



Adherence to safety practices and risks associated with toxic chemicals in the research and postgraduate laboratories at Sefako Makgatho Health Sciences University, Pretoria, South Africa

Liziwe Lizbeth Mugivhisa, Khanyi Baloyi & Joshua Oluwole Olowoyo

To cite this article: Liziwe Lizbeth Mugivhisa, Khanyi Baloyi & Joshua Oluwole Olowoyo (2020): Adherence to safety practices and risks associated with toxic chemicals in the research and postgraduate laboratories at Sefako Makgatho Health Sciences University, Pretoria, South Africa, African Journal of Science, Technology, Innovation and Development, DOI: [10.1080/20421338.2020.1797269](https://doi.org/10.1080/20421338.2020.1797269)

To link to this article: <https://doi.org/10.1080/20421338.2020.1797269>



© 2020 The Author(s). Co-published by NISC Pty (Ltd) and Informa UK Limited, trading as Taylor & Francis Group



Published online: 24 Aug 2020.



[Submit your article to this journal](#)



Article views: 221



[View related articles](#)



[View Crossmark data](#)

Adherence to safety practices and risks associated with toxic chemicals in the research and postgraduate laboratories at Sefako Makgatho Health Sciences University, Pretoria, South Africa

Liziwe Lizbeth Mugivhisa*, Khanyi Baloyi and Joshua Oluwole Olowoyo

Department of Biology, Sefako Makgatho Health Sciences University, Pretoria, South Africa

**Corresponding author. Email: Liziwe.Mugivhisa@smu.ac.za*

The study investigated the knowledge of postgraduate students in the Biology, Chemistry and Biochemistry departments regarding safety practices, protective measures and risks associated with toxic chemicals in the postgraduate and research laboratories. The study was exploratory and was conducted through administering 83 questionnaires. The results showed that the majority (78%) of the students received training on laboratory safety even though only 34% of them could identify all the warning signs associated with hazardous chemicals. Protective measures practised by students included wearing of buttoned laboratory coats (74%), closed shoes (78%), use of latex gloves (43%), correct use of dustbins for waste disposal (10%) and inspection of warning signs on chemical containers before use (54%), while only 25% of the students used fume cupboards. In case of an emergency, 72% knew what steps to take, whereas 28% were unaware of the steps to take. Students were aware of the potential risks associated with hazardous chemicals in the laboratory and had knowledge on the warning signs on chemicals even though adherence to the safety practices was still a problem. The majority of the participants felt that there was a need for continuous training on laboratory safety and regular reminders through the use of safety charts in laboratories.

Keywords: laboratory, management, perceptions, risks, toxic chemicals

Introduction

The determinants of the achievements of a nation arise from improvements in the sciences and technology and an increase in the education level of the general population (Ojera, Simatwa, and Ayodo 2013). Science laboratories have become the centres of acquisition of knowledge and the development of new materials for use in the future (Anza et al. 2016). As part of the curriculum, students in the science and technology faculty are introduced to the conducting of research and working in the biological, biochemical and chemical laboratories (Al-Zyoud et al. 2019). In the laboratories, the research skills of the students are enhanced and they become active participants in their learning (Feyziolglu et al. 2011). However, the academic world, which is considered to be the headquarters of validation of experiments associated with free research concepts, is also an environment which is particularly associated with risks (Meyer 2012), making academic laboratories unsafe for studying or working (Langerman 2009; Marendaz, Suard, and Meyer 2013). Scientific research, which deals with new materials and new methods, at universities has a continuous influx of new trainees who are inexperienced, and this may result in potentially hazardous situations if training on how to handle new chemicals, among others, is not offered regularly. Hence, the management of the associated risks through continuous training may be the only viable avenue to reduce associated accidents (Ménard and Trant 2019).

The laboratories which make comprehensive use of chemicals are in the fields of Chemistry and Biology (Lunar, Padura, and Dimaculangan 2014). Most attention has been focused on the exposure of the students to materials in the laboratories which can be explosive, irritant, radioactive, flammable or hazardous to health or result in pollution

in the environment (Walters, Lawrence, and Jalsa 2017). Some of the toxic chemicals, which include fumes, gases and liquids, can be highly flammable and easily catch fire resulting in fire hazards, while others can be explosive when they are exposed to air or agitated or not handled properly resulting in explosive hazards (Adane and Abeje 2012).

The likelihood rate of accidents at university laboratories is reported to be ten to fifty times higher than in industrial laboratories (Meyer 2012). According to Ménard and Trant (2019), there have been substantial injuries and deaths in the past ten years due to accidents in academic laboratories globally, making them more dangerous than industrial laboratories. Accidents which have recently taken place in the academic laboratories have resulted in questions being raised on whether there is sufficient safety information given to students, staff and postdoctoral fellows in research laboratories at universities and colleges (Langerman (2011); Mulcahy et al. 2013). As a result, the American Chemical Society recommended the strengthening of safety cultures and the provision of safety education to undergraduates at institutions of higher learning (Hill 2016) with some universities such as the St. Olaf College in Minnesota in America and Wittenberg University in Ohio incorporating safety education into the chemistry curriculum (Hill 2016).

Academic laboratories are more dangerous than those in industry due to the fact that the approach to safety in academic laboratories is more relaxed (Meyer 2012) and they do not have a well-established culture of safety (Schröder et al. 2016). This points to the need that similar safety and health policies implemented in industrial workplaces should be considered at institutions of higher education (Sumadsad and Ruiz 2013).

The hazardous or risky chemicals used in the laboratories are useful in advancing research if handled or used appropriately (Adane and Abeje 2012). These toxic chemical substances can either be organic or inorganic or can be in the form of liquids, gases or solids (in particulate, flakes and powder) (Mehrifar et al. 2016). Students together with their supervisors need to have thorough knowledge of and expertise in handling these toxic substances with different toxicities and properties so that unnecessary dangerous exposures which might have a negative impact on their health, life and the environment are prevented (Anza et al. 2016).

Some of the factors which contribute to accidents in chemical laboratories include mishandling of chemicals, lack of knowledge on the steps to take during an emergency, limited experience of working with harmful chemicals, failure to use protective equipment, lack of awareness and inexperience or carelessness with regards to the dangers and risks associated with the handling of hazardous toxic substances (Mehrifar et al. 2016; Walters, Lawrence, and Jalsa 2017). Hence, students and researchers must be educated on the dangers and risks associated with these toxic substances so that accidents and their harmful consequences can be minimized or totally prevented (Walters, Lawrence, and Jalsa 2017). Each chemical used in the laboratory has a list of potential risks and safety precautions associated with it (Meyer 2012) and each chemical should be labelled with the appropriate precautionary symbols such as images and colours which indicate the features of the chemicals (Anza et al. 2017) to assist with the correct and safe use of the chemicals.

