Statistical Evaluation of Safety Procedures and Chemical Security in Chemical Laboratories / College Ibn Al Haitham

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Abstract. In order to minimize the significant incidents in chemical laboratories, especially the academic laboratories, one must be able to identify and evaluate hazards. Familiar with safety rules and responsibilities. Assessing implementation of safety rules and securities. The aim of this paper is to evaluate and assess the chemical safety procedures and chemical policies in academic laboratories using statistical questionnaire. A form is written, suggested two main parts, safety and security. Safety part includes three classes, hardware requirements, training and application of safety procedures. The second part is security. The form design is based on four points Likert scale. The forms were distributed to more than 90 persons who works in the chemistry department laboratories, of Ibn Al Haitham college of education, university of Baghdad. Statistical analysis is carried out using IBM Statistics SPSS, Version 24, 2016. An internal consistency reliability was estimated using Cronbach’s alpha measuring scale, a value of 83.4% was achieved it indicates a good reliability. The research emphasized a shortage in the application of safety procedures due to the lack of hardware requirements, as well as training. Control banding chemical uses in research and education laboratories, checklists and development of standard operating procedures are the most important things to achieve the safety in chemical laboratories.

Keywords: chemical safety, SPSS, laboratories, Security

Introduction:

Safety is defined as “The control of exposure to potentially hazardous substances to low risk of exposure”. Security is: “The prevention theft or abuse of chemicals [1].

Academic laboratories have a responsibility to build students with a lifelong attitude of safety and security as a top priority. A culture of safety and security within academic institution forms a solid foundation on which a successful laboratory chemical management program can be built. A successful safety and security program requires a daily commitment from everyone in the institution. Individuals at all levels should understand the importance of eliminating the risk of exposure to hazardous materials in the laboratory and must work together toward this end.
New laboratory workers and students faces risks due to many reasons, they have no experience of the dangers and risks related to the use of hazards of materials, equipment’s and tools [2].

Prestigious universities have a safety committee, the committee includes representatives from the faculty, graduated students, environmental health, and fire department. Such these issues of safety are lacked in Baghdad university which is the biggest university in Iraq. Safety committee receives a feedback from researchers and staff regarding safety and health concerns, workplace hazards identification, reviewing accidents reports, deciding and updating safety and health policies and periodically inspecting laboratories [3].

Evaluation and assessment of chemical safety and environmental health in chemical laboratories should be well established to investigate of a future serious incident in an academic laboratory, especially for research’s, the potential hazards belong to a research should be addressed and documented. A standard operation procedure should describe the use and handling of chemicals, equipment, and processes for each lab [4] [5].

Identification of hazards, evaluation of the risks concerns with these hazards, and conduction the risks of hazards that related to the experiment to be performed is a task of experimental design process. Observation, theory experiment and prediction are the main lines of any research are shown by circles. The basic elements of evaluation and hazards and control are shown by boxes. The interaction is illustrated in Figure 1.

![Figure 1: Integration of Hazard Identification, Evaluation, and Control with the Scientific Method [5]](image)

In this research the evaluation of the safety of laboratories depends on the safety hardware requirements, Training and Implementation of safety instructions. Hardware is the required materials, some of these are the self protection materials like coats googles masks –etc. some of them is instruction materials like signs and safety data sheets and procedures, the other materials like fountains showers are fixed in the place. Emergency doors, ventilation fire sprinkles are equipped within the buildings. See Figure 2, it shows some of safety hardware requirements.
Safety materials and procedures are specific to the type of hazard. Table 1 shows chemical safety levels. It is classified into four levels, grouped according to the type of hazard. Hazards of fire, hazards of reactivity, acute toxicity, and chronic toxicity.

