Safety and Health at Work 11 (2020) 193–198

Contents lists available at ScienceDirect

Safety and Health at Work

journal homepage: www.e-shaw.net

Original Article

Assessment of Chemical Risks in Moroccan Medical Biology Laboratories in Accordance with the CLP Regulation

Ghita E. Mourry [1,2], Rachid Alami [2], Adil Elyadini [3], Souad El Hajjaji [3,*], Saâd El kabbaj [2], Mimoun Zouhdi [1]

[1] Microbiology Department, Faculty of Medicine and Pharmacy of Rabat, Mohammed V University, Rabat, Morocco
[2] Research and Medical Analysis Laboratory of the Fraternelle of the Royal Gendarmerie, Rabat, Morocco
[3] Laboratory of Spectroscopy, Molecular Modeling, Materials, Nanomaterials, Water and Environment, Faculty of Sciences Rabat, Mohammed V University, Rabat, Morocco

ARTICLE INFO

Article history:
Received 15 August 2019
Received in revised form
4 March 2020
Accepted 17 March 2020
Available online 27 March 2020

Keywords:
chemical risk
medical biology laboratory
occupational exposure
risk assessment

ABSTRACT

Background: Medical laboratory workers are frequently exposed to a wide range of chemicals. This exposure can have adverse effects on their health. Furthermore, a knowledge lack of the chemical risk increases the likelihood of exposure. The chemical risk assessment reduces the risk of exposure to hazardous chemicals and therefore, guarantees health and safety of the workers.
Method: The chemical risk assessment was conducted using a modified INRS method, according to the new CLP Regulation, of 11 unit laboratories in a Moroccan medical laboratory. Observation of each workstation and analysis of safety data sheets are key tools in this study.
Results: A total of 144 substances and reagents that could affect the health of the analytical technicians were identified. Among these products, 17% are concerned by the low priority risk score, with 55% concerned by the average priority risk score and 28% concerned by the high priority risk score. This study also enabled to better identify the chemical agents that have restrictive occupational exposure limit value and controls were conducted to this effect. On the basis of the results obtained, several corrective and preventive measures have been proposed and implemented.
Conclusion: Risk assessment is essential to ensure the health and safety of workers and to meet regulatory requirements. It enables to identify all the risky manipulations and to adopt appropriate preventive measures. However, it is not a one-time activity but it must be continuous in order to master the changes and thus ensure the best safety of all.

1. Introduction

In Morocco, although the concept of occupational risk assessment has only become an obligation for the employer since 2013, after the publication of Decree no. 2-12-431 on the handling of substances or preparations that may affect the health of employees or compromise their safety [1], this approach has always been known and recognized in the international literature as the most effective tool for identifying risks and implementing preventive measures. Under this decree, the employer must ensure that the chemicals available and used by the workers are not harmful, are known, and are accompanied by their safety data sheets and that the preventive and corrective measures are put in place and applied.

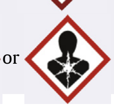
On the other hand, the obligation to ensure the health and safety of workers took effect since 1913 and has been supported year after year by the publication of various regulations [2] and the ratification of several international conventions, such as Convention no. 187 on the Promotional Framework for Safety and Health at Work through the publication, in July 2013, of the Law no. 16-12 in the Official Bulletin no. 6166 [3].

In the laboratories of medical biology, the operators are exposed to several biological hazards; therefore, it is expected that the operators underestimate the chemical hazard and risk that is present

* Corresponding author. Laboratory of Spectroscopy, Molecular Modelling, Materials, Nanomaterials, Water and Environment - CERNE2D, Faculty of Sciences Rabat, Mohammed V University in Rabat, 4 Ibn Batouta Avenue, postal code 1014, Rabat, Morocco.
E-mail addresses: emghita@gmail.com (G.E. Mourry), selhajjaji@hotmail.com; souad.elhajjaji@um5.ac.ma (S. El Hajjaji).

https://doi.org/10.1016/j.shaw.2020.03.003

Table 1
Characterization of chemicals according to their health hazard [12]

