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Semi-Quantitative Risk Assessment in the Chemical Stores of the University of Technology, Baghdad, Iraq

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K E Y W O R D S

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A B S T R A C T

Chemicals are used daily at the university, by its students or staff so it's necessary to develop a chemical management system to protect their workers and students from accidents caused by exposure to chemicals of various forms, the present study explains the methodology for assessing the health effects and risks of exposure to chemicals in the chemical stores of University of Technology (UOT) by using semi- quantitative risk assessment technique depends on a descriptive analytical approach, by collecting the requested information for seven main stores within the university by questionnaire form included inquiries about personal information about employees, level of education and years of experience, it also included inquiries about chemical stores and storage volumes, at first identified the exposed people, detected high demand chemicals, subsequently identified the chemical hazardous factors, exposure rate and risk level of each substance, ultimately the risk was identified for 41 chemicals among them four strong acids, hydrochloric, sulfuric, nitric and chromic with high exposure rate

benzene and xylene that have high risk level, from results of chemical survey can be conclude 71% of the total chemicals classified as high to moderate risk level, so the study recommends the continuity of the periodic assessment of chemical hazards within the stores of university, include laboratories in assessment procedures, providing of personal safety equipment.

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1. Introduction

Chemicals are produced in very large quantities to meet the growing needs in industry and scientific research [1], so the number of exposed people to risk of chemicals is increasing day by day [2]. Chemical materials can be found in different status within environmental work, solid, liquid, gases, vapors, and fumes or carried on suspended dust in laboratories and stores in academic institutions, because they may include people with poor expert particles [3]. It is necessary to develop a system of good management and assessment of chemicals risk, such as students and new employees who are constantly at risk of accidents [4], or manipulating the stocks of hazardous materials to threaten the lives of safe people by corrupt [5]. So the academic institute not quite safe on the contrary it is so dangerous, many accidents occur annually due to misuse and wrong storage of chemicals. There are several systematic methods to assess chemical hazards, some of them as online software apparatus may contribute to reducing accidents occurring in stores and laboratories [6]. Many studies were designed to assess chemicals hazardous in labs Bourrée et al., 2014 designs a comparative study with three methods to identified the chemical hazards in French teaching laboratories [7]. Whatever the methodology used to identify risks, they are undoubtedly useful enable us to make the right decisions for the measures needed to protect people [8]. In other words the comprehensive assessment of chemical health risk provide us the necessary information about appropriate control measures for exposed workers, health risk factors making it easier to take the the appropriate decision on, employees training, workers health protect and appropriate mitigation measures [9]. In current study that carried out in April 2018, used semi-quantitative technique to determine rate of exposure and the risk degree using risk assessment matrix.

2. Material and Methods

The present study was performed in the stores that belong to University of Technology (UOT), Baghdad, Iraq, that contain high variety of chemicals in different states, solid, liquid and. gases, where the stores employers are exposed to different levels of chemical substances. In current study, seven main stores were investigated and semi-quantitative risk analyses was carried out for 41 hazardous chemicals. Mass inventory method was used to detect total chemical quantities; there is no need to mention the sample size. Ultimately, the risk assessment of hazardous chemical substances in the chemical stores was calculated according to Winder and Stacey [10], by following the steps listed below:

1. Classification of workers in chemical stores to groups, store employee and supervisor of safety committee.
2. Analysis of their occupational duties according to exposure type of each.
3. Chemicals identification: in this step, all materials (involve active, expired and damaged) that have high demand or stagnate were well defined. All materials in the form of liquid, solid, mist, fumes and vapors, were studied
4. Use material safety data sheet (MSDS) of each substance .
5. Determination the hazard rate (HR) for all chemicals according on the quantity or toxicity risks by the following methods:

•Calculate the hazard rate, using of toxic or harmful effects of chemicals as shown in Table I.

