Chemical Safety Plan for Chulalongkorn University, Thailand

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Authorship

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Abstract

The purpose of this project was to develop a chemical safety plan for the Department of Chemistry at Chulalongkorn University in Bangkok, Thailand, for use in the new, twenty-storey science building. Because no universities in Thailand have formal safety plans, Chulalongkorn will serve as a model for other universities. The project team researched chemical safety in the laboratory setting, previous research, and existing chemical safety plans instituted in United States universities. As a result of surveys, observations, and interviews, the project team constructed a safety plan and implementation framework that is tailored to the new science building and the Department of Chemistry.

Executive Summary

This project developed a chemical safety plan for the Department of Chemistry at Chulalongkorn University in Bangkok, Thailand, for use in the new science building. This safety plan will assist the University in improving its current safety practices, protecting people and the environment, and will also serve as a model to other universities in Thailand that have yet to adopt formal safety plans. To develop the safety plan, the team researched existing safety plans, interviewed experts in the field of chemical safety, and observed and evaluated current practices in Chulalongkorn's Department of Chemistry.

First, the team consulted safety plans from four prominent universities in the United States to examine accepted chemical safety practices. There was a common thread throughout these safety plans since each university must comply with federal and state regulations. Each university has specific information dealing with hazardous waste management and standard operating procedures in the laboratory. The team evaluated the use of these stricter standards as the basis for Chulalongkorn's safety plan.

The team sought advice from many experts in the fields of chemistry, safety, and waste management to increase the knowledge of the team in the area of chemical safety. The team interviewed representatives from the Petroleum Authority of Thailand and ExxonMobil Chemical, current and former professors from Chulalongkorn and Mahidol Universities in Bangkok, and the safety officer from Worcester Polytechnic Institute. These specialists work in both academic and industrial settings. The interviews and discussions provided detailed information regarding all aspects of chemical safety. The information garnered from the interviews provided the team with the knowledge needed to create the safety plan for Chulalongkorn University.

In order to adapt the safety plan specifically for Chulalongkorn University the team assessed the current chemical safety practices in the Department of Chemistry. The team counted and estimated chemicals found in the stock rooms of the Department of Chemistry to discover the range of chemicals used in Chulalongkorn's chemistry labs. This process led to the conclusion that the chemicals utilized by this department are standard to most chemistry departments.

To gauge student awareness and interest in chemical safety, the team administered a survey to chemistry students. The survey results are that the students feel that chemical safety practices at Chulalongkorn need improvement. Overall, the surveys verify that chemical safety is a concern of the students and that the students are willing to alter their current practices to make the chemistry labs a safer atmosphere to work in.

Observing the actual safety practices of the students in the chemistry labs at Chulalongkorn also lead the team to develop a more appropriate safety plan for the University. While observing the organic chemistry labs, the team detected both poor and commendable common safety practices. The poor practices will be improved with the implementation of the chemical safety plan.

The team took note of the storage practices in the chemistry stock rooms and also of the Main Accumulation Area through the use of digital photographs and direct observations. The team found the chemical stockrooms to be cluttered and chemicals arranged in alphabetical order which is not a recommended practice. The Main Accumulation Areas in Chemistry Building 3 and behind Chemistry Building 1 contain a variety of drums, jugs, and bottles exposed to the elements. Most of these containers are not properly labeled. The team also interviewed representatives from Genco and BYL Environmental Services. These companies will facilitate the removal of waste from the Main Accumulation Areas.

The team constructed a three-phase implementation timeline to facilitate the adoption of the safety plan in the new science building. This timeline addresses budget issues as well as time constraints. It is a step-by-step guideline to the proper execution of the safety plan for the Department of Chemistry. The first phase of implementation addresses essential safety practices as well as safety components that can be easy implemented before the opening of the new science building. The second phase includes changes that require significant planning and budget consideration, such as purchasing proper hazardous waste containers. The third phase addresses areas that will complete the safety initiatives in the new science building. The timeline also serves as part of the team's recommendations for safety management in the new science building.

Formal chemical safety practices are a much needed throughout the academic community, including Chulalongkorn. The team concluded that the University will greatly benefit from instituting formal chemical safety practices because it is important for protecting people and the environment. With the implementation of the chemical safety plan, Chulalongkorn University will be able to improve the learning environment for its students. When implemented, the chemical safety plan at Chulalongkorn University will serve as a model for other universities in Thailand.

Table of Contents

1 INTRODUCTION 1

2 BACKGROUND 3

2.1 THAI CULTURE 3
2.1.1 Change 3
2.1.2 Criticism 4
2.2 ORGANIZATIONS 5
2.2.1 Chulalongkorn University 5
2.2.1.1 Faculty of Science 7
2.2.1.2 The New Science Building 8
2.2.2 Research Institutions in Thailand 9
2.2.2.1 ExxonMobil Chemical 9
2.2.2.2 Petroleum Authority of Thailand 10
2.3 LAWS AND REGULATIONS 10
2.3.1 Regulations in Thailand 10
2.3.1.1 Environmental Regulations 11
2.3.1.2 Chemical Regulations 13
2.3.2 Regulations in the United States 14
2.3.2.1 Environmental Regulations 14
2.3.2.2 Chemical Regulations 15
2.3.2.2.1 Transportation Laws 15
2.3.2.2.2 Storage Regulations 16
2.4 HAZARDOUS MATERIAL DISPOSAL AND TRANSPORTATION COMPANIES 17
2.4.1 Waste Disposal Companies 17
2.4.2 Chemical Transportation Companies 19
2.5 CASE STUDIES OF SAFETY PLANS 20
2.5.1 Definition of a Safety Plan 20
2.5.2 Chulalongkorn University 21
2.5.3 Worcester Polytechnic Institute 21
2.5.3.1 Waste Management 22
2.5.3.2 Transport of Hazardous Materials 24
2.5.3.3 Training in Hazardous Waste Management 25
2.5.3.4 Chemical Hygiene Plan 25
2.5.4 Massachusetts Institute of Technology 30
2.5.4.1 Chemical Research Safety Notes 30
2.5.4.2 Hazardous Waste Accumulation, Storage, and Pickup 32
2.5.4.3 Waste Reduction Guidelines 33
2.5.4.4 Sink Disposal and Wastewater 33
2.5.5 University of Massachusetts at Amherst 33
2.5.6 Michigan State University 37
2.5.6.1 Chemical Hygiene Plan 38
2.6 PREVIOUS RESEARCH 42
2.6.1 Surplus Chemical Exchange Program 42
2.7 LABORATORY ACCIDENTS AT UNIVERSITIES 44
2.7.1 Previous Accidents at Chulalongkorn 44
2.7.2 Previous Accidents at Worcester Polytechnic Institute 44

3 METHODOLOGY 47

3.1 DOMAIN OF INQUIRY AND DEFINITIONS 48
3.2 SPATIAL COVERAGE 48
3.3 EXAMINATION OF COMMON PRACTICES IN CHEMICAL SAFETY 49
3.3.1 Safety Comparison Methods 50
3.3.2 United States Academic Safety Plans 51
3.3.3 Professional Resources 52
3.3.3.1 Dr. Supawan Tantayanon 52
3.3.3.2 Dave Messier 53
3.3.3.3 Dr. Thawach Chatchupong 54
3.3.3.4 Mr. Montree 54

3.3.3.5 Krissana Auynirundornkul ... 55
3.3.3.6 Tanong Promma ... 55
3.3.3.7 Dr. Bhinyo Panijpan ... 55
3.3.3.8 Dr. Suchata Jinachitra ... 56
3.3.3.9 Dr. Yaron Yoel ... 56
3.4 ASSESSMENT OF CURRENT PRACTICES AT CHULALONGKORN ... 56
3.4.1 Accident Reports ... *57*
3.4.2 Inventory of Chemicals at Chulalongkorn ... *57*
3.4.2.1 Surplus Chemical Exchange Program ... 58
3.4.2.2 Counting and Estimating ... 58
3.4.3 Opinion Survey ... *59*
3.4.4 Observations of Laboratory Practices ... *60*
3.4.5 Storage Practices ... *60*
3.5 DEVELOPMENT OF A SAFETY PLAN FOR CHULALONGKORN UNIVERSITY ... 61
3.5.1 Presentation to Graduate Students ... *62*
3.5.2 Incorporating Cultural Differences ... *62*
3.5.3 Implementation Timeline ... *63*

4 RESULTS ... 65

4.1 COMMON PRACTICES IN CHEMICAL SAFETY IN THE UNITED STATES ... 65
4.1.1 Chemical Safety Plans ... *65*
4.1.2 Chemical Safety Practices ... *67*
4.2 CURRENT PRACTICES AT CHULALONGKORN ... 68
4.2.1 Chemical Safety Practices ... *68*
4.2.2 Storage Practices ... *69*
4.2.3 Surveys ... *69*
4.2.4 Fire Safety Equipment ... *70*
4.2.5 Chemical Data ... *71*

5 ANALYSIS ... 72

5.1 INTERPRETATION OF SURVEYS ... 72
5.2 EVALUATION OF CURRENT CONDITIONS AT CHULALONGKORN ... 78
5.2.1 Analysis of Chemical Inventory ... *79*
5.2.2 Analysis of Storage Practices ... *79*
5.2.3 Analysis of Laboratory Practices ... *82*
5.2.4 Analysis of Fire Safety Equipment ... *88*
5.2.5 Analysis of Waste Generation ... *89*
5.3 SAFETY MANAGEMENT IN THE NEW SCIENCE BUILDING AT CHULALONGKORN UNIVERSITY 89

6 RECOMMENDATIONS AND IMPLEMENTATION FRAMEWORK ... 92

6.1 PHASE ONE ... 93
6.1.1 Chief Safety Officer ... *94*
6.1.2 Chemical Hygiene Plan ... *94*
6.1.2.1 Standard Operating Procedures ... 94
6.1.2.2 Personal Protective Equipment ... 95
6.1.2.2.1 Eye Protection ... 95
6.1.2.2.2 Lab Clothing ... 95
6.1.2.2.3 Disposables Laboratory Accessories ... 96
6.1.2.3 Material Safety Data Sheets ... 97
6.1.3 Accident Reports ... *98*
6.2 PHASE TWO ... 98
6.2.1 Chemical Safety Information ... *98*
6.2.2 Chemical Preparation, Maintenance, and Disposal ... *99*
6.2.2.1 Chemical Preparation and Stockroom ... 99
6.2.2.2 Storage and Labeling ... 100
6.2.2.3 Transportation ... 102
6.2.2.4 Waste Disposal ... 103
6.2.3 Engineering Controls ... *104*
6.2.4 Fire Safety Measures ... *105*

6.3 Phase Three ... 105
6.3.1 Main Accumulation Area ... 106
6.3.2 Chemical Safety Office ... 106
6.3.3 Training Programs ... 106
6.3.4 Chemical Inventory ... 107
6.4 Ongoing Considerations ... 107
6.4.1 Education ... 107
6.4.2 Enforcement ... 109
6.4.2.1 Rewards for Safety ... 110

7 CONCLUSION ... 112

8 BIBLIOGRAPHY ... 114

APPENDIX A ANNOTATED BIBLIOGRAPHY ... 117

A.1 Laboratory Safety ... 117
A.2 Chemical Safety ... 118
A.3 Organizations ... 120
A.4 Waste Disposal Companies ... 121
A.5 Interviews and Surveys ... 122

APPENDIX B STUDENT SURVEY QUESTIONS ... 124

APPENDIX C INTERVIEWS AND INFORMATION SESSIONS ... 125

C.1 Interview with Dave Messier ... 125
C.2 Information Session with ExxonMobil Chemical ... 128
C.3 Information Session with ExxonMobil Chemical and Pfizer ... 129
C.4 Interview with PTT Safety Officers ... 130
C.5 Interview with Dr. Bhinyo Panijpan ... 134
C.6 Interview with Genco ... 137
C.7 Interview with Dr. Suchata Jinachitra ... 139
C.8 Interview with BYL Environmental Services ... 141

APPENDIX D PHOTOGRAPHIC DOCUMENTATION ... 143

D.1 WPI Main Accumulation Area ... 143
D.2 Chulalongkorn Laboratories ... 149
D.3 Waste Disposal Areas at Chulalongkorn ... 158
D.4 Observations of Student Labs ... 161

APPENDIX E FIRE SAFETY FORM ... 162

APPENDIX F INVENTORY OF CHEMICALS AT CHULALONGKORN ... 163

APPENDIX G CHEMICAL SAFETY PLAN ... 165

Table of Tables

TABLE 1: DIVISION OF FLOORS IN THE NEW SCIENCE BUILDING 8

TABLE 2: REPORTED ACCIDENTS AT WORCESTER POLYTECHNIC INSTITUTE 45

TABLE 3: RESULTS FROM THE STUDENT SURVEY 70

Table of Figures

FIGURE 1: KING CHULALONGKORN 5

FIGURE 2: KING VAJIRAVUDH 6

FIGURE 3: THE FACULTY OF SCIENCE BUILDING 7

FIGURE 4: THE NEW SCIENCE BUILDING AT CHULALONGKORN UNIVERSITY 8

FIGURE 5: VALVE OPENING CEREMONY AT THE PETROLEUM AUTHORITY OF THAILAND 10

FIGURE 6: MAP OF THE CHULALONGKORN CAMPUS 49

FIGURE 7: FIRE EXTINGUISHER AND AUTOMATIC HOSE REEL 70

FIGURE 8: FIRE EXIT SIGN 71

FIGURE 9: EMERGENCY LIGHTING 71

FIGURE 10: I FEEL SAFE WHEN WORKING IN THE CHEMISTRY LABS. 73

FIGURE 11: I FEEL THAT SAFETY PRACTICES AT CHULALONGKORN NEED IMPROVEMENT. 73

FIGURE 12: I AM CONCERNED ABOUT PROTECTING THE ENVIRONMENT THROUGH PROPER CHEMICAL WASTE DISPOSAL. 74

FIGURE 13: ONCE A YEAR, I WOULD BE WILLING TO ATTEND A CHEMICAL SAFETY SEMINAR RUN BY THE DEPARTMENT OF CHEMISTRY. 74

FIGURE 14: I ALWAYS WEAR APPROPRIATE PERSONAL PROTECTIVE EQUIPMENT WHILE WORKING IN THE LABORATORY. 75

FIGURE 15: I HAVE BEEN PROPERLY TRAINED TO USE LABORATORY EQUIPMENT. 75

FIGURE 16: I KNOW THE FASTEST EMERGENCY EXIT ROUTE IN THE EVENT OF A FIRE. 76

FIGURE 17: I HAVE BEEN TRAINED IN PROPER USE OF A FIRE EXTINGUISHER 76

FIGURE 18: I KNOW HOW TO DISPOSE OF CHEMICALS PROPERLY. 77

FIGURE 19: I PRACTICE METHODS TO MINIMIZE CHEMICAL WASTE. 77

FIGURE 20: I AM FAMILIAR WITH AND REGULARLY USE MATERIAL SAFETY DATA SHEETS. 78

FIGURE 21: I KNOW WHERE THE EYEWASH AND SHOWER STATIONS ARE IN THE LABORATORY AND I KNOW HOW TO OPERATE THEM. 78

FIGURE 22: WASTE CONTAINERS EXPOSED TO ADVERSE WEATHER 81

FIGURE 23: WASTE STORAGE IN CHEMISTRY BUILDING 3 81

FIGURE 24: LACK OF AWARENESS 83

FIGURE 25: CLUTTERED WORK ENVIRONMENT 83

FIGURE 26: WASTE CONTAINERS AT CHULALONGKORN 85

Figure 27: Student Dumping Chemicals down the Drain 85
Figure 28- Entrance to MAA, with warnings and placards 143
Figure 29 - Lab Packs of hazardous material 144
Figure 30- 55 Gallon Drums: organinc, nonorganics, and waste oil 144
Figure 31 - Drums, and flammable wastes 145
Figure 32 - Bottom half of ventilation system 145
Figure 33 – Sink and clean-up area in Chemical Stockroom 146
Figure 34 - Flammable materials cabinet 146
Figure 35 - Fume hood in stockroom, eyewash at bottom 147
Figure 36 - SAA in regular lab 147
Figure 37 - Compressed gas cylinders 148
Figure 38: Waste containers at Chulalongkorn 149
Figure 39: Unattended Bunsen burner 149
Figure 40: Student on mobile phone while performing an experiment 150
Figure 41: Student not wearing shoes 150
Figure 42: Crowded work environment 151
Figure 43: Inside of a fume hood 151
Figure 44: Stockroom in Chemistry 3 Building 152
Figure 45: Stock bottles with cork stoppers 152
Figure 46: Washing glassware 153
Figure 47: Pouring chemicals directly from stock bottle into test tube ... 153
Figure 48: Extremely cluttered laboratory 154
Figure 49: Chemistry lab bench 154
Figure 50: Trashcan in chemistry lab 155
Figure 51: Stockroom in Chemistry Building 1 155
Figure 52: Disorganized work area with flame 156
Figure 53: Work environment in first year Organic Chemistry lab 156
Figure 54: Chemical bottle label 157
Figure 55: Barrels of Waste in Chemistry Building 3 158
Figure 56: Jugs of Waste behind Chemistry Building 1 158
Figure 57: Barrels of Waste behind Chemistry Building 1 159
Figure 58: Jugs of Waste in Chemistry Building 1 159
Figure 59: Jugs of Waste behind Chemistry Building 1 160
Figure 60: Bags of Bottles of Waste in Chemistry Building 3 160

1 Introduction

As the field of chemistry progresses, evolves, and expands, the consequences of experimentation are perpetually increasing. Chemical safety is becoming a progressively more important consideration in research facilities where the presence of hazardous materials poses a serious risk to people and the environment. The potential dangers that arise from the lack of safety procedures lead governments and organizations to heavily regulate chemical safety in the interest of humanity and the environment. The ramifications of inadequate safety procedures are far-reaching, often affecting the surrounding environment and putting large portions of the population in tremendous danger.

Universities in Thailand have not established documented safety procedures or mandated safe practices in their laboratories. As a renowned institute of higher education, Chulalongkorn University would benefit from a comprehensive safety plan. With the completion of its new, twenty-storey science building, the faculty of the Department of Chemistry has the tremendous opportunity to begin safety initiatives that will protect and serve the University. Chemical safety is not a product that can be created in a single project; instead, safety is a constantly evolving and adapting process. This project forms the foundation of chemical safety development at Chulalongkorn University by establishing formal procedures for the new science building.

The ultimate goal of this project is to prepare a thorough evaluation of current chemical safety practices at Chulalongkorn University and develop a proposed chemical safety plan for the new science building that is forward looking and incorporates the standard practices from similar institutions. The team surveyed existing safety programs at several universities in the United States and, after arrival in Bangkok, similarly explored the safety plans of several research centers, including the Petroleum Authority of Thailand and ExxonMobil Chemical. The team identified specific concerns within the Department of Chemistry and the University administration to develop effective policies for the storage, transfer, and disposal of hazardous materials. This research informed the proposed safety plan for the new science building at Chulalongkorn University.

The Background chapter of this document presents information on chemical safety, laws, and regulations pertaining to hazardous materials, and previous safety studies completed at Chulalongkorn. The Methodology chapter details the processes leading to a safety plan including procedures for conducting opinion surveys and focus groups to gauge the concerns of the University, techniques used to analyze safety practices, and approaches towards the creation of a safety plan. The Results chapter of the project outlines the data collected about standard safety practices in the United States and Thailand, as well as information from the surveys, interviews, and observations conducted. The Analysis chapter provides a detailed assessment and interpretation of the data collected for this project. The Recommendations chapter outlines advice and suggestions that will facilitate the implementation of the safety plan. Finally, the Conclusion summarizes the project as a whole and proposes future studies stemming from this project.

2 Background

This chapter is a compilation of knowledge and research in the area of safety plans as they apply to chemical safety and the specific institutions examined. The following sections present an overview of material that must be considered in order for this project to be successful. These include the organizations involved, current chemical safety plans in universities of the United States, and the laws, regulations, and agencies that pertain to all aspects of chemical use.

Information about the organizations involved provided a general basis on which to build the rest of the project. Current chemical safety plans in the United States were examined in order to extrapolate standard practices in chemical safety that were used to form the safety plan for the new science building at Chulalongkorn. The laws, regulations, and agencies that relate to chemicals and their use are considered because chemical safety plans are often based on existing mandates.

2.1 Thai Culture

One of the most influential factors in constructing a chemical safety plan for the new science building at Chulalongkorn is the uniqueness of the culture of the Thai people. Although safety practices are often standard across national boundaries, many cultural factors affect the development and implementation of a formal safety plan. Because United States safety plans served as the foundation for the team's research, the safety plan for the new science building had to be altered for appropriateness in the Thai culture.

2.1.1 Change

Because Thailand was never colonized, the Thai people are often reluctant to accept policy, including chemical safety procedures, from foreign countries. According to Dr. Bhinyo Panijpan, Chairman of the Biochemistry Department at Mahidol University, Thai people are often reluctant to change, but with persistence they will eventually comply. Dr. Bhinyo said that it is easy to copy regulations from other countries, but difficult to implement them because Thai people question the need to accept regulations from other countries. Dr. Bhinyo recommends that a suitable approach to constructing a safety plan would be providing a set of regulations as well as explanations for why the regulations are appropriate. He also believes that

Thai people are not yet ready for safety measures, but that eventually the country will adopt them.[1]

Dr. Suchata Jinachitra, Program Director for Public Welfare for the Thailand Research Fund, provided insight into how the culture of Thai people may affect the chemical safety plan for the new science building. According to Dr. Suchata, the attitude of both students and faculty is the biggest hindrance to improving chemical safety at Chulalongkorn University. She feels that teachers and students are role models for the public when it comes to safety.[2]

Dr. Yaron Yoel, founder and Managing Director of BYL Environmental Services, provided valuable information about the ways that Thai people adapt to changes. He feels that like most developing countries, Thailand is often slow to accept changes. Because of this, the team acknowledges that Chulalongkorn will require more time to implement the safety plan in the new science building than would be required in a developed country.[3]

2.1.2 Criticism

The Thai culture influences many of the key components of the safety plan including enforcement and education. Without proper enforcement, the safety plan will not succeed. Constructive criticism is a key component of enforcing a safety plan; however, in Thailand, "criticism is not only disliked, it is also regarded as destructive to the social system."[4] Criticism relating to improper laboratory practices could be considered a "disturbance of the peace."[5]

Dr. Supawan Tantayanon, professor at Chulalongkorn and project sponsor, emphasized that the Thai people do not like to offer criticism to colleagues.[6] As an option to openly criticizing fellow peers, Dr. Suchata offered alternatives to enforcing and encouraging improved safety practices in the Department of Chemistry. She feels that encouragement through year-round competitions and providing the laboratories with the title "Green Lab" would be more beneficial than constructive criticism.

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[1] Dr. Bhinyo Panijpan, February 8, 2002.
[2] Dr. Suchata Jinachitra, February 12, 2002.
[3] Dr. Yaron Yoel, February 18, 2002.
[4] Cooper, Robert and Nanthapa. *Culture Shock! A Guide to Customs and Etiquette: Thailand.* Graphic Arts Center Publishing Company, 2000.
[5] *Idem.*
[6] Dr. Supawan Tantayanon, February 5, 2002.

2.2 *Organizations*

An examination of the organizations relevant to this project, both in Thailand and the United States, is very important for providing the rationale for how these institutions affect the project as a whole. The organizations explored in this chapter each contributed resources and knowledge that formed the foundation for this project.

The primary focus of this project was the new science building at Chulalongkorn University. ExxonMobil Chemical, Pfizer, and the Petroleum Authority of Thailand provide comparisons for the implementation of safety measures in a research environment in Thailand. Finally, educational institutions in the United States are included to present evaluations based on international organizations.

2.2.1 Chulalongkorn University

In the late nineteenth century, when the world was experiencing incredible changes in the areas of economics, societal structure, and politics, Siam,[7] under the direction of King Chulalongkorn, resolved to avoid colonization by western powers. Chulalongkorn recognized that governmental strength was essential to forestalling the colonization that would eventually envelop neighboring countries like Burma, Laos, and Vietnam.

Figure 1: King Chulalongkorn[8]

One of the key policies of King Chulalongkorn's reign was the education of talented and proficient individuals who were capable of undertaking the task of providing manpower to the developing country. Chulalongkorn understood the crucial role of education as the means for achieving the lasting sovereignty of Siam. To this end, he declared, "Education in this country is the first priority, which I am determined to develop." A speech by the King reflects his thoughts and intentions for his education system: "All of our subjects, from our royal children down to the lowest commoners,

[7] Siam became Thailand in 1939
[8] "About CU," Chulalongkorn University, http://www.chula.ac.th/history/index_en.html

will have the same opportunity to study-be they royals, nobles, or commoners." Throughout his reign, Chulalongkorn was instrumental in the establishment of many schools.[9]

Figure 2: King Vajiravudh[10]

In 1899, Prince Damrong Rajanupab proposed the creation of a training school in the area of civil service. In the first twelve years of the school, the Civil Service Training School later called the Royal Pages School, educated students in various disciplines of government. The successor to King Chulalongkorn, King Vajiravudh, recognized that the school was not serving the purpose set forth by Chulalongkorn. While the school was instructing an ever-increasing number of pupils, the school focused only on civil service. Chulalongkorn intended for the school to evolve to include disciplines that would serve the purpose of preserving Thailand's strength as a country. Consequently, in 1911, Vajiravudh restructured the school into an institution of higher education and renamed the institution the Civil Service College of King Chulalongkorn. The intent of this new college was to provide instruction in the areas of law, international relations, commerce, agriculture, engineering, medicine, and teacher education.[11]

After six years as the Civil Service College, King Vajiravudh finally felt that the college was ready to truly serve the purposes of King Chulalongkorn. In 1917, the Civil Service College was renamed again to bear the name of its principal visionary as well as to encompass the scope of its structure: Chulalongkorn University. Chulalongkorn University was Siam's first institution of higher learning. The University began with four faculties: Medicine, Public Administration, Engineering, and Arts and Sciences. Following King Chulalongkorn's design, the University evolved throughout the twentieth century and continues to develop and grow to this day.

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[9] *Idem.*
[10] *Idem.*
[11] *Idem.*

Today, the existence Chulalongkorn University (CU) is a testament to the vision of King Chulalongkorn. The University currently has a student body of approximately 18,000 undergraduates and 9,000 graduate students, totaling over 27,000 students. The academic staff of the university totals nearly 3,000, teaching over 11,000 courses in almost 350 majors. Chulalongkorn has four main areas of study: health sciences, science and technology, social sciences, and humanities. It is the practice of Chulalongkorn University to emphasize both research and instruction. In addition, CU believes that knowledge "transcends national boundaries." For this reason, CU has developed a strong international curriculum, and relationships with many universities around the world.[12]

2.2.1.1 Faculty of Science

The Faculty of Science was one of the original faculties of Chulalongkorn University. The Faculty was originally intended to provide prerequisite courses in the basic sciences for medical and engineering students. From that simple beginning, there are now fourteen areas of study within the field of science at Chulalongkorn. The Faculty consists of 400 instructors and student enrollment in the department consists of more than 2,800 students.[13]

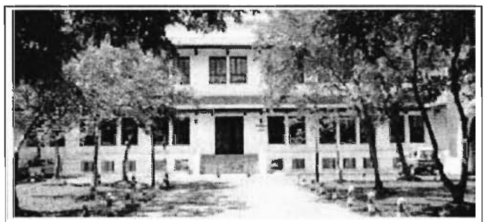

Figure 3: The Faculty of Science Building

Of particular relevance to this project is the Department of Chemistry. The Department at Chulalongkorn is one of the oldest at the University. Currently, the Department has nearly 80 faculty members and offers four areas of concentration: Analytical, Physical, Organic, and Inorganic Chemistry.[14] The Department actively conducts research in a wide range of topics within these areas including Analytical and Environmental Chemistry, Computational Chemistry, Coordination Compounds, Chromatography, Natural Products, Organic Synthesis, Petrochemistry, Spectroscopy, Supramolecular Chemistry, and the Chemistry of Zeolites.

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[12] *Idem.*
[13] *Idem.*
[14] "Department of Chemistry," Chulalongkorn University, http://chula.ac.th/about/index_en.html.

2.2.1.2 The New Science Building

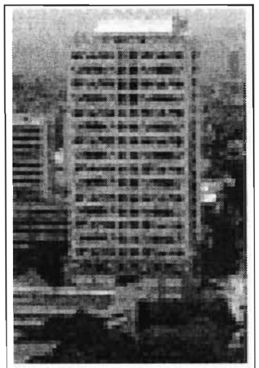

Figure 4: The New Science Building at Chulalongkorn University

Chulalongkorn recently completed construction of its new science building. The building consists of twenty floors and houses four departments: Biology, Physics, Chemistry, and Chemical Technology. The separation between the new science building and the old chemistry building, where chemical storage will be located, is approximately one half of a kilometer.[15] With construction on the new building complete, the departments have already begun moving resources into the building; once the building becomes regularly used, the University expects between 2,000 to 3,000 people in the building on weekdays and roughly 300 people during the weekend. The building is equipped with various safety measures such as drench showers, eyewash stations, fire hose and extinguisher stations, emergency lighting, and multiple escape routes. The working area in each floor is 1,800 square meters, with the division of floors indicated in Table 1. This project will focus primarily on floors seven through fifteen as well as floor eighteen.

Floor	Purpose or Designation
1-3	Six large lecture halls (accommodate 300 students each) Six medium lecture room (c each)
4	Department of Biology
5-6	Service Laboratories of Physics
7-9	Service Laboratories of Chemistry
10-15	Department of Chemistry
16	A research group on food testing and trace analysis
17	A graduate program of Environmental Science and Biotechnology
18	Department of Chemical Technology
19	Department of Physics
20 (Roof)	Rainwater collection facility

Table 1: Division of Floors in the New Science Building

Due to the nature of work conducted in the new building, a significant safety risk exists. The presence of dangerous chemicals introduces a direct hazard to the inhabitants of the building. In addition to potentially hazardous research, the general structure of the building lends itself to a variety of problems that the Faculty of Science needs to address; these problems range from logistical issues such as the storage of hazardous materials to more significant problems such as the identification of emergency escape routes.

Safety and environmental concerns were taken into account when designing the new science building. All the lab fume hoods are safely ventilated by having two separate systems, one for organic labs, and one for inorganic labs. The wastewater streams exiting the building will have two separate water treatment systems: one for sewage and the other for chemical treatment. The laboratories will also have electric heaters instead of Bunsen burners. Overall, many of the professors would like to use the move into the new science building as a step to improve the safety and chemical disposal plans at Chulalongkorn.

The new science building is the catalyst for chemical safety initiatives in the Department of Chemistry. With an appropriate implementation of safety policies in the new science building that addresses the needs and concerns of the Department of Chemistry, Chulalongkorn can manage the hazards and the new science building can continue to serve the students of Chulalongkorn in the manner that the King envisioned over a century ago.

2.2.2 Research Institutions in Thailand

In order to understand safety in a cultural environment similar to that of Chulalongkorn, it was necessary to examine the practices of other Thai institutions. The Thai culture lends itself to differences with regard to safety practices as compared to those in the United States. Because this project endeavored to develop a plan that addresses safety in the new science building as well as fits the setting of Chulalongkorn, the Thai institutions provided valuable insight into Thai culture that was used to properly address the social needs of Chulalongkorn.

2.2.2.1 ExxonMobil Chemical

ExxonMobil Chemical is one of the largest worldwide petrochemical companies. This subsidiary of ExxonMobil Corporation is responsible for all worldwide chemical businesses. ExxonMobil Chemical produces such products as olefins, aromatics, fluids, synthetic rubber, polyethylene, oriented polypropylene packaging films, plasticizers, synthetic lubricant basestocks, additives for fuels and

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[15] Dr. Supawan Tantayanon, October 5, 2001.

lubricants, zeolites catalysts, agricultural chemicals, plastics, solvents, elastomers, and other petrochemical products.[16] Among the top three petrochemical companies in the world, ExxonMobil Chemical has manufacturing companies in more than twenty countries and has product markets in more than 150 countries. This division employs about 17,000 people worldwide. The world headquarters is located in the United States in Darien, Connecticut.[17]

2.2.2.2 Petroleum Authority of Thailand

Figure 5: Valve Opening Ceremony at the Petroleum Authority of Thailand

The Petroleum Authority of Thailand (PTT) was established in 1973 by order of His Majesty King Bhumibol Adulyadej to procure, explore, develop, and produce petroleum. Since its beginning, the PTT has been restructured to include subsidiaries, such as the PTT Research and Technology Institute, in an effort to strengthen the energy stability of Thailand as well as reduce the dependencies on petroleum imports. Beyond exploration and production, today the PTT is a national enterprise involved in refining, distribution, and development of petroleum related industries with offices throughout Thailand.[18]

2.3 Laws and Regulations

The laws and regulations that govern the use of chemicals are an important aspect of this project. A significant portion of a chemical safety plan is grounded in the laws and regulations of the state and country where the plan is instituted. Without basic knowledge of these laws, the safety plan for the new science building could be in violation of international standards.

2.3.1 Regulations in Thailand

While regulations exist in Thailand regarding chemicals, these are not applicable to universities because most universities do not deal with large enough

[16] Multiple Choices: Careers at Exxon. 1990.
[17] ExxonMobil Chemical, http://www.exxonchemical.com.
[18] Petroleum Authority of Thailand, http://www.pttplc.com/ptt/corp/html/fact_2000.pdf

quantities of chemicals. Although the laws do not affect academia, it would be beneficial to Chulalongkorn to adhere to government regulations. Because the proposed safety plan may serve as an example to other universities in Thailand, an initiative based on existing laws in Thailand could serve to improve the observance of these laws by other institutions.

2.3.1.1 Environmental Regulations

The Enhancement and Conservation of the National Environmental Quality Act (ECNEQA) B.E. 2535,[19] created in 1992, is one of the most important regulations regarding Thailand's environment.[20] This act "established Thailand's principal public sector institutions concerning the environment and pollution control as well as the principal laws governing Thailand's environment."[21] In response to the ECNEQA, the Pollution Control Department (PCD) was established on June 4, 1992.[22] One of the responsibilities of this department is to perform and oversee all aspects of the ECNEQA. This Act is comprised of the National Environment Board, the Environment Fund, Environmental Protection, Pollution Control, Promotional Measures, Civil Liability, and Penal Provisions.

The National Environmental Board wields a significant amount of power for setting environmental standards in Thailand. The many aspects of environmental regulation that the Board has control of include submitting policy and plans for the enhancement and conservation of the national environmental quality to the cabinet for approval, setting environmental quality standards, improving laws relating to the environment, submitting reports on the national environmental quality to the cabinet at least once a year, and also approving emission standards.

The Environmental Fund is under the control of the Ministry of Finance. Some of the duties of the Environmental Fund include implementing rules and procedures for allowing loans from the Fund, deciding which activities the money of the Fund should be used for, and making rules for the managers of the Fund. The money in this Fund consists of capital from the Fuel Oil Fund, money from the

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[19] Buddhist Era (Thai Calendar; western year plus 543)
[20] Pollution Control Department, http://www.pcd.go.th/Information/.
[21] *Idem*.
[22] "About Pollution Control Department," Pollution Control Department, http://www.pcd.go.th/about.cfm#Location.

Revolving Fund for Environmental Development and Quality of Life, service fees and penalties collected by this Act, and grants from the government.

The National Environment Board also covers the area of the Act called "Environmental Protection." The Board has the power to implement many standards concerning water quality, groundwater, atmospheric ambient air, noise and vibration, and any other necessary environmental standards. Under Environmental Protection is the Environmental Quality Management Plan, which includes management of air, water, and environmental quality; pollution control from point sources; conservation of the natural environment and resources; and a plan for inspection, monitoring, and assessment of environmental quality.

The ECNEQA also instituted a Pollution Control Committee. Some of its responsibilities include producing an action plan with prevention and solutions to pollution hazards, making recommendations on ministerial regulations regarding the types and categories of hazardous waste, and coordinating all types of businesses to control pollution.

Promotional Measures offers assistance to companies that are point sources for pollution and require installation of on-site treatment facilities. This assistance entails aid for importing a specific type of equipment that is not available in the country, or permission to bring specialists from other countries into Thailand to carry out the installment procedures. Under Civil Liability, when a point source of pollution causes bodily harm to any person or damage to any property because of leakage or contamination, the owner is liable to pay compensation whether the source of contamination is the result of a willful or negligent act.

