Chemistry and Materials Research
ISSN 2224- 3224 (Print) ISSN 2225- 0956 (Online)
Vol.8 No.11, 2016

Investigation of Laboratory and Chemical Safety in Wolaita Sodo University, Ethiopia

Mathewos Anza [1*] Mesfin Bibiso [1] Berhanu Kuma [2] Kedir Osuman[3]
1.College of Natural and Computational Science, Department of Chemistry, Wolaita Sodo University, P. O. Box 138, Wolaita Sodo, Ethiopia
2.Office of Vice President for Research and Community service, Wolaita Sodo University, P. O. Box 138, Wolaita Sodo, Ethiopia
3.College of Natural and Computational science, Department of physics, Wolaita Sodo University, P. O. Box 138, Wolaita Sodo, Ethiopia

The authors confirm that the project has not funding or grants.

Abstract
The present work aims at investigating laboratory and chemical safety in the case of Wolaita Sodo University. It provides the information to policy makers' insights to establish laboratory and chemical safety in the developing countries, similarly in Ethiopia. The sample for the study comprised 39 respondents; 30 instructors and 9 laboratory technical assistances from chemistry and biology departments of Wolaita Sodo University. Data were collected using structured questionnaires and observation checklist. The collected data were analyzed using qualitative and quantitative analysis. The results revealed that the need for corrective action to establish functional and safe chemical laboratories in the institution; and the majority of respondents agree with the statements, share the skills that students and other workers need if they are to handle chemicals safely, and hazard warning labels are properly used (94.9%); care you and environments from hazard chemical misuses(92.3%); follow all of the safety protocols for the protection of themselves as well as others and reporting to the concerning bodies happened accidents immediately (89.7%); make clean and hygiene workplaces(82.1%); properly use personal protective equipment, appropriately sort chemicals in their compatibility, and take care waste management's (76.9%) are their responsibility and accountability. Furthermore, the major factors that influence establishment of safe and functional chemical laboratory is *Unplanned / low quality order and purchase of chemicals and instruments; lack of trained personnel; the cost or limited availability of safety equipment; lack of companies to discard dangerous wastes from laboratories; limitation of budgets; lack of proper drainage system in the buildings where the lab rooms are situated; absence of continuous water flow in the labs; less attention of top managements to laboratory and chemical safety; large size of students in practical classes in the labs; and inappropriate infrastructure to laboratory rooms.* From this result it was concluded that a successful chemical safety program requires a daily commitment from everyone in the institution; and finally recommendations were forwarded based on the major finding in order to improve functional and safe chemical laboratory in the institutions.
Keywords: Laboratory and Chemical Safety, Waste Management, Chemical Labeling

1. Introduction

The laboratory has been given a central and distinctive role in science education, and science educators have suggested that rich benefits in learning accrue from using laboratory activities (Hofstein & Lunetta, 2004). Laboratories are described as secure environments with adequate experimental material where open-ended activities can be carried out; the rules to be followed are clearly defined; designed properly for both individual and cooperative studies of students (Quek *et al.,* 2002; Lang *et al*., 2005**)**. Laboratory settings provide chances to observe scientific events, promoting conceptual understanding and conceptual change (Costu, Ayas& Niaz, 2010), develop scientific research skills, promoting a perception of science and generate various learning environment (Can, 2013). The culture of laboratory safety depends ultimately on the working habits of individuals and their sense of teamwork for the protection of themselves, their neighbors, and the wider community and environment. Safety in the laboratory also depends on well-developed administrative structures and supports that extend beyond the laboratory's walls within the institution (National Research Council, 2005). However, achieving the goal of balancing economic and social benefits of chemicals with their health and environmental risks is a highly complex problem since managing the risks of chemicals is interconnected with many other issues, including wastes and pollution, global warming, resource depletion, agriculture, biotechnology, loss of biodiversity, poverty, etc (UNEP, 2004). Safety is an integral part of all laboratory operations but it requires that laboratory worker considers this every time they start work **(**American Chemical Society, 2012**)**. Safety is, therefore, of prime importance in laboratory practices. Individuals must be informed about the risks of a laboratory environment and the necessary precautions must be taken (Pratt, 2002; Banda and Sichilongo, 2006; Karapantsios *et al*., 2008; Richards-Babb *et al*., 2010).

The chemical laboratory has become the center for acquiring knowledge and developing new materials for future use, as well as for monitoring and controlling those chemicals currently used routinely in thousands of

commercial processes. Most of the chemicals produced and used today are beneficial, but some also have the potential to damage human health, the environment, and public toward chemical enterprises. Chemical safety and security can mitigate these risks. A culture of safety consciousness, accountability, organization, and education has developed around the world in the laboratories of the chemical industry, government, and academe. Chemical laboratories have developed special procedures and equipment for handling and managing chemicals safely and securely. The development of a culture of safety results in laboratories that are safe and healthy environments in which to teach, learn, and work (National Research Council, 2005). Chemicals, when used in the laboratory, are dangerous and risky. It should always be remembered that they are beneficial provided that they have used appropriately (Warhurts, 2006). Even experienced individuals might be exposed to several hazards unless they follow certain precautions while working in the laboratories. Students of all age groups (secondary school, high school, undergraduate or graduate degree levels) might be exposed to several hazards unless they follow certain precautions while working at laboratories (Fivizzani, 2005). Moreover, these hazardous properties (information) of chemical accidents in science laboratories that happened chemicals must be due to mishandling or misusing of chemicals (Hara *et al*., 2007; Kan, 2007).

