

AN ANALYSIS OF CHEMICAL WASTE DISPOSAL IN THE DALHOUSIE UNDERGRADUATE CHEMISTRY LABORATORIES

Greening the Campus Term Project Proposal ENVS 3502

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Abstract

This research project is one of many within the Greening the Campus movement; using the campus as a laboratory for creating a model of sustainability within the community.

Chemical disposal practices were examined in the first year chemistry laboratory at Dalhousie University to determine whether current methods were sustainable or whether improvements could be made. There were a total of five main research objectives: to examine chemical disposal procedures, determine how chemical waste is treated once it leaves the first year chemistry laboratory, determine whether Dalhousie University's wastewater is in compliance with Halifax Regional Municipality's wastewater standards, determine what instructions are given to students in the first year chemistry laboratory, and determine if the students and the staff are following chemical disposal procedures if there are any.

Data was collected by administering group questionnaires to first year chemistry students, and conducting interviews with the Director of Environmental Health and Safety and the two first year laboratory instructors at Dalhousie University. Finally, a document analysis of

literature pertaining to chemical waste disposal in Dalhousie and its parent community, the Halifax Regional Municipality, was conducted.

It was found that Dalhousie University does not have a written policy on chemical disposal in the first year chemistry laboratory. Results from the questionnaire indicated that 83% of students felt they were given safety instructions, but not chemical disposal instructions. The students surveyed also responded that there either there was not or could not remember if there was a disposal containers present in the laboratory. The results also suggested that over 70 percent of the time the disposal methods were not emphasized adequately to students as they often were unaware of whether they were using the proper disposal methods.

Many recommendations have resulted from this report, all of which would lead to a more environmentally sustainable campus and more responsible disposal practices. Implementing a firm policy on chemical disposal, improving signage, written instructions in each lab procedure, microscaling, and emphasizing proper chemical disposal methods by the lab instructors would lessen Dalhousie University's impact on the environment.

1.0 INTRODUCTION

Summary of acronyms:

HRM: Halifax Regional Municipality

TA: teaching assistant

1.1 Background Information:

University campuses are able to serve as miniature, yet comprehensive, models for society. In the early 1980s an environmental educator named David Orr inspired the idea behind the first "greening the campus" project, which sought to use the campus in demonstrating how to create sustainable communities (Envs 3502 syllabus, 2007). Across

the United States and Canada, universities have initiated projects to examine their own environmental practices and how they can improve (Envs 3502 syllabus, 2007). Laboratory practices in universities create wastes that must be disposed of properly to minimize harm to the surrounding environment. At Dalhousie University, the Environmental Health and Safety Office places the onus on laboratory supervisors for ensuring that wastes generated in the laboratory are properly collected, stored, and picked up (Environmental Health and Safety Office, 2007). Chemicals that are to be disposal of down the sink must follow certain guidelines concerning their strength and quantity (Environmental Health and Safety Office, 2007). This research project seeks to investigate whether or not the Environmental Health and Safety Office is following proper guidelines with respect to Halifax Regional Municipality's Wastewater guidelines. The university policy regarding chemical disposal will also be analyzed to determine what guidelines are in place to deal with waste disposal in laboratories.

The members of the research team; Ashley David, Carole Daigle, Gillian Frenette, Anthony Heggelin, Cynthia Kendall, and Fred Walsh, have all taken a first year chemistry class, most of them at Dalhousie, and therefore have been involved in the chemical disposal practices in such laboratories. The bias of this research team is an high interest in the environmental impacts of chemical waste. The experiences of this team have shown that the disposal methods and education in place for students is inadequate to ensure proper chemical disposal with regards to the first year chemistry laboratories

1.2 Research Problem:

The issues discussed in this report involve the current chemical disposal practices in the first year chemistry laboratories at Dalhousie University. The research sought to determine if there are more environmentally sustainable alternatives to current disposal procedures. This issue was researched by surveying the first year chemistry class section with the largest enrolment of students. In total, there are sixteen first year chemistry laboratory sections at Dalhousie University, and since the largest class size was chosen to conduct the survey, it was assumed that the number of lab sections sampled within that class, was adequate. Interviews were also conducted with Dr. William Louch, the director of the Environmental Health and Safety Office, and both first year chemistry lab instructors Karen - Thompson and Sharon Barkhouse in addition to a document analysis of pertinent literature.

1.3 Research Objectives:

- 1.) Determine the procedures in place for disposal of waste in the first year chemistry laboratory.
- 2.) Determine how chemical waste is treated once it leaves the first year chemistry laboratory.
- 3.) Determine whether Dalhousie's first year chemistry laboratories are in compliance with Halifax Regional Municipality's (HRM's) wastewater standards.
- 4.) Determine what instructions, if any, are given to students in the first year chemistry laboratory with regard to handling chemical waste.
- 5.) Determine what procedures are being followed by the students and laboratory instructors in the first year chemistry laboratories.

Delimitations

With respect to the goals of our study, several delimitations were deliberately placed on our study design either due to time restrictions or due to the structure of our research goals. First, we explicitly focused on the first year chemistry laboratories rather than the chemistry department in general. This was done because of time restrictions; we felt that it would be too large of a task to take on the entire department of chemistry. Consequently, we felt it would be best to begin in the first year labs where students are introduced to many of the initial chemistry practices that will guide them through their university life. Second, the study goals of our design focused primarily on quantitative data rather than qualitative data. Although we did collect both genres of data, we put more weight on the concrete info rather than opinions. This was done partially due to ensuring that our recommendations would be accepted by members of the chemistry department, and thus, we focused on the concrete data.

1.4 Definition of Terms:

There are several terms that will be used within this report that must be operationalized. There are two main divisions of definitions: nominal and operational (Palys, 2003). Nominal definitions are those that define what a concept means, and what the researcher is after (Palys, 2003). Operational definitions alternatively describe the indicators that will be used to encapsulate what is being measured (Palys, 2003).

Nominal Definitions:

First year chemistry laboratories: The students enrolled in first year chemistry classes have been sub-divided into sixteen laboratories sections. Chemical laboratory, in this report,

refers to the physical space in which laboratory sections take place. For the purpose of this study, the largest first year chemistry class was surveyed, which included multiple laboratory sections. However, for privacy purposes it was not asked what laboratory section the students belonged to, therefore the exact number of laboratory sections surveyed is unknown.

Chemical waste: Any chemicals that are still present and must be disposed of after an experiment has been conducted in the laboratory

Improper chemical waste disposal: Disposal of chemical waste that has not been approved by the Dalhousie Health and Safety Office, the laboratory instructors, T.A's, and/or has violated HRM water safety guidelines.

Environmental Sustainability: Practices that do not degrade the natural environment beyond natural regenerative capacity.

Operational Definitions:

Improper chemical waste disposal: This was determined from student surveys that established where students frequently dispose of chemical waste and an analysis of Dalhousie's Environmental Health and Safety Office report on wastewater quality.

Interviews with first year chemistry lab instructors as well as Dr. William Louch, director of Environmental Health and Safety Office, helped to establish where and how wastes were disposed of, as well as the procedures that students are expected to follow in the first year chemistry laboratories.

