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Risk assessment of chemicals in the laboratories of Golestan University of Medical Sciences, Iran

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ABSTRACT

Several chemicals are used in the labrotaies of universities for teaching and research activities, and lack of awareness regarding their toxicity and safety may be hazardous to the health of staff and students. The present study aimed to identify the chemicals used in the academic and research laboratories of Golestan University of Medical Sciences in the north of Iran and classify them based on human health and environmental hazards. Data were collected through the observation of the chemicals in the laboratory and via interviews with the laboratory manager during March-August 2019. Hazard classification and risk description were performed using based on the guidelines of the International Agency for Research on Cancer (IARC) and National Fire Protection Association (NFPA). The results indicated 408 chemicals, five, eight, and 12 of which belonged to groups one (carcinogenic to humans), 2A (probably carcinogenic to humans), and 2B (possibly carcinogenic to humans), respectively based on the IARC guidelines. Additonally, three, two, and 15 chemicals had compounds with the capablity of severe flammability, reactivity, and health hazard, respectively based on the NFPA guidelines. The presence of hazardous chemical compounds such as benzene, chloroform, formaldehyde, vinyl chloride, diethyl ether, and picric acid revealed that medical science laboratories may be hazardous to the health of the staff, faculty members, and students if not properly managed. Therfore, the design and implementation of comprehensive programs are essential to the risk management of chemicals in academic laboratories.

Keywords: Chemical safety, Occupational exposure, Laboratories, Risk assessment

Introduction

Chemical substances refer to all organic and inorganic compounds in various forms (gas, liquid, vapor or solid) with a minimum of one chemical element.[1] According to the World Health Organization (WHO) guidelines, all chemical substances that may threaten human health with short-term or long-term effects or are resistant to biodegradation processes are classified as hazardous chemicals.[1] In addition, the United Nations Environment Program (UNEP) has classified hazardous chemicals as all the substances, such as solids, sludge, liquids, and gases in tanks (except radioactive/infectious substances) with properties such as activity, toxicity, explosivity or other properties that could pose risks to the human health and environment.[2]

Recently, the use of chemicals has been on the rise in various sectors, including industries, agriculture, and domestic and academic activities. Recent findings have indicated that chemical substances could threaten the human health through exposure to environmental agents (e.g., water, air, and

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food) or occupational exposure.[3] Notably, the adverse effects of these substances on the human health depend on the chemical concentration, duration and frequency of exposure, toxicity of the chemical material, and susceptibility of the individual.[2, 3] Some chemicals are stored and distributed within the body over a short period, while others may accumulate over a long period and show their effects in the form of cancer or other genetic complications.[3]

The increased rate of accidents at chemical plants has urged researchers to pay attention to these issues rather than laboratory accidents at academic institutions. This may be due to the severity and magnitude of chemical plant accidents; such examples are the release of toxic substances such as 8, 7, 3, 2-*tetrachlorodibenzodioxin* in the Seveso disaster in Italy[4] or the release of methyl isocyanate toxic gas due to the leakage of the Union Carbide Plant in Bhopal, India.[5]

Chemical accidents occasionally occur in the university environment although they are not reported in the public media possibly for political or social reasons. Consequently, there is a misconception regarding the low possibility of such incidents in university laboratories or that if they occur, no severe harm is caused to the staff.[6] The death of a university professor due to poisoning by dimethylmercury at Dartmouth College in New Hampshire showed that failure to comply with health and safety standards could threaten the health of the workers in any environment.[7] The U.S Chemical Safety and Hazard Investigation Board (CSB) has reported that more than 120 accidents occurred in university laboratories during 2001-2011.[8] Furthermore, the results of a survey conducted by the American Chemical Society indicated that 49 deaths occurred due to 34 laboratory incidents since 2000, 11 of which were in universities, and 23 cases occurred outside universities.[9]

In recent years, extensive educational and research centers in Iran have been focused on the development of supplementary and specialized courses in medical, health, food production, agricultural, and industrial fields regarding the use of various chemicals for the production of drugs or pesticides. The safe management of laboratories in the laboratory environment should be applied in every educational and research institution, and the activities that threaten the health of employees or the environment should be avoided.[6]

As many chemical incidents could be predicted and avoided, the timely and effective use of risk assessment approaches could be highly beneficial in this regard. The risk assessment process could contribute to the evaluation of hazards, elimination of the identified hazard, and minimization of the risk level through proper control measures if necessary.[10] For this reason, the identification and classification of the hazard degree of the chemicals used in universities in terms of health and safety is an effective step toward the safe management of chemicals and preventing the potential adverse effects on human health and workplaces.

