Availability of safety measures and knowledge towards hazardous waste management among workers in scientific laboratories of two universities in Lebanon

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***Abstract*: Hazardous Waste Management (HWM) is critical to human health outcomes and environmental protection. A survey-based observational study was conducted in scientific laboratories of a public and a private university in Lebanon, where a total of 309 participants were recruited to evaluate the knowledge regarding safety measures to be applied when collecting and storing waste. Chi-square and Fisher's exact tests, Independent Sample T-test, Pearson correlation coefficient, and ANOVA were used for comparing differences and associations among socio-demographic variables. Linear regression models were used to map predictors of knowledge score and its relationships with demographic variables as well as training on proper HWM.**

A significant association (p<0.05) was found between knowledge score and job function, years' experience, educational level, professional status, work schedule, and training on HWM. Participants had adequate perceptions regarding the impact of HWM on health and the environment. Linear regression modeling revealed that knowledge score was significantly higher among bachelor level lab workers compared to those with doctoral degrees (p=0.043), full-time workers versus part-timers (p=0.03), and among public university participants compared to those of private university (p<0.001). It highlights the importance to improve the culture, attitude, and practice of proper HWM in scientific laboratories.

***Keywords*: Hazardous waste, waste management, university, safety measures, knowledge score, scientific laboratory workers.**

I. INTRODUCTION

University laboratories are specialized sites for learning and conducting research, in which a large amount of waste are generated. Based on their properties, these wastes can be classified as inert (non-hazardous) or hazardous.

Hazardous waste (HW) is a priority issue for the State Members of the World Health Organization (WHO) Regional Office for Europe and was on the agenda of the Sixth Ministerial Conference on Environment and Health [1]. WHO has also published a biosafety manual outlining the basics of laboratory biological safety, which is considered a guide for safe laboratory practice [2].

At the beginning of the 1980s, the United States of America (USA) defined hazardous waste for the first time. This waste was described as corrosive, explosive, easily oxidizing, flammable, harmful, irritating, reactive or toxic [3]. According to the Resource Conservation and Recovery Act (RCRA), HW is defined as any waste or combination of waste which poses a substantial presence or potential hazard to human health or to living organisms because such waste can be non-degradable, persistent in nature, biologically magnified and they may cause or tend to cause detrimental cumulative effects [4].

Among others, HW may include chemical, biological and radioactive waste. Chemical waste is considered hazardous when it presents a potential risk to humans and/or to the environment, where the Environmental Protection Agency (EPA) definition of either "listed" waste or a "characteristic" waste applies, as per 40 Code of Federal Regulations (CFR) Chapter 1 Subpart A 261.3. Chemical waste can be in the form of liquid, semi-solid and solid wastes and can be categorized basing on their characteristics of toxicity, reactivity, flammability and/or corrosively [5]. Improper handling and disposal of these kinds of waste may lead to critical harm on personal safety and on the environment pollution [6]. As for biological waste, it consists of any material that contains or has been contaminated by a bio-hazardous agent including, but not limited to, petri dishes, surgical wraps, culture tubes, syringes, needles, blood vials, and that presents a potential source of infections and occupational hazards [7]. Previous studies revealed gaps in the knowledge and attitude of some laboratory workers at the academic university laboratories regarding the biological waste practices [8]. For example, laboratories manipulating human blood must adhere to Occupational Safety and Health Administration's (OSHA) standard for occupational exposure to blood borne pathogens (29 CFR 1910.1030), which requires waste containment, labeling and treatment [9].

As for radioactive waste, it can be classified as solid, liquid, and gaseous if they are suspected or have contacted radioactive material. Besides, biological radioactive waste is defined if any waste generated from the incorporation of a radioactive substance into a living organism or system(animals, plants, tissues, cell cultures, viral material, bacterial organisms). Each type of radioactive waste requires different procedures for handling, reporting and disposal [10].

As academic scientific laboratories in universities generate different types of HW, they have several particular challenges in managing HW as compared to industry. Those include the possession, storage, collection, transport and disposal with appropriate labeled and safe containers of HW in research laboratories [11]. In addition, one of the main key aspects of chemical, biological safety is the waste management (WM) principles, which should be communicated to the laboratory workers and applied effectively in order to avoid their harmful impact [12].

For this purpose, designated staff must follow a structured guideline concerning the handling and disposal of these HWs. Several methods of treatment may be used before disposing HW such as incineration, neutralization, and chemical fixation. These methods are important to weaken the toxicity of substances and to transform the HW into more inert form.