Environmental Sustainability: Measured through the degree of compliance with HRM wastewater guidelines, an analysis of the wastewater report by Dalhousie's Environmental

Health and Safety Office, and scientific knowledge of the types of, and dangers associated with, chemicals that are used in the first year laboratories.

1.5 Research Importance:

Environmentally sustainable chemical disposal practices in chemistry laboratories are worthy of further study for a variety of reasons. Chemicals deposited into the environment, specifically entering waterways, can have many negative effects such as causing problems with the taste, odour and colour of the water (Environment Canada, 2007). Fish and wildlife can experience reduced fertility, generic deformities, immune system damage, and an increased incidence of tumours, and death (Environment Canada, 2007). Many chemicals do not break down and can persist in the environment for long periods of time (Sierra Legal Defence Fund, 2006). Some heavy metals and synthetic chemicals also bioaccumulate as they move up the food chain, posing risks to benthic invertebrates, fish, sea birds, and mammals (Sierra Legal Defence Fund, 2006). Ultimately, they can contaminate humans, through consumption of fish and other sea creatures. Chemicals used in the first year labs include acids, bases, and heavy metals. This study investigates the disposal methods of such chemicals. If a large number of students dispose of such chemicals, particularly heavy metals, down the drain, this pollutes the Halifax Harbour. Proposed sewage treatment plants that will be initiated in the HRM, in the coming year, will contain advanced primary treatment (Halifax Regional Municipality, 2003). While secondary treatment removes over 90 percent of toxic, bioaccumulative substances like heavy metals and persistent organic pollutants, primary treatment does not adequately treat these substances (Sierra Legal Defence Fund, 2006). Therefore, the best treatment is to ensure that toxic chemicals do not enter the sewage system.

This study is also important because it deals with students in the first year chemistry laboratories, which is compulsory for most first year science students. Therefore; hundreds of students pass through this course each year. It is important to instill environmentally friendly laboratory practices in the students while they are developing their laboratory techniques and personal habits. It is also an opportunity for the university to become leaders and stewards of the environment by increasing sustainability in departmental practices.

1.6 Significance of Problem with respect to Greening the Campus:

The present research is important to the university community in various ways. If it is found that there are environmental problems associated with the laboratories, the results of this project will enable recommendations to reduce the impact that Dalhousie's first year chemistry laboratory has on the environment. This will allow Dalhousie University to reduce its overall environmental footprint and aid in the movement towards a more sustainable campus. In 1990, Dalhousie signed the Talloires Declaration, in which Universities pledged to increase sustainability through the implementation of new policies, through enhancing curriculum and by applying changes in physical operations reflecting a commitment to sustainability (Envs 3502 Syllabus, 2007). Suggested recommendations deal with chemical disposal education in the first year chemistry labs to be integrated into the first year chemistry course curriculum. Additional recommendations deal with awareness and education issues by the chemistry students. Consequently, this recommendations of this research study contribute to Dalhousie's pledge to the Talloires declaration while also contributing to greening the curriculum.

1.7 Report Composition:

This report will utilize several research methods in order to answer the outlined objectives concerning the study's purpose. The methods employed in order to answer the research objectives are described in detail. Justification concerning the research tools used, including the reliability and validity achieved in the research process is provided. The results of the surveys are presented in pie charts. A discussion ensues, summarizing the significant findings, the implications for theory and practice, as well as a comparison to existing research studies in similar areas. Recommendations for further research are suggested at the end of the report.

2.0 METHODS

2.1 Design of the Study

The chosen methodology was designed in order to complete the goals of this research project. Student questionnaires were conducted in order to accomplish goals 1 and 4 (see Project Definition, Goals). An interview with Dr. William Louch, Director of the Environmental Health and Safety Office for Dalhousie University, functioned to determine information for goals one and two. Lab instructor interviews were conducted in order to complete goals one, four and five. Document analysis of appropriate literature enabled the research team to fulfill the third goal.

2.2. Student questionnaires

Purpose

Following pilot testing and ethics approval (ethics request submitted with proposal) a student questionnaire (Appendix A) was conducted in order to determine how and why

students are disposing of chemicals in first year chemistry labs. This method was essential for determining whether students are instructed on proper disposal techniques and if so, whether they are following the guidelines provided. Furthermore, it is important to determine what proportion of the chemicals used in first year chemistry labs (if any) are being disposed of down the sink.

Justification of Instrument

A group-administered questionnaire was thought to be appropriate for this study because it is useful in gathering a large amount of information in a timely fashion, it guarantees the anonymity of the subjects, and is helpful in organizing participant responses in a way that can easily be analyzed (Palys, 2003). The majority of the questions in the questionnaire were structured such that the respondents had three choices; “yes”, “no” and “I don’t know” (Appendix A). The length of the questionnaire was short in order to minimize the time that it would take for students to complete. This was prioritized because the questionnaire was conducted during first year chemistry class time and a short questionnaire was necessary in order to obtain the professor’s approval.

Procedure

A group-administered questionnaire (Appendix A) was given to a sample of first year chemistry students. There are approximately six hundred first-year chemistry students enrolled at Dalhousie University during the winter semester of 2007. For the purpose of this report it was felt that a sample size of 10% of the sampling frame was an appropriate representation of the population. Thus, a target sample size of sixty first-year chemistry

students was the goal. The class with the largest size was chosen as the sample population in order to guarantee that an adequate representation of first year chemistry students was taken. The instructor, Dr. Guy, was asked for approval to conduct a short questionnaire that would take approximately 5 to 10 minutes in total. Three of the group members attended the approved class date and began by briefly over viewing the research team and the purpose of the questionnaire. Students that were late attending, and thus missed the introduction, were passed a questionnaire and asked to read the introductory paragraph and to complete the survey.

Sampling a class as opposed to a lab was desirable because it sampled students from multiple labs as opposed to just one. Different lab periods have different instructors and TAs. This method accounts for inconsistencies in the way the labs are conducted with regard to the instruction and guidance provided.

Analysis

The questionnaires that were distributed to the first year chemistry students were pre-coded so that their results could easily be analyzed. Since the questionnaires contained mainly close-structured questions and followed a standard form, patterns from the respondents' answers were more recognizable than patterns arising from multiple interviews. The participants' responses were compared and analyzed to determine such information as the proportion of students who agree with a particular statement made in the survey. This was possible to ascertain since respondents were given "yes", "no" or "I don't know" choices in the majority of the questions. The responses were compiled and inserted into Microsoft Excel for visual illustration. The final question was open-ended and thus could not

be pre-coded. Following the completion of the questionnaire, the final question was analyzed for key comments or ideas addressed by the students.

Limitations

A limitation of the study was that it did not inquire in the questionnaire as to what laboratory section the student is enrolled in. This would have been helpful in determining whether there was proper representation among lab sessions, or to relate inconsistent responses with different TAs and/or lab instructors. After careful thought and consideration, it was felt that this was an inappropriate question to ask students since it may have caused first year chemistry staff members to feel as though they were being monitored, and thus cause tension and mistrust between the study group and staff members. This question may have also caused the students being surveyed to feel that their anonymity was being compromised.