Penal Provision includes the criminal sentences and fines for breaking environmental laws. An example of a breach of these laws would be a person who occupies public land illegally and causes damage to the natural resources or produces pollution that harms the environment. According to the Penal Provisions, this person may be held in prison for no longer than five years and may be fined up to 500,000 baht[23] (roughly U.S. $11,000).[24]

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[23] Baht is the Thai unit of currency (44 baht is roughly 1 U.S. dollar).
[24] "The Enhancement and Conservation of the National Environmental Quality Act," http://www.pcd.go.th/Information/Regulations/neqa/Full_NEQA.htm

2.3.1.2 Chemical Regulations

The environmental regulations in Thailand are closely related to the chemical regulations. The Hazardous Substances Act (HSA) B.E. 2535 was established in 1992.[25] This act explains the criteria for "import, production, transportation, consumption, disposal and export not to influence and danger to human, animals, plants, properties or environment [*sic*]" of hazardous materials.[26] In Section Four of the HSA a hazardous substance can be described by any of the following properties:

- Explosive
- Flammable substance
- Oxidizing agent and peroxide
- Toxic substance
- Substance causing diseases
- Radioactive substance
- Mutant causing substance
- Corrosive substance
- Irritating substance
- Other substances which may cause injury to persons, animals, plants, property, or environments[27]

This section of the HSA also includes many other definitions. One important definition is that of a hazardous waste label. A label is a picture, logo, or any statement placed on the container of a hazardous substance. A label also includes a manual for the substance.

Another important part of the HSA is the Committee on Hazardous Substances. One power that this committee has is to advise the authority regarding the registration or revocation of a hazardous substance. This committee also informs the public about information relating to hazardous substances and can propose ideas to the Ministry of Industry regarding the control of hazardous substances, including solutions for damage caused by these substances.

There is an Information Center for Hazardous Substance under the Ministry of Industry that is a coordinating center for information on these substances. This information is available to all sectors of Thailand. In Section Eighteen of the HAS, hazardous materials are classified according to the level of control needed for them. A Type One hazardous substance must comply with specified criteria and procedures.

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[25] *Idem.*
[26] *Idem.*
[27] Laws and Regulations on Pollution Control in Thailand. October 1997

Possession of a Type Two hazardous substance signifies the need to notify the authority plus the abovementioned control measure. If a person is in possession of a Type Three hazardous substance, a permit must be obtained. A Type Four hazardous substance is strictly prohibited.

The authority has many powers and duties pertaining to the Hazardous Substances Act. The authority may determine that a producer, exporter, importer, or any person that is in possession of a hazardous substance is in violation of the Act and requires them to remedy the situation. This person has the power to enter a storage or production building housing a hazardous substance or to enter a vehicle and inspect the hazardous substance, containers, or documents related to the substance.

2.3.2 Regulations in the United States

As noted previously, existing regulations in Thailand regarding chemicals are not applicable to universities. In the United States, however, universities usually fall under the same laws as industry. Chemicals are regulated by an extensive system of laws that have been proposed by organizations such as the EPA and are set forth by Congress or state assemblies. Partial enforcement of these regulations is through regular, thorough inspection. In addition, the government holds organizations accountable for their actions. When violations occur, harsh penalties are often given to offending organizations. By examining the laws and regulations of the United States, the foundation of the chemical safety plans in the United States is made clear. These foundations are often applicable in settings outside of the United States.

2.3.2.1 Environmental Regulations

It is important to examine the regulations regarding the environment in the United States in order to compare them with the regulations in Thailand. In the United States, the Environmental Protection Agency (EPA) has been in existence for thirty years. Their mission is to "protect human health and safeguard the natural environment."[28] The National Environmental Policy Act of 1969 establishes the base for national protection of the environment. Other important legislation includes the Pollution Prevention Act, which was passed in 1990 to reduce pollution in all sectors

[28] U.S. Environmental Protection Agency, http://www.epa.gov/.

of the country through "cost-effective changes in production, operation, and raw materials use."[29]

2.3.2.2 Chemical Regulations

The EPA also deals with some chemical regulations. One of these regulations is the Toxic Substances Control Act (TSCA) of 1976. This act allows the EPA to track the 75,000 industrial chemicals either produced in or imported into the U.S. At its discretion, the EPA can ban any chemical that poses an unreasonable risk.

The TSCA regulates hazardous chemical substances and mixtures. If it is found that a chemical substance may pose a risk to human health or the environment while being manufactured, processed, distributed, or disposed of, there are sets of regulations that apply to this substance. This chemical substance may be prohibited or limited in its production. This substance may also need to be clearly marked as to its dangers and the processors will need to keep a record of the way in which the chemical is made.

There is also a section under the TSCA dealing with quality control. If there were reason to believe that the manufacturer is producing a chemical that poses unreasonable risk to humans or the environment, the company would have to submit a document on the quality control procedures used. If it were determined that the chemical has been distributed in commerce and poses a risk to humans or the environment, the manufacturer must inform the public and whoever else is necessary of the risks associated with the chemical.[30]

2.3.2.2.1 Transportation Laws

In the United States, the Resource Conservation and Recovery Act (RCRA), as mentioned previously, covers the regulations dealing with hazardous waste. The RCRA Subtitle C established the federal program to "manage hazardous wastes from cradle to grave."[31] The Subtitle C program is meant to make sure that hazardous waste is handled properly so that human health and the environment are protected.

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[29]"Major Environmental Laws," United States Environmental Protection Agency, http://www.epa.gov/region5/defs/html/ppa.htm.
[30] "USEPA: Laws and Regulations," United States Environmental Protection Agency, http://www.epa.gov/epahome/laws.htm.
[31] "Waste Programs," United States Environmental Protection Agency, http://www.epa.gov/region02/waste/csummary.htm.

Hazardous waste transporters are strictly regulated under Subtitle C. These regulations apply only when the hazardous waste is moved off-site. Under these regulations, the transporter must have an EPA identification number, follow the Manifest system, and handle hazardous waste discharges properly. The EPA ID number is not given to each individual transporter but is assigned to the transporting company as a whole.

The Hazardous Waste Manifest, which is a document that must accompany any hazardous waste shipment, is picked up with the waste by the transporter and signed. This document must always stay with the shipment and the generator of the waste must also have a copy. The transporter must bring the entire shipment to either the next transporter or designated facility. The Manifest must be signed and dated by the next recipient of the waste and the transporter must keep this document for three years after the event.

If a release of the waste occurs during transportation, the transporter is required to take immediate action to protect human health and the environment. If a serious accident occurs, the driver must call the National Response Center. These regulations also allow certain federal, state, or local officials to handle transportation accidents. Also, during the course of transportation, the waste may be held at a transfer facility for up to ten days.[32]

2.3.2.2.2 Storage Regulations

The storage regulations followed in the United States also fall under the RCRA Subtitle C program. A Treatment, Storage, Disposal Facility (TSDF) is a facility that is involved in one or more of these activities: treatment, storage, or disposal of hazardous waste. The general facility standards include keeping track of the amount and type of wastes entering the facility, training employees to safely manage hazardous waste, and preparing to avoid hazardous waste emergencies. TSDF operators are required to have an EPA ID number so that it is known what waste the facility plans on treating, storing, or disposing of. Upon receiving a shipment of waste, the TSDF operator is required to sign and date the Manifest and

[32] "Regulations Governing Hazardous Waste Transporters," United States Environmental Protection Agency, http://www.epa.gov/epaoswer/general/orientat/rom34.pdf.

must send a copy of the Manifest to the waste generator within thirty days to verify that the waste has been accepted.

There are basic management requirements pertaining to the containers in which hazardous waste is stored. These containers should be in good condition; they should not be opened unless more waste is being added; they should be inspected weekly for leaks; and containers holding liquid waste must have a secondary containment system.

Containment buildings are completely enclosed, self-supporting structures used to store or treat noncontainerized waste. The operational requirements of the containment buildings focus on maintenance and inspection of the building, record keeping, and maintaining equipment required in the event of a release of hazardous material. There are design standards that apply to the containment building, which includes structural soundness and waste leak prevention. Also, these buildings must be inspected once a week.

2.4 Hazardous Material Disposal and Transportation Companies

Because the scope of a chemical safety plan is so great, the plan often includes aspects that are beyond the abilities of the organization implementing the plan. Waste disposal and transportation of chemicals are two such areas that fall outside of the capabilities of Chulalongkorn University. These facets of chemical safety required additional outside resources in the form of waste disposal and hazardous transportation companies.

2.4.1 Waste Disposal Companies[33]

A major problem for the universities in Thailand is that there are few options regarding the chemical waste disposal. There are a small number of existing private companies that handle disposal, but these companies generally do not deal with the universities. Because the universities do not produce a volume of waste sufficient enough to warrant the efforts of these private companies, the universities are left to manage their own waste.[34] In the United States, there are very specific and highly

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[33] Hall, Stephen K. 1994. *Chemical Safety in the Laboratory.* Boca Raton: CRC Press, Inc. pp.186-187

[34] Dr.Supawan Tantayanon, November 16, 2001.

regulated ways to dispose of chemical waste. There are also sufficient companies to handle the waste produced in the country. It would be to Thailand's advantage to implement a uniform chemical waste disposal system. Such a system would allow more small organizations access to disposal companies and as a result serve to protect the environment. If a uniform system were created, an economic boost would also potentially occur.

In the U.S., most labs dispose of hazardous laboratory wastes through waste disposal companies in an off-site EPA-permitted hazardous waste landfill. It is important to use a permitted treatment and disposal facility since the sole responsibility rests on the generator of the hazardous material. Most of the disposal facilities in the U.S. accept solids, liquids, and "lab packs." A "lab pack" is a fifty-five gallon steel drum filled with waste that is Department of Transportation approved. As mentioned previously, the Uniform Hazardous Waste Manifest is used to follow waste from its origin to final destination.

As noted previously, there are only a few private waste disposal companies in Thailand. One that came into existence in November 2000 is BYL Environmental Services. BYL is using the same Manifest as the one mandated by the EPA.[35] The focus of this company is to provide a "compliant and cost effective waste management service."[36] They use the same waste collection containers as those used by other organizations around the world. This company uses cement kiln incineration technology to dispose of organic waste. This disposal method is favored around the world because of its "recycling abilities, waste destruction efficiency, lower disposal costs, and the fact that the use of this technology yields no residuals."[37]

There is also another private waste disposal company that is U.S.-based: Waste Management Siam (WMS). WMS was founded in 1998 by Waste Management International and later bought by Modern Asia Environment in 2000. Waste Management Siam serves commercial, industrial, and municipal customers in the areas of non-hazardous waste collection and transport, sanitary landfills, incineration, recycling, composting and bioremediation.[38]

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[35] BYL Environmental Services Co., Ltd, http://www.byl-environmental.com/
[36] *Idem.*
[37] *Idem.*
[38] "Waste Management Siam Ltd.," The American Chamber of Commerce in Thailand, http://www.amchamthailand.org/asp/corpDetail.asp?CorpID=389.

The most prominent industrial-waste disposal company in Thailand is the General Environmental Conservation Public Company (Genco). There are three facilities that Genco owns in Thailand and it has operated these since April 1996. These facilities handle chemical treatment for electroplating, chemical treatment for dyeing wastewater, and stabilizations and landfill of industrial solid waste. Genco also utilizes quality transportation systems such as tank trucks and dump trucks. Drivers are specially trained in personal and environmental safety. Genco as the environmental service operator conducts business in a manner which protects the environment and solves environmental problems to conserve Thailand's environment to achieve the sustainable developments.[39]

Unfortunately, Genco has a monopoly over the Thai industrial-waste disposal industry. According to a report in the Far Eastern Economic Review dated July 5, 2001, the government owns twenty-five percent of the company and it holds the prices high while limiting services. The report also states that Genco can only handle about twenty percent of Thailand's waste disposal needs, but right now it is only managing about half of that. In addition to problems with efficiency, Genco's landfills have reached capacity and they have no plan to correct this issue. Beyond not being able to handle the country's waste needs, Genco's pricing policy makes it difficult for companies to utilize its services. For example in January 2001, Genco increased the cost of standard hazardous waste disposal by 200% and highly toxic waste by 400%. Because of an economic collapse in the mid-1990s, many companies cut expensive proper waste disposal from their budgets.[40]

2.4.2 Chemical Transportation Companies

At Chulalongkorn University, there is the necessity for proper methods of transportation of chemical waste because the Department of Chemistry will be transporting their waste from the new chemistry building to Chemistry Building 1. Hazardous and chemical waste transportation such as what will be required by Chulalongkorn is a highly regulated activity in the United States. The way in which materials are transported across a campus is supervised closely to ensure the safety of

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[39] "Genco," General Environmental Conversation Public Company Limited, http://www.genco.co.th/
[40] "Thailand: Time to Come Clean," Far Eastern Economic Review, http://www.feer.com/2001/0107_05/p031region.html

the community at the institution. Chulalongkorn will need to have staff trained in this area along with having the necessary safety equipment in the vehicle that will be transporting the chemical wastes.

2.5 Case Studies of Safety Plans

In order to propose an effective safety plan, it was beneficial to consider existing plans already in place in comparable environments. In addition, the safety plan often must adhere to laws and regulations mandated by the country government as well as state authorities. By utilizing past research in the area of safety plans, the team was able to determine what a safety plan encompasses as well as to apply valuable past experiences from other institutes.

In the United States, where laws and regulations regarding safety are often strict, universities have adopted a set of measures that govern practices and procedures relating to safety. In particular, universities focusing on chemical research often have in-depth safety plans that deal specifically with all aspects of chemical safety. This section provides a detailed examination of the safety plan currently in use at Worcester Polytechnic Institute (WPI) in Worcester, Massachusetts. In addition, synopses of safety plans at the Massachusetts Institute of Technology, the University of Massachusetts at Amherst, and Michigan State University are presented to provide comparisons between WPI's safety initiatives and those of universities of different sizes, focuses, and under different state jurisdiction. The institutes outlined in this section are leading universities in the United States that have each adopted safety plans regarding chemical safety.

2.5.1 Definition of a Safety Plan

Based on information from Dave Messier, Environmental and Occupation Safety Manager at Worcester Polytechnic Institute,[41] the team constructed the following definition of a safety plan:

> A safety plan is a comprehensive plan for a building or department, the purpose of which is to protect both the occupants of the building and the environment in which it exists. It consists of a description of the building, its occupants, a floor plan and includes specific information about the potential hazards within the building as well as specific plans to manage these hazards.

[41] E-mail from Dave Messier; Environmental and Occupational Safety Manager: WPI, November 17, 2001

It also includes emergency response planning, training to avoid accidents, and guidelines for reporting accidents.

2.5.2 Chulalongkorn University

As with all universities in Thailand, Chulalongkorn does not have existing internal policies to govern its activities with regard to chemical safety. The government of Thailand does not actively enforce regulations dealing with chemicals and chemical safety for universities. Universities often are not subject to regulations because they do not deal with large enough quantities of hazardous materials to fall under government restrictions. Despite the lack of governmental involvement and exemption from some existing laws, the staff of Chulalongkorn University wishes to improve on the University's practices regarding chemicals. The safety plan that this project develops will serve as an example for other institutions in Thailand that wish to initiate modern safety practices.[42]

2.5.3 Worcester Polytechnic Institute

Worcester Polytechnic Institute (WPI) was founded in 1865 as a pioneer in technological higher education. Almost from its inception, WPI developed an influential curriculum that balanced theory and practice. In 1970, WPI formalized this philosophy in the form of the WPI Plan, an innovative outcomes-oriented undergraduate program. Currently, there are approximately 2,800 undergraduate and 1,000 graduate students with over 300 faculty members in 44 majors covering sciences, engineering, liberal arts, and management. Today, as a leader in globalizing technological education, WPI operates a network of project centers spanning the globe enabling students to interact with worldwide societies. The main goal of WPI's global initiative is to relate technology and society on a global scale, thus molding engineers and scientists for the future.[43]

Worcester Polytechnic Institute, like most institutions of higher learning, is dedicated to the safety of its students, and is in tune with the need to protect the environment. For this reason, WPI has put in place an extensive set of compartmentalized policies and practices to protect the students and faculty, as well as the environment. The Environmental and Occupational Safety Office (EOSO) is

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[42] Dr. Supawan Tantayanon, November 16, 2001

[43] Worcester Polytechnic Institute, http://www.wpi.edu.

the administrative body on campus that regulates three main areas of potential risk: Occupational Safety, Environmental Safety, and Laboratory Safety. The focus of this report will be on Lab and Occupational Safety, since the relevant aspects of Environmental Safety, such as waste management, are included in Lab Safety. WPI categorizes its Lab Safety Plan into these main components:[44]

- Hazardous Waste Management Plan
- Chemical Hygiene Plan
- Hazardous Waste Management: Best Practices in the Lab
- Written Hazard Communications Program
- Exposure Control Plan for Occupational Exposure to Bloodborne Pathogens: Lab Safety Rules
- Medical Exposure Guidelines
- Protecting Yourself from Bloodborne Pathogens

2.5.3.1 Waste Management

One of the best-documented parts of the WPI Lab Safety plan is the section on waste management. Waste refers to chemical material that is unusable or unwanted by the individual controlling the material.[45] Furthermore, if the waste material is capable of harming humans or the environment, it is classified as hazardous waste. In order to ascertain if a material is hazardous, one may ask the following questions:

- Is the material included in the definition of solid or hazardous waste?
- Is the material subject to regulation?
- Is the waste listed as a hazardous waste in the EPA Tables?
- Does the waste exhibit one or more hazardous characteristics – ignitable, corrosive, reactive, or toxic?
- Is the material a Commonwealth-regulated waste?

Once waste is deemed hazardous, it falls under the regulation of the United States Environmental Protection Agency (EPA), as well as appropriate state regulation. In the case of WPI, this agency is the Massachusetts Department of Environmental Protection (MADEP). Very stringent regulations determine the handling of hazardous materials. Because the MADEP and EPA may have different regulations concerning hazardous waste, WPI adheres to whichever is stricter for the given scenario. In general, Massachusetts' state regulations are stricter than federal regulations regarding hazardous waste.

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[44] "Laboratory Safety," Worcester Polytechnic Institute, http://www.wpi.edu/Admin/Safety/Laboratory/.
[45] Hazardous Waste Management Plan: Worcester Polytechnic Institute; p. 5 Last Updated: December, 2000

Any person or institution that creates hazardous waste is termed a "generator". The MADEP defines WPI as a Small Quantity Generator (SQG); SQGs can only store less than 1,000 kilograms of non-acutely hazardous waste and one kilogram of acutely hazardous waste in one month. Once waste is created, its storage is closely regulated. In the interest of minimizing handling and transportation, hazardous waste can be stored in an area close to the point of creation, known as a Satellite Accumulation Area (SAA). There is an entire set of regulations for the SAA. These regulations focus on the amount that can be stored, for how long, and in what type of container. All containers must be clearly labeled and an individual must be responsible for the area. All satellite accumulation areas must be on record with the university, and the MADEP requires weekly checks. Once a container is full, it must be moved to a Main Accumulation Area (MAA) within three days. The MAA that WPI has chosen is Room 114 in Goddard Hall. This room is equipped with explosion proof lighting and ventilation to minimize the risk in holding large volumes of hazardous waste. The entrance to the MAA is located on the outside of Goddard Hall which makes it easier to remove the hazardous waste. Once a waste container is moved to the MAA, it may not stay there for more than 180 days from its date of arrival. The MAA, according to MADEP policy, must be inspected weekly. The safety officer, Dave Messier at WPI, is usually assigned to inspect the MAA. Dave Messier has created a checklist for the inspection; the results of the inspection are recorded and kept on file for three years.

An important aspect of hazardous waste management relates to the containers that hold the waste. Each container must be cleaned and prepared for the type of waste it will hold, consistent with US Department of Transportation (DOT) regulations. WPI uses two varieties of containers in its waste management: reconditioned and reusable originals. Any container that is being reused must be thoroughly cleaned and triple-rinsed. If the container previously held or may have held hazardous waste, all the cleaner and the water used to rinse the container are then considered hazardous waste. The final step in packaging waste is proper labeling. Any hazardous waste that is stored in an SAA must have a label that contains the following information:

- The words "Hazardous Waste"
- The chemical name in words (i.e. acetone, peroxide)
- The components and their percentages

- The hazard associated with the chemical mixture (i.e. ignitable, toxic)
- The date when the container was filled

If a material is held in the MAA, the label must include the above information, as well as the date the container arrived in the MAA. The DOT provides another label for waste that is prepared for transportation off-site.

Aside from the strict regulations detailed above, WPI has adopted a plan to minimize hazardous waste, in an effort to minimize damage to the environment, control liability, and reduce costs. The basic methods of waste minimization are chemical redistribution, purchasing control, laboratory inventory control, recycling, and micro-scale experiments.[46]

2.5.3.2 Transport of Hazardous Materials

The transport of hazardous waste both within the WPI campus and off of the campus is closely regulated. Once a container is full or reaching capacity, the person responsible must notify the EOSO so that the container can be moved to the MAA within three days, as required by the MASDEP. After that initial transport, the EOSO is solely responsible for any and all hazardous waste transportation. During the weekly inspection of the MAA, the EOSO staff must evaluate the amount of waste and the containers stored in the MAA. If the following conditions are met, the EOSO must arrange for a waste pick-up with the appropriate authorities:[47]

- When there are a sufficient number of containers in the MAA for economic disposal of the waste
- Containers are approaching the 180 day storage limit described earlier
- The MAA is approaching the accumulation limits for a Small Quantity Generator
- The MAA room is approaching capacity

The Environmental and Occupational Safety Manager (EOSM) determines if waste must be removed from the MAA, and must select a licensed Disposal Transporter. WPI is responsible for selecting a suitable organization to dispose of the waste it produces, so for this reason WPI retains records of all Licensed Transporters and Disposal Facilities in the EOSO.

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[46] Hazardous Waste Management Plan: Worcester Polytechnic Institute; p.23. Last Updated: December, 2000

[47] *Ibid*; p. 21

In order to limit liability, WPI keeps all required records of any and all hazardous material generation, storage, and transport. As stated previously, the MADEP requires weekly inspections of all satellite accumulation areas and the main accumulation area. MADEP mandates that proof must be available that WPI complies with the standards set forth. Any time a hazardous material is taken from the University, WPI must document its pick-up, as well as its safe arrival at its final destination. The document that is ultimately the record of hazardous materials taken off the campus is the Hazardous Waste Manifest, and the only WPI representative authorized to sign this paper is the Director of Physical Plant, currently Mr. John E. Miller. Once the Manifest is signed, WPI must mail a copy by certified mail to the state agencies of both the generator and the disposal facility, and the disposal facility must mail a copy to their own state agency, as well as the generator state agency. Of course, copies are kept by each party involved, and must be kept on file for at least three years. If the disposal facility does not mail its copy of the Manifest to the appropriate agencies within forty-five days of pick-up by the transporter, thus signifying its receipt of the material, WPI must fill out an Exception Report with the MADEP, and investigate the discrepancy.

2.5.3.3 Training in Hazardous Waste Management

In the interest of safety and in order to reduce the likelihood of an incident related to hazardous waste, WPI trains all faculty and students that may come in contact with hazardous materials as necessary. The U.S. Resource Conservation and Recovery Act (RCRA) is an important part of hazardous waste management that dictates many of the regulations previously discussed. The EOSM is required to receive RCRA training, as well as an annual refresher. All EOSO staff with waste management responsibilities must complete DOT training that includes emergency response procedures, as well as procedures for inspecting, repairing, and replacing facility emergency and monitoring equipment, and shutdown of operations. WPI keeps records of training for a minimum of three years after an employee leaves a position requiring waste handling.

2.5.3.4 Chemical Hygiene Plan

In order to protect laboratory workers while in the lab, WPI has implemented the Chemical Hygiene Plan (CHP). The principal focus of the WPI Chemical

Hygiene Plan is to protect laboratory workers from health hazards associated with hazardous chemicals and keeping exposures below the Permissible Exposure Level (PEL).[48] WPI issued its first Chemical Hygiene Plan in 1992, which has been revised four times since, most recently in May of 2000. It is meant to be a working document that can be updated as better procedures and practices are found. The CHP is a generic plan that applies to all WPI laboratories. The lab supervisor must supply any specific safety information pertaining to his or her experiments. The CHP consists of these elements:

- Standard Operating Procedures
- Criteria to Determine and Implement Control Measures to Reduce Exposure to Hazardous Chemicals
- Measures to Assure Proper Function of Fume Hoods and Other Engineering Controls
- Laboratory Worker Information and Training
- Laboratory Operations or Operations That Require Prior Approval
- Exposure Assessments, Medical Consultations, and Examinations
- Designation of Responsible WPI Personnel, Including the Chemical Hygiene Officer
- Procedures for Carcinogens, Reproductive Toxins, Substances That Have A High Degree of Acute Toxicity, and Chemicals of Unknown Toxicity

The most fundamental rule of chemical safety is awareness of one's surroundings. In order to be safe while in the lab, one must be aware of any and all chemical hazards, safeguards from those hazards, the limitations of those safeguards, location and use of emergency equipment, proper chemical handling and storage, and proper emergency response, among others. There are four ways by which a chemical can affect a person: eye and skin contact, ingestion, inhalation, and injection. In order to minimize these routes of entry, a lab worker should exercise proper personal hygiene and utilize the proper Personal Protection Equipment (PPE). Personal hygiene practices include washing skin when it comes in contact with a chemical, avoiding smell-testing, avoiding the use of a mouth-pipette, washing with soap before leaving the lab, and changing clothes after leaving. There should never be any foodstuff, drinks, tobacco products, or cosmetics in the lab, as chemical vapors may be absorbed into them. Appropriate clothing should always be worn in the lab; for

[48] WPI Chemical Hygiene Plan: WPI EOSO; p.1
Last updated: May 2000

example, no torn, loose, or baggy clothing, no shorts or short skirts, and no unrestrained long hair should be allowed.

Personal Protection Equipment is an integral piece of lab safety. There are six main pieces of PPE that are recommended in the CHP: eye protection, face shields, gloves, respirators, lab coats, and aprons. No person should enter the lab without proper eye protection. The minimum standard for eye protection is impact resistant lenses with side shields. Goggles provide the best eye protection as they fit tightly to the face, thus preventing foreign materials from entering the eye. Some laboratory work requires specialized eye protection and the laboratory supervisor must determine what type of eye protection is called for in certain situations. Face shields used in conjunction with eye protection provide optimum protection of the eyes, face, and neck from chemical splashes and objects thrown at high velocity. Gloves should be chosen to provide optimum protection from any corrosive or toxic materials or processes that may be encountered during an experiment. In the case of harmful vapors being present in the lab, appropriate respiratory equipment should be provided. Lab coats provide protection for one's clothing, and some skin protection, but rubber aprons provide the best protection against splashes or spills.

As stated previously, in order to maintain a safe environment in the lab, one must always be aware of one's surroundings. Many toxic materials can take vapor form and may or may not emit an odor. If it is thought that a harmful vapor may be present in the lab, respirators must be provided until proper measurements of the vapor can be taken. If the vapor is not in sufficient concentration to be harmful, and it is not suspected that the concentration will increase, respirators may be removed.

Anyone working in the lab must also be aware of any potential dangers associated with the chemicals that are present. If a chemical is determined to be toxic, flammable, reactive, or corrosive, proper measures must be taken in order to prevent an accident or harmful spill. A chemical's toxicity is determined by state regulation or the Occupational Safety and Health Administration (OSHA) and is readily available on a Material Safety Data Sheet (MSDS). Flammability is determined by the flash point of a substance. The flash point is the lowest temperature at which a liquid gives off vapor in sufficient concentration to form an ignitable mixture with air near the surface of the liquid.[49] WPI uses this data as the reference standard for the

[49] WPI Chemical Hygiene Plan; p. 8 WPI EOSO; Last updated: May 2000

flammability of a substance. Any chemical with a flash point below 200 degrees F are considered a fire hazard. Within that characterization any chemical with a flash point between 100 and 200 degrees F is considered "combustible," and below 100 degrees F is considered "flammable." These standards are set forth by OSHA and the National Fire Protection Association (NFPA). Reactivity is also defined by OSHA and NFPA, as well as DOT and MADEP. Each organization has its own guidelines for reactive substances, but reactivity can usually be determined by the chemical MSDS. A chemical with corrosive properties can also be identified by an MSDS and is classified by OSHA, DOT, and EPA.

An important piece of lab equipment is the fume hood. The purpose of a fume hood is to provide an area that will isolate and evacuate any harmful gaseous byproducts of a chemical reaction. WPI sets the following requirements for fume hoods:

- All fume hoods must maintain an average linear face velocity of 75-100 linear feet per minute at a sash height of at least 15 inches
- All fume hoods should be ducted and should have the fan located on the roof
- All new stacks should extend at least six feet above the roof line for optimum flow efficiency
- No hood should be used for a function for which it was not designed.

The Environmental and Occupational Safety Office inspects all fume hoods on campus annually to assure that the hoods are in compliance with the above listed criteria. The certification is placed on the left side of the fume hood cabinet. If there is a problem with a fume hood, it must be taken out of use. When maintenance or repair must be done on a fume hood, the Physical Plant department must get approval from the EOSO to prevent unsafe operating conditions.

All those who work in the labs at WPI will be informed of the content and requirements of the OSHA lab standard, the content, location, and availability of the WPI CHP, necessary information on all hazardous materials in the lab which includes MSDS, PELs, and recommended exposure limits. Also, WPI lab workers will be trained in how to deal with hazardous chemicals, including handling, storage, and disposal, as well as how to respond to spills and accidents.

All lab workers must receive prior approval from their immediate supervisor before proceeding with lab work, should the following situations present themselves:

- A new lab procedure or test is about to be carried out

- It is likely that the toxic limit concentrations could be exceeded or that other harm is likely.
- There is a change in a procedure or test or the conditions under which it is to be conducted
- There is a failure of any of the equipment used in the process
- There are unexpected results
- Members of the laboratory staff become ill, suspect that they or others have been exposed, or otherwise suspect failure of any safeguards.
- Whenever a student, faculty, or staff member introduces a new hazardous material into the lab

Should someone become ill, or suspect exposure to hazardous material, a licensed physician must carry out proper medical assessment promptly. An assessment as to why the exposure occurred should be completed, and a plan to insure it does not occur again should be in place. Documentation of the details of complaints of actual or possible exposures to hazardous materials should be kept for the duration of the exposed worker's employment, plus thirty years thereafter.

While in the lab, it is the responsibility of the individual lab workers to be aware of present hazards in the lab, and to ask for information if they are unsure. It is the duty of the lab supervisor to give all necessary safety instructions to those working in his or her lab, and to see that they are carried out. The lab supervisor should be familiar with the CHP, and is responsible to ask if any part is unclear. The Chemical Hygiene Officer (CHO) is an individual qualified by training and experience to provide technical guidance in the development and implementation of the CHP.[50] At WPI the CHO is the Environmental and Occupational Safety Manager, David Messier.

The final portion of the WPI CHP involves procedures for substances that are deemed particularly hazardous. If a chemical is defined as a carcinogen, reproductive toxin, a substance with a high degree of acute toxicity, or a chemical of unknown toxicity, it can be classified as 'particularly hazardous.' Carcinogens are defined by OSHA and on applicable MSDS. Reproductive toxins are also so defined on the MSDS. A substance of high acute toxicity is measured by lethal dose data, is found on the MSDS, and is defined as "highly toxic" by the American National Standards Institute (ANSI). Should one of the aforementioned substances be used in the lab, all workers must use the lowest possible amount in the experiment, store them in a

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[50] WPI Chemical Hygiene Plan, p. 16

designated area, decontaminate the area when work is completed, and dispose of any waste properly.

2.5.4 Massachusetts Institute of Technology

Dedicated to producing, propagating, and preserving knowledge, the Massachusetts Institute of Technology (MIT) admitted its first students in 1865, four years after the approval of its founding charter. Specifically, MIT works to apply knowledge to problems that face the world. Like Worcester Polytechnic Institute, MIT attempts to provide its students with an education that combines study and discovery. The Institute has more than 900 faculty and nearly 10,000 undergraduate and graduate students. MIT offers 27 degrees in the schools of architecture and planning; engineering; humanities, arts, and social sciences; management; and science.[51]

Like WPI, MIT is also dedicated to the safety of its staff and students as well as to preserving the environment. Their safety office or Environmental Management Office (EMO) is set up much differently from WPI's. Included on their environmental safety webpage are only brief descriptions dealing with the many aspects of safety in a lab environment. The Safety Office website also includes brief information of special fire safety concerns dealing with disabled people. Each department is required to devise its own chemical safety plan, unlike WPI, which has a general plan for all labs. MIT's Industrial Hygiene Office's mission statement is to protect the community of the institution by controlling the hazards that result from chemical use.

2.5.4.1 Chemical Research Safety Notes[52]

The Chemistry Department's Chemical Hygiene and Safety Committee periodically updates notes on chemical safety to provide the most up to date information for the MIT community. The Chemical Research Safety Notes cover a wide range of topics. The most relevant notes are outlined in this section.

The first chemical safety note deals with the use of a Material Safety Data Sheets (MSDS). This states that a MSDS comes with every chemical ordered and it is

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[51] "About MIT," Massachusetts Institute of Technology; http://web.mit.edu/about-mit.html.
[52] "Department of Chemistry," Massachusetts Institute of Technology; http://web.mit.edu/chemistry/www/safety/issues.html.

essential for the lab worker to know how to interpret one. MSDS on a variety of chemicals can be obtained from the Safety Office.

The second safety note deals with laboratory fume hood usage. The general regulations on the operation of a fume hood are the same for both MIT and WPI. One general rule to follow while working in the hood includes never putting your head inside of the hood. Another rule is that the lab worker should always work with the sash in the lowest position comfortable for them because this will act as a barrier between the person and the chemicals. The hood should also be kept clean and uncluttered. Only the chemicals that are being used should be in the hood in case of an accident. The grill in the bottom slot of the hood should be cleaned regularly so that it does not become clogged. At MIT if there are problems with a hood, the lab supervisor is to contact the Industrial Hygiene Office (IHO).

Lab safety note number three involves information on respiratory protection. The IHO has a respiratory program that should be used during chemical spill cleanups or when a chemical is used that will not be contained by a hood. As required by law, a medical examination must first be performed on the person requesting a respirator. Next a review of the experimental procedures causing the exposure must occur. Lastly, the selection of a properly sized respirator and the required cartridge (for purifying the air) must take place along with obtaining the use and care instructions.

The fifth laboratory safety note, like the first, covers the fact that the lab workers should be familiar with the chemicals that they are working with. MIT has created a room dedicated to this purpose named the Library of Laboratory Safety. In this room, staff and students can find MSDS for chemicals along with useful reference books.

The sixth laboratory safety note deals with eye protection in the lab. All people entering chemistry labs at MIT must wear eye protection even if they are not working with chemicals. Most of this section contains the same information regarding eye protection as WPI. Under MIT's policy, prescription safety glasses must be provided free of charge to any person working in a lab that requires eye correction. Contact lenses are not to be worn in a chemistry laboratory at any time.

The seventh note addresses disposing of excess and waste chemicals generated in the laboratory. When a person is preparing for an experiment he or she should consider how the chemical waste would be disposed of afterwards. It is extremely expensive to dispose of excess waste, so MIT advises that the smallest possible quantities of a chemical should be ordered. The lab worker is responsible for determining if the excess chemicals require special handling procedures. The MIT Safety Office will pick up chemical waste when it is ready in a break-resistant container. The container must have a special label (red tag), which can be obtained from the EMO.

The eighth lab safety note deals with the storage of extremely hazardous substances. The guidelines for this can be found in the Department of Chemistry's Hygiene Plan.

Laboratory safety note number nine covers emergency procedures. In the case of an accidental release of hazardous substances there is a specific set of procedures that MIT requires the lab worker to carry out. First, the person should notify other personnel about the accident. The most important step to accomplish is to take care of any injured or contaminated individuals in the area. Next, the person should attempt to limit and confine the spill if it would not cause additional risk. It is MIT's policy that the person that caused the spill is responsible for getting it cleaned up.

