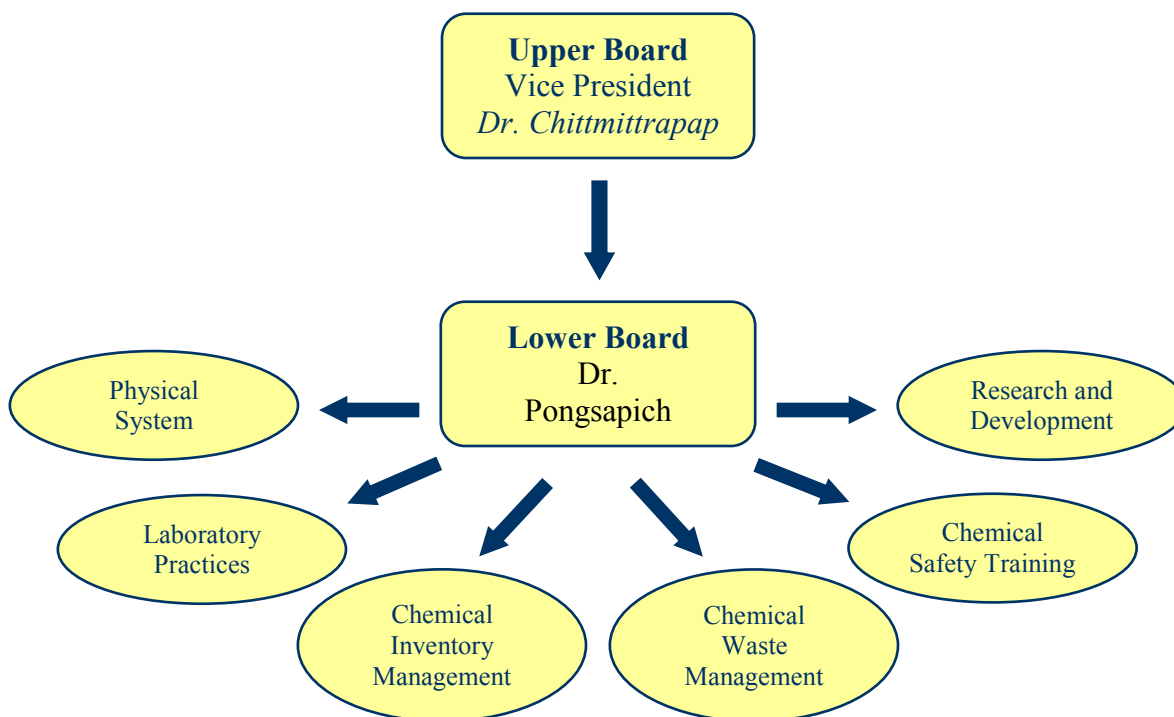
The Faculty of Science at Chulalongkorn University has recognized the need for a comprehensive chemical safety program on its campus. In this section we will describe the steps that the school has taken to address this need. Currently a chemical safety committee has been set up within the Faculty of Science, and there are three projects underway to improve chemical safety. The first project concentrates on laboratory safety and chemical safety training, the second addresses chemical inventory management, and the third deals with chemical waste disposal.

#### **4.1.1 Structure of the Current Chemical Safety Program**

Chulalongkorn University has implemented a structure for the oversight of its current chemical safety practices and the future expansion of these practices into a comprehensive chemical safety program. This structure consists of an upper board and a lower board, as shown in Figure 4.1.1.1 below. The upper board is managed by the Vice President, who has control over any formal policy regarding chemical safety. The lower board, managed by Dr. Pongsapich, an



administrative member of the university, is divided into six different branches. Each of these branches is made up of a work group with a manager and, as shown in Figure 4.1.1.1, focuses on a particular dimension of chemical safety (S. Chittmittrapap, personal communication, February 1, 2007).



**Figure 4.1.1.1:** Structure of chemical safety program administration at Chulalongkorn University

The first of these branches is called the Physical System. What this refers to is the physical condition of the laboratories and facilities on campus and the engineering controls present in each of them, such as fume hoods, ventilation systems, electrical wiring, etc. This branch is responsible for ensuring that laboratories on campus have the appropriate physical chemical safety equipment.

The second branch, Laboratory Practices, focuses on specific sets of standards and procedures for those that work in the laboratory, such as guidelines and procedures for handling and storing chemicals and maintaining a clean work environment.

The third branch is named Chemical Inventory Management. This group is responsible for the development and the usage of an online chemical inventory management program to keep track of the flow of chemicals in and around the Chulalongkorn University Campus.

The fourth branch, called Chemical Waste Management, concentrates on the storage and disposal of chemical wastes from Chulalongkorn University, such as hazardous chemicals from the Department of Chemistry or biological waste from the Department of Biology.

The fifth branch, Chemical Safety Training, focuses on training for Chulalongkorn University's students, faculty, and staff on chemical safety practices, policies, and procedures.

Finally, the sixth branch is called Research and Development. It works to develop new techniques for both the synthesis of useable chemicals and the disposal and recycling of chemical wastes on the Chulalongkorn University campus.

Together these six branches make up an administrative structure that appears to be quite capable of effectively managing a comprehensive, university-wide chemical safety program. Because chemical safety on the Chulalongkorn University campus is a relatively new proposition, only four of these branches—two working independently and two working in collaboration—have had any success at making headway towards effective, sustainable chemical safety practices. Within these four branches, including Laboratory Practices, Chemical Safety Training, Chemical Inventory Management, and Chemical Waste Disposal—three projects have been undertaken to improve chemical safety. The next three sections below describe the three

projects, titled Laboratory Safety and Training, Chemical Inventory Management, and Chemical Waste Management, and detail their various successes and weaknesses.

#### **4.1.2 Laboratory Safety and Training**

The first project begun on Chulalongkorn University's campus, which has yet to be completed, is a result of collaboration between the Laboratory Practices branch and the Chemical Safety Training branch of the school's lower board on chemical safety. Dr. Supawan Tantayanon, the vice president of the Faculty of Science, has been placed in charge of this project, which aims to accomplish two things: to ensure that laboratories have a standard set of operating procedures and any necessary safety equipment; and to educate students, faculty, and staff on general chemical safety and chemical safety within the laboratory.

##### *Laboratory Standard Operating Procedures*

Standard operating procedures and laboratory safety equipment are two requirements of a comprehensive chemical safety program: the effective use of both maximizes efficiency and safety. Standard operating procedures are specifically designed to protect the health and safety of those using chemicals. At Chulalongkorn University, there has been no standard set of operating procedures developed for its laboratories. In the survey of seventy-one laboratories within the Faculty of Science, for example, graduate students and faculty members within the laboratories were each asked if they contacted the appropriate staff members in the event of an accident, such as a chemical spill. Only 72% contact appropriate staff in every case, while 24% contact them in only moderate to severe cases and 4% never contact them. Typical standard operating

procedures, however, would generally require that any accident, chemical spills included, be reported to the appropriate faculty or staff.

In another example, the same group of laboratories was asked if volatile and hazardous chemicals are always poured in the fume hood for proper ventilation. Only 78% actually do this on a regular basis, while 22% do not use a fume hood for pouring volatile and hazardous chemicals at all. This relatively simple practice of using a fume hood for hazardous chemicals is usually something that a standard set of operating procedures addresses and requires. When combined with laboratory safety equipment, standard operating procedures help to minimize the risk for those working in the laboratory.

#### *Laboratory Safety Equipment*

Laboratory safety equipment can be split into two different types: engineering controls and personal protective equipment. There are many engineering controls located within laboratories at Chulalongkorn University; however, a great deal of this equipment is neither maintained nor used properly. In the survey of seventy-one laboratories within the Faculty of Science, for example, 90% of laboratories do not have fume hoods with working ventilation systems. A fume hood is designed specifically to create a workspace for using hazardous and volatile chemicals by venting harmful gasses and vapors to the outside. This protects those using the fume hood by allowing them to continue their work without breathing any of these harmful chemicals. The fact that 90% of the fume hoods within these seventy-one laboratories do not function properly essentially renders them useless. In laboratories within universities in the United States, not only must fume hoods be functioning properly, but they must be inspected on a regular basis according to government regulations.

In a second example, 67% of the laboratories surveyed have no sprinkler system for fire suppression. This has already proven to be a problem. According to Dr. Supawan, one of the chemistry laboratories on campus has had a fire within the past few years (personal communication, November 6, 2006). In laboratories where chemicals are used, a sprinkler system is generally considered vital. The United States, for example, requires all laboratories that use chemicals to have some sort of sprinkler system or automatic fire suppression system.

Personal protective equipment is also a problem and is used inconsistently throughout the university's campus. In the same survey, a question asked students and laboratory staff of the seventy-one laboratories if there were respirators available for those working in the lab. Respirators allow people to breathe in the event that some chemical or vapor makes the air in the laboratory unsafe to breathe. Of the fifty-six laboratories from which personnel responded, 45% of them (that is twenty-five) do not have respirators available for students or staff working there. In the United States, having respirators in all laboratories is regulated by the government and is mandatory. This lack of PPE is a major risk to students, faculty, and staff on the Chulalongkorn University campus.

In another example, the same laboratories were asked if safety goggles were available for use by those working in the laboratories. We found that 23% of laboratories have either broken goggles or no goggles at all. In the United States, goggles are required in the laboratory at all times. This is necessary as part of the Occupational and Health and Safety Administration's chemical hygiene plan requirements for universities. The fact that eighteen laboratories within the Faculty of Science do not wear safety goggles because they are broken or they do not have them is another major risk to the people working in them.

### *Chemical Safety Training*

According to the Vice President of Chulalongkorn University, education is one of the most essential ways to improve chemical safety on campus. People will not follow rules, regulations, and standard operating procedures or use and maintain laboratory safety equipment properly unless they understand their purpose (S. Chittmittrapap, personal communication, February 1, 2007). Current students, faculty, and staff at the university are not very well trained on chemical safety practices, procedures, and equipment. In the survey of seventy-one laboratories within the Faculty of Science alone, we found that many of the respondents, who were graduate students or faculty members working in the laboratory, do not understand many basic concepts that could prevent an accident or save their lives in the event of a serious incident. 51% of those surveyed, for example, do not know what to do in the event of a fire drill.

In another example, only 42 % of those surveyed know what types of personal protective equipment (goggles, laboratory coat, etc.) should be used in the laboratory. Without the knowledge of what protective equipment should be used in the laboratory; students, faculty, and staff are putting themselves in extreme danger.

Currently there is a five year plan within the Faculty of Science at Chulalongkorn University to educate students on general chemical safety. Starting in June, freshmen will be required to take an online tutorial and quiz on laboratory safety and basic chemical safety procedures before working in a laboratory. Students must pass this quiz without answering incorrectly and are allowed to repeat the quiz if they do not pass. Each passing student earns a safety card that permits them to work in the laboratory (S. Chittmittrapap, personal communication, February 1, 2007). During each subsequent year, incoming freshmen will continue to be trained until all four grade levels and those at the graduate level have received the

training. The online tutorial is expected to take about two hours. A chemical safety manual has also been written and is available to students, faculty, and staff. It is hoped that this chemical safety training will be successful. If it is a success, an additional training program will be developed for faculty and staff within the Faculty of Science. Ultimately, it is hoped that both training programs will serve as models for the entire university (S. Fuangswasdi, personal communication, January 19, 2007).

Although Chulalongkorn University lacks a great deal of the safety policy and equipment necessary to protect its students, faculty, and staff, it plans to implement a new training program for students and eventually faculty and staff. It is hoped by several administrators at the university—including Dr. Supawan—that this education will help people realize the importance of and need for standard operating procedures, engineering controls, and personal protective equipment. The next section discusses the second project that has been started within the Faculty of Science to improve chemical safety.

#### **4.1.3 Chemical Inventory Management**

The second project under way within the Faculty of Science at Chulalongkorn University focuses on the management of the inventory of chemicals on campus. It is the product of the Chemical Inventory Management branch of the lower board of chemical safety at the university, which has created a chemical inventory management computer program called ChemTrack. This program was recently completed in January of 2007.

According to Dr. Lursuang Mekasut, one of the program's developers, this program is accessible from any computer connected to the internet and records certain information about a chemical when it is purchased for use at the university. The information recorded includes the

name of the chemical, its concentration, its supplier, the quantity of the chemical, its invoice number, the person who purchased it, and its location on campus. One feature that it lacks, however, is the ability to track the exact quantity of each chemical at a given time. Thus, it is impossible to know how much of any chemical in the program still remains until the chemical is completely gone and is removed from the program's databank (L. Mekasut, personal communication, January 19, 2007).

One of the major weaknesses in this chemical inventory management program lies in the absence of another program for purchase control. Both purchase control and inventory control are two related elements as they seek to manage the flow of chemicals on campus. Chulalongkorn University, however, has no uniform system of purchase control. Many purchase chemicals through the school with the department's money, while others, according to Dr. Supawan, choose to use their personal money to purchase chemicals on their own for special experiments and choose to remain independent of the department.

In the laboratory survey, only 44% of the laboratories always purchased chemicals from the central chemical store. While this creates an unnecessary surplus of chemicals on campus, it also impacts the adoption of the new chemical inventory management system, ChemTrack 2007. Those who purchase chemicals independently may choose not to enter the chemicals they have purchased into the chemical inventory system, effectively defeating the purpose of the program.