Lab hazards signs are not enough to minimize accidents from exposure to chemicals without education and implementation of safety issues. Laboratory training includes the following points:

- Site-specific emergency procedures
- Site-specific standard operating procedures
- Specific physical and health hazards of materials in the work area
- Methods to prevent exposure of identified hazards and personal protective equipment
- Descriptive information on the function and use of general and local exhaust ventilation that serves the lab in use” [6]

| Hazard | Fire | Reactivity | Acute Toxicity | Chronic Toxicity |
|--------|------|------------|----------------|-----------------|
| CSL 1  | Flashpoint above ambient temp (140 F) | No chemical changes expected in the process | All chemicals have known toxicities and OELs > 500 ppm | None known |
| CSL 2  | Flashpoint near ambient, expected concentration < 10% LEL | No known incompatibilities between chemicals being used | All chemicals have known toxicities and 10 ppm < OELs < 500 ppm | Specific target organs or irreversible effects suspected |
| CSL 3  | Expected concentration > 10% LEL | Chemicals with known reactions or contamination hazards present | Unknown toxicities or OEL < 10 ppm | Specific target organs or irreversible effects probable |
| CSL 4  | Pyrophorics, air, or water reactives, etc. | High hazard reactions in use | OEL < 1 ppm | Irreversible toxicities require use of designated areas |

Table1. Chemical Safety Levels [5]
Security topic: its importance is not less than safety for chemical lab rotaries, it protect labs from theft, loss, Accidents etc. Security is summarized by four points:

- Asset evaluation
- Threat assessment
- Site survey and analysis
- Physical vulnerability survey

These points are described thoroughly by Lisa Moran and Tina Masciangioli. [7]

According to the university of California, There are two levels of security Normal Security Level and elevated Security Level. See Figure 3. Normal Security level is applied to area characterized of low risk for unusual environmental. Loss to theft or damage would have minimal impact to research operations or surrounding environment. In this level:

- Doors and windows are locked when the laboratory is not occupied.
- All laboratory personnel receive and review their Department Emergency Action.

**Figure. 2** Some of hardware materials for safety requirements.

**Figure. 3**: security levels
Elevated Security

A laboratory or area characterized as an Elevated Security Level poses a higher risk. The laboratory may contain equipment or material that is attractive for theft (e.g., controlled substances), could threaten the public, or might be misused. Loss or damage would have moderately serious impact on the research programs and the reputation of the institution.

Follow Elevated Security protocols by ensuring that:

- Normal Security protocols are followed.
- Doors and door frames are hardened with high-security lock cores.
- Prevent access from one area to the other over a drop ceiling with perimeter walls extending from the floor to the ceiling.
- foreigners cannot enter lab. unless laboratory personnel are present. [8]

Results and Discussion

Questionnaire form is designed to cover two topics, safety and security issues. A thirty of forms were distributed among more than 90 precipitants. The participants profession are postgraduate students, undergraduate students, lecturers, and storekeepers at Ibn Al Haitham college, chemistry department.

A three-points Likert scale, is used to describe questionnaire form see table (2). In Likert scale shown below, option no.4 is excluded answers, so it is better to do read the valid percent instead of percent. Calculation is carried out using IBM statistics, version 24.

Table (2): Likert scale for questionnaire answers

| Selection     | Code | Range   |
|---------------|------|---------|
| Yes           | 1    | 1 - 1.67|
| Rather        | 2    | 1.67 - 2.33|
| No            | 3    | 2.34 - 3  |
| No Information| 0    | No information or Blanc answer |

Reliability Statistics is carried out on the questionaries’, the estimated Cronbach's Alpha is 0.838, this is an indication of reliable questionaries’. We took a sample 90 participant to fill the questionnaire. see table (3)

Table (3) Reliability Statistics

| Cronbach's Alpha Based on Standardized Items | N of Items |
|---------------------------------------------|------------|
| 0.811                                       | 0.838      |
| 55                                          |            |
Analysing topics shows safety requirements at critical zone, most of materials required for self-protection is not available, to be safe you have to expense. Some of questions seem be not clearly answered, participants want a secure case which is not available. For examples, most of refrigerators are used for food keeping because lack of offices. Laboratory is used as an office as well as lab, so the numbers are less than the true values. See tables 4, 5 and 6.

Most of items have shown a disagreement in safety assessment. Security issues are not better than safety issues this is a general case in postgraduate labs. No emergency plan meets no security plan. Security is viewed only as police sight, which is not. It is adjacent and second face of a safety coin, safety of persons should have the first priority. Although Laboratories and stores are designed to be safe and secure, the slackness of laboratories for many more than two decades, make them in a worst condition. Chemical storage building need a rehabilitation it is better than the new building, it is like a big storage cabinet equipped with a ventilation system. the current store may be useful for furniture storage, electrical equipment's but not for chemicals. Table, 6 indicates the situation of security in the college. In table 4, some of laboratories has an emergency door, but they are locked, need maintenance, and cleaning the area near it. Results shows that about 60% of the points in the hardware requirements are not satisfied.