2.5.4.2 Hazardous Waste Accumulation, Storage, and Pickup[53]

Waste must be stored in the Satellite Accumulation Area (SAA) for safety and environmental reasons. Like WPI, these waste containers must be removed from the SAA within three days of it being full. If the container is not full and is properly labeled, it must stay in the SAA.

If the waste is stored in a container that is a gallon or larger, it must be a break-resistant container. If the chemical waste is stored in a breakable container, it must have approved secondary containment. As at WPI, the containers must be closed at all times except when waste is being added or removed. Funnels are not allowed to stay in waste containers after filling. The labels that must be put onto waste containers as soon as waste is added are very similar to the ones used at WPI. One difference is that there does not have to be an estimated percentage of each chemical in the container on the labels at MIT. The labels at MIT are not stickers like at WPI but are red tags that are tied onto the waste container. Unlike at WPI, MIT's regulations only allow storage of full waste containers for ninety days in a 90-day Hazardous Waste Storage Area.

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[53] "MIT Safety Office," Massachusetts Institute of Technology, http://web.mit.edu/safety/env/.

At MIT, when waste containers are full and properly labeled, an online form must be filled out. The form must have the following information:

- The name of creator
- Location of hazardous waste
- Phone number (office and/or lab) of the creator
- Amount ready for pickup (number and size of bottles)

The Environmental Management Office is responsible for collecting the chemical wastes at MIT.

2.5.4.3 Waste Reduction Guidelines[54]

MIT is committed to improving the environment through minimizing its chemical wastes. The suggestions that MIT makes to its staff and students include ordering only the amount of the chemical needed for that experiment no matter what, to only use the amount of the chemical that is needed for conclusive results, and to avoid storing excess chemicals just because someone may want to use them in the future. Another suggestion is that a lab worker should not throw out an unwanted chemical before checking with other personnel in the department to see if they want it. The last two suggestions are that once a research project is over, the chemicals that are to be kept should be properly labeled, and that items to be disposed of should be identified, properly labeled, and containerized.

2.5.4.4 Sink Disposal and Wastewater

The wastewater from all buildings at MIT enters the public sanitary sewerage system and then it goes to the treatment facility on Deer Island in Boston Harbor. All members of the MIT community are responsible for maintaining acceptable quality in the wastewater discharges. At MIT, only water, soaps, and detergents are allowed down the drains. Hazardous waste of any type or concentration may not be poured down the drain.

2.5.5 University of Massachusetts at Amherst

Founded as the Massachusetts Agricultural College in 1867, the University of Massachusetts at Amherst (UMass) has grown to become one of the best public

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[54] "Waste Reduction Guidelines," Massachusetts Institute of Technology, http://web.mit.edu/safety/env/reduction.html.

universities in the country, dedicated to making education more accessible to everyone.[55] UMass is comprised of 18,000 undergraduates and 5,000 graduate students with more than 1,000 faculty members. In the ten undergraduate schools and one graduate school, UMass offers more than 200 degree programs spanning an extensive range of fields.[56]

The University of Massachusetts at Amherst, in the interest of protecting its faculty and students, has formed a body named Environmental Health and Safety (EH&S). The purpose of the EH&S is to review any operation that can pollute the air, water, and environment, and recommend ways to maintain a clean and healthy environment.[57] In an effort to reach this goal, the EH&S published the Laboratory Health and Safety Manual (LHSM). This document was written and approved by the Chemical Hazards Use Committee and the EH&S staff.[58] The LHSM consists of the following chapters:

- Laboratory Health and Safety Plan
- Laboratory Practices and Equipment
- Personal Protective Equipment
- Ventilation
- Emergencies and Accidents
- Exposure Monitoring and Medical Treatment
- Training and Information
- Recordkeeping
- Handling and Disposal of Chemicals
- Biological Safety
- Radiation Safety
- UMass Policies and Procedures
- Individual Laboratory Health and Safety Plan

There are also many appendices that contain useful information about chemicals, as well as many of the forms one might need when working in the lab. UMass incorporates such appendices as well as a Glossary, while WPI does not.

The first issue that the LHSM addresses is that of the responsibility of those involved with laboratory hazards. It is the duty of the EH&S to oversee the general safety of the campus, including guidance, instruction, and coordination of resources

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[55] University of Massachusetts at Amherst, http://www.umass.edu/umhome/slideshow/history.html
[56] University of Massachusetts at Amherst, http://www.umass.edu/umhome/about.html
[57] "Environmental Health and Safety," University of Massachusetts at Amherst, http://www.umass.edu/safety/

for the many departments. The responsibility of implementing the policy that the EH&S creates belongs to the individual department heads. The faculty at UMass has a fairly large responsibility; it is up to them to provide specific information to the students and employees in the lab. This includes developing written procedures specific to their lab, communicating hazards to the students and employees, training, supervising, reporting accidents, and maintaining lab equipment. Finally, it is up to the students and employees to follow all regulations set forth by the faculty and EH&S, as well as to promptly report any hazards or unsafe conditions to the appropriate authority.

As in the safety plans discussed previously, the UMass safety plan begins with a set of general procedures that are almost identical to the other universities. The most general principals in safety refer to awareness of one's surroundings, and common sense safety measures, for example, no food or drink in the lab. The next section of the LHSM discusses important laboratory equipment, such as: drench showers, eye and face washes, fire extinguishers, first aid kits, door postings and other signs, mechanical pipetting aids, sharps containers and glass only boxes, laboratory vision panel, floor drains and sink traps, as well as the placement of safety equipment. There are some policies that UMass has adopted that other universities have not; for example, first aid kits are recommended in the labs. Also there must be three feet in each direction under the drench shower that can never be obstructed, in order to remove stagnant water from the eye wash plumbing, the wash must be run for three minutes every week, first aid kits must contain gloves, gauze, bandages, and ice packs, and may not contain any type of cream or ointments; These are some of the regulations that UMass imposes on the equipment found in the lab. There must be appropriate signs alerting students and faculty, as well as potential emergency response personnel, to any hazards that may be encountered in the lab. An interesting mandate that is not written in any other safety plan is the requirement for a one-square-foot window in the door to the lab, so that dangerous situations can be observed from outside. In any new facilities, the above listed equipment is to be located near the main door to the lab, as well as any emergency shut-offs.

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[58] "Laboratory Health and Safety Manual," University of Massachusetts at Amherst, http://www.umass.edu/safety/lhs.html

UMass recognizes the importance of Personal Protection Equipment, and recommends all of the same measures be taken to stop hazardous material from coming in contact with humans or the lab environment, i.e. goggles. Also ventilation systems, such as fume hoods are described in the same detail as the other safety plans. However UMass does mention some specialized safety equipment, for example glove boxes, perchloric acid hoods, gas cabinets, biological safety cabinets, and vacuum systems, which serve to isolate different types of hazardous material from the lab environment.

There is no outstanding part of the emergency response section, or the medical examination section; both are almost identical to similar sections in other safety plans, and so are not worth discussing.

Training, as has been stated before, is an integral piece of safety in the lab. As a result, UMass requires that its employees and students undergo some basic measure of safety training before working in the lab. UMass offers a class called Laboratory Safety Seminar. Basic lab safety includes most of the topics covered in the Laboratory Health and Safety Manual, including basic toxicology, general information on hazards present in the lab, and proper use of lab equipment. Fire safety training will include fire hazards, how to prevent them, what to do in case of a fire, and the many fire protection systems available. Faculty members will also receive some hazardous waste training and other supplemental training.

The section of the LHSM on chemical handling and storage is a very large and important section. UMass covers all of the important aspects of chemical storage, labeling. Essentially, there are very few differences in the rules and regulations concerning chemical safety between UMass and the other universities that have been examined. In this section specific guidelines are set forth for how to dispose of the many types of hazardous waste, for example, flammable, corrosive, etc. A very unique piece of the LHSM is its section on controlled substances, for example pesticides, drugs, and hypodermic needles, which is section 9-2.

One area that has not been previously explored in this report is that of biological safety. The U.S. Department of Health and Human Services determines the regulations concerning biological safety. Any research that will involve animal tissue or pathogens must be cleared with the department head and EH&S. All blood, tissue, or body fluids are considered infectious as a general precaution. Any animals that are used in research must be approved by the Institutional Animal Care and Use

Committee (IACUC). When an animal carcass is to be disposed of, it is incinerated, and its bedding, if not thought to be hazardous, is disposed of in ordinary garbage removal. There are also special provisions for recombinant DNA creation and handling. Biohazard waste must be disinfected by autoclaving. Once the waste product has been disinfected, it may be disposed of through the sewer system, or placed in unmarked plastic bags and disposed of with regular trash.

One of the final sections of the UMass LHSM is on an individual Laboratory Health and Safety Plan. The aim of this section is to help those persons running a lab to formulate their own safety plan. It should include any special training needed to handle chemicals or equipment in the lab, as well as any forms or protocols that have been developed to help lab procedures run smoothly.

2.5.6 Michigan State University

Michigan State University (MSU), founded in 1855, was the nation's first land-grant university. It was a model for many institutions to follow. Today, Michigan State has grown into a comprehensive research university with nearly 4,500 faculty and academic staff, and almost 35,000 undergraduate, 8,000 graduates, and 1,500 professional students.[59] The total enrollment of nearly 45,000 students is among the largest in the country. MSU places a great emphasis on excellence in undergraduate education. The curriculum includes more than two hundred programs of undergraduate and graduate studies in fourteen degree-granting colleges and Michigan State University-Detroit College of Law. Ninety-four percent of non-medical faculty is involved in undergraduate education through teaching and research opportunities. Michigan State is a leader in scientific and technological advancement and since 1964 has been a member of the prestigious Association of American Universities, a group of sixty-one leading graduate research institutions.

In accordance with state and national law, Michigan State University is responsible for providing its employees and students with a safe work environment while in the lab. The state agency that determines the safety standards is the Michigan Occupational Safety and Health Administration (MIOSHA), with direction from the Michigan Compiled Laws and the Occupational Safety and Health

[59] Michigan State University; http://www.ur.msu.edu/fib/p1.html

Administration. Michigan State University has created the Office of Radiation, Chemical, and Biological Safety (ORCBS) to oversee all lab safety standards.

2.5.6.1 Chemical Hygiene Plan

The ORCBS first published its Chemical Hygiene Plan (CHP) in May 1995, which was revised twice: first in October 1996 and again in April 1998. The CHP is broken down into six major components: Scope, Standard Operating Procedure, Standard Lab Safe Handling/Storage Requirements, Emergency/Medical Procedures, Standard Lab Facility Requirements, and Standard Repair/Close-Out/Decontamination Procedures. The appendices of the MSU safety plan provide specific chemical information and list various forms that are commonly used in the lab.

The scope of the MSU CHP is that of a campus-wide laboratory safety document. Any lab under the jurisdiction of Michigan State University must comply with this said document. The CHP establishes the safety principles for laboratory procedures, equipment, and work practices that are capable of protecting employees from physical and health hazards of hazardous chemicals in laboratories.[60] The MSU CHP goes as far as to restate the MIOSHA definition of both physical and health hazards. A physical hazard is defined by MIOSHA as a chemical that is:

- A flammable or combustible liquid
- A compressed gas
- An organic peroxide
- An explosive
- An oxidizer
- A pyrophoric
- An unstable material (reactive)
- A water reactive material

A health hazard is defined as a chemical that is evidenced to cause acute or chronic health effects. Some examples of MIOSHA defined health hazards are:

- Allergens
- Embryotoxins
- Carcinogens
- Toxic or highly toxic agents
- Reproductive toxicants
- Irritants

[60] Michigan State University Chemical Hygiene Plan, ORCBS, Last Revised 1998; Sect 1, p. 2

- Corrosives
- Sensitizers
- Hepatoxins (liver)
- Nephrotoxins (kidneys)
- Neurotoxins (nervous system)
- Hematopoietic systems agents (blood)
- Agents which may damage the lungs, skin, eyes, or mucous membranes

Any substance that fits the above criteria is classified as a hazardous chemical. If a chemical has a uniquely high degree of acute and chronic toxicity, it is defined as particularly hazardous. Further definitions of the above terms can be found in the Glossary of Michigan State's safety plan.

The MSU CHP specifically assigns responsibility to the persons that will be in charge of the laboratory safety, starting with the ORCBS. It is the job of the ORCBS to develop the CHP for Michigan State University. The Chemical Hygiene Officer can assign responsibilities to any of the responsible parties involved in chemical safety. Persons lower in the ranking are unit directors, project directors, employees and students. Unit and project directors are responsible for providing all relevant training and documentation in order to ensure knowledge of the dangers of working in a lab. Employees are ultimately responsible for their own safety, as long as they have been provided with the proper information. Students are not covered under the provisions of the MIOSHA lab standard, but should be informed as to the hazards in the lab, so that they can remain safe in the lab.

The Standard Operating Procedures (SOP) portion of the MSU CHP is strikingly similar to the WPI CHP. All of the points listed in the General Safety Principles and the Health and Hygiene sections of the SOP, for example being aware of the chemical one is using, being aware of ones surroundings, wearing protection where appropriate, washing after handling chemicals, and knowing the symptoms of overexposure to a substance, are all very common-sense and are stated in WPI's CHP. Food and drink is prohibited in all MSU labs as well. Included in the SOP is a directive to keep all work areas clean, to clean all spills immediately, to keep all exits free of blockages, and to dispose of all wastes properly, which will be discussed later. The MSU CHP differs from WPI in some ways regarding the Chemical Handling and Storage section. Michigan State University requires that no chemicals be stored more than two feet from floor level, the department ordering chemicals should never order more than what is necessary for operation, and should never accept chemicals with defaced or altered labels. Also, all chemicals must be stored by compatibility, and the storage area must be clearly marked as to its contents. Section 2.2.6 of the MSU CHP points out specific instructions for the transporting of chemicals:

- Glass containers should be carried in specially designed containers, or a leak resistant, unbreakable container
- Any cart used to transport chemicals should have high edges to contain spills
- Freight elevators are preferred to passenger elevators, so not to expose passengers to harmful substances

Another unique piece of the MSU CHP is its provisions for compressed gasses, as they pose a different hazard than liquid chemicals. There are regulations concerning the storage and handling of compressed gas cylinders.

Chemical storage and handling are an important part of any CHP. The MSU CHP states that any and all chemicals must be properly labeled, and at the barest minimum, have the chemical name and hazard identification. Unlike WPI, MSU offers a scenario for chemicals developed in the lab in Section 3.3 of the CHP. It is the responsibility of the creator to determine any hazards and to properly label the chemical, and provide an MSDS. Labels are broken down into several types, stationary process containers, portable containers, sample containers, and waste containers. All must list the contents, all hazards, as well as specific data for each container, as listed in Section 3.4.1 and 3.4.2 of the MSU CHP. Of course there are special considerations for particularly hazardous chemicals, which are defined by the hazards associated with the chemical. These hazards are defined in a standard manner, for example flammable/combustible, corrosive, toxic, or reactive, however, the MSU CHP goes into much more detail in describing the many physically hazardous chemicals which may be available in the lab. Examples of such chemicals are organic peroxides, pyrophoric materials, which ignite when in contact with air, and cryogens. Definitions of all of these many types of materials can be found in the Michigan State's Glossary.

In case of an emergency, Section 4 of the MSU CHP gives definitions and protocols to handle a hazardous situation. Specific situations that are addressed are fires and spills. The protocol for a fire is fairly simple: pull the alarm, call 9-1-1, and evacuate. In the event of a spill, the protocol is also intuitive: call 9-1-1, evacuate personnel and alert those in neighboring areas, isolate the spill, remove any ignition sources, and establish ventilations. All of this should be done as long as there is no immediate hazard to those carrying out the procedure. All labs should be equipped with spill kits, a feature not mentioned in WPI's CHP. A spill is typically not considered an emergency if it is less than one liter and does not exhibit the hazards discussed previously. In the case of injury, it is interesting to note that the MSU CHP does not recommend providing first aid kits in anyplace but a remote location where other care is not readily available. In the case of minor first aid, never administer any drugs, never use ointments or crèmes on burns, and refer to the MSDS for other safety measures. Section 4.3 gives the procedure for any medical consultations or examinations. The University must provide its employees with the opportunity to receive medical care.

One of the most important pieces of a safety plan is a section on physical lab requirements. Once again, the Material Safety Data Sheet is stressed as a necessity to identify any hazards associated with a substance, and must be made available to anyone working in a lab. Signs are a requirement for any lab; they must list emergency phone numbers, chemicals in use in the lab, and certain hazards present in the lab. Some examples of chemicals for which the storage area must be marked are carcinogens, corrosives, flammables, oxidizers, perchloric acid, or biohazards. In order to minimize accidents in the lab, MSU has implemented three different types of control measures: Administrative controls, such as work shifts, engineering controls, such as fume hoods, and personal protective equipment. The following general control measures are recommended for use in most situations requiring the use of hazardous chemicals:[61]

- Determine the source of exposure
- Determine the path the contaminant follows to reach the employee
- Determine the employee's work pattern and use of personal protective equipment
- Change one or more of the above pathways to reduce or eliminate exposure
- Substitute less harmful chemicals for more harmful chemicals whenever possible
- Change or alter processes to minimize exposure
- Isolate or enclose a process or work operation to reduce the number of employees exposed (for example, use a fume hood)
- Use wet methods to reduce the generation of dust

[61] MSU CHP; Section 5.2.3

- Use local exhaust ventilation (hoods) at point of generation or dispersion of contaminants and use dilution (general) ventilation to reduce air contaminants
- Practice good housekeeping procedures to reduce unnecessary exposures
- Use training and education as primary administrative controls for reducing exposures
- Use special control methods such as shielding and continuous monitoring devices to control exposures in special situations

Personal protective equipment is an integral part of lab safety. Michigan State University recommends much of the same equipment as WPI, different types of goggles, gloves, coats, as well as showers and eyewash stations. The MSU CHP explains locations and vicinities that a shower or eyewash must be in to certain chemicals, and proper maintenance of this equipment in Section 5.3. Fume hoods are also important pieces of equipment in the lab. In Section 5.4 the MSU CHP offers several guidelines for proper fume hood use and maintenance in different detail that the WPI CHP.

2.6 Previous Research

When conducting any research, it is essential to consider previous studies in the field to avoid overlooking and recreating past work. Considerable research has been conducted in the field of chemical safety. Studies involving Chulalongkorn University were particularly useful to this project. Using a past Interactive Qualifying Project assisted the project by providing background information about the Department of Chemistry.

2.6.1 Surplus Chemical Exchange Program[62]

The *Surplus Chemical Exchange Program* is a former WPI Interactive Qualifying Project completed at Chulalongkorn University. The Program consisted of an online database used to facilitate the exchange of chemicals within the Department of Chemistry. The purpose of the exchange was to reduce the University's chemical waste by encouraging reuse of chemicals. In addition to describing the implementation of this exchange, the project provides information on the general way in which the Chemistry Department at CU operates including information about

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[62] Godleski, Christine A., Hamel, Scott E., and LeClair, Matthew D.. February 2000. "Surplus Chemical Exchange at Chulalongkorn University." (WPI IQP) pp. 34-45

current waste disposal and safety practices. This will provide an overview of what practices need improvement and which practices need to be implemented. The *Surplus Chemical Exchange Program* also describes the laboratory and personal protective equipment CU already utilizes.

Safety and disposal guidelines vary from lab to lab at CU. Most professors insist, "The students wear lab coats, safety goggles, gloves, and closed toe shoes."[63] One professor in the Department of Chemistry goes so far as making the students bring the Material Safety Data Sheet (MSDS) on the chemicals to be used in the laboratory that day. Most rules in other labs are less demanding and the lab instructors believe that they cannot force the students to do the right thing. However, in most laboratories professors require that the students not pour the chemicals down the drain but put them in the correct disposal containers, there being one for solvents, organics, and heavy metals.

The *Surplus Chemical Exchange Program* report states that all of the current chemical practices at CU, including safety and disposal practices, vary from department to department and in different classes in each department.[64] Even with these differences, it is obvious that these practices need to be improved. Since the chemicals that are ordered through the University take a long time to be delivered, professors and students often order larger volumes of a substance than what is needed because it is more time-efficient. There are no regulations or costs pertaining to chemical waste disposal at CU, so the staff and students can dispose of any amount of waste without suffering financial penalties.

Proper chemical waste disposal does not exist in the Department of Chemistry. In many labs, students fill one container with all the products and waste from the whole class. It is unclear what happens to the containers after that, they may be left in the lab or put in a storeroom. Some waste is packed in steel drums with sand and other materials, which are then left to pile up behind Chemistry Building 1.

The previous project reports that when collectors come to pick up the wastes in the labs, they combine the existing separate containers, and possibly bring the mixture to the pile behind Chemistry Building 1.[65] This pile of waste has been getting larger over the past couple of years and there are at present no plans to remove it.

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[63] *Idem.*
[64] *Idem.*
[65] *Idem.*

In these labs, it is more likely that if the wastes are carefully separated that they will stay this way, but at least some of it will be poured down the drain. Students have been told that they can pour wastes down the drain as long as they dilute it with water. As of last year, there were "no treatment facilities connected with the drainage system of any building" on the campus.[66] This creates a problem because the municipal waste treatment facility deals only with organic waste.

The staff at CU agrees that their current safety guidelines are dangerous and that new ones need to be put in place. The correct Personal Protective Equipment (PPE) is not always utilized and some of CU's equipment is old and dangerous. Though the professors have reported only a small number of accidents related to chemical use, there is the potential for more serious accidents to occur.

2.7 Laboratory Accidents at Universities

Accident reports are a key aspect to any chemical safety plan. These accident reports directly reflect the success of a safety plan. This section compares Chulalongkorn University's accidents record in their old chemistry building with the accident reports from WPI. Although Chulalongkorn has a much larger chemistry department, these reports can be used to compare per capita accidents in each school.

2.7.1 Previous Accidents at Chulalongkorn

According to Dr. Supawan, proper documentation of accidents presently does not exit at the University, so it is crucial that the team helps the department implement a proper reporting system through the chemical safety plan. Although accidents are not recorded at CU, the accidents are infrequent and minor as reported by Dr. Supawan.

2.7.2 Previous Accidents at Worcester Polytechnic Institute

Knowledge of accidents in a comparable institution's chemistry department will enable Chulalongkorn's chemistry department to prevent accidents. Because many of these accidents are common in a laboratory setting, methods for dealing with the results of accidents as well as processes to prevent the accidents already exist. These methods have been tested and improved through many years of experience. As

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[66] *Idem.*

a result, Chulalongkorn can benefit from the practices without the lengthy, iterative trial and error period of developing common lab safety practices.

When dealing with accidents in the new science building at Chulalongkorn, it is essential that accidents are reported in a uniform way. A standard method of reporting accidents may increase the probability that the department will become more diligent about reporting accidents. Often, such activities as reporting accidents are neglected simply because there is no accepted means of reporting incidents. A standard procedure may facilitate the improvement of the reporting policies. In the past five years in Goddard Hall, at WPI, there have been nineteen accidents reported: only one led to time away from work. None of these accidents was severe, and the types of accidents reported are relatively common while operating in a chemistry lab. These are the accidents as reported in Table 2.

Date	Victim	Description
3/20/96	Staff member	Slip and fall; headache and dizziness
2/18/97	Staff member	Hand laceration; contact with a hand tool
9/25/97	UG student	Finger laceration; contact with broken glass
10/6/97	UG student	Hand laceration; contact with broken glass
3/25/98	UG student	Hand laceration; contact with broken glass
4/23/98	UG student	Hand laceration; contact with broken glass
8/26/98	Grad. student	Skin irritation; contact with corrosive chem.
9/21/98	UG student	Hand laceration; contact with broken glass
10/6/98	UG student	Hand burn; contact with hot glassware
11/17/98	Grad. student	Skin irritation; contact with corrosive chem.
12/9/98	Grad. student	Skin irritation; contact with corrosive chem.
1/4/99	Staff member	Arm injury; fall on icy sidewalk
7/19/99	Staff member	Respiratory irritation; inhaled fumes
8/17/99	UG student	Skin irritation; contact with corrosive chem.
8/26/99	Grad. student	Wrist laceration; contact with broken glass
9/8/99	UG student	Finger laceration; contact with broken glass
2/20/00	Staff member	Finger injury; contact with a needle
9/26/00	Grad. student	Finger laceration; contact with broken glass
10/24/01	Grad. student	Skin irritation; contact with corrosive chem.
10/29/01	UG student	Hand laceration; contact with broken glass

Table 2: Reported Accidents at Worcester Polytechnic Institute

Simple instruction and proper execution of laboratory safety could have prevented many of these accidents. It is inevitable that some accidents will occur in a university's chemistry department due to lack of attention to detail and general adherence to lab safety practices. No training program or system of policies can create a universal adherence to policies within a lab setting. It is essential to note that accidents are sometimes unavoidable and unforeseeable. In these cases, it is important to learn why the accident occurred and to seek ways to correct deficiencies in practices or policies.

3 Methodology

The ultimate goal of this project was to prepare a thorough evaluation of current chemical safety practices at Chulalongkorn University and develop a safety plan for implementing a forward-looking safety policy for the University, incorporating strategies and procedures from similar institutions as well as recommendations from past studies at the University. The team surveyed existing safety programs at several universities in the United States and similarly explored the safety plans of the research centers of ExxonMobil Chemical and the Petroleum Authority of Thailand. The team also identified specific concerns within the Department of Chemistry as well as within the University administration to arrive at an effective system of policies that address the storage, transfer, and disposal of hazardous materials to make the new science building as safe as those in similar institutions.

The primary objectives for this project are:

- Identify the best chemical safety practices at various universities in the United States as well as ExxonMobil Chemical and the Petroleum Authority of Thailand.
- Evaluate current chemical safety practices at Chulalongkorn University.
- Propose a safety plan for the Department of Chemistry at Chulalongkorn University.

The rest of this chapter is divided into sections that illustrate the methods and procedures used to complete these objectives. The section Domain of Inquiry and Definitions specifies the precise boundaries of the issues addressed in the project and defines key terms, such as "safety plan," that are particularly important to the study. The section Spatial Coverage depicts the spatial extent of the study and displays the locations of the institutions and buildings that will be investigated. The section Examination of Common Practices in Chemical Safety explains how information regarding chemical safety practices will be gathered, organized, and analyzed. The section Assessment of Current Practices at Chulalongkorn contains details about the evaluation of current practices at Chulalongkorn University. Finally, the section Development of a Safety Plan for Chulalongkorn University illustrates the steps that will be taken to propose an effective safety plan for the Department of Chemistry at Chulalongkorn University.

3.1 Domain of Inquiry and Definitions

In its recommendations to the Department of Chemistry, this project uses the definition of a safety program provided in section 2.5.1. The concentration of the project is a safety plan focusing on laboratory safety for the Department of Chemistry. This includes waste management, transportation and safe handling of chemicals, along with chemical storage. In addition, the project recommends training programs relating to proper techniques for transportation and handling of chemicals as well as outlines administrative procedures dealing with and reporting accidents. Finally, the team prepared a very general overview of basic fire safety measures for the entire science building.

3.2 Spatial Coverage

This project focuses primarily on the Chulalongkorn University campus, specifically the new science building and the old chemistry building. Building 35 in Figure 6 represents the old chemistry building, Chemistry Building 1. The new science building is roughly located near building number 43 in Figure 6. The distance between these buildings is approximately one-half kilometer.

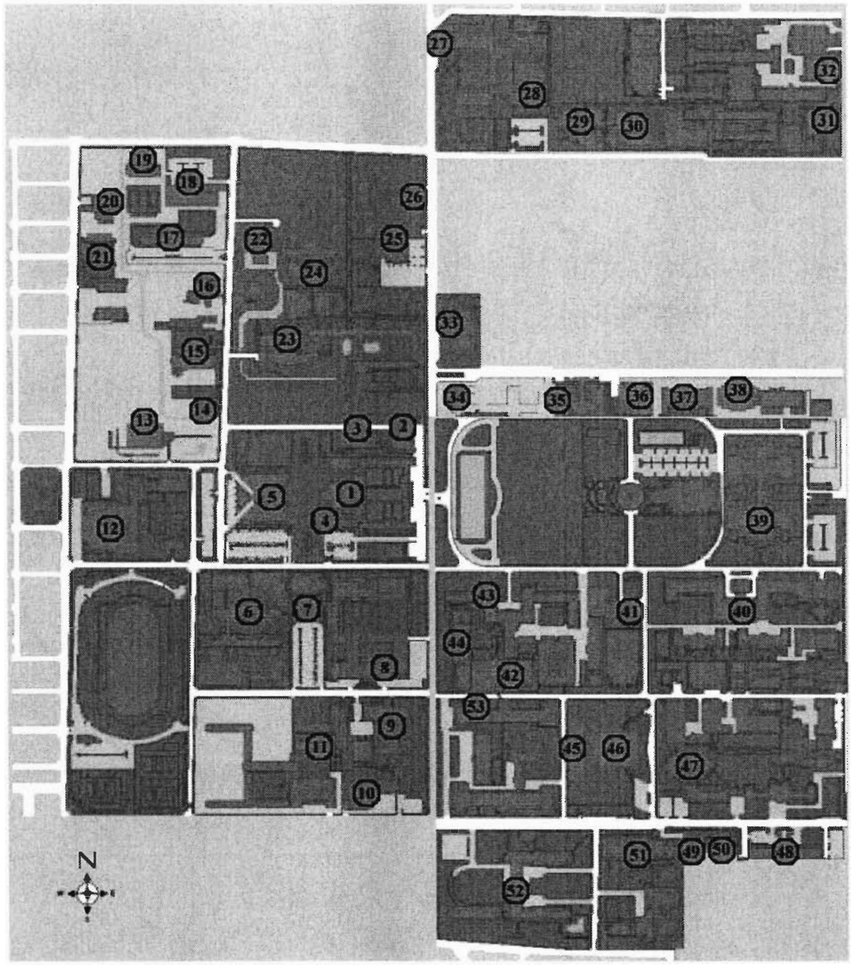

Figure 6: Map of the Chulalongkorn Campus[67]

In addition, the team conducted research by meeting with representatives from ExxonMobil Chemical and the Petroleum Authority of Thailand. The Petroleum Authority of Thailand has offices throughout the country, but this project focused on the Research and Technology Institute in Ayuthaya.

3.3 Examination of Common Practices in Chemical Safety

This section details how the team juxtaposed and summarized the safety information from Worcester Polytechnic Institute (WPI), Massachusetts Institute of Technology (MIT), Michigan State University (MSU), and the University of Massachusetts at Amherst (UMass). In addition, a discussion of the methods that were used to incorporate practices of the ExxonMobil Chemical and the Petroleum Authority of Thailand is provided.

[67] "Campus Maps," Chulalongkorn University; http://www.chula.ac.th/about/index_en.html

3.3.1 Safety Comparison Methods

Because safety is an iterative process, institutions often publish their safety plans so that other organizations can benefit from existing knowledge and research. As mentioned earlier, the team feels that safety is not a product but a process. In the United States, institutions often publish their safety plans via the Internet so that the information can be available to the widest possible audience. In fact, the chemical safety practices that the team collected from the U.S. universities were obtained primarily through the universities' websites. Unlike for the other universities in the United States, the team was able to discuss Worcester Polytechnic Institute's safety plan with the Safety Officer.

Since the safety plans are subject to government regulations, there was a common thread throughout all of the safety plans collected from United States institutions. Dissimilarities occurred primarily because of differing state regulations although these differences were often subtle. Although all universities must meet federal and state regulations, each individual school is responsible for composing its own safety plan. Each safety plan that the team examined differed in the amount of detail it contained; because of this, the team chose a single safety plan to serve as the basis for all future research. The team chose WPI for this role because it was the most accessible in terms of availability to the labs and safety personnel responsible for implementing the plan.

After the team selected WPI as the basis of research, the differences between each school's plan was identified. WPI, UMass, and MSU each separated its safety plan into two distinct parts: a chemical hygiene plan and a hazardous waste management plan. Conversely, MIT leaves the responsibility of formatting and preparing the safety plan to each department. In order to determine the more appropriate implementation, the team consulted the expert advice of Dave Messier, Environmental and Occupational Safety Manager at Worcester Polytechnic Institute. Because of his training and experience, Mr. Messier could offer insight into the most practical method to construct a safety plan. The team questioned Mr. Messier about the advantages and disadvantages of a centralized system versus a decentralized system. With the counsel of Mr. Messier, the team determined the format of a safety plan that is most appropriate for Chulalongkorn.

Aside from differences in the general format of a safety plan, some discontinuities exist in storage practices of hazardous waste because of the amounts of waste that each school generates. In Massachusetts, the Massachusetts Department of Environmental Protection classifies waste generators as either small or large quantity generators. Partly because of their size, both MIT and UMass are considered large quantity generators while WPI is a small quantity generator. The different classifications result in differences in the amount of time the hazardous waste can be held in the Main Accumulation Area. In order to assess the classification of Chulalongkorn according to MASDEP standards, the team consulted Dr. Supawan regarding chemical waste generation. In addition, information regarding chemical waste storage and disposal procedures influences the classification of Chulalongkorn.

Because many safety plans are rooted in laws and regulations, differences between the safety plans of the three Massachusetts schools and Michigan State University resulted. These were made obvious by studying the chemical and environmental safety laws in each state that affects universities. The team chose to utilize the laws that were stricter between the two states as the basis of the laws that would advise Chulalongkorn's chemical safety plan because this leads to heightened safety. The team then had to consider applicable laws in Thailand. Although chemical safety laws do not apply to universities in Thailand, laws pertaining to industry are often stringent. The next step was to consult the Petroleum Authority of Thailand, ExxonMobil Chemical, and Dr. Supawan to determine which, if any, laws and regulations would be appropriate to apply to Chulalongkorn. In addition, cultural differences needed to be addressed. These differences were handled through interviews with professionals in Thailand.

3.3.2 United States Academic Safety Plans

Worcester Polytechnic Institute was selected as a source of information for this project because its resources were readily available to the team. While WPI is not nearly as large as Chulalongkorn, many of the practices in place will be applicable to CU because they are universally accepted safety methods. WPI chemical safety information was collected on November 17, 2001. Information was also collected from Dave Messier (Environmental and Occupational Safety Manager) and the WPI website.

The University of Massachusetts at Amherst was chosen because it is of comparable size to Chulalongkorn. Although UMass Amherst is not located in an urban setting, the students and staff conduct a wide range of research in chemical fields and have extensive chemical safety policies. The team collected the UMass chemical safety plans on November 17, 2001.

Massachusetts Institute of Technology is a large urban school that is similar to CU in many ways: the large campus and urban setting mirror Chulalongkorn. The team collected MIT's safety information from MIT's website on November 27, 2001.

The team selected Michigan State University because it is a very large, out of state school and because the safety information is located online. Since MSU is not located in Massachusetts, it is subject to different state laws than WPI, UMass, and MIT. These differences provided the team with a wider range of information pertaining to regulations. The team collected the safety plans of MSU on November 27, 2001, from the MSU website.

The team selected the information from ExxonMobil Chemical and the Petroleum Authority of Thailand as models because they are institutes in Thailand that deal with chemicals in various settings. The team obtained information pertaining to the safety plans at ExxonMobil Chemical and PTT in Thailand through a series of visits and interviews. The gathering of data for ExxonMobil Chemical began on January 13, 2002, and was continued on January 27. The team visited the Petroleum Authority of Thailand on January 28, 2002, and held an informal discussion with their representatives.

3.3.3 Professional Resources

Conducting interviews with experts on chemical safety provided information on the common safety practices from a variety of institutions. Speaking to specialists in safety clarified details of chemical safety plans and how various institutions apply them. Interviewing people both in the United States and in Thailand, the team determined additional factors to consider in constructing a safety plan.

3.3.3.1 Dr. Supawan Tantayanon

During the project preparation process, Dr. Supawan Tantayanon visited the team in Massachusetts to discuss how the project would proceed once in Thailand. During this discussion, Dr. Supawan further defined the project. The team asked questions regarding general safety practices in Thailand and the particular practices at Chulalongkorn. Questions pertaining to the existing equipment, such as if there were eyewash stations and drench showers in the new science building, informed the team of the kinds of safety equipment found in the labs in Thailand. Thailand's laws and regulations were also discussed with Dr. Supawan. Because this interview was conducted early in the project process, the team did not yet have specific concerns regarding issues such as waste disposal and the implementation process of the safety plan; as a result, did not formulate formal questions for Dr. Supawan.