The present study aimed to identify all the chemicals used in the laboratories of Golestan University of Medical Sciences, Iran and classify them in terms of human health and environmental hazards.

Materials and Methods

This cross-sectional study was conducted during March-August 2019 in Gorgan, the capital city of Golestan province, located in the north of Iran. Golestan University of Medical Sciences has six schools, including the medical, dentistry, health, paramedical, nursing and midwifery, and advanced technologies in medicine schools. These schools have a total of 17 education and research laboratories.

In this study, all the chemical components used in the laboratories for educational and research purposes were determined by an environmental health expert (PhD, BSc). Data were collected through observations and interviews with the laboratory managers. After collecting the required data on the chemical compounds,

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hazard classification and the risk description were performed in accordance with the IARC and NFPA guidelines.

Results and Discussion

In total, 408 chemicals were used in the laboratories of the schools of biochemistry, physiology, parasitology, immunopharmacology and microbiology (school of medicine), nanotechnology, biotechnology, cellular and molecular (1 and 2) and cytogenetic (school of advanced technologies in medicine), environmental microbiology, environmental chemical and nutrition laboratory (school of health), immunohematology, and microbiology (school of paramedicine). According to the IARC recommendations, five, eight, 12, 33, and 350 of these compounds were classified as groups one (carcinogenic to humans), 2A (probably carcinogenic to humans), 2B (possibly carcinogenic to humans), three (unclassifiable as to carcinogenicity in humans), and four (probably non-carcinogenic to humans), respectively. The frequency of each compound is shown in Table 1, and the examples of the carcinogenic chemicals in each group are presented in Table 2.

According to the findings, the most harmful compounds were identified in the faculties of health, medicine, and paramedical and advanced technologies in medicine. Based on chemical composition, the School of Health (n=103) and the School of Medicine (n=565) had the lowest and highest number of chemical compounds, respectively. Furthermore, the compounds associated with the hazard of flammability, reactivity, and health were utilized in the studied laboratories. Table 3 shows the type and number of the chemicals in line with the NFPA guidelines. Tables 4-6 show the examples of these chemical compounds.

Table 1. Frequency of chemicals used in schools of Golestan University of Medical Sciences based on IARC guidelines

School of	Number of chemical were classify in group …					Total
	1	2 A	2 B	3	4	
Health	3	1	3	7	44	58
Medicine	1	3	3	14	124	145
Paramedicine	1	1	3	5	102	112
Advanced Technologies in Medicine	0	3	3	7	80	93
Total	5	8	12	33	350	408

Table 2. Examples of chemicals in different groups of IARC classification

Groups	Hazard description	Chemical compounds
Group 1	Carcinogenic to humans	Benzene, Chloroform, Formaldehyde, Orthotoloeidine, Vinyl Chloride
Group 2 A	Probably carcinogenic to humans	Acrylamide, Chloramphenicol, Cadmium, Diazinon, Di Chromate Sodium Di Hydrate, N, N-Dimethylformamide, Potassium Dichromate, Sodium Chromate,
Group 2 B	Possibly carcinogenic to humans	Acetamide, Auramine, Carbon Black , Di Ethyl Amine, Nitrobenzene, Phenol Phethalein, Pyridine, Tetra Hydrofuran, Tetrachloride Carbon, Trichloroacetic acid,

Table 3. Frequency of chemicals used in schools of Golestan University of Medical Sciences based on NFPA guidelines