**Table (4). Safety topic: Hardware requirements**

| No. | Item                                                                 | Yes | Rather | No  |
|-----|----------------------------------------------------------------------|-----|--------|-----|
| 1   | The lab/store has emergency door.                                     | 2.89|        |     |
| 2   | The lab is furnished with eye washer.                                 | 2.88|        |     |
| 3   | The lab/store is furnished with shower.                              | 2.92|        |     |
| 4   | The lab is furnished with fume hood.                                 | 1.22|        |     |
| 5   | The lab is furnished with a first aid kit.                           | 1.75|        |     |
| 6   | The lab is furnished with a useful gloves, googles and general purpose masks. | 2.84|        |     |
| 7   | The lab is furnished special masks for gaseous materials.            | 2.89|        |     |
| 8   | The lab is furnished with soap and detergent materials.              | 1.20|        |     |
| 9   | The lab is furnished with coloured and labelled containers for chemical wastes. | 2.36|        |     |
| 10  | The lab/store is monitored by fire fighting alarm system.            | 2.18|        |     |
| 11  | The lab/store is furnished with fire fighting cylinders.             | 1.48|        |     |
| 12  | The lab/store is furnished with ventilation system.                  | 2.04|        |     |
| 13  | Electronic monitors and alarms are available to prevent hazards due to asphyxiant, flammable, and many toxic gases | 2.93|        |     |
| 14  | Heat sensors and/or smoke detectors are fitted in the lab/ store building | 2.58|        |     |

In table 5. Here is a big lack in training issue, statistical analysis shows that about 80% of students and workers in the college are females. So any emergency case will be treated in difficulty if there are not trained enough.
Table (5) Safety topic: Training

| No. | Item                                                                 | Yes | Rather | No |
|-----|----------------------------------------------------------------------|-----|--------|----|
| 1   | We have ever get training courses deals with safety issues regarding our experiments. | 2.02 |        |    |
| 2   | We make safety demonstrations regarding chemicals, fire fighting and first aid. | 2.94 |        |    |
| 3   | Students get a safety training course at the first year.             | 2.94 |        |    |
| 4   | Students get safety lecture in each lab.                             | 1.48 |        |    |
| 5   | Students taught for the handling of glassware in lab                 | 2.01 |        |    |
| 6   | All laboratory workers are trained in what to do in an emergency.    | 2.30 |        |    |
|     | Mean                                                                 | 2.28 |        |    |

In table 6. The implementation of safety considerations is poor, because of lack of the safety environment. Some facilities are not available in the college, some of them are new, there is no safety and health committee, no safety officers appointed to employ this job. Safety urgent materials like coats, and masks are not supplied by the institution.

Table (6): Implementation of safety issues

| No. | Item                                                                 | Yes | Rather | No |
|-----|----------------------------------------------------------------------|-----|--------|----|
| 1   | The faculty tracks implementation of safety rules in the labs.       | 2.00 |        |    |
| 2   | There are Chemical Safety and Security Officers existed in the Skeleton of the institution. | 2.20 |        |    |
| 3   | The faculty following the supplying of safety materials to the labs. | 1.56 |        |    |
| 4   | Lectures already start with safety subjects, identify hazards of chemicals used in the lab. | 2.28 |        |    |
| 5   | The lab/store has a classified area for gas cylinders.               | 2.81 |        |    |
| 6   | There is a staff for handling and supplying chemicals and glassware using special trolley between the store and labs | 2.90 |        |    |
| 7   | There is an emergency plan applied in case of hazards               | 2.88 |        |    |
| 8   | The college has a safety department responsible for safety orders and following its implementation. | 2.97 |        |    |
| 9   | The college has a safety committee responsible for safety orders and following its implementation. | 2.94 |        |    |
| 10  | Safety technical reports already written in case of accidents        | 2.12 |        |    |
| 11  | Cleaning staff is trained on handling chemical waste of labs.       | 2.45 |        |    |
| 12  | Gas manifolds, electrical connections, electrical wiring lighting and equipment's are periodically checked by technical college department. | 2.85 |        |    |
| 13  | Refrigerator is used only for storing chemicals.                    | 1.56 |        |    |
| 14  | Safety sheets are prepared for each Chemical near the material in the lab/ store. | 1.28 |        |    |
| 15  | Label storage areas with appropriate warning signs                   | 1.55 |        |    |
| 16  | Each respirator in the laboratory should have written information available that shows the equipment’s limitations, fitting methods, and inspection and cleaning procedures. | 2.85 |        |    |
| 17  | Only few number of laboratory persons are authorized to access dual use materials. | 1.37 |        |    |
|     | Mean                                                                 | 2.29 |        |    |

