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Laboratory Chemical Safety Assessment and Compliance in Nigeria Tertiary Institutions

Oladotun B. Isola*, Mary T. Akintelu, Oseghale C. Inetianbor

Chemical Sciences Department, College of Basic and Applied Sciences, Samuel Adegboyega University, Ogwa, Edo State, Nigeria

Abstract The enormous burden of work related injuries has created a global concern and major risk factors may be traced to exposure to chemical, biological, mechanical and electrical hazards among others. Laboratory chemical safety control is critical and important to the avoidance of hazards and therefore this study identify the level of awareness and compliance on chemical safety by laboratory users, the effectiveness of safety procedures and the effects it has on the laboratory users were also examined. Primary data source were employed for the study through the use of questionnaire administered to 34 laboratory technologists in four tertiary institutions in Edo state which include University of Benin, Ambrose Ali University, Samuel Adegboyega University and College Education Igueben. Data collected were analyzed using descriptive and inferential statistical techniques through special package for social sciences, SPSS (version 20). The result revealed that the use of Warning symbols and safety charts, control use of hazardous and radioactive chemicals, and chemical hygiene plans were effective in reducing the incidence of accident in the laboratory but compliance by laboratory users have been very low. Also, the result of Kruskal-Wallis test shows that the effects of PPE ($F= 6.815$; $p<0.05$) and warning symbols and safety charts ($F= 14.625$; $p<0.05$) are statistically significant and effective in reducing hazards in the laboratory. In conclusion, safety practices among laboratory users need to be improved and focus should be on establishing safety standards of operation for laboratories in educational institutions with continuous inspection to ensure compliance by relevance regulatory agencies.

Keywords Chemical safety, Assessment, Compliance, Tertiary institutions

1. Introduction

Laboratory chemical safeties are guidelines or procedures put in place to ensure safe handling, storage, transportation and disposal of chemicals in the laboratory. This is important in educational institutions, research institutes and industries where chemicals are in constant use because the procedures guide students and other laboratory users on safe handling of chemicals in the laboratory in order to prevent chemical hazards and accident in the laboratory.

Chemicals are substances used to synthesize or manufacture chemical products in the industry and are also used for experiment by scientists in the educational sector. Current standards on hazard evaluations, risk assessments, and hazard mitigation are only applicable in the industrial settings without been replicated in the academic research laboratory environment because there is no comprehensive guidance on managing the hazards unique to laboratory chemical research in the academic environment (American Chemical Society, 2015). Safety issues should not only be peculiar to the industries but also in educational institutions such as University laboratories where chemicals and reagents are in constant use (Nurul *et al*, 2017). Chemical laboratories possess a greater number of unique hazards than most other general worksites and as a result present some of the greatest challenges in the prevention of injury and illness. Thus, laboratory users in educational institutions should be mandated to include hazard identification, assessment, and management in their operations, and ensure a safe working environment for themselves and other laboratory users.

Hazard associated with the use of chemical can be categorized in three ways which includes hazard in chemical dispensation and use, hazard in chemical storage and transportation, hazard in disposal and environmental pollution. Chemical hazards occurs during the process of carrying out activities or scientific investigations in the laboratory, some of these activities involves chemical pouring, reagents and solution preparations, chemical labeling, chemical boiling and heating, chemical pipetting, chemical storage, transportation and disposal. The actions of preparing and pouring acids in the laboratory or other dangerous substances may result in toxic and corrosive injuries on workers from chemical spillages and spurting hazards. Hazards of mistaken identity occur when chemical

* Corresponding author:
dotmanchope@gmail.com (Oladotun B. Isola)
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bottles are not properly labeled which perhaps are often destroyed by the action of corrosive fumes and pests. The injection of chemicals through chemical pipetting could result in poisoning, irritation and in severe cases may lead to death. Boiling and heating operations is often accompanied by spilling and splashing of dangerous chemicals which has the tendency to cause hazards not only to the person carrying out the operation but also to the surroundings. Sometimes storing incompatible chemicals together has the potential of causing serious explosion due to peculiar nature of some chemicals. Exposure to sunlight, water and heat can gingered explosive reactions or create an atmosphere for chemicals to reacts. Fumes of chemicals in storage may corrode the metal parts of equipment that is kept within the vicinity of a chemical storage. The corrosive action may cause stiffness of moving parts in such equipment. This action may eventually damage the equipment and make it a hazard to a prospective user. Some of this equipment includes ovens, centrifuges, balances, homogenizers, and microscopes. Any chemical can be toxic or harmful under certain conditions (Aluko, 2007). There are generally four type of toxic entities; chemical, biological, physical and radiation: chemical toxicants include inorganic substances such as lead, mercury, hydrochloric acid, and chlorine gas, and organic compounds such as methyl alcohol, most medications, and poisons from living things (Aluko, 2007).

