CHEMICAL SAFETY IN LABORATORIES OF AFRICAN UNIVERSITIES*

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ABSTRACT

Universities in Africa are in need of chemical safety and security facilities, professionals and resource materials. It seems that the more the universities engage themselves with advanced chemistry research, the more they need the safety and security facilities and skills. This survey study explores the situation in a number of African universities. It gives highlights of the practices in selected universities but it is by no means exhaustive. *[AJCE, 1(2), July 2011]*

* The first version of this paper was presented at the meeting of the Committee on Promoting Safe and Secure Chemical Management in Developing Countries, National Research Council, Washington, D.C., June 2009 and at the American Chemical Society (ACS) National Symposium, Boston, August 2010.

INTRODUCTION

The National Research Council (1) argued that "The culture of laboratory safety depends ultimately on the working habits of individual chemists and their sense of teamwork for 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." It is therefore necessary to study the practices of chemistry laboratory safety as part of a chemistry program that promotes sustainable development in a country/continent.

However, achieving the goal of balancing the 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 (2).

Currently, Africa is neither a major consumer nor a producer of chemicals in global terms. There is also disparity among the sub-regions of Africa, with the most advanced chemical industries in the region found in Northern, Western and Southern Africa. The development of Universities and their respective Chemistry Departments in Africa seem to follow this trend.

With these premises in mind, this article aims at exploring the state of chemical safety in the laboratories of African universities. The paper is by no means exhaustive but it tries to highlight the picture as much as available data permit.

METHODOLOGY

In order to get data for this paper, I used several sources and techniques. First of all, I administered to undergraduate (B.Sc. final/4th year) chemistry students of the Addis Ababa University/Ethiopia a chemical safety quiz that also consisted of few open-ended questions that ask for the students' experiences about chemical safety. All the 51 students completed the quiz. Secondly, I sent via e-mail few questions on chemical safety to heads of chemistry departments in FASC member countries. As usual, the response rate was not that much encouraging but valuable information was obtained. Third, I contacted the office of the Pan African Chemistry Network (PACN), a sister network of FASC, based in Nairobi/Kenya. The response from the PACN complemented my request to the heads of the chemistry departments. Fourth, I also contacted the US-based Chemical Security Engagement Program (CSP) that has cooperated with FASC in holding a satellite workshop on chemical safety and security for chemists selected from African universities and the Middle East in January 2009 in Cairo/Egypt. The data from CSP has greatly enriched my search for the state of chemical safety in laboratories of African universities.

RESULTS AND DISCUSSION

I. University Students' Perspectives

In March 2009, fifty one 4th year undergraduate students (graduating class) of Chemistry in the Addis Ababa University were requested to respond to a questionnaire that consisted of two parts: 1) Open-ended questions that request students to forward their experiences related to chemical safety, and 2) Multiple choice chemical safety quiz. The results are presented as follows.

Undergraduate Students' Experiences on Chemical Safety

This section of the questionnaire attempted to survey the students' experiences while responding to the following three questions:

a. Have you ever participated in a training program/course on chemical safety in laboratories?
b. Have you ever faced/saw any hazard/accident while you were working in a chemistry laboratory?
c. Please briefly describe the strengths and weaknesses of the chemistry laboratory you are currently working in from chemical safety point of view.

In terms of students' participation in chemical safety programs, it is learnt that only 18% (9) of the 4th year undergraduate students got some form of training on individual basis. However, all have expressed that they did not receive formal training on chemical safety and security at any level of their undergraduate training. They have, however, been provided with a written safety manual for personal reading. Most of the laboratories also post brief safety rules on the inside walls of the labs.

With regard to the occurrence of hazards while the undergraduate chemistry students were working in the labs, 31% (16) of them reported that they had some minor incidents at different times throughout the undergraduate program. Some among these are presented in Appendix 1. The most important implications that can be deduced from the students' responses in Appendix 1 are: students were not using protective gloves, students were handling the incidents with little or no professional background, and it seems that there is little or no recording of incidents in the lab in a manner that provides lessons for future actions in the lab.

The undergraduate chemistry students also assessed the strengths and weaknesses of the undergrad chemistry laboratories as presented in Appendix 2. It can be deduced from their responses that, while they appreciate and recognize the value of chemistry laboratory work in their future career, the students worry about the lack of proper chemical safety and security practices. They also stated that students' good laboratory safety practices were neither praised nor evaluated at all during their undergraduate chemistry study.

