Eastern Kentucky University
Encompass

Online Theses and Dissertations | Student Scholarship

January 2015

The Current Status Of Safety In High School Chemical Laboratories In Kentucky

Ahmed Rashed Alyammahi
Eastern Kentucky University

Follow this and additional works at: https://encompass.eku.edu/etd

Part of the Occupational Health and Industrial Hygiene Commons, and the Science and Mathematics Education Commons

Recommended Citation

Alyammahi, Ahmed Rashed, "The Current Status Of Safety In High School Chemical Laboratories In Kentucky" (2015). *Online Theses and Dissertations*. 331.
https://encompass.eku.edu/etd/331

This Open Access Thesis is brought to you for free and open access by the Student Scholarship at Encompass. It has been accepted for inclusion in Online Theses and Dissertations by an authorized administrator of Encompass. For more information, please contact Linda.Sizemore@eku.edu.

THE CURRENT STATUS OF SAFETY IN HIGH SCHOOL CHEMICAL LABORATORIES IN KENTUCKY

By

Ahmed Alyammahi

Thesis Approved:

Scott Dunlap

Chair, Advisory Committee

Dr. Bill Pellar

Member, Advisory Committee

Member, Advisory Committee

Dean, Graduate School

STATEMENT OF PERMISSION TO USE

In presenting this thesis in partial fulfillment of the requirements for a Master's degree at Eastern Kentucky University, I agree that the Library shall make it available to borrowers under rules of the Library. Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of the source is made. Permission for extensive quotation from or reproduction of this thesis may be granted by my major professor, or in [his/her] absence, by the Head of Interlibrary Services when, in the opinion of either, the proposed use of the material is for scholarly purposes. Any copying or use of the material in this thesis for financial gain shall not be allowed without my written permission.

Signature

Date : November 6, 2015

THE CURRENT STATUS OF SAFETY IN HIGH SCHOOL CHEMICAL LABORATORIES IN KENTUCKY

By

Ahmed Alyammahi

Bachelor of Science
Eastern Kentucky University
Richmond, Kentucky
2012

Submitted to the Faculty of the Graduate School of
Eastern Kentucky University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
December, 2015

Copyright © Ahmed Alyammahi, 2015
All rights reserved

ACKNOWLEDGMENTS

My heartfelt thanks and gratitude go to the chair of my research committee, Dr. Scotty Dunlap for his patience, support, and guidance throughout all the stages of this research project.

A big “thank you” and deep gratitude go to the other members of the research committee, Dr. Ron Dotson and Dr. Bill Sullivan for their comments, suggestions, and support; to Dr. Jack Gerlovich, the nationally recognized science safety professor, for granting me permission to conduct a follow-up study to his 2003-2004 project; and to Dr. Teresa Wallace, a former assistant professor at the Leadership and Policy Studies Department at Eastern Kentucky University (EKU) for her help in distributing the study survey online to all high schools in Kentucky.

Finally, I would like to extend my warmest thanks to the faculty and staff of the College of Justice and Safety at EKU and to the staff of EKU libraries for their most appreciated and highly regarded help.

ABSTRACT

This project is construed as a follow-up of the study conducted by Dr. Jack Gerlovich and his team to assess the status of science safety in Kentucky high schools in 2003-2004. The current study gathered online responses to an expanded survey from 57 high school chemistry teachers in Kentucky. The survey was developed to find answers to four main questions: What is the current status of safety in high school chemical laboratory in Kentucky? To what extent has this status improved or deteriorated since the creation and publication of the *Total Science Safety-The Kentucky Edition* CD in 2003? What are the main causes and relative frequency of accidents in the chemistry laboratories? And, what aspects of laboratory safety still need improvements in these laboratories and why? Our results indicated that a considerable number of classrooms and laboratories in Kentucky still did not meet the safety laws and standards especially with respect to area, size, and the existence of proper equipment. Chemistry teachers in Kentucky high schools communicate to their students the importance of safety practices and responsible conduct at the beginning of each chemistry course. The majority of the teachers, however, are not familiar with many applicable science safety regulation and regulatory agencies other than OSHA. Most accidents in chemistry laboratories resulted from dealing with broken glassware or heat source and there has been a relatively high incidence of "serious" laboratory accidents in the past five years. Altogether, these results call for putting in place a continuous safety education system to store and share data about science safety and accidents among educators and possibly students in the Commonwealth of Kentucky. The results also suggest requiring teachers to have proper safety training before being allowed to teach any science class.

Table of Contents

List of Tables

CHAPTER 1

Introduction

Background

The ability of any country to produce well-qualified scientists with a solid background in science requires the implementation of a science curriculum that fosters scientific enquiry and engages students in practical experience meeting the needs of the society throughout all levels of education (Wrightson et al., 2008). Chemistry laboratory courses are typical examples of such curricular requirements. But, unfortunately, working in a science laboratory in general and a chemical one in particular is often associated with the potential exposure to hazardous materials or unhealthy situations and the risk of occurrence of accidents (Young, 2003; Ong, McLean & Greco, 2012). Creating and ensuring a safe and healthy learning environment in a school laboratory setting and preparing students who are productive, respectful, and easily supervised who would avoid participating in dangerous activities in lab have become a major concern and priority for many schools (Bradley, 2011).

The intricate multifaceted life we live requires us to pay particular attention to safety issues (Gerlovich, Rarsa, Frana, Drew & Stiner, 2002). Again, this is particularly true in the increasingly highly demanding middle and high school science curriculum, which leans toward fostering hands-on, inquiry-based laboratory investigation, and exploration for students who probably have not been trained on safety practices before becoming engaged in lab activities (American Chemical society, 2001; Young, 2003).

The establishment of an academic institution that provides students with a safe learning environment could be achieved by observing or implementing relevant protective measures such as tort laws and professional standards and by adhering to safety rules and guidelines set by national organizations such as the Occupational Safety and Health Administration (OSHA), American Chemical Society (ACS), and the National Science Teachers Association (NSTA) as well as by other local and state regulatory agencies (Gerlovich, 1997).

Laboratory safety and health problems became apparent after the passage of the Occupational Safety and Health act of 1970 which led to the establishment of the Occupational Safety and Health Administration (OSHA) in the following year. OSHA regulations provide direction for the protection of all personnel and facilities in most, if not all, fields of industry and academia and the establishment of OSHA has, in fact, led to more understanding of the risk in a work environment. Since the inception of OSHA, several laws and regulations have been enacted on federal and state levels that require schools to take precautionary actions in order to minimize hazards, harmful exposure, and injuries in any school laboratory and mandates the keeping of an accurate record of accidents in these laboratories (Nord and Howard, 2007).

On their part, both the ACS and NSTA recommend that in order to create a safe science classroom, schools and school districts should provide teachers with the right tools, adequate knowledge, and the proper educational safety solutions. Teachers should also be made aware of their legal and professional obligations and responsibilities for safety (Gerlovich et al., 2002).

In addition to the above, several research projects and articles have addressed the safety concern and the status of school science laboratories in individual states in an effort to drive away the growing feeling of the inadequacy of the existing safety training programs to fully meet the needs of modern society (Hagelberg, 1987; Fuller, Picucci, Collins & Swann, 2001; Gerlovich, Whitsett, Lee & Parsa, 2001; Gerlovich et al., 2002; Gerlovich, Rarsa & Jordna, 2004; Ewing Marion Kauffman Foundation, 2007; Stroud, Stallings & Korbusieski, 2007). The effort of these states can also be construed as a reflection of a widespread interest in the study of safety training and the specific interest among academic institutions to avoid lawsuit (Gerlovich et al., 2002; Stroud et al. 2007). The most common findings in these research projects are: 1) The identification of a "gap between policy and policy compliance." and 2) The fact that although not everything in lab is expected to run perfectly, the majority of lab accidents can be preventable or avoidable resulting in a significant reduction in the number of lawsuits and financial compensation paid by school districts to injured students and/or their families (Fuller, 2001; Gerlovich et al., 2002; Ewing Marion Kauffman Foundation, 2007; Stroud et al., 2007).