Class	Classification and labeling of health hazard	Corresponding pictogram
I	**Product not subject to labeling, no particular toxicity.** Hazard statements: none.	None
II	**Irritant or product without labeling, or product with an OEL[*].** Hazard statements: Skin irritation: H315, H316. Eye irritation: H319. STOT[†] (single exposure): H335 (respiratory irritation), H336 (drowsiness or dizziness).	
III	**Harmful product.** Hazard statements: Acute toxicity: H302 (oral), H312 (dermal), H332 (inhalation).	
IV	**Toxic, sensitizing, or corrosive product.** Hazard statements: Acute toxicity: H301 (oral), H311 (dermal), H331 (inhalation). Skin corrosion: H314. Eye damage: H318. Sensitization: H334 (respiratory), H317 (skin). Liberates toxic gas: EUH029 (contact with water), EUH031 (contact with acids).	 or   or 
V	**Very toxic, even fatal, carcinogenic, mutagenic, and reprotoxic.** Hazard statements: Acute toxicity (fatal): H300 (oral), H310 (dermal), H330 (inhalation). Aspiration hazard (may be fatal): H304. STOT[†] (single exposure): H370, H371. STOT[†] (repeated exposure): H372, H373. Germ cell mutagenicity: H340, H341. Carcinogenicity: H350, H351. Reproductive toxicity: H360, H361, H362 (breast-fed children). Liberates very toxic gas: EUH032 (contact with acids).	 or 

* OEL: Occupational Exposure Limit.
† STOT: Specific Target Organ Toxicity.

in the work space. A wide range of hazards with significant consequences have been identified, ranging from a simple irritation to death. The chemical risk in medical biology laboratories is therefore still poorly understood and insufficiently perceived by the operators [4]. Chemical agents can have several effects on the technician's health, depending on the conditions and the exposure routes, as well as on their physicochemical and toxicological properties. On the other hand, the chemical risk is not limited to the laboratory but also extends to nearby and distant areas depending on the establishment activities and environmental impacts that it can generate [5]. These products are identified and characterized, so that the operator is aware of the hazard prior to performing the tasks assigned to him. The extent of the chemical hazard is determined by the dose, duration, and frequency of exposure, as well as the route of exposure. It is also important to study the operating procedures, the use of collective and personal protective equipment, the individual behaviors, and the working conditions to assess the chemical risk and to put in place the necessary and adequate preventive measures [6,7].

The chemical risk assessment, its communication, the awareness of the operators, and the performance of emergency simulations are tools used by the Research and Medical Analysis Laboratory of the Fraternelle of the Royal Gendarmerie (LRAM) to enable its operators to face those hazards and thus to apply and observe preventive measures to ensure their health and safety and to preserve the environment. In addition, the work environment assessment and field survey, prior to and after the use of these tools, allowed us to better measure the perception of the chemical risk by the operators and to propose the appropriate actions for an optimized management of these hazardous products.

The present work was conducted within the LRAM and is part of a sustainable development approach. Indeed, having been accredited according to the ISO 15189 standard since 2012 [8], as well as ISO 14001 [9], OHSAS 18001 [10] since 2013, and ISO 45001 [11] since 2018, the LRAM has the obligation to ensure the safety of its staff and any visitor to the laboratory. At the same time, the LRAM is also committed to protecting the environment. These obligations toward the ISO organism have resulted in different preventative and corrective measures, continuous trainings, and awareness spreading on health, safety, and environmental requirements, for each technician since introduction to the laboratory. The originality of our study lies in the re-adaptation of the INRS risk assessment method to the CLP European Regulation [12], which aligns the Classification, the Labeling, and the Packaging of chemical substances and mixtures according to the Globally Harmonized System (GHS). This rehabilitation is not mentioned in the existing literature on health facilities.

2. Materials and methods

This study was conducted in 11 medical laboratories of the LRAM, during the months January to April 2019. It presents the chemical risk assessment process in its entirety from the chemical

Table 2
Determination of occurrence: frequency and duration of use of chemicals

Use	Occasional	Intermittent	Frequent	Permanent
Day	<30 min	[30–120] min	[2–6] d	>6 d
Week	<2 h	[2–8] h	[1–3] d	>3 d
Month	<1 d	[1–6] d	[7–15] d	>15 d
Year	<15 d	[15 d–2 mo]	[2–5] mo	>5 mo
Class	**1**	**2**	**3**	**4**

inventory to the implementation of appropriate corrective and preventive actions according to the results obtained.