3.3.3.2 Dave Messier

Dave Messier is the Environmental and Occupational Safety Manager (EOSM) at WPI. Mr. Messier is the head of all the safety activities on campus and is responsible for writing WPI's chemical safety plan and for handling hazardous waste. Through continued communication, Mr. Messier has offered his expert opinion on a wide range of chemical safety issues. Throughout the course of this project, the team has continuously consulted Mr. Messier on important matters that have arisen at Chulalongkorn, where an expert opinion was required. Although email was the primary means of communication, the team conducted an interview with Mr. Messier while in the United States. The team questioned Mr. Messier concerning his education and credentials, the process of creating a safety plan, its implementation, and the common hazards in a laboratory. Because Messier created the safety plan for WPI, he could suggest the proper means of constructing and implementing a safety plan. The interview with Mr. Messier also allowed him to offer his professional views on why certain practices are chosen, as well as their inherent usefulness. The team asked him a wide range of questions regarding WPI's practices and the rationale behind them. More specifically, the team questioned Mr. Messier as to how the safety plan at WPI is enforced and what training is provided for the faculty and students at WPI. Also, the team developed questions that would provide information about the necessary training that would be useful for the safety officer at Chulalongkorn. At the conclusion of the interview, Mr. Messier accompanied the team on an inspection of the Main Accumulation Area, the chemical stockroom, and the chemical preparation area. Appendix C.1contains a transcript of the interview. Mr. Messier granted the team permission to use WPI's safety plan in its entirety for the purposes of this project.

3.3.3.3 Dr. Thawach Chatchupong

After touring the Petroleum Authority of Thailand's (PTT) Research and Technology Institute's laboratories in Ayuthaya Province, the group interviewed the chemical safety authority at the facility. Dr. Thawach Chatchupong is an environmental researcher in the Analytical and Petrochemical Research Department and is a member of the institute's safety committee. The team questioned Dr. Thawach about common safety practices found in the institutions in the United States to find out if PTT also follows these practices. For example, in the United States there are restrictions on the varieties of chemicals that can be stored together. By inspecting chemical stockrooms at PTT, the team determined PTT's adherence to commonly accepted chemical storage procedures. In addition, many of the problems that Chulalongkorn face are issues that PTT deals with on a regular basis. For example, CU has had problems with chemical waste disposal services; the project team was able to find out which waste disposal company PTT utilizes and why. The team used this information to tailor a plan for Chulalongkorn that includes a list of available industrial resources. Using the information gained from the interview with Dave Messier (Appendix C.4), the team compiled a similar interview for the safety officers at PTT. These questions were reviewed by Dr. Supawan before the interview took place. The team also discussed with Dr. Thawach the possible cultural factors that affect safety programs, including enforcement both by the government and lab directors. Dr. Thawach provided information on the general lab safety training as well as the transportation training that PTT provided for all employees. This interview/informal discussion can be found in Appendix C.4.

3.3.3.4 Mr. Montree

As with the Petroleum Authority of Thailand, the team consulted with a representative from ExxonMobil Chemical on two occasions. There were no prepared questions for either meeting because they were both information sessions. In these information sessions Mr. Montree shared the details of ExxonMobil's chemical safety plan. Mr. Montree also discussed the company's training program and details about the Safety Committee at ExxonMobil. Transcripts of these information sessions can be found in Appendices C.2 and C.3.

3.3.3.5 Krissana Auynirundornkul

At the second meeting with ExxonMobil Chemical, a representative from Pfizer was also present. Ms. Krissana Auynirundornkul outlined the chemical safety plan that exists at Pfizer Global Manufacturing located in Samutprakarn Province. She also provided information on the safety training of employees, hazardous waste disposal, and fire safety procedures. As mentioned previously, this was an information session, but the team members asked questions where appropriate for clarification.

3.3.3.6 Tanong Promma

Because Genco is the largest hazardous waste disposal company in Thailand, the team interviewed Tanong Promma, Public Relations Manager at Genco. This is important because Chulalongkorn University currently does not utilize a waste disposal company. Since waste disposal is an integral part of chemical safety, it is desirable for the team to find a suitable company for the University. Dr. Supawan has informed the team that waste disposal companies in Thailand do not deal with the universities because they do not produce enough waste to make the investment feasible for the disposal companies. Because waste disposal is so important, the team met with Tanong Promma, exploring the possibility that the company assist in Chulalongkorn's developing safety program. The team conducted an interview and discussion with Genco involving issues such as the companies to which Genco offers services, the fees Genco charges to remove a certain amount of hazardous waste, and the laws and regulations by which Genco must abide. The interview took place on February 12, 2002, and is detailed in Appendix 0.

3.3.3.7 Dr. Bhinyo Panijpan

Dr. Bhinyo Panijpan is a professor and also the chairman of the Biochemistry Department at Mahidol University in Bangkok. He is also the former president of the Chemical Society of Thailand. As an expert in chemical safety in an academic setting, Dr. Bhinyo provided information from the point of view of both a professor and chemical safety expert. This interview was held on February 8, 2002. Dr. Supawan reviewed the questions that the team prepared. The questions for this interview aimed at determining Dr. Bhinyo's opinions on chemical safety in Thailand.

The team chose open-ended questions that would foster discussion about cultural aspects of chemical safety. Dr. Bhinyo provided a frank and forthcoming examination of Thailand's view of chemical safety from both a governmental and academic perspective. The information from this interview is found in Appendix C.5.

3.3.3.8 Dr. Suchata Jinachitra

Dr. Suchata Jinachitra is the Program Director for Public Welfare of Thailand's Research Fund and is a former employee of Chulalongkorn's Department of Chemistry. At CU, she taught Organic Chemistry and created and instructed the first chemical safety course, which was an elective class for third year students. The questions that the team constructed were similar to the questions that were asked of Dr. Bhinyo but with an emphasis on Chulalongkorn University. Dr. Suchata provided the team with an insider's view of the safety concerns that exist at Chulalongkorn. The team also asked Dr. Suchata's advice on the best way to implement the safety plan at Chulalongkorn. This interview took place on February 12, 2002, and is detailed in Appendix C.6.

3.3.3.9 Dr. Yaron Yoel

The team interviewed Dr. Yaron Yoel, founder and Managing Director of BYL Environmental Services, on February 18, 2002, to discuss waste disposal options for Chulalongkorn University. The team prepared a list of questions that were appropriate to determining whether BYL Environmental Services is a suitable company for Chulalongkorn to utilize for chemical waste disposal. The team also asked Dr. Yoel questions involving the specifics of BYL Environmental Services, for example what methods the company uses to dispose of hazardous waste. The interview dialogue can be found in Appendix C.7.

3.4 Assessment of Current Practices at Chulalongkorn

A second major objective of this project was to prepare a thorough evaluation of existing safety practices at Chulalongkorn University. The assessment identified problem areas in the current safety practices at the University. The current practices provide the starting point for implementation of an appropriate safety plan for the University. The information required for the assessment of these practices at

Chulalongkorn included a wide range of specific data covering all aspects of the chemical use at Chulalongkorn.

3.4.1 Accident Reports

Accident reports are an integral part of a chemical safety program. The frequency and severity of accidents are often a direct indication of the success of a safety program. Accident reports often highlight areas of a safety program that need improvement. In addition, an organization can use accident reports to identify areas of its program that require additional training or attention from the safety staff.

A comparison of accidents at Chulalongkorn with those at other schools could determine the effectiveness of the existing safety program at Chulalongkorn. To achieve this comparison, the team attempted to obtain accident reports from Chulalongkorn. The University, however, does not currently require accident reports to be completed. Despite the lack of record-keeping, the team was able to estimate the frequency and severity of accidents through approximations provided by Dr. Supawan and other professors in the Department of Chemistry.

In order to draw comparisons between Chulalongkorn and other educational research institutes, the team compared accidents at Chulalongkorn with accidents at Worcester Polytechnic Institute. The team obtained accidents reports from the past five years at WPI from Dave Messier. The team consulted with professors from the Department of Chemistry at Chulalongkorn regarding accidents in their labs that deviated from the standard accidents experienced in a typical research laboratory. In areas where there were inconsistencies between typical lab accidents and accidents experienced at Chulalongkorn, the team provided detailed information on how to address the problem. Based on the range and severity of accidents, the team determined areas in Chulalongkorn's current safety practices that require improvement. This information exists as recommendations in the safety plan.

3.4.2 Inventory of Chemicals at Chulalongkorn

An inventory of the chemical stocks at Chulalongkorn was required to fashion a more robust safety plan. By composing an inventory of the chemicals stored and used at Chulalongkorn University, the team completed a more comprehensive safety plan for the Department of Chemistry incorporating very specific requirements and recommendations for handling, storage, and disposal of the specific chemicals at Chulalongkorn.

3.4.2.1 Surplus Chemical Exchange Program

One potential existing data source for this project was a past WPI Interactive Qualifying Project from 2000: *Surplus Chemical Exchange Program* by Christine Godleski, Scott Hamel, and Matthew LeClair. This project concerned a chemical exchange program that was intended to reduce waste produced at the University. That project team also completed a cursory investigation of relevant safety practices in the Department of Chemistry, although the information was specific to practices in the old chemistry building as the new science building was not in use at the time. Since the report was written, safety practices at Chulalongkorn have not changed.

The team hoped to establish a chemical inventory partially through existing data available through the *Surplus Chemical Exchange Program*. The surplus program team created a database that contains some information on the types and the quantities of chemicals that are located at Chulalongkorn. The purpose of the database was to facilitate exchange of surplus chemical within the Department in an effort to reduce unnecessary chemical waste. One problem with this approach is that the database includes only chemicals that faculty or research students wish to make available. Despite the good intentions of this project, the *Surplus Chemical Exchange Program* is not yet in use at Chulalongkorn. Dr. Supawan, the liaison of the team that wrote *Surplus Chemical Exchange Program*, informed the safety plan team that the Internet-based exchange program is currently being translated into Thai and may be used in the future.

3.4.2.2 Counting and Estimating

An inventory of chemicals was necessary for determining the range of chemicals that the safety plan would need to address. Because no inventories of chemicals exist at the University, the team constructed an estimate of the chemical inventory at Chulalongkorn. The team counted and estimated the chemicals in the stockrooms and laboratories. It is important to note that the information about chemical stock is not a comprehensive inventory of Chulalongkorn's chemicals resources. A thorough inventory was not necessary for this project because the range of chemicals and rough estimates of the volumes were sufficient for making the safety plan more specific to Chulalongkorn University. Specifically, the team was looking for particularly dangerous chemicals, such as mercury or benzene, which require special attention through the safety plan. The means for handling the range of chemicals is addressed by the safety plan. Because a complete inventory was not required, the team did not develop a database containing quantity information, but such a database could be created as part of a future endeavor and exists as a recommendation from this project.

In order to complete this approximate inventory, the team recorded the full chemical name, location, and general volume of chemicals in three of the five chemistry labs on campus. The chart used to accomplish this task is included in this report as Appendix F. While recording chemical stock information, the team simultaneously noted storage practices in the labs. Recommendations regarding storage procedures are including in the safety plan.

3.4.3 Opinion Survey

The team composed a survey that was distributed to a selection of chemistry students. The survey-takers were students in Dr. Surachai Ponpakakun and Dr. Polkit Sangvanich's laboratories. The purpose of the survey was to measure the extent of knowledge of chemical safety among current students at Chulalongkorn. The professors distributed the survey in the labs and returned the completed surveys to the team. The survey asked the students questions about their concerns regarding safety at the University. The team used the student responses to address specific areas of safety that the students and faculty share concerns about. The survey that was administered to the students in the Department of Chemistry is included in Appendix B and details both the style of questions and the scope of the data the team was able to obtain.

The team modeled the survey format after the Worcester Polytechnic Institute course evaluation form. This form has been used for a number of years and has proved to be an effective tool at quantifying student's opinions. The survey has five options for each statement: Don't Know (simplified from Not Applicable), Strongly Disagree, Disagree, Agree, and Strongly Agree. The team chose general questions that would reveal the student's attitude towards and knowledge of chemical safety. The questions that were asked dealt with integral parts of a chemical safety plan to determine how well students feel they are adhering to standard operating procedures.

The students were also questioned about their level of concern with safety in the chemistry labs to justify the need and creation of a safety plan.

3.4.4 Observations of Laboratory Practices

The team performed thorough observations of the behavior of students in various levels of chemistry labs at CU. This measured the actual safety practices used in the laboratories. The team members observed two labs: one at the beginning level of Organic Chemistry and the other at the intermediate level. Two team members filled out a safety checklist while they observed student's actions in the laboratory. Another team member photographed the overall actions of the class performing experiments. The evaluation form listed some of the standard safety practices that the team agreed are significant and the team members indicated the level of adherence, with these categories: always, sometimes, and never. Many of the safety practices listed are found in the Standard Operating Procedures in the Chemical Hygiene Plan. The team also recorded comments about practices performed that are considered dangerous. This form is located in Appendix D.4, and the results are located in Section 4.2.1, and the analysis is in Section 5.2.3.

Another issue that this project addresses is fire safety equipment. The team filled out a form on the fire safety equipment located throughout the floors of the Department of Chemistry in the new science building. The fire safety equipment was only observed in the new science building because the Department of Chemistry will soon be conducting its laboratory classes in this building. The team noted whether there are exit signs, sprinkler systems, where and what type of fire extinguishers there are, and what fire escape routes exist. Using the fire prevention practices at Worcester Polytechnic Institute and the Petroleum Authority of Thailand as standards, the team derived the fire safety equipment checklist. This form is located in Appendix E.

3.4.5 Storage Practices

The Department of Chemistry decided that it would use Chemistry Building 1 as the main storage area for chemicals. The team used digital photographs to evaluate the current chemical safety practices in the Department of Chemistry. The team photographed the chemical waste collection area that is located behind Chemistry Building 1. The documentation from the Main Accumulation Area of WPI is included in Appendix D.1 and the documentation from Chulalongkorn University is in Appendix D.3. The photographs were used to compare hazardous waste storage procedures at Worcester Polytechnic Institute and Chulalongkorn University. In view of the fact that WPI is in compliance with state and federal regulations, a comparison between practices at Chulalongkorn and Worcester Polytechnic Institute highlighted areas at Chulalongkorn that could use improvement.

The team also photographed the chemical stockrooms of the Department of Chemistry at Chulalongkorn University. There are also photographs of the setup of the Chemical Stockroom at Worcester Polytechnic Institute located in Appendix D.1. The comparison of the photographs from Chulalongkorn and Worcester Polytechnic Institute identified hazards that existed in the chemical stockroom at Chulalongkorn. The team also photographed the methods in which each professor stores the chemicals that are located in the laboratories.

3.5 Development of a Safety Plan for Chulalongkorn University

The overall objective of this project is to develop a safety plan that is tailored to the University's needs. In this stage of the project, the deficiencies of the current system at CU will be contrasted to the policies of other institutions both in Thailand and the United States. Once a comparison has been drawn, the policies that best fit the environment of CU can be extracted from policies at the other universities and institutions.

Before arriving in Thailand, the team developed a comprehensive safety plan derived from common practices at four leading universities in the United States. This plan served as the foundation for the safety plan that was developed specifically for Chulalongkorn University. Although the initial plan was thorough, the safety plan required some degree of modification before it would be appropriate for Chulalongkorn to adopt. Issues specific to Chulalongkorn needed to be addressed to ensure that the University could accept and implement the plan with relative ease.

In order to address the appropriateness of the safety plan for Chulalongkorn University, the team worked closely with both faculty and students from the Department of Chemistry as well as faculty from other departments that share the new science building. With assistance and insight from these individuals, the team identified and revised areas of the plan that were not suitable for Chulalongkorn.

This section examines the methods used to isolate portions of the plan that needed special consideration. Further, the process applied to adjust the safety plan is described in detail.

3.5.1 Presentation to Graduate Students

The team prepared a presentation for 30 graduate students who have also been researching chemical safety at Chulalongkorn. The presentation explained all aspects of a safety plan as well as an implementation timeline for adopting the plan. The graduate students also presented their knowledge in the area of chemical safety. The purpose of the presentations was to discover if any important aspects of a safety plan have been overlooked. Particular attention was paid to aspects affected by cultural differences such as enforcement policies and discipline. The team altered the proposed safety plan to reflect these new developments.

3.5.2 Incorporating Cultural Differences

Because the Petroleum Authority of Thailand and ExxonMobil Chemical research institutes are located in Thailand, they are subject to a variety of laws and regulations that may provide a local framework for Chulalongkorn. In addition, they share cultural similarities with Chulalongkorn, such as individual attitudes towards safety that may affect the implementation of a safety plan. These cultural similarities offer a unique insight into the challenges involved in the implementation of a safety plan that U.S. educational institutions could not, as well as information pertaining to Thai regulations and laws. The team asked representatives from the Petroleum Authority of Thailand questions pertaining to the cultural differences that may exist between Thailand and the U.S. While speaking with Dr. Thawach of the Petroleum Authority of Thailand, the team addressed cultural differences that may exist between the United States and Thailand. The main issue that was discussed is the enforcement of PTT's chemical safety plan. This part of the discussion was to determine what differences need to exist in the way that the chemical safety plan at Chulalongkorn is enforced.

Because Dr. Supawan has been both a student and a teaching assistant in the U.S., she was able to comment on cultural differences that exist in a lab setting. The team also discussed the current enforcement policies at Chulalongkorn with Dr. Supawan. Because these policies are often quite lenient, the team discussed the possibility of using the enforcement techniques that Worcester Polytechnic Institute employs in its chemistry department. The team also discussed the utilization of the techniques that PTT uses to enforce its safety rules. This format would consist of safety policies that are required, recommended, and suggested. The team chose essential safety practices that were determined through the extensive research conducted on the four universities and the research institutes in Thailand, to be requirements. These practices were determined to be essential because they were found in all of the safety plans researched. The team chose to make some practices recommendations because they are less critical in protecting the lab worker from harm. These were chosen through examination of PTT's recommended safety practices. Lastly, there are safety practices that are suggestions to the laboratory worker. These will include practices that are only contained in the strictest of safety plans. The suggested safety practices from PTT were also considered in the making of the list of practices for Chulalongkorn.

3.5.3 Implementation Timeline

An essential section of the chemical safety plan presented to Chulalongkorn was the implementation timeline. In order for a safety plan to be effective, the plan must be practical for the organization. The safety plan for Chulalongkorn accommodates the time, resource, and budget requirements of the Department of Chemistry. Further, it was presented in a manner that encouraged the University to continue to adhere to the policies set forth by the plan.

Because the initial adoption of a safety plan requires significant adjustment, the implementation was divided into phases to ease the dramatic change of policies in the Department of Chemistry. To assist with the adjustment period, an implementation timeline was included as part of the safety plan. This timeline considers budget issues because this is a fundamental aspect in the success of the implementation of the safety plan at the University. To ensure the efficiency of the implementation, the timeline includes a step-by-step outline of the measures that need to be adopted. In order for this plan to be practical, the adoption of this safety program has been broken up into three phases: first, second, and third.

The first phase of the timeline will initiate safety practices in the new science building. The faculty in the Department of Chemistry believes that by embracing new safety procedures as soon as the new science building is occupied, adapting to the new policies will be easier for the students. These immediate changes will address standard laboratory practices that are important components of lab safety. These changes will not be so dramatic that students will have difficulty adjusting. The most straightforward changes will be included in the first phase. These changes were chosen because they require the least amount of time and money to implement.

Changes that are included in the second phase include practices that will be adopted within one year. These changes require budget considerations. The changes in the second phase affect faculty more than students as the changes are more administrative adjustments rather than changes in lab practices.

Practices that will be implemented in the third phase include safety measures that require great expense and planning. As with the second phase, these changes are also mostly administrative.

4 Results

This chapter outlines the data the team obtained during the study. After examining chemical safety plans from other institutions, the team developed a comprehensive safety plan that includes common practices from educational institutions as well as research facilities. Before the team proposed it, the safety plan was adjusted to fit the environment at Chulalongkorn University. By examining the views of students and faculty at Chulalongkorn, the team molded the plan specifically for the University. This chapter includes the composite safety plan as well as results from the surveys, quantified responses from interviews, and observations.

4.1 Common Practices in Chemical Safety in the United States

This section consists of common practices in chemical safety that the team derived from examining safety plans from Worcester Polytechnic Institute, Massachusetts Institute of Technology, Michigan State University, and University of Massachusetts at Amherst. The team collected information on the chemical safety practices of the universities in the United States from their respective websites. The team examined the chemical safety plans to find a minimum level of safety that must be maintained, as well as common practices that are followed by several universities.

4.1.1 Chemical Safety Plans

The safety plans from Worcester Polytechnic Institute, the Massachusetts Institute of Technology, the University of Massachusetts at Amherst, and Michigan State University each contain similar components that address laboratory safety. The safety plans from these four schools each consists of a Chemical Hygiene Plan and a Hazardous Waste Management Plan. At MIT, each department is responsible for constructing these two documents, while the other schools have a standard safety plan for the entire university. The plans are often supplemented with glossaries that provide definitions of key terms and Material Safety Data Sheets that outline the hazards of particular chemicals. Further, lab safety notes are often included to describe specific details about proper usage of lab equipment and chemicals.

The Chemical Hygiene Plan (CHP) is a written plan designed to protect laboratory workers from health hazards related to chemicals. The Chemical Hygiene

Plan for each university is a general document that is applicable to any lab on campus, regardless of discipline. It is the responsibility of each department, and in many cases each lab director, to create and implement a safety plan for the site-specific hazards involved in a particular field of research or experimentation. Worcester Polytechnic Institute has adopted a very thorough and standard CHP. Worcester Polytechnic Institute's CHP contains the following elements:

1. Standard Operating Procedures for the use of hazardous chemicals.
2. Criteria for determining and implementing control measures to reduce exposure.
3. Measures to assure proper functioning of fume hoods and other engineering controls.
4. Provisions for employee information and training.
5. Circumstances under which a laboratory operation or procedure will require prior approval.
6. Provisions for medical consultation and examination.
7. Designation of responsible personnel, including the Chemical Hygiene Officer.
8. Provisions for particularly hazardous substances.

Another essential piece of a comprehensive safety plan is a Hazardous Waste Management Plan (HWMP). Federal, state, and local law, as well as organizations such as the Department of Transportation and the Occupational Safety and Health Administration, dictates the details of a Hazardous Waste Management Plan. The many regulations that compose an HWMP are aimed at isolating hazardous materials from the environment, storing them properly, and ensuring that they are disposed of in a safe manner. The Hazardous Waste Management Plan of WPI contains the following sections:

1. Hazardous Waste Determination
2. United States Environmental Protection Agency Identification Numbers
3. Temporary Accumulation of Hazardous Waste
4. Waste Storage Pending Off-Site Disposal
5. Waste Packaging
6. Labeling
7. Disposal Management
8. Waste Minimization
9. Training
10. Record Keeping and Reporting
11. Emergency Preparedness and Response

There are many ways to organize a safety plan. One method is to incorporate everything into one large document, though it appears that some separation is necessary so that the safety plan components are more accessible. Some universities create separate documents for the different pieces of safety equipment in the lab, for example a document on fume hoods, or fire extinguishers, whereas others may include such a document within the Chemical Hygiene Plan.

The safety plans from the different universities did not contain many differences. Those differences that did exist arose because of the diverse size of the universities. For example, the Massachusetts Department of Environmental Protection classifies MIT as a "large quantity generator" while WPI is a "small quantity generator." The different classifications result in differences in the amount of time the hazardous waste can be held in the Main Accumulation Area. Also, unlike most other universities, MIT decentralizes the responsibility of making the safety plans.

After reviewing these safety plans, several conclusions can be drawn. The most important aspect of laboratory safety is general awareness of one's surroundings. If a lab worker is aware of his or her surroundings and aware of the hazards of the chemicals present, then protecting himself or herself becomes easier. Knowing the hazards associated with a chemical allows one to take proper measures to protect oneself, such as, using personal protective equipment or a fume hood. In the most basic terms, in order to be protected from chemical hazards, one must eliminate all means of contact which include inhalation, ingestion, injection, and eye and skin contact.

4.1.2 Chemical Safety Practices

Standard operating procedures are the basis of chemical safety. In the United States, universities follow the same general policies. The lab worker must wear proper personal protective equipment at all times in the laboratory. Donning safety glasses before entering a laboratory is a common practice. While working with chemicals, a lab apron and gloves are to be worn. Clothes are also an important line of defense against exposure to chemicals. Long pants and closed-toe shoes are worn in the laboratory. If the lab worker has long hair it must be restrained to prevent hair from interfering with flames or equipment. Also, respirators and hearing protection should be used under conditions that call for such measures.

Another significant aspect of chemical safety in the laboratory is the proper disposal of waste. In the United States, universities have separate waste containers for broken glass. For hazardous waste, there are separate containers to collect different classifications of waste. These containers are stored in the Satellite Accumulation Area (fume hood, bench top) and are kept closed at all times except for when more waste is being added. These bottles are usually glass or plastic and have screw on caps. These waste containers have secondary containment that is able to hold all the waste if it were to leak. Also, waste container labels are crucial because they allow anyone in the laboratory to acknowledge the dangers of the chemicals. These labels have an area to write out the full chemical names of all the components of the bottle, the percentage of each chemical, the date that the bottle became full, and a number to call for removal of the hazardous waste.

Proper chemical storage procedures must be followed in chemical stockrooms. There are specially designed cabinets that house flammable chemicals. The acids and bases are separated from each other and from other chemicals in the room. All containers must have the original labels on them. Also, it is important not to place the chemicals in alphabetical order because this could result in incompatible chemicals being stored together.

4.2 Current Practices at Chulalongkorn

The team applied the information obtained from other institutes to conduct a thorough evaluation of practices at Chulalongkorn University. The assessment identified certain problem areas in practices at the University. By detecting problems in the current system, the team adopted an appropriate safety plan for the University. In order to attain this information, the group employed methods such as surveys, interviews, and chemical data collection in the Department of Chemistry. This data is presented in the following sections.

4.2.1 Chemical Safety Practices

In the chemistry labs at Chulalongkorn, the students always wear laboratory coats while performing experiments. The team observed that none of the students wore gloves, while some had on safety goggles. Most students were wearing prescription glasses instead of safety glasses. The male students all wore long pants along with closed-toe shoes. The female students, on the other hand, wore skirts but also had on closed-toe shoes. Very few of the students had their hair properly restrained while operating Bunsen burners.

The students often poured chemicals down the drain with running water. There were hazardous waste containers on a bench top that were always kept open with glass funnels located in the opening of the jug. There were no waste labels describing all of the contents of the containers. There was newspaper under the hazardous waste containers to collect spills.

4.2.2 Storage Practices

The chemical stockrooms that the team viewed had the chemicals arranged in alphabetical order. The labels consisted of chemical formulas and names. Some of the chemical stockrooms had the chemicals arranged in the categories of solids and solutions. The team also found that bottles were reused and the old label was scratched out and written over.

The hazardous chemical waste produced by the Department of Chemistry is found in Chemistry Building 3 and behind Chemistry Building 1. Some of the containers are labeled clearly, while others do not appear to have any labeling at all. There are 50 gallon drums of liquid waste and various bottles and jugs of waste strewn about on the floor.

4.2.3 Surveys

The surveys conducted regarding the current chemical safety practices at CU gauged the student's attitudes towards current regulations. The students who took the survey were non-chemistry majors taking an organic chemistry lab. The results of the survey are presented in Table 3 which depicts how the 38 students responded to each question.

Questions	Don't know	Strongly Disagree	Disagree	Agree	Strongly Agree
I feel safe when working in the chemistry labs.	2	4	13	18	1
I feel that safety practices at Chulalongkorn need improvement.	2	1	8	20	7
I am concerned about protecting the environment through proper chemical waste disposal.	1	3	11	21	2
Once a year, I would be willing to attend a chemical safety seminar run by the Department of Chemistry.	7	5	7	17	2
I always wear appropriate personal protective equipment while working in the laboratory.	0	3	3	14	18
I have been properly trained to use laboratory equipment.	1	2	12	23	0

I know the fastest emergency exit route in the event of a fire.	4	4	8	16	6
I have been trained in proper use of a fire extinguisher.	1	16	10	9	1
I know how to dispose of chemicals properly.	0	3	7	27	1
I practice methods to minimize chemical waste.	1	1	12	22	2
I am familiar with and regularly use Material Safety Data Sheets.	5	7	12	13	1
I know where the eyewash and shower stations are in the laboratory and I know how to operate them.	7	8	5	16	2

Table 3: Results from the Student Survey

4.2.4 Fire Safety Equipment

The team scrutinized the fire safety equipment strictly in the new science building on the floors that will be occupied by the Department of Chemistry. Fire safety equipment is located in two locations on each floor, in front of and behind the main stairs. The equipment at each location consists of a dry chemical fire extinguisher and an automatic fire hose reel, as shown in Figure 7.

Figure 7: Fire Extinguisher and Automatic Hose Reel

There are no fire extinguishers in the labs. There were also fire exit signs and fire alarms located in the hallways; a fire exit sign is show in Figure 8.

Figure 8: Fire Exit Sign

In addition to the main stairwell, there are two fire escape stairs on each floor which clearly labeled. Emergency lighting, as shown in Figure 9, can be found in the main stairwell but not in the hallways or laboratories.

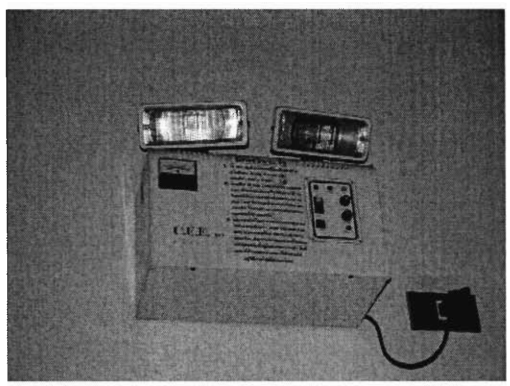

Figure 9: Emergency Lighting

4.2.5 Chemical Data

Information about the location and range of chemicals in Chulalongkorn's Department of Chemistry was collected. This data includes information from three chemical stockrooms in the Department of Chemistry. Appendix F contains the partial inventory of chemical stock at Chulalongkorn. A variety of chemicals ranging from dichlorobenzene to sucrose were found in the stock rooms. No acutely toxic chemicals were located.

5 Analysis

In order to develop a safety plan for the new science building at Chulalongkorn University, the project team performed an analysis of the pertinent data collected through surveys, interviews, research, and observations. The safety plan encompasses common practices at other institutes as well as addresses the particular concerns of the University.

5.1 Interpretation of Surveys

In addition to evaluating practices based on accepted standards, the team customized the safety plan for Chulalongkorn by incorporating the concerns and needs of the students of the Department of Chemistry. By identifying trends in the responses of students to survey questions, the team further adjusted the safety plan to address the needs of the Department. This was an essential step in the process towards proposal as the safety plan should be a system of policies that the Department is comfortable using.

The survey results in Figure 10 indicate that while half of the students feel safe in the chemistry labs, the other half does not feel safe. All students should feel safe in the laboratory; otherwise, the atmosphere is not conducive to learning. Although many students feel safe in the lab, 27 of the 38 students surveyed expressed concerns with the current safety practices at Chulalongkorn. Figure 11 shows that the students have an interest in improving safety practices. In addition to recognizing the need for increased safety awareness, 23 students also were concerned about protecting the environment through proper chemical waste disposal, as shown in Figure 12. This was a positive result from the survey because waste disposal is an integral part of a chemical safety plan. The students also responded positively to the idea of attending a chemical safety seminar run by the Department of Chemistry. Nineteen students were willing to attend, while twelve were uninterested in learning more about chemical safety. Additionally, some students were unsure if they would want to attend, as shown in Figure 13.

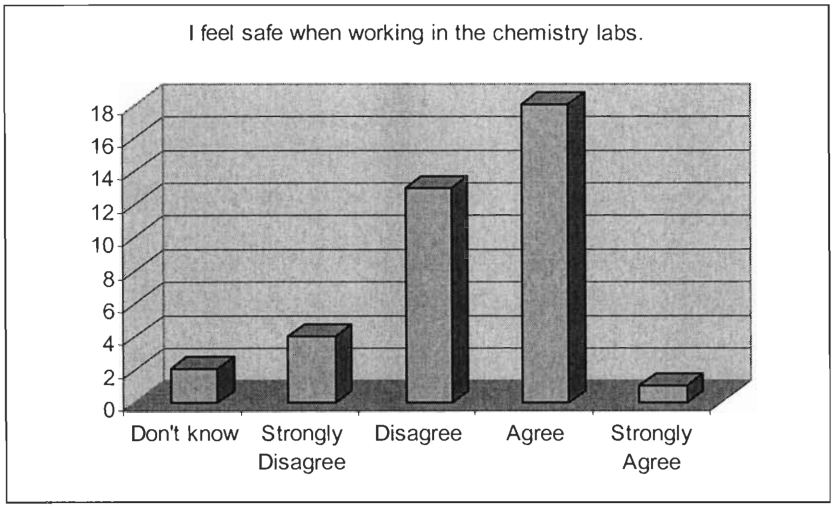

Figure 10: I feel safe when working in the chemistry labs.

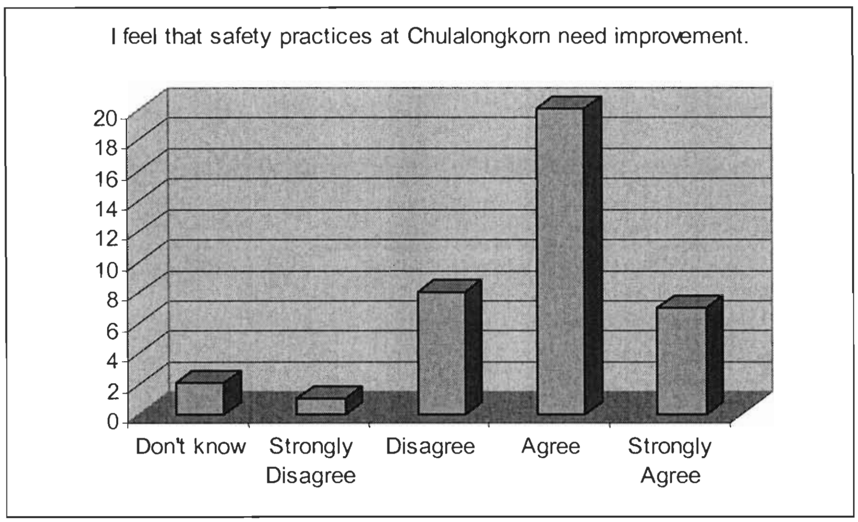

Figure 11: I feel that safety practices at Chulalongkorn need improvement.

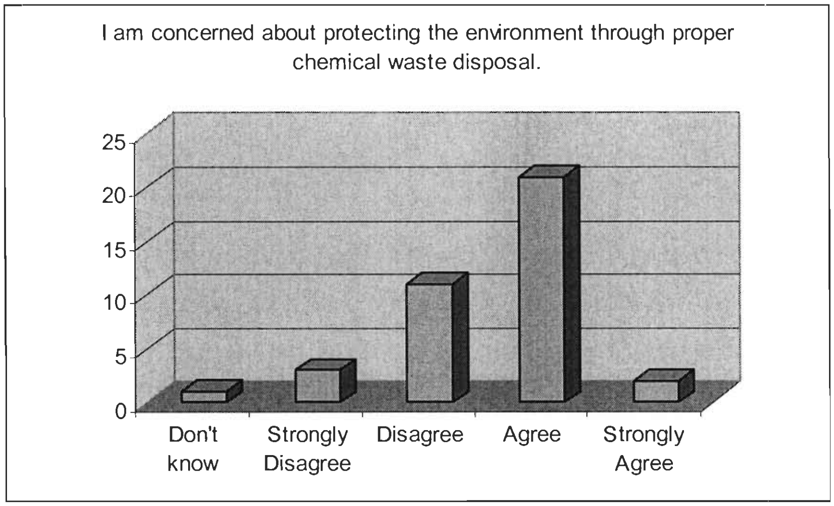

Figure 12: I am concerned about protecting the environment through proper chemical waste disposal.