It is wrong to conclude that chemicals are totally hazardous or risky. They are beneficial if they are properly utilized (Warhurts, 2006). The benefits of utilization of chemicals in different research activities and laboratory classes in science subjects of higher institutions can be considered as typical examples in this regard. Chemical accidents mostly occur due to the neglect of safety precautions or the absence of related precautionary symbols on the chemicals (Su & Hsu, 2008). So as to classify chemicals and draw users' attention, each chemical should be labeled with precautionary symbols indicating its features (Pratt, 2002). These symbols (flammable, corrosive, irritant, environmentally harmful, radioactive, oxidizing, toxic or harmful) include different colors and images and are designed to inform users about the features of the chemicals **(**Kan, 2007**)**. These hazard and risk precautionary symbols must be known by everybody who enters the laboratory and knowing the meanings of these hazard symbols on chemicals aid the safe use of chemicals (Duffus and Worth, 2006).

Ethiopia is one of those developing countries aggressively working on the expansion of higher institutes to increase yearly enrollment of students in different fields including natural sciences to meet the demand of skilled, well-qualified, scientifically literates and competent educated human power (Yizengaw, 2003; Saint, 2004). More emphasis has been given to science fields and students are expected to gain adequate practical knowledge parallel to the theoretical knowledge of science disciplines. Researchers in the field of science widely use varieties of chemicals and equipment. Moreover, the Ministry of Education of the Federal Democratic Republic of Ethiopia (FDRE), states in its policy as it gives much concern to the importance of science laboratory activities. Even though, in the developing country, similarly in Ethiopia, most of the higher institutes practical classes are conducted in a group of students that consisting of up to 5 students / group in their subgroups of lab rooms particularly those in undergraduate levels. This is a worry that students could face health risks due to mishandling or misuse of chemicals or failures to understand chemical hazard signs labels and to comply with safety measures. In the histories' of laboratories of higher institutes of the country, there are no reports on chemical accidents except minor incidents and easily controlled, similarly in the Wolaita Sodo University in which the present study was carried out.

1.1. Statement of the problem

It is difficult to anticipate the happening of chemical accidents/incidents in laboratories; the institutions should take initiative measurement to make laboratories safe and secure. And students and workers develop safety habit of using equipment and chemicals to feel a responsibility for their safety strictly follow safety rules. But safe and functional chemical laboratories in higher institution to producing qualified, practically skilled manpower is under serious problems and questionable in developing country, particularly in Wolaita Sodo University. Moreover, the actual practices and associated problems of laboratory and chemical safety are not well assessed.

1.2. Objectives of the study

1.2.1. T*he General Objective of the study*

- The present study aimed at investigates the laboratory and chemical safety in case of Wolaita Sodo University.

1.2.2. The specific objectives of this study

The specific objectives of this study are:

- Assessing the existing practice of laboratory and chemical safety in carrying out science practical activities
- To identify major factors that imfluence safe and functional chemical laboratory
- To explore the roles and readiness of academic staffs, department heads and laboratory technical assistances towards establishing functional and safe chemical laboratory.

1.3. Purpose of the study

The study may show the strength and weakness of the chemical laboratories in the institution to take the correction actions in the establishment and improvement of laboratories and chemical safety; providing insight for policy makers and developers how to establish functional and safe chemical laboratory; as a guideline for institution to make policy and regulation regarding laboratory and chemical safety.

Research questions

The present study aimed at answering the following research questions:

1. What are the current statuses of chemical laboratory safety in the institution?
2. Whose responsibility is establishing functional and safe chemical laboratory?
3. What are the major factors that influence the establishment of functional and safe chemical laboratory?
4. How to establish safe and functional chemical laboratory?

2. Literature Review

Science is one of the few subjects which provide the most pedagogically sound learning environment that results in potentially dangerous situations for students and teachers in the school environment (National Research Council 1996). Every day, students at all grade levels from kindergarten to seniors in high school participate in science instruction involving hands-on science activities. Many of these activities include heat, electricity and/or chemicals, thus presenting potentially dangerous or unsafe conditions (Linda M. Stroud, 2007). Fear is driving many school districts to cyber labs. This is robbing chemistry students off lab experience this safety crisis by providing fundamental training to build teacher′s knowledge. At a minimum rate, the training should include chemical hygiene, potential hazards and risks. Proper storage and handling, stock records and safety audits, safe physical, facilities and equipment, chemical waste, management and how to select experiments for students while knowledgeably considering both educational impact and safety risks should also be considered (Sarquis, 2003).

It is not a necessity but an obligation for the science teachers to be competent on safety since they need the laboratory applications more because of the characteristics of the lesson. A Science teacher is competent when he/she knows the dangers and takes precautions in his/her occupation (West, et al., 2002). The teacher candidates do not know how to operate safely in laboratories and they will not be able to provide their students in the future with safety. However, it is essential for the individuals to recognize the chemicals and their hazard symbols not only for their own health and safety but also for the safety and health of the laboratory and environment in the laboratory operations allowing practical applications (Osmangazi, 2010).

Chemical safety has evolved into more than a skill and deserves to be recognized as a valid curriculum topic. Instilling a culture of safety into the next generation of chemists is a worthy goal and safety professionals should advocate for this sub-discipline to have a place in the chemistry curriculum. Not all graduating chemistry majors must have the skills and knowledge of a chemical hygiene officer, but every student that graduates with a degree in science should have some basic chemical safety coursework under their belt (Bahram et, al. (2013).

According to Munir Ahmad, (2003*),* Hazards in the laboratory fall into three general categories: **Equipment:** A wide variety of equipment is used for different activities. Most of the equipment is delicate, sensitive and expensive. Before you use any equipment you must learn about its operation and its safety implications. Misuse of equipment can lead to injury delay in project work and substantial cost in repair bill.