According to Miyagawa (2010), some countries use the 'Occupational Safety and Health Act' (OSHA) for the employees and employers so that there is provision of a safe healthy working environment. However, the majority of the acts in most countries do not take into account the safety of the students at universities, except for the Australian OSHA which is used by chemistry departments at Australian universities (Goodwin, Cobbin, and Logan 1999). There should also be strict standards for the protection of students like there are for the employees. It should be the duty of the universities to ethically and legally protect the students and laboratory safety should be considered to be more important in academic institutions since that is where future workers are trained. The staff and more especially the students who are exposed to hazardous toxic substances on a daily basis in the laboratories are the ones who are mostly at a higher risk (Walters, Lawrence, and Jalsa 2017; Puteri and Nurcahyo 2018). As a result, safety measures should be undertaken by staff, students, and other stakeholders to reduce or eradicate conditions which are risky or are threats which might lead to accidents, bodily injuries or harm or psychological or emotional stress (Gongo, Warutere, and Nguhiu 2018).

There has been increased attention focused on how the contents in laboratories can be effectively utilized so that the goals in scientific education are achieved (Fagihi 2018). Due to accidents which have occurred in academic laboratories there have been questions put forward as to whether students, staff and postdoctoral

fellows in the research laboratories at universities and colleges have received enough attention regarding safety (Schröder et al. 2016). As a result, calls have been made for an emphasis on safety at institutions of learning (Benderly 2016; Kemsley 2013) through measures such as the development of advice and resources to assist with safety education by organizations which include the American Institute of Chemical Engineers and the American Chemical Society in developed countries (Wenzel, McCoy, and Landis 2015; Hill 2016; Czornyj et al. 2018).

Several studies have been carried out on laboratory safety with the first studies dating from as early as 1910 (Ayi 2014). An international study was carried out to investigate and assess the state of safety at wet laboratories in a majority of the universities (Ayi 2014). The results indicated that there were still many safety gaps and the general absence of a solid safety philosophy at the laboratories in most universities in America and Canada (Ayi 2014; Gibson, Schröder, and Wayne 2014; Schröder et al. 2016). Ayi (2014) also assessed the state of safety at wet laboratories of a medium-sized university in Canada and the study showed that there were many safety insufficiencies and undesirable perceptions on safety issues and that, just as in the case of most universities in the United States of America, there was a need to improve the philosophy of safety at their university. Similarly, at a German university in Jordan, the majority of the students had acceptable safety practices and awareness but not attitudes suggesting that there was a need for the implementation of safety procedures through more professional safety education and clear management practices on risks and safety (Al-Zyoud et al. 2019). Álvarez-Chávez et al. (2019) assessed the risk perceptions of safety hazards in undergraduate students from the departments of Biology and Chemistry in Mexico.

Other studies to understand the familiarity and understanding of chemical hazard warning signs have been done on undergraduate students of Chemistry and Biology (Adane and Abeje 2012; Mehriifar et al. 2016; Walters, Lawrence, and Jalsa 2017), such Physics in the Philippines (Ponferrada et al. 2017), Pharmaceutical, Biomedical Engineering and Chemical Engineering departments (Al-Zyoud et al. 2019), secondary science schools (Gongo, Warutere, and Nguhiu 2018) and teachers (Feyziolğlu et al. 2011; Sedghpour, Sabbaghan, and Sataei 2013; Cruz et al. 2015; Fagihi 2018).

To the best of our knowledge and as at the time of conducting this research, similar studies to assess the adherence to safety practices of postgraduate students in the Biology, Chemistry and Biochemistry departments of universities have not been conducted. Also, there are few or no reports of similar studies in South Africa. Hence, the current research was designed with the aim of investigating the adherence practices among these postgraduate students. The research question was: '*What is the level of awareness of the postgraduate students on the safety practices, protective measures and risks associated with toxic chemicals in the postgraduate and research laboratories in the departments of Chemistry, Biology and Biochemistry?*'

Methodology

This study, which was exploratory, was conducted at the Sefako Makgatho Health Sciences University (SMU) which is a historically disadvantaged Health Sciences University in the north of Pretoria. SMU is a university that is striving to provide guidance and support for sound knowledge in the health and natural sciences (SMU Research Strategy 2017). The schools or faculties at SMU include School of Science and Technology, School of Medicine, School of Health Care Sciences, School of Pharmacy and School of Oral Health Sciences. The School of Science and Technology serves as an option of a knowledge centre for students who are seeking to be future innovative researchers and scientists (School of Science and Technology 2018). One of the academic streams in the School of Science and Technology is Life Sciences which offers among other courses Biochemistry, Biology, Chemistry and Physiology from undergraduate to postgraduate levels (Honours, Masters and PhD).

A self-administered questionnaire was given to 83 postgraduate students (Honours, Masters and PhD) in the departments of Chemistry, Biochemistry and Biology in the School of Science and Technology over a period of two years (2018 and 2019) after consent had been sought and received from the students. The postgraduate students were selected for the study since they spend more time in the research or postgraduate laboratories by themselves. In undergraduate laboratories, practicals, are based on the repetition of well-known and well-established procedures while in the postgraduate research laboratories there is production of new materials using new methods which might increase the likelihood of unknown hazards (University of Johannesburg 2018). The other departments within the school were excluded since research in them does not include the use of toxic chemicals.

The questionnaire consisted of 25 questions divided into 5 sections. Data collected included information on demographics (gender, age, level of study), training on laboratory safety, knowledge on guidelines / policy / legislation regarding hazardous toxic chemicals handling, colour coding and signs on the chemical substances containers, awareness of chemical hazards, correct usage of containers for disposal, segregation, storage and disposal of chemical waste, recapping of needles before disposal

and knowledge on risks or health hazards associated with chemical waste in the laboratories. Other information which was sought was on whether students had been exposed to any hazards or accidents in a laboratory and knowledge and familiarity with emergency procedures and equipment. The students were also given pictograms which they had to match with corresponding hazards. The collected data was analyzed using descriptive statistical analysis which included frequency counts which were displayed using frequency tables and bar charts graphs. The completion of the questionnaires, which was done anonymously, was based on the willingness of the students to participate.

Results and discussion

The demographics data of the students as represented in Table 1 shows that of the 83 students who responded, 37% were male while 63% were female. These results are comparable with those in Al-Zyouud et al. (2019) where about 54% of the students were females. The highest number (79.5%) of the postgraduate students was in the 20–25 years age group followed by the 26–31 years which was represented by 10.8% while the age groups 32–37 and 38 years and above had the least number of postgraduate students with 4.8% in each. These results are due to the fact that the majority (78%) of the respondents were honours students who are still young, 16% were masters and only 6% were PhD students who could have been in the 30 years and above age group. The three major departments under life sciences in the School of Science and Technology were evenly distributed with 34% coming from the Chemistry department, 30% from the Biochemistry department with 36% being from the Biology department.