A good planning is also necessary to meet the recommended requirements of storing, disposing, and treating HW in order to avoid their potential impact on the environment and public health [13, 14]. A previous study in Trinidad revealed that the majority of undergraduate students had a high level of awareness about the importance of labeling and collecting of waste generated during their laboratory sessions for proper waste management and disposal procedure [15]. Another study done at Kermanshan University of Medical Science, Iran reported a good knowledge level with respect to proper hazardous waste management (HWM) (collecting, processing and disposal) to manage its adverse effects on health and the environment [16]. Unfortunately, there are no reported data and existing regulations related to HWM knowledge and practices of academic laboratories in public university in Lebanon. Consequently, the objective of this study was to assess the HWM knowledge among workers in scientific laboratories of the Lebanese public university and at research facilities of the private university and to explore the impact of proper HWM on health and the environment.

II. MATERIALS AND METHODS

2.1 Study design and population

This was a survey-based observational study conducted during 2019-2020 at the research and practical laboratories of faculties and branches of the public Lebanese University, located in 6 different governorates, and in the research core facilities of a private university in Lebanon. In total, 309 lab workers participated in the survey, with 220 from the public university and 89 from the private university. At the beginning, 210 participants from the public university and 55 from the private university responded to a face-to-face interview and answered the paper-based questionnaire. Then, due to COVID-19 outbreak, the survey was converted to an online-based survey distributed to lab workers in the public and private university, where only 10 out of 100 lab workers from the public university and 34 out of 465 lab workers from the private university responded to the online survey.

2.2 Criteria for participation in this study

The targeted population are senior researchers, research assistants, post-doctoral fellows, volunteers, masters and Ph.D. candidates of both genders from chemical or biological fields of research and practical laboratories of scientific faculties at the Lebanese public university and at research facilities of the private university.

2.3 Data collection and study instrument

The survey was prepared by our team panel based on existing literature of the prudent practices in the laboratory [17] and guidelines of OSHA regulations [7]. It consisted of 26 main questions organized into five parts. All of the questions were close-ended.

The first part consisted of 10 questions about the geographic distribution, affiliation and socio-demographic information of the studied population (location, region, sections and type of scientific laboratories, functions of laboratory workers, their years of experience, age, gender, educational level, professional status and type of work schedule).

The second part contained 8 questions concerning the HW generated from these laboratories and their proper management (types, categories, components of HW, training and information communication of HWM, availability of safety measures, equipment for collection and labeling of HW).

The third part consisted of one question that dealt with the evaluation of the knowledge of participants towards the safety measures to be applied during the collection and storage of waste. It contains 13 requirements provided from OSHA regulations for laboratory safety [7].

The fourth part consisted of 5 questions related to the disposal method and treatment of HW.

The fifth part contained 2 questions assessing the perception of participants on the impact of HW on health and the environment in case of negligence of proper security measures application during their collection, storage and treatment.

Before the study initiation, the survey was pre-tested with a small sample of scientific laboratory workers to assess its clarity and feedback. Following the pre-survey, some questions were reworded. Participants were approached in a way where no interference in their duties or work schedules occurred.

2.4 Statistical analysis

Descriptive results were reported as frequency and percentages for categorical variables and mean ± standard deviation (SD) for continuous ones. Statistical evaluation was conducted through a bivariate and multinomial analyses to identify factors of main outcomes. Data was entered and analyzed using IBM SPSS 25 (IBM Corp, Armonk, NY) software. Waste management knowledge scale consistency assessment and factor analysis were performed using R statistical software version 4.0.3 (The R Foundation for Statistical Computing, Vienna, Austria) in R Studio v.1.3.1 environment and with “psych” package.

Based on the 13 yes/no questions evaluating knowledge of optimal waste management practices (third part), a score was calculated by summation of all responses to these questions (each yes: score of 1; no: score of 0; minimum score: 0; maximum score: 13). To confirm the unidimentionality of the question set (knowledge), an optimal implementation of Parallel Analysis (PA) (Timmerman, & Lorenzo-Seva, 2011) was used. A tetrachoric correlation matrix was computed based on the dichotomous nature of the question set. Internal consistency of these questions was assessed using Cronbach’s Alpha (special case Kuder–Richardson Formula 20).

All analyses were conducted with a confidence interval of 95%, and a p-value <0.05 was considered significant. Chi-square and Fisher’s exact tests, Independent Sample T-test, Pearson correlation coefficient, and one-way and Welch’s ANOVA were used for comparing differences and associations among variables. Further post-hoc tests (Tukey HSD and Bonferroni) were calculated to evaluate relation between knowledge score on one hand and professional status and work schedule on the other hand. Moreover, linear regression models were used to map predictors of knowledge score and assess nature of relationships with demographic as well as core variables. Furthermore, associations were studied between the dependent variable “knowledge score” and the different independent variables of socio-demographic characteristics (function, years of experience, age, gender, educational level, specialty, professional status, work schedule) and training.

The study protocol at the public university was approved by the office of the Dean of Doctoral School of Science and Technology (DSST) under protocol ID 18-757. Prior to respondents’ verbal consent, they were informed about the purpose of the study and highlighting that participation was voluntary and refusal to participate in the study has no penalty.