•Detecting the hazard rate (HR) by detecting the lethal dose (LD50) or lethal concentration (LC50), is a way to measure the short-term poisoning (acute toxicity) of a substances, given all at once, which causes the death of 50% (one half) of a group of test animals, LD50 can be taken from the MSDS as shown in Table II.

6. Detection of the exposure rate (ER) and the exposure index (EI): by using the following formula:

$ER= [EI1 \times EI2 \times EI3 \times \ldots EIn]^{1/n}$ …………..…. (1)

Where (n) refers to the number of exposure factors.

The EI was calculated depending on a numerical measure from 1 - 5; (5 = very high, 4= high, 3 = medium, 2= low, and 1 = very low) as shown in Table III.

Table I: Toxic or harmful effects analyses to identified the hazardous rate of chemicals (Manpower 2005)

Description of hazardous rate		Examples
1	• Non-health influence substances • Group A5 substances (not probable as a human carcinogen) by the American	Sodium chloride, calcium carbonate

	Conference of Governmental Industrial Hygienists (ACGIH)	, butane, butyl acetate,
2	• Reversible effects chemicals on mucous, eyes, membranes, and skin. • • Group A4 substances according to ACGIH classified. (not classifiable as a human carcinogen)	Acetone, butane, acetic acid and salts of barium
3	• Compounds that are possibly mutagenic or carcinogenic to animals or humans, limiting data for cancer-causing according to ACGIH categorized as group A3 (unknown data relevance to humans with confirmation animal carcinogen).	Toluene, xylene, ammonia, butanol, acetaldehyde, aniline, antimony
4	• Substances that probable teratogenic, carcinogenic and mutagenic depending on studies conducted on animals, classified group A2 (unsure human carcinogen).	Formaldehyde, cadmium, methylene chloride, ethylene oxide, acrylonitrile
5	• Well known mutagenic, carcinogenic, and teratogenic chemicals that have been classified as group1 by the ACGIH (confirmed human carcinogen)	Benzene, benzidine, lead, arsenic, beryllium, bromine, polyvinyl chloride, mercury

Table II: Determination of hazardous rate using acute chemicals toxicity (Manpower 2005)

HR	LC50 intake by inhalation in rats (mgL^{-1} aerosols and particulate matter during 4 hrs.)	LC50 intake by inhalation in rats (mgL^{-1} gases and vapors during 4 hrs.)	LD50 intake by the skin ($mgkg^{-1}$ body weight of rats)	LD50 intake orally ($mgkg^{-1}$ body weight of rats)
2	LC50 > 5	LC50 > 20	LD50 > 2000	LD50 > 2000
3	1 < LC50 < 5	2 < LC50 < 20	400 < LD50 < 2000	200 < LD50 < 2000
4	0.25 < LC50 < 1	0.5 < LC50 < 2	50 < LD50 < 400	25 < LD50 < 200
5	LC50 < 0.25	LC50 < 0.5	LD50 < 50	LD50 < 25

Table III: Calculation of exposure index (EI) (Manpower 2005)

EI	1	2	3	4	5
Exposure agents Particle size or vapor pressure according to aerodynamic diameter	Less than 0.1 mmHg wet and rough particles	0.1-1 mmHg dry and Fine particles	More than 100 µm 0.1-10 mmHg dry and Fine particles	from 10 - 100µm 10-100 mmHg dry and Fine particles	More than 100 mmHg, Fine powder less than 10 µm
Olfactory ratio threshold to permissible limit (TPL) for	< 0.1	0.1-0.49	0.5-0.99	1-2	2 <
Control measures	Appropriate With continued maintenance	Appropriate With continued maintenance	Appropriate With continued maintenance (dust mean)	not serious control (huge dust)	un controlled (huge amount of dust)
Weekly use of materials	The quantity used is less than 1kg or liter Negligible	low quantity of use 1-10 kilograms or liters	Average amount of use1-100 kilograms or liters Laborers are trained to work with chemicals	High usage quantity 10-1000 kilograms or liter Laborers are trained to work with chemicals	- High rate of uses - untrained workers - above 1000 Kgm or 1000L

Weekly working hours	>8	8-16 hrs.	16-24 hrs.	32-42 hrs.	32-42 hrs.