In 2003, the state of Kentucky followed in the footsteps of other states in an effort to examine the status of science safety laboratories in the state's schools. A team led by the prominent expert on science safety, Dr. Jack A. Gerlovich, then Professor of Science Education/Safety at Drake University, assisted by Mr. Dennis McElroy, a technical advisor, was commissioned to assess the state of safety in school science laboratories and then present tools to address the safety needs of the schools. Practically, the team formed a science safety advisory committee which drew members from the Kentucky Department of Natural Resources, Kentucky Department of Education (Facilities Consultant, Science Consultant), Kentucky State Fire Marshal's Office, Kentucky Occupational Safety and Health Administration (OSHA State Plan), and the Kentucky

Department of Health. A questionnaire/survey reflecting information shared by the committee members about their respective state agency's safety measures, guidelines, and priorities was developed. The focus of the questionnaire/survey was used to collect information that could serve as a starting point for "[assessing] the safety status of Kentucky elementary and secondary school science facilities, equipment, procedures, and teacher understanding of legal and ethical obligations." (Gerlovich, McElroy, Parsa & Kidwell, 2008)

The survey results revealed that the majority of Kentucky's middle and high schools were faced with quite a few critical challenges to safety of teachers and students. The challenges were mainly attributed to the presence of old lab facilities, small space in labs and/or classrooms, large class enrollment, the absence of adequate safety lab equipment, lack of periodic testing and/or maintenance of lab equipment, no current safety training for teachers, not requiring or utilizing Student Safety Contracts by some teachers, and teachers' unawareness of applicable science safety laws, codes, and standards.

The committees concluded its work by recommending that informing and improving school science laboratory safety in Kentucky could be achieved using a combination of professional development sessions and a CD-ROM created by the committee entitled: *Total Science Safety System-The Kentucky Edition* CD (2003). A number of full-day workshops were conducted by Dr. Gerlovich and Mr. McElroy in the period between November 2003 and November 2004 to facilitate the effective use of the CD by science teachers from all geographic locations in the state.

The production of the safety CD and the subsequent professional training sessions refuted the widely accepted view that no evidence exists as to whether the government is willing to organize safety training workshops for interested parties. The study has also served as a route to provide people interested in a career in safety training or safety officer with concrete ideas as to the scope and methods that could be used.

Statement of the Problem

A landmark for students' success in advanced science courses is acquiring good chemical safety habits early in their academic journey. The safe use and handling of chemicals in laboratories and student classrooms has, in particular, been the subject of a multitude of publications by professional organizations and other regulatory bodies (American Chemical society, 2001).

Investigating the status of science safety in Kentucky secondary schools by Gerlovich et al. (2008) has led to the unequivocal conclusion that significant safety concerns existed in schools, especially with respect to age and condition of the facility, class size and area, lack or regular testing or complete absence of essential safety equipment, the inconsistent observation of most standard safety procedures by school teachers, and unfamiliarity of science educators with a number of vital and pertinent science safety laws, codes, and standards. Thus, conducting a follow-up study to look into this status and identify any new major concerns or an old existing one a decade after the initial study was done seems not only justifiable but also compelling for moving science laboratory safety in Kentucky schools forward.

Purpose of the Study

The purpose of this study was to determine the status of high schools in the Commonwealth of Kentucky with respect to creating a healthy environment and promoting safe practices in their chemical laboratories and whether or not any improvements in science laboratory safety had occurred in Kentucky high schools over the 2003-2014 period. To achieve this purpose, an exploration of and expansion on the previous study by Gerlovich was conducted. Dr. Gerlovich gave his permission to the researcher to pursue the planned project and welcomed any possible future collaboration (Appendix A). More questions in each section and a new section investigating the type, frequency, and cause of accidents in these labs were added to the survey developed by Dr. Gerlovich and his team in 2003 to form a more comprehensive survey that was wider in scope.

Potential Significance

A remarkable difference between this study and any study done before was that it focused on only chemical laboratories in high schools in Kentucky but with a wider safety spectrum which covered accidents in labs and their causes in addition to what was examined in Gerlovich's prior study. Initially, this study aimed to place emphasis on descriptive statistical analysis to aid in understanding the relationship between several scrutinized safety variables, an example of which is the relationship between safety training for teachers and wearing goggles in a lab. The practical issues associated with the small number of respondents to the developed survey and the fact that not every question in the survey was answered by all participants prevented the researcher from performing statistical tests.

Definition of Terms

Chemical Hygiene Plan- A document that contains standard operating procedures for precise laboratory tasks, as well as related emergency interventions and instruction manuals. The chemical hygiene plan ensures laboratory users work in a safe and sanitized environment to avoid the adverse effects of toxic substances (Roy, 2007).

Eyewash stations- Emergency equipment used to instantly decontaminate the eyes of a user who has suffered short-term exposure to highly toxic substances to avert any harmful effects of the chemicals.

First Aid Kit- A box containing various medical paraphernalia and supplies, such as gauze, bandages, antibiotics, antiseptics, tweezers, gloves, a first aid manual, and emergency phone numbers, which helps to initiate medical care the moment a user suffers an accident in a chemical laboratory (Roy, 2007).

Goggle Sterilization- A process where shared safety glasses or goggles are sanitized to minimize the risk of transmission of ocular or skin illnesses from one user to another. Ultraviolet radiation is the main sanitizing agent used in this process where goggles are exposed to the radiation for approximately 15 minutes (Roy, 2007).

*Ground Fault Interrupters (GF*I*)*- Instruments that are designed with an aim of protecting individuals from electric shock (Armond, n.d.). It works by interrupting electric circuits when there is a difference in the current that flows through neutral and hot wires. Any difference in the two wires' current is a clear indication that the hot line is diverting current irregularly. As a result, the discharged current flows into the ground wire.

Lab ventilation system- A set of the equipment used to ensure there is a constant flow of air in and out of the laboratory; laboratory ventilation systems protect users by getting rid of toxic fumes, letting in fresh air, and avoiding exposure (Roy, 2007).

Safety Data Sheet (SDS)- A document used to record information and data concerning any potential dangers or hazards in a chemical laboratory. The hazards noted in a SDS include potential fire accidents, medical risks, ecological effects, and any harmful chemical reactions. The SDS also guides the user on the content of specific materials and how to use or store them in a safe manner (Roy, 2007).

Assumptions

Data collected in this survey is assumed to be true, unbiased, and as such, reflective of the actual status of chemical laboratory safety in high schools in Kentucky for the following reasons: 1) Participation in this survey was completely optional. 2) The selected participants were provided with a guide on how to complete the survey and were assured that no retaliation or reprisal of any form would result from their participation which was completely anonymous. 3) Supervisors would not be informed of teachers' participation in the survey nor would they have access to any survey responses.

Limitations

High school chemistry teachers in some geographic regions, especially the rural areas of Kentucky, might have chosen not to participate in the survey. This small sample size of respondents could be a direct consequence of this limitation. The effect of this issue on how much the sample actually represents the targeted population is not certain but could be significant.