Gases: A variety of compressed gases are used, some of which may be toxic, corrosive, flammable, or explosive. These hazards have been minimised by the use of proper equipment, proper confinement, ventilation, safety valves, etc., and by procedural controls. You must learn about the safe handling of gases before embarking on their use. An accident with any of these could be catastrophic.

Chemicals: Acids, bases, etching solutions and solvents are commonly used in materials chemistry and device fabrication. These are "hands on" hazards which are hard to control by engineering controls only. These chemicals can cause severe burns, tissue damage, organ damage, asphyxiation, and genetic damage if used improperly. You must take chemical safety instructions before using any chemical.

3. Methodology of the study

3.1. Research Design

The design of a study considers as a road map/blueprint of a research work. Among the research designs the one which is suitable for the research of investigation of laboratory and chemical safety is a descriptive survey in which the researchers can show current status; the responsibilities of instructors, lab technicians and respective department heads in the establishment and major that influence the safety laboratory; and how to improve safe and functional chemical laboratory in the institution.

3.2. Sampling techniques

We know that the sample should be representative of the population of the study. The population for this study is chemistry and biology department academic staffs, and laboratory technical assistances. In order to gather the

information of the existing situation of laboratories and chemical safety; constraints that affect the laboratory and chemical safety practice in science; the roles and readiness of academic staffs, department heads and laboratory technical assistances towards establishing functional and safe chemical laboratory, and the improvement strategies of functional and safe chemical laboratories totally 39 respondents, 17 and 13 respondents from chemistry and biology academic staffs respectively; and 9 laboratory technical assistances were selected for the study. The selection was made by purposive sampling methods.

3.3. Data collection instrument

The researchers to collect sufficient and rich data a variety of instruments, such as for primary data questionnaires and observational checklist; and for the secondary data document analysis were used. The questionnaire was prepared and dispatched to academic staffs, department heads and laboratory technicians. The observations were supported by standard checklist adopted from (National Research Council, 2005) to gather qualitative information; and finally integrated and triangulated to enrich and elaborate the quantitative data gather though questionnaire during the analysis of data (Table 1).

Table 1: Types and description of instrument

No.	Instruments	Participants	Description of purpose
1.	Questionnaire	Instructors, Department heads, and lab technicians	A standard structured questionnaire was prepared in English, help to collect primary information.
2.	Observation Checklist	The researchers	Helps to record data about the actual practice of chemical laboratory.
3.	Document analysis	The researchers	Helps to analysis the related works and standard guidelines regarding laboratory and chemical safety.

3.4. Research procedure

After determining target population, sample size and deciding types of sampling techniques, the next step was revising and analyzing related literature data to prepare standard questionnaires and checklists. So, related review literature was thoroughly and deeply revised and samples of questionnaires identified and critically examined. Then questionnaires were prepared. After collecting comments finally, the developed questionnaires were distributed to the academic staffs and laboratory technical assistances. Responses of the participants were coded; categorized; major themes were developed, and triangulated to the quantitative data at the time of analysis. In addition, the observation checklist was prepared, and data collected from the actual existing status of the laboratory and chemical safety practice in Wolaita Sodo University chemistry laboratories. All the data were analyzed and the results were triangulated.

3.5. Methods of data Analysis

The data collected were organized and coded. For quantitative data, Statistical Package for Social Sciences (SPSS) version 20.0 was utilized. The main statistics yielded were analyzed using simple quantitative descriptives such as frequency count and percentage. Percentage and frequency are important data analyzing techniques to show the constraints that inhibits the laboratory and chemical safety and to explores the responsibility and accountability of academic staffs and laboratory technical assistances to establishing safe and functional chemical laboratory in the institution. In addition, the data gathered through observation were coded and categorized into themes and analysis of document used to develop an important idea which can support and emphasize the numerical data analyzed by percentage, frequency.

4. Result and discussion

4.1. Investigation of the existing situation of laboratory and chemical safety in the institution

The researchers were gathering qualitative information to explore the existing situation of laboratory and chemical safety in the Wolaita Sodo University through daily observation supported with a structured observation checklist. In the observation time, the researchers have assessed the physical and the practical works conducted by researchers and students in their tenure. Finally, researchers were evaluated the existing situation of chemical laboratory in line with three points: general chemical laboratory safety; laboratory equipment and its safety; and chemical handling and waste management's practice in the institutions as follows:

General chemical laboratory safety:

- *Laboratories are not controlled and mentored by trained and authorized personnel.*
- *Lack of continuous water flows in the chemical lab rooms.*
- *A safety handbook is not provided to each new arrival.*
- *Hazard warning labels are not properly used.*
- *Laboratory is not equipped with water and a powder fire extinguisher.*

- *Emergency exits in the laboratory are not clearly marked.*
- *Emergency instructions in case of exposure to chemical hazards are not posted in the labs.*

Regarding laboratory equipment and its safety:

- *Laboratory equipment is not clearly labeled with hazard symbols, toxic risk, etc.*
- *Scientific instruments are not checked regularly in accordance with recommendations, and dates of maintenance are recorded.*
- *Fume hoods are not properly installed and not functional.*
- *The temperatures of refrigerators and freezers are not recorded daily.*
- *The policy of assigned materials and equipment to specific rooms is not respected.*
- *The measurement accuracy of balances and pipettes is not checked.*

Regarding chemical handling and waste management practice:

- *Chemicals and reagents do not supported by computer database.*
- *Flammable substances are not stored in a safety cabinet.*
- *Reactive chemicals and reagents and samples are not labeled with the following information: name, date, storage temperature, expiry date.*
- *There is no waste disposal policy and regulation in the institution.*
- *Chemical waste containers are not identifiable, labeled, dated, and sealed.*
- *Containers for sharp and cutting waste are not properly handled and disposed of.*
- *Acid waste, basic waste, and solvents are not stored in separate containers.*
- *Decontaminate substances carried outside of the laboratory are not placed in hard, sealed, leak-proof containers in accordance with local regulations.*

In line with achieving the country goal to meet the demand of skilled, well-qualified, scientifically literates and competent educated human power, it is unquestionable to establish functional and safe chemical laboratory in the higher institution for students to gain adequate practical knowledge parallel to the theoretical knowledge of science disciplines. The chemical laboratory has become the center for acquiring knowledge and developing new materials for future use. However, educational institutions have been slower to adopt safety practices and programs in developing country, similarly in Wolaita Sodo University, Ethiopia. From this result, it was recommended that the respective bodies must take an immediate measurement to overcome these problems; that are why functional laboratory and chemical safety is a prime importance to assure the quality of education. Moreover, to achieve the vision of Wolaita Sodo University, "aspires to be one of the best five universities nationally and top ranked university in east Africa by 2020" it needs aggressively working in the issue of laboratory and chemical safety.

4.2. The responsibility of establishing functional laboratory and chemical safety practices.

The questionnaire was prepared using a four-point Likert scale in which the instructors, department heads, and laboratory technicians were required to give their views as strongly agree, agree, disagree or strongly disagree with the nine positive statements relating with whose responsibility and accountability of establishing functional laboratory and chemical safety practices. As shown in table 2, the majority of respondents strongly agree and agree with the statements: share and teach the skills that students and other workers need if they are to handle chemicals safely; and hazard warning labels are properly used (94.9%); care you and environments from hazard chemical misuses (92.3%); follow all of the safety protocols for the protection of themselves as well as others; and reporting to the concerning bodies happened accidents immediately (89.7%); make clean and hygiene workplaces (82.1%); properly use personal protective equipment; appropriately sort chemicals in their compatibility; and take care waste management's (76.9%) are as their responsibility.

However, during daily observation and our experience, there is a limitation in the side of instructors, laboratory technicians, researchers as well as students in the institutions; that is why in the chemical laboratory we observed that the presence of personal protective equipment (PPE), but the majority of workers do not use PPE properly. The workers were asked to respond to the open-ended question, why they haven't used PPE properly? , and how they dispose the waste chemicals? , they claimed that *a lack of habit and understanding of the importance of wearing PPE*; *and also nobody cares for chemical waste disposal system at standard levels*. Almost every laboratory experiment generates some waste, which may include such items as used disposable Labware, filter media, aqueous solutions, and hazardous chemicals (National Research Council, 2005). The overriding principle governing the safe and secure handling of laboratory waste is that no activity should begin unless a plan for the disposal of nonhazardous and hazardous waste has been made. The decisions that are made when dealing with chemical waste affect the person who generated the waste, that person's institution, and society as a whole. Laboratory personnel who generate waste have an obligation to consider the ultimate fate of the materials resulting from their work. This includes consideration of the cost of disposal, the potential hazards to people outside the laboratory, and the potential impacts on the environment. [National Research Council, 2010].

Therefore, it is recommended that the institution should be taking the corrective measurements regarding

the laboratory chemical waste management system. Teachers, laboratory technical assistances and department heads have an obligation to instruct their students in the basic safety practices required in chemical laboratories. They also have an obligation to instruct them in the basic principles of health hazards that are found in chemical laboratories. Instructors must provide safety information and training to the students for every stage of experiment planning and be there to observe, supervise, instruct, and correct during the experimentation and exemplar use / develop the habit of using PPE. Teachers play the most important role in insuring a safe and healthful learning environment for the students. In practical classes, instructors, lab technical assistances are responsible for promoting a culture of safety as well as for teaching the requisite skills needed to handle chemicals safely. Academic and teaching laboratories have a unique responsibility to instill in their students a lifelong attitude of safety and security consciousness and prudent laboratory practice. Teaching safe practices should be a top priority in the academic laboratory. By promoting safety during the undergraduate and graduate years, faculty members have an impact not just on their students, but on everyone who will share their future work environments. People at all levels must understand the importance of eliminating risks in the laboratory and work together toward this end. Institutional leaders have the greatest power and authority, and therefore the greatest responsibility for cultivating a culture of safety and security. That is why a successful chemical safety program requires a daily commitment from everyone in the institution.

Table 2: The responsibility of establishing functional, safe and secure chemical laboratory

In what extent do you agree to the following terms are/is your responsibility to establish safe laboratory and chemical safety practices?	**Strongly Agree**	**Agree**	**Disagree**	**Strongly disagree**
	Freq (%)	**Freq (%)**	**Freq (%)**	**Freq (%)**
Share and teach the skills that students and other workers need if they are to handle chemicals safely.	23(59.0)	14(35.9)	2(5.1)	0(0.0)
Hazard warning labels are properly used	25(64.1)	12(30.8)	2(5.1)	0(0.0)
Follow all of the safety and security protocols for the protection of themselves and others	22(56.4)	13(33.3)	3(7.7)	1(2.6)
Reporting to the concerning bodies happened accidents immediately	19(48.7)	16(41.0)	4(10.3)	0(0.0)
Care you and environments from hazard chemical misuses	17(43.6)	19(48.7)	2(5.1)	1(2.6)
Properly use personal protective equipments	16(41.0)	14(35.9)	8(20.5)	1(2.6)
Make clean and hygiene work places	18(46.2)	14(35.9)	6(15.4)	1(2.6)
Appropriately sort chemicals in their compatibility	16(41.0)	14(35.9)	9(23.1)	0(0.0)
Take care waste managements	16(41.0)	14(35.9)	7(17.9)	2(5.1)