Figure 1 represents the responses of the participants on how often the individual students worked in the laboratories doing research per week. The majority (57%) of the participants worked alone in the laboratory 3–5 days a week followed by 35% of the participants who worked in the laboratory once a week while 6% of the participants worked alone in the laboratory daily. Only 2% of the respondents did not respond to this particular question and this shows the first limitation of using self-administered questionnaires in the study, namely of some

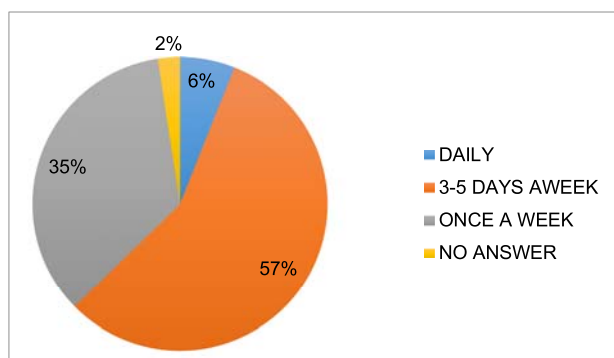


Figure 1: The frequency of working alone in the laboratory by students.

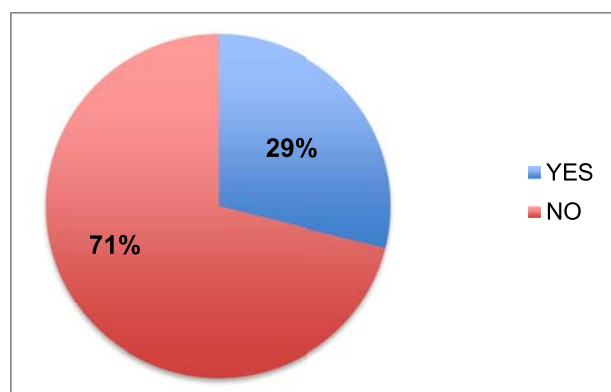


Figure 2: The number of students who often work alone in the laboratories after working hours.

Table 1: Demographics of the postgraduate students who participated in the study.

Demographics		Number of students
Gender	Male	37%
	Female	63%
Age in years	20–25	79.5
	26–31	10.8
	32–37	4.8
	38 and above	4.8
Level of study	Honours	78%
	Masters	16%
	PhD	6%
Departments	Chemistry	34%
	Biochemistry	30%
	Biology	36%

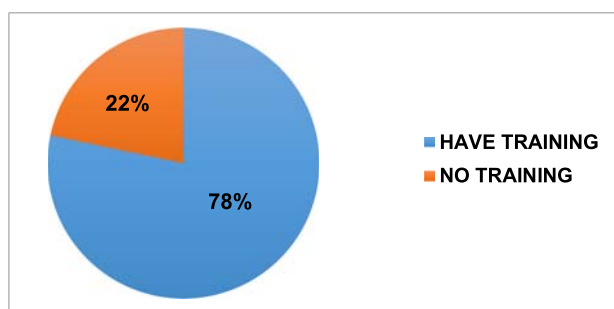
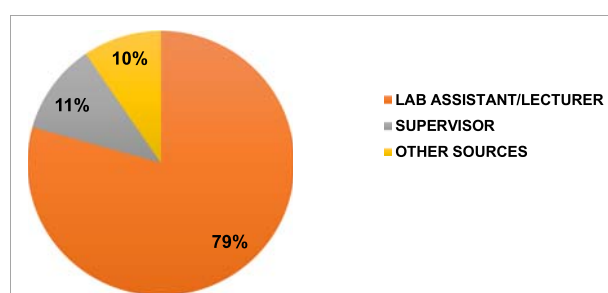
participants not responding to some of the questions in the questionnaire.

The responses on whether the students ever worked alone in the laboratories after working hours are represented in Figure 2. The majority (71%) of the students did not usually work alone in the laboratories after hours, whereas 29% of the respondents usually worked by themselves in the laboratories without any supervision of staff. The results of the present study do not agree with those in Engida (2011) where 57% of the students mentioned that undergraduates worked by themselves alone in the laboratory. Students who work alone in the laboratories are more prone to accidents, especially if they do not have adequate training in laboratory safety. Conversely, students working alone in the laboratories could be additionally vigilant since they are not subjected to careless mistakes resulting from distractions from mates or others when they work with others in the laboratories.

Most (78%) of the students had received laboratory training as shown in Figure 3, whereas 22% of the students had not received any training on laboratory safety. These results are comparable to those in Engida (2011) where only 18% of the undergraduate students in their 4th year of study had received some training with the majority of the students stating that they had not received any formal training on chemical safety at any level of their undergraduate levels. Having 22% of postgraduate science students not having received any training on laboratory safety is risky since the biggest causes of laboratory accidents is lack of or having limited experience in working with chemicals in laboratories (Al-Zyoud et al. 2019). In Engida (2011), some universities admitted to

not providing student any training on chemical safety due to large numbers of students and time restrictions. The relatively high numbers of the students not receiving any training could according to Al-Zyoud et al. (2019) be due to them not being present at the beginning of the year when most of the training would be offered. These high numbers not only place the untrained individuals in danger but also place other students and staff who work in the laboratories with them at risk. There is a need for training on safety in a research environment to provide researchers with confidence so that they carry out experiments without putting themselves and their co-workers in danger (Schröder et al. 2016). It has also been shown by a number of studies that programmes entailing education, training and re-training can show potential in the improvement of precautions in safety among students (Islam et al. 2002; Goswami et al. 2011; Odeyemi 2012). The effectiveness of the training programmes on laboratory safety can be improved if there is understanding of how risks associated with settings in a chemical laboratory are perceived by undergraduate students (Álvarez-Chávez et al. 2019).

Figure 4 shows the different sources of training on laboratory safety. Of the 78% postgraduate students who had received laboratory training, 79% had received it from laboratory assistants and lecturers followed by 11% who had received training on laboratory safety from their supervisors while only 10% of the respondents had received training from other sources. In a study by Al-Zyoud et al. (2019), some of the students had received training on chemical laboratory safety from a self-dependent form of study, namely using e-learning, which was reliant on the

**Figure 3:** The number of students who had received training on laboratory safety.**Figure 4:** Sources of training on laboratory safety for the students.