Before starting the study at the private university, the survey was approved by its institutional review board under the ID SBS-2019-0384. Participants were provided with a hard copy of the study summary and consent form in English in the physical recruitment phase, and online informed consent was obtained in the online recruitment phase. Anonymity, privacy and confidential issues were respected throughout the study, and all analysis were conducted in a de-identified manner.

III. RESULTS

3.1 Geographic distribution and affiliation of the studied population in scientific laboratories of universities in Lebanon (N=309)

A total of 309 participants were recruited from different sections of scientific laboratories, where 220 participants (71.2%) belonged to public university and 89 (28.8%) to the private university. Regarding affiliations of participants from the public university, 47.7% were from the Faculty of Sciences, 25.5% from the Doctoral School of Science and Technology, 16.8 % from the Faculty of Public Health, 9.1% from the Faculty of Pharmacy, and only 0.9 % from the Faculty of Medical Sciences, while all of the respondents from the private university were from Research Core facilities at Faculty of Medicine.

Respondents from the public university were from different branches and in different regions of Lebanon with 62.3% from Hadath, 18.6 % from Tripoli, 5.9 % from Nabatieh, 4.5 % from Zahle, 6.8% from AlFanar, 1.8% from Saida, while all of the respondents from private university were from Beirut.

Among all participants, 66.3% worked in biology labs, 25.6% in chemistry labs and 8.1% in biochemistry labs. As for lab types, most of them (72.8%) were recruited from research labs and 27.2% from practical labs.

3.2 Socio-demographic characteristics of the participants

Regarding socio-demographic characteristics of participants, 40.5% were research assistants, 14.9% researchers, 5.8% post-doctoral fellows, 9.7% Ph.D candidates, 24.3% master students and 4.8% were volunteers. In terms of experience, 63.8% had more than 10 years and 36.2% had less than 10 years of experience. More than half of participants (54.4%) were aged between 20 and 30 years old, while 24.3% were between 30-40 years old, 1.0% less than 20 years old and 20.3% older than 40 years old. The majority of the workers (79.9%) were female. As for the educational level, the majority of laboratory workers (58.6%) had a master’s degree, 28.2% had doctorates and 13.3% had a bachelor’s degree.

Concerning participants’ professional status, 37.9% were employed with determined duration contract (DDC), 21.4% with undetermined duration contract (UDC), 27.2% had an academic and 11.0% had a non-academic position, 1.3% were students and 1.3% were volunteers. In addition, only 262 out of 309 answered about their specialty, where 64.1% of them belonged to biological sciences, 14.9% biomedical sciences, 15.3% chemical sciences and 5.7% to organizational/industrial/public health domains. Besides, full-time schedule laboratory workers represented the majority of them (75.4%) while 24.6% were part-timers.

3.3 Training on proper management of the hazardous waste of the studied population Out of total 309 respondents, only 31.1% (96) reported having received training on proper HWM, while 68.9% did not receive such training. Few of them (23.3%) had communicated the training information with occupational and health safety (OHS) service of the university, while only few had communicated these information with waste manager or hygienist designated in the laboratory (10.2%) or with the core facility coordinator (11.0%).

3.4 Types of hazardous wastes generated from scientific laboratories Figure 1 shows the types of HW generated from the studied scientific laboratories. Among participants, (75.4%) classified the types of HWs generated from their laboratories as chemical wastes, (60.5%) as biological wastes, (7.8%) as radioactive wastes, (31.7%) as organic wastes and (16.5%) as mixed wastes.

Based on HW categories, among the chemical wastes, the flammable liquid was declared by (50.8%) as a dominant category, following by non-flammable toxic (39.8%), flammable & corrosive toxic waste (29.4%), flammable toxic (21.5%), flammable solid (19.4%), and gaseous (13.6%). Concerning the categories of biological wastes, the highest rate was related to biological fluids as stated by (42.1%) of the participants, followed by wastes generated during animal handling (27.8%) and from infectious waste (microorganisms) (34.0%).

Among laboratory workers (82.2%) identified the components of wastes produced as fermentable materials, (19.7%) of as miscellaneous wastes and (9.1%) as electrical waste and electronic equipment.

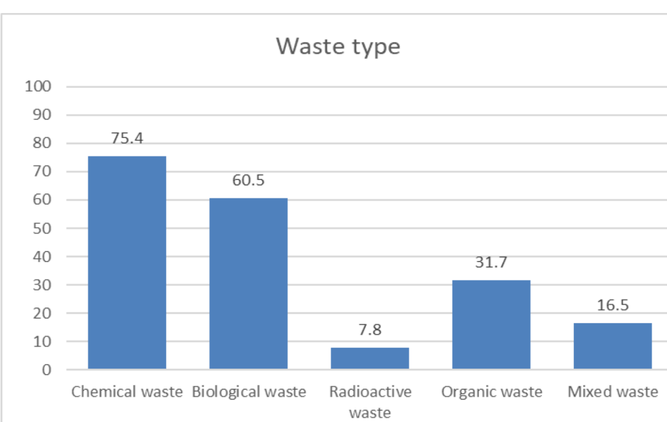

Figure 1 : Type of generated hazardous wastes (%) reported from the studied laboratories