2.3 Expert interviews

Purpose

Following ethics approval, expert interviews were conducted with the first year chemistry lab instructors, Sharon Barkhouse and Karen Thompson, as well as with Dr. William Louch, the Director of the Environmental Health and Safety Office. The interviews with the lab instructors were helpful first, in determining what protocols are in place to ensure proper disposal as well as what information the first year lab instructors are relaying to students concerning chemical disposal. This objective is important because this research team believes it is the university's responsibility to inform the students of proper chemical

disposal procedures. A top down approach is often necessary in order to ensure and promote sustainability for institutions such the Dalhousie campus. Furthermore, the lab instructors provided insight on whether students are following lab instructions and helped determine if students are respecting the guidelines that are being given to them. This is important in determining if chemicals are, in fact, going down the drain. The interview with Dr. William Louch served to obtain information regarding the infrastructure that the university has implemented to deal with these chemicals. This includes university protocols and tools in place to mitigate the environmental harm of the chemicals used.

Justification of Instrument

We felt that the extra time and effort in conducting a face-to-face interview format for gathering information from experts was worthwhile and most appropriate for several reasons. The information that the researchers are seeking from the experts were not single response questions that could be satisfied through a questionnaire or survey. Elaborate explanation and discussion was required in order to obtain of full understanding of the elements. Moreover, interviews, as opposed to surveys or questionnaires, have a much greater success rate in the number of questions respondents will answer. In a questionnaire, it is easy for a participant to skip a question either accidentally or purposefully. However, in a face-to-face interview, the interviewer can ensure that the questions are in fact answered, for example, by reposing the same question in a different manner if a thorough response was not received the first time. Additionally, the ability to hear from respondents directly is helpful in that the interviewer is able to hear the explanations for the respondent's viewpoints, and allows the interviewee to expand on his/her thoughts. There is great versatility in interviews

in terms of their structure. An interviewee may open up new questions that the interviewer had not thought of, or may give the researcher more information than they were expecting on a candid subject, if the two form a trust. Respondents may be more willing to share information with a person face-to-face rather than a piece of paper, as is the case in a questionnaire (Palys, 2003). Furthermore, face-to-face interviews ensure that the interview stays on track and allows you to observe the interviewee's facial expressions and reactions while answering the questions. This provides insight as to the measure of truth in the responses.

Procedure

One interview was conducted with Dr. William Louch on January 25th, 2007. Prior to the interview, Dr. Lauch was contacted in-person in order to introduce our project and set up an appropriate meeting date. Five of our group members met with Dr. Lauch on the approved date at his office. Several topics were discussed, beginning with a brief overview of the mechanisms in place within the first year chemistry laboratories that aid in the chemical disposal process. Policies that lab instructors and students are expected to follow with regards to environmentally friendly chemical disposal were also explained by Dr. Louch. An open discussion on several topics related to the first year chemistry laboratory sessions facilitated a relaxed and trusting environment and served to yield information that we would not have otherwise inquired.

The senior lab instructor was contacted in-person by one of our group members to familiarize her with our project and to discuss an approved meeting date for an interview. Interviews were conducted with the two first year chemistry lab instructors on March 6th,

2007. The two instructors were interviewed simultaneously at their request in order to minimize time taken from their occupation. Many questions were asked, such as if and how the lab instructors facilitate proper chemical disposal, whether they feel students respect these guidelines and whether there is a policy outlined by the university to guide proper chemical disposal. Both of the lab instructors were interviewed to account for different training to students on chemical disposal depending on the laboratory session.

Analysis

All the questions were open-ended and, as a result, coding was conducted after the data was collected. Our analysis of the results was conducted by looking for key themes and patterns in subjects responses. For example, key words and the overall main ideas that were presented during the interviews. Additional information that was not intentionally sought was also recorded. Some was useful for providing recommendations or may have inspired new ideas or questions by the research team.

Limitations

Our original study design included interviews with first year chemistry teaching assistants in order to triangulate the topics we wanted to address. Unfortunately, due to privacy issues, the group was unable to contact them to conduct interviews or questionnaires. Another limitation included the method for which the lab instructors were interviewed. This report would have preferred to conduct individual interviews with the lab instructors since this would have allowed us to ensure that both of the instructors were able to properly represent themselves. Unfortunately, this was not possible due to the circumstances. It is

important to take into consideration that participants are busy and cannot always be flexible, this is a limitation beyond the control of a time constrained research design.

2.4. Document analysis

Purpose

Document analysis was undertaken to verify the types of chemicals being used in first year chemistry labs, as well as to determine HRM's wastewater guidelines and to find out if there is evidence indicating that Dalhousie University's first year chemistry laboratories meet these guidelines. The importance of this objective was to determine the toxicity of chemicals being used in the labs, and to measure the severity of the consequences of improper chemical disposal. Some chemicals are neutralized in the university's limestone pits, whereas others may not be treated prior to entering wastewater thus having negative impacts on the environment. HRM's guidelines are helpful in investigating whether Dalhousie University's wastewater is within the expected standards. The municipality has wastewater policies in place in order to prevent harm to the environment; therefore, they are a useful baseline to determine the university's, and specifically its first year chemistry laboratories', environmental impact. When looking at potential recommendations that can be made, this study investigated how other universities are conducting their chemistry labs in terms of chemical disposal.

Justification of instrument

Document analysis of relevant literature or policies related to Dalhousie University's chemical disposal practices served as useful tools in the study. A document, by its very

nature, is a stable and persistent piece of literature that is available to refer to numerous times. This is helpful in a research process, to further analyze a work or to subject it to additional scrutiny. Although researchers may disagree on the interpretation of a particular document, every researcher is working with the same record, unlike an oral history for instance, where every researcher may interpret a different story. Document collection is also less expensive than many other research methods and may be easier to obtain in some circumstances due to wide availability from the Internet as well as electronic library databases. Documents may contain information that experts in their own field have collected through their own research methods. Such experts may not be available for interviews, therefore a literature review of their work is extremely beneficial.

Procedure and Analysis

Relevant university documents, primary literature, and HRM documents were examined. First year chemistry laboratory manuals were analyzed in order to categorize the chemicals (e.g. acidic, heavy metal) and approximate the amount of chemicals being used in the laboratory by each student. A review of primary literature allowed a clarification of the environmental concerns related to the chemicals used in the first year laboratory. The estimated wastewater content from the first year laboratory was compared to the guidelines directed by HRM.

Limitations

Some documents could not be utilized to their full potential due to concerns of privacy. For example, one of the group members was able to obtain a document listing

information regarding to quantities of chemicals used in the first year chemistry laboratories. Unfortunately, the information from this document could not be used to conduct a comprehensive analysis of the types and quantities of chemicals.

2.5. Reliability and Validity

This study strived to ensure the reliability of the research project by providing descriptive steps in the research methods such as how questionnaires were conducted, who were the research participants, and how the data was analyzed. As a result, future research teams are able to replicate our study.