According to liquid chemicals, the exposure risk can be calculated by measuring vapor pressure at room temperature from the safety data sheets (MSDS), while solid materials the exposure risk of it depends on size of particles which can be determined according to the following equation:

$$Da = Dp \sqrt[2]{sg} \text{ .... } (2)$$

As (Dp) refers to diameter of particle, (Da) refers to diameter of aerodynamic, and (sg) is the density.

Moreover, the exposure level to different a chemicals, depends on the quantity and period of exposure. In the case of workers in chemical stores, exposure occurs within 30 hours per week that can be adopted as the basis for detection the factor of exposure.

1. Risk assessment stage: the risk assessment can be calculated from the following equation (3).

$$\text{Risk level} = \sqrt[2]{HRxER} \text{ .... } (3)$$

2. The HR represents hazardous rate (measured from 1-5 as in Table I and II and ER represents exposure rate (measured from 1-5 as in Table III of chemical substances, therefore, the calculated risk level is rounded for the nearest integer number.

3. Risk ranking: chemicals occupational exposure can be ranked from 1 to 5 as follows: (Risk level 1 neglected, 2: low, 3: medium, 4: high, 5: very high), the risk level can be identified from the risk matrix.

. Table IV: Matrix of risk level

ER / HR	1	2	3	4	5
1	1	1.4	1.7	2	2.2
2	1.4	2	2.4	2.8	3.2
3	1.7	2.4	3	3.5	3.9
4	2	2.8	3.5	4	4.5
5	2.3	3.2	3.9	4.5	5
Guide	Little	Low	Medium	High	Very high

3. Results

This study was conducted on seven main stores of chemicals at the University of Technology. Each store is managed by a store employee under the supervision of a member of the safety committee in the department, the responsibility of store employee is, the follow up inventory and storage of chemicals as well as to provide researchers and laboratories with the required materials, in addition to separate damaged and expired materials, submit periodic reports for total store, documenting needs and accidents, fourteen exposed workers were investigated in the current stud, the age mean and standard deviation was 47.28±8.4 year while the mean and standard deviation of years of experience is 8.5±4.45 years all store employees are married 100%.

Table V refers to assesment of health risk for exposure to chemical contaminants in the seven stores in five engineering departments. Chemical Engineering Department (CED), Applied Science

Department (ASD), Production Engineering And Metallurgy Department (PEMD), Petroleum Technology Department (PTD), Civil Engineering Department (CiED) and two researcher centers are Environmental Research Center (ERC) and Nanotechnology Center (NTC) respectively, from studying the monthly and quarterly inventory of chemicals of these departments and centers, it has been noted that there are 41 high demand of chemicals as shown in Table V, from results the Chemical Engineering Department, recorded the highest utilization rate of the chemical substances 100%, followed by Applied Science Department 78%, Environmental Research Center 68.3%, Civil Engineering Department 65.8% finally, Production Engineering And Metallurgy Department 9.7%. Generally in the University of Technology, the consumption of chemicals is low compared to other universities because of the nature of its departments activities like modeling, designing and simulation, while chemical work is limited to some laboratories. Actually, five departments out of sixteen and two centers out of three and fourteen employees two person in each department, divided in two groups, store employee directly exposed to chemicals because of they conducted all chemical store functions like inventory, materials providing, treated of accident and spills. While the second group is represented by safety officials in the department they are highly trained doctors, observed the work of the stores staff, training the workers in the chemical laboratories, preparing the manuals for safe handling of chemicals, and disseminate the concepts of chemical safety and security. university staff worked 30 hours per week, the daily exposure rate of workers is up to two hours so risk levels calculated on this exposure time in Table V the exposure rate, hazardous rate and risk level of each department were calculated according equations written in experimental work of this study, findings refer to Chemical Engineering Department has highest risk level according other department due to the amount of used chemicals.