3.5 Availability of safety measures and disposal methods for the different waste generated

Table 1 displays the availability of safety measures and the disposal methods adopted for the different waste generated in scientific laboratories. 21.8% of laboratory workers answered that they have posted instructions on sorting and packaging waste, (23.9%) have displayed instructions on the collection and storage according to a waste category, (25.2%) have followed the safety instructions in case of accidental spills of dangerous products and (37.2%) have followed labeling of waste containers according to their types/categories.

In addition, (56.6%) answered they have specific bins/containers to eliminate waste generated according to their types or categories, (34.6%) used black color for general wastes, used yellow color for HWs and (36.4%) or used yellow boxes for sharp wastes.

Concerning the elimination of recyclable wastes, (34.0%) of the participants declared that their laboratories are equipped with specific bins for recyclables waste containers, (28.5%) had applied the waste sorting (triage) systematically for ordinary waste**,** (28.2%) had applied the paper savings policy **(**re-use of the papers or double-sided duplicate) and (23.0%) of them, use scanner, digital workspace and email. Regarding the elimination of non-recyclable wastes, (22.0%) manipulated the properties of chemical wastes by neutralization, (38.2%) discharged the laboratory equipment soiled by a biological agent, by autoclaving or inactivation before incineration, (21.1%) eliminated the sharp objects by incineration or autoclaving. Among the participants, (28.2%) stated that HW were disposed by internal management, (13.6%) by external management and (48.5%) stated that HW were discarded into normal waste containers.

Table 1: Availability of safety measures for proper waste management in the studied laboratories (N=309)

Safety measures (N%)		
Posted instructions on sorting and packaging waste	No Yes	242(78.3) 67(21.8)
Display instructions on the collection and storage according to the category of this waste	No Yes	235(76.1) 74(23.9)
Safety instructions in case of accidental spills of dangerous products	No Yes	231(74.8) 78(25.2)
Labeling of waste containers according to their types / categories	No Yes	194(62.8) 115(37.2)
Presence of specific bins / containers to eliminate waste generated according to their nature / category	No Yes	134(43.4) 175(56.6)
Introducing black color for general waste container	No Yes	202(65.4) 107(34.6)
Introducing yellow color for hazardous waste bags	No Yes	202(65.4) 107(34.6)
Introducing yellow boxes of sharp and sharp waste	No Yes	202(65.3) 107(36.4)
Disposal methods for different waste generated by scientific laboratories		
Elimination of non-recyclable waste by		
Presence of bins for recyclable waste	No Yes	204(66.0) 105(34.0)
Waste sorting (triage) systematically for ordinary waste	No Yes	221(71.5) 88(28.5)

Application of paper saving policy		
Re-use of the papers (double-sided duplicate)	No Yes	222(71.8) 87(28.2)
Use scanner, digital workspace and email	No Yes	238(77.5) 71(23.0)
Elimination of non-recyclable waste by		
Neutralization by a reagent the properties of chemicals	No Yes	241(78.0) 68(22.0)
Autoclaving or inactivation before incineration laboratory equipment soiled by a biological agent	No Yes	191 (61.8) 118(38.2)
Incineration / Autoclaving sharp, sharp objects	No Yes	244(78.9) 65(21.1)
Internal management	No Yes	222(71.8) 87(28.2)
External management	No Yes	267(86.4) 42(13.6)
Normal waste containers	No Yes	159 (51.5) 150(48.5)
More than 1 option may be selected in each section therefore percentage may add up to more than 100		

3.6 Perception of participants regarding the impact of hazardous waste on health and on the environment in case of negligence of effective measures during their collection, storage and treatment

Figure 2 showed the participants' perception regarding the impact of HW on health and on the environment in case of the negligence of adequate security measures during their collection, storage and treatment. Half of participants (52.4%) knew that HW may lead to an acute toxicity, (60.8%) reported possible skin corrosion, (36.6%) linked it to serious eye damage,(61.8%) to respiratory sensitization, (34.6%) to mutagenicity, (62.8%) to carcinogenicity and (30.7%) to reproductive toxicity (teratogenicity).

Regarding the impact of HW on the environment, (29.1% of the participants) stated that HWs may be harmful to the aquatic environment. Moreover, (64.1%) reported that it may lead to the diffusion of pollutants, to climate change (36.9%), to the depletion of natural resources (38.5%), to soil contamination (66.3%), to the air pollution (53.7%) and to the dissemination of odor, olfactory and visual nuisances (57.1%).