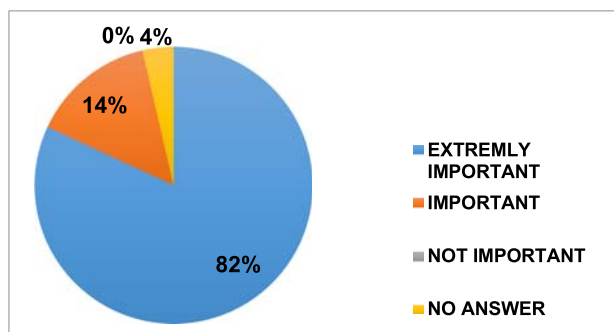


Figure 5: The responses of the students on the importance of taking warning signs seriously.

students going through the training on the internet. Standard training of all students and staff on laboratory safety assists in them working in laboratories with knowledge of the safety practices, storage of chemicals and labelling of samples of the chemicals which can contribute to a reduction in the causes of hazards or dangers in laboratories.

Figure 5 shows that 82% of the postgraduate students thought it was extremely important to take warning signs on the chemicals seriously, whereas 14% of the students thought it was just important. Of those students who responded, none (0%) responded that it was not important to take warning signs on the chemicals seriously while 4% of the respondents did not provide an answer to the question. It is important that all students take warning signs seriously as this can result in more students being cautious and hence contributing to increased safety in laboratories. It is crucial that warning signs are taken seriously by all the individuals working in the laboratories so that accidents are prevented.

The results in Figure 6 show that 96% of the postgraduate students were aware of the dangers and risks of working in science laboratories while 3% of the respondents were not aware and 1% of the participants did not provide an answer to the question in the questionnaire. These results are in agreement with the results of Mehrifar et al. (2016); Adane and Abeje (2012); Puteri and Nurcahyo (2018) and Lunar, Padura, and Dimaculangan (2014) where the majority of the students indicated that they were aware of the hazards of chemicals in the laboratories. Awareness of the risks and dangers in laboratories has

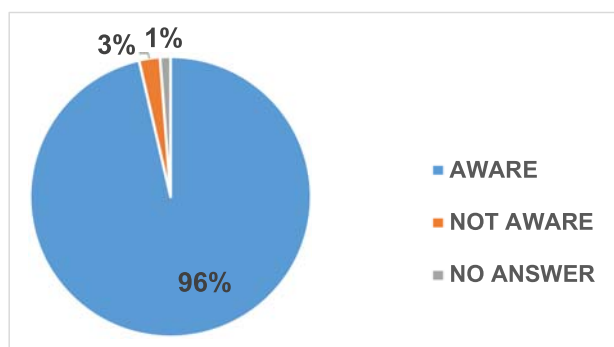


Figure 6: The awareness of the students on the types of risks in the laboratory.

the potential of instilling the correct attitudes towards safety in the students.

Figure 7 shows that most (78%) of the respondents had knowledge on the storage of flammable liquids but 18% did not. The lack of this kind of knowledge can result in laboratories being prone to accidental fires and accidents involving fire.

The majority (67%) of respondents were aware of the steps to take during an emergency, whereas 27% of the respondents did not know about the steps to take during an emergency and 6% did not respond to the question (Figure 8). In Engida (2011), 39% of the students had no idea of the procedures which they could follow, for example if a chemical got in the eye. Knowing the steps to take during an emergency could result in the saving of lives and it is crucial that all the students are aware of such steps. These results do not compare to those in Al-Zyoued et al. (2019) where about 47% of the students did not know where the emergency equipment was kept in the Chemistry laboratory.

Figure 9 represents the responses on whether the participants had ever been exposed to any health risks or injuries while working in the science laboratories. Most (71%) of the participants had never been exposed to injuries in the laboratory while 29% had been exposed to injuries. These results are in agreement with those in Engida (2011) where 31% of the undergraduate students in the Chemistry department indicated that they had been involved in minor incidents while they were working in the laboratory.

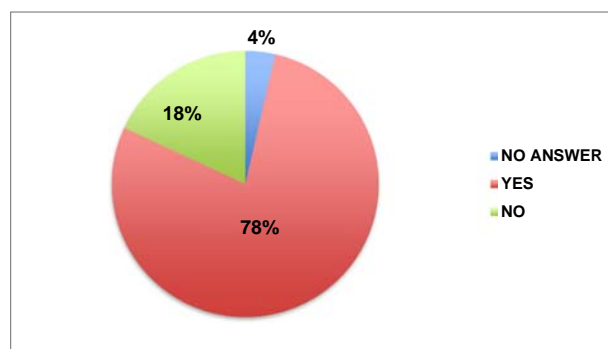


Figure 7: Knowledge of students on the storage of flammable liquids in the laboratories.

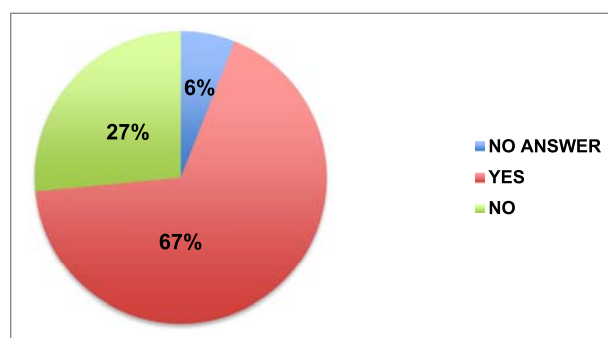


Figure 8: Responses of students on the knowledge on steps to be taken in an emergency.

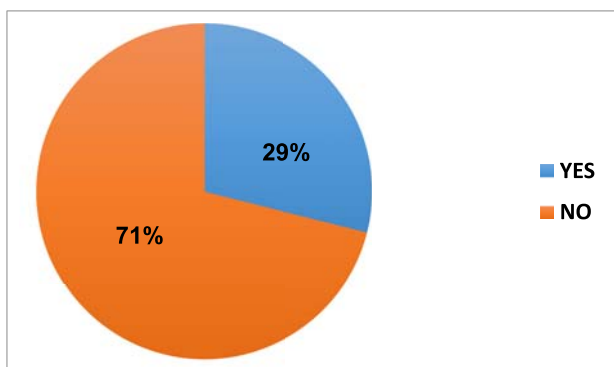


Figure 9: The number of students who had been exposed to injuries in the laboratories.

The most common types of injuries which the students had been exposed to in the laboratory are shown in Figure 10. Acid burns were the most common example of accidents, followed by respiratory problems and then injuries to the skin, while the eye irritation and cuts were the least common types of injuries.