In recent times, new educational policies in Nigeria have favoured the creation of more private and public tertiary institutions which will definitely increase demands for chemicals and reagents used in the laboratory for science and science related programs. Students, staff and all users working in chemical laboratories must be properly exposed to safety regulations associated with the use of chemicals. Therefore, to prevent and reduce the risk of accidents, awareness of the importance of safety practices need to be improved. Universities in Africa are in need of chemical safety and security facilities, professionals and resource materials as they engaged themselves in more advanced chemistry research (Temechegn Engida, 2011).

The National Research Council 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, the wider community and environment, and that 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). Accidents are caused by negligence, lack of knowledge of works to be carried out as well as damage or failure either on materials, equipment and chemical used (Jamaludin, 2001). In addition, laboratory design flaws have been identified to have the potentials of increasing accidental injuries (James *et al*, 2014).

Safety rules in laboratory should be practiced from time to time and staff should be responsible for preventing the occurrence of accidents (Sohin, 2002). Nurul *et al*, (2017) studied safety and health practice among laboratory staff in Malaysian education sector and their study established that, understanding of safety and health practice are low while doing some research activities in the laboratory. Their study concluded that some of the staff also did not implement safety practices that may contribute to unplanned event of accident occurring in laboratory. Students working in a chemical laboratory are more vulnerable to chemical hazards due to inexperience and negligence. Even the very experienced laboratory individuals who fail to follow safety precautions to understand potential hazard of each and every chemical may be at risk.

Study on 42 construction contractors in Nigeria also found out that accident record in 2006 confirmed 5 injuries per worker and 2 accidents per 100 workers (Idoro, 2011). Although, Okolie and Okoye (2012) argued that there were no reliable accident data in Nigeria, because Occupational Safety and Health (OSH) regulatory system in the country does not report occupational accidents required as OSH regulations. This may be the reason why many universities in Nigeria are not reporting accident due to work related injuries in the laboratories. In addition, Temechegn (2011) in his research on chemical safety in laboratories of African Universities deduced from the students response on the types of laboratory hazards and how they could be controlled that: students were not using protective gloves, students were handling the occurrence of hazard with little or no professional background, and it seems that there is little or no records of accidents in the laboratory for future reference. Eguna *et al*., (2011) pointed out that protection management is often a belated idea in the academic laboratories of developing countries, leading to unsafe and inadequate conditions for the disposal of expired chemicals.

In Ethiopia, there were 16 cases of accidents in school involving mercury spill in laboratories from 2016 to 2017 (Nurul *et al*, 2017). In the United States alone, Sigmann documented 164 injuries in 32 incidents (primarily in K−12 classrooms) as a result of the unsafe use of flammable liquids, inadequate safety precautions, and lack of safety training in chemical hazards among science teachers. In 1996, chemistry laboratory was engulfed in fire in the University of Texas as a result of improper disposal of sodium metal according to news report. Also, In January 2010, a chemistry graduate student at Texas Tech University was seriously injured in an explosion. The Chemical Safety Board of the University that investigated the incident while writing its report noted several factors contributed to the incident, including lack of comprehensive guidance on managing the hazards unique to laboratory chemical research in the academic environment. It revealed that current standards on hazard evaluations, risk assessments, and hazard mitigation are geared toward industrial settings and are not transferrable to the academic research laboratory environment.

In 2001, there was a report of a flash fire that burned seven students of Genoa-Kingston High School in a chemistry class when an experiment went awry leaving one of the

students in critical condition. Three students carrying out waste experiment in the laboratory were killed in an explosion at Beijing Jiaotong University in china as reported by the capital's fire services (South China Morning Post, 2018).