4.3. Factors influence establishment of functional laboratory and chemical safety

In order to gather the views of the instructors', laboratory technical assistances', and respective department heads' towards factors that influence the establishment of functional laboratory and chemical safety, the respondents were required to indicate their views. As shown in table 3, the majority of respondents shown their views as strongly agree and agree to the statements: Unplanned / low quality order and purchase of chemicals and instruments(74.4%); lack of trained personnel(66.6); the cost or limited availability of safety and security equipment(82.1%); lack of companies to discard dangerous wastes from laboratories(89.8%); limitation of budgets(58.9%); poor or lack of proper drainage system in the buildings where the lab rooms are situated(82.1); absence of continuous water flow in the labs(89.8); less attention of top managements to laboratory and chemical safety (89.5); large size of students assigning for practical classes in the labs(82.1%); inappropriate infrastructure to laboratory rooms (87.2%). However the majority of respondents claimed to the statements: environmental conditions, such as climate, that makes compliance difficult (76.9%), cultural beliefs that minimize the importance of individual health and safety (74.3%), are not influencing the establishment of functional laboratory and chemical safety in their institution.

Moreover, the information gathered through our observation in the chemistry laboratory room, revealed that 30-40 undergraduate students from chemistry and biology departments conducting their tenure in one group; and also the legislation of the Wolaita Sodo University recently approved by the institutional senate members and applied in the institution limited the student size for practical/laboratory classes 30-40. And in our observation time we asked students, laboratory technicians and instructors to respond to, are they interested in the student to class room arrangement. All of them claimed that *they are not interested even challenged to conduct the practical classes.* From these results, it was concluded that the major factors that influencing establishment of functional laboratory and chemical safety is: *Unplanned / low quality order and purchase of chemicals and instruments; lack of trained personnel; the cost or limited availability of safety and security equipment; lack of companies to discard dangerous wastes from laboratories; limitation of budgets; poor or lack of proper drainage system in the buildings*

where the lab rooms are situated; absence of continuous water flow in the labs; low attention of top managements to laboratory and chemical safety ; large size of students conduct practical classes in the labs; and inappropriate infrastructure to laboratory rooms. The finding is inconsistence with the challenges of chemical laboratory safety and security of developing country reported by Temechegn Engida, (2011); and National Research Council, (2010).

Science education organizations at the national and state levels have long advocated for limiting science class size to 24 students (if the minimum square footage per occupant is in concert with the established occupancy load) and adequate work surface space is provided (National Science Teachers Association, 2007; National Science Education Leadership Association; American Chemical Society, 2012; Motz, Biehle, and West. 2007). That is why most accidents occur in classrooms particularly in the lab classes with an enrollment of greater than 24 students. Major problems with overcrowding include two issues: the teacher's ability to supervise a large number of students doing science activities and the amount of individual workspace per student. Overcrowding in regards to supervision likely affect a teacher's ability to properly manage and oversee their classroom/activities and, therefore, may prevent the adequate supervision of students conducting science activities (Stephenson et al., 2003 and West and Kennedy, 2013).

Thus, it is recommended that the respective body of the institution must give attention to the student size to the practical classes in the chemical laboratory. When chemicals and instrument purchasing should be need consideration through purchasing to legal disposal of the chemical and/or its end product; the laboratories should be controlled and mentor by trained personnel; the institution provide safety and security equipment; manage and plan to discard dangerous wastes from laboratories; plan to the safety issue before start the fiscal academic year of budgets; aggressively work to provide proper drainage system in the buildings where the lab rooms are situated; continuous water flow in the labs are unquestionable for chemical laboratory so the respective body take the correction measurements; top managements should be closely work with respective department heads and instructors regarding safety issue of chemical laboratory.

Table 3: Factors influencing establishing laboratory and chemical safety

In what extent you agree the following factors affect establishing functional and safe chemical laboratory?	**Strongly Agree**	**Agree**	**Disagree**	**Strongly disagree**
	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Unplanned / low quality order and purchase of chemicals and instruments	12(30.8)	17(43.6)	7(17.90	3(7.7)
Lack of trained personnel	13(33.3)	13(33.3)	10(25.6)	3(7.7)
The cost or limited availability of safety and security equipment	15(38.5)	17(43.6)	5(12.8)	2(5.1)
Environmental conditions, such as climate, that make compliance difficult	0(0.0)	3(7.7)	17(43.6)	13(33.3)
Cultural beliefs that minimize the importance of individual health and safety	2(5.1)	8(20.50)	24(61.5)	5(12.8)
Lack of companies to discard dangerous wastes from laboratories	20(51.3)	15(38.5)	4(10.3)	0(0.0)
Limitation of budgets	13(33.3)	10(25.6)	11(28.2)	5(12.8)
Poor or lack of proper drainage system in the buildings where the lab rooms are situated	20(51.3)	12(30.8)	7(17.9)	0(0.0)
Absence of continuous water flow in the chemical laboratories	26(66.7)	9(23.10	3(7.7)	1(2.6)
Less attention of top managements to laboratory and chemical safety.	16(41.0)	15(38.5)	5(12.8)	3(7.7)
Large size of students conduct practical classes in the labs	15(38.5)	17(43.6)	7(17.9)	0(0.0)
inappropriate infrastructure to laboratory rooms	15(38.5)	19(48.7)	2(5.1)	3(7.7)