Undergraduate Students' Responses to Chemical Safety Quiz

Taken altogether, the students' average score on the chemical safety quiz was found to be 13.7 out of 20, with a minimum score of 6, a maximum of 19 and a mode of 14. At a glance this may not seem bad, particularly if the quiz were the usual test of chemistry content knowledge. But given the importance of knowledge of safety in a chemistry laboratory long before completing once undergraduate study, the performance of the 4th year (last semester) chemistry B.Sc. students is a bit worrying. The following examples will illustrate this point.

- 80% (41) of the students were not able to differentiate among chemicals whose toxic effects can occur after single (acute), intermittent (repeated), or long-term, repeated (chronic) exposure.
- 75% (38) of the students were unable to identify the most easily technique to extinguish a small contained fire.
- 63% (32) of the 4th year undergraduate students could not identify a picture of the eye wash fountains.
- 57% (29) believe that an undergraduate student can work alone in the laboratory.

- 51% (26) could not identify the procedure for smelling a chemical; they rather believe that they should never smell a chemical.
- 37% (19) do not know the procedures to be followed if a chemical gets in the eye.

II. University Instructors' Perspectives

A survey of the state of chemical safety in chemistry laboratories of universities could not be a complete study by simply focusing on the students. I therefore posed some questions via e-mail to chemistry department heads in Ethiopia and some other parts of Africa on the challenges and needs related to chemical safety. The following universities (countries) responded: University if Benin (Nigeria), Haromaya University (Ethiopia), and Mekelle University (Ethiopia). These universities stated the following as what they lack/need:

- The lack of functional basic equipments like regulated oven, magnetic stirrers, IR spectrophotometer, insufficient balances for training students, lack of continuous water flow, shortage of spares for the already existing equipments, etc
- Lack of trained technical personnel for laboratory work specially in instrumentation, lack of accessibility of laboratory materials in the local market, lengthy procedure in purchasing of laboratory materials, absence of standardized training related to chemical laboratories in the country, inability to participate in chemical laboratory training workshops abroad due to financial constraints, i.e., lack of capacity building schemes in our institutions, very limited access to books, journals, e-journals in the area of chemical laboratory and related fields.

With the exception of Mekelle University, the other two universities admitted that they do not provide any training on chemical safety to their students for such reasons as

large number of students working in a lab and time constraint on the part of instructors. Haromaya University, however, stated that it is currently working by videotaping all the experiments in a way that supplements the hands on exercise including safety.

In relation to providing chemical safety training to students, it is worth mentioning the experience of Mekele University as stated by the respondent:

> *Before each course, every member of the Department is creating awareness in our students about chemical safety at the beginning of each semester. It will be handled by the individual instructor that is assigned to teach the courses. Some of the safety rules are posted in the laboratory and were also included in the laboratory manual. Moreover, we also give training for high school teachers in the Region (Tigray Region) on practical/laboratory activities in which safety is part of the training. We have one document which until now not used but on its final stage on "Laboratory Safety". … However, there is no separate and well-organized laboratory training course in our Department.*

All the heads of the departments in this study stated that they never faced any major hazards in their chemistry laboratories. This could be due to the fact that the universities were totally engaged in teaching activities rather than research in the laboratories. In this regard the National Research Council (3) states as follows:

> *Chemical laboratories in developing countries have large numbers of students in teaching laboratories, but they typically have a relatively small (although increasing) number of people engaged in high-level research. In general, use of hazardous laboratory chemicals is greater in institutions that offer graduate programs and that engage in basic research.*

The instructors also stated that they are not aware of whether there are government regulations on safe use of chemical laboratories in their countries. This indirectly indicates that the existing safety practices depended more or less on the

individual institutions and that there is little enforcement from the government side. In this regard, the National Research Council (3) states that in developing countries

> *… government regulations are targeted at the chemical or manufacturing industries, and many of them are concerned primarily with waste management. However, government agencies tasked to institute and implement the regulations often lack the resources and trained enforcement staff needed to be effective. Most agencies can barely police industry, let alone private and academic laboratories. In addition, the regulations appropriate for large-scale industrial operations are not readily adaptable to academic laboratories.*

In addition to the above universities, I contacted via e-mail the Pan Africa Chemistry Network (PACN) to provide me related information. PACN, established in November 2007 by the Royal Society of Chemistry (RSC) with financial support of Syngenta, operates with hubs in Kenya and Ethiopia. As part of its activities, it conducted a needs assessment survey among African universities in the area of instrumentation. Appendix 3 depicts what seems relevant to safety and security.