The majority (77%) of the respondents stated that there was a need for more training on laboratory safety regarding hazards in the laboratories, whereas 23% of the respondents stated that there was no need for further training on laboratory safety as shown in Figure 11. Students at higher institutions of learning should be exposed to and educated on regulations and practices on safety (Ismail, Arifin and Aiyub 2015). According to West et al. (2003), the beliefs and attitudes on laboratory safety should be instilled early or even while students are still at high school. There have also been several calls made for more meaningful training on safety to be included in studies at the undergraduate level of study, resulting in more training on safety being done at undergraduate level in the teaching laboratories (Nelson 1999; Withers, Freeman, and Kim 2012; Fivizzani 2016), compared to the training being done at the research laboratories (Withers, Freeman, and Kim 2012).

The laboratory safety measures which were taken by the students when in the laboratory are shown in Table 2. The majority (81%) of the students wore laboratory

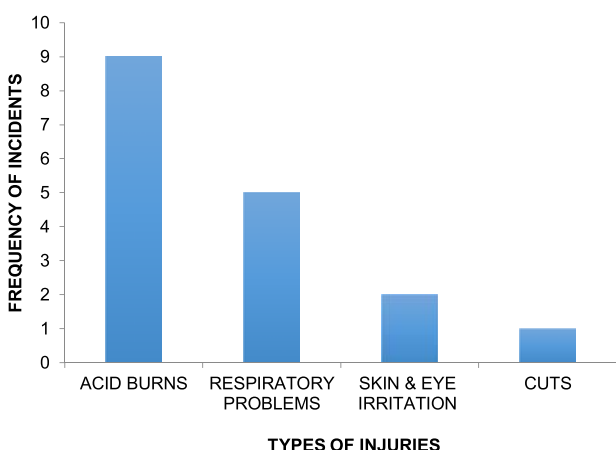


Figure 10: The types of injuries which the students have suffered in the laboratories.

coats whenever they entered the laboratories while 6% of the students responded that they did not always wear the laboratory coats with 13% stating that they only sometimes wore the laboratory coats. From those who stated that they wore laboratory coats when they were in the laboratory, 74% responded that their laboratory coats were always buttoned up while 8% and 18% responded that their laboratory coats were never buttoned or sometimes buttoned, respectively. The results of the present study agree with those in Walters, Lawrence, and Jalsa (2017) and Al-Zyoud et al. (2019) where the majority of the undergraduate students stated that they always wore personal protective equipment (PPE) when they were in the laboratory. In Al-Zyoud et al. (2019), students were not permitted to enter Chemistry laboratories without wearing personal protective equipment. In a study by Anza et al. (2016), the majority of the workers did not make use of PPE properly.

However, the results in the present study are not in agreement with those in Ponferrada et al. (2017), where the lowest numbers (45% and 37%) of students used PPE in the laboratories of Physics 10 and Physics 11, respectively, due to the absence of laboratory procedures in the Physics laboratories. Also, in Ayi and Hon (2018), only 40% of the undergraduates and academic researchers indicated that they used personal PPE all the time when they were working in the laboratory. In Schröder et al. (2016), the academic researchers were less likely to wear PPE such as laboratory coats with only 66% always wearing them all the time and 61% of them always using protection for the eyes, compared to 87% in industry who always used laboratory coats and 83% who used eye protection or 73% and 76% for government employees who used eye protection and laboratory coats, respectively. Compliance with the PPE can be related to the perception of the risk level in the laboratory by the researchers which can be lowered with a decrease in the perceived risk (Schröder et al. 2016). In the present study, the reason the majority of the postgraduate students wore laboratory coats could be attributed to the fact that it was a habit they adopted from when they were undergraduates under supervision. The frequently practised protective measure of wearing laboratory coats, which are buttoned, and closed shoes, is probably because these measures were always stressed and were the key to being allowed access to the laboratories in undergraduate

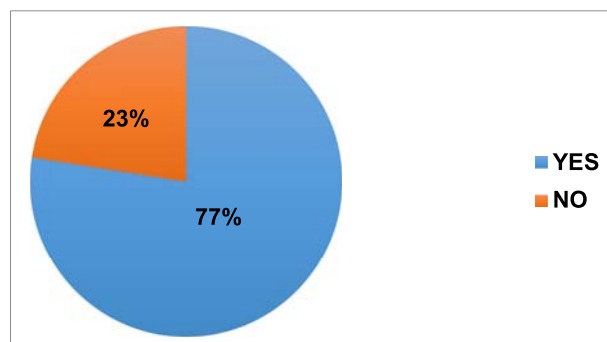


Figure 11: Students wanting more training / information on laboratory safety.

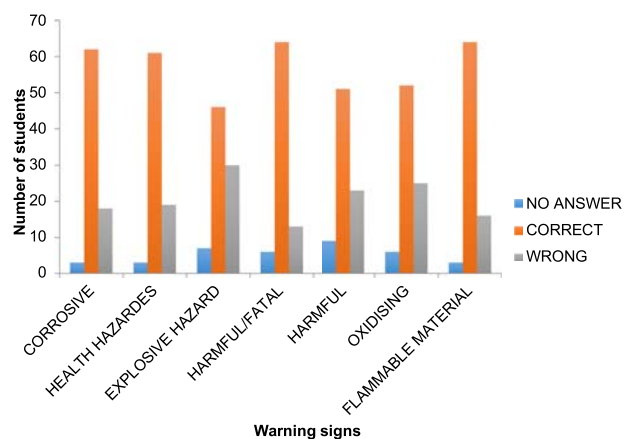


Figure 12: The responses of students on the knowledge of warning signs on chemicals in the laboratory.

years in the Chemistry and Biochemistry departments at SMU.

With regards to closed shoes, 78% of the students responded that they always wore closed shoes all the time, while 5% responded that they did not always make sure that their shoes were closed and 16% stating that they sometimes wore closed shoes. About 1% of the students did not respond to the question. Latex gloves were always worn by 43% of the students while 15% and 40%, respectively, responded that they did not always or only sometimes wore gloves. Students who did not respond to the question made up 2%. The failure of the respondents always to use latex gloves in the laboratories could be due to the fact that they were not readily available in most of the laboratories when needed. These results do not agree with those in Sieloff et al. (2013), where 65% of the participants mentioned that they did not wear gloves.

Only 25% of the students indicated that they made use of fume cupboards in the laboratory while 50% indicated that they did not use the fume hoods and 24% responded that they only sometimes used the fume hoods. About 1% of the students did not respond to the question (Table 2). The failure to use fume hoods when dealing with solutions with strong fumes can also result in the laboratories and the people working in them being at risk to fire hazards. According to Abbas et al. (2016), fume hoods are the first line of a safety measure which form an essential part of any chemical laboratory as they result in the prevention of detrimental exposure of workers to vapours and fumes by continuously taking the conditioned and filtered air out of the laboratory.