Field observations were conducted regarding the different workstations to observe and analyze the tasks performed by the laboratory technicians and to interview them about the work processes, substances, and preparations that can be linked to health hazards, to assess their potential risks according to safety data sheets (MSDS) provided by the various manufacturers. Indeed, only the products having an effect on health were analyzed during this study. The methodology chosen is the simplified methodology proposed by the French National Institute of Research and Safety (INRS) [5], however, modified and adapted according to the new European Regulation CLP, which aligns the European Union system of Classification, Labeling, and Packaging of chemical substances and mixtures to the GHS and took effect since June 1, 2015 for both substances and mixtures [12]. The originality of our study consists in the re-adaptation of this risk assessment method to the CLP regulation as mentioned above, this new approach not being mentioned in the existing literature on health facilities. This methodology is a decision support tool that allows the laboratory to carry out a gradual chemical risk assessment. Considering that the chemical hazard refers to the inherent properties of a chemical substance that make it capable of causing harm to a person or the environment and that the chemical risk is the possibility of a harm arising from a particular exposure to a chemical substance, under specific conditions [5], the hierarchy of the chemical risk was carried out according to the following items:

- The hazard class of substances/preparations, characterization of physicochemical, toxicological, and environmental hazards according to the hazard statements available on MSDS (Table 1); when the product has several hazard statements, the highest hazard class is preferred.
- Frequency including the duration of their handling. The stratification was carried out according to the number of minutes, hours, days, and months, and according to the daily, weekly, monthly, or annual periodicity (Table 2).
- The nature of their manipulation: placed in a machine, manual (such as pipetting), re-packaging, dispensing, deposition on plates or blades, homogenization, and agitation.
- The volume of substances/preparations: the quantity class based on the quantity consumed (Qi) of the product under consideration in relation to the quantity of the product most consumed (Qmax): Qi/Qmax (Table 3).

Table 3
Calculation of quantity classes of chemicals

Classes	Qi/Qmax
1	<1%
2	[1–5]%
3	[5–12]%
4	[12–33]%
5	[33–100]%

Table 4
Determination of classes of potential exposure

Quantity class					
5	4	5	5	5	
4	3	4	4	5	
3	3	3	3	4	
2	2	2	2	2	
1	1	1	1	1	
	1	2	3	4	Occurrence class

The potential exposure class was then determined by combining the quantity classes and the classes of chemical use occurrence. In fact, the higher the quantity and the occurrence of use of a chemical, the greater the probability of exposure of the test technicians (Table 4).

Thus, these different classifications made it possible to determine the potential chemical risk score at the different laboratories, resulting from the combination of the hazard class and the potential exposure class (Table 5). According to the result of this score, and thanks to the decision grid (Table 5), the chemicals that can have the greatest impact on the health and safety of the technicians are prioritized, in order to determine imminent implementation actions of adequate preventive and corrective measures. Thus, products with a risk score greater than or equal to 10,000 have a high priority and are represented by red color, which indicates an unacceptable situation. Those with a score between 100 and 10,000 have a medium priority and are represented by orange color, which indicates a situation to be monitored and requires further study. For those with a risk score of less than 100, their priority is low, and they are represented by green color indicating an acceptable situation (Table 5).

During this data collection, we focused our observations as well as built the interviews destined to the staff around the following topics:

- the chemical risk perception,
- the knowledge and the availability of pictograms and the safety data sheets,
- the good practices for handling chemicals, their storage, and their re-packaging,
- the use of collective protection equipment,
- the availability and the wearing of personal protection equipment,
- the waste and empty bottles management, and
- the emergency procedures application (spill or accidental exposure).

3. Results

The inventory of chemicals in the 11 medical biology laboratories studied, 144 substances and reagents were identified that could have an effect on the health of the test technicians, 17% being concerned by the low priority risk score, 55% are concerned by the average priority risk score, and 28% are concerned by the high priority risk score (Table 6), which are subject to urgent corrective actions. The specific activities of the various laboratories require the use of numerous solvents, dyes, and reagents, which accounts for 76% of all the products identified. Other products composed of a single substance represent 24%.

The laboratories using the most high priority risk score chemicals are hematology, parasitology, toxico-pharmacology, and mass spectrometry laboratories with percentages of 55%, 45%, 44%, and

Table 5
Determination of the potential chemical risk score

Potential exposure class						
5	100	1000	10000	100000	1000000	
4	30	300	3000	30000	300000	
3	10	100	1000	10000	100000	
2	3	30	300	3000	30000	
1	1	10	100	1000	10000	
	1	2	3	4	5	Hazard class

40%, respectively (Table 6). Urolithiasis and molecular biology laboratories do not have high priority chemicals. Regarding carcinogenic, mutagenic, and reprotoxic (CMR) products, the parasitology laboratory contains the most products, with three carcinogenic substances, indicated as H351 for crystal violet and fuchsin and H350 for formaldehyde, and a mutagen mentioned as H3s41 for phenol. Other CMRs have also been identified in the immunochemistry, biochemistry, toxico-pharmacology, hematology, and bacteriology laboratories, such as lactophenol blue, DxH Coulter® diluent containing imidazole, UIBC® containing hydroxylammonium chloride, BILT3® containing sodium metaborate tetrahydrate, Vitamin B12® calibrator and Folate® calibrator containing sodium borate decahydrate, n-hexane, and dichloromethane. These observations show that there are different types of hazard depending on the chemicals and the nature of the activities of each laboratory.