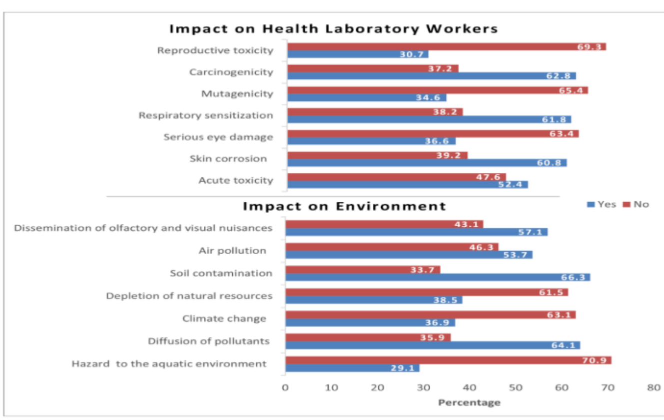

Figure 2: Perception of the participants regarding the impact of hazardous waste generated from the scientific laboratories of universities in Lebanon on health and environment in case of the negligence of effective measures during their collection, storage and treatment (N=309)

3.7 Knowledge score of safety measures regarding HW collection and storage

As mentioned, the knowledge score was established based on 13 questions evaluating waste management practices extracted from OSHA regulations for laboratory safety [17]. The established correlation matrix was very good (Kaiser-Meyer-Olkin (KMO)) test = 0.96707). Out of 13 hypothesized factors, only 1 factor had an Eigevalue higher than 1 (factor 1, Eigenvalue = 9.604). All the questions concerning the knowledge of waste management had high factor loading. Kuder–Richardson Formula 20 indicated that this score possessed an excellent internal consistency [7].

The mean total knowledge score of participants was 9.02±4.34 (maximum attainable score, 13). Referring to the knowledge of safety measures to be used when collecting and storing HWs, Table 2 showed that 86.4% of participants had knowledge about the importance of wearing personal protective equipment (PPEs). Knowledge about Material Safety Data Sheets (MSDS), fire extinguishers and use of retention bins were reported by (78.3%, 60.2%, and 61.8% respectively). 78.3% of the participants showed knowledge regarding the container collection program for each waste category. In fact, 68.9% of participants reported awareness of designation of on-site storage places, and 69.6% application of a regular inspection of the waste storage according to the suitable conditions. Moreover, 65.0% of respondents showed awareness towards signaling of a security protocol during waste shipments, and 63.4% presence of a warning for non-compliance with waste treatment regulations. Similarly, 67.0% showed knowledge of signaling regulations for the storage of waste according to their type, 67.7% participants reported knowing waste treatment planning by type, 67.6% also showed knowledge of installation of a centralized alarm in case of incident/accident during the transport of the waste, and 59.2% were aware about the presence of a procedure of the traceability of the fire.

Table 2: Knowledge towards safety measures when collecting and storing waste in scientific laboratories of the studied population (N=309)

Safety measures		(N%)
Wearing personal protective equipment (PPE)	No Yes	42(13.6) 267(86.4)
Materials Safety Data Sheets (MSDS)	No Yes	67(21.7) 242(78.3)
Fire extinguishers	No Yes	123(39.8) 186(60.2)
Use of retention bins	No Yes	118(38.2) 191(61.8)
Establish a container collection program for each waste category	No Yes	67(21.7) 242(78.3)
Designation of on-site storage places	No Yes	96(31.1) 213(68.9)
Application of a regular inspection of the waste storage according to the suitable conditions	No Yes	94(30.4) 215(69.6)
Signaling of a security protocol during waste shipments	No Yes	108(35.0) 201(65.0)
Presence of a warning for non-compliance with waste treatment regulations	No Yes	113(36.6) 196(63.4)

Signaling regulations for the storage of waste according to their type	No Yes	102(33.0) 207(67.0)
Waste treatment planning by type	No Yes	72(23.3) 237(67.7)
Installation of a centralized alarm in case of incident / accident during the transport of the waste	No Yes	100(32.4) 209(67.6)
Presence of a procedure of the traceability of the fire	No Yes	126(40.8) 183(59.2)

3.8 Association between knowledge score and participants' characteristics (N=309)

The associations between socio-demographic characteristics and training on waste management with knowledge score is shown in Table 3.

There were significant associations between knowledge score on safety measures for waste management and job function (<0.001). The highest knowledge score was among research assistants (10.46±0.36) followed by researchers and Master's students (8.67± 0.68; 8.61±0.51 respectively) then by PhD candidate, volunteers and post-doctoral fellows (7.4±0.75; 6.53± 1.02 ; 6.44± 0.72; respectively); Significant associations were also found between knowledge score and years of experience (p=0.008) where participants with less than 10 years of experience (9.87± 0.37) had better knowledge score than those with more than 10 years of experience (8.55± 0.32); educational level (p=0.001) where participants with Bachelor degree had the highest knowledge score (10.78± 0.61) as compared to Master degree (9.5518± 0.32) and doctorate (7.87± 0.46); professional status (p=0.001) where participants with CDD or CDU (9.16± 0.36 and 10.85 ± 0.52, respectively) had better knowledge score than non-academic (7.21± 0.72) and academic (8.50± 0.51) positions volunteer (5.0± 0.90) and students (5.5± 1.85); work schedule (p=0.004) where full timer had better knowledge score (9.42± 0.28) than part timer (7.8± 0.47); and training on proper waste management (p<0.001) where trained participants had lower knowledge score (7.40± 0.40) than non-trained (9.76± 0.30) participants.