The report's questionnaire had a high degree of reliability since it was pilot tested and reformatted several times before conducting the questionnaire and providing each student with the same questionnaire and introductory information. Pilot testing and reformatting of the questionnaire improved its internal and external validity. It improved the internal validity because it was appropriately designed to determine the specific information that this study was trying to access from the students. Additionally, it was externally valid in that it could be used to determine the same information from other students from different universities, colleges, or high schools. The validity of the data analysis was elevated by re-counting the responses several times to ensure that the questionnaire responses were properly recorded prior to transporting to an excel file.

The reliability of conducting the interview with the lab instructors may have been compromised because they were conducted simultaneously. Pairing up individuals for face-to-face interviews may yield different results, than separate interviews, because one of the interviewees may dominate the conversation, and valuable information from the other interviewee may not be covered.

3.0 RESULTS

3.1 Student Questionnaires

The student questionnaire was composed of eight questions (see Appendix A). The first seven questions provided choices for the students to respond. The results of such responses have been tabulated into percentages and are presented in figures 1-7. Question 8 was an open-ended question in which the students were able to provide comments and feedback regarding the disposal of chemical wastes in their respective laboratory sections and/or experience.

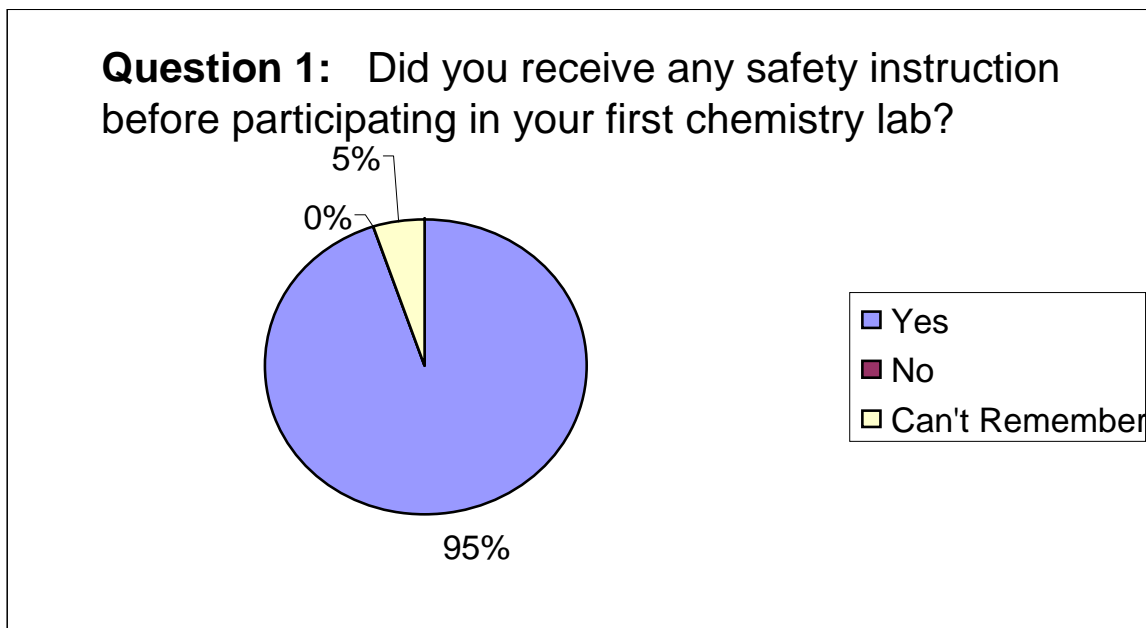


Figure 1. Results from Question 1 in the student survey.

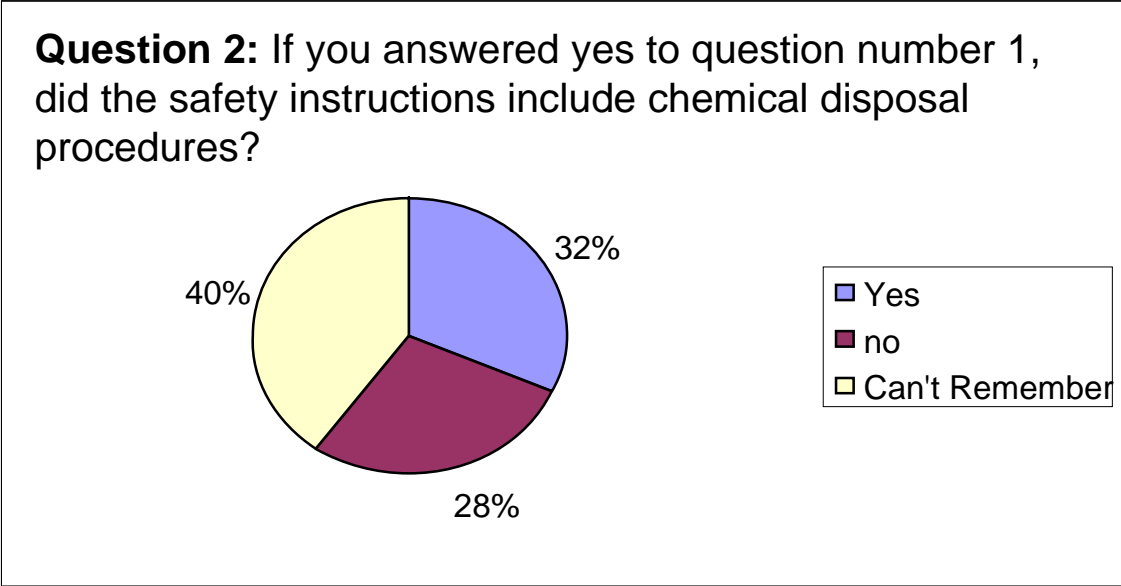


Figure 2. Results from Question 2 in the student survey.

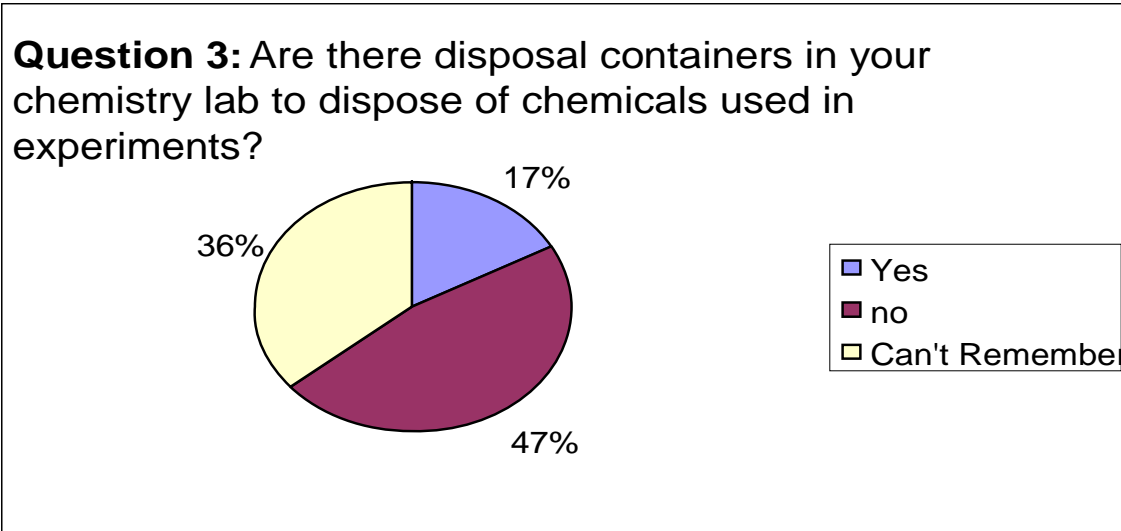


Figure 3. Results from Question 3 in the student survey.