On the basis of the results obtained, several suggestions for improvement were made in order to minimize or even eliminate the health risks related to these chemicals, which in the long term will increase performance in occupational safety and health in the studied laboratories.

As a result of this chemical risk assessment, and with respect to limited professional exposure chemicals, according to the reference Occupational Exposure Limit values in accordance with Order no. 4576-14 [13], the measurement of indoor air quality was achieved in two stages:

- targeted research of the following products: xylene, phenol, formaldehyde, acetone, ethyl ether, methanol, acetonitrile, hydrochloric acid, and acetic acid.
- screening of alcohols, volatile organic compounds, carboxylic acids, and inorganic acids, after carrying out several corrective and preventive actions, such as the substitution of certain products, the limitation of the quantity of products inside the laboratory, the construction of a room for the storage of chemicals, the drafting of instructions describing good handling practices and rules of storage, and the installation of hoods, ventilated cabinets, and air purifier.

The results obtained were consistent during these two stages and highlight the effectiveness of the actions put in place for the reduction or elimination of the chemical risk for the analysis technicians, and more particularly through the good practices and the installation and ongoing verification of collective protective equipment. Also, these operators receive regular training and safety instructions, while the safety rules are posted at strategic locations in each laboratory. In addition, the insignificant number of chemical-related workplace accidents also reflects the effectiveness of the measures put in place.

Finally, in addition to the afore-mentioned corrective and preventive actions, the use of adequate personal protective equipment is one of the appropriate actions to put in place to reduce the probability of exposure to hazardous chemicals.

Table 6
Results of the chemical risk assessment

Laboratories	Workers details						Number of chemicals with health effect	Potential chemical risk score			Number of CMR[¶]
	Number	Gender		Working experience				High priority	Medium priority	Low priority	
		W[*]	M[†]	J[‡]	Md[§]	S[‖]					
Bacteriology and mycology laboratory	9	33%	67%	22%	33%	45%	11	18%	55%	27%	1
Parasitology laboratory	4	25%	75%	25%	25%	50%	11	45%	55%	0%	4
Hematology laboratory	7	29%	71%	28%	28%	44%	11	55%	45%	0%	1
Protein laboratory	5	20%	80%	20%	20%	60%	12	8%	67%	25%	0
Biochemistry laboratory	11	27%	73%	27%	18%	55%	21	24%	57%	19%	2
Immunochemistry laboratory	7	14%	86%	28%	44%	28%	27	33%	59%	8%	3
Immuno-serology laboratory	8	25%	75%	25%	25%	50%	18	12%	44%	44%	0
Urolithiasis exploration laboratory	6	50%	50%	17%	33%	50%	3	0%	64%	33%	0
Molecular biology laboratory	5	80%	20%	20%	20%	60%	7	0%	71%	29%	0
Mass spectrometry laboratory	3	67%	33%	0%	33%	67%	5	40%	60%	0%	0
Toxicology and pharmacology laboratory	5	40%	60%	20%	40%	40%	18	44%	44%	12%	2
Total	**70**	**34%**	**66%**	**23%**	**28%**	**49%**	144	28%	55%	17%	13

[*] W: Women.
[†] M: Men.
[‡] J: Junior ≤2 years.
[§] Md: Medium: [2–10] years.
[‖] S: Senior >10 years.
[¶] CMR: Carcinogenic, Mutagenic, and Reprotoxic.

4. Discussion

The use of chemicals in the work environment can have various consequences for human health, and health care facilities, more specifically medical biology laboratories, are among the most affected establishments [14,15]. Indeed, the diversity, the hazardousness, and the large number of chemical products handled make periodic risk assessment an indispensable tool to better identify hazardous situations and to provide the staff with effective, practical, and adapted solutions. In addition, this aspect of multi-exposure to hazardous chemicals, where toxic risks accumulate, requires a comprehensive toxicological study of each incriminated product [16]. In addition, several studies report cases of spontaneous abortion, congenital malformations, and excess chromosomal abnormalities among laboratory technicians [17], undoubtedly related to the handling of CMR products that are part of the most feared hazard category [18,19]. However, this does not diminish the impact of toxic, corrosive, and irritant products, which can also cause several pathologies, such as solvents and volatile organic compounds [20–22].