No significant associations were found between knowledge score and age, gender, and specialties groups (p= 0.145, 0.317 and 0.610 respectively). Furthermore, one-way ANOVA revealed no significant association between specialties groups and knowledge score (p=0.610).

Table 3: Associations between knowledge score and participant characteristics

Variable		**N(%)**	**Mean(SD) of Knowledge Score of waste management**	**p-value**	**Statistical Test**
Job function	Researcher	46(14.9)	8.67 (0.68)	<0.001	ANOVA
	Research assistant	125(40.5)	10.46 (0.36)		
	Ph.D candidate	30(9.7)	7.40 (0.75)		
	Master's student	75(24.3)	8.61 (0.51)		
	Volunteer	15(4.9)	6.53 (1.02)		
	Post-doc fellow	18(5.8)	6.44 (0.72)		
Years of experience	<10 years	112(36.2)	9.87 (0.37)	0.008	Independent Samples T-test
	>10 years	197(63.8)	8.55 (0.32)		
Age	<20 years	3 (1.0)	6.0 (2.52)	0.145	ANOVA
	20-30 years	168(54.4)	8.66 (0.33)		
	30-40 years	75(24.3)	9.23 (0.47)		
	>40 years	63 (20.4)	9.90 (0.61)		
Gender	Males	62 (20.1)	8.53 (0.59)	0.317	Independent Samples T-test
	Females	247(79.9)	9.15 (0.27)		
Educational level	Bachelor	41(13.3)	10.78 (0.61)	0.001	ANOVA
	Master's	181(58.6)	9.18 (0.32)		
	Doctorate	87(28.2)	7.87 (0.46)		
Specialties groups	Biological sciences	168(64.1)	9.88 (0.31)	0.610	ANOVA
	Biomedical	39(14.9)	9.26 (0.67)		
	Chemical	40(15.3)	9.35 (0.70)		
	Organizational Industrial/ Public health	15(5.7)	8.67(1.36)		
Professional status	DDC	117(37.9)	9.16 (0.36)	0.001	ANOVA
	DUC	66(21.4)	10.85 (0.52)		
	Non-academic position	34(11.0)	7.21 (0.72)		
	Academic position	84(27.2)	8.50 (0.51)		
	Volunteer	4(1.3)	5.0 (0.90)		
	Student	4(1.3)	5.5 (1.85)		
Work schedule	Part time	233(75.4)	7.80 (0.47)	0.004	Independent Samples T-test
	Full time	76(24.6)	9.42 (0.28)		
Training on proper waste management	No	213(68.9)	9.76 (0.30)	<0.001	Independent Samples T-test
	Yes	96 (31.1)	7.40 (0.40)		

3.9 Knowledge score determinants

Linear regression models were constructed to map predictors of knowledge score and assess nature of relationship with different characteristics while adjusting for possible confounding factors, as shown in Tables 4 and 5.

It seems that those with bachelor degree (constituting master's students or staff whose highest obtained degree was a bachelor's) were associated with significantly increased knowledge score than those with a doctoral degree p=0.043 (Table 4).

Moreover, respondents from the public university had significantly higher knowledge score than those of the private university. Additionally, those working full-time schedule were significantly associated with higher knowledge score than part-time p=0.030 (Table 5).

Table 4: Linear regression model of knowledge score with demographics and educational characteristics

Model 1	**Unstandardized Coefficients**		**Standardized Coefficients Beta**	**T**	**p**	**95.0% Confidence Interval for B**		**VIF**
	B	**Std. Error**						
(Constant)	5.804	.813		7.136	<.001	4.203	7.404	
Age>40 years (reference)	-	-	-	-	-	-	-	-
Age=Less than 20 years	-2.950	2.393	-.067	-1.233	.219	-7.659	1.758	1.058
Age=20-30 years	-.381	.711	-.044	-.536	.593	-1.781	1.019	2.414
Age=30-40 years	-.082	.715	-.008	-.115	.908	-1.489	1.324	1.806
Gender=Female	.353	.608	.033	.580	.562	-.844	1.550	1.141
Educational level: Doctoral (reference)	-	-	-	-	-	-	-	-
Bachelor	1.678	.824	.131	2.037	**.043**	.057	3.299	1.501
Master	1.078	.575	.123	1.875	.062	-.053	2.210	1.543
University=Public university	3.289	.532	.344	6.178	<.001	2.241	4.337	1.117