Question 4: In your first year chemistry lab, which of the following locations have you used to dispose of chemicals?

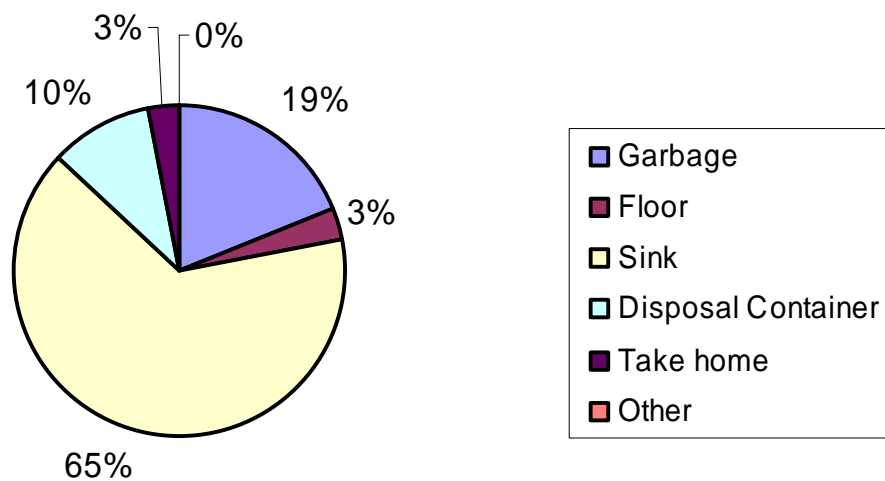


Figure 4. Results from Question 4 in the student survey.

Question 5: Was this the appropriate location for the disposal of the compound/solution you were using?

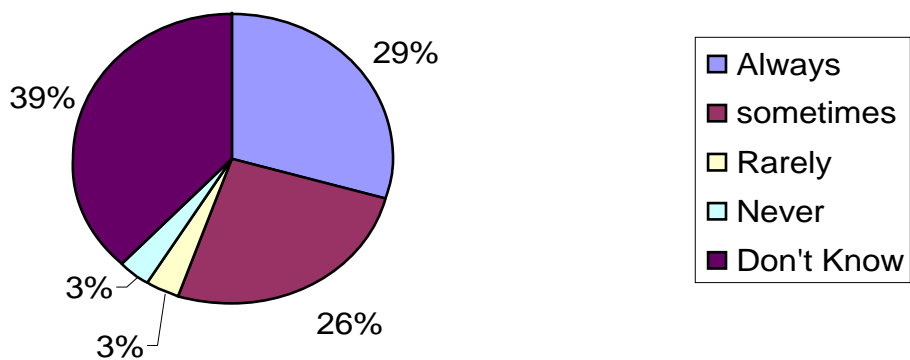


Figure 5. Results from Question 5 in the student survey.

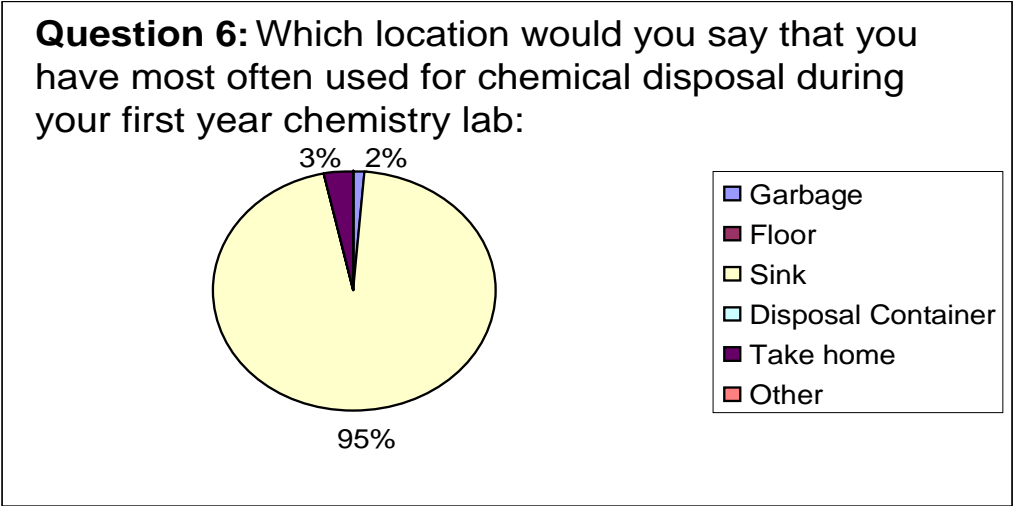


Figure 6. Results from Question 6 in the student survey.

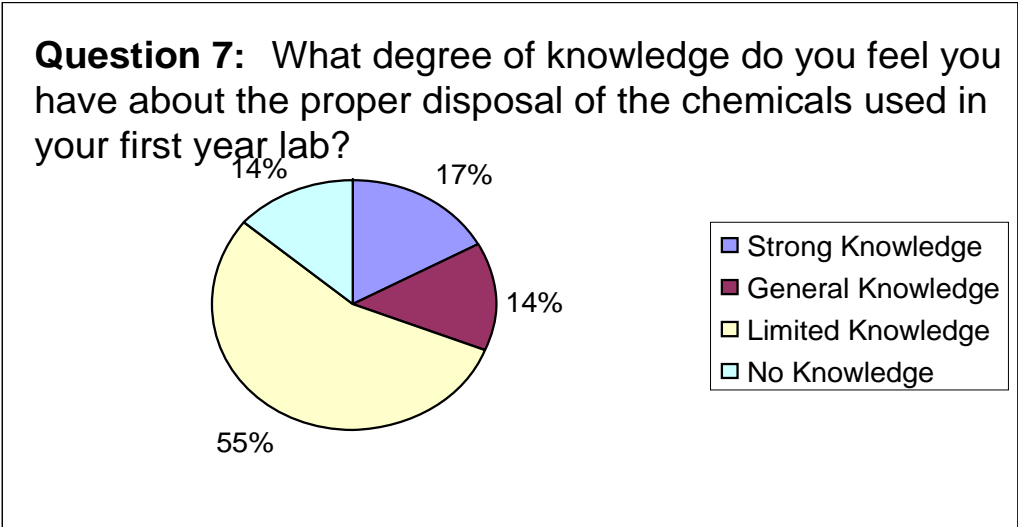


Figure 7. Results from Question 7 in the student survey.