#### **4.1.4 Chemical Waste Management**

The third and final project started at Chulalongkorn University concentrates on chemical waste management. This project is split into three different parts. The first is a university-wide cleanup of chemical wastes that have been stored on campus for the past 50-100 years. The



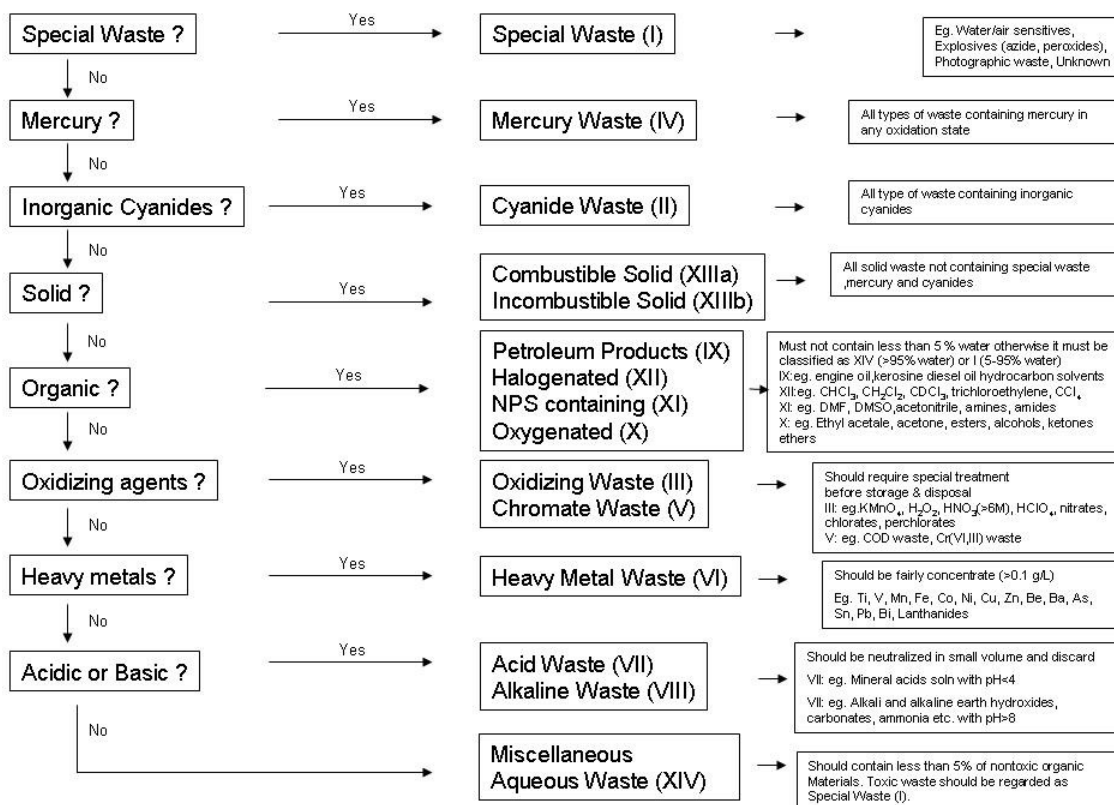
second is the development of a program to regularly dispose of any future waste in the most efficient and cost-effective way possible. The third is to reduce the demand for chemicals, and ultimately reduce the amount of chemical waste produced through waste minimization techniques.

### *Cleanup of Chemical Waste*

The first phase of the project, the disposal of chemical wastes from past years, has already been completed. Over a recent school break, students, who were better trained on how to properly categorize chemical waste than current staff members, were paid to organize chemical wastes and to relocate waste for proper disposal. Over the course of six months more than five metric tons of waste was removed from the university (S. Chittmitrapap, personal communication, February 1, 2007).

### *Chemical Waste Disposal Program*

The second phase of the project, the development of a waste disposal program, has begun and is currently in the process of being tested in several different faculties through pilot programs. A procedure for the disposal of chemical wastes has already been developed for the Faculty of Science at Chulalongkorn University. First, waste is classified and stored in appropriate containers as depicted in Figure 4.1.4.1, which shows the nine different groups that chemical waste must be separated into for proper disposal. Each category of waste requires specific treatment procedures and therefore it is imperative to properly separate them. Then, approximately once a year, a company is hired to pick up this waste, treat it, and dispose of it at their facilities.



**Figure 4.1.4.1:** System of classification of waste at Chulalongkorn University  
(P. Reubroycharoen, personal communication, January 19, 2007)

This company is called the General Environmental Conservation Public Company, or Genco for short. Established in 1994, Genco is a collaboration between Thailand's Ministry of Industry, the Industrial Estate Authority of Thailand, and the private sector to manage the wastes created by industrial development in Thailand. The company has two plants; the first is located in Map Ta Phut, which is part of the Rayong province. This plant has the capacity to both treat and stabilize waste, then dispose of it in an on-site landfill. Map Ta Phut also has a fuels blending system, which combines combustible wastes for burning rather than disposal in the ground where they have the potential to leak into groundwater supplies. The second plant is split between two locations: one in Bangkok and the other in the Ratchaburi province. The facility located in Bangkok is equipped to separate solid wastes from industrial wastewater, treat and

stabilize the solid wastes, and treat the wastewater, which is then discharged back into the public drainage system. The facility located in Ratchaburi consists of a landfill in which the treated and stabilized solid wastes from the Bangkok facility are stored (General Environmental Conservation Public Company, 2007).

Although Genco is an effective means for Chulalongkorn University to dispose of any chemical wastes, one long-term goal of the waste management project started by Dr. Supawan is to eventually have the facilities, staff, and equipment to dispose of chemical wastes internally. This would allow the university to store fewer wastes within each laboratory, creating a safer environment for students, faculty, and staff; this would also be cost effective for the university. Ultimately, it may be possible for the university to dispose of both their own waste and the chemical wastes from other universities and industries in the greater Bangkok area, which would provide additional revenue for the school (P. Reubroycharoen, personal communication, January 19, 2007)

Pilot programs have been initiated within certain faculties to combine wastes to reduce the overall cost of disposal. Rather than pay a disposal company once a year to go to each individual laboratory to collect chemical waste, these pilot programs will collect waste from various laboratories into centralized storage areas, where it is easy for a disposal company to come and pick up the waste. This costs less because larger quantities of chemical waste are being disposed of at one time. According to Dr. Chittmittrapap, Associate Professor and Vice President at Chulalongkorn University, this waste combination program could cut disposal costs up to 90% if done effectively throughout the entire university (personal communication, February 1, 2007).

### *Waste Minimization Techniques*

The third phase of this program, waste minimization, has also been developed and various techniques are being used throughout the Faculty of Science at Chulalongkorn University. The first is through recycling of chemicals, which takes place in a limited fashion on campus. The chemicals that are currently being recycled are solvents, which are mainly used to clean glass after being recycled. Additional techniques, however, are being developed to increase the amount of recycling that the university actually does (P. Reubroycharoen, personal communication, January 19, 2007).

The second way waste is minimized is with scale reduction. Scale reduction is the process by which experiments reduce the amount of chemicals used in a reaction by performing that reaction on the smallest scale possible. This reduces the demand for chemicals while maintaining the experiment's educational value. Although scale reduction is practiced on the Chulalongkorn University campus, it is done so only in a few laboratories; no formal policy exists to guide its practice (P. Reubroycharoen, personal communication, January 19, 2007). Consistent use of scale reduction techniques will reduce the quantity of chemicals purchased and reduce the need for disposal, in turn saving money.

### **4.2 Chemical Safety at King Mongkut University of Technology at Thonburi**

King Mongkut University of Technology at Thonburi began the implementation of a chemical safety program in 1999. Since then, the program has become quite successful. Although it has not completely reached the university-wide level, there are many pilot programs set up across campus that aim to spread knowledge of proper chemical safety practices, policies, and procedures. In this section we will describe our findings pertaining to the chemical safety

program at KMUTT, specifically its organizational structure, its safety training program, its pilot laboratory program, its chemical inventory management program, its chemical waste management program, and its yearly evaluation program.

#### **4.2.1 Structure of the Current Chemical Safety Program**

King Mongkut University of Technology at Thonburi has formed the Commission on Energy, Environment, Safety, and Health to manage the budget, make any important decisions, and constantly evaluate the success of the program to make any improvements that it may think are worthwhile. In 1999 the university received funding from the government for a span of two years. The funding helped to begin a new chemical safety system, addressing both chemical management and chemical waste management, and the Commission on Environment, Health, and Safety was formed. After two years, the university was given more money to begin a two to five year long energy conservation project. In 2005, it resulted in the formation of the Commission on Energy, Environment, Safety, and Health.

This school has also appointed Assistant Professor Suchada Chaisawadi to be the Chemical Hygiene Officer, and as such she is responsible for overseeing the program as a whole. It is her job to ensure that the decisions made by the Commission on Energy, Environment, Safety, and Health are reflected by the actions of students, faculty, and staff on the King Mongkut University of Technology at Thonburi campus (S. Chaisawadi, personal communication, February 6, 2007).

### **4.2.2 Chemical Safety Training**

Four years ago, a student chemical safety education program was put into place. With this program, people who work in a laboratory more than four weeks per semester must participate in a six and one-half hour long chemical training session. This session consists of a lecture, a demonstration, and a quiz. The student must earn 75% or higher on the quiz in order to receive an official safety card that will permit them to work in the laboratory. Each card expires after two years, and thus the student must participate in the session again if he or she wishes to continue using the card. When a student passes the training and receives a card, he or she also receives safety goggles and a laboratory coat. Also, both a chemical management manual and a chemical safety manual have been written and are available to students, faculty, and staff. (S. Chaisawadi, personal communication, February 1, 2007).

Faculty and staff are always invited to this training so that more than just students are educated on the university's policies and procedures with regard to chemical safety. Oftentimes, however, these faculty and staff do not show up for the training. It is hoped that within the near future the training program is expanded to include faculty and staff (S. Chaisawadi, personal communication, February 1, 2007).

### **4.2.3 Pilot Laboratory Program**

King Mongkut University has received a great deal of funding from the government to set up pilot laboratories throughout its campus. In these pilot laboratories, of which there are twenty across campus, a proper chemical hygiene plan is followed at all times (S. Chaisawadi, personal communication, February 1, 2007). This chemical hygiene plan ensures that each pilot laboratory utilizes the following:

- a standard set of operating procedures;
- proper engineering controls, such as fume hoods, ventilation systems, and chemical showers;
- proper personal protective equipment, such as laboratory coats, goggles, and gloves; and
- Material Data Safety Sheets for each chemical in the laboratory.

By using a proper chemical hygiene plan, the pilot laboratories ensure the maximum amount of protection for the students, faculty, and staff working inside of them.

Faculty and staff from other laboratories on campus are brought around to observe the practices at these pilot laboratories on a regular basis. If they like what the pilot laboratories are doing, they may sign up their own laboratories for the pilot program (S. Chaisawadi, personal communication, February 1, 2007).

Because a great deal of the funding for these laboratories comes from the Thai government, people from the government sector visit the pilot laboratories at King Mongkut University often. Not only does this provide motivation for the continuance of good chemical safety practices, but it also gives the entire program more credibility. With the formal support of the government, the Commission on the Energy, the Environment, Safety, and Health has been able to persuade many laboratories around campus to follow the model set by the pilot laboratories and use proper chemical safety practices and techniques (S. Chaisawadi, personal communication, February 1, 2007).

#### **4.2.4 Chemical Inventory Management**

The chemical inventory management system used at King Mongkut University of Technology consists of two parts: a color coding system for the easy identification of chemicals

within the physical inventory and a database to keep track of the usage of chemicals on the university's campus.

### *Color Coding System*

According to Asst. Prof. Suchada, King Mongkut's Chemical Safety Officer, the school uses a modified version of the J.T. Baker system to color code chemicals. With this system, chemicals are separated into 8 categories according to the types of hazards that they present. Each category is assigned a color code, which allows students, faculty, and staff on campus to know by the color of the label what type of hazard a specific bottle of a chemical might present. Table 4.2.4.1 shows the specific colors that correspond with each category of chemicals. The students, faculty, and staff at King Mongkut University must all know this color coding system in order to safely handle and store the chemicals that they use in the laboratory.

<b>JT Baker Color Classification System</b>	
Blue	Health Hazard
Red	Flammability Hazard
White	Corrosive Hazard
Yellow	Reactivity Hazard
Red-Striped	Extreme Flammability Hazard
White-Striped	Extreme Corrosive Hazard
Yellow-Striped	Extreme Reactivity Hazard
Green	Non-Hazardous

**Table 4.2.4.1:** Color coding system for chemicals used on the King Mongkut University campus (S. Chaisawadi, personal communication, February 1, 2007)

### *Chemical Database*

The chemical database at KMUTT keeps track of two different sets of information, the first of which is the purchase of chemicals by the university. Chemicals can be purchased in one of two ways: either through the central chemical purchasing system, in which purchases are recorded in the database, or by individual members of the faculty, who are then responsible for



entering the information about the purchased chemical into the database themselves (S. Chaisawadi, personal communication, February 1, 2007).