Occupational accident is an occurrence arising in the course of work, which results in fatal injury. Over 7 600 people die each day from work-related accidents resulting to over 2.78 million every year. The burden of occupational injuries is significant, both for employers and the wider economy, resulting in losses from early retirements, staff absence and rising insurance premiums (International Labour Organization ILO, 2013). According to an estimate by the ILO in 2013, 2.34 million deaths were recorded as a result of work activities. The Institute of Occupational Safety and Health, IOSH, estimated that there are 660 000 deaths a year as a result of cancers arising from work activities (Occupational Health and Safety, 2018).

This study therefore examined the spate of chemical hazards among laboratory professionals and scientist. The study also identified chemical hazards occurrences among laboratory users, and the effects of safety measures put in place in the laboratory.

2. Methodology

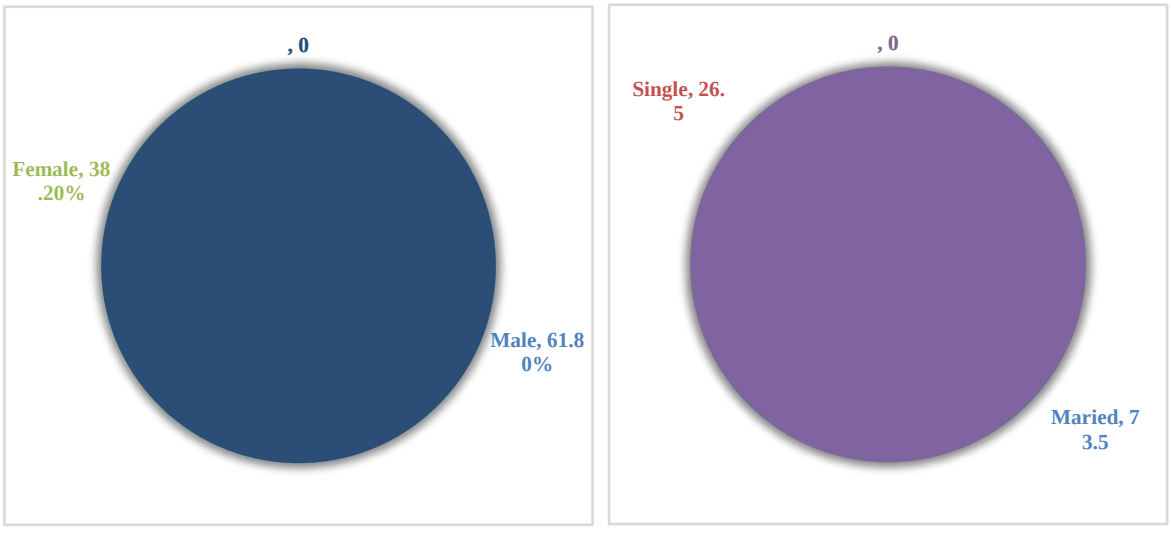
Survey research design was used for this study. Nwodu (2006) opined that survey research is a research method that focuses on a representative sample derived from the entire population of study. The study population from which the sample was drawn for the study consists of laboratory staffs, technologist, students and lecturers in the selected tertiary institution in Edo state. This research work was carried out in four different higher institutions of learning, which includes University of Benin, Ambrose Ali University, Samuel Adegboyega University and College of Education Igueben.

Data were collected through a well-structured questionnaire. Survey research method was used for the study through distribution of copies of questionnaire to collect necessary information from respondents Thirty four (34) questionnaire was developed and used as research instrument for the study, the questionnaire contained four inter- related sections, section A elicited information on the bio-data of the respondents, section B elicited information on the level of awareness on safety consciousness among laboratory technologists, section C provided information on the effectiveness of safety procedures and regulations in the laboratory, while section D elicited on the impact of safety procedure and regulations on laboratory users.

The data was analyzed using descriptive statistical analysis through statistical package for social sciences (SPSS, version 20).