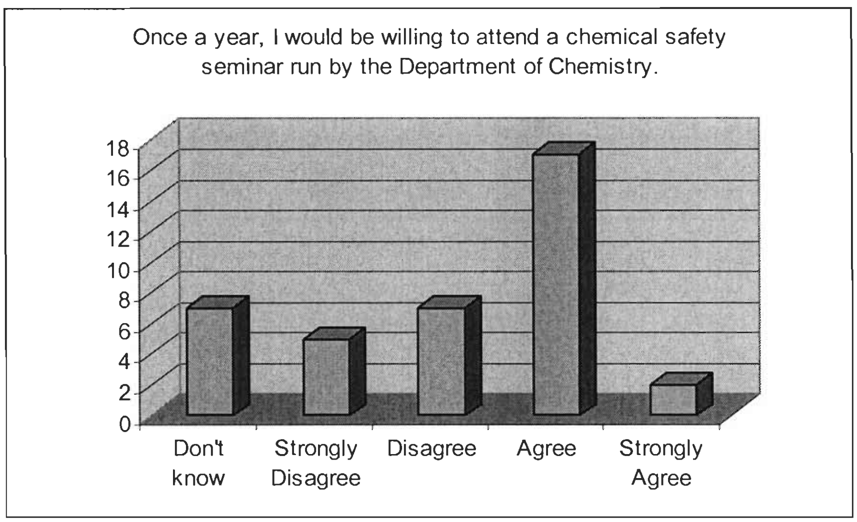

Figure 13: Once a year, I would be willing to attend a chemical safety seminar run by the Department of Chemistry.

Figure 14 shows that 32 of the students surveyed felt that they always wore proper personal protective equipment while working in the lab. After observing the surveyed students working in the lab, the team determined that these numbers are misleading. While the students may feel that they are wearing appropriate personal protective equipment, education dealing with proper attire and safety standards will show them that this is not the case. Twenty-three students indicated that they have been properly trained in the use of laboratory equipment. While the students may have been trained to use such equipment as a Bunsen burner, the team found that they did not use the equipment properly. The observations that lead to this conclusion are discussed in detail in Section 5.2.3. Figure 15 also shows that fourteen of the students did not feel they were properly trained.

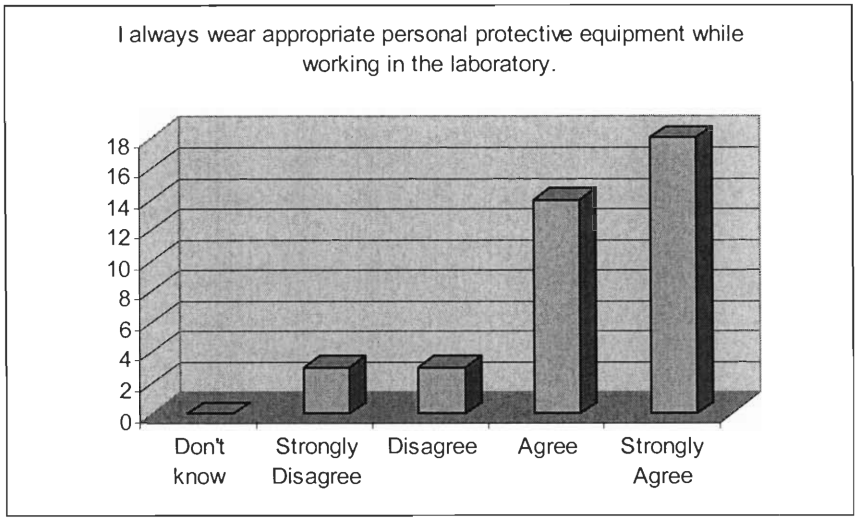

Figure 14: I always wear appropriate personal protective equipment while working in the laboratory.

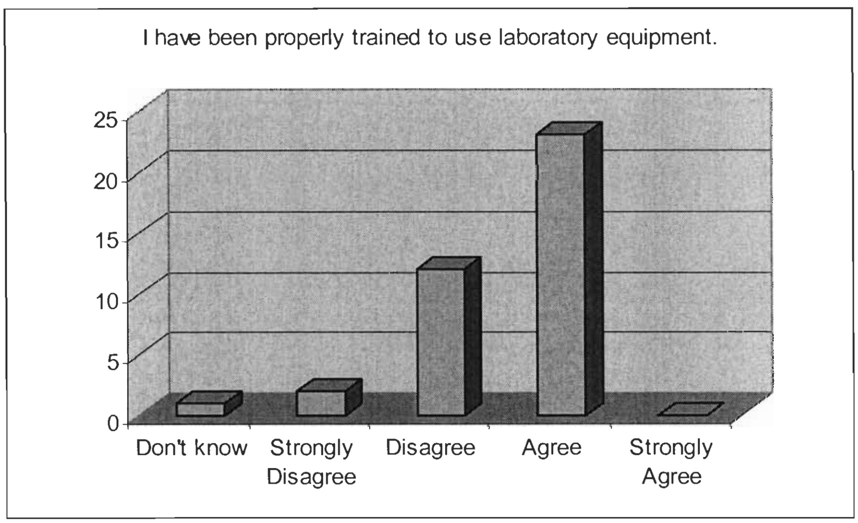

Figure 15: I have been properly trained to use laboratory equipment.

The consensus was that most students know the fastest exit route from the building in the event of a fire, as shown in Figure 16. However, Figure 17 shows most students have not been trained in the use of a fire extinguisher. Fire safety is an important part of lab safety and students should be trained in dealing with small fires that can be controlled with a fire extinguisher. Because exit routes are not explained to the students nor posted on the doors of the lab for reference, confusion can result in an emergency.

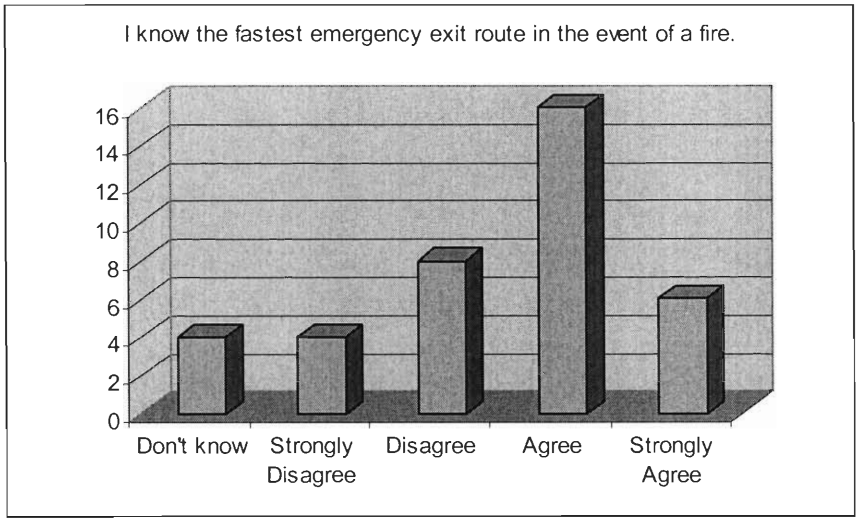

Figure 16: I know the fastest emergency exit route in the event of a fire.

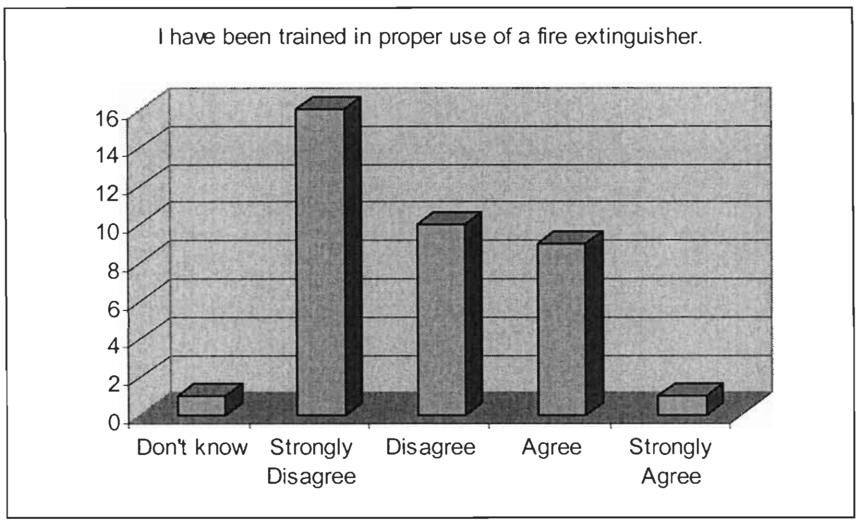

Figure 17: I have been trained in proper use of a fire extinguisher.

While Figure 18 shows that students overwhelming indicated that they know how to properly dispose of chemicals, this is not the case. The team observed students disposing of chemicals in the laboratory sinks and also combining waste in large containers. Section 5.2.3 also notes the waste disposal practices observed in the labs. In the older chemistry buildings where wastewater is not treated, chemicals may eventually contaminate water supplies. In the new science building, non-hazardous waste can be disposed of in laboratory sinks as the wastewater will be neutralized before leaving the building. Waste minimization is included in all chemical safety plans and is important for protecting the environment. Figure 19 shows that many students feel that they practice waste minimization techniques, which is accurate as the University has begun practicing micro-scale experiments in which only small amounts of chemicals are used.

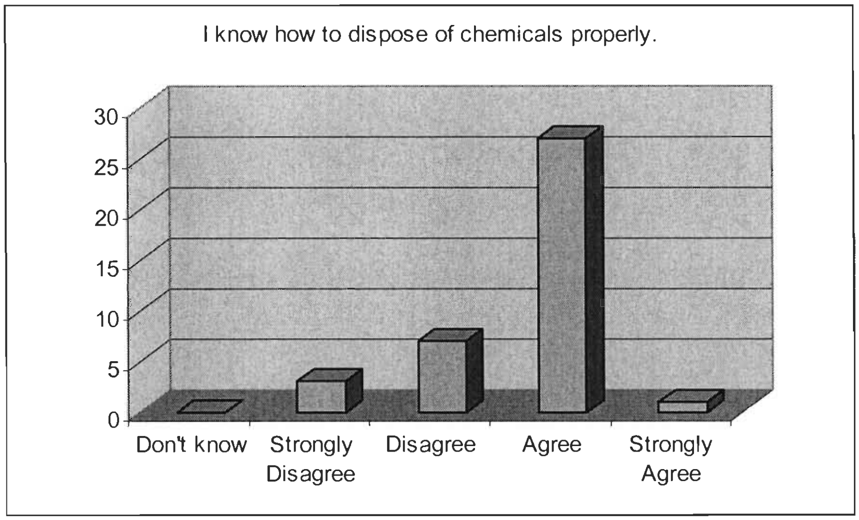

Figure 18: I know how to dispose of chemicals properly.

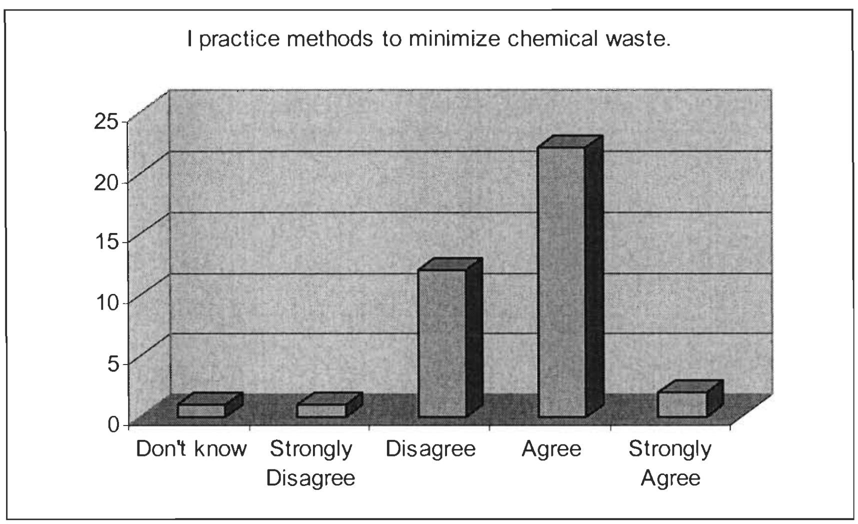

Figure 19: I practice methods to minimize chemical waste.

Most students do not know how to use a Material Safety Data Sheet, as shown in Figure 20. This is not ideal for students because Material Safety Data Sheets are important for protecting themselves and the people who work around them. Through the chemical safety plan, students at Chulalongkorn will be educated on how to locate and use Material Safety Data Sheets.

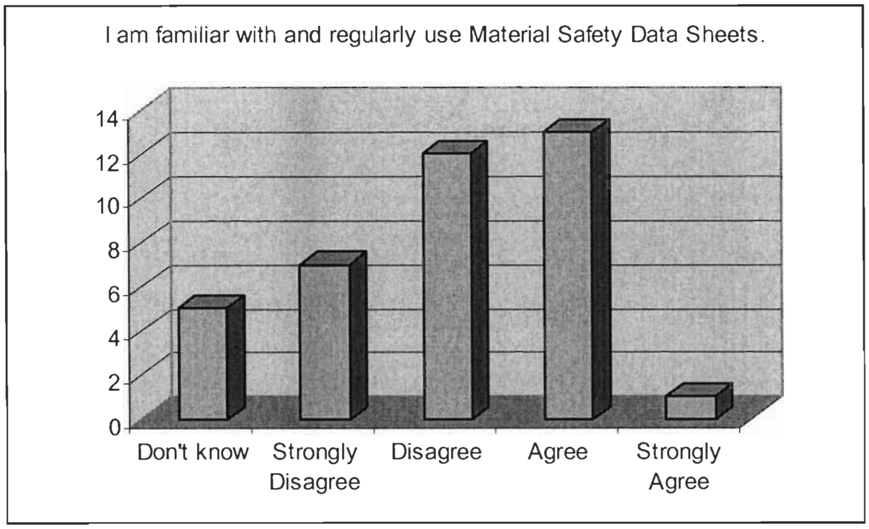

Figure 20: I am familiar with and regularly use Material Safety Data Sheets.

Most students know where eyewash and shower stations are located in the lab and are able to operate them, as shown in Figure 21. The figure also shows, however, that some students do not know where the equipment is or how to operate them. This is a serious situation because these stations are important aspects of safety and offer a means of dealing with accidents quickly and effectively.

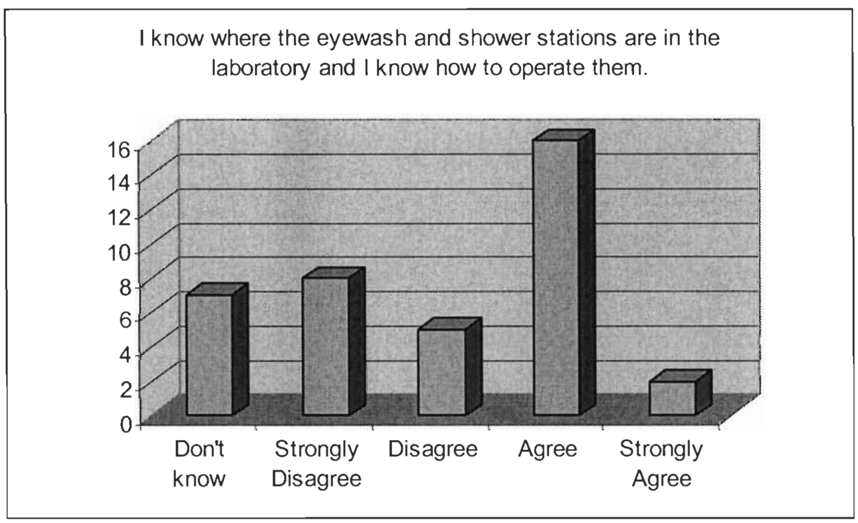

Figure 21: I know where the eyewash and shower stations are in the laboratory and I know how to operate them.

5.2 Evaluation of Current Conditions at Chulalongkorn

One of the objectives of this project was to evaluate the current chemical safety practices at Chulalongkorn University. In order to do this assessment, the team observed storage practices and laboratory safety practices. In addition, the team also constructed an approximate inventory of the chemicals in the Department of Chemistry. This section explains how these measures were instrumental in the creation of the safety plan for Chulalongkorn.

5.2.1 Analysis of Chemical Inventory

The inventory established by the team is only a partial inventory of the chemical stock at Chulalongkorn. As a result, an analysis of such an inventory cannot be thorough. As described earlier, the inventory was taken solely to identify uncommon chemicals so that appropriate recommendations could be included in the safety plan. The team was looking for chemicals such as mercury or benzene which require highly controlled lab environments. While the team did not encounter acutely toxic chemicals, these may exist at the University. Although some of the chemicals encountered in the chemical stock rooms are toxic, these chemicals are typical of those in organic laboratories. Some of these standard chemicals include hydrochloric acid, aniline, and sodium sulfate. The partial inventory of chemicals that the team constructed can be found in Appendix F. A toxic chemical is one capable of harming people or the environment, while an acutely hazardous chemical is very dangerous and often severe conditions develop quickly. Because the team discovered no acutely toxic chemicals in use at Chulalongkorn, the safety plan did not need to address special precautions at this time and the measures that are included are adequate. The means of handling the range of chemicals found at Chulalongkorn is addressed in the appendices of the Chemical Hygiene Plan, included in Appendix G.

If in the future the University obtains or discovers through the completion of a complete inventory that particularly dangerous chemicals, such as mercury or benzene, exists at the University, the safety plan will need to be adjusted to include specific storage, disposal, and use requirements for these chemicals. The storage, disposal, and use sections of the safety plan for particular chemicals would need to be adjusted to include pertinent information about these chemicals.

5.2.2 Analysis of Storage Practices

While composing the chemical inventory, the team also noted storage practices in chemical stock rooms. The storage practices at Chulalongkorn deviate from accepted standards both in the United States and in industrial practices in

Thailand. Chemical stocks were arranged alphabetically and this storage system allows for incompatible chemicals to be stored next to each other. These chemicals could interact and cause serious hazards and emergency situations. The stock rooms in the Department of Chemistry were cluttered with chemicals being stored both on the floor and on shelves. The chemicals that were stored on the floor were directly in front of the main storage shelves. To access the shelves, the chemicals on the floor needed to be stepped over or around. This storage of chemicals on the floor presents a tripping hazard that could result in serious injury or spills. If the chemicals that were spilled were incompatible, dangerous chemical interaction could occur causing explosions, harming vapors, or other serious hazards. Some of the containers in the stock rooms were labeled with chemical symbol and not the full chemical name. Using only the chemical symbol could lead to confusion about the contents of the container which in turn could result in adding a wrong chemical to a mixture. Some of the labels used on the containers were not the original label and consequently did not contain useful information such as associated hazards and concentrations that are included by the manufacturer on the original label. This information is essential for the proper use of any chemical.

Chulalongkorn University stores hazardous waste in two locations: inside Chemistry Building 3 and behind Chemistry Building 1. Photographs of these areas are included in Appendix D.3. Because the waste areas are in two separate locations, it is more difficult to monitor the condition of the accumulation area. In addition, security surveillance is more difficult when multiple areas are involved. The process of regularly inspecting the area is easier if the hazardous waste is one location. Because the waste storage areas are in high traffic zones of the buildings, students and staff could accidentally become exposed to dangerous material. Because the waste containers at Chulalongkorn are located outside, they might be subject to damage from adverse weather conditions, such as rain and extreme heat. Figure 22 shows containers behind Chemistry Building 1 that are corroded and leaking.

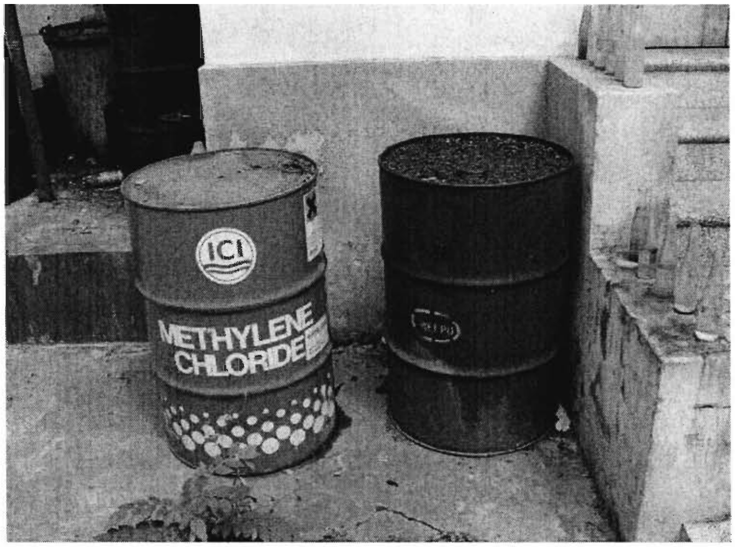

Figure 22: Waste Containers Exposed to Adverse Weather

Waste containers at Chulalongkorn are not organized by type. This practice could result in incompatible materials being stored in close proximity which presents the same hazards discussed previously with storage. Figure 23 shows the disarray of the waste storage areas.

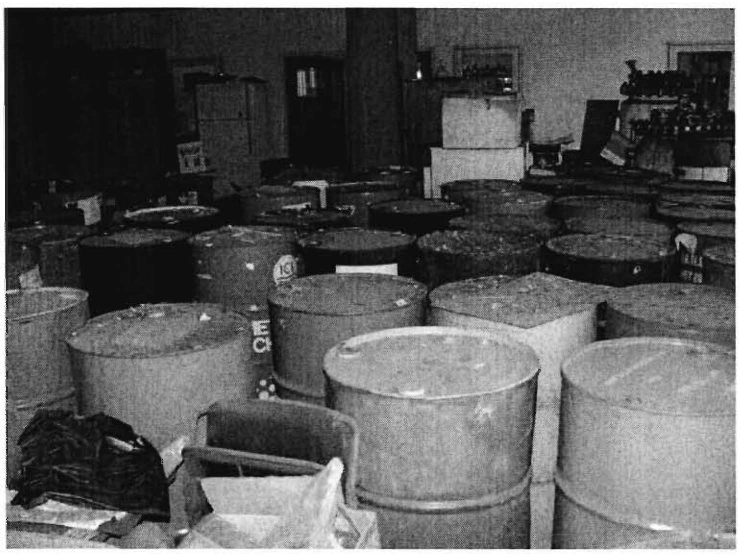

Figure 23: Waste Storage in Chemistry Building 3

As is evident in this photograph, there are no labels on the hazardous waste containers. In addition, many of the drums labeled as "methylene chloride," visible in both Figure 22 and Figure 23, have been reused and may not actually contain methylene chloride. Further, the date that these containers became full is not indicated. Because the waste is not labeled or dated, no one can be sure of the contents or age of the containers. The University may have trouble sending this waste to a disposal company because companies such as BYL require that the waste be identified on the container and on the Uniform Industrial Waste Manifest before pick-up.

5.2.3 Analysis of Laboratory Practices

On January 17, 2002, the team observed two Organic Chemistry laboratory sessions: one for first-year, non-chemistry majors, and the other for second-year, non-chemistry majors. The first lab that the team observed was the second-year laboratory course that was instructed by Dr. Surachai Ponpakakun. The team took photographs and recorded observations dealing with laboratory safety procedures performed by the students. Some photographs are included in this section, while others are located in Appendix D.4. The experiment that the students were performing involved the following chemicals: arabinose, glucose, fructose, maltose, sucrose, beta-naphthol, sulfuric acid, aniline, acetic acid, cupric oxide, hydrochloric acid, sodium hydroxide, sodium thiosulfate, resorcinol, rosaniline, hydrated copper sulfate, and sodium citrate.

Dr. Surachai's students were performing a qualitative, polysaccharides lab. The team observed how well students performed laboratory safety throughout the period. Some positive actions performed by the students included labeling their test tubes, wearing lab coats, wearing closed-toe shoes, male students wearing long pants, and using forceps to remove hot test tubes from beakers.

The team observed a number of deficiencies in the student's safety practices as well. These flaws can be broken down into a number of categories: general awareness, storage, waste management, and personal protective equipment. The students did not appear to be aware of their surroundings while in the lab. As stated in Section 2.5.3.4, awareness is the most fundamental principle of safety. Some examples of a lack of awareness were Bunsen burners left unattended while liquids boiled over them, and students walking through the lab while carrying chemicals with their heads down, not watching where they were going. Figure 24 shows a student who has turned her back on a Bunsen burner with chemicals boiling over it.

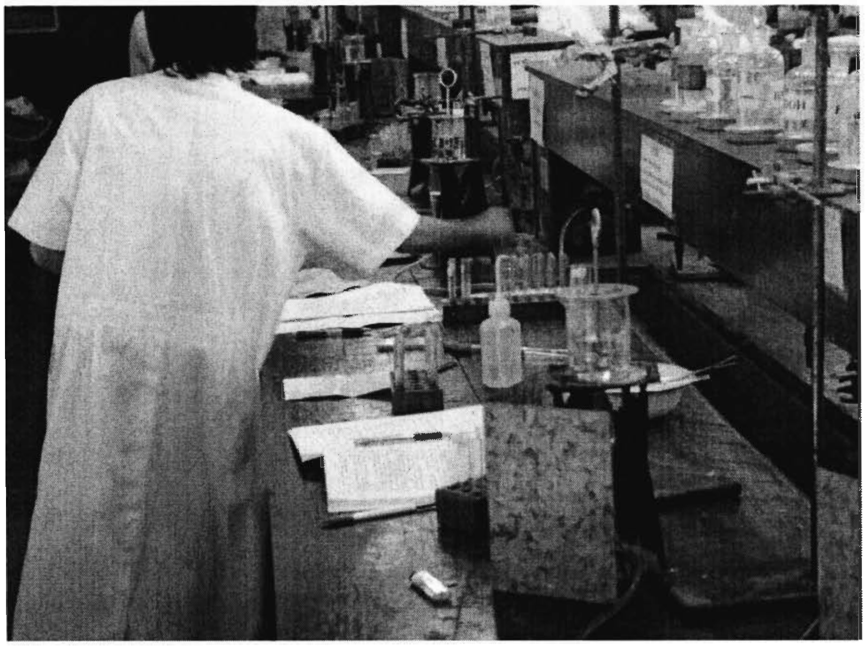

Figure 24: Lack of Awareness

The students also worked in a cluttered environment often putting all of their belongings on the bench top where they were performing their experiments, as shown in Figure 25.

Figure 25: Cluttered Work Environment

This not only interferes with the experiment, but risks contamination of their belongings. Because Bunsen burners were used in this lab, the items on the bench top could have caught fire. In addition to keeping belongings on their bench, many students left their belongings on the floor. These articles would be a fire hazard in the event of an emergency and would prevent rapid egress from the building. One student answered his mobile phone and carried out a conversation while still performing an experiment. Many other students ran through the lab carrying beakers and test tubes and some were engaged in horseplay while in the lab: for example, joking around and literally hitting one another.

The team also observed problems with storage procedures of chemicals. A number of the stock bottles for the class were labeled with the common name of the chemical rather than the full chemical name. Also, some of the stock bottles were left in an open area on a shelf, which creates a hazard because the bottles are made of glass. The stock bottles had corks in them, which is dangerous because the cork will absorb the chemical in the bottle. If these bottles were reused, the absorbed chemicals could interact with the new contents of the bottle.

Another important aspect of a safe lab environment is proper waste management. In this lab, one of the waste containers was visibly steaming, indicating a potentially dangerous chemical reaction. There was a fan located by the hazardous waste containers, which circulated the hazardous fumes into the room. Waste containers were left open for the duration of the lab. This is dangerous because fumes were escaping from the containers. Also, the containers could be easily knocked over and spilled. The waste containers were stored on newspaper which is not sufficient for containing a spill. The newspaper can absorb many chemicals and the paper could easily catch fire. These hazardous conditions are shown in Figure 26.

Figure 26: Waste Containers at Chulalongkorn

The students were also observed dumping waste chemicals used in their lab down the drains of laboratory sinks. The wastewater from these buildings is not treated before it is released and could potentially enter the water table and contaminate drinking water in the city. Figure 27 shows a student disposing of chemicals in a sink.

Figure 27: Student Dumping Chemicals down the Drain

The students did not always use proper Personal Protective Equipment. As discussed in Section 2.5.3.4, Section 2.5.5, and Section 2.5.6.1, PPE is in integral part of lab safety; examples of PPE are lab coats, eye protection, latex gloves, etc. All of the women were wearing skirts, which is the dress code for CU. As pointed out previously, one of the means of contamination by chemicals is contact with the skin, for this reason it is considered a safe practice to minimize the amount of exposed skin while in the lab by prohibiting skirts, short pants, and open shoes. Chemical spills could splash on the student's legs and/or feet causing serious bodily harm. Also, individuals with long hair did not have it restrained or tied back; it is advisable to do so because the hair could get into chemicals or the flames of Bunsen burners. When asked what he thought the most important piece of PPE in the laboratory, Dave Messier, the Safety Manager at WPI, told the group it was eye protection. Although many of the students were wearing prescription glasses, only four or five of them were wearing safety goggles. Prescription eyeglasses are not sufficient eye protection, as the lenses are too small, they do not have side shields, and are often not shock resistant. In addition, contact lenses should never be worn in the laboratory. Even if proper eye protection is worn, there is the chance that harmful chemicals may come in contact with the eyes, possibly in vapor form, and contact lenses may trap the chemical between the lens and the eye, preventing it from being washed out, and thus causing more damage. No one in the lab was wearing gloves, which is advisable considering the chemicals being used.

Some students displayed a lack of laboratory safety knowledge that is widely accepted in safety conscious international organizations as common practice. While washing out test tubes in the sink, one student dumped the chemicals in the test tubes onto her hands, potentially exposing herself to a harmful substance. Another student lit a Bunsen burner with a lighter instead of a striker or matches which are generally recommended. Lighters are not recommended because they are less efficient and add flammable gas to the environment around the Bunsen burner creating a dangerous situation. There were also unmarked squeeze bottles and spray bottles on the lab benches. This is dangerous because a student or faculty member may be unaware of the bottle's contents, and potentially mix two incompatible chemicals. Students were also seen pouring chemicals from stock bottles into test tubes without using a funnel, which may lead to a chemical spill. These practices are all related to a lack of awareness of the hazards involved with the chemicals in the laboratory.

The second lab session that the team observed was the first-year lab course instructed by Dr. Polkit Sangvanich. The subject of the lab was Organic Chemistry and the students were attempting to identify unknown elements through a series of experiments. A partial list of chemicals used in this experiment is as follows: carbon tetrachloride, silver nitrate, nitric acid, ferrous ammonium sulfate, potassium fluoride, and acetic acid.

As with the second year students, the first year students exhibited a number of improper lab practices. In this lab, Bunsen burners emitted huge flames and were often left unattended for long periods of time. The cluttered work environment and the unattended, unnecessarily large flames presented a fire risk. As with Dr. Surachai's lab, many students ran through the lab carrying beakers and test tubes.

In the lab, the students disposed of chemicals in the sinks. This presents a particular hazard in Chemistry Building 1 because of the very old drainage system in the laboratory. Every sink drains into a trough that runs along the floor and ultimately into the sewer system. The trough is covered with a wooden grate, which may absorb many different chemicals. In some sections the wooden grate has deteriorated, presenting a walking hazard. Also, residuals of harmful chemicals may remain in the troughs, mixing with other chemicals, and potentially creating harmful vapors.

Similar problems with personal protective equipment appearing in the first lab were also observed in this lab. The women in this lab wore skirts, and did not have their hair restrained despite the use of Bunsen burners. Approximately 80 percent of the students in this laboratory were wearing safety glasses. While this is an improvement from the previous laboratory every student should practice eye protection techniques.

A comparison of these two laboratory sessions suggests that more first-year than second-year students used proper personal protective equipment. The observed trend indicates that as students become more comfortable in a lab setting, they may neglect fundamental safety measures.

It is important to note that the poor safety practices exhibited by the students do not reflect directly on the quality of the professors and instructors, but rather indicates that the faculty and students have simply never been exposed to the type of regulation and safety policies that other countries and industry in Thailand have adopted and strictly enforce. Chulalongkorn University does not currently have a written safety policy, which is the primary goal of this project. Although some professors that are particularly safety conscious and often those that were educated in settings where lab safety is heavily regulated may attempt to enforce certain safety practices, it would be very difficult to do so without administrative enforcement from the University, for example from the Dean of Students or the President of the University.

5.2.4 Analysis of Fire Safety Equipment

Fire safety equipment is a significant part of a safety plan. The fire safety measures already in place on each floor of the new science building are important features of any building. On each floor, there are two fire safety stations: each contains a fire hose reel and a chemical fire extinguisher, or type ABC extinguisher, which will extinguish most types of fires. The fire safety stations are centrally located in the hallways: one directly in front of the stairwell and one behind the stairwell, near the south wall. While the current fire safety stations will provide protection for the hallways and the stairwell, the likelihood of a fire occurring in the laboratories is far higher due to the flammable, combustible, and reactive nature of the chemicals that may be present. Fast reaction time is crucial to controlling a fire, and the time taken to retrieve a fire extinguisher from one of the hallway stations may result in the fire spreading out of control. Further, the fire may block the exit to the hallway, trapping the lab worker inside. Since there is no sprinkler system installed in the building there should be more emphasis on storing fire extinguishers in each laboratory as a precaution. It should be noted that a sprinkler system is not necessarily the best fire suppression system for a chemical laboratory system, due to the possible water reactive properties of some chemicals. Also it is important to consider that at the time of this writing, the building is not yet complete and is not currently in use; this may explain the lack of fire extinguishers in the laboratories.

The new science building features two emergency fire escape stairwells equipped with fans to remove smoke. To facilitate rapid escape from the building in the event of an emergency, emergency lighting has been installed in the stairwells and signs pointing to the fire escape stairways have been hung in the hallways. Signs and lighting will aid occupants during their exit from the building. At the time of this writing, emergency lighting has not been installed in the hallways or laboratories. If the building were to lose its power supply, the occupants would be forced to navigate dark hallways and laboratories to find the escape routes and only after reaching the stairwells would occupants have a lighted path to follow to an exit.

5.2.5 Analysis of Waste Generation

Dr. Supawan provided the team with information regarding the waste generation of Chulalongkorn. The Department of Chemistry has recently adopted micro-scale chemistry experiments in its labs. The result of these experiments is that considerably less waste is produced. In addition, Chulalongkorn does not produce waste with high toxicity, which is another factor in determining the size of the generator in Massachusetts. Finally, because Chulalongkorn does not have means to dispose of its hazardous waste, the team determined that it would be appropriate to recommend that Chulalongkorn store its waste for longer periods of time. If more waste is allowed to accumulate, companies such as Genco or BYL Environmental Services may be more inclined to assist Chulalongkorn with its waste disposal needs as it would be more financially feasible for such companies to dispose of waste in large quantities. Based on this information, the team classified Chulalongkorn as a small quantity generator for the purposes of this safety plan.

5.3 Safety Management in the New Science Building at Chulalongkorn University

The culmination of the project team's research and data analysis is a complete safety plan for the new science building for the Department of Chemistry at Chulalongkorn University. The safety plan, which is included as Appendix G, consists of the following components:

- Statement of Purpose
- Chemical Hygiene Plan
- Waste Management

The safety plan also contains other documents that will act as supplements to the safety plan, such as Material Safety Data Sheets, reference laws and regulations, and a condensed "Golden Rules of Lab Safety" for quick reference. The group expects that this plan will serve as a model to other universities in Thailand and other developing nations.

Because laws and regulations in Thailand do not apply to universities, and further, laws set forth for industry are often inadequate and not enforced, many industries and organizations utilize standards set forth by foreign agencies, such as United States Environmental Protection Agency and European Union standards. Because of this, the chemical safety plan is advised by United States laws and regulations where applicable.

By evaluating plans from other institutions along with the current safety practices employed in the Department of Chemistry at Chulalongkorn University, the team designed a safety plan that is tailored to its needs. All of the data the team has collected contributed to a comprehensive safety plan for the Department of Chemistry, which the team anticipates will improve safety practices followed in the Department of Chemistry when the new science building is used.