Organization of the Study

This research account is divided into five standard chapters: Introduction, Literature Review, Methodology, Research Findings, and Discussions and Recommendations. Tables were used to present the data extracted from survey responses. Appendices include a copy of the consent message received via e-mail from Dr. Jack Gerlovich to use the results of his study as a basis for this project and expanding on it, a copy of the survey questions, and other relevant materials were added at the end of the report for reference and validation.

CHAPTER 2

Literature Review

Emphasis on teaching laboratory safety has grown over the last four decades since the American Chemical Society (ACS) published the first edition of *Safety in Academic Chemistry Laboratory* (SACL). Experience has shown that teachers' knowledge of the hazards and risks associated with the use of chemicals in school laboratories cannot be as effective as desired if this knowledge is not communicated to and shared with colleagues and students (American Chemical society, 2001; Young, 2003; Ong et al. 2012). Thus, the development of a robust system of sharing chemical laboratory safety information and practices should be a necessity for any school district. Involved parties should continue their efforts to make academic chemistry laboratories much safer places with fewer accidents and injuries (American Chemical society, 2001; Young, 2003; American Chemical society, 2012). To this end and as mandated by the OSHA 29 CFR 1910.1450, a chemical hygiene plan (CHP) is established and a chemical hygiene officer is appointed in every academic institution (Young, 2003). Another vital requirement is conducting safety training sessions on the hazards of chemicals present in the laboratory as outlined below (Young, 2003). The ACS recommends that two intertwining requirements be met in order to control the hazardous characteristics of chemicals and consequently prevent, or at least reduce, the likelihood of accidents in school chemical laboratories. These two requirements are knowledge and the habit of safety. Knowledge entails gaining the necessary information about any chemical before, during, and after using it. These three phases are technically called storing, handling, and disposing of chemicals. This information can be obtained mainly by reading labels, studying Safety Data Sheets

(SDS's), consulting a supervisor or a chemical hygiene officer, and by taking a comprehensive training course in safety at the time of an employee's initial assignment. Acquiring the habit of safety entails the practical implementation of knowledge and taking precautions in order to prevent accidents and/or responding to an accident (American Chemical society, 2001). The list of safety habits includes, but is not limited to, the use of personal protective equipment (goggles, gloves, lab coats, etc.) by lab attendees at all times, handling chemicals in hoods, installing and familiarizing oneself with the use of essential laboratory safety equipment, such as fire extinguishers, eye wash, safety shower, and fire blankets. In fact, a lot of researchers argue that the nuts and bolts of safety can be learned in a science laboratory because a lot of students do not have the opportunity to learn them at home or in other classes in school and because capricious and careless actions are completely prohibited in the laboratory (Ong et al. 2012). Furthermore, researchers argue that students can be active participants in advanced science classes if they acquire safety habits early on in their academic life (American Chemical society, 2001).

In the process of developing laboratory safety policies and procedures, schools and teachers should be provided with the necessary materials and assisted by qualified individuals who possess the skills required to carry out this task (Cotman, 2000; Ong et al. 2012).

In his comments on the state of laboratory safety, David Rainer (2012) notes that academic institutions are expected and probably required to review and upgrade their laboratory safety programs due to any current laboratory accidents and the "recent enforcement actions" that have been put in place. He also argues that the notion that academic institutions do not enforce lab safety in their campuses, as perceived by the media, might be only half the truth because some schools do offer rigorous safety training, do require students to take safety classes (both for- and not-for-credit) and do ultimately impose serious penalties on violators of safety rules and standards. The following list summarizes some of the responsibilities and measures that should be assumed or taken to assure the creation of a full-bodied safety culture in a school science laboratory (Rainer, 2012).

- Having safety leadership
- Identifying and providing safety orientation for new personnel
- Having safety training sessions
- Assessing hazards before an experiment
- Putting in place plans a chemical hygiene plan
- Ensuring availability of laboratory clothing and individual protective equipment
- Conducting laboratory inspections and personal assessment
- Providing laboratory users with emergency information

Similar points were pointed out by Peter C. Ashbrook, the Director of Research Safety at the University of Illinois at Urbana-Champaign, in his remarks on what researchers should try to accomplish with respect to laboratory safety in academia (Ashbrook, 2013). Overall, it can be said that researchers agree on the following: the safety vision of a school is driven by the safety vision of its administration and training teachers to be role models for safety practices constitutes one of the most basic elements of the creation of a positive safety culture in schools (Hill Jr. and Finster, 2013). They also agree that the creation of a “Safety Culture” should be an on-going high priority for school districts. The districts should assemble a safety training program for their staff and students and should also develop a system for implementing the program through mandatory safety lectures and orientation, distribution of self-study materials, and necessitating the passing of a safety test in order for students to register for a science class. Organizing periodic workshops for teachers to share their safety practices might also prove helpful (Kennedy and Palmer, 2011).

One of the possible and probably compelling approaches of reviewing an institution's policy on safety and analyzing the level of adherence with lab safety rules is surveying parties involved in safety issues such as school administrators, teachers, and students. The survey will focus on assessing the participants' skills and knowledge pertaining to science safety. The following are summaries of survey studies conducted in several states for the purpose of carrying out this mission.

North Carolina

North Carolina is an OSHA-approved "State Plan" state. A study by Stroud et al. (2007) found that almost 32,000 accidents occur in North Carolina middle and secondary schools every year and that 17 percent of the accidents arise from science related incidents that occur in a laboratory. Other studies in the state showed that most laboratory accidents occurred in North Carolina schools because of inexperienced and poorly trained lab attendants, overcrowding in laboratories and because of the slow response of the majority of the schools to the federal and state regulations that require adhering to suitable laboratory safety protocols. The results of a survey conducted by (Stallings, Gerlovich & Parsa, 2001) indicated hat 40 percent of the laboratories in North Carolina are outdated and the majority of these laboratories lack proper air ventilation and are hence unsuitable for practical use.

Stroud et al. (2007) highlight in their article several measures taken by the North Carolina State Board of Education to ensure that school laboratories remain a safe place for both teachers and students. These measures include the adoption of the Occupational Exposure to Hazardous Chemicals in Laboratories lab standards to reduce laboratory accidents and the enacting of an initiative to train laboratory attendants and teachers (Stroud et al., 2007).

Kentucky

Kentucky is another OSHA-approved "State Plan" state. A study by Gerlovich et al. (2008) assessed the environment within which science programs are taught in the state. The study considered 54 school districts in order to identify science-related safety issues and to specifically determine the extent to which safety procedures are followed. The level of safety observation and compliance by both teachers and students was also evaluated. Toward this end, the authors of the study surveyed teachers to identify the existing functional safety procedures and inquire about any potential needs that call for immediate attention. The study focused on the state's relevant and applicable laws, codes, and safety standards. The conclusion about the degree to which schools' facilities met the set of safety requirement was reached by analyzing responses from lab attendants about lab size, space, ventilation, harmful chemical containments, in addition to the type and status of safety equipment installed in school facilities for science purposes.

According to the study, over 75% of schools in the State of Kentucky complied with basic safety procedures in science labs. However, the participating schools fell drastically short in meeting the laws, codes, and safety standards that govern science programs in Kentucky, especially OSHA requirements and standards. The minimum square footage per student in science labs, which was not met by 65% of surveyed facilities, was an example (Gerlovich et al., 2008).

Arizona

Arizona is also an OSHA-approved "State Plan" state. Hagelberg and Dombrowski (1987) explored Arizona's high school laboratories to determine science safety issues, needs, and concerns in the state's schools. The authors developed a questionnaire that was distributed to over 700 teachers and supervisors who were engaged directly in the state's science programs. The questionnaire sought to find answers to questions regarding laboratory conditions, the teachers and supervisors understanding in performing duties and responsibilities within science programs, and most importantly, the types and frequencies of accident in science laboratories. The conclusions were drawn from data obtained from 300 fully and correctly completed questionnaires returned by 242 teachers and 58 supervisors.