4.4. Improving functional laboratory and chemical safety

Out of the total 39 respondents, as shown table 4, the majority of respondents shown their views as strongly agree and agree for the statements related to how to improve functional laboratory and chemical safety: chemical laboratory controlled and mentored by trained personnel (89.8%); peer assessment by laboratory coworkers from different departments (77.0%); environmental health and safety inspections conducted on a regular basis (84.6); establish general guidelines for what constitutes safe and secure practices in laboratory work (92.3%), develop safety and security management system (94.7%); develop laboratory and chemical safety policy (89.7%), implement administrative controls and processes for performance measurement for laboratory and chemical safety

(94.9%), identify and address particularly hazardous situations (97.5%), evaluate facilities and address weaknesses (94.9%), establish procedures for chemical handling and management (97.4%), use personal protective equipment and engineering controls (92.3%), plan for emergencies (89.7%), train, communicate, mentor (92.3%). Establishing functional and safe chemical laboratories in the academic institution is mandatory for enhancing the quality of education in developing country, similarly in the country Ethiopia. A culture of safety requires sustained commitment to high standards at all levels—from the top institutional leadership to the day-to-day laboratory worker. Creating a safety management system will improve laboratory operations and anticipate and prevent circumstances that might result in injury, illness, or adverse environmental impact. [National Research Council, 2010]. From this result it was concluded that to improve the laboratory and chemical safety in the institution, chemical laboratory controlled and mentored by trained personnel; peer assessment by laboratory coworkers from different departments; environmental health and safety inspections conducted on a regular basis; establish guidelines for what constitutes safe and secure practices in laboratory work; develop safety and security management system; develop laboratory and chemical safety policy; implement administrative controls and processes for performance measurement for laboratory and chemical safety; identify and address particularly hazardous situations; evaluate facilities and address weaknesses; establish procedures for chemical handling and management; use personal protective equipment and engineering controls; plan for emergencies; train, communicate, mentor.

Table 3: Improving functional laboratory and chemical safety

In what extent you agree the following guidelines used to improving the establishment of functional laboratory and chemical safety?	**Strongly Agree**	**Agree**	**Disagree**	**Strongly disagree**
	Freq (%)	Freq (%)	Freq (%)	Freq (%)
Chemical laboratory controlled and mentored by trained personnel	23(59.0)	12(30.8)	2(5.1)	2(5.1)
Peer assessment by laboratory coworkers from different departments	18(46.2)	12(30.8)	4(10.3)	5(12.8)
Environmental health and safety inspections conducted on a regular basis	20(51.3)	13(33.3)	4(10.3)	2(5.1)
Establish general guidelines for what constitutes safe and secure practices in laboratory work.	21(53.8)	15(38.5)	2(5.1)	1(2.6)
Develop safety and security management system	23(59.0)	14(35.9)	1(2.6)	1(2.6)
Develop a chemical safety and security policy	25(64.1)	10(25.6)	2(5.1)	2(5.1)
Implement administrative controls and processes for performance measurement	20(51.30	17(43.6)	1(2.6)	1(2.6)
Identify and address particularly hazardous situations	23(59.0)	15(38.5)	1(2.6)	0(0.0)
Evaluate facilities and address weaknesses	15(38.5)	22(56.4)	1(2.6)	1(2.6)
Establish procedures for chemical handling and management	22(56.4)	16(41.0)	0(0.0)	1(2.6)
Use personal protective equipment and engineering controls	26(66.7)	10(25.6)	2(5.1)	1(2.6)
Plan for emergencies	27(69.2)	8(20.5)	3(7.7)	1(2.6)
Train, communicate, mentor.	27(69.2)	9(23.1)	1(2.6)	2(5.1)

5. Conclusion

The present study revealed that sharing the skills that students and other workers need if they are to handle chemicals safely, and hazard warning labels are properly used; care them and their environments from hazard chemical misuses; follow all of the safety protocols for the protection of themselves as well as others and reporting to the concerning bodies happened accidents immediately; make clean and hygiene workplaces; properly use personal protective equipment; appropriately sort chemicals in their compatibility; and take care waste management's are responsibility and accountability of the academic staffs, laboratory technical assistances and respective department heads of chemistry. Moreover, the major factors that influence establishment of safe and functional chemical laboratory is Unplanned / low quality order and purchase of chemicals and instruments; lack of trained personnel; the cost or limited availability of safety equipment; lack of companies to discard dangerous wastes from laboratories; limitation of budgets; lack of proper drainage system in the buildings where the lab rooms are situated; absence of continuous water flow in the labs; less attention of top managements to laboratory and chemical safety; large size of students in practical classes in the labs; and inappropriate infrastructure to laboratory rooms. From this result it was concluded that a successful chemical safety program requires a daily commitment from everyone in the institution. A strong culture of safety within an organization creates a solid foundation upon which a functional laboratory and chemical safety program can be built in the institutions. As

part of that culture, all levels of the organization (i.e., administrative personnel, scientists, laboratory technicians) should understand the importance of minimizing the risk of exposure to hazardous materials in the laboratory and should work together toward this end. Finally the following general guidelines are recommended that to improve laboratory and chemical safety in the academic institutions

- ✓ Should be care chemical waste disposal.
- ✓ No more than 25 students assigned at the same time work in a laboratory under the supervision of instructors.
- ✓ Instructors and laboratory technical assistance should lead by example and wear PPE. They should be proactive in every aspect of laboratory safety, making safety a priority.
- ✓ Follow and enforce safety rules, procedures, and practices.
- ✓ Demonstrate safety behavior and promote a culture of safety.
- ✓ Design institutional policy and regulation for waste management system.