3. Result and Discussion

Fig. 1 & 2 are pie and bar charts result of demographic characteristics among laboratory users in Edo State Tertiary Institutions. The result shows that majority of the laboratory users were male (61.8%) against the female (38.2%) counterparts. The result also revealed that the age of the respondents ranges from 21-30(20.6%), 31-40(52.9%), 41-60(23.5%) and 61 above (2.9%). From the result it was observed that majority of the respondent were in their middle age. The result further shows that 73.5% of the laboratory users in Edo state tertiary institution are married and 26.5% are single which means that majority of the respondents are highly responsible, dependable and this underscores the importance of having people who are emotionally stable to work in a complex science laboratory environment. Finally, the results shows that most (47.1%, 35.5%) of the laboratory users acquired post graduate degree and have the minimum of 6 years work experience respectively.

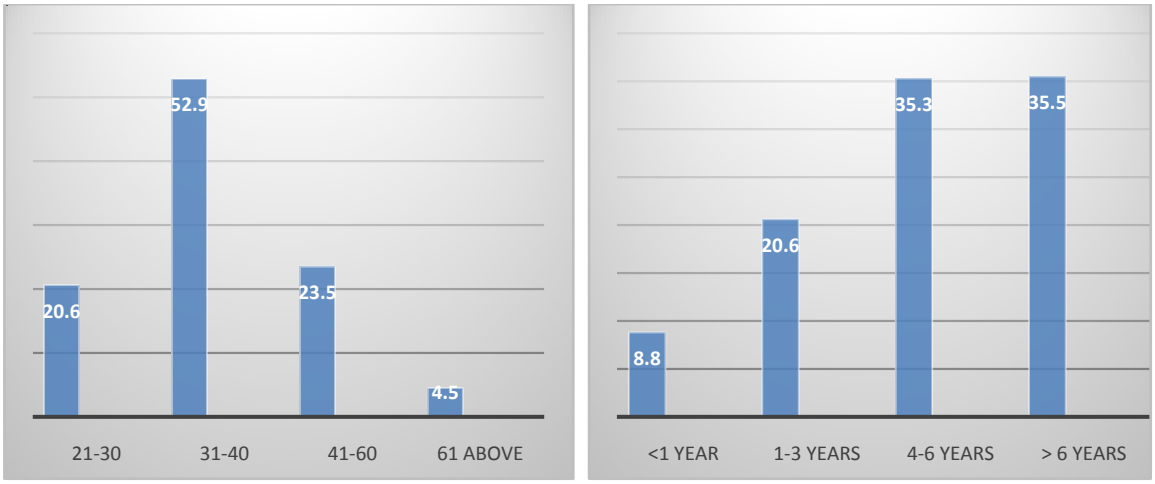


(a) (b)

Figure 1. (a) Percentage of respondent gender (b) Percentage of respondent marital status

Table 1. Level of awareness or consciousness of safety in the laboratory

Variable	Distribution	Frequency	Percentage (%)
Chemical pouring occur during experiments in our laboratory	Strongly agree	14	41.2
	Agree	10	29.4
	Strongly disagree	4	11.8
	Disagree	2	5.9
	Undecided	-	
I am aware that there is laboratory regulations	Strongly agree	28	82.4
	Agree	6	17.6
	Strongly disagree	_	_
	Disagree	_	_
	Undecided	_	_
Safety procedure and regulation are physically present in the laboratory	Strongly agree	2	5.9
	Agree	30	88.2
	Strongly disagree	2	2.9
	Disagree	_	_
	Undecided	_	_
Accident are caused by negligence of laboratory user on personal protective equipment	Strongly agree	3	8.8
	Agree	30	88.2
	Strongly disagree	1	2.9
	Disagree	_	_
	Undecided	_	_
Accident are caused by lack of knowledge of works to be carried out	Strongly agree	4	11.8
	Agree	28	82.4
	Strongly disagree	2	5.9
	Disagree	_	_
	Undecided	_	_
Accident are caused by materials, equipment and chemical used	Strongly agree	17	50.0
	Agree	9	26.5
	Strongly disagree	6	17.6
	Disagree	2	5.9
	Undecided	_	_
Safety rules in laboratory should be practiced from time to time	Strongly agree	14	41.2
	Agree	20	58.8
	Strongly disagree	_	_
	Disagree	_	_
	Undecided	_	_
Student knowledge on safety and health practices are low while doing some job activities in laboratory	Strongly agree	2	5.9
	Agree	31	91.2
	Strongly disagree	1	2.9
	Disagree	_	_
	Undecided	_	_
Staff using laboratory are not implementing safety practices that may contribute to unplanned event occurring in laboratory	Strongly agree	30	88.2
	Agree	1	2.9
	Strongly disagree	2	5.9
	Disagree	1	2.9
	Undecided	_	_