The study revealed that significant changes were needed in order to improve the safety conditions in most high school science labs. Fire extinguisher and fume hoods, for instance, were either not functioning or fitted with low standard equipment. The average lab space per student was between 24 and 41 square feet, which is less than the recommended standard of at least 45 square feet. Additionally, schools lacked a systematic method to document major and minor lab accidents. The study found no relationship between accident rate and the gender of the teacher or between accident rate and the teacher's level of education (Bachelor of Science vs. Master of Science). But the mean of frequencies of both injury and non-injury accidents were lowest in the group of teachers with 1-5 years of teaching experience. The study concluded by highlighting the need to improve safety-related equipment, procedures, and standards in the state's high school science facilities (Hagelberg, 1987).

Texas

Texas is not an OSHA "State Plan" state, but the Texas State has enacted several laws and regulations that are essential for protecting science students in public schools. One of these laws requires all public schools in the state to provide students with safety codes in laboratories. Another state law demanded that schools reconstruct old laboratories and install new science equipment to prevent injuries to students (Fuller et al., 2001).

The report by Fuller et al (2001) describes how researchers at the University of Texas at Austin administered a modified version of an earlier study that surveyed science teachers in Texas. The researchers intended to collect data on the safety conditions of school laboratories and to which extent these labs provide students with a safe learning environment. Thus, the survey consisted of questions about general and personal safety equipment, safety rules, and student and teacher laboratory training. The study presented evidence that by inspecting safety programs in public schools, the Texas state authority facilitated schools to implement safety measures in their laboratories. Some of these measures encompassed installing firefighting devices and tools such as fire alarms, fire extinguisher, and fire blankets in the laboratories. This at least minimized chances of student's physical injuries in case of fire.

The same study found that approximately 460 minor laboratory accidents occurred in schools between the years 2000 to 2001. Most of these accidents occurred because of inexperienced science teachers and/or overcrowding of labs. In addition, the study found that 54% of the participants said that their schools did not have an adequate number of functioning personal and lab safety equipment. Schools with such conditions in the laboratory had almost 85 major laboratory-related accidents in the last five-year period preceding the time of the study. Moreover, only 33% of the teachers attended safety training during the year of the study (Fuller et al., 2001).

Summary

By examining the contents of the studies summarized above, one can conclude that creating a culture of safety in an academic institution requires a combined effort of many entities. The summaries also indicate that what constitutes a safety practice in a science laboratory should never be a subjective issue. Clearly, states, especially those that have OSHA-approved safety plans, have taken the major first step to ensure their school laboratories comply with applicable safety rules and regulations. This major step involved identifying problems and suggesting solutions or making recommendations to improve the status of safety in schools labs. What remains unclear, however, is to what extent these states--in this case the Commonwealth of Kentucky—have succeeded in their intelligible efforts to instill safety in the minds of all involved parties (students, teachers, administrators, etc.) and whether school facilities in the state can be considered safe for conducting laboratory experiments from the 21st century science curriculum. This research project is designed to address these and other related safety questions with respect to only chemistry laboratories/classrooms in Kentucky high schools. Similar studies that are wider in scope (middle/high schools) that can include other science disciplines are certainly warranted.

CHAPTER 3

Methodology

Context of Study

This study was designed to assess the safety conditions in the chemical laboratories of Kentucky high schools, measure chemistry teachers' awareness of essential laboratory safety procedure and regulations, and determine whether or not adopting the *Total Science Safety System-The Kentucky Edition* CD by the Kentucky Department of Education and the training sessions that followed this adoption had been effective in improving the status of safety in the laboratories. Five major aspects of laboratory safety were surveyed: facilities, equipment, procedures, accidents, and standards.This was accomplished by administering a questionnaire that was distributed to chemistry educators in Kentucky high school.

Selection of Participants

The sample group consisted of chemistry educators in public and private high schools in all the geographic regions of the Commonwealth of Kentucky, regardless of the age, gender, race, ethnicity, national origin, highest degree held, or years of experience of the educator. All demographic information of the respondents was considered irrelevant to the scope of the study and were not collected, although in at least one previous similar study, age, gender, and highest degree held had been factored (Hagelberg, 1987). Participation was completely voluntary. Dr. Teresa Wallace, then Assistant Professor at the Leadership and Policy Studies Department at Eastern Kentucky University (EKU), helped distribute the survey after the researcher obtained approval of the proposed survey and research plan from the Institutional Review Board (IRB) of

Eastern Kentucky University. The survey was distributed online to 202 high schools and 20 schools that were a combination of high/middle schools in Kentucky.

Research Questions

This study sought to find the answers to a number of research questions. What is the current status of safety in high school chemical laboratories in Kentucky? To what extent has this status improved or decreased since the creation and publication of the *Total Science Safety System-The Kentucky Edition* CD in 2003? What aspects of laboratory safety still need improvement in these labs and why?

Data Collection

Chemistry teachers in a total of 222 Kentucky high and high/middle schools were contacted via e-mail. Teachers were solicited to read and take a web-based survey that consisted of 44 multiple-choice questions covering the five major areas of chemical laboratory safety: facilities, equipment, procedure, accidents, and understanding laws, codes, and standards. The survey questions were drawn from several previous studies on the topic of safety in elementary, middle, and high schools in different regions in the United States and was structured to gain a more comprehensive understanding of the status of safety in Kentucky schools a decade after a similar study was conducted in the state. The survey was accompanied by a guideline on how to complete the survey. Reading the guideline and taking the survey was expected to last less than 30 minutes.

A link to the survey was sent in an initial e-mail message on November 6th, 2014 to Kentucky high school teachers and a similar e-mail message was sent to the administrators of the schools soliciting their help in encouraging teachers to participate in the study. As mentioned earlier in this report, participants were not asked to include any demographic information. Participants were also assured that their participation in the survey was completely optional and this participation, along with the results of the survey they submitted, would remain confidential leaving out any room for reprisal by supervisors and school district administrators. Two follow-up e-mail messages were sent on November 19th and December 3rd, 2014 to remind teachers to participate in the study. The last day to take the survey was December 13, 2014. A total of 57 responses were received but not every response was fully completed. This resulted in a variation in the number of responses to each question in the survey. Question #20 in the survey was answered by a minimum of 44 responders. No response was discarded because questions that were left unanswered did not affect the answers to other questions in the same response.

Data Analysis

The structure of the survey and the wording of its questions did not imply any specific answer and gave a chance to respondents to select a "neutral" choice if they were not sure whether to answer "yes" or "no" to a question. The structure also allowed the researcher to retrieve and tabulate the data immediately after the survey had been completed.

Post data analysis focused mainly on recording the number of teachers who answered each choice of each question and then finding the corresponding frequency. The results obtained for each question in this study were compared to the corresponding ones in the study by Gerlovich et al. (2003) in a single table.

CHAPTER 4

Results and Discussion

This project had dual purposes. The primary purpose was to examine if there was any improvement in the status of safety in the chemistry laboratories in Kentucky high schools over the ten-year period following the adoption of the *Total Science Safety System-The Kentucky Edition* CD (2003) by the Kentucky Department of Education and subsequent follow-up workshops and training sessions. The secondary purpose was to expand on the study conducted by Gerlovich et al. in their effort to establish baseline information about high school science facilities, equipment, and the understanding of laws, codes, and regulation in Kentucky and by science teachers in Kentucky. The latter purpose was sought by adding a section on lab accidents to the original survey developed by Dr. Gerlovich (2003). Results were based on analyzing the data obtained from all the correctly completed and useable surveys which, depending on the questions answered, ranged from 44 to 57 as outlined in Chapter 3 of this project

A. Facilities

All but one of the responses (98%) to the survey came from teachers who worked in a public high school (Table 1). This is fairly close to the 94% outcome received by Dr. Gerlovich and his team in 2003. This also still raises a concern about the reluctance of teachers in private high schools to participate in safety studies and probably the unwillingness of the administration of these schools to let their staff participate in such a study.