Both of these methods for recording the purchase of chemicals on the KMUTT campus seem to be rather ineffective. Most faculty neglect to use the central purchasing system and choose to buy their own chemicals. However, those that do buy their own chemicals, which are the majority of the teachers on campus that use chemicals, do not enter the information into the chemical database as they should. This essentially renders the portion of the database that keeps track of the flow of chemicals onto the university's campus useless.

The second set of information recorded by the database is the daily usage of chemicals on the KMUTT campus. Each laboratory on campus that is currently part of the school's chemical safety program has one person with the ability to edit information within the database. This person is responsible for recording—on a daily basis—the types of chemicals used in the laboratory and what amounts of each chemical were used (S. Chaisawadi, personal communication, February 1, 2007). If utilized correctly, this system would be effective in ensuring that an excess amount of chemicals were not used in any given laboratory.

#### **4.2.5 Chemical Waste Management**

Chemical waste management, much like at Chulalongkorn University, is a top priority of the administration at King Mongkut University. Programs have been set up to remove waste from campus using a certified disposal company, treat and dispose of waste on site, and minimize waste production through recycling and scale reduction techniques.

### *Waste Disposal*

King Mongkut University generates about fourteen metric tons of waste per year, on average. This waste is separated into twenty-three categories, thirteen of which are removed from the university's campus by a certified disposal company. Officials from the university visit the disposal company's facilities to verify that the proper disposal techniques are being utilized and that the waste is being disposed of in a manner that is environmentally safe (S. Chaisawadi, personal communication, February 1, 2007).

The Thai government's environmental sector has set up and funded a pilot program on King Mongkut University's campus consisting of a municipal waste management system. This waste management system acts as a treatment facility for both the city surrounding the school and for the wastes generated by the university's many laboratories.

The remaining ten categories of waste that are not removed by a disposal company are treated on site with this municipal waste management system. Once laboratory waste has been properly treated and neutralized, it is discharged back into the waste management system's drainage system (S. Chaisawadi, personal communication, February 1, 2007).

### *Waste Minimization*

Waste minimization on the King Mongkut University campus, much like at Chulalongkorn, can be split into two different categories: recycling and scale reduction. Recycling is done in many ways at KMUTT. As mentioned above, ten different categories of waste are treated at the school's waste management facility, and then these neutralized wastes are discharged back into the university's and the community's water system. This is one form of recycling.

In addition, KMUTT has a recycling waste bank set up on campus. Biodegradable wastes, such as food, are put into this waste bank and the result is fertilizer that can be sold to the community to draw additional profits for the school (S. Chaisawadi, personal communication, February 1, 2007).

Technology wastes are also recycled at KMUTT. Things such as old computers, monitors, printers, spare parts from the electrical and computer engineering departments, and more are brought to a single area and are sold to anyone who is willing to buy, including surrounding community members, students, faculty, and staff (S. Chaisawadi, personal communication, February 1, 2007).

Finally, as with the recycling program at Chulalongkorn University, solvents are widely recycled on campus. Experiments are conducted to remove impurities from the solvents, which can then be reused for a number of purposes, including cleaning and sterilizing (S. Chaisawadi, personal communication, February 1, 2007).

Scale reduction is performed at King Mongkut in many laboratories. Analytical processes are used to determine exactly what chemicals can be reduced in a given experiment to reduce the demand for chemicals and the overall production of wastes (S. Chaisawadi, personal communication, February 1, 2007).

#### **4.2.6 Yearly Evaluation of the Chemical Safety Program**

According to Asst. Prof. Suchada, one of the many keys to the success of King Mongkut University's chemical safety program thus far has been its yearly evaluation. When the program was initially set up in 1999, the university received help from a woman by the name of Chulee Grove from the University of Honolulu, Hawaii. She is a Thai person who has lived in the

United States for about twenty years, and as such has familiarized herself with the country's Occupational Safety and Health Administration standards for chemical safety within laboratories at institutions (S. Chaisawadi, personal communication, February 1, 2007). She has been instrumental in the development, implementation, improvement, and expansion of KMUTT's chemical safety program.

Since her initial visit, she has returned each year to audit the chemical safety at KMUTT. As part of her visit, she performs a risk assessment of select laboratories on the school's campus, and works closely with the university's Commission on Energy, Environment, Safety, and Health to make changes in policy and procedure on chemical safety in order to minimize the risks of the students, faculty, and staff using hazardous chemicals (S. Chaisawadi, personal communication, February 1, 2007).

#### **4.3 Summary of Findings**

While many chemical safety practices exist at both Chulalongkorn University and King Mongkut University of Technology, it is obvious that because KMUTT began the implementation of their chemical safety program nearly eight years ago, many of their chemical safety practices have been expanded to cover all or many laboratories on campus rather than just a few. Table 4.3.1 compares the chemical safety practices at both Chulalongkorn University and King Mongkut University to the elements of an ideal chemical safety program as established in the Background chapter. This comparison accomplishes two things. First, it shows the areas in which Chulalongkorn University should improve its chemical safety program, and second it shows the areas in which Chulalongkorn University may benefit from understanding and applying the methods that King Mongkut University utilized to implement their own chemical

safety program. The next section presents a synthesis of our empirical research and our findings in order to provide recommendations for the improvement and expansion of Chulalongkorn University's current chemical safety program.

Elements of an Ideal Chemical Safety Program	Faculty of Science at Chulalongkorn University		King Mongkut University	
	Presence (Yes/No)	Frequency of Application	Presence (Yes/No)	Frequency of Application
<i>Chemical Hygiene Plan</i>				
Standard Operation Procedures	No	-	Yes	Pilot Laboratories Only
Engineering Controls	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only
Personal Protective Equipment	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only
Information and Training	Yes	Inconsistent among Laboratories	Yes	Consistent among All Laboratories
Chemical Safety Officer	No	-	Yes	Pilot Laboratories Only
<i>Hazard Communication Plan</i>				
Hazardous Materials List	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only
Material Safety Data Sheets	No	-	Yes	Pilot Laboratories Only
Labeling	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only
<i>Chemical Waste Disposal Plan</i>				
Waste Determination	Yes	Inconsistent among Laboratories	Yes	Consistent among All Laboratories
Waste Storage	Yes	Inconsistent among Laboratories	Yes	Consistent among All Laboratories
Off-Site Disposal	Yes	Consistent among All Laboratories	Yes	Consistent among All Laboratories
Record Keeping	No	-	Yes	Pilot Laboratories Only
Contingency Plan	No	-	Yes	Pilot Laboratories Only
<i>Chemical Waste Minimization</i>				
Chemical Exchange	No	-	No	-
Purchase Control	No	-	No	-
Inventory Control	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only
Recycling	Yes	Inconsistent among Laboratories	Yes	Consistent among All Laboratories
Scale Reduction	Yes	Inconsistent among Laboratories	Yes	Pilot Laboratories Only

**Table 4.3.1:** Comparison of chemical safety practices within the Faculty of Science at Chulalongkorn University and at King Mongkut University to an ideal chemical safety program

## 5. Recommendations

The three areas of chemical safety currently practiced at Chulalongkorn University, described above in the Findings and Discussion chapter, were compared to the ideal chemical safety program, established in the Background chapter, to determine a series of recommendations for a comprehensive, university-wide chemical safety program. The recommendations in this chapter provide suggestions for:

- a series of phases to design and implement a university-wide chemical safety program,
- strategies for the success and longevity of the program, and
- areas of future research.

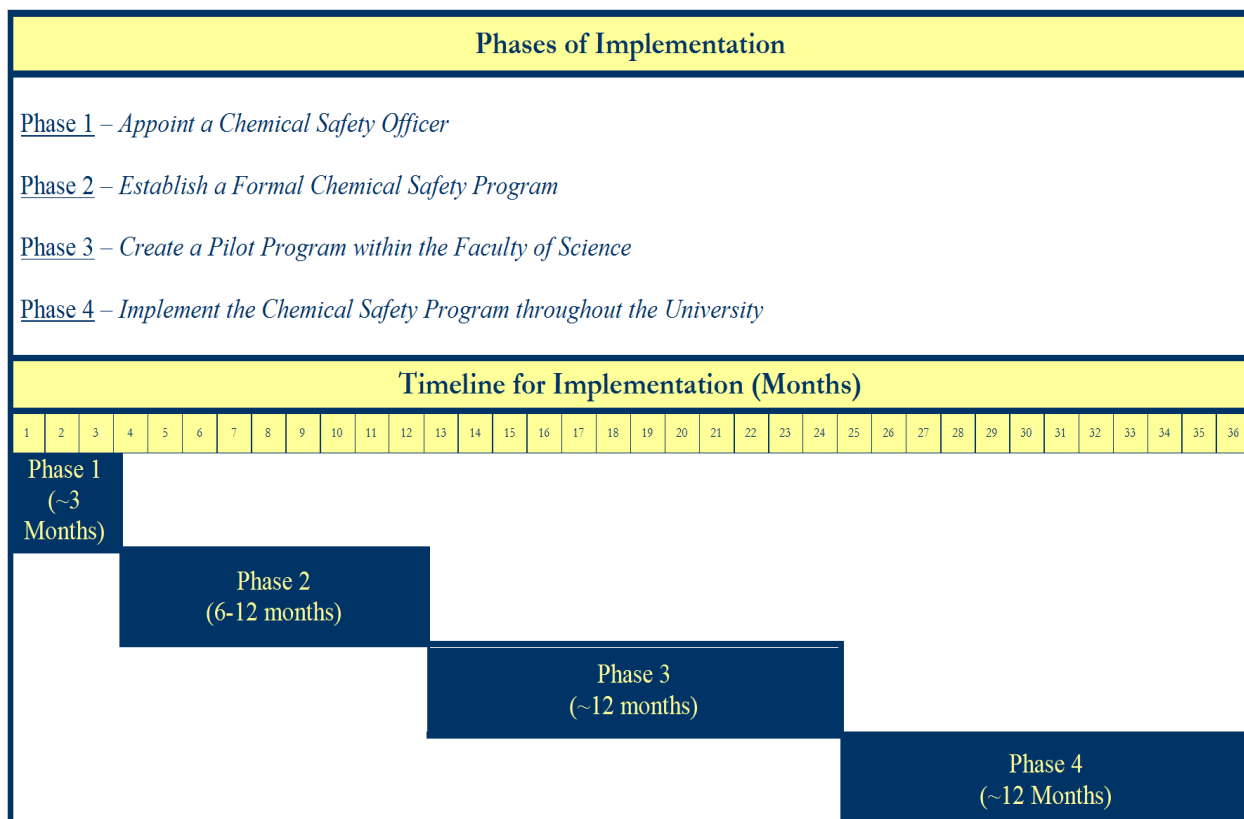
Providing recommendations on these topics should aid in the development and continued success of a chemical safety program at Chulalongkorn University.

### 5.1 Phases of Design and Implementation of a Chemical Safety Program

A university-wide chemical safety program cannot be created and implemented all at once. The success of a program can be enhanced by implementing it in phases and continually reevaluating it for effectiveness. This section contains our recommendations for four phases to implement a university-wide chemical safety program at Chulalongkorn University:

1. appoint a Chemical Safety Officer;
2. establish a formal Chemical Safety Program based on the four elements of an ideal program, including a chemical hygiene plan, a hazard communication plan, a chemical waste disposal plan, and a chemical waste minimization plan;
3. create a pilot program within the Faculty of Science; and
4. implement the program throughout the university.

Implementation of the chemical safety program throughout the university should be possible in approximately three years, as diagramed in Figure 5.1.1. The following subsections contain our recommendations for each phase of implementation for this extensive chemical safety program.



**Figure 5.1.1:** Timeline for the Phases of Implementation of a Chemical Safety Program at Chulalongkorn University

### **Phase 1- Appoint a Chemical Safety Officer**

**Appoint a Chemical Safety Officer who is responsible for chemical safety throughout the university.** The chemical safety programs at each university researched: WPI, MIT, University of California, Berkeley, and KMUTT all have chemical safety officers who oversee the verification and implementation of their chemical safety programs. Thus, the Vice President and the members of the chemical safety committee at Chulalongkorn should make finding a chemical safety officer their first priority.

**The Chemical Safety Officer should be qualified based on OSHA standards.** The Chemical Safety Officer should have a Bachelor's degree in chemistry or the equivalent laboratory experience, and one or more years of supervising experience (Alaimo & Fivazzani, 1996). Additionally, this individual should have knowledge on the regulations for good laboratory practices and an understanding of the operation of the facilities. The Chemical Safety Officer should also have good written and verbal communication skills. He or she should also have a long-term commitment to chemical safety at Chulalongkorn. Ideally, this person should be known and respected on campus with the time to do the job well. Appointing a chemical safety officer promotes the enforcement of practices and gives an individual the capacity to institute change and improvement within the university.

If sufficient funding for hiring the Chemical Safety Officer is unavailable, we recommend that the responsibilities of the safety officer be divided among the members of the chemical safety committee. However, the members of the chemical safety committee are not solely responsible for chemical safety. Thus, the division of the duties of the Chemical Safety Officer should only occur if absolutely necessary.

It will take approximately three months to hire the Chemical Safety Officer.