(a) **(b)**

Figure 2. (a) Percentage of the respondent age (b) Percentage of respondent work experience

Table 1 elicited information on the level of awareness of safety among laboratory users. The result shows that majority (41.2%) of the respondents strongly agreed that chemical is been used regularly in the laboratory. Also, 29.4% of the respondent were in agreement that chemical is been used regularly in the laboratory while 5.9% among the respondent disagreed. This shows that the use of chemicals varied from laboratory to laboratory.

In the same vein, 82.4% of the laboratory users strongly agreed that they were aware of laboratory safety and regulations present in the laboratory. Moreover, 82.4% of the respondents strongly agreed and (11.4%) agreed that accidents are caused by lack of knowledge of works being carried out while only (5.9%) strongly disagreed. The respondents also strongly agreed (50%) and agreed (26.5%) that accident are caused by materials, equipment and chemicals used, although, (17.6%) strongly disagreed. Again, 41.2% and 58.8% of the respondents strongly agreed and agreed that safety rules in laboratory should be practiced from time to time.

Furthermore 88.2% of the respondents agreed that accidents are caused by negligence of laboratory users on use of personal protective equipment, (8.8%) strongly agreed and only (2.9%) were undecided. The table also gave information that majority of the respondents agree (82.4%) that staff should be responsible for preventing the occurrence of accident while (5.9%) strongly agree and disagree.

In all, it is obvious that the respondents were well aware of laboratory safety and that safety procedure and regulations were physically present in the laboratory. However, the result revealed that accident are caused by materials, equipment and chemical used, negligence of laboratory users on personal protective equipment and inadequate knowledge on the work being carried out also contributed to accident in the laboratory which confirms the findings of (Jamaludin, 2001). The result also shows that staff should be responsible for the prevention of accident in the laboratory which agrees with the position of (Sohin, 2002).

Table 2. Evaluation of safety procedures and regulation put in place in the laboratory

Variable	Distribution	Frequency	Percentage (%)
Use of warning symbols and safety charts	very often	4	11.8
	Often	4	11.8
	less often	10	29.4
	Occasionally	14	41.2
	not at all	2	5.9
Training on laboratory safety and regulations	very often	6	17.6
	Often	24	70.6
	less often	2	5.9
	Occasionally	1	2.9
	not at all	1	2.9
We use personal protective equipment	very often	22	64.7
	Often	9	26.5
	less often	1	2.9
	Occasionally	2	5.9
	not at all	Nil	Nil
Provision of safety equipment	Very often	4	11.8
	Often	24	70.6
	Less often	6	17.6
	Occasionally	-	-
	Not at all	-	-
Control use of hazardous or radioactive chemicals	very often	4	11.8
	Often	5	14.7
	less often	13	38.2
	Occasionally	11	32.4
	not at all	1	2.9
Chemical hygiene plan	Very often	-	-
	Often	1	2.9
	Less often	5	14.7
	Occasionally	14	41.2
	Not at all	13	38.2

Table 2 revealed the level of effectiveness of safety procedure and regulation put in place in the laboratory. The result shows that the use of warning symbols and safety charts is occasionally being used (41.2%) or less often (29.4%), Training on laboratory safety and regulation are very often done (17.6%) or often done (70.6%). Also the result shows that the use of laboratory personal protective equipment is very often used (64.7%), with (5.9%) of the respondent who believed it is less often used. Majority of the respondents believed that safety equipment is often (70.6%) and very often (11.8%) provided in the laboratory. Moreover, the result revealed that use of hazardous and radioactive chemicals are less often being controlled (38.2%) or occasionally (32.4%) and in some cases not at all (2.9%). Likewise, chemical hygiene plan is less often (14.7%) being used or occasionally (41.2%) and in some cases not at all (38.2%).