Table 1
What is your type of school?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Public	56	57	98	94
B) Private	1		2	6

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Most of the responses (87%) in the study came from teachers who worked in teaching facilities that hosted only high school science students and 13% from teaching facilities that hosted a combination of both high school and middle school students (Table 2).

Table 2
What kind of school does your school building house?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) High School	47	54	87	N/A
B) Combination of both high and middle school	7		13	

From the data, it is obvious that more than 40% of all the chemistry laboratory facilities in Kentucky high schools are more than 20 years old (Table 3). This is slightly more than the 33% outcome obtained by Dr. Gerlovich.

Table 3
How old is your lab facility?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 0-10	16	56	29	35
B) 11-20	17		30	28
C) 21-30	12		21	13
D) 30+ years	11		20	20

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

The majority of high school chemistry lab activities (70%) are held in a combination laboratory/classroom setting (Table 4). The survey by Dr. Gerlovich did not contain a comparable question.

Table 4
Which of the following describes the room you use?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Laboratory	7	57	12	N/A
B) Classroom	10		18	
C) Laboratory/Classroom	40		70	

Table 5 shows that a little more than 67% of all chemistry classes have enrollment higher than the maximum recommended number of 24 students per class (Biehl, Motz & West, 1999). Again, no similar question existed in the 2003 study.

Table 5

What is the average size of the chemistry classes/labs you teach in this school?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 13-18	8	57	14	N/A
B) 19-24	11		19	
C) 25-30	32		56	
D) More than 30	6		11	

The maximum number of students per square foot recommendation by the National Science Teachers Association is supplemented by another recommendation that asks for providing a minimum of 45 ft^2 per student of open space in science labs which should be expanded to a minimum of 60 ft^2 per student in lab/classroom combination setting (Biehl et al., 1999). The above findings are confounded by the percentage of chemistry laboratories that have an average area of less than 1000 ft^2 (82%) which is considerably larger than the corresponding percentage found in 2003 (68%) as shown in Table 6. The percentage of mixed laboratory/classroom that have an average area of less than 1000 ft^2 in the study presented here was 65%, matching Gerlovich's finding (Table 7).

Table 6

What is the average area (in square feet) of chemistry laboratories in your school?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 500-749	18	48	38	43
B) 750-999	21		44	25
C) 1000-1450	8		17	20
D) More than 1450	1		2	7

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 7

If the room you use is a mixed laboratory/classroom, what is its area (in square feet)?

Response	Count (2014)	N (2014)	% (2014)	% (2004)
A) 500-749	9	44	20	32
B) 750-999	20		45	33
C) 1000-1450	12		27	25
D) More than 1450	3		7	6

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Older facilities, in general, lack the capacity to meet the modern-day science safety regulation (Gerlovich et al.,2008). This is especially true when such a facility is overcrowded with students since a positive correlation is found between the number of students in a science lab and the number of laboratory accidents (Brennan, 1970).

Most regulations require the presence of at least two outward opening doors for science labs. Approximately 36% of the responding teachers reported the presence of one or fewer outward opening doors in their labs (Table 8). This finding is similar to the findings by Gerlovich in 2003, which indicates this item still poses a threat for vital processes such as the rapid evacuation of labs during emergencies.

Table 8

How many exits with outward opening doors does your lab have?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 1	20	55	36	30
B) 2	31		56	47
C) 3	4		7	14
D) Not Applicable	0		0	7
E) Other	0		0	3

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Safety standards and regulations designate chemical fume hoods as an indispensable lab component. OSHA regulations, in particular, advise that laboratory fume hoods be tested every 90 days to ensure the full protection of teachers and students alike from any exposure to chemicals in the lab (Gerlovich et al. 2004). The results show that 20% of lab facilities in Kentucky high schools do not have fume hoods compared to 32% that did not have a hood in 2003 (Table 9). More than 77% of the existing fume hoods in 2014 had not been tested in more than two years. This is considerably higher than the 67% found in the earlier study by Gerlovich (Table 10). The results also indicate that 76% of lab facilities still use the exhaust fume hood type and only 4% of these labs use the more advanced ductless fume hoods (Table 9). The latter type of fume hoods meet all the safety standards for high school science. Ductless fume hoods are also self-contained, self-monitoring, and are very easy to use (Gerlovich, Whitsett, Lee & Parsa, 2001).

Table 9

What type of hood do you have in your science lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Exhaust type	39	49	76	63
B) Ductless Type	2		4	0
C) None, however, I need one	10		20	14
D) None-not needed	N/A*		0	18
E) Other	N/A**		0	5

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 10

When was the last time you tested your fume hood with proper instrumentation?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
F) Never	21	54	39	37
G) Within the past 90 days	6		11	14
H) More than 2 years ago	12		22	24
I) No hood	11		20	23
J) Other	4		7	3

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Adequate room ventilation is another critical safety component in science laboratories. The National Fire Protection Association (NFPA) recommends that, depending on the activities performed, room air in science labs be turned over 4-12 times per hour. Seventy percent of the participating responders in this study were not aware of this lab requirement. This result is slightly better than the corresponding results (88%) reported in 2003 (Table 11).

Table 11

How many turnovers of air per hour can your lab ventilation system provide?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 3	2	54	4	4
B) 6	0		0	1
C) More than 10	1		2	1
D) I do not know	38		70	88
E) No vent	13		24	6

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

B. Equipment

According to the results of this survey with regard to the equipment status in the chemistry labs in the participating high schools, more than 70% of the electrical outlets in these labs were protected with either Ground Fault Interrupters (GFI's) or Ground Fault Circuit Interrupters (GFCI's). This shows an increase from the corresponding results (52%) obtained in 2003 (Table 12). It is still disturbing, however, that even in the second decade of the twenty first century, close to 30% of chemistry labs either lack this easy and essential laboratory protection item. The general consent is that electrical outlets that are within an arm's length of grounding sources, such as water pipes, should have GFI/GFCI protection (Gerlovich et al., 2001).

Table 12

Are all lab electrical outlets near water sources GFI/GFCI protected?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	37	52	71	52
B) No	9		17	30
C) I do not know	6		12	18

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Safety rules demand the existence of at least one ABC tri-class fire extinguisher capable of extinguishing paper and wood products, flammable liquids, and electrical fires in each science laboratory (Gerlovich et al., 2002) . The rules also call for teachers to have training in using this lab safety equipment. Yet, 6% of responders in 2014 and 9% in 2003 either did not have one or did not know if their lab facility had such an essential science lab safety item (Table 13).

Table 13

How many ABC Tri-class fire extinguishers do you have in your lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 0	2	52	4	6
B) 1	29		56	60
C) 2 or more	20		38	31
D) I do not know	1		2	3

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Several federal and state regulatory agencies, such as OSHA, the American National Standard Institute (ANSI), and the Kentucky Building Plan Review Guide, provide instructions and information about the need to install functioning eye/face wash stations and drench showers in science labs. These stations should be ready for use at all times, especially when working with chemicals or materials that pose potential damage to the eyes. Eighty-nine percent of the responders to our survey indicated that they had this essential lab equipment, slightly higher than the outcome of 85% recorded in the 2003 survey for the same item (Table 14).