## **Phase 2- Establish a Formal Chemical Safety Program**

**Create a standard Chemical Safety Plan for the entire university.** This will be done by the Chemical Safety Officer. Standardizing a chemical safety program will make the expectations of chemical safety the same throughout every faculty on campus.

The plan will initially be used within the pilot program in the Faculty of Science, discussed in phase 3, but eventually will be used throughout the entire university. If the plan is



initially thorough, not many changes will have to be made when implementing the program throughout Chulalongkorn.

Our research suggests an ideal chemical safety program consists of four sections: a chemical hygiene plan, a hazard communication plan, a chemical waste disposal plan, and a chemical waste minimization plan. The following subsections contain our recommendations for each part of the program.

### *Chemical Hygiene Plan*

**Develop a formal university-wide Chemical Hygiene Plan (CHP).** This program should include: standard operating procedures, details on required engineering controls and personal protective equipment (PPE), information and training for the safe utilization of chemicals, and the duties of the chemical hygiene officer. Stating proper procedures for each of these categories of chemical safety in one document will provide uniform standards of chemical safety throughout the university.

**Combine policies and procedures from the chemical management and chemical safety manuals utilized by King Mongkut University of Technology at Thonburi (KMUTT) with the extensive Chemical Hygiene Plan employed at WPI to create a comprehensive CHP for Chulalongkorn.** Currently, KMUTT has a chemical safety system that includes a chemical management manual and a chemical safety manual written in Thai (S. Chaisawadi, personal communication, February 6, 2007). The documents from KMUTT can be used as the foundation for the Chemical Hygiene Plan and any additional elements of a CHP not included in these documents, but present in the WPI plan, should be translated into Thai to create a comprehensive plan for Chulalongkorn.

**Create a set of standard operating procedures using the Chemical Hygiene Plan of WPI as a model.** Standard operating procedures provide safety within the laboratory through the promotion of proper behaviors. The survey conducted within laboratories in the Faculty of Science revealed that simple acts like contacting appropriate personnel whenever accidents occur, which is a standard operating procedure, only takes place 72% of the time. Normalizing these procedures throughout the university will encourage consistent chemical safety practices and ease enforcement of chemical safety.

**Inspect all laboratories for proper engineering controls (i.e. fume hoods, vapor detection equipment, etc.) and improve training on the use of engineering controls.** If engineering controls do not exist, additional equipment should be purchased, and any engineering control not functioning properly should be repaired. Engineering controls are required to support the application of standard operating procedures. Since 90% of fume hoods in the laboratories surveyed within the Faculty of Science do not function properly, and 22% of workers do not use fume hoods when pouring chemicals, an evaluation of the engineering controls and the training received is necessary.

**Train individuals who work in laboratories on how to use PPE (i.e. laboratory goggles, aprons etc.) properly and the benefits of using such equipment.** Faculty and staff should undergo training on teaching the importance of PPE and serve as role models when using PPE. Currently, there are no regulations on the use of PPE within the laboratories at Chulalongkorn, and only 42% of the people surveyed within laboratories in the Faculty of Science knew when to use different types of PPE. During student training at KMUTT, students are given their own PPE for the laboratory; the Chemical Safety Officer may want to observe

KMUTT's program to determine if providing PPE to students after safety training is something that should be done at Chulalongkorn.

**Require general chemical safety training for all students, and evaluate the quality of the information presented in student training.** Currently, the strongest aspect of the CHP is training students on chemical safety practices. Despite this strength evaluation of the material being taught should occur, because many students still do not understand basic safety concepts, as shown through surveys of students within the chemistry department.

**Train students annually on both laboratory-specific safety training and hazardous waste management.** These types of training occur at MIT and would be useful for expanding the training program at Chulalongkorn University.

**Determine a standard time to administer training for all students every year similar to the program at KMUTT.** Additionally, safety trainers from Chulalongkorn may want to attend safety week at KMUTT to get an idea of the extent of training at KMUTT. Training should also occur for professors and other staff who come into contact with chemicals. Strengthening the chemical safety training will lead to a safer and more chemical-safety cautious community.

**Define the role of the Chemical Safety Officer in the CHP.** The Chemical Safety Officer is responsible for conducting inspections of laboratories and equipment, training laboratory workers, organizing the storage and disposal of hazardous wastes, responding to accidents, evaluating high-risk experiments, and managing information on chemical safety to ease accessibility.

These recommendations address the first of the four branches of a chemical safety program, the chemical hygiene plan. Recommendations for the second branch, the Hazard

Communication Plan, begin to outline ways to improve communication of safety risks to students, faculty, and staff on campus.

### *Hazard Communication Plan*

**Develop a standard hazard communication plan for the university**, including policies for the maintenance of hazardous materials lists, Material Safety Data Sheets (MSDS), and labeling procedures.

**For proper identification and storage of chemicals, determine a university-wide system for labeling chemicals.** Use a color coded labeling system, based on the abridged JT Baker database used at KMUTT, to label wastes in eight categories: health hazard (blue), flammable (red), corrosive (white), reactive (yellow), extreme flammable (red striped), extremely corrosive (white striped) , extremely reactive (yellow-striped), and non-hazardous chemicals (green).

**As the inventory program is implemented in each laboratory, print hazardous materials lists for each location.** These lists should be updated every few months. Knowledge of the chemicals present in a laboratory alone, even when properly labeled, does not fully portray the dangers those chemicals pose. Information about each chemical must be readily available to those who use the chemical.

**Keep a printed copy of the MSDS for each chemical where the chemical is stored.** MSDS should be integrated into the ChemTrack inventory program, so this information can be printed each time a chemical is entered into the system. Information about the chemicals present should be duplicated and kept both inside and outside of the laboratory so that in the event of an emergency, this information can be accessed even if one storage location can not be reached.

KMUTT keeps MSDS in three locations: hardcopies in the laboratory and in the office as well as on the computer.

### *Chemical Waste Disposal*

Chulalongkorn University has begun to implement an effective chemical waste disposal program within the Faculty of Science; however, we recommend that improvements are made before bringing the program to the university level.

**Train all faculty and staff in categorizing wastes**, because currently only faculty heads are trained. Properly categorizing wastes reduces the cost of waste disposal. If wastes are categorized properly, like wastes can be combined. The more waste that is initially combined at Chulalongkorn, the cheaper it is to dispose of waste through an outside company (S. Chittmittrapap, personal communication, February 1, 2007). This is because different types of waste have different disposal procedures, and the outside company will have to do less work if wastes are already separated. If all faculty and staff are trained in categorizing wastes, their knowledge can then be passed to students, ensuring that waste is properly separated by everyone. After the nature of hazardous chemicals has been determined and hazardous wastes have been sorted into proper categories, they should be stored properly.

**Identify a centralized storage location of wastes, and hire personnel specifically for managing hazardous waste collection when university-level expansion occurs.** When implementing the pilot program within the Faculty of Science, all laboratories within the pilot program should have combined storage of chemical wastes. After centralized storage of wastes is implemented within the Faculty of Science, the pilot program can be used as a model when the

program is spread to other faculties within the university with the ultimate goal of complete centralization of wastes.

**Treat some waste on-site to reduce the costs of disposing hazardous wastes.** After waste has been assembled and categorized it must be disposed of at the cost of the institution. Treating even a fraction of the waste on-site can help reduce disposal costs significantly. There were five tons of waste removed from Chulalongkorn (S. Chittmitrapap, personal communication, February 1, 2007); on-site treatment of some of that waste would have been very beneficial. Currently, KMUTT treats some waste on-site, so look at those practices to help reduce the cost of disposing hazardous wastes. At KMUTT, waste that cannot be treated on-site is turned over to outside companies for treatment and disposal. Each company has its own method of disposal, and some of these methods are more harmful to the environment than others.

**Follow-up on the chosen waste disposal company to assure that the environment is not harmed by the company.** The company used should meet the environmental management standard of the International Organization for Standardization. There are a number of organizations in Bangkok that meet this standard including: General Environment Conservation PCL (Genco), Siam Waste Management Consultant Co., Ltd., and TARF Co., Ltd. Currently, Chulalongkorn University is using Genco, but we recommend considering other companies within Thailand as well. KMUTT physically verifies that wastes are disposed of properly by the organization they use, and we suggest that Chulalongkorn do the same.

**Create a contingency plan for all who use chemicals so that in the event of an emergency the proper course of action will be taken,** because the chemical waste disposal plan should seek to limit the potential dangers posed by chemical spills.

Recommendations for the fourth branch of a chemical safety program, the chemical waste minimization plan, strive to decrease exposure to chemicals on campus.

### *Chemical Waste Minimization*

Chemical Waste Minimization strategies should be utilized as often as possible. Methods for waste minimization require professors to keep better track of the chemicals within their laboratory before ordering more chemicals, to collaborate with other professors to utilize the chemicals present on campus, and to scale down experimentation. The first step towards university-wide chemical waste minimization is a functioning inventory program.

**Register chemicals using ChemTrack, the inventory program for Chulalongkorn University.** The inventory program has been created recently, so most chemicals are not registered in the program. As a pilot program is implemented in the Faculty of Science, each laboratory should enter all chemicals into the inventory program. When the chemical safety program is implemented in other faculties, goals should be set for when all of their chemicals must be registered in ChemTrack. One goal could be to register all of the chemicals in a laboratory when the engineering controls within the laboratory are evaluated. After registry of chemicals occurs, chemical exchange, purchasing control and inventory control should be facilitated through the inventory program.

**Use chemical exchange, purchasing control, and inventory control to reduce the amount of waste on campus.** Guidelines for these programs should be integrated into ChemTrack, and the tutorial on the use of ChemTrack. Once laboratories begin using ChemTrack, professors can use the program to determine if a chemical is already present on campus before purchasing an additional chemical. Encouraging the exchange of chemicals

between professors will help to minimize the amount of chemicals present on campus, because professors will be exchanging chemicals with one another and not bringing additional chemicals on campus. Other ways to minimize the use of chemicals are recycling and scale reduction.

**Initiate a research program about how to effectively and efficiently recycle more chemicals.** Currently, solvents are recycled (P. Reubroycharoen, personal communication, January 19, 2007), but other chemicals should also be recycled. KMUTT has a recycling program that Chulalongkorn University could look at as a model. Recycling more chemicals will reduce the amount of waste sent directly for disposal and the overall cost of disposal.

**Expand current scale reduction practices to include all laboratories where this method is possible.** Scale reduction is a waste minimization method used to reduce the amount of waste generated through experimentation. The chemical technology department within the Faculty of Science currently uses scale reduction in teaching laboratories (P. Reubroycharoen, personal communication, January 19, 2007). Scale reduction should be used whenever possible throughout the university.

These recommendations seek to reduce the potential for waste by establishing suggestions for improving practices and increasing the efficiency of the entire chemical system.

### **Phase 3- Create a Pilot Program within the Faculty of Science**

**Following the development of a formal chemical safety program, create a pilot program within the Faculty of Science.** This faculty has been chosen for the pilot program, because it has already begun to implement elements of a chemical safety program. After the chemical safety program within the Faculty of Science has been strengthened other faculties will be able to use the Faculty of Science as a model for implementing the chemical safety program.



**Fully implement the chemical safety program within the laboratories with the highest levels of chemical safety in each department of the Faculty of Science first.** These laboratories can be identified through the surveys conducted on chemical safety practices within the Faculty of Science. KMUTT began implementing their chemical safety program by establishing excellent chemical safety practices in a single laboratory and then slowly expanding the chemical safety program to include other laboratories. Using good models, such as pilot programs, is a strategy for implementation that is often successful (Nervis, Lancourt & Vassallo, 1996). Pilot programs have already been successful for implementing a chemical safety program in Thailand; thus, using pilot laboratories as models for implementing a chemical safety program at Chulalongkorn may be successful.

**Within each laboratory implementing the full chemical safety program:**

- **train professors, students, and staff** on: application of the elements of the CHP, ways to assess proper use of engineering controls and personal protective equipment, hazard communication practices, the inventory program, characterization of hazardous wastes, and waste minimization practices;
- **evaluate engineering controls and personal protective equipment** to ensure that the standards outlined in the Chemical Hygiene Program are met;
- **label all chemicals properly; and**
- **input all chemicals into the ChemTrack inventory program.**

**Dispose of any waste produced by the pilot program's laboratories in a centralized location to model centralized waste disposal through the pilot program.** For this to occur, a centralized location for waste disposal for all of the laboratories included in the pilot program needs to be identified.

**As the elements of the chemical safety program are implemented, have the Chemical Safety Officer routinely inspect the laboratories in the pilot program.** MIT routinely inspects laboratories, and these inspections strengthen their program significantly. Thus inspections

should occur regularly to make strides towards improving their program. Inspections will identify weaknesses within the program, which should be improved before implementing the program into additional laboratories.

Based upon the amount of time required to implement pilot laboratories at KMUTT, implementation of a chemical safety program within the initial laboratories will take between six months to a year.

**Once the program is successfully implemented in these laboratories within the Faculty of Science, expand the program to include all the other laboratories within the faculty.** This process should be relatively easy, because laboratories within each department already have implemented chemical safety programs and in turn each department within the Faculty of Science has a role model for chemical safety. The expansion of the program throughout the Faculty of Science should take an additional six months to one year, based on the timeframe of KMUTT.