The Chemical Hygiene Plan (CHP) that has been provided to the Department of Chemistry is a written plan designed to protect laboratory workers from health hazards related to chemicals. The CHP for the Department of Chemistry is a general document applicable to any chemistry lab in the new science building. Modeled after the plans discussed previously in Section 4.1.1, the CHP contains the following elements:

1. Standard Operating Procedures for the use of hazardous chemicals.
2. Criteria for determining and implementing control measures to reduce exposure.
3. Measures to assure proper functioning of fume hoods and other engineering controls.
4. Provisions for employee information and training.
5. Circumstances under which a laboratory operation or procedure will require prior approval.
6. Provisions for medical consultation and examination.
7. Designation of responsible personnel, including the Chemical Hygiene Officer.
8. Provisions for particularly hazardous substances.

Another essential piece of this comprehensive safety plan for the Department of Chemistry is a Hazardous Waste Management Plan (HWMP). The HWMP is aimed at isolating hazardous materials from the environment, storing them properly, and ensuring that they are disposed of in a safe manner. The Hazardous Waste Management Plan contains the following sections:

1. Hazardous Waste Determination
2. United States Environmental Protection Agency Identification Numbers
3. Temporary Accumulation of Hazardous Waste
4. Waste Storage Pending Off-Site Disposal

5. Waste Packaging
6. Labeling
7. Disposal Management
8. Waste Minimization
9. Training
10. Record Keeping and Reporting
11. Emergency Preparedness and Response

The safety plan, included as Appendix G, and the implementation framework, detailed in Chapter 6, for the new science building provides the Department of Chemistry with the tools necessary to overhaul the current practices at Chulalongkorn.

6 Recommendations and Implementation Framework

In addition to providing Chulalongkorn University (CU) with a comprehensive safety plan, it is a goal of the project team to also provide the University with a guide with which to implement it. After researching common practices in chemical safety, interviewing experts in the field of chemical safety, and observing current chemical safety practices in the Department of Chemistry at Chulalongkorn University, the team has created a list of recommendations for the University. These recommendations will serve to improve the awareness and actual chemical safety practices at the University.

The project team divided the ultimate adoption of the complete safety plan for the new science building into three phases. The determination of when a change should take place at CU was made by considering budget, availability of resources, ease of adjustment, and overall importance to safety. It is recommended that the starting point for implementing the safety plan be the opening of the new science building. The project team recommends this date because the new building has many more resources and safety controls installed in it, such as fume hoods, drench showers, and more work space. Both the project team and the Chulalongkorn faculty expect that the new, modern building will offer a fresh start and a new point of view concerning safety.

The first phase of implementation includes both essential safety improvements as well as changes that are easy to initiate. The vital changes include incorporating Standard Operating Procedures (SOP) in everyday lab practices in the new science building. Another important change that must be made is that professors require students to become familiar with Material Safety Date Sheets (MSDS) in order to raise awareness of the potential dangers of the chemicals used in the lab. Safety elements such as Personal Protective Equipment (PPE) should also be embraced by the Department of Chemistry when the new science building opens. PPE is included in the first phase because it is important to the protection of students and requires only minimal budget consideration. The first phase will begin to take effect when the students begin laboratory classes in the new science building.

Planning for the second phase should begin immediately, but complete compliance with its policies is not expected until the first phase is satisfactorily in place. The elements of the second phase involve more planning and budget considerations than the first phase. This phase includes providing each lab in the new science building with a complete copy of the Chemical Hygiene Plan (CHP) as well as establishing a "cradle-to-grave" protocol for dealing with chemicals.

The final phase of implementation includes features that require significant financial investment as well as considerable amounts of time to establish. As with the second phase, planning for these facets of safety, which include the creation of a Main Accumulation Area (MAA) and a Chemical Safety Office, should begin immediately. These changes are long-term goals that will take a lengthy time to complete, but are essential to finalizing the implementation of the safety plan.

In addition to these three phases, there are factors which must be considered throughout the course of implementing the safety plan. These topics include both educating the faculty and students regarding chemical safety and methods to encourage compliance with the new procedures set forth. These changes should be considered throughout the implementation in the new science building as they serve to unify the elements of the safety plan.

The timeframe that the project team recommends is in no way binding; there will certainly be overlap of the different phases, but it serves to build a solid foundation from which to implement the safety plan. The faculty of the Chemistry Department will ultimately determine the speed with which the safety plan is implemented in the new science building.

The safety plan that the team developed for Chulalongkorn is able to serve all science labs at the University; however, by first implementing the plan in the new science building, the Department of Chemistry will be leading the initiative for safety. As the Department of Chemistry gradually implements the safety plan, the rest of the Faculties on the campus should follow.

6.1 Phase One

The project team recommends that the changes in the laboratory practices in the new science building at Chulalongkorn described in this section be implemented immediately as the team believes that they are crucial to the safety of the students and lab workers and because of their ease of implementation. The first phase of implementation focuses on changes that must take place in order to pave the way for further development of the safety plan. These topics include components of the

Chemical Hygiene Plan which contain the basic principles of safety such as Standard Operating Procedure and Personal Protective Equipment.

6.1.1 Chief Safety Officer

The first step that the University should take is the appointment of a Chief Safety Officer (CSO) to direct the effort of implementing the safety plan and a Safety Committee to support him or her. Selection of a Chief Safety Officer is imperative so that there is a person responsible for managing the safety budget, maintaining the safety plan, educating the faculty and students, and enforcing the rules. The CSO must be aware of the many hazards associated with academic and research laboratory settings. The Department of Chemistry has already appointed Dr. Surachai Ponpakakun to act as the CSO while the safety plan is in its developing stages. He is not expected to be able to handle all of the responsibilities that were set forth during this early stage, but he should be responsible for ensuring that the recommendations put forth in this section are implemented as soon as possible.

6.1.2 Chemical Hygiene Plan

In many ways the Chemical Hygiene Plan (CHP), which is included in Appendix G, is the most important piece of the overall safety plan, as it provides the most basic guidelines for remaining safe while working in the lab. For this reason, implementing several parts of the CHP is a large part of the first phase. The document itself should be read by the entire faculty as they try to familiarize themselves with the new safety policies.

6.1.2.1 Standard Operating Procedures

The Standard Operating Procedures (SOP) set forth in Section 2 of the Chemical Hygiene Plan are an integral part of lab safety. The SOP should be implemented immediately in order to protect the students and faculty from accidents and hazards. This piece of the safety plan is included in the first phase of the implementation framework because it does not require purchasing any new materials or equipment; the only change is in the attitudes of the students and faculty. Both faculty and students must keep the SOP in the forefront of their minds while working in the lab, until it is a habit. It is suggested that each student be given a copy of Section 2.1, General Safety, and Section 2.2, Personal Health and Hygiene, in a condensed form. This should be done so that each student may have constant reference to the most important safety practices while in the lab.

6.1.2.2 Personal Protective Equipment

Practicing the SOP will significantly reduce the likelihood of an accident in the lab; however, Personal Protective Equipment (PPE) is one measure that will also keep hazardous materials from contacting lab workers. Chulalongkorn University should make the proper PPE available to students and faculty who are working in the lab.

6.1.2.2.1 Eye Protection

Eye protection is one of the most fundamental components of Personal Protective Equipment. Prescription eyeglasses are not sufficient eye protection, and contact lenses should never be worn in the laboratory. Even if proper eye protection is worn, there is the chance that harmful chemicals may come in contact with the eyes, possibly in vapor form. Contact lenses may trap the chemical between the lens and the eye, preventing it from being washed out, and thus causing more damage. For these reasons, the CSO in conjunction with the Safety Committee should select a type of eye protection that will fit over prescription eyeglasses, is made of impact resistant plastic, and has adequate side shielding as the minimum standard. Once this minimum standard of eye protection has been established, a suitable distributor should be found and the University should purchase enough safety glasses to keep an adequate stock in the campus bookstore. It is the decision of the University to offer a variety of eye protection, such as goggles, to students that prefer more than the minimum amount of protection.

BYL Environmental Services has provided many useful contacts that Chulalongkorn could use to obtain donations of lab supplies, such as safety goggles, latex gloves, and disposable tissues. 3M has often in the past donated safety goggles for charitable purposes, which would alleviate the financial burden of supplying safety goggles for all of the students. The Department of Chemistry should contact BYL as soon as possible to initiate the relationship between 3M and Chulalongkorn.

6.1.2.2.2 Lab Clothing

Chulalongkorn University students and lab workers already wear lab coats, which are another important element of PPE. The lab coats should be kept at the

University rather than brought home by the students because doing so could carry contamination outside the laboratory. It would be in the best interest of safety for the University to institute a laundry service for cleaning the lab coats. Because this may be a considerable expense, the responsibility for cleaning the coats may be left to the students. Also, the University should invest in enough rubber aprons to equip at least one lab, perhaps 30 to 40 which is the average lab size. These aprons are very heavy and offer a far greater degree of protection from chemicals that may cause serious damage to the skin. At a later date, a greater number of lab coats may be purchased to accommodate more laboratories.

While observing the laboratories in Chemistry Building 1 and Chemistry Building 3, the team noted that the female students were wearing skirts. While it is understood that skirts are part of the female uniform, the project team advises that wearing them is an unsafe laboratory practice, as it leaves the lower legs exposed to possible chemical spills. Ideally, each laboratory could offer female students a pair of loose pants, equivalent to hospital pants, which they may wear over or under their skirt. More feasibly, the team suggests requiring female students to wear long skirts during lab classes. Longer skirts would still adhere to the dress code at Chulalongkorn and also offer more protection for the students' legs. The team also noticed that many individuals had unrestrained long hair which could easily interact with lab equipment or chemicals. The lab instructor should not allow individuals who have not tied back their long hair to work in the lab, as it is an unsafe practice that can be easily avoided.

6.1.2.2.3 Disposables Laboratory Accessories

CU should also purchase latex or rubber gloves and disposable tissues for the labs on campus as soon as possible. The gloves will offer protection from hazardous materials coming into contact with the skin, and they may be disposed of after use. However, since gloves result in less sensitivity when holding test tubes, and in some cases may trap a chemical on the skin in the event of a spill, they are only recommended for mandatory use with particularly dangerous chemicals. Disposable tissues are not necessarily considered part of PPE, but are very important to cleanliness. These wipes are lint-free, chemical-free, and absorbent. Of course one must note that while the tissue alone is non-hazardous, should it contact hazardous material, it must also be considered hazardous waste, and disposed of appropriately.

Through contacts provided by BYL Environmental Services, the team has identified Kimberly-Clark, manufacturer of the well known brand of disposable laboratory wipes Kimwipes™, as a possible source of free, disposable wipes for Chulalongkorn. Also, Safe Skin would be able to provide Chulalongkorn with latex gloves free of charge. It is important to note that Dr. Yoel from BYL is confident that these companies will be interested in assisting with Chulalongkorn's safety initiatives; however, these companies should be contacted for confirmation and discussion. Again, a relationship with BYL Environmental Services should be established as soon as possible.

6.1.2.3 Material Safety Data Sheets

Material Safety Data Sheets (MSDS) offer important information concerning the hazards associated with a particular chemical. The lab instructor should review MSDS for all chemicals to be used in an upcoming lab and prepare any necessary hazard controls accordingly. If a material is hazardous (flammable, reactive, corrosive or toxic) then the lab instructor should require that each student review the MSDS for those chemicals before coming to the lab session. In order for the student to become familiar with the MSDS, it is suggested that as part of a pre-lab preparation, the lab instructor ask questions that must be answered and turned in before the lab begins. Examples of possible questions include:

- What is a PEL?
- What is the PEL for Chemical X?
- What is the flashpoint of Chemical Y?
- What hazards are associated with Chemical Z?

If a student fails to do the assignment or does poorly, the professor may want to require the student to redo the assignment. Another option to having the students answer questions about an MSDS is to have the students record in their pre-lab assignments information pertaining to the chemicals that will be used in the lab that day. The group has located two online sources of MSDS in English, one in both English and Thai, and one provided by the University which is only in Thai:

- http://hazard.com/msds.index.php (English)
- http://www.ilip.com/msds/index.htm (English)
- http://chemtrack.trf.or.th/ (Thai and English)
- http://www.sc.chula.ac.th/msds (Thai)

It is also recommended that the lab instructor make the MSDS available in the lab for reference purposes.

6.1.3 Accident Reports

Accident reports are a fundamental component of a thorough safety plan. Reports will help the Department of Chemistry determine the parts of the safety plan that need improvement. Reports are also instrumental in determining why accidents have occurred and also help establish means to prevent similar accidents from happening in the future. The purpose of an accident investigation is to locate the cause of an accident to prevent recurrence rather than to place blame on any individuals. The accident form should be completed by the individual supervising the lab as well as the person involved in the accident. The form itself should contain the names of the individuals involved, background information on the accident, an account of the accident, an analysis of the accident, and recommendations for immediate and long-range action to remedy the causes. The form should then be submitted to the Chief Safety Officer to keep on file for future reference. The form is located in Appendix D of the Chemical Hygiene Plan.

In addition to filing the reports, the Chief Safety Officer should also issue safety advisories to faculty in the Department of Chemistry in order to make them aware of accidents. The safety advisory should highlight the incident *what happened*, review its cause *why did it happen*, and suggest ways to prevent future occurrences *how can similar occurrences be avoided*.

6.2 Phase Two

Once the first phase of adjustments has been set in motion, the Department of Chemistry can change its focus to reaching a new set of goals. Once the first phase is underway, the faculty and students should begin to adjust to the new way of operating in the lab, thus facilitating the second phase goals. These goals include methods to adopting protocol which manages a chemical from its origin to its ultimate disposal.

6.2.1 Chemical Safety Information

The project team recommends that each laboratory contain the Chemical Hygiene Plan portion of the safety plan in order to have constant reference to the SOP and other important elements of safety as soon as possible. Within one year of adopting the safety plan, each lab in the new science building should possess a complete copy of the chemical safety plan. The safety plan should be kept in a binder which is organized by both the CSO and the Safety Committee. Each binder should contain:

1. Chemical Hygiene Plan and its appendices
2. Hazardous Waste Management Plan
3. Written Hazard Communication Program
4. A list of chemicals stored in the lab
5. Appropriate MSDS
6. Any safety information specific to that lab

As the second phase of implementation begins, each lab should have all pertinent safety information, not just the minimum required for the first phase. The difficulty of this task arises from the need to amass MSDS as well as specific safety information for each lab. An example of such specific information is a petrochemistry lab that may contain large quantities of very flammable or combustible chemicals that require special storage. The additional safety information that is necessary, such as specialized emergency response, would be added to the safety plan by the faculty member responsible for the lab.

6.2.2 Chemical Preparation, Maintenance, and Disposal

Once the students and faculty have begun to comply with the regulations and standards of the safety plan, the CSO and the Safety Committee can begin to take the necessary steps to properly use and improve the facilities in which they work. The following sections essentially follow a chemical from the preparation process through disposal.

6.2.2.1 Chemical Preparation and Stockroom

Once the labs in the new science building are actively being used for research and teaching, the chemicals in the labs should be stored in a centralized location within the building. This is recommended for any building containing a laboratory facility. Chemicals that are ordered in bulk or for special experiments will be kept in Chemistry Building 1, to limit the amount of chemicals in the new science building. Hazardous waste storage will also be in Chemistry Building 1. A room has already been chosen in the new science building to serve as a temporary storage and preparation area. The door that leads to this room should state the hazards associated with the chemicals present in the room. The National Fire Protection Association (NFPA) diamond is an internationally recognized symbol for identifying chemical hazards, specifically health hazards, fire hazards, reactivity, among others. The project team has provided the Department of Chemistry with a sample NFPA sign, as well as a hazardous waste advisory sign.

In order to furnish this room properly, the Department of Chemistry should purchase engineering controls in order to properly store hazardous materials, for example ventilated cabinets for holding acids, bases, flammables, combustibles, and corrosives. In addition to marking the door to the storage area, the individual cabinets should be similarly labeled with the hazards contained therein. Due to the wide variety of chemicals, and thus the wide variety of hazards, present in this room, proper fire protection measures should be taken. Fire suppression systems for the different types of fires that may occur should be made available, for example, dry chemical extinguishers, and Metal X extinguishers.

Since the room will also be used as a preparatory room for chemicals and containers, there should be bins or cabinets for dirty or used containers, so that they can be separated from containers that are ready for use. Also a container for broken glass should be clearly marked, so that it does not pose a safety risk. The water from the sinks in this room should be, if possible, routed through the chemical neutralizing system that has been installed in the building.

This room may also contain a Satellite Accumulation Area, where hazardous waste can be temporarily stored, but should not be used as a Main Accumulation Area for permanent storage of hazardous waste hazardous waste.

6.2.2.2 Storage and Labeling

Proper storage of chemicals both in the new science building and in the old chemistry building will be a large undertaking. Nevertheless it is important enough to warrant consideration in this phase. While most of the chemicals are expected to be stored in the central chemical stockroom, it may be necessary to store some chemicals in the laboratories where they are frequently used. If hazardous materials are to be stored permanently in a laboratory then the door to that laboratory should list the hazardous materials contained therein. Also, the lab should contain proper controls for containment of the materials.

Both chemicals stored in the main stockroom and those stored in the individual laboratories must be segregated by hazard. While some may warrant special storage containers, such as cabinets for flammables, many may not. These chemicals should be stored in cabinets or shelf systems that allow for separation by hazard. For example, acids should not be stored in close proximity with bases, or bromine should not be stored with acetaldehyde, alcohols, or alkalis, among others. Other incompatible chemicals are listed in Appendix A of the CHP, found in Appendix G of this document. As with the specialized storage cabinets, a list of chemicals stored in a cabinet should be posted on the cabinet door.

Most of the chemicals used by Department of Chemistry are in their original containers, but many containers have been reused. While this is an acceptable practice, it may result in improper labeling if not done accurately. Once a container has been emptied, it should be thoroughly cleaned and all labels should be removed before refilling. A new standard label should be placed on the container stating the chemical name (for example, "sulfuric acid") and, if possible, the chemical formula (for example, "SO_4"). Also, the label must state the hazards associated with the chemical. It is imperative that the Department of Chemistry begin the process of replacing all of the labels on its chemicals as soon as possible so that they may be identified and handled safely. The project team has provided the Department of Chemistry with a sample label.

The Main Accumulation Area (MAA) should be determined as soon as possible. The Chemistry Department has chosen Chemistry Building 1 as the desired location, but has not at the time of this writhing selected a specific room. While it may not be up to the ideal standards for an MAA as set forth in the safety plan, designating the area early will allow for all of the hazardous waste to be stored and maintained in one area, allowing for easier monitoring. The Hazardous Waste Management Plan (HWMP) states that hazardous waste cannot be stored for more that 180 days in the MAA because dangerous situations may arise as certain wastes begin to break down and form more dangerous chemicals. Waste disposal is discussed later in Section 6.2.2.4. The Department of Chemistry should attempt to adhere to this regulation as soon as possible.

Satellite Accumulation Areas (SAA) throughout the new science building, and ideally throughout campus, should be recorded, and listed in Appendix A of the Hazardous Waste Management Plan. The HWMP requires that once a container is full it must be moved within three days from the SAA to the MAA. Methods for transporting these chemicals are discussed in Section 6.2.2.3.

Also within a one year period the Chief Safety Officer (CSO) should have implemented the SAA and MAA inspection process as outlined in Sections 1.4.1.2 and 1.5.1.1 of the HWMP, using the forms provided in Appendix B of the same document. These inspection forms should be posted in close proximity to the SAA, or near the door of the MAA. It is understood that a regulation MAA may be difficult and expensive to build, so the CSO is expected to take whatever precautions possible with the resources available.

6.2.2.3 Transportation

Since the Main Accumulation Area is not located in the new science building, special considerations should be made for transporting hazardous materials across campus. Only small amounts of material should be transported at one time and all the containers used for transportation of hazardous materials should be tightly closed and undamaged. Breakable containers should be placed in a secondary container and loaded into the vehicle so that they will not shift during the transportation. The easiest means of transporting chemicals across campus would be by handcart. This method is feasible as the cost will not be much. A simple steel handcart with a wide base could be used to transport hazardous materials across campus. Another option for the Department is a motorized vehicle with placards denoting the hazards located within the vehicle as well as flashing lights that serve as a warning to individuals nearby. Such a vehicle would be significantly more costly for the University, but may become a feasible option in the future.

Even though the chemicals need only travel a short distance (approximately .5 kilometers), there is heavy pedestrian and automobile traffic in the area that must be considered. Separate trips should be made if the chemicals to be transported are two or more highly reactive materials or incompatible materials. In addition, the people who transport the material must be trained how to handle an emergency.

Ideally, hazardous waste containers should be removed from an SAA within three days of becoming full. In order to insure that this happens, when a container is reaching capacity, the professor should inform the CSO that a pickup will be needed. Since this is a new approach to waste disposal, the Chief Safety Officer may initially need to inspect labs on a regular basis for full or nearly full bottles that should be transported to the MAA. This way he can remind the professor to call him when a container reaches capacity.

6.2.2.4 Waste Disposal

Waste disposal is an important facet of chemical safety. The Department of Chemistry at Chulalongkorn does not currently use the services of a waste disposal company. Because of this the team recommends that the Department work with a company such as Genco to arrange chemical waste disposal. In order for Genco to participate, the Department of Chemistry must package and separate its waste appropriately to facilitate Genco's waste pick-up. In a discussion with Genco, the project team suggested a collaborative pick-up of waste from universities in close proximity to Chulalongkorn, such as Mahidol and Bangkok University. Tanong Promma, a Public Relations Manager at Genco, seemed receptive to this suggestion, alluding to the idea that Genco will be more likely to work with universities if it is easier for the company to pick-up waste. In order for Genco to handle Chulalongkorn's waste, the University must provide a sample of the substance to be disposed of to Genco and complete a Uniform Industrial Waste Manifest form as well as a Waste Profile form as found in Appendix I. The University must decide where the Manifest form will be filed and who will be in charge of this aspect of recordkeeping. Substances that can be resold or reused by Genco would be disposed of at no charge to the University. Interviews with members of the academic and industrial communities indicated that Genco cannot handle the full range of waste that the Department of Chemistry will create in a manner that is ecologically sound.

The team specifically recommends the services of BYL Environmental Services to the Department of Chemistry for their waste disposal needs. BYL Environmental Services is not only a waste disposal company but also an environmental consulting firm that specializes in providing advice to its customers and waste disposal through subcontractors. BYL is also well connected in various industries which could result in advice on how Chulalongkorn can obtain free safety equipment and training for its faculty and students. BYL Environmental Services is willing to arrange for all of Chulalongkorn's waste to be picked-up and disposed of free of charge. For waste that BYL Environmental Services cannot handle they will offer free advice to the Department of Chemistry on how they can dispose of it. Dr. Yaron Yoel, one of the founders of BYL Environmental Services, stated during a meeting with the project team that the company would be willing to work with Chulalongkorn on a permanent basis. BYL Environmental Services is an attractive option because the company stresses recycling and minimization instead of land-filling. BYL Environmental Services uses organic wastes as alternative fuel in cement kilns. Also, the company provides supplemental information to the Uniform Industrial Waste Manifest, such as a travel log of the material, the name of the driver transporting it, and other pertinent information. Dr. Yoel informed the group that BYL Environmental Services adheres to the strictest international laws governing safety. The project team strongly recommends that the Department of Chemistry develops a relationship with BYL as soon as possible.

6.2.3 Engineering Controls

In order to keep the equipment in the new science building in proper operating condition, the Department of Chemistry should implement the inspection system such as the one outlined in Section 3 of the CHP. In addition, the results of the inspections should be maintained as specified in the CHP. The Chemical Safety Officer should set aside an area for these records to be kept until a Chemical Safety Office has been established as discussed in Section 6.3.2

The most important engineering control used in the lab is the fume hood, and it must be properly maintained to insure that it functions correctly. Section 3.1.3 of the CHP lists the many requirements of fume hoods, including inspections. Section 3.1.3.2 states that annual inspections should be made on every fume hood in the new science building. The results should be posted on a sticker placed on the fume hood. Since each fume hood is already equipped with an airflow sensor, if the airflow should fall below the critical value, and the lab instructor is not able to fix the problem, the CSO should be notified immediately. The project team has provided the Department with both a sample sticker to place on the fume hoods, and inspection forms for the Safety Office records.

Other important engineering controls include eyewash stations and drench showers. These should each be inspected weekly by the lab instructor in order to ensure that they will operate in the event of an emergency. During the earliest stages of this phase of implementation, monthly inspections of these devices should be done and recorded. The test should consist of turning on the shower and eyewash stations and allowing water to flow for approximately three minutes. This procedure both insures that it is working properly and removes stagnant water from the pipes, which is of particular importance for eyewash stations. The date of inspection, the results of the inspection, and the name of the inspector should be kept on a clipboard in the laboratory.

6.2.4 Fire Safety Measures

Because fire suppression systems need to be available in all labs, fire extinguishers should be added to each individual laboratory in the new science building. Fire extinguishers should not be located only in the hallways because in the event of an emergency it may take a person too long to retrieve the extinguisher or it may be impossible to reach. Depending on the hazards associated with the chemicals being used, a special type of fire extinguisher may be required to properly extinguish a possible fire, for example a Metal X extinguisher is required for use on certain flammable solids. Also, each individual laboratory should have emergency procedures posted so that occupants can exit the building quickly and safely in the event of an emergency. An example of this would be a primary and secondary emergency exit route sign for each laboratory, such as shown in Appendix B of the safety plan which is found in Appendix G.

6.3 Phase Three

Some of the adjustments that must be made in the Department of Chemistry will need to take place on a long-term scale. The final phase of implementation is essentially the further development of the changes begun during the first two phases. While the final goals listed below may take a significant amount of time to accomplish, the project team recommends that the faculty begin implementing them at the earliest possible date.

During the last phase of implementation, the students and faculty should have incorporated the Chemical Hygiene Plan and Hazardous Waste Management plan into their daily work. Proper PPE and engineering controls should be used at all times. Chemicals should be stored and labeled properly. The means to achieve these goals began during the first two phases of implementation, and only three significant changes remain.

6.3.1 Main Accumulation Area

During the previous phase of the implementation framework an informal Main Accumulation Area (MAA) should have been chosen and put into use. However, the Department of Chemistry will ideally need to construct a MAA that meets the safety requirements set forth in the Hazardous Waste Management Plan. This task, however, may be expensive and require a large time commitment. Some specific characteristics of an ideal MAA consists of isolation from other laboratories, proper ventilation, explosion-proof lighting, and proper containers. It is understood that budgeting for these requirements may be difficult to obtain and many of the other expenses listed in previous sections will provide more immediate and direct benefits.

6.3.2 Chemical Safety Office

The many duties and responsibilities regarding safety on a campus as large as Chulalongkorn University will soon become too great for the Chief Safety Officer to handle alone. The project team strongly recommends that the aforementioned Safety Committee eventually evolve into a formal body with a full-time staff dedicated to safety. This group should have its own mission statement, chain-of-command, and the power to enforce the safety plan that it will issue and update regularly. With this commitment of resources the Department of Chemistry can ensure that all of the work that it has done will not have been in vain, and that safety will spread as a campus-wide concern. The Chemical Safety Office is one of the final steps to implementing the safety plan in the new science building.

6.3.3 Training Programs

In order to fully equip the Chief Safety Officer with the necessary knowledge required for his or her post, the CSO should undergo training in hazardous material safety, OSHA training, and emergency response training. There are many universities in the United States that offer courses that lead to certification in chemical safety. An example of where the CSO could receive a certificate in Hazardous Waste Management is from Quinsigamond Community College in Worcester, Massachusetts. In the United States there is an organization that offers the test required for certification in hazardous materials management called the Institute of Hazardous Materials Management. Information can be obtained about this organization through the Internet at http://www.ihmm.org.

6.3.4 Chemical Inventory

The Department of Chemistry should ideally have an inventory of all chemicals present the new science building. In order to begin this undertaking, the University should have a standardized inventory form that the CSO can give to each lab instructor so that he or she can list all of the chemicals in the lab and their approximate amounts. As soon as the inventory sheet has been filled out and the date it was completed has been recorded on it, the faculty member should immediately begin to record chemical usage on a separate form, kept in a standard place in each lab. Once this system is in place it will provide a wealth of information to the CSO and the Department of Chemistry so that the process of ordering and stocking chemicals will eventually become more streamlined. The Department of Chemistry will be able to anticipate the usage of certain chemicals, as well as determine which labs consume the most of a certain chemical. This will allow for a more centralized chemical ordering system, and thus reduce waste. The CSO will be responsible for placing the orders for chemicals in the Department of Chemistry. Also, if a lab is in need of a certain chemical, the lab supervisor will be able to obtain it from a lab that has an excess supply of it rather that ordering more of the chemical.

There are also many computer based inventory systems that, once the data has been initially entered, are very easy to maintain. Such a system could provide instant access to chemical stock information to the entire Department of Chemistry, as well as hazard information

6.4 Ongoing Considerations

Many facets of this chemical safety plan require continual considerations from the faculty of the Department of Chemistry. While these sections may prove to be the most trying to accomplish, they are crucial to the success of the safety plan. Education and enforcement will unify all that has been mentioned previously.

6.4.1 Education

In order to raise awareness with respect to laboratory safety, the students and staff must be properly educated. The faculty must be the first to learn the importance of a safety plan in an academic setting. Once the faculty decides to adopt the safety plan and incorporate it into their labs in the new science building, then the students will be able to practice it also.

The Department of Chemistry has made the first steps towards raising its safety standards. Dr. Supawan Tantayanon, an Associate Professor in the Department, is the project sponsor, and Dr. Surachai Ponpakakun, also a member of the Department of Chemistry faculty, has been selected as the acting Chief Safety Officer. The Chief Safety Officer will report directly to the Head of the Department of Chemistry, indicating the importance of safety to the Department. Adopting this safety plan is a substantial change and a large commitment, and it should be approached as such. Once it has been proposed to the project sponsor Dr. Supawan Tantayanon, the Chief Safety Officer, Dr. Surachai Ponpakakun, and the members of the Safety Committee, the safety plan can be unveiled to the entire Department of Chemistry. This should be done during a meeting of the entire Department, not on an individual basis, so that concerns from the faculty can be addressed, and the faculty can be reassured of the value of the safety plan.

After the introduction of the safety plan, the faculty should become well versed in the Chemical Hygiene Plan, Written Hazard Communication Program, and Hazardous Waste Management Plan. Training for the faculty should include basic safety, as outlined in the Standard Operating Procedures section of the CHP, how to handle and dispose of waste produced in the laboratory, how to prepare students for a lab, and how to utilize safety information. The training should also include procedural information such as the chain-of-command and the consequences of not adhering to the safety plan. This training should be covered in one safety training session which is organized by the Chief Safety Officer.

Students should also be trained in the content of the Chemical Hygiene Plan. They should be especially familiar with the Standard Operating Procedures, Personal Protective Equipment (PPE), and any engineering controls used in the lab. This information should be provided before the students begin to perform experiments in the lab. One suggestion is that the first lab period be used for learning chemical safety while performing practical experiments so that students will have an interactive approach. Copies of important safety information may also be handed out for later reference. This safety information may include the "Golden Rules of Lab Safety" and highlights of the Standard Operating Procedures. In the beginning of the first lab session, the lab instructor should:

- Point out the "Do's and Don'ts" that are set forth in the Standard Operating Procedures of the CHP, i.e. no food and drink in the lab, keep the work area clean, etc.
- Point out the location and proper use of all Personal Protective Equipment, as well as how to inspect that it is working properly and what to do if it is not.
- Demonstrate the proper use of the engineering controls present in the lab, such as fume hoods.
- Point out the location of all emergency response equipment, such as fire extinguishers, drench showers, and eyewash stations.
- Instruct the students as to the procedures to follow in the event of a fire or other emergency.
- Educate the students as to the many insignia and signs present in the laboratory, for example the National Fire Protection Association (NFPA) hazard identification diamond, Material Safety Data Sheets (MSDS), and container labels.
- Inform the students of the dangers of the chemicals present in the lab, and how to determine if an overexposure has occurred and how to respond.

Another option that could encourage students to follow proper safety procedures could entail the professor demonstrating proper and improper safety procedures through a series of pre-set experiments. The instructor could create a mock chemical spill and ask members of the class to clean it up. Also, a fire drill would help the students become familiar with the fastest escape routes in the event of a fire.

This training can be given in more depth for first-year students as well as transfers, perhaps as a separate, brief class, and repeated as suggested above, as an introduction to each semester class. Dr. Supawan currently teaches a lab safety class, available to second-year students. The project team recommends that the safety class be offered to first-year students during their first semester, as stated above.

6.4.2 Enforcement

Perhaps the most important feature of implementing this safety plan is enforcing it. Once the faculty and students have been informed of the importance of a safety plan, and educated in its policy, it must be enforced. It must be understood that attempting to adopt a new set of procedures and standards is a considerable change for the Department of Chemistry. As a developing nation, Thailand is typically slow to change, as shown through the interviews with Dr. Bhinyo Panijpan and Dr. Suchata Jinchitra found in Appendices C.5 and C.6 respectively and discussed in Section

2.1.1. Also, the Thai people are not very critical of one another, so Western method of enforcing rules, such as written warnings, would not be a recommended course of action.

In order to assure compliance with the new safety plan as it is gradually being implemented, the Chief Safety Officer should take a hands-on approach. Whenever possible, the CSO should observe lab sessions. During the earliest stages of implementation, he should make an attempt to visit one lab a day, even if only for a short while. While observing a lab, Dr. Surachai may want to comment on the ways in which the professor has improved his or her safety practices and the practices of the students in the lab period. Where appropriate the CSO may want to make suggestions that would improve the level of safety in the lab. These suggestions should be made in private in order to avoid public criticism. Since Dr. Surachai is a fellow professor, his words would be viewed more as advice from a peer than criticism from a superior. Dr. Surachai should make an earnest attempt at leading by example in his own lab periods, adhering to the safety plan as closely as possible. The project team strongly recommends that the CSO keep a log of his daily observations, so that he may track the progress of the safety plan as it matures.

If a student fails to follow the regulations set forth by the professor teaching the lab period, then that student is endangering his or her safety and the safety of the other students in the lab. The professor may want to issue a written reminder before the lab period in order to provide ample notice of the changes such as expected dress, and materials that should be brought to class. Depending on the degree of compliance the professor wishes to attain in his or her lab, he or she may consider preventing a student from participating in an experiment if he or she does not take appropriate safety measures. Some may consider compliance with the safety plan when calculating grades. A professor may choose any of the methods listed above to encourage compliance with the safety plan, and any innovative or more effective methods should be discussed with the CSO.

6.4.2.1 Rewards for Safety

Once the faculty has begun to adopt the safety plan, the Department of Chemistry should offer an end-of-semester award to a professor that has most improved his or her safety practices in the lab, had the least number of accidents, had the most compliant students, or has minimized the waste produced in his or her lab.

This positive reinforcement should encourage the faculty to adopt the safety plan. The award should be given out to a professor that has been nominated by a student or colleague and voted on by the Safety Committee or, once it has been established, the Chemical Safety Office. Also, a yearly award should be given to professors or lab supervisors that displayed exemplary performance in safety in their lab. Prerequisites for this award should be a nomination from a colleague or student, an accident free year in the lab, as well as showing a dedication to leading safety initiatives.

Another option to reward a faculty for improving safety in the laboratory setting would be to have the CSO give positive feedback about this faculty member to the Dean of the Faculty of Science. The Dean could then privately congratulate the professor on his safety record. This method of rewarding compliance avoids public praise which may imply criticism of other professors.

This method of positive reinforcement is not particularly common in United States universities because a safety plan is required by law, and the university expects compliance, or it will punish the faculty member or student who fails to meet the requirements. Due to the uncritical nature of the Thai people, punishing a faculty member or student who fails to meet the requirements of the safety plan would be inappropriate in a Thai university. The project team feels that recognizing progress is far more effective that pointing out deficiencies.

7 Conclusion

In the United States, the team researched safety plans from a variety of leading universities in order to establish a composite safety plan that incorporates common practices. To further understand the many aspects of chemical safety, the team also consulted experts in the field of safety as well as literature concerning laboratory safety methods. Using this background information as a foundation, the team considered feedback from interviews, student surveys, and observations in order to adjust the safety plan to suit the opening of the new science building at Chulalongkorn University.