Table 14

How many eyewash stations do you have in your lab capable of delivering aerated, running water for 15 minutes?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 0	6	52	12	16
B) 1	31		60	71
C) 2 or more	15		29	14

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Wearing safety goggles is a vital requirement for any science lab activity, especially for one that involves dealing with chemicals. It is encouraging that 98% of the participating responders in this survey require their students to wear safety goggles (Table 15), although only 33% of those who do so require their students to wear goggles all the time while in the lab (Table 16). Also, it is not surprising that 46% of the teachers who indicated they adhered to this essential requirement in their labs found it difficult to enforce (Table 17). The alarming fact is that 13% of the responders in 2003 and 25% of the participating responders in this study either did not have OSHA "approved" safety goggles in their laboratories (Table 18). It is also disturbing that 35% of responders here reported the absence of goggle sterilization machines in their lab (Table 19).

Table 15
Do you require your student to wear safety goggle in the lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	52	53	98	N/A
B) No	1		2	

Table 16
If you answer "YES" to the previous question, how often do you require the students to wear goggles?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) All the time	17	52	33	N/A
B) Sometimes	7		13	
C) While working on the experiment	28		54	

Table 17

If you require students to wear goggles at any time, do you find it difficult to enforce this rule?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	23	50	46	N/A
B) No	27		54	

Table 18

Do you have OSHA "approved" safety goggles for use in your lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	40	53	75	86
B) No	4		8	2
C) I do not know	9		17	11

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 19

Do you have a goggle sterilization machine in your lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
C) Yes	35	54	65	N/A
D) No	19		35	
E) I do not know	0		0	

When asked if they had other personal protection equipment (PPE) in their labs, the science teachers provided highly varied responses for each item with aprons being the most commonly provided item (90%) (Table 20). It is certainly disconcerting to know that more than 16% of responders did not provide any kind of gloves (heat-resistant or disposable) to their students (Table 20) and that 18% of the lab facilities did not have a First Aid Kit (Table 21). Wearing gloves to protect hands and the existence of First Aid Kits are two absolute requirements for any chemistry lab activity.

Table 20

Do you provide students in your lab with the any of the following? (Please circle all the applicable choices).

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Heat-resistant gloves	10	49	20	N/A
B) Disposable gloves	31		63	N/A
C) A Safety shield	4		8	N/A
D) Apron	44		90	N/A

Table 21

Which of the following items does your lab include? (Please check all that apply)

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Fire blanket	45	51	88	N/A
B) First aid kit	42		82	N/A
C) Acid cabinet	38		75	N/A

The above-mentioned findings are further confounded by the fact that 76% of teachers either did not have a scheduled regular maintenance program in their facilities or did not know if such a program existed in their facility (Table 22). The regular maintenance program is essential to ensure the safety equipment in each laboratory is in good working condition.

Table 22

Do you have a scheduled regular maintenance to ensure that safety equipment in your lab is in working condition?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
D) Yes	12	51	24	N/A
E) No	18		35	
F) I do not know	21		41	

C. Procedure

To assess and/or measure the teachers' awareness of essential safety procedure, this survey asked several questions related to safety training. Seventy-four percent of the responders reported they were not required to receive laboratory safety training at the time of hiring (Table 23).

Table 23

Were you required to receive laboratory safety training at the time of your hiring?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	14	53	26	N/A
B) No	39		74	

Only 42% of the responders indicated they received frequent or periodic safety training (Table 24), but the responses to the frequency and date of the last time a safety training was received varied highly among responders (Tables 25 and 26). Responses to the type or mode of safety training received also varied greatly among responders with online courses being the most common (Table 27). This is not surprising given that it is an easy task to conduct or deliver online training but it is very worrisome to find that even with this latter fact, 29% of the responders never received any type of safety training.

Table 24

Do you receive frequent or periodic safety training?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
C) Yes	24	57	42	N/A
D) No	33		58	

Table 25
If you answered "YES" to the previous question, how often do you receive safety training?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Every 1 year	8	24	33	N/A
B) Every 2 years	2		8	
C) Every 3 years	1		4	
D) No specific time period	13		54	

Table 26
When was the last time you received or attended safety training/workshop and where?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) 1-2 years ago	18	52	35	20
B) In the past 3-5 years	5		10	25
C) More than 5 years ago	14		27	55
D) Never	15		29	N/A

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 27
Place of safety training.

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Online course	16	34	47	N/A
B) Conference/Workshop	7		21	N/A
C) In an academic institution	4		12	N/A
D) On-site	4		12	N/A
E) Previous job	2		6	N/A
F) I do not remember	1		3	N/A

A promising finding in this study is that 94% of the responders provided their students with safety training at the beginning of each semester or year (Table 28). The majority of such safety training (80%) came in the form of in-class lectures (Table 29). It is also encouraging that 72% of the responding teachers administered safety tests that students needed to take and pass (Table 30). Eighty-five percent of the teachers required their students to sign a Safety Contract/Laboratory Code of Conduct at the beginning of the academic semester/year (Table 31). Implementing these measures, which ensure that teachers highlight the importance of safety and that students understand their responsibility before being involved in any practical activity, improved between 2003 and 2014. It is generally understood that understanding the responsibility and adhering to the rules leads to the decrease in the number of accidents in any laboratory.

Table 28
Do you provide your students with safety training at the beginning of each semester/year?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	51	54	94	N/A
B) No	3		6	

Table 29
If you answered "YES" to the previous question, what is the format of the safety training you provide your students with?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) In-class lecture	41	51	80	N/A
B) Online video	7		14	N/A
C) Software	0		0	N/A
D) Other	3		6	N/A

Table 30
Do you require your students to take and pass a safety test?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	38	53	72	59
B) No	15		28	41

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 31

Do you require your students to sign a Safety Contract/Laboratory Code of Conduct?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	45	53	85	77
B) No	8		15	23

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

In the area of inquiry-based science where chemistry labs are heavily embedded in the high school curriculum, it is recommended that both students and teachers be aware of the potential hazards associated with the use of any material. Material Safety Data Sheets (MSDS's, now referred to as Safety Data Sheets (SDS) under the new Globally Harmonized Standard) provide necessary information such as physical and chemical properties and proper ways of handling and disposing of any chemical. Therefore, these and other useful resources should be readily available to anyone working in a chemistry lab. More than 75% of the responders indicated that they and their students have easy access to chemical safety resources (Table 32) but only 13% of the these responders pointed out that they reviewed the relevant SDS's and labels before allowing students to perform any laboratory procedure. This indicates an area that holds opportunity for improvement (Table 33).

Table 32

Do you and your students have easy access to chemical safety resources such as MSDS's?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	41	53	77	N/A
B) No	12		23	

Table 33

Do you go over the relevant MSDS's and labels before allowing students to perform any laboratory procedure?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
C) Yes, always	7	52	13	N/A
D) Yes, for only select experiments	28		54	
E) No, this is not needed	17		33	

The responses to the survey indicates a slight increase in the use of the more convenient alphabetical chemical storage system where chemicals can be easily retrieved at the expense of the safer chemical compatibility family storage system by the participating teachers or their schools between 2003 and 2014 (Table 34). This trend can be a source of significant safety problems, especially when incompatible chemicals are stored adjacent to each other (Gerlovich et al., 2002).