#### **Phase 4- Implement the Program throughout the University**

**Following the implementation of a full pilot program in the Faculty of Science, implement the chemical safety program in the other colleges and faculties.**

**Choose and train chemical safety officers within each faculty to initiate the chemical safety program in their respective faculties, because Chulalongkorn is such a large university.** This should be done by the university-wide Chemical Safety Officer. These individuals should be trained in the same manner as the professors implementing the pilot program within the Faculty of Science. Also, observation of the practices within the Faculty of Science should occur during their training to gain a better understanding of chemical safety.

**Choose the laboratories in each of the other faculties with the strongest chemical safety practices for the initial implementation of the chemical safety program.**

Each faculty will probably need to make additions and revisions to the Chemical Safety Program based on the types of chemical safety they need. These additions and revisions should be made by the Chemical Safety Officer based on evaluation of the practices within the laboratories that initially implement chemical safety.

**Once the chemical safety program is successfully implemented within the initial laboratories, implement the program throughout the entire faculty.** Implementation within the initial laboratories in each faculty and throughout the entire faculty should each take between six months to a year.

If all faculties cannot implement chemical safety immediately, implement the program within the following faculties first: the College of Petroleum and Petrochemicals, Faculty of Engineering, Faculty of Medicine, and the Natural Research Center for Hazardous and Environmental Waste (P. Reubroycharoen, personal communication, January 19, 2007). These faculties have been identified as locations where chemical safety is of particular concern.

**Evaluate the chemical safety program on a continual basis during and after this implementation process, to meet the changing needs of the institution.** There are some additional factors that will influence the implementation of this university-wide program identified through our research, which are further discussed in the following section on the success and longevity of the program.

## 5.2 Program Success and Longevity

In addition to the recommendations and implementation strategy discussed above for a comprehensive chemical safety program, we offer recommendations on other components influencing the overall success and longevity of any program implemented within the Faculty of Science or at the university level.

**Encourage active participation in the program among students, professors, and staff**, because the success of a program depends upon the people participating (Nervis, Lancourt & Vassallo, 1996). The encouragement should begin with the higher ranking members of Chulalongkorn University and move downwards. Administration and faculty must be motivated to implement a chemical safety program for it to be successful. Also, for people to be convinced that a program will work, they must see it in action and have a basic understanding of or education in the benefits the program provides.

One good way to share ideas about chemical safety and increase the knowledge and awareness of both administration and faculty about the chemical safety program is through networking. Professors with laboratories that are being used as a part of a pilot program network should, for example, show other faculty members, who may be less enthusiastic about the chemical safety program, the benefits of using sound chemical safety practices.

After faculty and staff have begun to accept the chemical safety program and the benefits that it offers, students must also be motivated to participate in the program, as much of the experimentation on campus is conducted by graduate and undergraduate students. One technique that King Mongkut University of Technology at Thonburi uses is to hold several events for students to increase the awareness of chemical safety practices and help motivate students to

practice good chemical safety techniques. Because the chemical safety program at that university has been successful, we recommend that Chulalongkorn hold events to increase awareness about chemical safety as well.

**Enforce regulations set forth by the chemical safety program.** Enforcement of penalties is one of the key strategies for the implementation of a program (Nervis, Lancourt & Vassallo, 1996). Enforcement of the chemical safety program includes monitoring the application of the chemical safety program by performing inspections of laboratories to ensure exhibition of proper practices, such as maintenance of safety equipment, proper chemical storage, and proper waste disposal.

**Continuously evaluate the program's goals and effectiveness in minimizing risk due to chemicals at Chulalongkorn University.** Not only will a routine, in-depth analysis of the chemical safety program identify which areas are improving, but it will also help to identify aspects of the program that still need to be improved. Thus, the program will grow stronger and stronger until the entire university follows a comprehensive safety program.

Chemical safety is an ongoing process and cannot be addressed just once, so the continual support of the faculty and students at Chulalongkorn University is necessary. A way to enforce the policies within the chemical safety program is also necessary for the success of the program. Additionally, reevaluating the chemical safety program should occur on a regular basis. These recommendations help to guide the steps that need to be taken for the long term success of a chemical safety program at Chulalongkorn University.

### **5.3 Limitations of Current Research and Possibilities for Future Research**

The recommendations for the university-wide chemical safety program and implementation of the program establish a foundation for the initial phases of integrating a chemical safety program at Chulalongkorn University. However, there are some limitations of our research that point to important areas for future research. This section discusses the limitations of the research conducted and identifies the potential areas for future research.

For this project, a case study of the Faculty of Science was done to provide recommendations for the university-wide chemical safety program. Due to time constraints, almost all interviews and surveys were conducted within the Faculty of Science. Additionally, the people interviewed and surveyed often had a direct tie to chemical safety programming at Chulalongkorn, so their opinions on the chemical safety program may not be representative of all the individuals within the Faculty of Science, let alone the entire university.

**In the future, explore chemical safety practices within other colleges and faculties so that the chemical safety program can be adapted to fit the safety needs of other parts of the university.**

Within the Faculty of Science, there is currently a chemical safety training program for students. Research on the impact and effectiveness of the training is yet to be conducted.

**Conduct additional research on determining the effectiveness and impact of the current chemical safety training.** This safety programming may need many improvements to properly educate the students being trained, but further investigation of the program is needed to make such a claim.

In terms of waste disposal, many companies in Thailand do not properly dispose wastes due to the lack of enforcement of proper waste disposal procedures.

**Research methods of waste disposal used at outside disposal companies. Also, find ways to treat some of Chulalongkorn's wastes on site.** It may take some time to develop the methods and the means for treating chemical wastes, but will save the university money in the future. Additionally, by treating wastes on-site, proper treatment of wastes is more likely to occur.

#### **5.4 Summary of Recommendations**

The recommendations for the establishment of a university-wide chemical safety program identified within this chapter outline phases for the design and implementation of a formal, university-wide chemical safety plan, provide recommendations for how to implement this plan within the various colleges and faculties of Chulalongkorn University, highlight areas which must be focused on to successfully implement the program, and offer suggestions for future research on chemical safety at Chulalongkorn University that can be used to further enhance the program and its implementation.

It is important to note that recommendations for implementation are phased so that learning, reassessment, evaluation, and monitoring can occur as the program is implemented. Additionally, the members of the campus community utilizing these recommendations should remember that efforts to improve safety do not stop at the implementation of a university-wide program. Continual reevaluation and improvement of the program should occur frequently after the program is implemented to meet the changing needs of the institution.

## 6. Conclusion

A comprehensive chemical safety program can be created at Chulalongkorn University by using the four elements of a chemical safety program outlined by this IQP: the chemical hygiene plan, the hazard communication plan, the chemical waste disposal plan, and the chemical waste minimization program. We have presented recommendations to Chulalongkorn University on each of these four elements based upon our research in three different areas: on programs at universities within the United States, on King Mongkut University of Technology at Thonburi, and on the current progress of programs at Chulalongkorn University.

Our findings show that while Chulalongkorn has been successful at implementing a few elements of a complete chemical safety program, there are many areas which still need to be addressed, as many elements of the safety program have yet to be implemented and the program does not currently encompass the entire university. Therefore, we have presented recommendations for a four-phase implementation plan for the creation of university-wide chemical safety program. The first phases suggest the appointment of a chemical safety officer and the creation a formal chemical safety program for use by the entire university. The later phases recommend the creation of pilot laboratories for each of the departments within the Faculty of Science, and eventually each of the colleges and faculties at Chulalongkorn University. Once the program has been implemented throughout the university, the program should be continually assessed and reevaluated.

The creation and utilization of the university-wide chemical safety plan corresponds with the Thailand's national goal to increase chemical safety practices throughout the country, as established by the second National Master Plan on Chemical Safety (FDA of the Thai Royal Government, 2005). By increasing the standards for chemical safety programming at the



university level, the graduates of Chulalongkorn will have a better understanding of the hazards chemicals present and the proper practices for using them. As graduates move into industry they will be prepared to aid in the development of higher standards for safety within industrial settings. This becomes of increasing importance as Thailand's industrial economy continues to grow, and more people's lives are impacted by chemicals and safety practices designed to minimize the risks of using them.

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## Appendix A – Interview Questions

**Who:** Dr. Lursuang Mekasut, Head of chemical inventory program development

**What we wanted to know:** Program, MSDS Data Sheets

**Questions:**

1. What does the program do?
2. What information about each chemical is recorded?
3. Does the program keep accurate records of the kinds and amounts of chemicals present in laboratories?
4. Does the inventory program provide Material Safety Data Sheets for each of the chemicals?
5. Where/how is the information from the inventory program available?
6. How are new chemicals entered into the program?
7. Will the information from the inventory program be readily available in the event of an emergency?
8. Does the inventory program impact the removal of unused/outdated chemicals or purchasing of new chemicals when stocks of chemicals are low?
9. Who will have the responsibility for updating the system?

**Who:** Dr. Prasert Reubroycharoen, Subordinate helping develop Hazardous Waste Disposal / Minimization

**What we want to know:** Information about their findings

**Questions:**

1. Who determines what waste is hazardous, and how is this determination made?
2. How and where is waste stored before it is disposed of?
3. How is waste disposed of?
4. Who keeps the records for what waste is present, and when it is disposed of?
5. What happens if a spill of hazardous waste occurs?
6. What is the current state of the surplus chemical exchange program?
7. Is any of the chemical waste currently recycled?
8. What are the barriers to scale reduction for chemical experiments?
9. What new procedures would allow for a reduction in hazardous waste?
  - a. How much could this potentially reduce waste?

**Who:** Dr. Saowarux Fuangswasdi

**What we want to know:** Training, Current Programs

**Questions:**

1. What chemical safety training do first year chemistry students receive?
2. What chemical safety training do first year Faculty of Science students receive?
3. What chemical safety training do first year university students receive?
4. What chemical safety training do upperclassmen receive?
5. What chemical safety training do professors receive?
6. What are the responsibilities of the individual professors, with regard to chemical safety?
7. What are the responsibilities of the chemical safety committee?
8. What are your goals for chemical safety at the faculty level?

9. What are your goals for chemical safety at the university level?
10. Who has the authority to bring a chemical safety program to the university level?
11. Who has the authority to enforce the university wide chemical safety program?
12. When an emergency occurs in a laboratory, what is a typical response?
13. What personal protective equipment exists in the laboratories?

**Who:** Assistant Professor Suchada Chaisawadi, King Mongkut University

**What we want to know:** Current Chemical Safety Program

**Questions:**

1. Do you have a formal chemical hygiene plan? (may need explanation)
2. What personal protective equipment is available in the laboratory?
3. What kind of chemical safety training do students, faculty and staff receive?
4. Are there any courses on chemical safety that students must take during their studies?
5. Are students taught about chemical safety every year? If so, which students are taught every year?
6. Is there a specific person, such as a chemical safety officer, who has the authority to enforce policies on chemical safety?
7. When an emergency occurs in a laboratory, what is a typical response?
  - a. Is there a hazard communication plan?
8. Are there hazardous materials lists within laboratories?
9. Are there Material Safety Data Sheets for all chemicals within laboratories? How are the MSDS stored?
10. Is there is specific procedure for labeling chemicals? If so, what is that procedure?
11. Have there been any efforts to reduce the amount of hazardous waste used at the institution?
12. How are hazardous substances controlled/handled/disposed?
13. What records exist on waste disposal practices?
14. Do you have a chemical waste minimization plan? If so, what does this plan consist of, and who utilizes this plan?
15. Is there any form of inventory system by which all chemicals are tracked?
16. Are there any planned changes to the chemical safety program in the future?
17. How are changes in the chemical safety plan implemented?

**Who:** Dr. Soottiporn Chittmittrapap, Vice President of Chulalongkorn University

**What we want to know:** Structure

**Questions:**

1. What are your goals for chemical safety at the university level?
2. Is there a decided structure for the new chemical safety program?
3. What are your responsibilities regarding chemical safety?
4. Who are the people that will put the chemical safety program into place at the university level?
5. When do you think a chemical safety program will be put into practice at the university level?
6. What is the organizational structure of the chemical safety personnel at the university and faculty levels?

**Who:** Dr. Wasant Pongsapich, chemical safety and hazardous waste management for the university

**What we want to know:** Safety responsibilities and implementation plans

**Questions:**

1. What are your responsibilities for chemical safety and hazardous waste management?
2. What are your goals for the chemical safety and hazardous waste management programs?
3. Who is in charge of implementing new chemical safety and hazardous waste management procedures?
4. How are changes in hazardous waste management enforced?
5. What are the barriers to implementing changes in chemical safety and hazardous waste management at Chulalongkorn University?
6. How is hazardous material collected?
7. Are there records of the removal of hazardous waste?

**Who:** Dr. Warapran – retired professor, member of Safety Committee, creator of former inventory program

**What we want to know:** Safety Committee Responsibilities

**Questions:**

1. What is your role on the chemical safety committee?
2. What are the main goals of the chemical safety committee?
3. What are your goals for chemical safety at CU?
4. What are the specific responsibilities of those on the safety committee you are a part of?
5. Who is responsible for enforcing chemical safety practices at Chulalongkorn University?
6. How did the former inventory program that you created work?
7. What were the strengths and weaknesses of the first chemical inventory program you created?
8. What do you think of the new chemical inventory program?