Students making use of the correct bins for waste disposal accounted for 10% of the sample, while 70% responded that they did not always use the correct bins. Only 2% of the students reported that they sometimes used appropriate bins for waste disposal with a high (18%) number of them not responding to the question as shown in Table 2. The least-practised measure was disposal of waste in the correct containers and this measure could have a direct negative impact on the environment and indirectly have an impact on the safety of humans. Only 50% of the students always inspected the containers in the laboratory for warning signs. Of those who

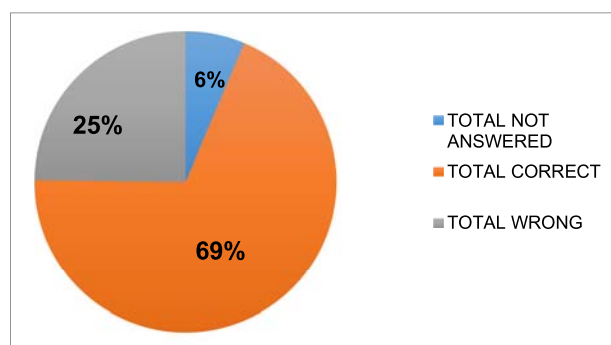


Figure 13: The responses of the students on identification of warning signs on the chemicals.

inspected the containers, 54% responded that they did not always inspect containers for warning signs, while 27% responded that they only sometimes took note of warnings on containers and 1% did not respond to the question.

Figure 12 shows the knowledge of the warning signs on the chemicals which are used in the laboratory. The signs that were mostly identified correctly were flammable material and harmful / fatal corrosive while the ones that were mostly identified wrong were explosive hazard, oxidizing and harmful warning signs. These results are in agreement with those of Adane and Abeje (2012) which showed that the hazard signs that were mostly identified wrong were explosive hazard, oxidizing and harmful signs, whereas in Walters, Lawrence, and Jalsa (2017) the symbols associated with hazardous chemicals that were mostly recognized by the undergraduate students were corrosive, oxidizer and irritant. In Lunar, Padura, and Dimaculangan (2014), the signs which were correctly identified were flammable (57%), toxic (45%) and irritant (32%) and in Mehrifar et al. (2016) they were flammable (85%), explosive (20%) and toxic (67%). According to Hill (2007); Nicol and Tuomi (2007), the most important aspect of teaching safety in the laboratory should be to teach the students how to recognize and understand hazards and on how to be able to recognize and recall the hazard signs. To increase the comprehension of the hazard signs by the students, it is important to regularly give the students quizzes and trainings which can be done through group discussions. According to Al-hilali, Al-Badri, and Mahdi (2018), there is a need to re-assess the issue of safety in all the laboratories. It is also important that internationally adopted hazard signs are displayed together with relevant information on chemical accidents with an aid of colourful posters of pictures (cartoons) in all the laboratories (Adane and Abeje 2012).

With regards to the identification of the hazard warning signs, 69% of the answers were correct while 25% were wrong with 6% not being answered as shown in Figure 13. Results on knowledge of warning signs on chemicals in the present study are in agreement with those in Al-Zyoud et al. (2019) where 71% of the respondents had a fair to good knowledge of the chemical warning signs while they are not comparable with the results from the studies by Karapantsios et al. (2008); Adane and Abeje (2012) and Anza et al. (2017), who

Table 2: Students practising protective measures.

	Yes	No	Sometimes	No response
Laboratory coat	81%	6%	13%	0%
Buttoned laboratory coat	74%	8%	18%	0%
Closed shoes	78%	5%	16%	1%
Latex gloves	43%	15%	40%	2%
Fume hood	25%	50%	24%	1%
Waste in correct containers	10%	70%	2%	18%
Inspection of containers for warning signs	54%	18%	27%	1%

also showed that the majority of the students responded that they were not familiar with the hazard warning symbols of chemicals in the laboratory. It is crucial that the number of the answers which were wrong in the present study should be brought down since it is mandatory that the hazard and precautionary symbols are known by the students working in the laboratories.

The present study did not assess participants on whether they were following any standard procedures in laboratories which include the use of an acronym RAMP (which stands for Recognize the hazards; Assess the risks of the hazards; Minimize the risks of the hazards; Prepare for emergencies from uncontrolled hazards) to assist students and educators with maintaining safety in science in the forefront of their work in the laboratories (American Chemical Society 2015). However from the results, it can be stated that the participants were following only some of the standard procedures since participants were aware of the hazards [96%] (recognize the hazards), used personal protective equipment [81%] (minimize the risks of the hazards) and were aware of what to do when there is an emergency [67%] (prepare for emergencies from uncontrolled hazards). However, 50% did not assess the risks of hazards such as inspection of chemical containers for warning signs and did not minimize the risks of the hazards since only 10% of them used fume cupboards. Even though regulations according to the Occupational Safety and Health Administration (OSHA) in the United States are used as safety standards, they are not applicable at all the universities or to the people working in the laboratories at the universities depending on the status of their employment (Ménard and Trant 2019). This implies that the participants in the present study were not obliged to follow the OSHA regulations.

Conclusion

The majority of science postgraduate students in the departments of Biology, Biochemistry and Chemistry had received training in laboratory safety, could correctly identify warning signs on chemicals and had knowledge on the potential risks associated with chemicals in the laboratory. Most of the students adhered to safety practices in laboratories and used protective measures in the form of personal protective equipment (lab coats and gloves) in the laboratories. However, the minority of them used fume cupboards and correct bins for waste disposal, inspected the chemical containers for warning signs and were not able to identify all the warning signs on the chemical containers. The majority of the students indicated that there was a need for more training on laboratory

safety and this could imply that students wished to practise more caution in the science laboratories. It was recommended that there should be a standard training on laboratory safety for all students and staff working in the science laboratories which is offered regularly. Safety charts can also be put in all the laboratories. Emergency safety drills can also be done every year to familiarize students with what steps to take during an emergency. There is also a need to have information signs put up to indicate where the emergency exists are situated. It is also recommended that all postgraduate students in the departments of Chemistry, Biology and Biochemistry be given an assessment on the safety practices and hazard warning signs at the beginning of each year to ensure that the students have sufficient knowledge and are well equipped to work independently in the laboratory and are not prone to accidents in the laboratories.

Acknowledgements

The authors would like to thank all the postgraduate students in the departments of Biology, Biochemistry and Chemistry at the Sefako Makgatho Health Sciences University for making time in their busy schedules to complete the questionnaires.

Disclosure statement

No potential conflict of interest was reported by the author(s).