Table 34

How do you store chemicals?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Alphabetical	5	51	10	0
B) Compatible families	44		86	91
C) Other	2		4	3
D) I do not know	0		0	6

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Regulatory agencies require the conducting, on a regular basis, of a thorough laboratory inspection by the school/district officials. This and other measures aim to establish and maintain records of compliance to safety regulations by the inspected lab facility (Environment Directorate, 1995). Determining how well schools are prepared to handle potential hazards associated with lab science is of particular interest to lab inspectors (Ewing Marion Kauffman Foundation 2007). The results of this survey reveal that, unfortunately, 94% of the respondents either did not have frequent safety inspections conducted on their facilities or were not aware that such a fundamental principle of good safety practice existed in their school/district (Table 35). It was encouraging, however, to find that 92% of the respondents indicated that their school/district officials conducted appropriate safety and evacuation drills on regular basis (Table 36).

Table 35

Does your school/district conduct frequent and thorough laboratory inspections?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	3	52	6	N/A
B) No	25		48	
C) I am not sure	24		46	

Table 36

Does your school/district conduct appropriate safety and evacuation drills on a regular basis?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	49	53	92	N/A
B) No	3		6	
C) I do not know	1		2	

D. <u>Accidents</u>

Seventy-four percent of respondents reported having minor accidents in their labs each year (Table 37). Of those reporting a minor lab accident, 92% reported the occurrence of an average of one to three accidents, while the remaining 8% reported the occurrence of an average four to six accidents. No more than six accidents a year were reported by the teachers (Table 37). Taking into consideration the previously discussed results of the existence of high a percentage of labs with small square footage and high enrollment, the reported results of the number of accidents is highly positive.

Table 37

On average, how many minor accidents (those not requiring medical attention), if any, occur in your lab every year?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) None	14	53	26	N/A
B) 1-3	36		68	
C) 4-6	3		6	
D) 7-9	0		0	
E) More than 9	0		0	

Approximately 23% of respondents reported during their overall teaching career the encountering of at least one serious laboratory accident that required medical attention (Table 38). Interestingly, all the reported serious accidents were encountered in the past five years (Table 39). It cannot be determined whether this was because a lot of the respondents who reported the serious accidents had a short teaching experience, that recently a lot of schools incorporated science laboratories in their curriculum, or because of any other reason(s).

Table 38

In your teaching experience, have you ever encountered a serious laboratory accident that required medical attention?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Yes	12	52	23	N/A
B) No	40		77	

Table 39

If you answered "YES" to the previous question, how many of such accidents have you encountered in the past five years?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
F) 1-3	10	10	100	N/A
G) 4-6	0		0	
H) 7-9	0		0	
I) More than 9	0		0	

When asked about the frequent causes of accidents in their labs, respondents reported that broken glass and heat burns accounted for 85% of causes, while chemical burns and other causes accounted for the remaining 15% (Table 40). These results indicate that taking precaution when dealing with lab glassware and being mindful to the hazards associated with using a heat source may significantly lead to reducing the number of accidents in high school chemistry labs.

Table 40

Which of the following is the most frequent cause of accidents in your lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Explosion	0	47	0	N/A
B) Chemical burn	4		9	
C) Broken glass	21		45	
D) Faulty equipment	0		0	
E) Heat burn	19		40	
F) Electrical shock	0		0	
G) Foreign material in the eye	0		0	
H) Ingestion of foreign material	0		0	
I) Other	3		6	

E. *Understanding Laws, Codes, and Standards:*

Tables 41-44 provide a summary of the responses to questions that aimed to assess the understanding of laws, codes, and professional standards by the responding teachers. Table 41 shows that only 11% of responders in both the 2003 survey and the current survey could correctly identify NSTA as the regulatory agency that establishes minimal floor space requirements per student for science laboratories. The percentage of respondents who were not aware of the minimum floor space requirement went down from 46% in 2003 to 34% in 2014.

Table 41

What organization recommends minimal floor space/student in science lab?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) NSTA	6	53	11	11
B) OSHA	28		53	36
C) KY Education Code	1		2	7
D) I do not know	18		34	46

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 42 shows that 89% of the respondents to the 2003 survey and 85% of the respondents to the current survey were not aware that in order to protect special needs students in science settings, the National Science Education Leadership Association (NSELA) had a recommendation that established minimal enrollment requirements for these students.

Table 42
What organization(s) recommend(s) lowering of science enrollment in science labs for special needs students?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
E) EPA	0	53	0	0
F) ANSI	2		4	2
G) NSELA	8		15	11
H) I do not know	43		81	87

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 43 shows that the majority of respondents (94% in 2003 and 92% in 2014) could not correctly identify the Kentucky Education Code as the source of the specific eye protection legislation. These results may lead one to believe that this state legislation is not fully enforced by the responsible state agencies or that teachers are not made aware of the existence of such legislation.

Table 43
In Kentucky, specific Eye Protective Equipment legislation for science students appears where?

Response	Count (2014)	N (2014)	% (2014)	% (2003)
I) KY OSHA	22	53	42	36
J) KY Education Code	4		8	6
K) KY Fire Code	0		0	1
L) I do not know	27		51	57

Note. The 2003 data reprinted from "The Status of Science Safety in Kentucky Secondary Schools" by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

Table 44 shows that 50% of the respondents in 2003 and 57% in 2014 understood that to avoid being accused of negligence in student injury cases, teachers must adequately satisfy and properly carry out the three duties of instruction, supervision, and maintenance of the academic activity setting. If these three duties are carried out, the likelihood of having a student injured in a lab should be reduced, which in turn results in having a low chance of charging a teacher with negligence.

Table 44

In deciding teacher negligence in student injury it is important that teachers can show that they performed these three duties:

Response	Count (2014)	N (2014)	% (2014)	% (2003)
A) Instruct, Supervise, Maintain	30	53	57	50
B) Practice, Maintain, Report	9		17	15
C) Teach, Test, Verify	1		2	7
D) I do not know	13		25	28

Note. The 2003 data reprinted from “The Status of Science Safety in Kentucky Secondary Schools” by Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell, 2008, Journal of The Kentucky Academy of Science, 69, P. 22-23.

CHAPTER 5

Implications and Summary

The introduction of rigorous science curriculum requires the coupling of science curiosity with safety awareness. A person need not be advanced in science to understand the importance of safety in science laboratories (Moore, 2014). This study intended to evaluate the overall status of safety in the high school chemistry laboratories in the state of Kentucky almost a decade after a similar study conducted on science laboratories in high and middle schools in the state assessed this status, identified area of concerns, and suggested solutions to address such concerns. The results of this study, although based on a relatively small sample size, provide through its exploratory nature a depiction of the current status of safety in these laboratories. This project specifically identified areas of concern for lab safety that still need to be accurate and where no improvement has occurred in more than a decade.

The existence of crowded chemistry classrooms and labs in Kentucky high schools poses a non-trivial threat to safety. This threat can have disastrous effects given that it is mostly coupled with doing experiments in facilities that are ill-equipped for the twenty-first century. A considerable number of these classrooms and labs need an upgrade or substantial renovation to meet indispensable safety standards, such as the existence of an adequate number of outward opening doors and the installation of modern and proper equipment like ductless fume hoods, air ventilation systems, and GFI/GFCI protected electrical outlets.

A startling issue found in this study is the non-existence in the era of the internet of an appropriate safety training for some science teachers in Kentucky high schools before or after hiring and the lack of periodic testing and maintenance of laboratory equipment in these schools. The potential danger associated with this issue can be imagined if we think of the occurrence of an incident in a lab where the teacher does not know where the fire extinguisher is located, does not know what kind of fire extinguisher should be used, does not know how to use one, or the much needed eye/face washing station does not function.

Of all basic safety practices, having personal protective equipment, such as safety goggles and aprons, stands as the most enforced one, although teachers acknowledged that they found it hard to do so. It is troubling to know, however, that a lot of laboratories do not provide or do not have other equipment such as heat resistant/disposable gloves, safety shields, fire blankets, first aid kits, and acid cabinets.