**Who:** Head of Chemistry Department

**What we want to know:** Current Lab Safety Practices

**Questions:**

1. What are the goals of chemical safety for the chemistry department, and when do you expect them to be achieved?
2. What are the current safety practices in the chemistry laboratories?
3. What chemical safety training do faculty and staff receive? If none, do you think there should be a chemical safety training program for faculty and staff?
4. What chemical safety training do graduate students receive? If none, do you think there should be a chemical safety training program for graduate students?
5. What are the responsibilities of individual professors, with regard to chemical safety?
6. What are the responsibilities of the chemical safety committee?
7. When an emergency occurs in a laboratory, what is a typical response?



## Appendix B – Laboratory Survey Questions and Criteria

The following questions were applied to 71 laboratories within the Faculty of Science. The questions here are presented in order with the corresponding criteria to answer each question. The answers also apply to a scale of one to four with the first response representing a four unless otherwise indicated in parenthesis.

### General Management

1. How often is the laboratory cleaned?
  - Every day
  - 2-3 times a week
  - Once a week
  - Less than once a week
2. How organized is the laboratory?
  - Everything is organized
  - Most things are organized
  - There is no organization
  - There are many obstructions in the walkways
3. Are critical signs present?
  - All critical signs present: Fire extinguisher, waste, first aid, and chemical list/inventory
  - Three or the four signs listed above
  - Two of the four signs
  - One of the four sign
4. Dose the laboratory have a smell?
  - The laboratory dose not have a smell, doors and windows are always opened when appropriate for ventilation
  - The laboratory dose not have a smell, doors and windows are sometimes opened for ventilation
  - The laboratory has some smell
  - The laboratory smells very bad, and is never rarely ventilated
5. Is there adequate light in the laboratory
  - Can read a book within 1½ feet of “?”
  - Can read a book within 1 foot of “?”
  - Can read a book within ½ foot
  - Can not read a book
6. Is there proper grounding?
  - All outlets have ground, no use of multi plugs
  - Multi-plugs used a lot, sometimes without a ground
  - Ground lines are damaged and/or inconsistent
  - No ground available in the laboratory

7. What is the quality of laboratory map?
  - The map is very clear and easy to understand
  - The map just has general details, and is not very specific
  - The map is very general, and has no specific details
  - There is no map available
8. Is there food drink in the laboratory?
  - No food or drink in the laboratory
  - There is occasionally food or drink in the laboratory
  - There is always food or drink in the laboratory
  - Food and drink are stored in the laboratory
9. Is there a soap and towel present in the laboratory?
  - Has soap and towel in every sink
  - Has soap and towel in some sinks
  - Has only one (soap or towel)
  - Has neither
10. Are there hazardous and volatile chemicals inspections?
  - Inspections conducted every month
  - Inspections conducted every three months
  - Inspections conducted every six month
  - Inspections conducted every year
11. What is the quality of vacuum lines in the laboratory?
  - Vacuum lines are in good condition and tested frequently
  - Vacuum lines are present, but they are not fully maintained
  - Vacuum lines are present but they are not maintained at all
  - Vacuum lines are not present
12. Are there circuit breakers and fuses, and are they in good condition?
  - Circuit breakers and fuses are in good condition, and are tested once every three months
  - Circuit breakers and fuses are in good condition, and are tested once every six months
  - Circuit breakers and fuses are in good condition, and are tested once a year
  - G Circuit breakers and fuses are in good condition, and are tested once every two years

### **Engineering Controls**

13. What is the quality of the fume hood?
  - The fume hood has some residue from recently used chemicals is present, but in general is very clean
  - The fume hood always have some residue, but the residue is negligible
  - There is a lot of residue in the fume hood, and little space left to work
  - There is no space available in the fume hood

14. Is the fume hood mirror functional?
  - The mirror goes down all the way
  - The mirror goes down  $\frac{3}{4}$  of the way
  - The mirror goes down  $\frac{1}{2}$  of the way
  - The mirror will not go down
15. What is the quality of light in the fume hood?
  - User can read the alphabet at a distance of  $1\frac{1}{2}$  feet
  - User can read the alphabet at a distance of 1 foot
  - User can read the alphabet at a distance of  $\frac{1}{2}$  foot
  - User can not read the alphabet
16. Is the fume hood certified?
  - The fume hood is recertified every year
  - The fume hood is recertified every 2 or 3 years
  - The fume hood has never been recertified
  - The fume hood has never been certified
17. What is the quality of the ventilation system within the fume hood?
  - The fume hood exhibits good and efficient ventilation
  - The fume hood has a ventilation system, but it is not used
  - The fume hood has a ventilation system, but it is broken
  - The fume hood does not have a ventilation system
18. What is the quality of the fume hood instructions and recordkeeping?
  - The fume hood instructions are clear, and there is a record of each use
  - The fume hood instructions are clear, but not every use is recorded
  - The fume hood instructions are unclear, and there is no record of usage
  - The fume hood does not have instructions, and there is no record of usage
19. Are gas and water lines labeled?
  - Both the gas and the water lines are labeled clearly
  - Some of the gas and water lines are labeled, but they are not labeled clearly
  - Most of the gas and water lines are not labeled, and the labels are not clear
  - The gas and water lines are not labeled

### *Compressed Gas*

20. What is the quality of the compressed gas tank restraints?
  - Has both of the restraints ( $\frac{1}{3}$  and  $\frac{2}{3}$  of the way down the tank)
  - Has one at least one chain in any position
  - Has something to restrain it but not very secure
  - Has no restraints
21. Are compressed gas turn off valves used?
  - Valves are turned off every time at the head of the gas canister and at the nozzle at the equipment
  - Valves are turned off at the tank or at the equipment, every time
  - Valves are turned off at the tank or at the equipment some of the time
  - Valves are never turned off

22. What is the compressed gas storage distance from heat sources and flammable materials?
- Compressed gas stored more than one meter away from heat and flammable materials
  - Compressed gas stored 0.7 meters to 1 meter away from heat and flammable materials
  - Compressed gas stored 0.5 meters to 0.7 meters away from heat and flammable materials
  - Compressed gas stored less than 0.5 meters away from heat and flammable materials
23. Is there a clear, obstruction free zone around the compressed gas tank?
- There is at least 2 meters of unobstructed space surrounding the compressed gas tanks
  - There is at least 1.5 meters of unobstructed space surrounding the compressed gas tanks
  - There is at least 1 meter of unobstructed space surrounding the compressed gas tanks
  - There is less than 1 meter of unobstructed space surrounding the compressed gas tanks
24. Is the area surrounding the compressed gas tank clear of water?
- The tanks are more than 2 meters away from any water
  - The tanks are more than 1.5 meters away from any water
  - The tanks are more than 1 meter away from any water
  - The tanks are less than 0.5 meters away from any water
25. Are caps present on new compressed gas tanks?
- Every new compressed gas tanks has a cap
  - 50% of the new compressed gas tanks have a cap
  - 25% of the new compressed gas tanks have a cap
  - None of the new compressed gas tanks have caps
26. Are empty compressed gas tanks present within the laboratory?
- There are no empty tanks in the laboratory
  - There are 1 to 3 empty tanks in the laboratory
  - There are 4 to 5 empty tanks in the laboratory
  - There are more than 5 tanks in the laboratory

### *Refrigerator*

27. Is the refrigerator tidy?
- Chemicals in the refrigerator are labeled and organized into groups
  - Chemicals in the refrigerator are tidy but are not organized into groups
  - Chemicals in the refrigerator are untidy and are not organized into groups
  - Chemicals in the refrigerator are untidy, not organized into groups, and are difficult to retrieve from the refrigerator

28. Are food and drink present within the refrigerator (for chemicals)?
- (4) No food and drink in the refrigerator
  - (1) Food or drink present in the refrigerator
29. Are flammable chemicals present in the refrigerator?
- All flammable chemicals that need to be refrigerated are kept in the refrigerator
  - Flammable chemicals that need to be refrigerated are kept in the refrigerator except when they are part of an experiment
  - Flammable chemicals that need to be refrigerated are sometimes kept in the refrigerator
  - Flammable chemicals that need to be refrigerated are not kept in the refrigerator

### *Shelves*

30. What is the frequency of shelf cleaning?
- Each shelf is cleaned on a daily basis
  - Each shelf is cleaned 2 to 3 times a week
  - Each shelf is cleaned once a week
  - Each shelf is cleaned less than once a week
31. Are shared chemicals present on shelf?
- (4) Shared chemicals are not present on shelves
  - (1) Shared chemicals are present on shelves

### **Emergency Protection Equipment**

32. Are the emergency call numbers on the emergency call notice board?
- Security number, hospital number, fire station number, and staff number all present
  - Only 3 of the 4 above numbers are present
  - Only 2 of the 4 above numbers are present
  - Only 1 of the 4 above numbers are present

### *Users know about ...*

33. Where is the nearest fire alarm?
- User knows 4 or more fire alarm locations
  - User knows only 3 fire alarm locations
  - User knows only 2 fire alarm locations
  - User knows only 1 fire alarm locations
34. Where is the nearest emergency exit?
- User knows 4 or more emergency exits
  - User knows only 3 emergency exits
  - User knows only 2 emergency exits
  - User knows only 1 emergency exit

35. Where is the nearest emergency exit?
- User knows 4 or more emergency exits
  - User knows only 3 emergency exits
  - User knows only 2 emergency exits
  - User knows only 1 emergency exit
36. Is the basic cleaning equipment present?
- Dustpan, trash, and broom, mop, rags/old clothes all present
  - Most, but not all of above are present
  - Only rags/old clothes are present
  - None
37. Do they know the general emergency plan?
- Emergency plan is clear, easy to understand, and readily visible
  - Emergency plan is clear and easy to understand, but not readily visible
  - Emergency plan is present, but not clear, and not readily visible
  - No emergency plan is present
38. Do they know the fire drill?
- User knows the fire drill plan, and practiced often
  - User knows the fire drill plan and practices occasionally
  - User knows the fire drill plan, but never practice
  - User does not know the fire drill plan
39. Do they know who is contacted when an accident occurs?
- In every case, teachers and staff concerned are contacted
  - Only in moderate cases are teachers and staff contacted
  - Only in serious cases are teachers and staff contacted
  - Teachers and staff are never contacted when an accident occurs

### *Fire Protection*

40. Are sprinklers systems present and functional?
- The sprinkler systems is checked every six months, and fully maintained
  - The sprinkler systems is checked every six months, and is not fully maintained
  - The sprinkler system is not checked regularly, and is never maintained
  - There is a sprinkler system, but they do not know if it works
41. Is the eyewash working?
- The eyewash is checked every six months, and fully maintained
  - The eyewash is checked every six months, and is not fully maintained
  - The eyewash is not checked regularly, and is never maintained
  - There is an eyewash, but they do not know if it works
42. What is the cleanliness of area around eyewash and safety shower?
- Area clear within 4 meters
  - Area clear within 3 meters
  - Area clear within 2 meters
  - Area clear within 1 meter

43. Dose the fire extinguisher work?

- The fire extinguisher is checked every six months, and fully maintained
- The fire extinguisher is checked every six months, and is not fully maintained
- The fire extinguisher is not checked regularly, and is never maintained
- There is a fire extinguisher, but they do not know if it works

44. Dose the fire blanket work?

- The fire blanket is checked every six months, and fully maintained
- The fire blanket is checked every six months, and is not fully maintained
- The fire blanket is not checked regularly, and is never maintained
- There is a fire blanket, but they do not know if it works

### *Personal Protective Equipment*

45. Is hearing protection available?

- Hearing protection is available, and is suitable for each job
- Only 1 type of hearing protection is available, not necessarily suitable
- Only 1 type of hearing protection is available, and broken
- No hearing protection is available

46. Is a respirator available?

- Respirator is available, and is suitable for each job
- Only 1 type of respirator available, not necessarily suitable
- Only 1 type of respirator is available, and broken
- No respirator is available

47. Are safety goggles available?

- Safety goggles have full coverage and are suitable
- Safety goggles covers just the eyes
- Safety goggles cover just eyes, and are broken
- No safety goggles are available

48. Are lab coats and closed toed shoes worn?

- Lab coats and closed toed shoes are always worn
- Lab coats and closed toed shoes are sometimes worn
- Only 1 of the above 2 is worn
- Lab coats and closed toed shoes are never worn

49. Are gloves present and worn?

- Gloves in the laboratory are suitable for the job, and used all the time
- Gloves are used just with hazardous chemicals
- Gloves are only sometimes used
- Gloves are never used

50. Do people use PPE?

- Both lab coats and goggles are worn, maintained and stored clean always
- Both lab coats and goggles are worn, maintained and stored clean some of the time
- Lab coats or goggles are worn, but not both, and only maintained and stored clean some of the time
- Lab coats and goggles are not present, or are never cleaned

## Chemical Storage

51. How often is the chemical inventory list in the laboratory revised?

- The list is revised every time that the inventory changes
- The list is revised once a month
- The list is revised every 3 months
- The list is revised every 6 months or more

52. Do you use the central chemical store for ordering chemicals?

- (4) The central chemical store is always used when chemicals are needed
- (2) Sometimes orders from central store, other times directly
- (1) Students or teachers order by themselves