The result from the table revealed that majority of the respondents believed warning symbols and safety charts are not effectively being used by their laboratories. Also the control use of hazardous or radioactive chemicals, and chemical hygiene plans have not been effective. However, provision of safety equipment, training of laboratory users and use of personal protective equipment was seen to be more effective in reducing laboratory hazards or accidents. The training on laboratory safety should not be limited to the technologist and scientist using the laboratory but to students and other laboratory users. A survey was carried out in 2011 on the state of chemical safety in chemistry laboratories of universities in Africa. University of Benin (Nigeria) and Haromaya University (Ethiopia) admitted that they do not provide any training on chemical safety to their students because of the large number of students using the laboratories and time constraint on the part of instructors (Temechegn Engida, 2011). Many of our academic institutions in Nigeria did not see the occurrence of chemical hazards as major treat because they engaged more in teachings than research. Although, chemical laboratories in developing countries may 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 (National Research Council, 2010).

Since chemical laboratory work involves application of numerous procedures, operations, extensive or continuous use of chemicals and reagents, they therefore require safety precautions, which should include: chemicals safety, fire safety, electrical safety, and other safety issues. Common chemical hazards emanates from use of toxic, corrosives, flammables, and reactive chemicals and to avoid chemical laboratory hazards, laboratory users must maintain high level of awareness on safety. Occurrence of accident can be reduced through: proper identification of chemicals, reduced risk of exposure, adherence to safety instructions and regulations, good chemical storage system, availability of safety devices and installations, and disposal mechanism or safe clean out mechanism (acronym PRAGAD).

Hazards control in chemical laboratories can be achieved if the safety measures are implemented. Laboratory users should always be familiar with the chemicals and the cautionary information printed on the chemical containers before putting the content into use. Also, provision of safety equipment and use of personal protective equipment (PPE) while dealing with chemicals in the laboratory such as lab coat, gloves, goggle, and so on has a great effect in reducing chemical hazards in the laboratory.

Table 3 revealed the effect of safety measures on laboratory users and fig. 3 below shows the hierarchy of effects of safety measures on laboratory users. The result in table 3 showed that all the parameters used have effect on the safety of laboratory users and majority (76.5%) of the respondents agreed that the use of personal protective equipment has very high effect on laboratory users. The use of warning symbols and charts (79.4%) have high effect- this may be due to the fact that if the instructions and warning symbols on the labels of chemical bottles or safety charts in the laboratory are strictly followed, incident of accident or occurrence of accident will be minimal. Provisions of safety equipment (85.3%), chemical hygiene plan (94.1%), and control use of hazardous or radioactive chemicals (91.2%) also have high effect on laboratory users.

The results of Kruskal-Wallis test compare distributions of Effects of PPE, warning symbols and safety charts, safety equipment, chemical hygiene plan and control use of hazardous or radioactive chemicals across the various years of experience groups. Out of the five (5) lab safety measures used for the study, the result shows that only two (2); effects of PPE ($F= 6.815$; $p<0.05$) and effects of warning symbols and safety charts ($F= 14.625$; $p<0.05$) are statistically significant. These results indicate that the effects of warning symbols and safety charts, and PPE have significant effect on safety measures.

Table 3. Effects of safety measures on laboratory users

Parameters	Low (F/ %)	Very low (F/ %)	Undecided (F/ %)	High (F/ %)	Very high (F/ %)
Personal protective equipment	-	3(8.8)	-	5(14.7)	26(76.5)
Warning symbols and safety charts	-	-	-	27(79.4)	7(20.6)
Safety equipment	-	1(2.9)	-	29(85.3)	4(11.8)
Chemical hygiene plan	-	1(2.9)	-	32(94.1)	1(2.9)
Control use of hazardous or radioactive chemicals	-	1(2.9)	-	31(91.2)	2(5.9)

Figure 3. Showing hierarchy of effects of safety measures on laboratory users

Table 4. Table showing the results of Kruskal-Wallis test

Distribution is the same across categories of Years of Experience	Test Statistic	Asymp. Sig
Effects_PPE.	6.815	0.021
Effects_warning symbols and safety charts	14.625	0.002
Effects_safety equipment.	0.994	0.803
Effects_chemical hygiene plan	6.875	0.076
Effects_control use of hazardous or radioactive chemicals	5.767	0.124

Thus, PPE and warning symbols and safety charts should be strongly use across all level of scientific laboratories due to the great effects on the safety of laboratory users. Also, there is need to improve the level of compliance to these safety procedure or equipment.