Security topic is a very important issue, it is not a responsibility of officers or faculty only, it’s a responsibility of the whole college society. Any release of dual use chemical may be utilized in
terrorism. The security electronic system including monitoring and alarm, tracking the mobility of chemicals, tracking the wastes, and applying Enforcement and incentive policies to maintain security issues shows a shortage in this subject table 7. Shows security topic questionnaire form results.

Table (7) : Security topic

| No. | Item                                                                 | Yes | Rather | No |
|-----|----------------------------------------------------------------------|-----|--------|----|
| 1   | Lab/store have electronic smart locks.                               | 2.67|        |    |
| 2   | Lab/store have conventional locks.                                   | 1.20|        |    |
| 3   | Lab/store is monitored by digital Cameras.                           | 2.67|        |    |
| 4   | Chemicals are tracked by the faculty.                                | 2.12|        |    |
| 5   | Chemicals are tracked by the chemistry department.                   | 2.66|        |    |
| 6   | All consumed materials are registered in special documents.          | 2.12|        |    |
| 7   | Stock chemicals are stored in special cabinets properly designed for chemicals. | 2.75|        |    |
| 8   | Audit inventories and tracking systems periodically to remove any inaccurate data | 1.98|        |    |
| 9   | Higher education chemicals are supplied by purchase orders through the purchasing department | 2.75|        |    |
| 10  | Purchased chemicals are subjected to quality control/ certificate    | 1.76|        |    |
| 11  | Stored materials are periodically inspected and checked with the inventories. | 1.40|        |    |
| 12  | Audit inventories and tracking systems periodically to remove any inaccurate data | 1.48|        |    |
| 13  | Every year, a physical inventory of chemicals stored is made, verified the data on each item, and reconcile any differences. | 1.38|        |    |
| 14  | Store has isolated fence, controlled by electronic system            | 2.65|        |    |
| 15  | Dual used materials are subjected to special withdraw orders.        | 2.75|        |    |
| 16  | Each lab set up a process for incident reporting and investigation.  | 1.92|        |    |
| 17  | Enforcement and incentive policies are applied to maintain security issues. | 2.47|        |    |
| 18  | Site survey of areas for material deliveries, truck routes, parking, and building entries and exits is analysed . | 2.75|        |    |

Mean 2.2
Recommendations:

- Development of safety and health committee in each Iraqi university to be aware of laboratory chemical hazards.
- Most of labs required personal protective equipment, as well as training.
- Each research program should involve a chemical use and storage, a laboratory specific chemical hygiene plan should be created.
- Chemical stores should be checked for suitability for keeping chemicals, classified into zones according to the chemical hazard level.

References

[1] W. M. Abdou, "To Professionals: Chemical Safety And Chemical Security Overview," AJCE, vol. 4, no. 3, 2014.
[2] E. A. f. S. a. Health, "Checklist for the Prevention of Accidents in Laboratories," [Online]. Available: www.osha.mddsz.gov.si/resources/files/pdf/E-Fact_20.. [Accessed 1 2 2018].
[3] "Laboratory Safety Manual," Harvard Department of Chemistry and Chemical Biology, 2012.
[4] "Laboratory Safety Assessment Form Guide," Oregon State University, 2015.
[5] Committee, Identifying and Evaluating Hazards in Research Laboratories, Copyright 2015 American Chemical Society.
[6] "Lab Safety and Chemical Hygiene Plan," Grand Valley State University, Michigan, 2018.
[7] Lisa Moran and Tina Masiangioli,, "Chemical Laboratory Safety and Security," National Academy of Sciences, 2010.