53. Do you use the central chemical store for picking up chemicals?

- (3) Chemicals are always picked up from the central chemical store
- (2) Chemicals are sometimes picked up from the
- (1) Chemicals are picked up directly from the distributor

54. Are MSDS updated and present?

- MSDS sheets are updated regularly and are easy to use
- MSDS sheets are present and easy to use, but not updated regularly
- MSDS sheets are present, but are not easily accessible and are not updated regularly
- MSDS sheets are not present in the laboratory

55. Are chemical warning labels present?

- All chemical containers have chemical warning labels
- Only some chemical containers have chemical warning labels
- Only hazardous chemicals have chemical warning labels
- Chemicals are labeled with their name, but no warning label is present

56. What is the distance between flammable materials and ignition sources?

- Flammable materials are more than 3 meters away from ignition sources
- Flammable materials are more than 2 meters away from ignition sources
- Flammable materials are more than 1 meters away from ignition sources
- Flammable materials are less than 1 meters away from ignition sources

57. What volume of flammable solvents is present in the laboratory?

- 30 L
- 40 L
- 50 L
- More than 50 L



58. Are liquids poured in the fume hood, and is a funnel used?
- Every liquid is poured in the fume hood using a funnel
  - Just volatile and hazardous liquids are poured in the fume hood using a funnel
  - Every liquid is poured outside the fume hood using a funnel
  - Every liquid is poured outside the fume hood, and a funnel is not used
59. What is the color of desiccant in the laboratory?
- Blue
  - Purple
  - Pink
  - White
60. Are materials synthesized in the laboratory labeled fully?
- A complete, fundamental label, including date, is on all synthesized materials
  - Only the name of the material and a caution statement are present on synthesized materials
  - Only the name is present on synthesized materials
  - The label on the synthesized materials is in code
61. What is the quality of container covers?
- Containers are always covered and sealed
  - Containers are always covered, but not always sealed
  - Container covers are sometimes on, and when on they are not always sealed
  - Containers are never covered
62. How much time elapses from when a peroxide or ether is opened and when it is disposed of?
- Peroxides and ethers are used within 6 months from when they were opened
  - Peroxides and ethers are used within 8 months from when they were opened
  - Peroxides and ethers are used within 1 year from when they were opened
  - The date of opening is not labeled on the peroxides and ethers, so they do not know how long it has been since they were opened
63. Is a mercury spill cleaning kit present?
- The laboratory has a mercury clean kit
  - The laboratory does not have a mercury clean kit
64. Do liquid chemicals have a tray underneath them?
- Every container has a tray
  - Some containers have trays
  - Only special bottles have trays
  - No containers have trays

## **Waste Management**

65. How many groups is the waste divided into?
- The waste is divided into 11 or more groups
  - The waste is divided into 8-10 groups
  - The waste is divided into 5-7 groups
  - The waste is divided into less than 5 groups

66. Is the waste disposed of every 8 months, and if not, how often is it disposed of?
- The waste is disposed of every 8 months or less
  - The waste is disposed of every 8 months, but may be slightly late
  - The waste is disposed of within 1 year
  - It takes more than a year for the waste to be disposed of
67. Is the waste properly labeled with the fundamental documents (who is responsible)?
- The waste is properly labeled
  - The waste is labeled, but not all details are present
  - The waste is labeled only with its name
  - The waste is not labeled
68. Are glass, plastic, and garbage separated?
- Yes, glass plastic and garbage are separated
  - Glass and plastic are separated, but there is no garbage bin
  - Glass and plastic are not separated, but there is a garbage bin
  - There is only 1 bin for everything
69. Is glass and plastic waste labeled and sterilized?
- Glass and plastic waste is wrapped, sterilized, and labeled
  - Glass and plastic is labeled and wrapped, but not sterilized
  - Glass and plastic are wrapped, and a name is given, but are not sterilized
  - Glass and plastic are not wrapped, labeled, named, or sterilized
70. Is scale reduction used?
- Scale reduction is used in every experiment
  - Scale reduction is used just with the hazardous chemical experiments
  - Scale reduction is used only with the expensive chemicals
  - No scale reduction is used
71. What is done with biological waste?
- Biological waste is always sterilized
  - Biological waste is sterilized just when it is hazardous
  - Biological waste is sometimes sterilized
  - Biological waste is never sterilized
72. Are solvents recycled?
- 100% of solvents used are recycled
  - 70% of solvents used are recycled
  - 50% of solvents used are recycled
  - 30% or less of solvents used are recycled
73. Is hazardous chemical waste sent to chemical waste disposal center?
- Hazardous chemical waste is always sent to the chemical waste disposal center
  - Hazardous chemical waste is sometimes sent to the chemical waste disposal center
  - Hazardous chemical waste is occasionally sent to the chemical waste disposal center
  - Hazardous chemical waste is never sent to the chemical waste disposal center

74. Are the waste containers properly closed and sealed?
- Strong waste containers are used, properly closed and covered and sealed, and separated
  - Strong waste containers are used, properly closed and covered and sealed, but are not separated
  - Strong waste containers are used, properly closed and covered and sealed, but everything is just poured together
  - Weak waste containers are used

### **General Laboratory Safety**

Have they had training on ...

(All questions bellow are Y/N answers)

75. -----

76. -----

77. How to move hazardous substances?

78. Waste Management?

79. How to clean a chemical spill?

80. Which PPE that you need to use and how to clean it?

81. How to use special equipment (IR, UV, Gas chromatography)/

82. How to use fume hood?

83. Fire in laboratory procedure (burner)?

84. How to use the fire extinguisher?

85. How to use safety shower?

86. How to use eyewash?

87. Evacuation procedure (general fire alarm)?

## Appendix C – Summary of Laboratory Survey

The data below represents the results obtained from a survey of 71 laboratories within the Faculty of Science at Chulalongkorn University. The data has been sorted according to the elements of a chemical safety program. Not all of the questions from the survey have been included in this appendix.

### Chemical Hygiene Plan

#### *Standard Operating Procedures*

1- How often is the laboratory cleaned?

93% clean at least once a week

7% clean less than once a week

2- How organized is the laboratory?

82% are well organized

18% are disorganized

8- Food and drink in the laboratory

71% never have food or drink

17% very rarely have food or drink

18- Quality of fume hood instructions and record keeping

55% have unclear/no instructions, and no record of use

45% have some kind of instructions or record of use

21- Compressed gas turn off valves

95% turn off the gas valves when not in use

5% do not

22- Compressed gas storage distance from heat and flammable materials

56% store compressed gas within 1 meter of and flammable materials

44% store more than 1 meter away

23- Is there a clear, obstruction free zone around the compressed gas tanks?

56% have at least 1.5 meters of unobstructed space around the compressed gas tanks

44% have less than 1.5 meters of unobstructed space

24- Dryness of area surrounding compressed gas tanks

85% have no wetness within 1.5 meters of the compressed gas tank

15% do

26- Presence of empty compressed gas tanks within the laboratory

58% have no empty tanks

26% have at least one, but less than 4

16% have more than 4

28- Presence of food and drink in the refrigerator

92% have no food or drink in the refrigerator

8% have food or drink in the refrigerator

30- Frequency of shelf cleaning

91% clean the shelves at least once a week

9% clean the shelves less than once a week

39- Who is contacted when an accident occurs

72% contact teachers and staff in every case

24% contact only in moderate to serious cases

4% never contact

42- Cleanliness of area around eyewash and safety shower

59% have cleared area within 2 meters of safety shower

41% have cleared area within 1 meter of safety shower

56- Distance of flammable materials from ignition sources

96% store flammable materials more than 1 meter away from ignition sources

4% store flammable materials within 1 meter

58- Are liquids poured in the fume hood, and is a funnel used

78% pour volatile and hazardous liquids in the fume hood using a funnel

22% do not

61- Quality of container covers

75% are always covered and sealed

14% are always covered, but not always sealed

11% are not always covered

64- Do liquid chemicals have a tray underneath them

56% do not have trays for any liquid chemicals

19% have trays only for special bottles

25% have trays for most or all liquid chemicals

## *Engineering Controls*

### 4- Ventilation and smell within the laboratory

79% do not smell from lack of ventilation

21% smell from lack of ventilation

### 6- Quality of electrical grounding

61% use only grounded wall outlets

32% use some multi plugs, but are mostly grounded

7% have ground lines that are damaged, inconsistent, or not present

### 11- Quality of vacuum lines in the laboratory

17% have fully maintained vacuum lines

36% have vacuum lines that are not fully maintained

47% do not have vacuum lines

### 12- Circuit breakers and fuses

100% have circuit breakers and fuses in good condition

77% test at least once every 6 months

23% test at least once every year

### 13- Quality of the fume hood

35% keep fume hoods very clean

33% have a small amount of chemicals left in fume hood

30% have a lot of chemicals in the fume hood, and little space to work

2% have so many chemicals in the fume hood that there is no space to work

### 14- Functionality of the fume hood mirror

54% of fume hood mirrors go down all the way

32% only go down  $\frac{3}{4}$  of the way

14% only go down half way

### 16- Fume hood certification

35% are recertified at least once every 3 years

13% have never been recertified

53% have never been certified in the first place

### 17- Quality of ventilation system within the fume hood

6% have good ventilation

4% have working, but unused ventilation

90% do not have a ventilation system

20- Quality of compressed gas tank restraints  
33% use two chains, 1/3 and 2/3 of the way down the tank  
26% use only one chain  
18% use an unsuitable restraint  
23% have no restraints

25- Presence of caps on new compressed gas tanks  
56% have caps on all new tanks  
18% have a cap on at least half of their new tanks  
26% have caps on less than half of their new tanks

40- Sprinkler systems  
2% have fully maintained sprinkler systems  
31% have sprinkler systems that are not fully maintained  
67% have no sprinkler systems

41- Eyewash  
14% have fully maintained eyewash systems  
39% have eyewash systems that are not fully maintained  
47% have never checked their eyewash, and do not even know if it works

43- Fire extinguisher  
28% have fully checked and maintained fire extinguishers  
45% have irregularly checked and not fully maintained fire extinguishers  
17% have never checked their fire extinguisher, and do not even know if it works

44- Fire blanket  
19% have checked their fire blanket  
81% have not, and do not know if it works

63- Presence of mercury spill cleaning kit  
33% have a mercury spill cleaning kit  
67% do not

### *Personal Protective Equipment*

45- Hearing protection  
15% have hearing protection  
85% do not

46- Respirator  
55% have a respirator available  
45% have either broken respirators or no respirator at all

47- Safety goggles

77% have safety goggles available

23% have either broken goggles or no goggles at all

48- Lab coats and closed toed shoes

51% always wear lab coats and closed toed shoes

27% usually wear lab coats and closed toed shoes

17% never wear both

5% never wear either

49- Gloves

87% use gloves with hazardous chemicals

13% do not always use gloves when they are necessary

50- Usage of general PPE

85% wear lab coats and goggles, and keep them well cleaned and maintained

22% do not consistently maintain lab coats and goggles

2% either do not have lab coats and goggles or never maintain them

*Information and Training*

33- Where is the nearest fire alarm?

32% know the location of at least 3 fire alarms

32% know the location of 2 fire alarms

36% know the location of 1 fire alarm

34- Where is the nearest emergency exit?

44% know the location of 3 or more emergency exits

33% know the location of the 2 emergency exits

23% know the location of 1 emergency exit

35- Where is the nearest fire extinguisher?

44% know the location of 3 or more fire extinguishers

27% know the location of 2 fire extinguishers

29% know the location of 1 fire extinguisher

37- General emergency plan

15% have visible and clear emergency plans

17% have clear but not readily visible emergency plans

29% have unclear, not readily visible emergency plans

39% do not have an emergency plan



38- Emergency training  
44% know and practice the fire drill  
5% know the drill, but never practice  
51% do not know what to do for a fire drill

(77-87, do you know/did you receive training in or on ...)

77- How to move hazardous substances  
32% Yes  
68% No

78- Waste Management  
51% Yes  
49% No

79- How to clean a chemical spill  
51% Yes  
49% No

80- Which PPE that you need to use and how to clean it  
42% Yes  
58% No

81- How to use special equipment (IR, UV, Gas chromatography)  
68% Yes  
32% No

82- How to use fume hood  
245% Yes  
55% No

83- Fire in laboratory procedure (burner)  
31% Yes  
69% No

84- How to use the fire extinguisher  
34% Yes  
66% No

85- How to use safety shower  
11% Yes  
89% No

86- How to use eyewash  
14% Yes  
86% No

87- Evacuation procedure (general fire alarm)

42% Yes

58% No

## **Hazard Communication Plan**

### *Hazardous Materials List*

51- How often is the chemical inventory list in the laboratory revised?

32% every time the inventory changes

21% once a month

18% once every 3 months

29% once every 6 months

### *MSDS*

54- Presence and contemporaneity of MSDS sheets

29% MSDS updated regularly and readily available

34% MSDS not updated regularly, not always readily available

37% MSDS not present

### *Labeling*

19- Labeling of gas and water lines

15% both labeled clearly

15% labeled clearly, but not always labeled

17% not labeled clearly, most are not labeled

53% not labeled at all

55- Chemical warning labels

51% All chemical containers have chemical warning labels

33% Only some chemical containers have chemical warning labels

6% Only hazardous chemicals have chemical warning labels

10% Chemicals are labeled with their name, but no warning label is present

60- Are materials synthesized in the laboratory labeled fully?