4. Conclusions

This study examined the effectiveness of safety procedures and its effects on laboratory users. Results shows that safety practices among laboratory users need to be improved and focus should be on establishing safety standards of operation for laboratories in educational institutions with continuous inspection to ensure compliance by relevant regulatory agencies.

5. Recommendations

Based on the findings and conclusion, the following recommendations are put forward for consideration by technologists and all laboratory users.

1. Technologists in collaboration with the environment health and safety officers should always train all laboratory users on causes and effects of chemical laboratory hazards and how it can be controlled.
2. Laboratory staff should ensure the compliance to laboratory rules and regulations.
3. There should be safety regulations and standards for operating a science laboratory in academic institutions.
4. Regular safety inspections and control should be put in place in every institution or by relevant regulatory agencies.
5. Every laboratory should have a chemical hygiene plan.
6. Updated records of experience on laboratory accidents should be kept by laboratory staff.
7. Students taking science practical should be given safety test as part of their laboratory course requirement to reinforce knowledge of safety on semester basis.
8. Use of personal protective equipment (PPE) should be enforced from time to time on all laboratory users by laboratory managements.
9. Technologists, scientist and other institutions concerned like the Nigeria Institute of Science Laboratory Technologists should create awareness and assess the level of compliance to safety procedure and regulation by laboratory users.

Appendix

QUESTIONNAIRE
LABORATORY CHEMICAL SAFETY ASSESMENT AND COMPLIANCE IN NIGERIA TERTIARY INSTITUTION

The purpose of this study is to examine the occurrence of chemical hazards among laboratory users and the effects of safety measures put in place in the laboratory.

Section A: Bio Data of respondents

Please tick the appropriate answers where options are given

1. Sex: (A) Male ☐ (B) Female ☐
2. Age: (A) 21-30 ☐ (B) 31-40 ☐ (C) 41-60 ☐ (D) 61 above ☐
3. Marital status: (A) Married ☐ (B) Single ☐ (C) Divorced ☐ (D) Widow ☐
4. Academic qualification: (A) No formal education ☐ (B) S.S.C.E ☐ (C) OND/HND ☐
   (D) B.Sc/B.Tech ☐ (E) Post graduate ☐ (F) If others specify……
5. State of origin (A) Ogun State ☐ (B) Oyo State ☐ (C) Ekiti State ☐ (D) Edo State ☐
   (F) Others specify……
6. Years of experience (A) Less than 1year ☐ (B) 1-3years ☐ (C) 4-6years ☐ (D) Above 6years ☐

Section B: Level of awareness or consciousness of safety in the laboratory

S/N	Variable	Strongly agree	Agree	Strongly disagree	Disagree	Undecided
7	Chemical pouring occur during experiments in our laboratory					
8	I am aware that there is laboratory regulations					
9	Safety procedure and regulation are physically present in the laboratory					
10	Accident are caused by negligence of laboratory user on personal protective equipment					
11	Accident are caused by lack of knowledge of works to be carried out					
12	Accident are caused by materials, equipment and chemical used					
13	Safety rules in laboratory should be practiced from time to time					
14	Staff should be responsible for preventing the occurrence of accident					
15	Student knowledge on safety and health practices are low while doing some job activities in laboratory					
16	Staff using laboratory are not implementing safety practices that may contribute to unplanned event occurring in laboratory					

Section C: Evaluation of safety procedures and regulation put in place in the laboratory

	Variable	Very often	Often	Less often	Occasionally	Not at all
17	Use of warning symbols and safety charts					
18	Training on laboratory safety and regulations					
19	We use personal protective equipment					
20	Provision of safety equipment					
21	Use of hazardous chemicals or Radioactive Chemicals					
22	Chemical hygiene plan					

Section D: Effects of safety measures on laboratory users

S/N	Variables	High positive impact	Positive impact	No impact	Negative impact	High negative impact
23	Use of personal protective equipment					
24	Use of warning symbols and safety charts					
25	Provision of safety equipment					
26	Chemical hygiene plan					
27	Control use of hazardous and radioactive chemicals					

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