Nitric acid in row 7 has HR value reach to 4 but the risk level differs from department to other depends on frequency of use, concentration of material, duration of exposure, in Chemical Engineering Department the risk level of nitric acid is 3.16 but in production and metallurgy engineering department reach to 4 because of heavy use of this material, other chemicals is subject to the same method in calculating the level of risk as shown in Table V, the first department (CED) recorded 9 items, 21.9% of materials with high risk level up to 4 were [hydrogen peroxide, arsenic, benzene, formaldehyde, cadmium, lead , bromine, methylene chloride and ethylene oxide), while in (PMED) three of four materials have 4 risk level 75%.

Table V: Risk factor of chemical materials in university of technology stores

Chemicals	CED			ASD		PMD		PTD		ERC		NTC		CiED	
	HR	ER	Risk factor	ER	Risk factor	ER	Risk factor	ER	Risk factor	ER	Risk factor	ER	Risk factor	ER	Risk factor
Hydrochloric acid	4	2.5	2.03	2.3	3.03	4	4	2.8	3.34	2	2.8	1.2	2.2	3.3	3.36
Hydrogen peroxide	5	4.6	4.8	4.1	4.52	US	-	3	3.8	1	2.2	2.3	3.39	2.5	3.53
Aldrin	2	1.4	1.6	US	-	US	-	1.2	1.54	US	-	US	-	US	-
Zinc oxide	3	2.5	2.7	1.5	2.12	US	-	US	-	0.25	0.86	US	-	1.25	1.93
Sulfuric acid	4	2.5	3.16	2.3	3.03	4	4	3.2	3.57	2.5	3.16	2.3	3.03	3.7	3.84
Potassium hydroxide	3	0.23	0.83	0.23	0.83	US	-	US	-	0.23	0.83	1.2	1.89	0.5	1.22
Nitric acid	4	2.5	٣.١٦	2.3	3.03	4	4	1.9	2.75	3	3.46	2.8	3.34	3.2	3.57
Acetaldehyde	3	4.6	3.7	1.5	2.12	US	-	3.5	3.24	2	2.45	1.8	2.56	2.2	2.56
Acetic acid	3	4	3.4	3.2	3.09	US	-	US	-	2	2.45	2.2	2.32	2.8	2.89
Chromic acid	4	2.5	٣.١٦	1.5	2.44	US	-	US	-	2.5	3.16	US	-	2.5	3.16
Ethyl Ether	3	4.6	٣.٧	3.6	3.28	US	-	3.8	3.37	1.5	2.12	1.1	1.8	0.8	1.54
Calcium carbonate	1	0.46	0.67	0.46	0.67	US	-	US	-	1.5	1.22	1.8	1.34	2.5	1.58
Zinc sulfate	1	1.5	1.22	1.5	1.22	US	-	US	-	1.5	1.22	0.4	0.63	1.5	1.22
Acetone	2	4.6	3.03	2.5	2.23	US	-	4	2.82	2	2	2.2	2.09	US	-
Ammonia	3	3	3	1.5	٢.١٢	US	-	US	-	1	1.73	US	-	2.2	2.56
Arsenic	5	4	4.4	2	3.16	US	-	US	-	3	3.87	US	-	3	3.87
Benzene	5	4	4.4	US	-	US	-	2.2	3.31	US	-	US	-	US	-