In this chemical risk assessment study, the various information collected made it possible to highlight the irrefutable exposure of medical biology laboratory technicians to hazardous chemicals and to characterize them from hazard statements H, according to the method proposed by the INRS [5], but adapted according to the new European regulation CLP of chemical substances and mixtures [12], by corresponding the hazard statements H to the risk phrase R. Its information was easily accessible given their presence in the safety data sheets, also improved according to the CLP, and provided by the supplier prior to any purchase, as specified by the Moroccan regulations [1]. The inventory stage of the chemicals used by the workplace is also mandatory and common to all evaluation methods [5,23–27]. Indeed, Article 6 of Decree no. 2-12-431 [1] states that the employer must carry out the chemical risk assessment, taking into account the hazardous properties of all chemicals present in the workplace as well as the health and safety information provided by the chemical supplier, including the information on the safety data sheets.

Several studies have been carried out on the exposure of workers at the level of the various research and analysis laboratories, in this case the study by Kauppinen et al. The evaluation of occupational exposure and the incidence of cancer in Finnish laboratory workers between 1979 and 1988 [15] revealed that even if these workers were exposed to carcinogens, no major cancer risk was detected, standardized incidence rates for cancers not being significantly elevated, except for non-Hodgkin's lymphoma and leukemia. Nevertheless, some chemicals classified as carcinogenic to humans by the International Agency for Research on Cancer, such as formaldehyde, have several studies that reported their harmful effects on health, including their immunotoxic and genotoxic effects [28]. Studies have shown that chronic exposure to formaldehyde by inhalation is associated with irritation of the upper respiratory tract [29–31]. Other epidemiological studies of industry workers, embalmers, and pathologists have identified high risks of cancer in various locations, including nasal cavities, lungs, and the hematopoietic system [32,33]. Otherwise, there is agreement in the field of toxicology of chemical mixtures that the usual risk assessment of chemical mixtures as the sum of the risks of individual items may be too simplistic. This poses a risk of underestimating risk chemicals for human health and the environment [34]. In fact, two or more chemicals can act synergistically, combined, or antagonistically, as well as exerting potentiating or inhibitory effects on defense mechanisms, leading to a risk or even a new hazard, possibly unidentified when testing individual components. Particular concerns are connected with various types of toxicity, such as neurotoxicity, cardiotoxicity, nephrotoxicity, hepatotoxicity, genotoxicity, and endocrine disruption [35,36].

Therefore, although the results of the risk assessment reveal a low percentage of high priority chemicals, these products should receive special attention; given their degree of severity and the effects they may have in short and long term, specific prevention measures must be adopted by users.

5. Conclusion

Control of chemical risk is not represented by a series of individual actions, it is a policy to adopt, a culture to be established, and a continuous process to maintain, by regular monitoring, compliance, prevention strategies, and the involvement and commitment of all interested parties. In addition, decisions and actions taken as a result of the chemical risk assessment may have local, regional, or national consequences, but those taken by a single country may also have consequences for the entire planet. Pollution does not take into account national borders, especially when it comes to discharges into the water and the atmosphere.

Although risk assessment is a long and tedious step because of the large number of products used in laboratories, it is essential to ensure the health and safety of workers and to meet regulatory obligations. The evaluation performed in this study shows that the risk of chemicals handled in medical laboratories is moderately high. Moreover, given the preventive measures put in place and the insignificant number of chemical-related work accidents, the chemical risk is under control and is on the decline. However, the annual update of the risk assessment, the carrying out of the controls through the audits, the regular sensitization, and continuous measures are essential in order to control the changes and thus to ensure safety for all.

Conflicts of interest

All authors have no conflicts of interest to declare.

Acknowledgments

The authors would like to thank the Research and Medical Analysis Laboratory of the Fraternelle of the Royal Gendarmerie (LRAM) of Rabat for the provision of the study site.

Abbreviation

CLP	Classification, Labeling, and Packaging of chemical substances and mixtures of the Globally Harmonized System
CMR	Carcinogenic, Mutagenic, and Reprotoxic
GHS	Globally Harmonized System of Classification and Labeling of Chemicals
INRS	The National Institute of Research and Safety
ISO	International Organization for Standardization
LRAM	Research and Medical Analysis Laboratory of the Fraternelle of the Royal Gendarmerie
MSDS	Material Safety Data Sheet.
OELs	Occupational Exposure Limit values
Qi	Quantity consumed
Qmax	Quantity most consumed
SIR	Standardized Incidence Rates
STOT	Specific Target Organ Toxicity

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2020.03.003.

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