During Chemical Handling:

- ✓ Check the label to verify it is the correct substance before using it.
- ✓ Wear appropriate chemical resistant gloves before handling chemicals.
- ✓ If you transfer chemicals from their original containers, label chemical containers as to the contents, concentration, hazard, date, and your initials.
- ✓ Always use a spatula to remove a solid reagent from a container.
- ✓ Do not directly touch any chemical with your hands.
- ✓ Never use a metal spatula when working with peroxides.
- ✓ Hold containers away from the body when transferring a chemical or solution from one container to another.
- ✓ Use a hot water bath to heat flammable liquids. Never heat directly with a flame.
- ✓ Add concentrated acid to water slowly. Never add water to a concentrated acid.
- ✓ Weigh out or remove only the amount of chemical you will need. Do not return the excess to its original container, but properly dispose of it in the appropriate waste container.
- ✓ Never touch, taste, or smell any reagents.
- ✓ Never place the container directly under your nose and inhale the vapors.
- ✓ Never mix or use chemicals not called for in the laboratory exercise.
- ✓ Use the laboratory chemical hood, if available, when there is a possibility of release of toxic chemical vapors, dust, or gases.
- ✓ When transporting chemicals (especially 250 mL or more), place the immediate container in a secondary container or bucket (rubber, metal or plastic) designed to be carried and large enough to hold the entire contents of the chemical.
- ✓ Never handle bottles that are wet or too heavy for you.
- ✓ Use equipment (glassware, Bunsen burner, etc.) in the correct way, as indicated by the teacher.

Institution should be Considered When Purchasing Chemicals:

- ✓ Establish a chemical procurement plan.
- ✓ Consider using a centralized purchasing program in which one person, who is knowledgeable of all the chemicals on hand, does all the purchasing, or links purchasing requests into an inventory tracking system so that excess chemicals in stock can be used before buying more.
- ✓ Train receiving room, storeroom, and stockroom personnel in the proper methods of receiving and handling of hazardous substances.

Do the following before ordering chemicals:

- ✓ Assess all the hazards and physical properties of the chemical using the MSDS; evaluate both short and long term risks.
- ✓ Consider the worst case scenario(s) in the event that the substance is mismanaged, spilled, or causes personal injury.
- ✓ Make sure the hazardous properties of the chemical do not exceed the educational utility of the experiment.
- ✓ Determine whether a safer, less hazardous chemical can be used.
- ✓ Determine whether the appropriate facilities are available for the proper storage of the chemical and the ventilation is sufficient.
- ✓ Determine whether the proper personal protective equipment and safety equipment is on hand for using the chemical.
- ✓ Establish whether the chemical or its end product will require disposal as a hazardous waste.
- ✓ Ensure that the budget will allow for the appropriate and legal disposal of the chemical and/or its end product.
- ✓ Have a mechanism in place to dispose of the chemical and its end product legally and safely.
- ✓ Determine whether lesser amounts of a chemical can be used to conduct the experiment.

When ordering chemicals, remember to do the following:

- ✓ Order minimum quantities that are consistent with the rate of use.
- ✓ Order only what will be used within a year or less.

- ✓ If possible, order reagents in polyethylene bottles or plastic coated glass bottles to minimize breakage, corrosion, and rust.

General Rules for Chemical Storage

Criteria for Storage Area

Store chemicals inside a closeable cabinet or on a sturdy shelf with a front-edge lip to prevent accidents and chemical spills; a ¾-inch front edge lip is recommended.

- ✓ Secure shelving to the wall or floor.
- ✓ Ensure that all storage areas have doors with locks.
- ✓ Keep chemical storage areas off limits to all students.
- ✓ Ventilate storage areas adequately.

Organization

- ✓ Organize chemicals first by COMPATIBILITY
- ✓ Store alphabetically within compatible groups.

Chemical Segregation

- ✓ Store acids in a dedicated acid cabinet. Nitric acid should be stored alone unless the cabinet provides a separate compartment for nitric acid storage.
- ✓ Store highly toxic chemicals in a dedicated, lockable poison cabinet that has been labeled with a highly visible sign.
- ✓ Store volatile and odoriferous chemicals in a ventilated cabinet.
- ✓ Store flammables in an approved flammable liquid storage cabinet.
- ✓ Store water sensitive chemicals in a water-tight cabinet in a cool and dry location segregated from all other chemicals in the laboratory.

Storage Don'ts

- ✓ Do not place heavy materials, liquid chemicals, and large containers on high shelves.
- ✓ Do not store chemicals on tops of cabinets.
- ✓ Do not store chemicals on the floor, even temporarily.
- ✓ Do not store items on bench tops and in laboratory chemical hoods, except when in use.
- ✓ Do not store chemicals on shelves above eye level.
- ✓ Do not store chemicals with food and drink.
- ✓ Do not store chemicals in personal staff refrigerators, even temporarily.
- ✓ Do not expose stored chemicals to direct heat or sunlight, or highly variable temperatures.

Conflict of interest statement

We declare that we have no conflict of interest.

Acknowledgment

Authors would like to acknowledge Wolaita Sodo University for providing facilities for this study. And chemistry and biology department instructors, laboratory technicians, respective department heads of Wolaita Sodo University for providing real information.

References

American Chemical Society, (2012). Creating safety cultures in academic institutions, a report of safety culture task force of the ACS committee on chemical safety, Washington, DC.