22% A complete, fundamental label, including date, is present

37% Only the name of the material and a caution statement are present

22% Only the name is present

20% The label on the material is in code

## Chemical Waste Disposal

### *Waste Determination*

65- How many groups is the waste divided into?

29% divided into all 11 groups

42% divided into 5-10 groups

29% divided into less than 5 groups

68- Are glass, plastic, and garbage separated?

48% Yes

52% No

### *Waste Storage*

69- Is glass and plastic waste labeled and sterilized?

23% wrapped, sterilized, and labeled

24% labeled and wrapped, but not sterilized

23% wrapped, and a name is given, but is not sterilized

30% not wrapped, labeled, named, or sterilized

71- Biological waste

65% always sterilized

6% sterilized when hazardous

20% rarely sterilized

9% never sterilized

74- Are the waste containers properly closed and sealed?

70% Strong containers used, properly closed, covered, sealed and separated

28% Strong containers used, properly closed, covered and sealed, but not separated

2% Weak waste containers are used, not closed, covered, sealed, or separated

### *Off-Site Disposal*

66- Is the waste disposed of every 8 months, and if not, how often is it disposed of?

68% on time with the disposal

20% dispose every 8 months, but may be slightly late

5% dispose once a year

7% dispose less than once a year

73- Is hazardous waste sent to chemical waste disposal center?  
44% hazardous chemical waste is always sent to the chemical waste disposal center  
23% hazardous chemical waste is sometimes sent to the chemical waste disposal center  
19% hazardous chemical waste is occasionally sent to the chemical waste disposal center  
13% hazardous chemical waste is never sent to the chemical waste disposal center

### *Record Keeping*

67- Is the waste properly labeled?  
25% the waste is properly labeled  
38% the waste is labeled, but not all details are present  
20% the waste is labeled only with its name  
17% the waste is not labeled

## **Chemical Waste Minimization**

### *Purchase Control*

52- Do you use the central chemical store for ordering chemicals?  
44% yes  
28% sometimes  
28% no

53- Do you use the central chemical store for picking up chemicals?  
51% yes  
29% sometimes  
20% no

### *Inventory Control*

57- What volume of flammable solvents are present in the laboratory?  
52% 30L  
28% 40L  
20% 50L or more

62- How much time elapses from when a peroxide or ether is opened and when it is disposed of?  
21% peroxides and ethers are used within 6 months from when they were opened  
34% peroxides and ethers are used within 1 year from when they were opened  
45% the date of opening is not labeled, so they time since opening is unknown

### *Recycling*

#### 72- Recycling of solvents

7% 70% of solvents used are recycled

22% 50% of solvents used are recycled

71% 30% or less of solvents used are recycled

### *Scale Reduction*

#### 70- Scale reduction

30% scale reduction is used in every experiment

40% scale reduction is used just with the hazardous or expensive chemicals

30% no scale reduction is used

## Appendix D – Response Summary of In-Class Survey

*The number of responses to a given question are represented by a number in parenthesis following that response.*

- 1) What is your major?
  - a. Applied Chemistry (27)
  - b. Pharmaceutical Sciences (5)
  - c. Chemistry (4)
  - d. Engineering (3)
  - e. Science (1)
  - f. Science – Biology (1)
  - g. Math (1)
  - h. No Response (4)
- 2) What is your year?
  - a. First (45)
  - b. Third (1)
- 3) How many laboratory courses have you taken?
  - a. None (21)
  - b. Three (10)
  - c. Two (4)
  - d. None in University (3)
  - e. None in University (one high school course) (1)
  - f. Two (not chemical related) (1)
  - g. Ten (1)
  - h. One (1)
  - i. No Response (4)
- 4) What type of experiments have you done in the laboratory?
  - a. Biology (7)
  - b. Chemistry (7)
  - c. Medical Physics (7)
  - d. None (5)
  - e. Physics (4)
  - f. Organic Chemistry (3)
  - g. Cation/Anion (2)
  - h. Computer (2)
  - i. Psychology (1)
  - j. Titration/pH (1)
  - k. Chromatography (1)
  - l. Organic/Inorganic Synthesis (1)
  - m. Quantitative/Qualitative Analysis (1)
  - n. Instrumental Analysis (1)
  - o. No Response (24)

- 5) In which courses have you used chemicals?
- General Chemistry (8)
  - Organic Chemistry (5)
  - None (5)
  - General Biology (4)
  - All of them [10 classes suggested] (1)
  - General Physics (1)
  - None, just in high school (1)
  - Two of them [Chemistry and Physics suggested] (1)
  - Yes, I have (1)
  - No Response (25)
- 6) How often do you... (responses are rated 1-5 with 1 meaning never and 5 meaning always) (16 Respondents)
- wear safety glasses in the laboratory?
    - 1 (4)
    - 2 (1)
    - 3 (3)
    - 4 (3)
    - 5 (5)
    - Average Score (3.25)
  - wear laboratory coats in the laboratory?
    - 1 (8)
    - 2 (0)
    - 3 (2)
    - 4 (0)
    - 5 (6)
    - Average Score (2.75)
  - wear gloves in the laboratory?
    - 1 (13)
    - 2 (2)
    - 3 (1)
    - 4 (0)
    - 5 (0)
    - Average Score (1.25)
  - wear sandals in the laboratory?
    - 1 (14)
    - 2 (2)
    - 3 (0)
    - 4 (0)
    - 5 (0)
    - Average Score (1.13)

- e. bring food or drink into the laboratory?
  - i. 1 (15)
  - ii. 2 (0)
  - iii. 3 (1)
  - iv. 4 (0)
  - v. 5 (0)
  - vi. Average Score (1.13)
- f. use chemicals in laboratories?
  - i. 1 (1)
  - ii. 2 (0)
  - iii. 3 (3)
  - iv. 4 (2)
  - v. 5 (10)
  - vi. Average Score (4.25)
- g. use hazardous chemicals in laboratories?
  - i. 1 (1)
  - ii. 2 (1)
  - iii. 3 (11)
  - iv. 4 (3)
  - v. 5 (0)
  - vi. Average Score (3.00)
- h. use compressed gasses in laboratories?
  - i. 1 (10)
  - ii. 2 (3)
  - iii. 3 (2)
  - iv. 2 (1)
  - v. 1 (0)
  - vi. Average Score (1.63)
- i. clean up chemical spills in laboratories?
  - i. 1 (3)
  - ii. 2 (0)
  - iii. 3 (3)
  - iv. 4 (3)
  - v. 5 (7)
  - vi. Average Score (3.69)
- j. handle chemical waste?
  - i. 1 (2)
  - ii. 2 (1)
  - iii. 3 (7)
  - iv. 4 (2)
  - v. 5 (4)
  - vi. Average Score (3.31)



- k. dispose of chemicals down the drain?
  - i. 1 (4)
  - ii. 2 (0)
  - iii. 3 (10)
  - iv. 4 (2)
  - v. 5 (0)
  - vi. Average Score (2.63)
- l. clean the laboratory after doing an experiment?
  - i. 1 (0)
  - ii. 2 (0)
  - iii. 3 (3)
  - iv. 4 (8)
  - v. 5 (5)
  - vi. Average Score (4.13)
- m. use fume hoods when handling chemicals?
  - i. 1 (1)
  - ii. 2 (1)
  - iii. 3 (9)
  - iv. 4 (4)
  - v. 5 (1)
  - vi. Average Score (3.19)
- n. put chemicals back when you are done using them?
  - i. 1 (3)
  - ii. 2 (2)
  - iii. 3 (1)
  - iv. 4 (5)
  - v. 5 (5)
  - vi. Average Score (3.44)
- o. Average Score of all Questions (2.77)

Note: Responses to these questions are from those who have taken at least one laboratory class and have completed this question

- 7) What concerns you about the use of chemicals in the classrooms or laboratories?
- a. Safety (15)
  - b. Potential harm to health (8)
  - c. Unexpected explosions (4)
  - d. Proper usage of chemicals (4)
  - e. Toxicity of chemicals (3)
  - f. Effects of chemicals (3)
  - g. Accident prevention (2)
  - h. Contact with corrosive chemicals (2)
  - i. Teacher (2)
  - j. Proper experimentation practices (2)
  - k. Types of chemicals (1)
  - l. Prevention of hazardous chemical events (1)
  - m. Reactions between solutions (1)
  - n. Properties of elements (1)

- o. Exposure to chemicals (1)
  - p. Did Not Understand (1)
  - q. Chemicals of high concentration (1)
  - r. Laboratories (1)
  - s. No Response (4)
  - t. Indeterminate Response
    - i. Pretest Point (1)
- 8) Do you feel safe working in the laboratories? If not, why not?
- a. Yes (34)
    - i. Personal knowledge about prevention of accidents (5)
    - ii. Presence of safety equipment in the laboratory (1)
    - iii. Usage of laboratory coats and safety glasses as well as the usage of low concentrations of chemicals (1)
    - iv. Always following Instructor (1)
    - v. Maid cleans up later (1)
  - b. No (5)
    - i. Potential for people to make mistakes leading to any kind of accident (2)
    - ii. Greater awareness of how to deal with chemicals as a result of a chemical hazard course (no actual experience) (1)
    - iii. Lack of safety materials for use in the laboratory (1)
    - iv. Afraid of the effects of chemicals (1)
  - c. Undecided (3)
    - i. No laboratory experience (3)
  - d. No Response (4)
- 9) Have you had chemical safety training at Chulalongkorn University? If so, please describe the training you have received.
- a. Yes (24)
    - i. Classes (8)
      - 1. Chemical Hazard Course in Progress (3)
      - 2. Chemical Hazard Course with MSDS (2)
    - ii. Video (5)
    - iii. Other (3)
    - iv. Must wear coats (2)
    - v. Lectures (1)
      - 1. No practical (exam) (1)
      - 2. Chemical Hazard (1)
    - vi. Teacher Explanation (1)
    - vii. General lab safety, how to prevent and control accidents
    - viii. No food or drink in laboratory (1)
    - ix. Must wear glasses (1)
    - x. Use of chemicals (1)
    - xi. Handle chemical waste (1)
    - xii. Hazard of chemicals (1)
    - xiii. Protection of self when using chemicals (1)
    - xiv. Additional Information not Provided (1)
  - b. No (21)

- c. No Response (1)
- 10) Have you had chemical safety training before coming to Chulalongkorn University? If so, please describe the training you received.
- a. Yes (9)
    - i. Laboratory Equipment Instruction (2)
    - ii. Lecture at school (1)
    - iii. Real experiments at school (1)
    - iv. Properties of Solutions (1)
    - v. Accident Response (2)
    - vi. Teacher Instruction (1)
    - vii. General training course about chemical safety in the laboratory (1)
    - viii. High school course, small laboratory with no hazardous chemicals (1)
    - ix. High school course where taught to read warning signs (1)
    - x. Behavioral lectures and demonstrations (1)
    - xi. No additional information (1)
  - b. No (36)
  - c. No Response (1)
- 11) Do you know what the parts of a chemical safety program are? If so, please list them?
- a. Yes (0)
  - b. No (37)
  - c. No with attempted response (5)
    - i. Wear goggles and gloves, and do not wear high heels (1)
    - ii. Classroom Theory and Laboratories (1)
    - iii. Know the types of chemicals and their toxicity, and how to identify and handle the chemicals (1)
    - iv. Chemical safety and safety acts (1)
    - v. Just answered "Yes" (1)
  - d. No Response (4)
- 12) Do you expect to learn more about chemical safety while at Chulalongkorn University? If so, what do you expect to learn?
- a. Yes (27)
    - i. Everything (6)
    - ii. Toxic chemicals (5)
    - iii. Everything that is exciting and fun (3)
    - iv. Waste disposal (3)
    - v. More from laboratory work (2)
    - vi. All that can make one safe (1)
    - vii. Chemical management with a specified chemical (1)
    - viii. Accident Reduction (1)
    - ix. Accident Response (1)
    - x. Chemical Safety Standards (1)
    - xi. Laboratory Behavior (1)
    - xii. Safe Experimentation Practices (1)
    - xiii. Identification of Harmful Chemicals (1)
    - xiv. How to make medicine (1)
    - xv. No Additional Information (1)

- b. No (15)
  - c. Undecided (1)
    - i. Need laboratory experience to know (1)
  - d. No Response (2)
- 13) Would you like to learn more about chemical safety? Explain.
- a. Yes (26)
    - i. Proper Accident Response (12)
    - ii. Potential use in the future (7)
    - iii. Welcome more knowledge (2)
    - iv. Safety (2)
    - v. Safe Practices (2)
    - vi. Part of degree program (2)
    - vii. Interest (2)
    - viii. Want more experience (1)
    - ix. Benefit to self and others (1)
    - x. Prevent injury or death of self (1)
    - xi. Waste Separation (1)
  - b. No (15)
    - i. Lab instructors will tell in every lab performed (1)
  - c. No Response (3)
  - d. Indeterminate Response (2)
    - i. Change the teacher (1)
    - ii. Safety of device (1)