Question 8 of the student survey was analyzed among all participants indicating students are concerned about the impact chemical wastes have on the local environment but do not feel they have sufficient knowledge or instruction regarding proper disposal practices.

3.2 Expert Interviews

Dr. Louch provided information, during his interview, regarding the infrastructure in place to mitigate the impacts of chemical wastes deposited in the first year chemistry laboratory sinks. He also provided information regarding the treatment of wastes collected from laboratory experiments and the various procedures and processes in place to deal with various sorts of chemical wastes created in the university's laboratories. Figure 8 outlines the various pathways of chemical waste in the first year laboratories. Dr. Louch was very knowledgeable and introduced to the group the practice of micro-scaling, which will be discussed in further detail in the recommendations section.

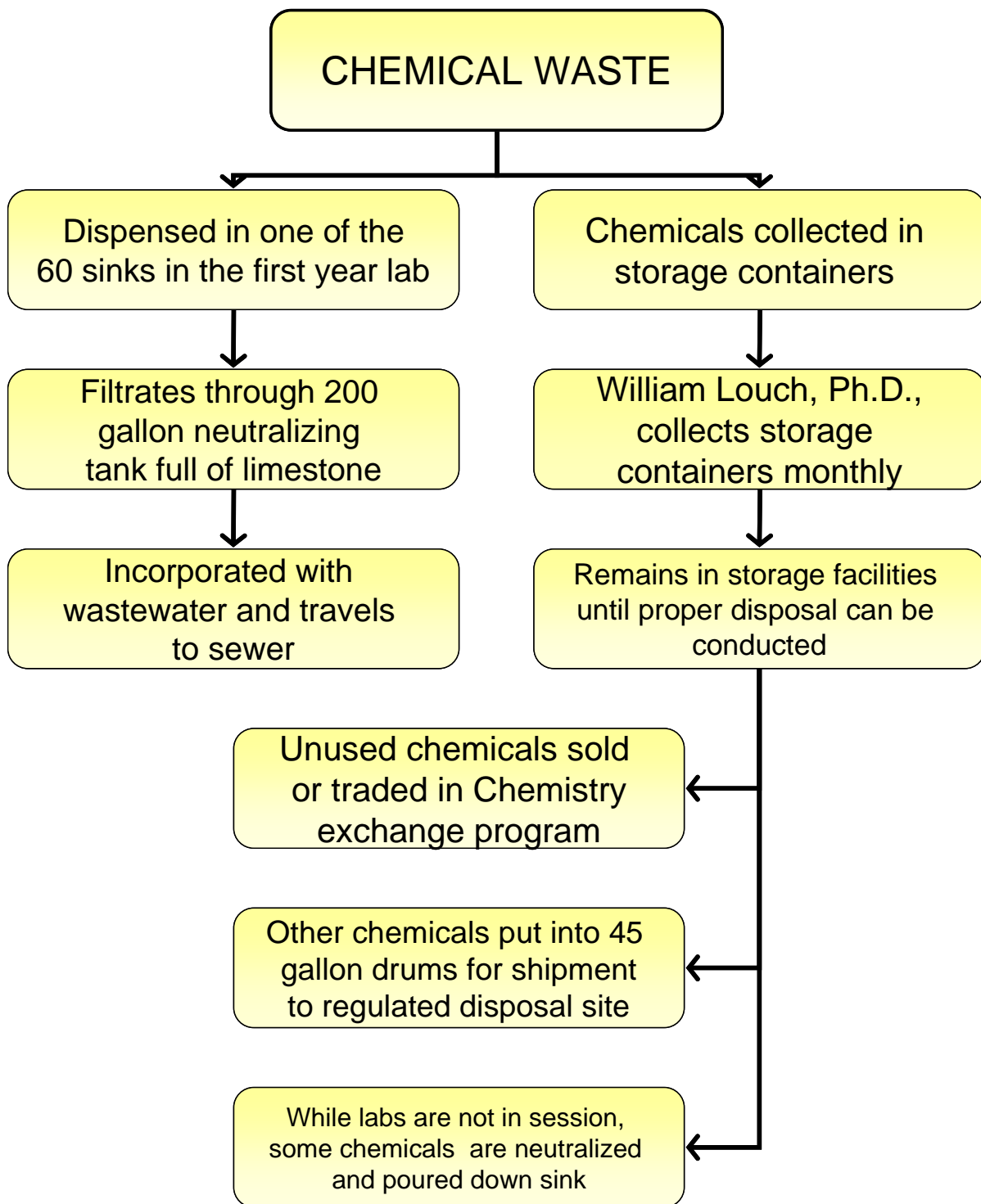


Figure 8. The various pathways for chemical waste leaving the first year chemistry laboratory at Dalhousie University. Information provided by Dr. Louch, Director of Environmental Health and Safety Office.

Several questions, similar in nature, were asked in the interview with the lab instructors. The first question posed regarded whether students received instruction at the beginning of the lab class on proper chemical disposal. Both instructors answered that they talked about safety and how to use chemicals properly, and did not really think of disposal until the end of class. They said that most times students asked where to dump the chemicals during the lab. The second question posed regarded where most students were disposing of the chemicals. The instructors answered the sink, stating that most of the chemicals being used in large amounts were benign and that most of those that were not had been micro scaled to smaller amounts. The instructors were asked what percentage, in their opinion, of chemicals that were not benign were disposed of in the sink. The lab instructors responded about 1%. It was then inquired whether they were aware of proper disposal procedures for chemicals used in laboratories. Both instructors answered yes and stated they had a lot of experience dealing with chemicals. The instructors were then asked if they thought students in first year chemistry lab were aware of the environmental ramifications of the inappropriate disposal of chemicals. They both replied that many students ask questions and were worried about it. The lab instructors were given the opportunity to add additional comments. Both mentioned that they would like to see a book with MSDS sheets in the first year lab for the chemicals being used.

3.3 Document Analysis:

Halifax Regional Municipality has specific guidelines pertaining to the disposal of chemicals by means of the wastewater system under the “Wastewater Discharge By-Law” number W-101 (Halifax Regional Municipality, 2001). The regulations that have been

developed are designed to protect the health and safety of Halifax wastewater and to maintain the integrity of the wastewater facilities. Acceptable concentration limits of various chemicals are outlined in parts per litres as well as pH and temperature levels. This information was obtained from the Halifax Regional Municipality website (www.halifax.ca) in order to review current regulations and guidelines for the Municipality and to determine the procedures Dalhousie must follow to comply with these regulations.

Under section 3(5), chemical contents that exceed the Halifax Regional Municipality's disposal regulations cannot be diluted with water to meet the acceptable standards then disposed of through the wastewater system (Halifax Regional Municipality, 2001). Under this section it is not acceptable to dispose of some solutions by dumping them down a sink drain with running tap water (Halifax Regional Municipality, 2001). According to the student questionnaires that were collected in this study, 95 % of students dispose of their chemicals down the drain (See results section). Exact acidity levels and temperatures of the chemicals disposed of within Dalhousie's first year chemistry laboratories could not be found, therefore it is difficult to determine whether or not Dalhousie University is violating this HRM regulation or not. Under section 3(1) of the HRM report, it states that no person shall discharge contents into wastewater that causes or may cause a health or safety hazard (Halifax Regional Municipality, 2001). Depending on the severity of the chemicals, it is possible that damage can be caused to the water system, as was discussed in section 1.5 of this report.