I also used data collected on chemical safety and security during the second congress of the Federation of African Societies of Chemistry (FASC). FASC held its 2nd Congress in Cairo/Egypt from 3 to 7 January 2009 in conjunction with the 8th Symposium of one of its member societies, the Egyptian Society of Analytical Chemistry. At that particular event, the US Chemical Security Engagement Program (CSP) requested to hold a satellite workshop on Chemical Safety and Security for chemists drawn from Africa and the Middle East. The countries represented in the workshop were Bahrain, Egypt, Ethiopia, Iraq, Morocco, Tunisia and Yemen The workshop consisted of breakout sessions in which the participants made group discussions guided by the following four questions:

Q1. What kinds of chemical safety equipment and practices do you typically use in your laboratories?

Q2. What are your priorities to improve chemical safety in your laboratories? What kinds of additional information or training do you want?

Q3. What should be the next steps to improve Chemical Safety and Security?

Q4. Who should do them?

In response to the above four questions the participants provided a number of valuable suggestions including the need for up-to-date chemical safety and security facilities, training, and policy interventions. The detailed responses are presented in Appendix 4 for groups of countries.

CONCLUSIONS

Generally speaking, universities in Africa are in dire need of chemical safety and security facilities, professionals and resource materials. It seems that the more the universities engage themselves with advanced chemistry research the more they need the safety and security facilities and skills. It is thus imperatives for those who strive for the advancement of chemistry world wide to do their best both to push the African chemistry education and research to the latest frontiers and to simultaneously ensure that the chemistry education and research in Africa is safe and secure.

The Federation of African Societies of Chemistry (FASC), though very young, has been trying to network African chemists to the world scientific community through facilitating their participation in international scientific conferences. It also hopes to do more in the future, particularly as a follow up to International Year of Chemistry, IYC-2011. FASC played a pivotal role in getting this proclamation through the UNESCO

Executive Board and then through the UN general Assembly. It is therefore necessary for FASC to organize major events across Africa aimed at popularizing the safe and secure application of Chemistry to the public, at developing a reasonably high standard for Chemistry education and research in Africa, at promoting a greater linkage among African governments, industries and universities, etc. I personally hope that the international scientific community will support FASC in accomplishing these ambitious but necessary goals.

APPENDICES

Appendix 1: Types of hazards and how they were controlled by undergraduate students

	Nature of the accident	**Approximate date and place**	**How it is controlled**
1	Slight burning of face by conc.H2SO4.)	2007, freshman analytical chem. lab.	Continual washing by water.
2	Acidic substance dropped on a student's cloth and burnt it.	2008, analytical chem. lab.	Washing with water
3	Fire accident.	2008-9, 1st semester Organic lab	I and my friend immediately called the assistant instructor and successfully stopped the fire.
4	Irritation on my hand and change of its color for long time.	December 2008.	Through time, it disappeared from my hand.
5	Burning of an organic compound.	1st semester of 2008-09 during Chem. 451 lab time.	By pouring plenty of water.
6	Ether caught fire during open flame heating.		By removing the heating source and covering with blanket.
7	Explosion of a Bunsen burner.	It is in the Organic lab.	Controlled by the lab instructor.
8	Breaking of a funnel.	Organic lab, 1st semester 2008/9	Simply by personal care.
9	Sulfuric acid was dropped on my finger and burnt it.	3 different times in the laboratory.	Immediately washed using soap.
10	A chemical in a test tube caught fire while students were working on it.	It happened a year ago in the Organic lab	
11	My hand was colored	On 10 May 2007.	By using other chemicals, less basic.
12	I was working in the chemical store. When I was arranging the chemicals, one of the bromine (small) broke and we could not survive in the store.	At the summer (break session) last year (2008)	
13	Contact with chemicals.	In 2007.	By washing with tap water for long period of time.
14	The Bunsen burner vigorously fired because of the chemical 2, 4-dinitobenzoate.	In the practical organic laboratory.	

15	Flow of H2SO4 on cloths.	In 2007/08 academic year.	The hazard was not that much significant at that time. (**train= No**)
16	Toxic vapor.		It is controlled in fume hood.