Formaldehyde	4	4.6	4.3	5	4.47	US	-	2.8	3.34	1	2	US	-	1.5	2.45
Toluene	3	3.2	3.09	US	-	US	-	3	3	US	-	1.2	1.89	US	-
Xylene	3	3.2	3.09	US	-	US	-	3.2	3.09	US	-	US	-	US	-
methylene chloride	4	4	4	US	-	US	-	3.8	3.89	US	-	US	-	US	-
ethylene oxide	4	4.2	4.09	4.2	16.8	US	-	1.2	2.19	US	-	0.8	1.78	US	-
Cadmium	4	4.2	٤.٠٩	1.2	2.19	US	-	US	-	3.5	3.74	US	-	3.5	3.74
Aniline	3	1.3	1.97	US	-	US	-	US	-	US	-	US	-	US	-
Calcium nitrate	1	0.23	0.48	1.2	1.09	US	-	US	-	0.57	0.75	1.2	1.09	1.5	1.22
Calcium carbonate	1	0.13	0.36	0.13	0.36	US	-	US	-	0.13	0.36	1.8	1.34	0.25	0.5
Lead	5	4.2	4.58	2.2	3.316	US	-	US	-	4.2	4.58	US	-	2.2	3.316
Bromine	5	3.8	4.35	US	-	US	-	US	-	US	-	1.8	3	US	-
Calcium hydroxide	2	1.2	1.54	3.2	2.53	US	-	1.2	1.54	1.2	1.55	2.5	2.23	1.2	1.55
Chlorine	5	4.3	4.6	US	-	US	-	2.5	3.53	US	-	US	-	US	-
Ethyl acetate	2	1.8	1.9	2.2	2.09	US	-	2.3	2.14	US	-	US	-	US	-
Ethanol	1	1	1	1.5	1.22	US	-	2.8	1.67	2.5	1.58	2	1.4	1.5	1.22
Methanol	1	0.8	0.89	2.7	1.64	US	-	2.6	1.61	2.5	1.58	2	1.4	1.8	1.34
Ethyl benzene	3	2.7	2.84	US	-	US	-	2.1	2.5	2.7	2.84	US	-	US	-
Iron oxide	2	1.09	1.47	1.09	1.47	3	2.44	US	-	US	-	0.45	0.94	US	-
Propanol	3	2.2	2.56	2.2	2.56	US	-	3	3	US	-	1.2	1.89	US	-
Kerosene	2	1.08	1.46	1.08	1.46	US	-	3.2	2.5	US	-	US	-	US	-
Magnesium oxide	3	2.2	٢.٥٦	2.2	2.56	US	-	US	-	2.2	2.57	0.8	1.54	2.2	2.56
Manganese compounds	3	1.34	2.004	1.34	4.02	US	-	US	-	1.34	2	0.75	1.5	1.34	2
Methylamine	4	2.45	3.13	2.45	3.13	US	-	US	-	2.45	3.13	US	-	2.45	3.13
Hexane	3	1.89	2.38	1.89	2.38	US	-	2.7	2.84	1.5	2.12	1.5	2.12	1.5	2.12

US: unused

4. DISCUSSION

In the present study, store employees exposed to different chemicals during the conducting of their duties, like high concentrated acids, ammonia, benzene, xylene with high risk levels. Exposure rate depends on the nature of the scientific department and its specialist, chemical use cannot be avoided for the need to be used in many aspects, such as industry and scientific research [11-14], but followed the clear regulations and put influence policy with continuous workers training aid in creating a base of workers they have experience in safe use with chemicals [15-17]. The experience with chemicals in Iraqi universities in general and the University of Technology in particular, the imposition of chemicals stock control [18], defining the responsibilities [19], reduce waste and leakage of hazardous materials, training workers and developing policies to improve performance in the field of chemicals work and followed the quality criteria and transparency in university performance in general and in the chemicals field specially. Significantly reduced the occupational exposure to these hazardous substances as well as provide environmental and health protection [19 and 20], the belief that periodic assessment helps to find immediate and strategic solutions, budget allocation to overcome obstacles, emphasis on inherent safety principles. Yari et al, [21], attempt to introduce chemical safety concepts into the curriculum because Hong et al, [22] considers educational programs as one of the most effective methods used to reduce the health risks.

5. CONCLUSION

From the survey of chemicals can be concluded that 71% of chemicals were rated as medium or high risk. Risk level can be controlled by reducing exposure time, supplied control measures and engineering modifications beside of administrative procedures, good practices and continuous training.

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