Bahram, S. S., Maryam, S. Fatemeh, M. S. (2013). A Survey on the Pre Service Chemistry Teachers' Lab Safety Education. Procedia - Social and Behavioral Sciences (90):57 – 62

Banda, S. F. and Sichilongo, K. (2006). Analysis of the level of comprehension of chemical hazard labels: A case for Zambia, *Science of the Total Environment, 363*, 22-27.

Can, S. (2013). Pre-service science teachers' concerns about chemistry laboratory (case of Mugla university,Turkey). *Procedia-Social and Behavioral Sciences*, *106*, 2102-2111.

Costu, Ayas & Niaz, M. (2010).Promoting conceptual change in first year students' understanding of evaporation, *Chem. Educ. Res. Pract.,11,* 5-16.

Duffus, J. H. and Worth H. G. J. (2006). Toxicology and the environment: An IUPAC teaching program for chemists, *Pure and Applied Chemistry, 78* (11), 2043-2050.

Dr Munir A, (2003*)*. Laboratory & chemical safety guide. *Imperial College, London*.

Fivizzani, K. P. (2005). The evolution of chemical safety training, *Chemical Health and Safety*, *12* (6), 11-15.

Hara, K., Mori, M., Ishitake, T., Kitajima, H., Sakai, K., Nakaaki, K. and Jonai, H. (2007). Results of Recognition Tests on Japanese Subjects of the Labels Presently Used in Japan and the UN-GHS Labels, *Journal of Occupational Health*, 49(4): 260-267.

Hofstein, A. and Lunetta, V.N. (2004). The laboratory in science education: foundation for the 21st century, Science

Education, 88, 28-54

Kan, C. W. (2007). Chemical safety management in Hong Kong, *Journal of Chemical Health and Safety, 14* (1), 13-16.

Karapantsios, T. D., Boutskou, E. I., Touliopoulou, E., and Mavros, P. (2008). Evaluation of chemical l aboratory safety based on student comprehension of chemicals labeling, *Education for Chemical Engineers, 3*, 66-73.

Lang, Q. C., Wong, A. F. L., & Fraser, B. J. (2005). Student Perceptions of Chemistry Laboratory Learning Environments, Student Teacher Interactions and Attitudes in Secondary School Gifted Education Classes in Singapore. *Research in Science Education, 35*, 299-321.

Motz, L. L., J. T. Biehle, and S. S. West. (2007). NSTA guide to planning school science facilities, Second Edition. Arlington, VA: NSTA Press.

National Fire Protection Association (NFPA).(2012). Section 3.3.162.2 Occupant Load

National Research Council, (2010). Prudent Practices in the Laboratory: Handling and Disposal of Chemicals, Washington, DC, *National Academies Press*.

National Research Council, (2005). Prudent Practices in the Laboratory: Handling and Disposal of Chemicals, Washington, DC, *National Academies Press*.

National Research Council, (1996). *National science education standards*. Washington, DC: National Academy Press

*Osmangazi, Eski_ehir, (*2010*). The recognition level of the students of science education about the hazard symbols of chemicals*. Procedia Social and Behavioral Sciences 2, 4092–4097.

Pratt, I.S. (2002). Global harmonization of classification and labeling of hazardous chemicals. *Toxicology Letters, 128*, 5-15.

Quek, C. L., Wong, A. F. L., & Fraser, B. J. (2002). Gender Differences in the Perceptions of Chemistry Laboratory Classroom Environments. *Queensland Journal of Educational Research, 18* (2), 164-182.

Richards-Babb, M., Bishoff, J., Carver, J.S., Fisher, K., and Robertson-Honecker, J. (2010). Keeping it safe: Chemical safety in the high school laboratory, *Journal of Chemical Health and Safety, 17* (1), 6-14.

Saint, W. (2004). Higher Education in Ethiopia: The Vision and Its Challenges. JHEA/RESA, 2(3): 83-113.

Sarquis, M. **(**2003). *Bulding student safety habit: Barrier and recommendations*. Journal of Chemical Health & Safety, March/ April, 10 – 12.

Stephenson, A. L., West, S., and Westerlund, J. (2003). An Analysis of Incident/Accident Reports from the Texas Secondary School Science Safety Survey, 2001.School Science and Mathematics,103(6), 293-303

Stroud, Linda, (2007*). Implementation of a science laboratory safety program in North Carolina school*. Journal of Chemical Health & Safety, 14, 20-30.

Su, T. S. and Hsu I. Y. (2008). Perception towards chemical labeling for college students in Taiwan using globally harmonized system. *Safety Science, 46* (9), 1385-1392.

Temechegn engida ,(*2011).* Chemical safety in laboratories of African universities. *AJCE, 1(2):*35

UNEP, (2004). Balancing the benefits of chemicals with their health and environmental risks, *Industry and Environment* 27(-3), 3.

Warhurts, A. M. (2006). Assessing and managing of the hazard and risks of chemicals in the real world the role of the EU's reach proposal in future regulation of chemicals, *Environmental International, 32* (8), 1033-1042.

West, S.S., Westerlund, J.F., Nelson, N.C., Stephenson, A.L., Nyland, C.K. (2002). *What the safety research Says to Texas Science Teachers*. The Texas Science Teachers, 31, 11-15.

West, S. and Kennedy, L.(2014). Safety in Texas Secondary Science Classrooms. Texas Academyof Science, (58)

Yizengaw, T. (2003), Transformations in Higher Education: Experiences with Reform and Expansion in Ethiopian Higher Education System. Keynote paper prepared for a Regional Training Conference on Improving Tertiary Education in Sub-Saharan Africa: Things That Work! *Accra*, Ghana, pp: 1-18.