Appendix 2: Students' assessment of the strengths and weaknesses of the laboratories

Strengths	Weaknesses
▪ Chemicals are available. ▪ Presence of fume hood to conduct vigorous and explosive reactions; presence of apron. ▪ It is well programmed, well assessed; there are enough chemicals; the instructors help the students sufficiently. ▪ Most of the chemicals are available and the instructors are also available in the lab. ▪ It is very important because, when we graduate, if things are only theoretical, it is difficult to work on any production areas.	▪ There is no proper safety material such as eye goggles, gloves, covering for mouth and nose. ▪ No control on purity of chemicals; since students use the same dropper for different chemicals, contamination is high; though newly bought chemicals are available in the store, students use the old ones. ▪ No enough and specific lesson or instruction is given, before the lab section, on potential hazards; we do not specifically know the safety materials and no one told us; no mark or advantage is given to a student who handles the materials/chemicals properly. ▪ Time management for some experiments. ▪ Students are not frequently advised to follow procedures and laboratory rules, and they are not evaluated for doing so. ▪ We do not know about and treatment for hazards/accidents, even not the location of fire extinguishers; no body knows how to use fire extinguishers and safety showers. ▪ The instructors may not check that all the students are wearing their safety materials. ▪ Mostly we do not give serious attention to safety rules written on laboratory manuals. ▪ Most of the hoods are not working properly; at the beginning of the lab, the instructors do not orient the students about chemical safety. ▪ The lab needs cleaning. ▪ We are registered for a 1 or 2 credit hour lab but mostly the labs take 4 to 8 hours so we get tired and do the experiments just to finish, not to succeed; there are many students in a single lab; the manuals are sometimes confusing. ▪ The chemistry laboratory does not give any orientation about the hazardous chemicals and their consequences. So please orient us as much as you can. ▪ There are no enough places to put liquid wastes. ▪ The laboratory manuals are so old or not updated; no clear evaluation. ▪ No new chemical (most of the chemicals stayed for long in the lab).

Appendix 3: Training needs of chemistry departments of African universities (adapted from PACN-Kenya)

COUNTRY	UNIVERSITY	TRAINING NEEDS FOR TECHNICAL /ACADEMIC STAFF
BOTSWANA	University of Botswana	Lab. Safety, ethical aspects of research, lab. waste
DRC	University of Kinshasa	New physical methods, new methods of data analysis, new methods in chemistry learning and teaching
GHANA	University of Cape Coast	Maintenance of specialized equipments, use of analytical equipments, research techniques
KENYA	University of Nairobi	Good lab practice, general training on maintenance of instruments and elements of electronics,
	Egerton University	New developments & maintenance of: GC & other chromatographic techniques, Modern lab management & safety
	Kenyatta University	Glass blowing, equipment handling and maintenance
	Masinde Muliro University of Science & Technology	Glass blowing, handling and repair of GC, MS, HPLC, UV and IR spectrometers
NIGERIA	University of Lagos	Repair of lab equipments, refresher courses in general lab safety
	University of Ilorin	Instrumentation, lab maintenance, equipment management, installation and repairs
	University of Benin	Handling, preparation and storage of chemicals; instrumentation and use of research equipments
	Federal University of Technology, Minna	Instrumentation, maintenance
RWANDA	National University of Rwanda	Operation and maintenance of equipments
	Kigali Institute of Science and Technology	Lab management and safety
SENEGAL	University of Sheik Anta Diop	Lab & equipment maintenance, quality management, lab security
SOUTH AFRICA	University of Johannesburg (Chemistry Technology dept)	Training in management, analytical instruments, safety health and environment (SHE)
	University of Fort Hare	Running instruments, instrument servicing & repair, upgrading equipment
	Mangosuthu University of Technology	Instrument operation and trouble shooting
	University of Zululand	Lab management and safety, instrumentation, web-based teaching
TANZANIA	University of Dar es Salaam	Handling modern equipments, newly discovered technologies, ICT use in teaching e.g. video conferencing
ZIMBABWE	Midlands State University	Training in handling GC, IR, and HPLC
	University of Zimbabwe	Glass blowing, use and maintenance of GC, HPLC

Appendix 4: A summary of group discussions on chemical safety and security issues (adapted from CSP)