This project reveals clearly that the majority of chemistry teachers in Kentucky high schools communicate to their students the importance of safety practices and responsible conduct at an early stage of the semester or year in which they take a chemistry laboratory course. Reducing liability and minimizing the number of accidents in the laboratory are two obvious reasons for this favorable practice by teachers. It is highly recommended that all teachers follow this practice and supplement it with other useful practices such as going over relevant SDS's and labels before every laboratory experiment.

In regard to other safety procedural measures, a major concern arise with respect to the system used to store chemicals. In this case, a more convenient chemical storage system is never meant to be the right one. Another major concern is the non-existence in most schools of a regular documented inspection that ensure compliance of the lab facility with the safety standards and regulations. Conversely, conducting regular safety and evacuation drills in school laboratories seems to be a constructive standard practice in the majority of the schools surveyed.

With respect to laboratory accidents, the average number of minor accidents per year is relatively small and encouraging, especially when the big enrollment and small square footage of most laboratory classes in the surveyed schools are taken into consideration, though relative high incidence of “serious” laboratory accidents in the past five years prompts safety researchers to look for an answer to how and why such accidents occur and what should be done to reduce their numbers. Taking careful care when dealing with lab glassware or using a heat source is especially suggested to reduce the number of both types of accidents.

Overall, responses to the survey indicate clearly that most laboratory science teachers in Kentucky do not acquaint themselves with regulatory agencies other than OSHA and are not familiar with many applicable science safety regulations. This could be largely attributed to the lack of a much needed safety training for science teachers.

Altogether, the findings in this study call for an immediate need to put in place a continuous safety education system to store and share data about science safety and accidents among educators in the state of Kentucky. This task is largely overdue, but in the era of advanced technology, is feasible and could be expanded to connect with similar systems in other states.

References

American Chemical society (2001). Chemical Safety for Teachers and Their Supervisors, American Chemical Society.

American Chemical society (2012). Tow-Year college chemistry Landscape 2012: Safety Practices Survey Summary Report Fall 2012.

Ashbrook, P. C. (2013). "Laboratory Safety in Academia." Journal of Chemical Health and Safety **20**(1): 62.

Biehl, J., L. Motz, and S. West. 1999. NSTA Guide to School Science Facilities. National Science Teachers Association, Arlington, Virginia.

Bradley, S. (2011). "Integrating safety into the undergraduate chemistry curriculum." Journal of Chemical Health and Safety **18**(4): 4-10.

Cotman, T., Ed. (2000). Safety in Science Teaching. Richmond, Virginia Virginia Department of Education.

Environment Directorate: Organization For Economic Co-operation and Development. (1995). Guidance for GLP monitoring authorities: Revised guidance for the conduct of laboratory inspections and study audits.

Ewing Marion Kauffman Foundation (2007). The Status of Middle School and High School Science labs in the Kansas City Ragion.

Fuller, E. J., A. C. Picucci, J. W. Collins and P. Swann (2001). An Analysis of Laboratory Safety in Texas. Austin, Texas: 1-20.

Gerlovich, J., D. McElroy, R. Parsa and K. Kidwell (2008). "the status of science safety in kentucky secondary schools." journal of the kentucky academy of science **69**(1): 19-28.

Gerlovich, J., R. Rarsa, B. Frana, V. Drew and T. Stiner (2002). "Science safety status in Iowa schools." The Journal of the Iowa Academy of Science : JIAS. **109**(3-4): 61-65.

Gerlovich, J., R. Rarsa and L. Jordna (2004). "The 2003 status of science safety in Tennessee secondary schools." Journal of the Tennessee Academy of Science. **79**(4): 83-90.

Gerlovich, J. A. (1997). "Safety standards: An Examination of What Teachers Know and Should Know About Science Safety." The science teacher. **64**: 46-49.

Gerlovich, J. A., J. Whitsett, S. Lee and R. Parsa (2001). "Surveying safety: How Researchers Addressed Safety in Science Classrooms in Wisconsin." The science teacher. **68**(4): 31-36.

Hagelberg, R. (1987). "What Research Says: A Survey of Safety in High School Science Laboratories in Arizona." School Science and Mathematics **87**(4): 328-344.

Hill Jr., R. H. and D. C. Finster (2013). "Academic leaders create strong safety cultures in colleges and universities " Journal of Chemical Health and Safety **20**(5): 27-34.

Kennedy, S. and J. Palmer (2011). "Teaching safety: 1000 students at a time." Journal of Chemical Health and Safety **18**(4): 26-31.

Moore, K. (2014). "School labs dangerous when safety preparation is lacking."

Nord, N. A. and J. Howard (2007). School Chemistry Laboratory Safety Guide. D. o. t. H. a. H. Services, Centers for Disease Control and Prevention National Institute for Occupational Safety and Health.

Ong, F., J. McLean and J. Greco, Eds. (2012). Science Safety Handbook for California Public Schools, California Department of Education.

Rainer, D. (2012). "Laboratory accidents, and safety program review." Journal of Chemical Health and Safety **19**(5): 58-59.

Roy, K. R. (2007). The NSTA Ready-Reference Guide to Safer Science. Arlington, Virginia, National Science Teachers Association.

Stallings, C.; Gerlovich, J.; Parsa, R (2001). A Status Report for North Carolina Schools. The Reflector. NCSTA, pp. 1–4.

Stroud, L. M., C. Stallings and T. J. Korbusieski (2007). "Implementation of a science laboratory safety program in North Carolina schools." Journal of Chemical Health & Safety **14**(3): 20-30.

Wrightson, I., S. J. Cooper, M. Crookes, C. L. Grundy, N. King, J. Larner, P. Lewis, D. H. Lohmann, C. Maxwell, D. Perry, M. Sanderson and S. Lipworth (2008). Environment, Health and Safety Committe Note on: Health and Safety in the Teaching of Practical Chemistry in Schools. Version 2. London, UK, Royal Society of Chemistry

Young, J. A., Ed. (2003). Safety in academic chemistry laboratories: Accident prevention for faculty and administrators, American Chemical Society.

Appendix

A. Permission from Dr. Gerlovich

Re: Research Inquire and Solicit for Help

Jack Gerlovich <jakel@netins.net>

Mon 3/24/2014 1:20 PM

To: Al Yammahi, Ahmed R. <ahmed_alyammahi@mymail.eku.edu>;

Ahmed,

I would be flattered to have you build on my journal article
"The Status of Science in Kentucky Secondary Schools"
published in the Journal of the Kentucky Academy of Sciences in 2008.
Perhaps we could even collaborate on a 2014 Edition of the study and training programs
in the effective use of the Kentucky Edition - Total Science Safety System (CD-ROM or USB Drive formats).
I look forward to your response.

Dr. Jack Gerlovich

On Mar 24, 2014, at 11:40 AM, Al Yammahi, Ahmed R. wrote:

> Dear Dr Gerlovich,
>
> I hope you are doing very well. I am Ahmed Alyammahi, a student at Eastern Kentucky University. I am doing my master's thesis in school safety which is a similar to your study on the journal article: The Status of Science in Kentucky Secondary School. which was published by the the Journal of Kentucky Academy of Sciences in 2008. I am contacting you to kindly ask for your permission to use some of the date and results that appeared in your study as a basis for my thesis project as I am planning to do a similar study that expands on the results of your data and intend to include a follow-up survey in my study. Also I will greatly appreciate it if you could provide me with more information on where I can find the statistic of school laboratory accident in the United State.
>
> Thank you so much for your time and help.
>
> yours sincerely
>
> Ahmed Alyammahi