School of	Flammability		Reactivity		Health	
	Severe	Serious	Severe	Serious	Severe	Serious
Health	3	2	3	1	8	14
Medicine	7	1	1	1	3	27
Paramedicine	6	0	1	0	1	12
Advanced technologies in medicine	10	0	1	0	3	16
Total	26	3	6	2	15	69

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Table 4. Examples of chemicals in different groups of NFPA classification

Types of hazards	Risk description: Some chemical compounds
Flammability	Severe; Di Ethyl Ether, Picric Acid, Vinyl Chloride Serious; Acetone, Benzene, Ethanol, Hexane, Isobutanol, Methanol, Methyl Acetate, Petroleum Ether, Pyridine, Tetra Hydrofuran, Toluene, Xylene, etc.
Reactivity	Severe; Picric Acid, Ozone Serious; Carbon Black, Di Nitro Phenil Hydrazin, Guanidine Hydrochloride, Hydrogen Peroxide, Phenol Phethalein, etc.
Deadly and poisonous	Severe; Formaldehyde, Guanidine Thiocyanate, Mercury, Potassium Cyanide, Sodium Cyanid, etc. Serious; Cadmium, Chromic Acid, Di Chromate Sodium, Di Hydrate,2-Mercapthanol, Ammonium Hydroxide, Hydrochloric Acid, Hydrogen Peroxide, Iodine, Lead, etc.

According to the results of the present study, some of the chemicals used in the laboratories of Golestan University of Medical Sciences contained toxic and carcinogenic compounds, which could cause severe damage to human health with short-term or long-term exposure. The results of a 20-year cohort study conducted in Sweden indicated that the high mortality rate of malignant cancers (especially leukemia) in chemists was associated with continuous working with chemical compounds in laboratories.[11]

The hazards of chemical substances are fundamentally classified as toxic hazards (local and systemic effects) and physical hazards (explosion or fire hazards).[12] The results of the present study showed that 25 chemicals out of the available chemical compounds were classified in groups one and two (A and B) of carcinogens in the IRAC guidelines. Therefore, the implementation of safety management systems is crucial for university, academic, and research laboratories, and the threat associated with the experiments in these laboratories could be substantial if not properly managed. Moreover, performing unsafe activities during teaching or research activities could adversely affect the health of individuals and lead to accidents in the workplace.[6] The results of a study in this regard demonstrated that 68 individuals died due to the leakage of anthrax bacteria from an army research laboratory, which was due to the failure to comply with safety standards and not using personal protective equipment.[13]

According to the current research, toxic and carcinogenic compounds such as cyanide, phenol, benzene, vinyl chloride, formaldehyde, mercury, chromium, and cadmium were present in the studied laboratories, and exposure to these substances could be extremely hazardous to those working in these places. Cyanide is one of the most toxic and unsafe chemicals that human could be exposed to through breathing or direct contact. It could cause headaches, anesthesia, respiratory failure, and death.[14] The threshold limit value and LD_{50} of hydrogen cyanide have been determined to be 5 mg/m^3 and 1 mg/kg of the human body weight, respectively.[15] Benzene is a perilous chemical that enters the human body through the respiratory tract, gastrointestinal system, and skin and could cause central nervous system leukemia. The main route of exposure to high doses of benzene and other volatile organic compounds is inhalation in the workplace. The occupational exposure limit of benzene is 0.5 ppm in the workplace. In 2011, the American Conference of Governmental Industrial Hygienists (ACGIH) reduced the permissible occupational threshold for benzene to 0.1 ppm due to its carcinogenic effects.[13, 16] Phenol is a derivative of benzene, which is highly important due to its carcinogenic properties, high toxicity, higher ecological damage, and low biodegradability. Phenol and its derivatives easily penetrate the skin, gastrointestinal tract, and lungs. Evidence suggests that exposure to these compounds may exert acute and chronic effects with a