The team foresees some difficulties resulting from both cultural characteristics and financial constraints that will affect implementation of an ideal safety plan. Due to these factors, implementing a safety plan in Thailand is a time-intensive process. Many universities in Thailand do not have the resources to properly address safety in their laboratories. The team is aware of this and has created an implementation framework in part to ease the burden of undertaking this safety initiative in the new science building. The timeline allows for the most fundamental and important changes to be made immediately, while those that are more costly and require more planning are recommended after the most basic changes have been made. In order to execute the safety plan, the team strongly recommends that the Department of Chemistry creates a dedicated safety committee headed by a full-time Chief Safety Officer.

Enforcement is a concern because of the difficult changes that the Department of Chemistry must undergo. The implementation framework suggests enforcement policies that have proven effective in international institutions but also considers differences that result from the culture of the community of Chulalongkorn. While the team has set forth the groundwork, it is the responsibility of the dedicated staff to ensure compliance with the safety plan as it develops. The team feels that if the faculty works closely with the administration, the safety initiatives will have a greater chance of succeeding.

Another difficulty that the University faces is the proper disposal of its hazardous waste. Correct waste disposal methods must begin in the labs of the new science building and be carried through to the ultimate disposal of the waste by a hazardous waste disposal company. To rectify the current situation, the team has suggested measures to begin proper disposal methods in the new science building and has provided information and recommendations regarding disposal companies in Thailand. The team believes that a partnership with BYL Environmental Services will provide the University with long-lasting, cost-efficient services.

The team foresees future areas of study resulting from this project. Since the University does not have a complete chemical inventory for the Department of Chemistry this could be the subject of a future study. Building a complete chemical inventory is a time consuming task and the University would greatly benefit from the results of such a project. Another project that could result from the safety plan project is an assessment of the improvements in the safety practices in the new science building. After the long-term phases of the chemical safety plan have been implemented, such a project could assess the effectiveness of the safety plan and modify it accordingly for Chulalongkorn. One last project that could result from the chemical safety plan would be a waste collaboration initiative with universities in Bangkok that produce hazardous waste. Because none of the universities currently utilize hazardous waste disposal companies, it would be beneficial and more cost-efficient for universities in the Bangkok area to have their hazardous waste collected at the same time.

The impetus behind this project is the importance of chemical safety in protecting humanity and the environment. As one of Thailand's leading universities, Chulalongkorn has the responsibility of protecting its students and teaching them proper safety practices. In time, this project team expects that the safety principles that the students learn during their time at Chulalongkorn will have far-reaching consequences that will influence safety practices in professional and research laboratories in Thailand. The team believes that the University can successfully implement the safety plan in the new science building leading it to be a model for other universities in Thailand. With the tools provided by this project, Chulalongkorn is poised to lead a revolution in chemical safety in Thailand.

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Appendix A Annotated Bibliography

A.1 Laboratory Safety

Kaufman, James A. "Laboratory Safety Guidelines: 40 Steps for a Safer Laboratory." (Handout)

This source provides specific tips on how to improve safety in a lab. There are steps requiring minimal expense and other steps that require moderate expense. Some of the steps requiring minimal expenses include establishing a safety committee that meets regularly to resolve problems, not allowing experiments to run unattended, and never working alone in the lab. Some of the steps requiring moderate expense include providing supplies of personal protective equipment, labeling all chemicals so that it is clear what the nature and degree of the hazard is of each chemical, and providing fireproof cabinets for the storage of flammable substances.

This source may be useful in assuring that the chemistry laboratories at CU are safe environments in which to operate. It could also provide a checklist to ensure that the labs have all the equipment and safety features that are appropriate.

Evertt, K., and D. Hughes. *A Guide to Laboratory Design*. Boston: Butterworths, 1975.

This book attempts to detail many of the problems encountered during the design of laboratories, specifically those that deal with hazardous materials. The authors utilize their past experience as well as the knowledge of an array of other sources to offer potential solutions to many common problems. The book covers a wide range of topics including very basic design features such as walls, ceilings, and furniture; general fire precautions such as fire detection mechanism and dealing with flammable and explosive materials; various methods of ventilation; and storage of various types of common lab materials. The appendices include discussions of radioactive, microbiological, chemically toxic, and carcinogenic materials.

While this book may prove beneficial for providing a general basis of the problems and requirements of laboratory safety, some of the material and suggestions are undoubtedly dated. Perhaps the information pertaining to the various considerations of lab safety can be extracted without including outdated suggestions relating to the remedy of problems.

National Research Council Committee on Hazardous Substances in the Laboratory. *Prudent Practices for Handling Hazardous Chemicals in Laboratories*. Washington, D.C.: National Academy Press, 1981.

This text introduces the concepts of handling hazardous chemicals in laboratories. It is prepared by the National Research Council which includes leading members of the chemical field. The scope of this book is quite broad and the information presented is thorough. It is a summary of best practices based on the current standards of the day.

Although the material is somewhat dated, it will probably be useful for a background on chemical safety. Although some laws and practices may have changed, much of the information is still useful.

Young, Jay A., ed. *Improving Safety in the Chemical Laboratory: A Practical Guide.* New York: John Wiley & Sons, Inc., 1991.

The OSHA Laboratory Standard, the Workplace Hazardous Materials Information System, and the Control of Substances Hazardous to Health Regulations are all discussed in this book. Beyond complete laboratory safety, personal protection is also discussed in this book. The hazards of handling flammable, reactive, corrosive, toxic, and physical materials are all discussed in some detail. Also, the laws and regulations that must be incorporated into lab work for various countries are covered.

This book will probably be very useful for this project. Many of the concerns that this project needs to address are included: chemical hygiene plans, safety inspections, controlling hazards, handling and management of substances, disposal, and storage are all covered. This book will prove invaluable for a preliminary proposal.

A.2 Chemical Safety

A. Keith, Furr, *CRC Handbook of Chemical Safety,* Boca Raton, FL: CRC Press LLC, 1995.

This book is an in-depth look on how to run a chemical or animal lab. It familiarizes the reader with how lab operations should proceed. Chemical waste transport is addressed along with waste management and how it should be handled internally. This author also communicates how to make a chemical emergency plan and what kind of equipment should be available to the lab users.

This source will be useful for its sections on the chemistry lab. Proper chemical storage is an important topic due to the possibility of an on-site storage facility at CU. Information on the safe transport of wastes will be invaluable because of the desire to remove wastes from the New Science building.

Hall, Stephen K., *Chemical Safety in the Laboratory,* Boca Raton, FL: CRC Press, Inc., 1994.

This book is a very informative overview of all laboratory safety practices. It explains many of the OHSA standards that most U.S. labs have to follow. It provides information on handling procedures and proper storage of chemicals. There are also details on chemical emergency plans. This book specifies how labs in the U.S. dispose of their hazardous wastes and the procedures that go along with this. Overall, *Chemical Safety in the Laboratory* provides a high-quality look at chemical safety in a U.S. lab.

This source will be useful in drawing up a chemical safety plan. It provides a standard in which to compare practices in a U.S. lab versus the ones in Thailand. This book also supplies the essential information on proper storage of chemicals needed to design a chemical safety plan. Since Chulalongkorn University plans on storing their chemical wastes in their old chemistry building, this book is useful because it supplies information on on-site storage of chemical wastes.

"University of Vermont Health and Safety Page,"

***Available From:* http://esf.uvm.edu/;**

***Last Updated:* 1 November 2001; *Last Accessed:* November, 2001**

This website contains the UVM Environmental Management Program. This describes their waste management and the pollution prevention program for their lab chemicals. It also provides hazardous waste information and their general lab safety rules. This source will be useful because it provides another view on chemical safety and waste management in a university in the U.S... It provides a model in which to base the CU chemical safety plan.

Green, Michael E., and Amos Turk. *Safety in Working with Chemicals*. New York: Macmillan Publishing Co., Inc., 1978.

This book aims to teach the subject of chemical safety in such a way as to provide an understanding of the fundamental concept of safe practices. The authors at least partially intended the book to serve as a text in a classroom setting. Further, it can function as an introduction to safe practices for anyone involved in a chemical facility. Indeed the book is an overview of safety procedures, covering such basic topics as handling glassware, avoiding poisons, and horseplay in the laboratory. The text continues by covering the hazards of the lab, including equipment, reaction, toxic, and physical hazards faced in everyday situations. The book concludes with a discussion of administrative procedures that should coexist with a proper safety program. Included are suggestions for safety committees, training, continuing education, and even dealing with the legal issues of accidents.

This text is relatively dated, but the basic concepts discusses should still pertain to current laboratories. In particular, the basic laboratory precautions and equipment hazards are generally consistent with issues still faced today. Some of the more advanced hazard topics, which may have been thorough for the day, are most likely lacking in some recent additions. Of particular use may be the section on administrative procedures. The information presented could provide a basic framework for an administrative program at Chulalongkorn University, although it will no doubt need to be expanded.

Lunn, George, and Eric B. Sansone. *Destruction of Hazardous Chemicals in the Laboratory*. New York: John Wiley & Sons, Inc., 1994.

This book is a collection of detailed measures that describe how to break down and dispose of a variety of hazardous chemicals. The procedures are applicable to laboratory and bulk quantities, solutions in varying solvents, as well as spills. Methods for cleaning up spills and solvents for wipe tests to ensure complete surface decontamination are frequently indicated. The authors also cover procedures and alternatives to the use of some highly toxic materials. Also included is a list of hazardous compounds which are indexed by name, molecular formula, and Chemical Abstracts Service Registry Number.

This is a very thorough examination of means of dealing with a wide variety of common materials found in a chemical laboratory. The authors examine each material individually and present methods for degrading and disposing of hazardous chemicals. Of particular merit is the fact that nearly anyone could use the book as the processes covered involve ordinary reagents and apparatus. This book could serve as a handbook for laboratory technicians and could be part of the safety plan.

Pekelney, David. July 1990. "Hazardous Waste Generation, Transportation, Reclamation, and Disposal: California's Manifest System and the Case of Halogenated Solvents." ***Journal of Hazardous Materials*** **23:293-315.**

This article examines data that was collected by the California Department of Health Services on the transportation of halogenated solvent wastes from 1984-1988. This paper shows how changes in public policies affected the generation and disposal patterns. Also, a materials balance model was developed to estimate the hazardous waste generation, reclamation, and disposal for the cleaning applications of halogenated solvents. This model is important for governments that base their policies on measurements of hazardous waste generation, transportation, reclamation, and disposal. This article also goes through the various laws and regulations that California has implemented over the years to control the transportation of hazardous waste.

This article may not be too helpful because there is no way to influence laws in Thailand regarding transportation and disposal of hazardous materials. It may be helpful to compare some of the US transportation laws with the laws in Thailand. Also, this article may not be too helpful because some of the laws and regulations may have been modified or deleted since 1990.

A.3 Organizations

"Laboratory Safety,"

Available From: **http://www.wpi.edu/Admin/Safety/Laboratory/;**

Last Updated: **18 April 2001;** ***Last Accessed:*** **November, 2001**

This website contains the actual written documents of the Hazardous Waste Management Plan and the Hazard Communication Program of WPI. It also includes the Chemical Hygiene Plan and the lab safety rules followed at WPI. This page provides all current information on how the labs at WPI operate and how the chemical waste is handled. This will be useful because it gives a standard on which to base the new chemical safety plan at CU.

"Pollution Control Department,"

Available From: **http://www.pcd.go.th/Information/;**

Last Updated: **9 November 2001;** ***Last Accessed:*** **November 2001**

This webpage contains databases concerning air quality and pollution estimates pertaining to certain areas of Thailand. It also provides information to the general public on many Thai environmental regulations along with other laws concerned with pollution control. It contains information about a pollution hotline also. This source will be useful because it is helpful to know which environmental laws and regulations govern the country of Thailand.

Godleski, Christine A., Hamel, Scott E., and LeClair, Matthew D., "Surplus Chemical. Exchange at Chulalongkorn University," WPI, 2000. (IQP)

This IQP explains the content of their project, which created a chemical exchange program at CU. The program uses an electronic format to exchange surplus chemicals at CU, which will help reduce the chemical waste that is disposed of at the University. The authors provide detailed information about the handling of hazardous material and the need for such a program at CU.

This source is very useful because it has a section dedicated to the new science building. It also contains a section that specifically provides data on the chemical use at CU. Another helpful section provides the current safety and disposal guidelines at Chulalongkorn University.

Chulabhorn Research Institute. **Chulabhorn Research Institute. <http://www.cri.or.th/>**

This is the website for the Chulabhorn Research Institute. The website provides general information concerning the Institute including history and mission statement. It also includes information about some of the specific research performed in the various laboratories.

The website includes a lot of information about the Institute. The information about the research being done at Chulabhorn may be useful as a comparison to what is done at Chulalongkorn. It is difficult to tell how old the information is; judging by copyright marks on the pages, the content may be as old as 1999. Safety in general does not seem to be discussed on the website and the word "safety" only appears twice on the entire site. The site may only be useful for a background of the Institute.

PTT Public Company Limited. **The Petroleum Authority of Thailand. <http://www.pttplc.com/>**

This is the website of the Petroleum Authority of Thailand. It contains background information on the PTT as well as some data about the petroleum industry in Thailand.

Useful information is rather sparse on this website. Aside from the mission statement of the PTT, there is nothing of much value to this project. Safety does not seem to be discussed at all. The website is probably only useful for the background section.

A.4 Waste Disposal Companies

"BYL Environmental Services,"

Available From: **http://www.byl-environmental.com;**

Last Updated: **2000;** ***Last Accessed:*** **November, 2001**

This website contains information on a Thai waste disposal company. The company formed in November 2000. Their mission is to service Thai industry with cost-effective industrial non-hazardous and hazardous waste management. This page comments on how the company started, along with all their specific waste disposal services. The other services they provide are also explained, such as remediation and restoration and onsite thermal treatment. It also makes clear the waste treatment technologies that they employ. They go on to list the company's operations and policies.

This source will be useful because at this time CU is accumulating waste behind Chemistry Building 1. They have no plan of action to remove the waste from their property. By researching companies that provide waste disposal services, this will give a better idea of what their options are regarding this topic. It may also help in finding a service that is reasonable for the University.

Crispin, Shawn W.. "Thailand: Time to Come Clean." ***FEER*** **July 5, 2001**

Available From: **http://www.feer.com/2001/0107_05/p030region.html;**

Last Updated: **2001;** ***Last Accessed:*** **November, 2001**

This article has interesting information on the state of Thailand's waste disposal practices. It states that Thailand has some of the toughest environmental regulations in S.E. Asia but that they are hardly followed. A very small amount of the industrial waste in Thailand is disposed of properly. Genco is mentioned in this article as being the monopoly of industrial-waste disposal in Thailand. The bottom line of this article is that if the companies in Thailand remain environmentally unfriendly, they will soon have problems with their export trade.

This article is useful because it discusses some of the problems with waste disposal in Thailand, a big reason being that Genco has a monopoly over the system. Also, it contains information on a United States-based disposal company and their view on the situation in Thailand. This may also be useful because it takes a realistic look at where Thai industries are heading if they do not start following environmental regulations.

A.5 Interviews and Surveys

Dillman, Don A., and Priscilla Salant. ***How to Conduct Your Own Survey,*** **New York, New York: John Wiley & Sons, Inc., 1994.**

This book provides a comprehensive summary on the best ways to conduct a survey. It starts with finding out if the survey is the best method to use for your purposes and continues with deciding exactly what information is to be gathered from the survey. This book also helps in choosing what survey method is proper to use, for example a mail, telephone, face-to-face, or drop-off survey. The authors then go into choosing an appropriate sample population and writing good questions to go on the survey. Finally, Dillman and Salant give useful information on how to report the survey results.

This book will be very useful for the safety plan project because the team will conduct surveys in Thailand. These surveys will deal with the current safety practices followed at Chulalongkorn University. The surveys will also deal with the students and faculty's views on the current practices and where improvements need to be made.

Berg, Bruce L. ***Qualitative Research Methods for the Social Sciences,*** **Needham Heights, MA: Allyn and Bacon, 2001.**

This book provides an in-depth look at many types of research methods. The book begins with how to design qualitative research and then moves to ethical issues dealing with research. There is a lot of information on different types of interviews including standardized, unstandardized, and semistandardized interviews. There is also information on long versus short interviews and telephone interviews. Berg goes into detail about focus group interviewing and also action research. Berg ends his book with important information on case studies and also how to analyze the data that all this research has produced.

This book will be very useful in helping to complete the implementation of a safety plan at Chulalongkorn University. *Qualitative Research Methods for the Social Sciences* will help the team choose which type of interviews will be appropriate and also how to interpret the results from these interviews. This book will also be helpful with case studies that will be performed involving comparable universities' safety plans. Overall, this book will provide helpful tips on how to conduct research in general.

Appendix B Student Survey Questions

Questions	Don't Know	Strongly Disagree	Disagree	Agree	Strongly Agree
I feel safe when working in the chemistry labs at Chulalongkorn University	1	2	3	4	5
I feel that safety practices at Chulalongkorn need improvement.	1	2	3	4	5
I am concerned about protecting the environment through proper chemical waste disposal.	1	2	3	4	5
Once a year, I would be willing to attend a chemical safety seminar run by the Department of Chemistry.	1	2	3	4	5
I always wear appropriate personal protective equipment while working the laboratory.	1	2	3	4	5
I have been properly trained to use laboratory equipment.	1	2	3	4	5
I know the fastest emergency exit route in the event of a fire.	1	2	3	4	5
I have been trained in proper use of a fire extinguisher.	1	2	3	4	5
I know proper chemical storage techniques.	1	2	3	4	5
I know how to dispose of chemicals properly.	1	2	3	4	5
I practice methods to minimize chemical waste.	1	2	3	4	5
I am familiar with and regularly use Material Safety Data Sheets.	1	2	3	4	
I know where the eyewash and shower stations are in the laboratory and I know how to operate them.	1	2	3	4	5

Appendix C Interviews and Information Sessions

C.1 Interview with Dave Messier

This interview took place on December 17, 2001 at 1:00 PM in Dave Messier's office. The interview lasted for one hour.

Tony: How long have you worked at WPI? In your field?

Mr. Messier: I started working here nineteen years ago. I came here with a degree in Business Administration. I was originally hired to manage the Chemistry Department Stockroom. I went back to school and became certified as a Hazardous Waste Material Manager two years ago.

Tony: How effective is the WPI Safety Plan?

Mr. Messier: Average or moderate. On a scale of one to ten I would give it a six to seven. It's only been since 1998 that WPI has made a full time commitment to safety. There are still lots of opportunities to improve.

Tony: How is it (WPI Safety Plan) enforced?

Mr. Messier: I work directly for the Business Administration. There is also an academic aspect involved in it. It's a combination of enforcement through business and academic.

Tony: What are the major components of a safety plan?

Mr. Messier: Training, accountability, inspections and audits, documentation, and a good website. Only in the last couple years has a good website become important.

Tony: What is the most important part of a safety plan?

Mr. Messier: Communication- you need to communicate through training and information.

Tony: How is WPI different from other universities?

Mr. Messier: WPI has roughly one hundred labs with chemicals. The larger schools have many more labs. The issues and regulations are the same for the most part. In the larger universities they have very large staffs that handle safety. At WPI there is only one full-time person. This person needs to cover a lot of territory. In the city of Worcester, we're (WPI) is unique. We (WPI) have unique facilities as compared to Holy Cross and Clark.

Tony: What is the biggest safety risk in the lab?

Mr. Messier: In a chemistry lab the biggest safety risk is the quantities of flammable and/or reactive chemicals. Because of this fire safety is a major concern.

Tony: Why was Goddard 114 chosen as the Main Accumulation Area (MAA)?

Mr. Messier: Lack of other space. Formerly it was part of the Chem. Department Stockroom. It does have some provisions to be the MAA including explosion proof lights and a sprinkler system. So, basically it was chosen because of location and space availability.

Tony: What kind of training is available for faculty and students [at WPI]?

Mr. Messier: Lab safety; hazardous waste management; emergency response training; first aid and CPR; and bloodborne pathogen training.

Tony: How much hazardous waste does WPI produce as a Small Quantity Generator?

Mr. Messier: On an annual basis the entire WPI campus produces six to eight fifty-five gallon drums of halogenated/nonhalogenated waste. About two fifty-five gallon drums of waste oil are also produced. One thousand pounds of lab pack waste (various materials) is also produced. Corrosive, reactive, and carcinogenic materials are all located in Goddard 114.

Tony: What percentage of the safety plan actually comes into practice on a regular basis?

Mr. Messier: The Hazardous Waste Management Plan is used consistently; it gets daily usage. The Chemical Hygiene Plan is more general and generic. We are making lab safety manuals for every lab at WPI. They include a sheet for chemical inventory which is very important; standard operating procedures which are generic; and a lab inspection checklist (the faculty have not been very cooperative so far).

The overall feedback on them [lab safety manuals] is good.

Cherie: What chemical waste disposal company does WPI utilize and why?

Mr. Messier: We currently use Triumvirate Environmental. We've used them for the past two years. They have outstanding service and support for higher education. They are a very competent company. We have utilized about four to five different waste disposal companies in the nineteen years that I've been here.

Cherie: How are accident reports organized and enforced?

Mr. Messier: There are two areas where the reports are organized. They are kept in my office [EOSO] and in the Human Resource Department. They get sent to the HRD first and I am only notified if the situation warrants immediate attention. Otherwise I receive the reports in a day or two.

Tony: What is the most important piece of safety equipment in the lab?

Mr. Messier: Well, I think that there are two. The fume hood is a very important piece of equipment and it gets used daily, if not hourly, in most labs. The other piece of safety equipment that I would choose is the eye wash station.

Cherie: Are there any other staff that works with safety other than your full-time position?

Mr. Messier: There is a Biosafety Officer named Paula Moravek who works less than five hours a week for me. The Radiation Safety Officer is Dave Adams and he also works five hours or less per week for me. Roger Steele is the assistant Radiation Safety Officer and also the Laser Safety Officer. He probably works more than five hours a week for me. There are also three undergraduate students that work for the EOSO. One does clerical work and the other two are working on making the lab safety manuals for every lab at WPI.

Tony: Are there any major faults with the WPI safety plan?

Mr. Messier: I would say that decentralized purchasing of chemicals is a significant problem. Some people don't realize how hazardous some of the chemicals that they order are.

C.2 Information Session with ExxonMobil Chemical

This session took place on January 13, 2002 at 2:00PM in the Chemistry 3 Building. The representative from ExxonMobil Chemical was Montree, who worked in a division that produces lubricant oil. Dr.Supawan served as the translator.

- Every department in this division has their own safety program.
- In these departments safety comes first. There are manuals available in both English and Thai.
- These manuals are available to everyone and must be read.
- If an accident occurs in the laboratory, the person must report it directly to the supervisor.
- The department that Montree works in has a Safety Committee which is broken down into different groups. Each group has different responsibilities, for example one group deals only with emergency situations
- This department has a maintenance checklist that must be filled out once a month.
- Once a week a different lab worker must conduct a five minute safety meeting. This time is used to alert other people of accidents that have occurred and how to prevent them from happening in the future.
- Once a year the company conducts a fire drill.
- Twice every year all employees must complete a training program.
- One general rule is that no food or drink is allowed in the laboratory.
- Outside of the laboratory there is a cabinet that is filled with goggles. Anyone entering the lab must put goggles on.
- The company provides safety face masks and goggles to all employees.
- For certain chemicals there is a list of personal protective equipment that must be utilized and the Material Safety Data Sheets must be on hand.
- There are specific regulations pertaining to hazardous materials for example flammable chemicals.
- The chemicals must be stored in a separate room that has good lighting and carts to transport the chemicals.
- The company provides a list of incompatible chemicals so that they will not be stored together.
- Once a month the safety showers and eye wash stations must be tested.

C.3 Information Session with ExxonMobil Chemical and Pfizer

This session took place on January 27, 2002 at 1:00PM in the Chemistry 3 Building. The representative from ExxonMobil was Montree, who works in a division that produces lubricant oil. Krissana is an analyst at Pfizer Global Manufacturing. There was no translator at this meeting making communication difficult.

- At Pfizer the new employees receive safety training and also take a test to reveal the employees previous safety knowledge.
- Once a year Pfizer practices the emergency safety plan.
- When raw materials arrive at the company, the employees move the materials from the truck on a cart about two hundred meters. Only small amounts of materials are transported at a time.
- Pfizer's flammable materials are stored in a cool room where the temperature is controlled. The other materials are separated by solids and liquids.
- Pfizer separates the chemical waste; for example by inorganic and organic solvents.
- Genco handles Pfizer's hazardous waste disposal. Genco picks up the waste every two months or when the storage area at Pfizer is full.
- There are no sprinklers in any of the buildings but there are many carbon dioxide fire extinguishers throughout the buildings.
- Pfizer also employs the use of fireballs which the employees throw on the fire. The fireball then explodes and smothers the fire.
- The eyewash stations, fume hoods, and drench showers are tested every three months.
- The training that the employees receive basically consists of fire safety training.
- At ExxonMobil Chemical, the employees practice fire safety procedures once a year. In the company everyone has a different responsibility if a fire breaks out.
- ExxonMobil Chemical tests the pressure in the fume hood.
- ExxonMobil Chemical uses appropriate hazardous waste labels.
- Overall, there are numerous accidents pertaining to chemical safety every year in these companies.

C.4 Interview with PTT Safety Officers

This informal discussion was held on January 28, 2002 at 2 PM. There was a tour of the Research and Technology first, followed by the meeting. Dr. Thawach Chatchupong led the discussion.

How long have you worked at PTT? In your field?

Dr. Thawach Chatchupong has worked at the Petroleum Authority of Thailand for about four years. He is an Environmental Researcher in the Analytical and Petrochemical Research Department.

How often is it reviewed and/or updated?

PTT does not have a scheduled revision period for their safety plan. Instead, the plan is updated as necessary, for example when the company acquires a particularly hazardous material.

How effective do you feel that your safety plan is?

He does not feel that the company's safety plan is very effective. Because the plan is not enforced, researchers are often not concerned with safety.

How do you enforce this safety plan?

The company does not enforce its safety plan.

What are the major components of the safety plan?

The safety plan consists of recommendations, suggestions, and rules that must be adhered to.

What is the most important part of your safety plan?

The most important parts of the safety plan are related to chemical hygiene. Hygiene covers safety procedures such as no food or drink allowed in the lab, details proper dress code, and outlines proper handling of chemicals. Important safety measures such as personal protective equipment are left up to the employees judgment.

What is the biggest safety risk in your work environment?

The biggest safety risk in the Petroleum Authority of Thailand's labs is the handling of mercury.

What kind of safety training is available for your employees?

Chemical training is very important at the Petroleum Authority. Employees are trained in chemical safety when they are hired. Once a year, the company holds a training session for all workers. The staff is trained by professors from universities. Dr. Supawan has held training sessions for PTT in the past.

Where are your storage protocols for hazardous materials? Where do you store your chemicals?

In the analytical and petrochemical research department, there is a specialized chemical storage room. In this room, there are specific cabinets for acids and flammable materials as well as glass enclosed shelves with clearly labeled containers. In addition, PTT maintains and inventory of the stock room on a clipboard near the door. The inventory contains the full chemical name, the location, the quantity, size of the container, and flammability rating. When a researcher removes a chemical from the storage room, a form must be filled out detailing the amount taken and the date that it was removed.

Where is the hazardous waste stored and for how long does it stay there before a disposal company is called?

The storage recommendations for hazardous waste vary depending toxicity. For example, only one liter of waste that is highly toxic can be stored in the lab. When the storage limit is reached, the waste is moved to a common waste storage area. The waste stays there until the room is full because there are no regulations in Thailand dictating how long hazardous waste can be stored.

How do you handle transportation issues regarding hazardous waste? What transportation training do you offer?

There is no special training specifically for the transportation of hazardous waste. PTT trains its employees in general chemical handling. PTT makes recommendations regarding the type of storage container that should be used for transportation.

Who is responsible for the transportation?

The lab researchers themselves transport the hazardous waste to the common area.

What company do you utilize for disposal of your hazardous materials?

PTT utilizes Genco for their hazardous waste disposal.

What other safety related positions are there in your company?

There is a safety team for the research institute that is composed of employees that have an education or past experience dealing with chemical safety.

Do you have a sprinkler system installed in your building?

There is no sprinkler system in the building because of the expensive analytical devices located there. Water from the sprinklers would destroy these devices. Because of this, PTT chose to use smoke detectors and equipment every room with fire extinguishers.

What types of fire extinguishers are in the building and where are they located?

There are carbon dioxide extinguishers located in every lab and they are easily accessible in the hallways. There are also automatic fire hose reels in the hallways. The fire extinguishers are small so that they are more accessible to more petite lab workers.

How often is the safety equipment, such as eye wash stations and drench showers, tested?

This safety equipment is tested regularly and there are schedules located on the wall nearby the equipment to be filled out when they are tested.

What laws and regulations is the company subject to regarding chemical safety?

There are not many laws and regulations that industries are subject to. The government does specify type of chemicals. The only time that the government will enforce regulations on a company is when it comes to the government's attention that there has been an accident.

Are there scheduled safety meetings held with the employees?

In the beginning of the safety team's existence there were meetings held once a month but over time the meetings have changed to quarterly instead of monthly.

General Notes:

- The hazardous waste labels on the containers in the laboratories have all the components filled out and the date when the container became full.
- At the end of every day, the researcher working in the lab must execute a lab closing procedure by filling out a form to make sure that everything is in proper order.
- There are drench showers and eyewash stations located in every lab. There were no drains located under the drench showers.
- The building was separated down the middle; laboratories one side of the building and offices on the other side. There are separate ventilation systems for each side of the building.
- There were emergency exit routes labeled on the doors at the end of the hallways. Fire exit signs were also located in the hallways.
- Near the elevators there were fire alarms along with signs that detailed no smoking or eating.
- The employees do not utilize Material Safety Data Sheets. PTT recommends that the employees read the warnings that come from the companies that ship the chemicals.
- The wastewater from labs is separated from the common wastewater at PTT.
- There are no regulations regarding exhaust from fume hoods so these fumes enter the atmosphere directly.
- The PTT modifies the building as necessary to improve the safety of the employees.
- PTT has accident report forms that must be filled out no matter how major or minor the accident is.
- There is not centralized purchasing of chemicals at PTT; every lab researcher orders his own chemicals as needed.
- It is the responsibility of the senior researchers to recommend proper procedures to the junior researchers.
- According to Dr. Thawatch Chatchupong practicality is an important facet of the safety plan process at Chulalongkorn University.
- Dr. Thawatch Chatchupong also informed the team that a knowledgeable staff working on the safety committee is another vital aspect to a safety plan.

C.5 Interview with Dr. Bhinyo Panijpan

This interview took place at Mahidol University in Bangkok on February 8, 2002. Dr. Bhinyo shared his expertise on various aspects of chemical safety in Thailand.

Where were you educated?

Dr. Bhinyo was educated in Australia, London, and Wisconsin in the areas of biochemistry and biophysics.

What is your work experience?

Dr. Bhinyo has worked at Mahidol University for 32 years in the biochemistry department. Over the years, he has performed research with vitamin B1 and malaria and is currently developing test kits for elements such as iodine. Dr. Bhinyo has also worked with the Ministry of Industry in Thailand. With the Ministry, he helped to pass laws and regulations regarding chemical safety. Dr. Bhinyo has also served as president of Thailand's Chemical Society. While in that capacity, he took charge of transporting chemical waste out of the port of Bangkok after a large chemical fire.

What do you see as the biggest threat to safety in the lab?

According to Dr. Bhinyo, fire is the biggest safety risk in the labs. Clutter also contributes to dangerous working conditions. Finally, students eating in labs present a danger to themselves.

Do you have any suggestions for waste disposal for universities?

Genco only handles heavy metals and regular waste. They cannot handle organic solvents. Dr. Bhinyo feels that Genco is no more knowledgeable about waste disposal than anyone else.

What can make industry and academia take safety more seriously?

Dr. Bhinyo warns that Thai people are often reluctant to change, but with persistence they will eventually comply.

Do you think that a safety standard like America's will ever be adopted and enforced by the government or by industry or academia?

Authorities in Thailand have reviewed American laws but are not willing to adopt other countries laws. Dr. Bhinyo said that it is easy to copy regulations from other countries, but difficult to implement them.

What is holding industry and academia in Thailand back from complying with accepted safety regulations?

Dr. Bhinyo cites Thailand's lack of colonization as a reason for its stubbornness in adopting accepted safety regulations from other countries. Because Thailand was never occupied or controlled by a foreign government, Thai people question the need to accept regulations from other countries.

Do you feel that it is appropriate for the safety plan that we propose to be based on American laws and regulations, such as those set forth by the EPA?

Dr. Bhinyo feels that a better approach to a safety plan would be providing a set of regulations as well as explanations for why the regulations are appropriate.

What do you think are the biggest cultural differences between America and Thailand that may hinder the adoption of a safety plan?

Dr. Bhinyo feels that Thai people do not fear any dangers in the lab and as a result do not see the need for safety. He says that Thai people are not ready for safety measures, but that eventually the country will adopt them.

General Comments:

While working at the Ministry of Industry, the country has made progress in some areas of safety; for example, placards are used to identify hazards on shipping trucks. The Biochemistry Department at Mahidol University is trying to minimize chemical ordering. Lab workers often do not read labels on chemicals and as a result do not realize how dangerous the chemicals really are. Mahidol keeps fire extinguishers in the hallways and chemistry labs and conducts fire drills to train its staff and students. Mahidol refuses to implement a chemical safety course for its students because the administrations feel that more valuable courses should be offered instead. Dr. Bhinyo suggests that the dean of Chulalongkorn may be able to convince faculty to adopt the chemical safety plan.

Interview with Genco

On February 12, 2002, the team met with representatives from Genco. Before the interviews took place, Genco played a short informational video, "Industrial Hazardous Waste Treatment and Disposal Facility Project," about the history of Genco and some of the details of its operation. Following the interview, the representatives discussed the operations of Genco and the possibility of servicing Chulalongkorn's waste disposal needs.

What companies do you service?

Genco's customers include companies from a variety of industries including petroleum, steel and metal, electroplating, dyeing, medical, rubber, pulp and paper, automobile, chemical, petrochemical, electronic, textile, and pharmaceutical industries.

What types of waste do you deal with?

Genco handles a wide range of both hazardous and non-hazardous waste. These wastes include solids, liquids, organics, inorganics, and heavy metals.

How do determine the cost of disposal for these companies?

Before Genco will pick-up waste, the customer must first provide a sample of the waste so that Genco can analysis it. From this analysis, Genco determines the cost for the waste pick-up and disposal and informs the customer. Cost is based on the contents of the waste and volume. For universities, Genco will not charge for service but only for secure landfill usage.

Do you utilize a Hazardous Waste Manifest form?

Genco utilizes a Uniform Industrial Waste Manifest form. Copies of the form are kept by the generator, transporter, Genco, and the government. These forms are used to deal with accidents so that Genco can properly deal with clean-up.

What methods do you use to dispose of these hazardous materials (ex: incineration)?

For inorganic waste, non-hazardous waste is brought directly to the secure landfill which is designed to prevent leeching. Hazardous waste is stabilized and neutralized before being added to the landfill. Genco treats waste water in a separate facility. For organic waste, solids are treated with thermal combustion while liquids are treated by fuel blending. The result of these treatments is synthetic fuel that is reused.

Would you ever consider dealing with universities' hazardous waste disposal needs?

Genco was receptive to the idea of working with universities. Genco is willing to pick-up and transport waste so long as it is separated and contained properly. Genco also understands the limited financial resources of universities and is willing to adjust pricing to try to accommodate the universities; for example, Genco will not charge universities to treat reagents that can be resold.

Would it be more cost effective for your company if the universities in Bangkok combined all of their waste before collection?

Genco will pick up waste from Chulalongkorn and other universities in Bangkok at the same time so they can share transportation costs.

What laws and regulations does Genco adhere to?

Genco uses U.S. EPA standards, European Union standards, and International Standards Organization certifications. Genco is part of the Department of Industrial Works under the Ministry of Industry and adheres to all regulations from the Ministry.

What training do you provide for your employees?

All of Genco's drivers are specially trained and receive a license for transporting hazardous waste. In addition, lab workers are certified in their field and provided training by Genco.