Institutions, such as Dalhousie University, are required to submit a discharger information report to the Halifax Regional Municipality explaining what chemicals are disposed of through the wastewater system, the concentration of the chemicals, and seasonal

variability (Halifax Regional Municipality, 2001). According to the HRM's guidelines, it is the institution's responsibility to monitor wastewater discharge and provide this information to the Municipality (Halifax Regional Municipality, 2001).

The Environmental Health & Safety Office publishes an annual report that outlines the provisions in place for the management of hazardous materials. Dr. William Louch, Director of Environmental Health and Safety Office, provided the 2006 Dalhousie Annual Report, published in February 2006, to be reviewed in this study. The purpose of analyzing this report was to understand Dalhousie's current chemical waste disposal practices. It was found that waste materials are collected monthly by the Safety Office and are disposed of by various methods. A large portion of the waste from the laboratories is disposed of during the summer months (Dalhousie University, 2006). According to Dalhousie's report, acid and base solutions are neutralized and radioactive wastes are chemically destroyed (Dalhousie University, 2006). This suggests that Dalhousie is not violating section 3(1) of the HRM guidelines. Hazardous fluid wastes are also shipped to a licensed hazardous waste facility for proper disposal, signifying compliance with HRM guidelines (Dalhousie University, 2006).

4.0 DISCUSSION/CONCLUSION

4.1 Purpose Statement

The purpose of the research conducted in this study was to determine the ways in which students in the first year chemistry laboratories disposed of their chemical waste, and whether or not they followed HRM and university protocol. An investigation on improved disposal practices was also made to determine if there were more environmentally sustainable methods in which to dispose of the waste.

4.2 Overview of significant findings

A substantial change in the certainty and consensus of students is shown from questions 1 and 2. In question 1, there was a strong consensus that safety instructions were given (95% Yes), whereas, in question 2, students were considerably divided as to whether chemical disposal procedures were instructed (32% Yes, 28% No, and 40% Can't Remember). This may reflect the fact that chemical disposal procedures were either not covered at the introduction of the lab, or that they were not emphasized such that it became memorable for students. This is further supported by the results expropriated from the lab instructors. The lab instructors stated that they put a large amount of emphasis on proper safety techniques in order to ensure the safeguard of the students. However; proper disposal techniques are not instructed perhaps until the end of class, or until students ask for directions on the subject.

A great deal of uncertainty was documented when students were asked whether chemical disposal containers are found in the lab (question 3). Many students said "No" (47%) or could not recall (36%). Nevertheless, according to lab instructors and Dr. William

Louch, chemical disposal containers are, in fact, located in the lab. The uncertainty among students is likely because either the disposal methods and equipment are not introduced to the students or not sufficiently emphasized to remain memorable. Additionally, perhaps the disposal containers may not be labeled boldly enough to catch the attention of busy students in the lab.

The results of question 5 indicate that students are not always certain as to whether the disposal methods they use in the lab are appropriate for the chemicals that are used. The results suggest that over 70% of the time, the disposal methods are not emphasized adequately to students such that they are aware that they are using the proper method of disposal. The students are thus left to their own inexperience to decide what method is appropriate. However, according to question 7, most students have “limited” or “no” knowledge as to proper disposal methods, thus, the method of disposal should likely not be left up to them; guidance must be given if proper disposal of chemicals are to be ensured.

The greater part of the time, students disposed of the chemicals by means of the sink (95%). The lab instructors’ interview was consistent with this result, and they reasoned that most of the chemicals are benign and do not cause problems being deposited in the sink. According to the lab instructors, chemicals that are harmful are only deposited down the sink approximately 1% of the time. However, assuming that the alternative disposal method would be by means of disposal containers, this estimate does not seem accurate; only 17% of students are even aware that there are disposal containers in the lab. Nonetheless, from question 4, there is evidence indicating that students use the disposal containers.

Additional comments given by the students indicated that some students were uncomfortable with the fact that they did not have enough knowledge and direction on how

to dispose of chemicals in the lab. Lab instructors also encountered students that were worried about proper chemical disposal and some students sought disposal instructions from the lab instructors. These results further support that students are not being given instructions on disposal methods, or that disposal methods are not properly emphasized. The results also show that many students would be accepting and would follow disposal directions and instructions if they were given and/or emphasized.

4.3 Implications of the research:

There are numerous implications that this study could possibly have on theory and practice. The results found in this report may be applicable to other universities with regard to their environmental policies on chemical disposal. The recommendations that will be made to the Dalhousie Chemistry Department as well as to Dalhousie's Environmental Health and Safety Office could also encourage innovation on other university campuses as well as Dalhousie's own. A superior environmental policy regarding chemical disposal may result as a consequence of the study's findings. A change or improved enforcement of disposal policies would be beneficial, not only for the surrounding environment that is affected by the presence of chemicals in the water system, but for Dalhousie's financial benefit. If chemicals can be used more efficiently to decrease the amount of chemical waste created, the university would save money in purchasing chemicals. This report is also expected to raise awareness in environmentally sustainable practices, specifically in the area of chemical disposal in the laboratories. Student education is clearly required in the chemistry laboratories, regarding proper chemical disposal. Following the recommendations, it is anticipated that there will be more information given to students on the consequences of

improper disposal as well as where to dispose of each type of chemical. The enforcement of such practices would ensure that the first year chemistry students have an understanding of the importance of such disposal methods.

4.4 Research in light of existing studies:

Comparisons to existing research studies in the area of chemical disposal can aid in determining the importance of this study in terms of research that has already been performed in other locations, specifically at other universities, and by researchers with different perspectives than those found in this report. A study done at the University of Waterloo in 1995 investigated similar questions to this study, concerning disposal practices in chemistry laboratories. In the Waterloo report it was found that all of the chemistry students studied, through first to fourth year, had engaged in WHMIS training (University of Waterloo: Chemical Disposal in Science Labs, 1995). The report found, however, that it was not required for first year chemistry students to enroll in a WHMIS training session (University of Waterloo: Chemical Disposal in Science Labs, 1995). Students were found to use the disposal containers more frequently in the Waterloo laboratories that were studied, as compared to the results found in this study. In the Waterloo report, it was also asked how often the students utilized each disposal method. In terms of disposal down the drain, the majority of students cited that they sometimes engaged in this method. However, when it was asked how frequently the students used the disposal containers present in the laboratories, the majority answered “frequently” (University of Waterloo: Chemical Disposal in Science Labs, 1995). The discrepancy between the Waterloo study and this study may have occurred as a result of the WHMIS training that the students received, or due to an increased enforcement of proper disposal practices in the laboratory.