VIF: Variance inflation factor

Adjusted R^2=0.146, p<0.0001
Variables included in first step: Age, Gender

Table 5: Linear regression model of knowledge score with work-related characteristics

Model 2	**Unstandardized Coefficients**		**Standardized Coefficients Beta**	**T**	**p**	**95.0% Confidence Interval for B**		**VIF**
	B	**Std. Error**						
(Constant)	6.089	1.395		4.366	.000	3.344	8.833	
Gender=Female	.203	.618	.019	.328	.743	-1.013	1.419	1.189
Age>40 years (reference)	-	-	-	-	-	-	-	-
Age less than 20 years	-2.890	2.457	-.065	-1.176	.241	-7.726	1.946	1.127
Age=20-30 years	-.667	.848	-.077	-.787	.432	-2.337	1.002	3.468
Age=30-40 years	-.148	.722	-.015	-.205	.838	-1.569	1.274	1.862
Educational level: Doctoral (reference)	-	-	-	-	-	-	-	-
Bachelor	1.713	.837	.134	2.046	.042	.065	3.360	1.566
Master	1.016	.576	.116	1.765	.079	-.117	2.149	1.562
Schedule: full time	1.224	.562	.122	2.179	**.030**	.119	2.329	1.136
Received training	.110	.647	.012	.170	.865	-1.164	1.384	1.743
University = Public University	2.843	.714	.297	3.984	.000	1.439	4.247	2.028
Experience ≥ 10 years	-.944	.674	-.105	-1.401	.162	-2.270	.382	2.037

VIF: Variance inflation factor

Adjusted R^2=0.160
Variables included in first step: Age, Gender, Educational level

IV. DISCUSSION

Academic research laboratories should be concerned with meeting the fundamental safety measures of HWM. The primary objective of the study was to assess the knowledge regarding safety measures to be applied when collecting and storing HW at scientific laboratories of two universities, as well as to explore related factors influencing such knowledge on HWM. To our knowledge this is the first study of its kind conducted in academic laboratories in universities of Lebanon.

In our study, most of the HWs generated from academic labs were chemical and biological. The number of academic labs that manipulates waste containing radioactive substance is very small. This is in concordance with a previous Brazilian study that was classified their HW as chemical, infectious and radioactive waste [17]. Our results suggest that safety measures for proper HWM may not be available and applied in studied laboratories. This was further reflected by the level of knowledge regarding the safety measures to be applied. In addition, a moderate performance was noticed regarding the proper disposal methods, segregation and elimination of recyclable wastes, paper saving policy and the adequate elimination of non-recyclable waste. Such practices seem substandard, especially when compared with other reports from health-related academic laboratories. For instance, this was in contrast with a study conducted in Isfahan University of Medical Sciences in which higher rates of recycling and better management of HWs generated from all their faculties were demonstrated [14].

The impact caused by HW on health and the environment is of increasing concern. As stated earlier, improper handling and disposal of waste may have a critical impact on personal safety and on the environment pollution [16]. Furthermore, HWs present potential risk of infections and occupational hazards [7].

Our results showed that participants were aware of such impact on health especially in terms of carcinogenicity, respiratory sensitization, skin corrosion, acute toxicity, and to a lesser extent on serious eye damage, mutagenicity, and reproductive toxicity; such awareness is essential due to the serious nature of this impact and the risk associated with working in laboratories with HWs; for example, accidents such as respiratory, due to inhalation, or skin or eye contact are reported as common in other studies [18]. Another study conducted at Turkey revealed a causal association between hazardous waste related exposures and chronic and reproductive health outcome [12].

Concerning their impact on the environment, the majority of participants reported soil contamination, diffusion of pollutants, dissemination of odor, olfactory and visual nuisances and air pollution, and, to a lesser extent, depletion of natural resources, climate change, and aquatic environment, which is aligned with the results of a study conducted at Kermanshah University of Medical Sciences, Iran, which revealed a good knowledge level about the health and environmental effects of HW [16]. A previous study conducted in Turkey revealed the importance of development of HWM program to avoid the environmental problems resulting from HWs [19].

One third of participants (31%) stated receiving training on proper HWM. In addition, the reported availability of safety measures adopted for the different wastes generated in scientific laboratories ranged from 21.8% to 56.6% regarding the various items. This indicates a lack of compliance with the requirements of HWM according to OHSA regulations [20]. Such lack should be further evaluated for the obstacles, whether the lack is due to unavailable safety measures/materials, or to issues related to the overall processing of such wastes.