C.6 Interview with Dr. Suchata Jinachitra

This interview took place on February 12, 2002, at 4 PM at the Thailand Research Fund office in Phayathai, Bangkok.

Where were you educated?

Dr. Suchata was educated at London University and received a degree in organic chemistry.

What is your work experience?

Dr. Suchata was a professor in organic chemistry at Chulalongkorn University five years ago. She also started the first chemical safety class at Chulalongkorn University. This class was offered to third-year students as an elective. At present, she is the Program Director for the Thailand Research Fund. Dr. Suchata supports research in the areas of natural resources, health, environment, science education, public welfare, and safety.

Why is safety important in the university setting?

The teachers and students are role models for the public when it comes to safety. The students need to become more aware of chemical safety.

What do you see as the biggest threat to safety in the lab?

According to Dr. Suchata, the attitude of both students and faculty is the biggest threat to chemical safety at Chulalongkorn University.

Do you have any suggestions for waste disposal for universities?

Dr. Suchata stated that she has had problems in the past with Genco.

What can make industry and academia take safety more seriously?

Dr. Suchata's advice was to be persistent, set forth all the conditions, encourage, and enforce. The encouragement could be through holding competitions year round and by providing laboratories with the title "Green Lab."

What is holding industry and academia in Thailand back from complying with accepted safety regulations?

Dr. Suchata stated that safety is not in the minds of Thai people at present.

What do you think are the biggest cultural differences between London and Thailand that may hinder the adoption of a safety plan?

Dr. Suchata feels that Thai people do not fear any dangers in the lab and as a result do not see the need for safety. In London safety is much more important and is more heavily regulated.

General Comments:

Dr. Suchata has worked diligently to translate MSDS from English into Thai so that the universities could take advantage of them. There was also a program set-up for the Department of Chemistry to record chemical inventory but it is not in use. In her current job Dr. Suchata has funded a project that looks after the environment at universities. This program encourages waste separation and helps in the waste pick-up from universities in any way possible.

C.7 Interview with BYL Environmental Services

On February 18, 2002, the team met with Dr. Yaron Yoel, the Managing Director of BYL Environmental Services. Dr. Yoel discussed the operations of BYL and the possibility of servicing Chulalongkorn's waste disposal needs.

What companies do you service?

BYL services both entities and companies. BYL works with the U.S. military and embassies as well as many U.S. companies. These companies include Chevron, Esso, Johnson & Johnson, Colgate, Palmolive, and many others.

What types of waste do you deal with?

BYL handles a wide range of both hazardous and non-hazardous waste through subcontractors such as Waste Management Siam. These wastes include solids, liquids, organics, inorganics, and heavy metals. BYL specializes in industrial and hazardous waste.

How do determine the cost of disposal for these companies?

BYL offers free advice and consulting on minimization of and expose to waste to its customers and charges for waste services only. For example, BYL will charge 240 baht to dispose of one drum of waste. The average cost per ton of hazardous waste is 75 U.S. dollars. However, if the customer uses the bulk tanks that BYL provides, BYL will dispose of the waste for free.

Do you utilize a Hazardous Waste Manifest form?

BYL uses a Uniform Industrial Waste Manifest form. Copies of the form are kept by the generator, transporter, BYL, and the government. These forms are kept for seven years by BYL.

What methods do you use to dispose of these hazardous materials (ex: incineration)?

BYL Environmental Services utilizes incineration, desalination, and landfills to dispose of hazardous waste. They use a Switzerland-based company to perform waste incineration. BYL Environmental Services also provides on-site hazardous waste disposal if the companies desires. IDE performs the desalination of waste for BYL Environmental Services.

Would you ever consider dealing with universities' hazardous waste disposal needs?

BYL Environmental Services worked with Chulalongkorn University about two years ago. The company provided free hazardous waste disposal to the University as charity. Dr. Yoel stated that the company would be willing to dispose of Chulalongkorn's waste at no charge on a permanent basis. If there was a service that BYL Environmental Services could not perform for the University then they would provide free advice and consultation on these issues.

What laws and regulations does BYL Environmental Services adhere to?

BYL Environmental Services adheres to a variety of laws and regulations issued by the USEPA, Thai Ministry of Industry, Industrial Estates Authority of Thailand, Ministry of Health, Science, and Transportation. The Environmental Resource Management Company advises BYL Environmental Services on which regulations they should be following.

What training do you provide for your employees?

Every employee must complete 40 hours of OHSA training to be certified. They are also trained in emergency response. The company brings lecturers from the United States or Singapore to train their employees. The employees of BYL Environmental Services must take a refresher course once a year. The drivers that transport BYL Environmental Services' hazardous waste are screened for drug and alcohol abuse and are also checked for driver competence.

General Notes:

Dr. Yoel provided the team with a variety of useful contacts that will aid Chulalongkorn in implementing the safety plan. Details about these contacts are included in the Implementation Timeline.

Appendix D Photographic Documentation

D.1 WPI Main Accumulation Area

Using a digital camera provided by WPI, the group took pictures of the Main Accumulation Area (MAA), the chemical stockroom, and a Satellite Accumulation Area (SAA) that is located in one of the labs. Worcester Polytechnic Institute chose room 114 in Goddard Hall as its MAA, initially for its availability, and it's isolation from the rest of the rooms on the floor. The only access to the room is from outside of the building, through a door on the loading dock. Since its selection, many safety features have been added, for example explosion proof lights, and a ventilation system at the floor and at the ceiling. Also, adjacent to the MAA is a chemical stockroom, where there is a room that contains non-waste hazardous materials. In addition, his room is where Mr. Messier, the EOSM, washes and prepares containers to hold chemicals.

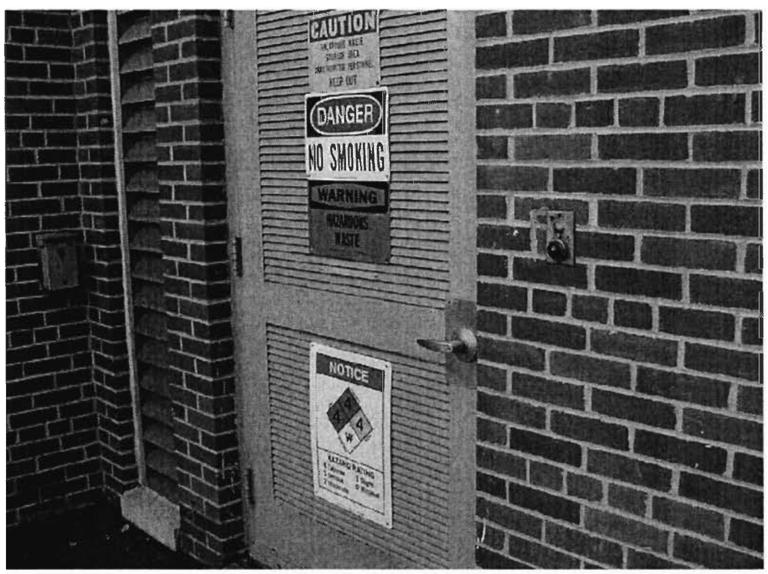

Figure 28- Entrance to MAA, with warnings and placards

Figure 29 - Lab Packs of hazardous material

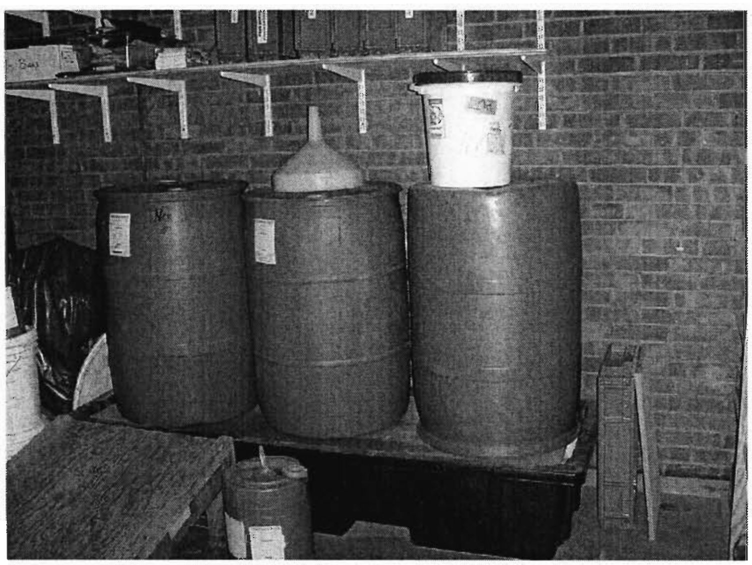

Figure 30- 55 Gallon Drums: organinc, nonorganics, and waste oil

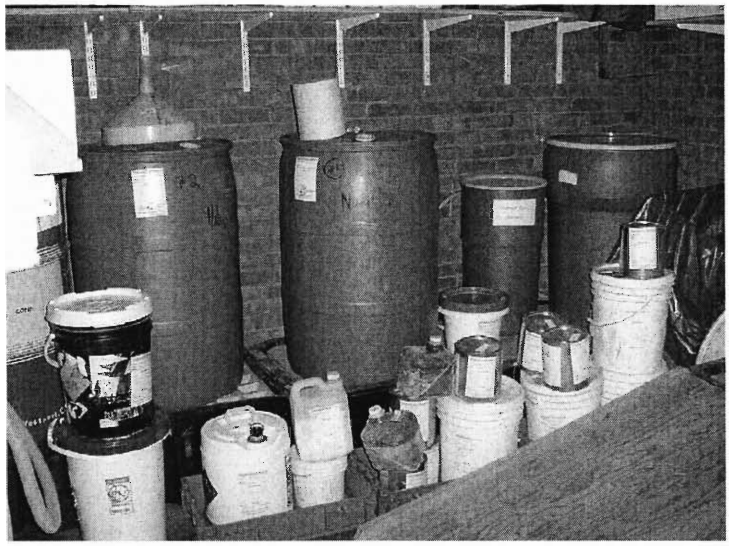

Figure 31 - Drums, and flammable wastes

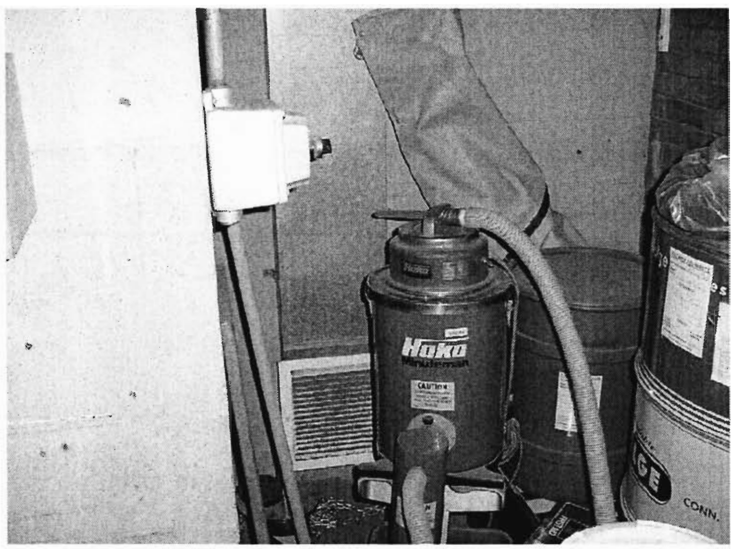

Figure 32 - Bottom half of ventilation system

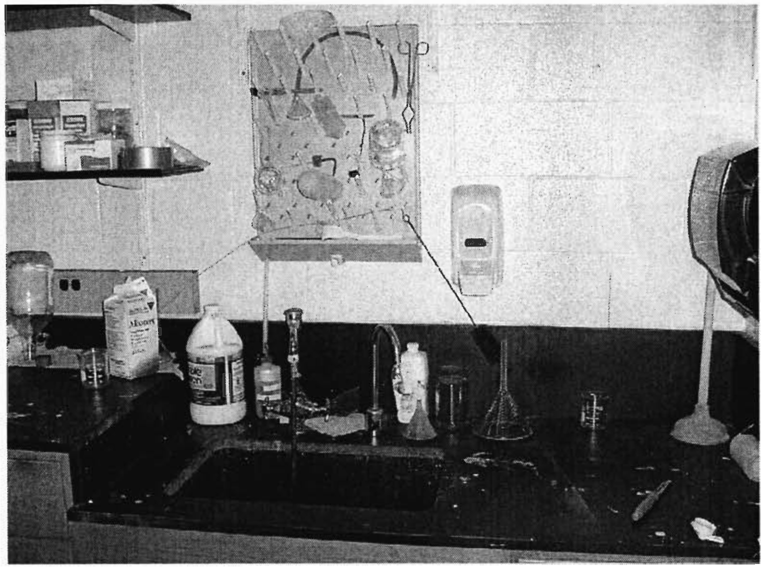

Figure 33 – Sink and clean-up area in Chemical Stockroom

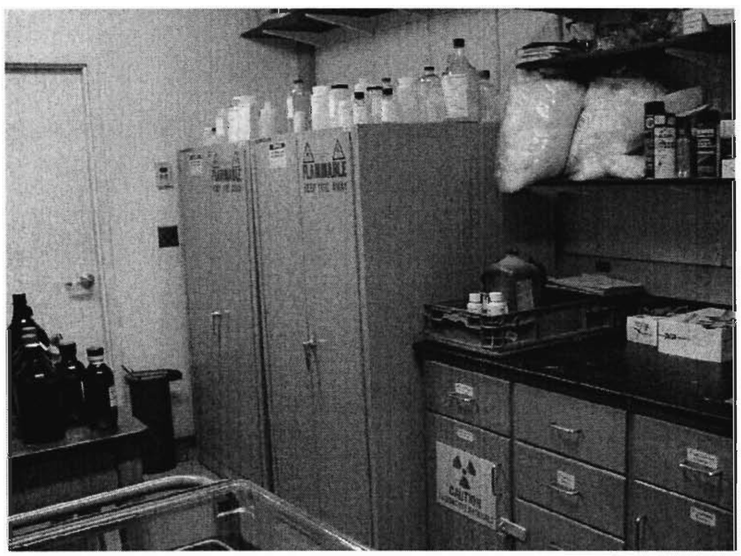

Figure 34 - Flammable materials cabinet

Figure 35 - Fume hood in stockroom, eyewash at bottom

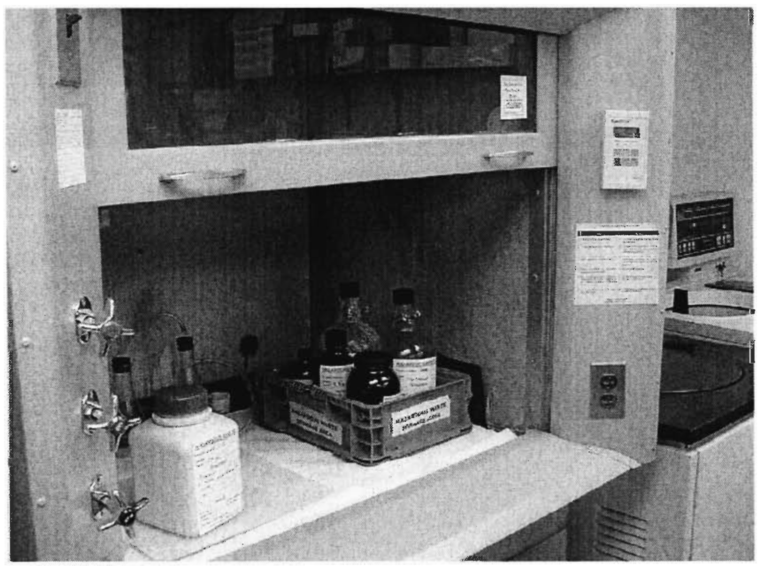

Figure 36 - SAA in regular lab

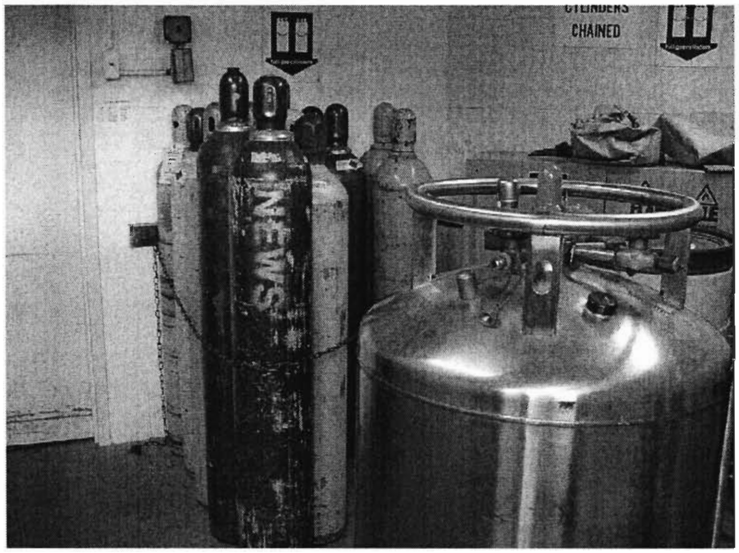

Figure 37 - Compressed gas cylinders

D.2 Chulalongkorn Laboratories

Figure 38: Waste containers at Chulalongkorn

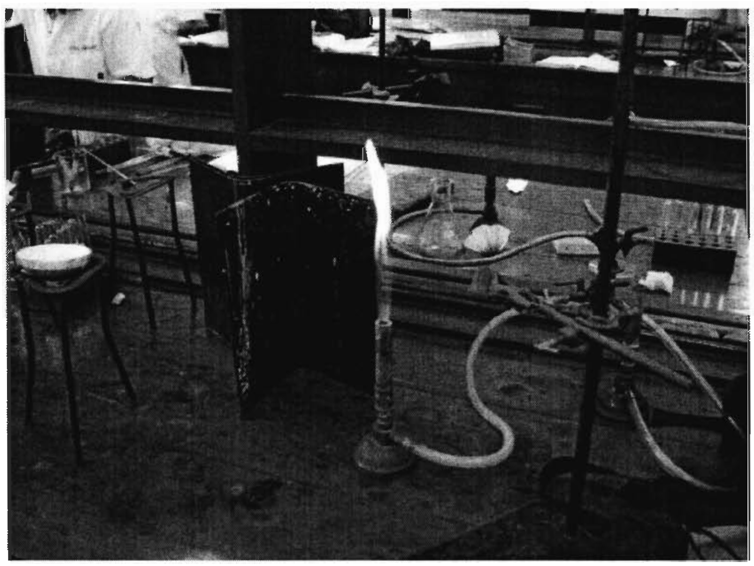

Figure 39: Unattended Bunsen burner

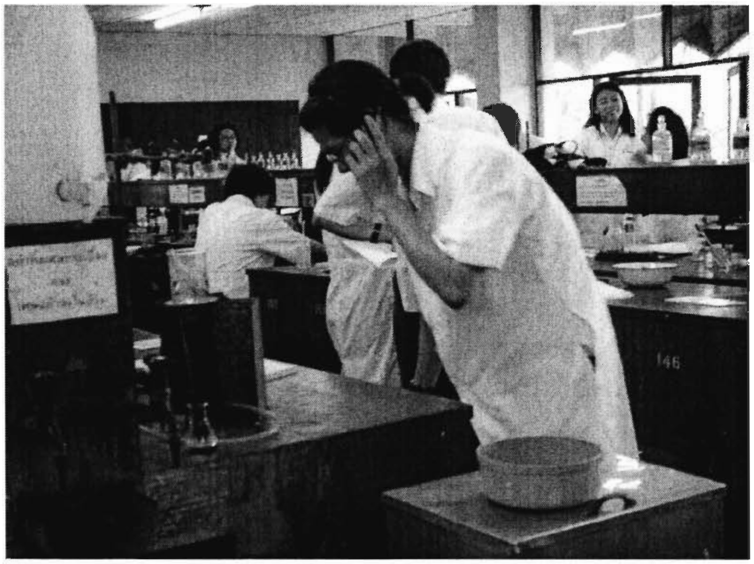

Figure 40: Student on mobile phone while performing an experiment

Figure 41: Student not wearing shoes

Figure 42: Crowded work environment

Figure 43: Inside of a fume hood

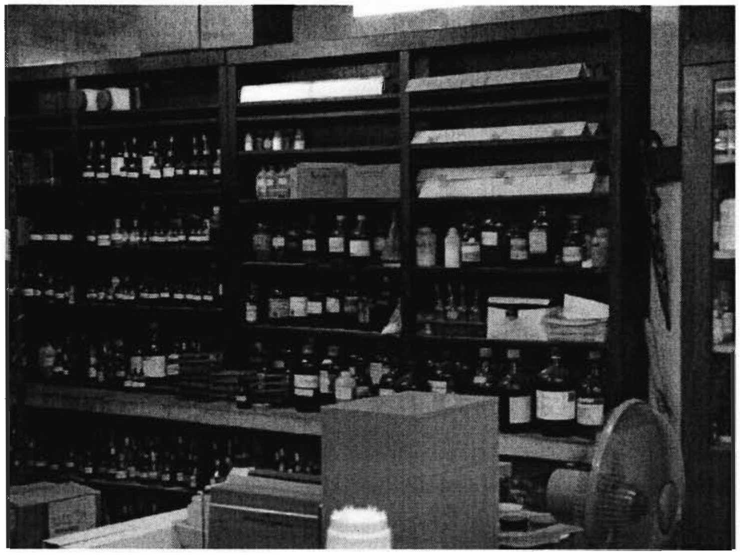

Figure 44: Stockroom in Chemistry 3 Building

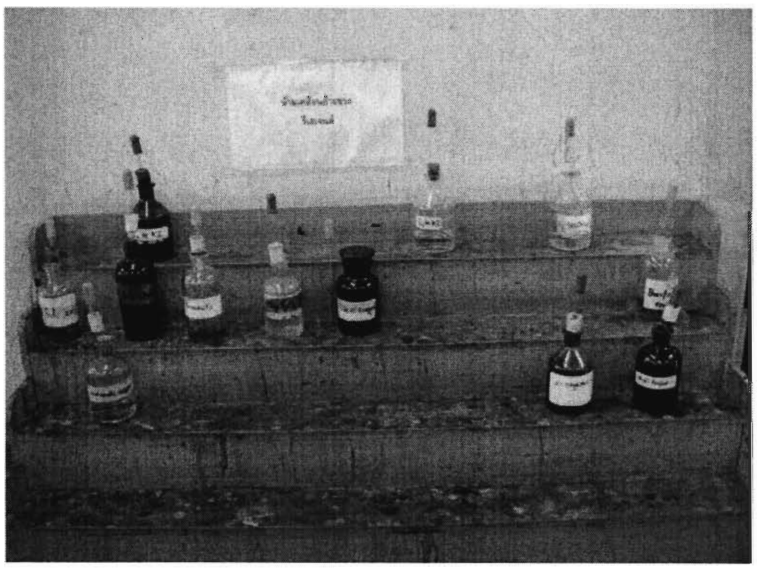

Figure 45: Stock bottles with cork stoppers

Figure 46: Washing glassware

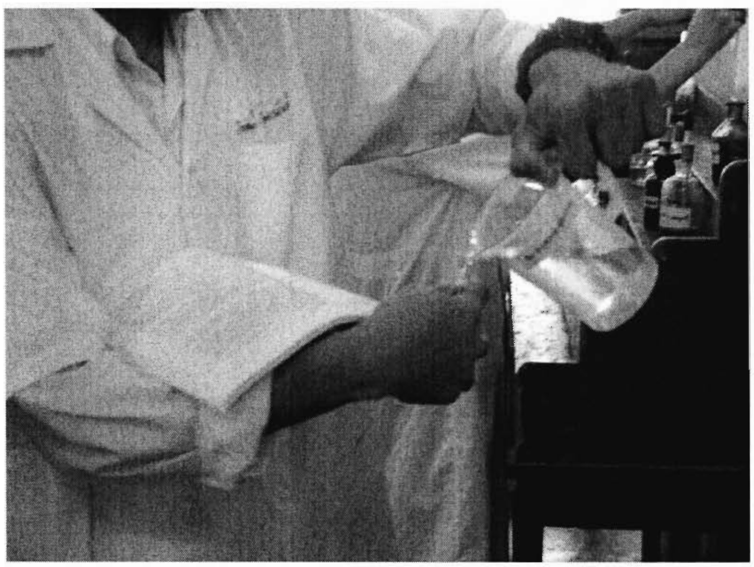

Figure 47: Pouring chemicals directly from stock bottle into test tube

Figure 48: Extremely cluttered laboratory

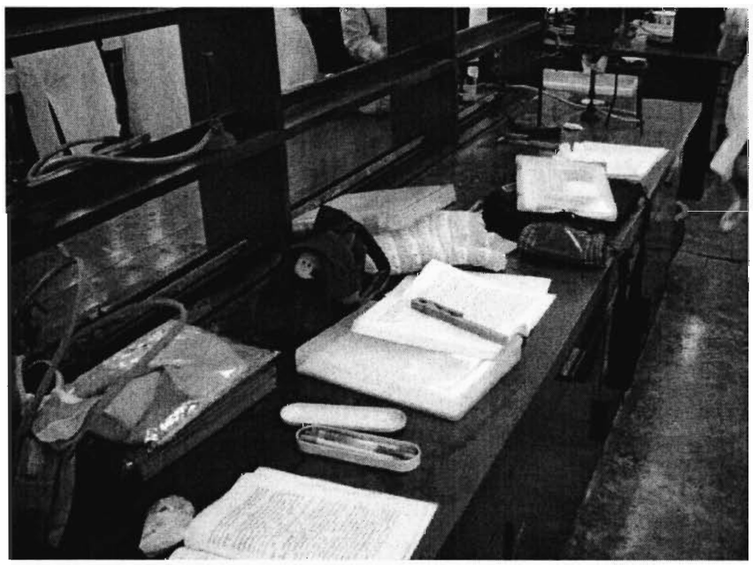

Figure 49: Chemistry lab bench

Figure 50: Trashcan in chemistry lab

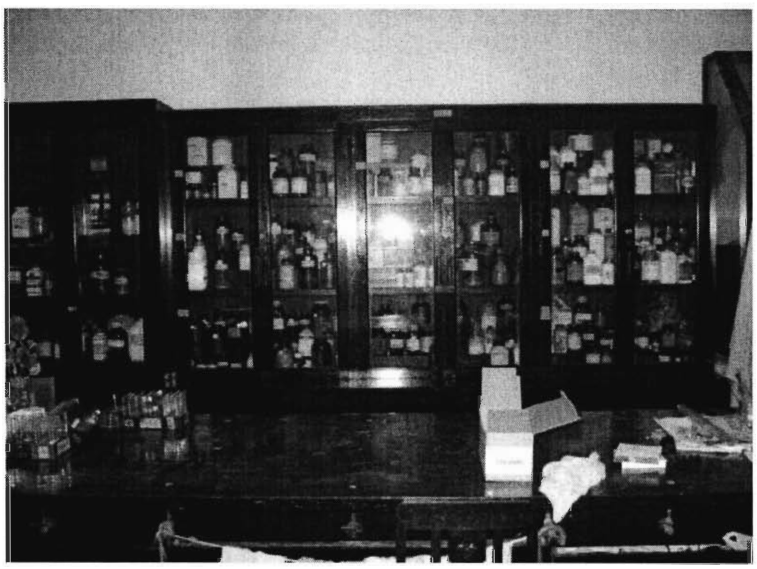

Figure 51: Stockroom in Chemistry Building 1

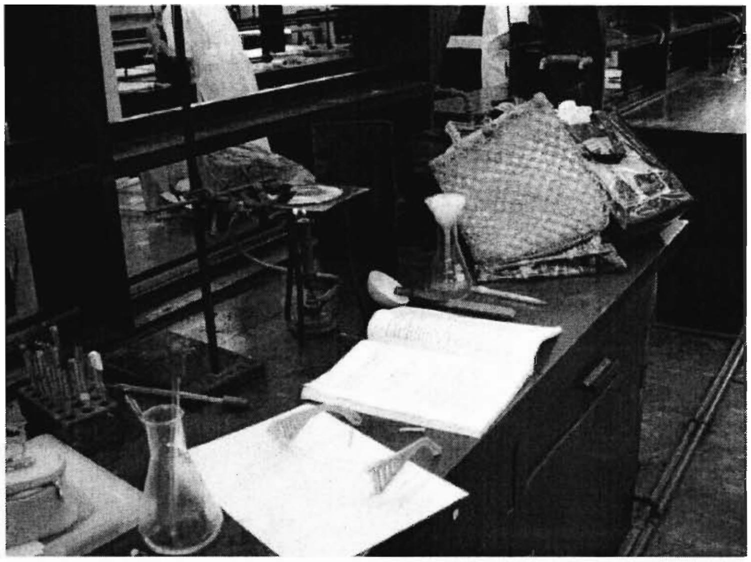

Figure 52: Disorganized work area with flame

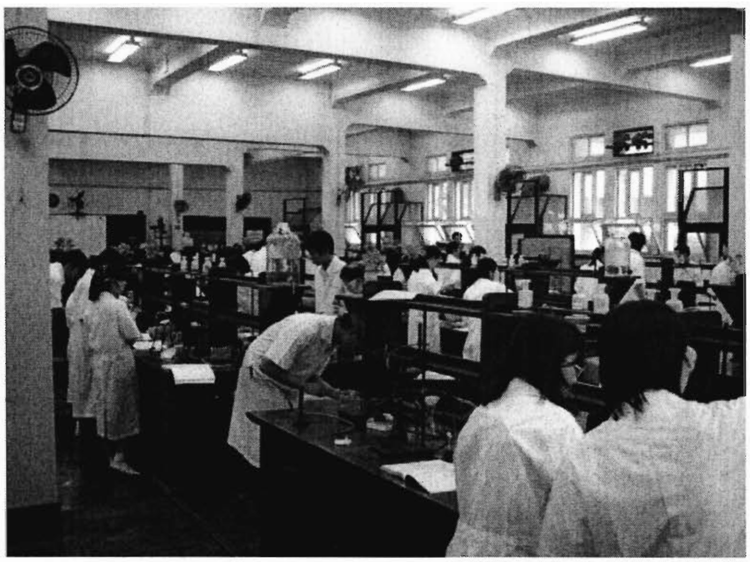

Figure 53: Work environment in first year Organic Chemistry lab

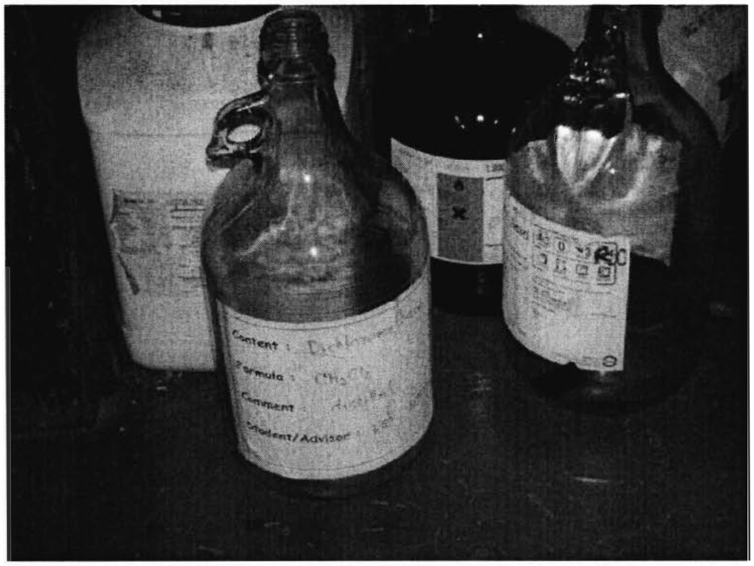

Figure 54: Chemical bottle label

D.3 Waste Disposal Areas at Chulalongkorn

Figure 55: Barrels of Waste in Chemistry Building 3

Figure 56: Jugs of Waste behind Chemistry Building 1

Figure 57: Barrels of Waste behind Chemistry Building 1

Figure 58: Jugs of Waste in Chemistry Building 1

Figure 59: Jugs of Waste behind Chemistry Building 1

Figure 60: Bags of Bottles of Waste in Chemistry Building 3

D.4 Observations of Student Labs

Second Year Organic Laboratory

Standard Practices	Never	Sometimes	Always
Wears gloves	X		
Wears safety goggles		X	
Puts waste in proper containers		X	
Does not contaminate class supplies of chemicals	X		
Is aware of his/her surroundings		X	

Appendix E Fire Safety Form

(applies to all floors of the new science building)

Fire Safety Equipment	Yes	No	Location
Fire Extinguisher/ Type	X		Near elevator/ Dry chemical
Fire Extinguisher/ Type	X		Near bathrooms/ Dry chemical
Fire Alarm	X		Near bathroom
Fire Alarm	X		Near stairwell
Fire Hose Reel	X		Near elevators
Fire Hose Reel	X		Near bathrooms
Sprinkler System		X	
Fire Exit Signs	X		Near bathroom
Exit Signs	X		Near stairwell
Emergency Lights	X		In stairwell
Fire Escape Route Maps		X	

Appendix F Inventory of Chemicals at Chulalongkorn

2002 Chemical Inventory

Chemical Name (no abbreviations)	**Location**
Barium Chloride	Chemistry Building 3, Room 209
Naphthol	Chemistry Building 3, Room 209
Urea	Chemistry Building 3, Room 209
Dichlorobenzene	Chemistry Building 3, Room 209
Ether	Chemistry Building 3, Room 209
Cyclohexene	Chemistry Building 3, Room 209
Acetone	Chemistry Building 3, Room 209
s-Butyl Alcohol	Chemistry Building 3, Room 209
Benzoic Acid	Chemistry Building 3, Room 209
Methanol	Chemistry Building 3, Room 209
Hexane	Chemistry Building 3, Room 209
Diphenylamine	Chemistry Building 3, Room 209
Linseed Oil	Chemistry Building 3, Room 209
Nitrotoluene	Chemistry Building 3, Room 209
Nitrobenzene	Chemistry Building 3, Room 209
Dichlorobenzene	Chemistry Building 3, Room 209
Aluminum Metal	Chemistry Building 3, Room 210
Aluminum	Chemistry Building 3, Room 210
Cuprous Oxide	Chemistry Building 3, Room 210
Phenylactic Acid	Chemistry Building 3, Room 210
Succinic Anhydride	Chemistry Building 3, Room 210
Sucrose	Chemistry Building 3, Room 210
Acetanilide	Chemistry Building 3, Room 210
Sodium Acetate	Chemistry Building 3, Room 210
Aniline	Chemistry Building 3, Room 210
Kupfer III Sulfate	Chemistry Building 3, Room 210
Calcium Chloride	Chemistry Building 3, Room 210
Tartaric Acid	Chemistry Building 3, Room 210
Ammonium Chloride	Chemistry Building 3, Room 210
Barium Nitrate	Chemistry Building 3, Room 210
Albumen	Chemistry Building One
Potassium Bichromate	Chemistry Building One
Trithanolamine	Chemistry Building One
Sodium Chloride	Chemistry Building One
Barium Hydroxide	Chemistry Building One
Stearic Acid	Chemistry Building One
Sulfamic Acid	Chemistry Building One
Sodium Sulfate	Chemistry Building One

Sodium Biphosphate	Chemistry Building One
Phenazone	Chemistry Building One
Naphthylamine	Chemistry Building One
Adipic Acid	Chemistry Building One
Benzioc Acid	Chemistry Building One
Benzil	Chemistry Building One
Benzanilide	Chemistry Building One
Arabinose	Chemistry Building One
Antranilic Acid	Chemistry Building One
Calcium Chloride	Chemistry Building One
Acetylsalicylcic Acid	Chemistry Building One
Benzophenome	Chemistry Building One
Lead Carbonate	Chemistry Building One
Oxamide	Chemistry Building One
Magnesium Sulfate	Chemistry Building One
Glycine	Chemistry Building One
Succinate Acid	Chemistry Building One
o-Nitrophenol	Chemistry Building One
Copper Acetate	Chemistry Building One
Galactose	Chemistry Building One
Sodium Bicarbonate	Chemistry Building One
Sodium Acetat	Chemistry Building One
Potassium Flouride	Chemistry Building One
Lead Acetate Trihydrate	Chemistry Building One
Potassium Iodide	Chemistry Building One
Salcyclic Acid	Chemistry Building One
Oxalica	Chemistry Building One

Appendix G Chemical Safety Plan