Participating Countries	Responses	
	Q1. What kinds of chemical safety equipment and practices do you typically use in your laboratories?	**Q2. What are your priorities to improve chemical safety in your laboratories? What kinds of additional information or training do you want?**
Egypt and Tunisia (many of them are from Egyptian universities)	Fire extinguishers, Fire blankets, First – aide cabinet, Safety goggles, Gloves, Showers (in some labs), Fire alarms, Fire station within the premise	Advance training techniques in the following: Hazardous Spills (evaluation of control and treatments), Waste Collection and transportation, Dual use chemical (explosives and weapons, toxic e.g. nitrates, percolates, azides, cyanides), Engineering considerations and precautions in crowded spaces and especially those confined (frequent drills)
Egypt, Ethiopia, Kenya, Morocco, USA,	Working Hoods, Protective Equipment, Disposal for chemicals, Drainage for chemicals, Emergency exits, Safety showers, Eye washes, Fire extinguishers, Safety managers	Hoods (establish maintain and increase the number of hoods as required), Safety protection (goggles, eye washes, safety showers, fire protection), Emergency exits, Safety disposal (establish and maintain a drainage system; recycling, and utilization of wastes if possible), Independent Safety Officers, Limit the amount of students in each lab, Code of practices and GLP including training, Classify chemical with all safety precautions and storage practices, Need professional societies to work on these issues.
Not specified (but they cannot be out of African and Middle East countries)	Fire extinguishers, Fumigation hoods, Fire alarm, Student safety guidelines (verbal/written), Emergency doors, First aid tools, Storage rooms are in remote area from Student labs	1. To minimize pollutants A. Gas filters and filter hoods B. Chemical incinerator (chemical wastes) C. Liquid treatment unit (dilute liquid wastes) 2. Training Program A. How to dispose the chemical wastes B. Environment safety precautions programs for chemists 3. Education A. Virtual labs B. Training Programs 4. Industry A. Factories must write the neutralizations processes for their products
Not specified (but they cannot be out of African and Middle East countries)	Hazardous signs and labels, Alarms, Fire extinguishers (one type), Vacuum hoods, Filters, Eye washes and showers, Evacuation plan, Emergency first aid kits, Emergency exits signs, Branch of fire department at our school	1. Priorities a. Training workshops i. Technicians ii. TAs iii. Graduate students b. Availability of MSDS 2. What Additional Information or Training a. Design a model of a perfect lab for training, or virtual lab b. Waste treatment roles and recycling of simple chemical and wastes

		c. Adapt core course about safety and security for undergraduates and make available for students on web. d. How can we reduce chance of accidental chemical release – normal operations
Egypt, Ethiopia, Morocco, Yemen	Safety goggles and safety manuals, First aid kit (not in all labs), Fire extinguishers (fire blankets), Fire alarms, Lab Coats, gloves, Safety showers, Hoods	(In order of Priority) Training of technical staff/ students Proper storage facilities for chemicals Installation of fire alarms/ extinguishers Hoods Proper storage/disposal of wastes Material safety data sheets Radiation and Gas Detection First aid kit Eyewash facilities

Participating Countries	**Responses**	
	Q3. What should be the next steps to improve Chemical Safety and Security?	**Q4. Who should do them?**
Egypt	1. Awareness programs for the university employees as well as community and students. a. Special programs should be developed for stores: men, storage and rooms 2. Training workshops, for chemists & others (for non-chemists) 3. Presenting of guidelines and proper chemical signs in proper positions 4. Frequent follow-up and maintenance. Upgrading of the security facilities currently present in labs 5. Frequent maintenance and upgrading of labs equipments	1 & 2 Staff members of the university (TOT: from different professionals in related disciplines; with demonstrations) 3. Staff member of scientific related departments 4 & 5. Related professional under departmental supervision • Documentation must be applied for all previously mentioned implementations • Exchange and collaborate ideas between different and among all universities locally, regionally and internationally.
Iraq and Bahrain	▪ To apply SICAM convention on regulation of chemical use ▪ Improve the chemical storage ▪ Do more workshops and training for the chemical community to improve their sense to chemical hazards ▪ Do more efforts in developing methods for recycling chemicals	▪ Chemical society in each country ▪ Environmental agencies ▪ Chemical department at each school Establish a foundation for chemical waste management in each country
Egypt	▪ National classification for hazards. ▪ Establish Guidelines, procedures for chemical safety	**ORGANIZATION** **RESPONSIBILITIES** Environmental Authority Policy, strategy, regulation,

	▪ Provide training for involved people (professors, students, experts, technicians) ▪ Implementation of action plans ▪ Evaluate the plans ▪ Follow up frequently ▪ Update with new trends frequently	inspections NGOs Financial Resources Donor Programs (Int'l) Provide/Transfer Technical Assistance Ministry of Education Policy Training, Commitment to support implementation
Yemen, Morocco, US	▪ Well trained people ▪ Availability of chemical safety tools such as CDs, videos, websites ▪ Introduce awareness of chemical safety and security in students' education ▪ Chemicals should have labels on their hazards ▪ Clean up spills properly ▪ Handle chemicals properly ▪ Enforce safety rules in labs ▪ Reduce the use of chemical as much as possible ▪ Proper storing of chemicals ▪ Work toward green labs	▪ Lab manager ▪ Lab technician ▪ Store keeper ▪ Interested students

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