A second study that was also done at the University of Waterloo in 1999 focused its objectives on determining environmental sustainability and effectiveness of the hazardous materials system at the University of Waterloo. It was found that there was a high level of compliance with respect to municipal, provincial, and federal regulations with regard to handling of hazardous materials (University of Waterloo: Hazardous Materials, 1999). Dalhousie's 2006 Environmental Health and Safety Report determined that Dalhousie is in compliance with HRM's wastewater guidelines. There was only one report conducted on the quality of Dalhousie's wastewater and chemical waste disposal, therefore the results may not have been representative of Dalhousie's compliance with HRM wastewater guidelines. The results of the Waterloo study also established that the student population was generally unaware of the importance of WHMIS training (University of Waterloo: Hazardous Materials, 1999). Through surveys, the students had responded that there was frequent improper disposal of hazardous materials in the chemistry laboratories (University of Waterloo: Hazardous Materials, 1999). This same outcome was found in this report as well. Even though the Waterloo report concluded that the university had generally had a high rate of compliance with hazardous materials, the students were still found to engage in improper disposal methods. Perhaps there needs to be more effort applied to student education and awareness in laboratory chemical disposal. Despite the fact that compliance to hazardous materials regulations was found to be adequate it was obvious that the student population is an ideal target to ensure environmentally sustainable practices in the laboratories.

4.5 Conclusion- Recommendations

During the present investigation of chemical disposal practices in the first year chemistry laboratory, several potential improvements were noted to improve current procedures and ensure more environmentally sustainable disposal practices. An excellent way to start improving chemical waste disposal in the first year chemistry lab would be to develop and implement a firm policy on chemical waste disposal. Other universities have developed guidelines specifically pertaining to chemical waste disposal in laboratory sink. Harvard has developed a document entitled “Laboratory and Building Operations Guidance on the Sink Disposal of Chemical Substances” (Harvard, 2003). A similar policy, here at Dalhousie, could be the foundation of a much more environmentally friendly waste disposal system for the first year laboratory. If this policy was established, a brief and easy to read version could be made into a poster, which could be posted many places in the chemistry lab. Proper disposal methods would be displayed on the poster. The poster could be sub-divided into specific laboratory experiments and the disposal location for the wastes created in each major part of each experiment.

Another method of improving proper chemical waste disposal is by including specific instructions in the lab manual. Each lab could have steps included in the methods section, with specific directions on chemical waste disposal. Students could also be required to take a Web CT quiz, administered by the chemistry department, on proper chemical disposal practices. These suggestions would ensure better disposal practices; however, there must be an enforced disposal policy in place for these suggestions to be effective.

Further research could be done on whether any of these suggestions were implemented and the same questionnaire could be distributed to first year chemistry students

in the following years. Results from the questionnaires can be compared to the results obtained in this study to determine if the suggestions made a difference in student awareness.

Reducing the amount of chemical waste created in the first year chemistry lab would be beneficial to the environment and the budget at Dalhousie University. The practice of using smaller amounts of chemicals to conduct experiments is known as micro-scaling. The first year chemistry lab currently practices micro-scaling in five of its experiments, but could further minimize waste if the remainder of the labs were converted to micro-scaling. Since microscaling in university chemistry laboratory experiments was initiated by Bowdoin College in New England in the 80's, many educational institutions across the globe have followed suit (Ferguson, 1999). Canadian universities that have instituted micro-scaling into their laboratory practices include McMaster, Brock, Waterloo and the University of Windsor. The incorporation of micro-scaling into laboratory practices saves the institution money through a decrease in chemicals purchased and decreased chemical waste processing fees. Future research studies could perform a feasibility analysis of purchasing the glassware and equipment necessary to convert all first year laboratory experiments into micro-scale experiments.

Another way to reduce the amount of chemical waste released into the environment from Dalhousie University is to emphasize the use of the disposal containers in the labs. According to the results of the student questionnaires, the disposal containers appear to be underutilized. There should be more emphasis put on using the disposal containers. Perhaps the containers could be boldly labeled or identified at the beginning of each lab. The chemicals could then be dealt with in an appropriate manner instead of being poured down the sink.

This report would recommend that Dalhousie University test its wastewater during the time period in which first year chemistry experiments are being conducted. The interview with Dr. Louch revealed that effluent testing from the chemistry building had only been performed once in the past. Regular testing would enable Dalhousie to become a better steward of the local environment. It is recommended that testing be performed during months that the laboratories are in full session (September through March). Future research studies could perform testing Dalhousie University's wastewater when the chemistry labs are being used for first year experiments.

This report shows that safety is a high priority at Dalhousie University in the first year chemistry labs. However, providing a Workplace Hazardous Materials Information System Course (WHMIS) periodically to students and ensuring that Material Safety Data Sheets (MSDS) are available in the laboratory would further improve on a safe working environment. A WHMIS course would raise awareness of the dangers of some of the chemicals that the students are working with in the lab. An MSDS binder in the laboratory would also be a beneficial resource for describing the proper handling methods of chemicals being used.

Most of the recommendations herein involve access to further information for students. As many of the students have indicated that they do not feel they possess a high degree of knowledge regarding the chemicals they are using, and the lab instructors have indicated that students are increasingly concerned about proper chemical use and disposal it is recommended the students become strongly involved in making the first year laboratories a more sustainable environment. This being said, it is extremely important that this is accomplished in a top-down approach as those instructing the students must be firmly

devoted to making the laboratories a more sustainable learning environment. If the proper policies were in place and enforced and the education was available to students they will leave the laboratory with a more comprehensive chemical education. They will become educated in chemical experiments, chemical disposal techniques, and the implications of chemicals in the environment. This will result in better future employees and better stewards of the environment.

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APPENDIX

Student Questionnaire

We are students at Dalhousie University taking Environmental Problem Solving. We are working on a group project known across Canada and the United States as "Greening the Campus". It involves using the Dalhousie campus as a laboratory for demonstrating how to create sustainable communities. Our group is researching the current chemical disposal practices in the first year chemistry labs and our project will determine if there are more environmentally sustainable alternatives to the current disposal procedures. Our group is going to use questionnaires to determine how and why students are disposing of chemicals in first year chemistry labs. All responses will remain confidential. We appreciate your participation.

1. Did you receive any safety instruction before participating in your first chemistry lab?

Yes

No (proceed to question 3)

Can't Remember

2. If you answered yes to question number 1, did the safety instructions include chemical disposal procedures?

Yes

No

Can't Remember

3. Are there disposal containers in your chemistry lab to dispose of chemicals used in experiments?

Yes

No

Can't Remember

4. In your first year chemistry lab which of the following locations have you used to dispose of chemicals (circle all that apply)

1- Garbage

2- Floor

3- Sink

4- Disposal Container

5- Take Home

6- Other (please specify) _____

5. Was this the appropriate location for the disposal of the compound/solution you were using?

1-Always

2-Sometimes

3-Rarely

4-Never

5-Don't Know

5. Which location would you say that you have most often used for chemical disposal during your first year chemistry lab:

1-Garbage

2-Floor

3-Sink

4-Disposal Container

5-Take Home

6- Other (please specify) _____

6. What degree of knowledge do you feel you have about the proper disposal of the chemicals used in your first year lab?

1-Strong knowledge

2-General Knowledge

3-Limited Knowledge

4-No knowledge

Additional Comments: _____