References

- Abbas, M., A. Zakaria, M. M. Balkhyour, and M. Kashif. 2016. "Chemical Safety in Academic Laboratories: An Exploratory Factor Analysis of Safe Work Practices & Facilities in a University." *Journal of Safety Studies* 2 (1), doi:10.5296/jss.v2i1.8962.
- Adane, L., and A. Abeje. 2012. "Assessment of Familiarity and Understanding of Chemical Hazard Warning Signs Among University Students Majoring Chemistry and Biology: A Case Study at Jimma University, Southwestern Ethiopia." *World Applied Sciences Journal* 16 (2): 290–299.
- Al-hilali, B. B. I., K. S. L. Al-Badri, and W. M. Mahdi. 2018. "Evaluation Safety Knowledge and Identifying the Reality of Some Labs for Safety Attitudes." *Iraqi National Journal of Chemistry* 19 (1): 1–7.
- Al-Zyoud, W., A. M. Qunies, A. U. C. Walters, and N. K. Jalsa. 2019. "Perceptions of Chemical Safety in Laboratories." *Safety* 5 (21), doi:10.3390/safety/safety5020021.
- American Chemical Society. 2015. "Undergraduate Professional Education in Chemistry. ACS Guidelines and Evaluation Procedures for Bachelor's Degree Programs." Spring 2015. Office of Professional Training, American Chemical Society, Washington, DC. Accessed at <http://www.acs.org/content/dam/acsorg/about/governance/committees/training/2015-acg-guidelines-for-bachelors-degree-programs.pdf>.
- Anza, M., M. Bibiso, B. Kuma, and K. Osuman. 2016. "Investigation of Laboratory Chemical Safety in Wolaita

- Sodo University, Ethiopia.” *Chemistry and Materials Research* 8 (11): 2224–3224.
- Anza, M., B. Kelta, A. Mohammed, and M. Bibiso. 2017. “Comprehension of Chemical Laboratory Safety and Hazard Warning Signs among Chemistry and Biology Department Students in Wolaita Sodo University, Southern Ethiopia.” *Chemical and Process Engineering Research* 48: 34–40. https://www.academia.edu/32435597/Comprehension_of_Chemical_Laboratory_Safety_and_Hazard_Warning_Signs_Among_Chemistry_and_Biology_Department_Students_in_Wolaita_Sodo_University_Southern_Ethiopia
- Ayi, H. 2014. “The Current State of Safety Within the wet Laboratories of a Canadian Academic Institution.” *Environmental Applied Science and Management*. Toronto, Ontario, Canada: Ryerson University.
- Ayi, H. R., and C. Y. Hon. 2018. “Safety Culture and Safety Compliance in Academic Laboratories: A Canadian Perspective.” *Journal of Chemical Health and Safety* 25: 6–12.
- Álvarez-Chávez, C. R., S. Luz, K. Perez-Gamez, M. Portell, L. Velazquez, and F. Munoz-Osuna. 2019. “Assessing College Students’ Risk Perceptions of Hazards in Chemistry Laboratories.” *Journal of Chemical Education* 96 (10): 2120–2131.
- Benderly, B. L. 2016. “Urging Universities to Act on Safety.” *Science*. Accessed at <http://www.sciencemag.org/careers/2016/05/urging-universities-act-safety>. doi:10.1126/science.caredit.a1600071.
- Cruz, C. P., S. A. A. Bakr, S. K. Thazha, and J. P. Cruz. 2015. “Biosafety Knowledge and Perceptions of Clinical Laboratory Science Educators in A Saudi University.” *International Journal of Health Sciences and Research* 5: 6.
- Czornyj, E., D. Newcomer, I. Schroeder, N. L. Wayne, and C. A. Merlic. 2018. “Proceedings of the 2016 Workshop Safety by Design - Improving Safety in Research Laboratories.” *Journal of Chemical Health and Safety* 25 (4): 36–49. doi:10.1016/j.jchas.2017.12.002.
- Engida, E. 2011. “Chemical Safety in Laboratories of African Universities.” *African Journal of Chemical Education* 1 (2): 35–49.
- Faghi, Y. A. 2018. “The Level of Awareness of Safety Measures Practiced in School Laboratories Among Pre-Service Science Teachers at Najran University.” *Journal of Educational Issues* 4 (1), doi:10.5296/jei.v4i1.12908.
- Feyziolğlu, B., B. Demirdağ, A. Ateş, I. Çobanoğlu, and E. Altun. 2011. “Chemistry Teachers’ Perceptions on Laboratory Applications: Izmir Sample.” *Educational Sciences: Theory and Practice* 11 (2): 1024–1029.
- Fivizzani, K. P. 2016. “Where are we with Lab Safety Education: Who, What, When, Where, and how?” *Journal of Chemical Health and Safety* 23: 18–20.
- Gibson, J. H., I. Schröder, and N. L. Wayne. 2014. “A Research University’s Rapid Response to a Fatal Chemistry Accident: Safety Changes and Outcomes.” *Journal of Chemical Health and Safety* 21 (4): 18–26.
- Gongo, E. S. S., P. N. Warutere, and P. N. Nguhiu. 2018. “Assessment of Level Compliance to Laboratory Safety in Secondary School in Kitui County, Kenya.” *Researchjournal’s Journal of Public Health* 4: 7. https://www.researchgate.net/publication/329311300_Assessment_of_level_of_compliance_to_laboratory_safety_in_secondary_school_in_Kitui_County_Kenya.
- Goodwin, V., D. Cobbin, and P. Logan. 1999. “Examination of the Occupational Health and Safety Initiatives Available Within the Chemistry Departments of Australian Universities.” *Journal of Chemistry Education* 76 (9): 1226–1229.
- Goswami, H. M., S. T. Soni, S. M. Patel, and M. K. Patel. 2011. “A Study on Knowledge, Attitude and Practice of Laboratory Safety Measures among Paramedical Staff of Laboratory Services.” *National Journal of Community Medicine* 2 (3): 470–473.
- Hill, R. H. 2007. “The Emergence of Laboratory Safety.” *Journal of Chemical Health and Safety* 14 (3): 14–19.
- Hill, Jr, R. H. 2016. “Undergraduates Need a Safety Education!” *Journal of Chemical Education* 93 (93): 1495–1498. doi:10.1021/acs.jchemed.5b00825.
- Ishmail, Z. S., K. Arifin, and K. Aiyub. 2015. “Promoting OSHA at Higher Institutions: Assessment of Level of Safety Awareness among Laboratory Users.” *A Contemporary Business Journal* 5 (2): 155–164.
- Islam, M. T., G. Mostafa, A. U. Bhuiya, S. Hawkes, and A. De Francisco. 2002. “Knowledge on, and Attitude Toward, HIV/AIDS among Staff of an International Organization in Bangladesh.” *Journal of Health Population and Nutrition* 20 (3): 271–278.
- Karapantsios, T. D., E. I. Boutskou, E. Toulipoulou, and P. Mavros. 2008. “Evaluation of Chemical Laboratory Safety Based on Student Comprehension of Chemicals Labelling.” *Education for Chemical Engineers* 3 (1): e66–e73.
- Kemsley, J. 2013. “Survey Exposes Lab Safety Gaps.” *Chemical and Engineering News* 91 (3): 30–31.
- Langerman, N. 2009. “Laboratory Safety?” *Journal of Chemical Health and Safety* 16 (3): 49–50.
- Langerman, N. 2011. “Deaths Continue.” *Journal of Chemical Health and Safety* 18 (4): 38–39.
- Lunar, B. C., V. R. S. Padura, and M. C. F. T. Dimaculangan. 2014. “Familiarity and Understanding of Chemical Hazard Warning Signs among Select College Students of De La Salle Lipa.” *Asia Pacific Journal of Multidisciplinary Research* 2 (5): 99–102.
- Marendaz, J., J. Suard, and T. Meyer. 2013. “A Systematic Tool for Assessment and Classification of Hazards in Laboratories (ACHiL).” *Safety Science* 53: 168–176.
- Mehrfar, Y., A. Eskandarnia, H. Pirami, and H. Mardanparvar. 2016. “Assessment of Awareness and Comprehension of Chemical Hazard Symbols among Chemistry Students.” *Journal of Occupational Health and Epidemiology* 5 (1). doi.org/10.18869/acadpub.johe.5.1.120.
- Ménard, A. D., and J. F. Trant. 2019. “A Review and Critique of Academic lab Safety Research.” *Nature Chemistry* 12 (1): 1–9. doi:10.1038/s41557-019-0375-x.
- Meyer, A. T. 2012. “How About Safety and Risk Management in Research and Education?” *Procedia Engineering* 42: 854–864.
- Miyagawa, M. 2010. “Globally Harmonized System of Classification and Labelling of Chemicals (GHS) and its Implementation in Japan.” *Nippon Eiseigaku Zasshi (Japanese Journal of Hygiene)* 65: 5–13.
- Mulcahy, M. B., A. Young, J. Gibson, C. Hildreth, P. Ashbrook, R. Izzo, and B. J. Backus. 2013. “College and University Sector Response to the U.S. Chemical Safety Board Texas Tech Incident Report and UCLA Laboratory Fatality.” *Journal of Chemical Health and Safety* 20 (1): 6–13.
- Nelson, D. A. 1999. “Incorporating Chemical Health and Safety Topics Into Chemistry Curricula: Past Accomplishments and Future Needs.” *Chemical Health and Safety* 6: 43–48.
- Nicol, A., and S. Tuomi. 2007. “Hazard Sign Comprehension among South African Illiterate Adults.” *Stellenbosch Papers in Linguistics* 37: 67–88.
- Odeyemi, O. A. 2012. “Knowledge, Awareness and Compliance of Postgraduate Students to Laboratory Safety Procedures.” *Bioresearch Bulletin* 4: 180–184.
- Ojera, D. A., E. M. W. Simatwa, and T. M. O. Ayodo. 2013. “Perception of Staff and Students on Factors that Influence Performance in Science Laboratory Technology in Institutes of Technology in Southern Nyanza Region, Kenya.” *International Journal of Academic Research in Business and Social Sciences* 3 (11). doi:10.6007/IJARBS/v3-i11/316.
- Ponferrada, C. O., E. J. L. Gabigon, J. G. Daque, G. D. Labial, et al. 2017. “Laboratory Safety Awareness among General Physics Undergraduate Students.” *Engineering, Technology and Applied Science Research* 7 (6): 2324–2327.