A significant association was shown between safety measures knowledge with trained and non-trained laboratory workers ($p<0.05$); the mean score was 7.40 ± 3.892 for trained workers and 9.76 ± 4.339 for non-trained laboratory workers. This is may be due to that non trained participants have other information resources than by training. In this regard, this high level of knowledge percentage can be attributed to the fact that students are informed during the orientation session by their assistant laboratory or their principal investigator before involving in the practical and research laboratories. Nevertheless, further assessment of such link is warranted because several regression models could not elaborate further training as a predictor of knowledge score.

An unsatisfactory performance was noticed regarding the proper disposal methods segregation and elimination of recyclable wastes, paper saving policy and the adequate elimination of non- recyclable waste. This is in contrast with the a study done in Isfahan University of Medical Sciences stating higher rates of recycling, and managing of HWs generated from all their faculties [14].

Concerning knowledge of participants towards proper HWM, the mean total knowledge score of participants was 9.02 ± 4.34 (maximum attainable score 13) which is consisting with the finding of study done at University of Trinidad that revealed a high level of knowledge score awareness regarding the waste disposal methods [21].

It was noticed also that most of participants had a better knowledge regarding the importance of PPEs as safety tools to be complied as well as the implication of MSDS as a good source of information to be referred in order to implement an effective HWM than other safety measures. This may be due to PPEs and MSDS are usually more highlighted than other required safety measures during the first orientation session of practical or research laboratories. This is in concordance with a study conducted at natural science laboratories of Bicol University College of Science, Philippines where participants had more knowledge on MSDS and PPEs than other safety measures in this regard [21]. These tools are required by the general guideline for hazardous waste handling and disposal recommended by EPA and the federal and State Department of Transportation [22].

An association was shown between knowledge score and job functions ($p<0.001$), years of experience ($p=0.008$), educational level ($p=0.001$), professional status ($p=0.001$) and work schedule ($p=0.004$), where research assistant followed by master's students level and workers with more than 10 experiences and part time workers had a high knowledge score (mean=10.46, 8.61, 8.55 and 9.42 respectively). Our results were in agreement with the finding of a study done in Iran that reported a significant association between the mean score of awareness with the job functions and the educational level of subjects [16]. This was also in agreement with another study at University of the West Indies showing that the difference in the mean percent awareness was due to variations in experience in the laboratory environment [23].

Besides, our findings revealed that there is a non-significant association between knowledge score of safety measures, age, gender and specialties' of participants ($p>0.05$). A study done in Iraq found that there was no gender difference in the participant's knowledge of the international biohazard, safety symbols and compliance with the recommended hazardous waste disposal [24], and other study at Egypt showing no significant differences between the mean scores of knowledge of waste management according to age, and gender [25].

Concerning specialties, our result differs from the findings performed at Najran University of Saudi Arabia study that revealed significant differences in the degree of participants' awareness on safety measures practiced in school laboratories according to specialization in favor of chemistry [26] and from the findings of Alahmadi (2016) that did not identify statistically significant differences due to specialization [27].

Our results show that only 31.1% of participants have received training on proper management of the HWs. This is similar to a study in Egypt that also reported that only 3 out of 5 personnel in teaching laboratories have received training on waste management [25]. Proper training regarding HWM should be conducted for all laboratory workers regularly since as mentioned above improper knowledge about safety measures to be applied regarding HWM leads to a negative impact on health and on the environment.

In order to assess the impact of the studied population characteristics with knowledge score multivariate linear regression models were performed, they revealed that those with bachelor degree (consisting of master's students or staff whose highest obtained degree was a bachelor's) were significantly ($p=0.04$) associated with increased knowledge score than those with a doctoral degree. These findings were consistent with in a study conducted at Kermanshah University of Medical Sciences in Iran, which reported that most of respondents having the highest level of awareness were those with a diploma degree ($p=0.005$) [16]. Moreover, regression models revealed that those working full-time schedule were significantly ($p=0.03$) associated with higher knowledge score than part-time. This may be due to that full time workers have more work stability so they can focus further on their work performance. No previous studies show an association between the work schedule of laboratory personnel and their knowledge regarding the safety measures for proper HWM.

V. LIMITATIONS AND FURTHER STUDIES

This study has some limitations. First, it is performed in only two institutions in Lebanon, so further studies are needed in other institutions across Lebanon in order to confirm and generalize our findings. Second, the self-reported nature of the survey done by some participants may lead to information bias. Additionally, sampling bias may have arisen due to the online recruitment phase. Therefore, future studies may done face to face and include pre and post effectiveness of safety awareness implementation at higher education institutions.

VI. CONCLUSION

The main contribution of this study is to provide good insight of academic lab workers in scientific laboratory of universities in Lebanon toward the required safety measures to be applied to ensure an effective HWM and on the impact of HW on occupational health and on the environment. However, the improvement of the culture, attitude, and knowledge of proper WM are needed in such laboratories. Additionally; regular inspections should take place concerning storing and eliminating HW. Furthermore, refresher trainings about safety measures for an effective HWM should be encouraged by the Environmental Health & Safety which could have protective impacts on health and on the environment.

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