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wide range of symptoms, such as headaches, vomiting, tissue damage, progressive renal and liver failure, pancreatic injury, protein-losing enteropathy, central nervous system diseases, carcinogenicity, and mutagenicity in humans.[17] Vinyl chloride is another chemical with toxic and carcinogenic effects on the liver, the damages of which manifest in the form of fibrosis, hepatic angiosarcoma, hepatic destruction, and portal hypertension.[18, 19] One of the most important issues in ensuring the health of those working with these compounds is the early detection of the effects of toxins.[20] The ACGIH reduced the environmental concentrations of vinyl chloride compounds from 5 ppm in 2003 to 1 ppm, suggesting that the substance may also have detrimental effects on the human health at lower concentrations.[21]

Chromium and cadmium are commonly used in laboratories. Occupational exposure to hexavalent chromium compounds could cause skin ulcers, respiratory tract irritation, nasal septal ulceration, and hepatic and renal diseases. The IARC has classified chromium 6-valent compounds as carcinogens, and exposure to very high levels of Cr(VI) in the long run has been linked to respiratory tract cancers in workers. After distribution in the body, chromium initially targets the lungs and affects the kidneys, liver, skin, and immune system.[22, 23] Cadmium is also a toxic substance in small amounts, which could accumulate in various tissues and organs of the human body. Long-term exposure to low levels of cadmium may cause bone deformities, such as the Itai-itai disease.[24, 25] Exposure to a small amount of cadmium and its entry into the human body in the long run could lead to the accumulation of this substance in the kidneys and subsequent chronic renal diseases, such as kidney failure.[26] The IARC has provided sufficient scientific evidence to measure cadmium as carcinogenic in humans, mainly in organs such as the lungs, prostate, and kidneys.[23]

Formaldehyde was another important compound in the present study, which is considered hazardous through causing irritations in the skin, mucous membranes, and respiratory tract, which is associated with the severe reduction of the total lung capacity. In addition, formaldehyde could cause respiratory tract tumors and nasal cancers after chronic exposure. According to the evidence observed in humans and laboratory animals, IARC has classified formaldehyde as a carcinogen for humans[27] The time-weighted average concentration of formaldehyde has been determined to be 0.75, 0.016, and 0.3 ppm by the OSHA and NIOSH. The ACGIH has also set the maximum limit of 0.3 ppm for formaldehyde based on its irritant effects.[15] Formaldehyde has been reported to induce stimulatory effects on the upper respiratory tract at the concentration of 1 ppm in humans, while it also causes cytogenic and pathogenic changes in the nasal membrane within the concentration range of 1.1-0.1 mg/m^3.[28] Exposure to formaldehyde could cause eye burn, tears, and upper respiratory tract irritation even at very low concentrations (0.1 ppm), while the manifestations could also extend to skin rashes, difficulty in breathing, wheezing, superficial mucosal injury, and changes in the lung function at high concentrations.[27, 28]

The identification of some chemical compounds with properties of flammability hazard, instability hazard, health hazard, and special hazard has indicated that chemical accidents could occur in the laboratories of Golestan University of Medical Sciences according to the US NFPA recommendations if workplace safety requirements are not observed. A study in this regard reported that failure to comply with chemical safety regulations led to fire at three Malaysian universities, including the Malaya University Chemical Laboratory, Putra University Engineering Laboratory, and Kebangsaan University School of Physics Laboratory.[29] Furthermore, the findings of Lunar *et al*. indicated that 21 incidents occurred in the laboratories of Taiwanese training centers during 1997-2004, which led to death and severe injuries in the students and staff.[30] Therefore, it is imperative to establish an

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efficient safety management system, such as the process of safety management planning[6] or implementing safety courses for all students before the completion of practical tasks and obtaining a passing grade in the laboratory.[31]

Conclusion

According to the results, the presence of hazardous chemicals such as benzene, chloroform, formaldehyde, vinyl chloride, diethyl ether, and picric acid revealed that medical science laboratories could be hazardous to the staff, faculty members, and students if not properly managed. Therefore, the design and implementation of a comprehensive program are essential to the risk management of chemicals in academic laboratories.

Author's Contributions

A. S. and Z. K. designed the study, fieldwork, and data analysis and approved the final manuscript.

Conflicts of interest

None declared.

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