- Puteri, N. A. F., and R. Nurcahyo. 2018. "Safety perceptions in university teaching laboratory." Proceedings of the International Conference on Industrial Engineering and Operations Management Bandung, Indonesia, March 6-8. 2018. School of Science and Technology. 2018. "School Calendar." Sefako Makgatho Health Sciences University.
- Schröder, I., D. Y. Q. Huang, O. E. J. H. Gibson, and N. L. Wayne. 2016. "Laboratory Safety Attitudes and Practices: A Comparison of Academic, Government, and Industry Researchers." *Journal of Chemical Health & Safety*. doi:10.1016/j.jchas.2015.03.001.
- Sedghpour, B. S., M. Sabbaghan, and F. M. Sataei. 2013. "A Survey on the pre-Service Chemistry Teachers' lab Safety Education." *Procedia – Social and Behavioural Sciences* 90: 57–62.
- Sefako Makgatho Health Sciences University (SMU). 2017. "Research Strategy" 2018-2022, Version 4.
- Sieloff, A. C., D. G. Shendell, E. G. Marshall, and P. Ohman-Strickland. 2013. "An Examination of Injuries and Respiratory Irritation Symptoms among a Sample of Undergraduate Chemistry Students From a Public Northeastern University." *Journal of Chemical Health and Safety* 20: 17–26.
- Sumadsad, C.R., and A. Jamorabo-Ruiz. 2013. "Occupational Safety, Health Conditions and Productivity of Faculty in Education Institutions at the National Capital Region, Philippines: An Assessment." Proceeding of the Global Summit on Education. 11-12 March 2013, Kuala Lumpur.
- University of Johannesburg. 2018. "Laboratory Safety Manual." Departments of Chemistry and Applied Chemistry, Faculty of Science. Walters, A.U.C., W.
- Walters, A. U. C., W. Lawrence, and N. K. Jalsa. 2017. "Chemical Laboratory Safety Awareness, Attitudes and Practices of Tertiary Students." *Safety Science* 96: 161–171. doi:10.1016/j.ssci.2017.03.017.
- Wenzel, T. J., A. B. McCoy, and C. R. Landis. 2015. "An Overview of the Changes in the 2015 ACS Guidelines for Bachelor's Degree Programs." *Journal of Chemical Education* 92 (6): 965–968. doi:10.1021/acs.jchemed.5b00265.
- West, S. S., J. F. Westerlund, A. L. Stephenson, N. C. Nelson, and C. K. Nyland. 2003. "Safety in Science Classrooms: What Research and Best Practice say?" *The Educational Forum* 67 (2): 174–183.
- Withers, J. H., S. A. Freeman, and E. Kim. 2012. "Learning and Retention of Chemical Safety Training Information: A Comparison of Classroom Versus Computer-Based Formats on a College Campus." *Journal of Chemical Health and Safety* 19: 47–55.