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Occupational hazards and associated risks in university laboratories: A case study of mining engineering department laboratory

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Abstract: Laboratories occupy a prominent role in the academic field through research, experimentation, and promoting educational practices for students. On the other hand, university laboratories' work is accompanied by some risks that may negatively impact the safety of researchers, students, technical staff, and visitors. This paper, through the mining engineering lab, carried out a risk assessment from an occupational safety perspective. The conducted risk assessment aimed to identify the equipment's potential induced hazards, review existing controls, minimize the associated risks, prioritize them, and then create a safe work area with additional control measures. The study covered sixteen significant pieces of machines in mineral processing and rock mechanics labs. Obtained results indicated around seventy-two identified hazards. A high-risforscale is assessed in the equipment of Electromagnetic and Magnetic Separators. Both required strict additional control measures as recommended. In addition, outcomes showed some medium-risk scale might be related to operating the manual drilling equipment and the crusher. The acceptable levels of risk scale have been achieved in most laboratory equipment; however, some additional control measures are suggested to reach the minimum levels of risks. The literature review revealed a significant lack of research conducted to examine the university laboratories' risk except for labs used in the chemical studies. Therefore, more studies are strongly recommended to investigate the occupational hazards and associated risks in university laboratories.

Keywords: Occupational hazards; university laboratories; mining laboratories; risk

1. Introduction

University laboratory plays a significant role in the academic field through the courses teaching and scientific research experiments. In addition to the lecture, the scientific university courses often have a separate educational laboratory [1]. At all levels of education, the laboratory is considered a high-profile place for experimental work [2]. Simultaneously, the laboratory area can be considered risky due to various hazards created while using the materials and equipment [3]. During the daily activities in the laboratory, types of mechanical, chemical, electrical, and physical hazards may affect the safety and health of students and researchers. Therefore, occupational safety and health procedures should be considered, continually improved, and appropriately

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managed to reduce the high level of risks and execute control measures [4]. Donaldson (2020) highlighted and summarized some reported incidents in the university laboratory with a broad spectrum of hazards as lessons learned [5]. The study concluded that laboratory safety management and sufficient training could achieve optimum safety culture and create a safe environment. A literature review revealed that humans cause 98% of accidents in university laboratories [6]. Over the last decades, there has been an apparent increase in the number of university lab accidents worldwide, resulting in severe injuries or fatalities **Table 1** [7]. According to the Laboratory Safety Institute, there are frequent lab accidents; unfortunately, more than fifty fatal laboratory accidents have been reported worldwide between 2000 and 2021 **Figure 1** [8].

The essential step to managing risks from laboratory hazards is to identify and control them in the workplace [9–10]. Halvani et al. (2011) conducted an investigation study to identify and evaluate the hazards in university laboratories using a reliable and standardized checklist to collect data. The obtained results indicate numerous hazards and defects that highly probable occurred [11].

Although the risks associated with academic labs are lower than those related to the industrial-scale operation, they remain severe concerns since the operator's proximity to the equipment while using, dealing with them for long periods, and some lack of safety knowledge at students [12]. Olewski and Snakard (2017) have studied the previous issues and the most prominent challenges that prevent identified and managed them in university laboratories. As the authors stated, many challenges are encountered, such as no robust safety culture due to leadership's absence of safety commitment. In addition to significant weakness in conducting risk assessment before initiating laboratory experiments, only 18% compared to 43% and 51% in industry and government labs, respectively. Moreover, providing low-quality equipment/materials standup with temporary employment and fast turnover caused inadequate training and limited awareness, thus, increasing the likelihood of risks occurring [12–15].

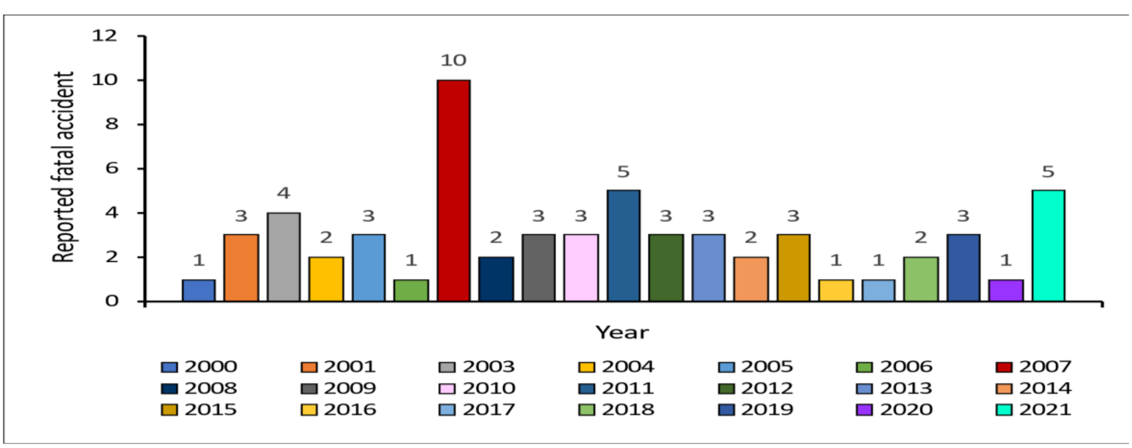

Figure 1. Statistic of reported fatal laboratory accidents from 2000 to 2021 [8].

Table 1. Description of some reported laboratory accidents [7].

Year	Institution	Location	Accident description
2018	Jiao Tong University	Beijing, China	Three graduate students (names unknown) killed during an explosion while researching wastewater treatment.
2018	Indian Institute of Science	Bengaluru, India	Manoj Kumar killed in high-pressure hydrogen cylinder explosion.
2015	Tsinghua University	Beijing, China	Meng Xiangjian, postdoctoral fellow, killed in hydrogen explosion.
2015	University of Health Sciences	Phnom Penh, Cambodia	Huy Siep killed when flammable gas ignited.
2014	Texas A & M University at Qatar	Doha, Qatar	Hassan Kamal Hussein killed in explosion in petroleum lab.
2012	Unknown university	Shanghai, China	Graduate student (unknown) opened a poison gas cylinder and died from inhalation.
2011	Yale University	New Haven, USA	Michele Dufault died during a lathe accident.
2009	University of Chicago	Chicago, USA	Malcolm Casadaban died from exposure to plague-related bacterium.
2008	UCLA	Los Angeles, USA	Sheri Sangji died from burns caused by ignition of tert-butyllithium

2. Background

Canadian center for occupational health and safety (CCOSH) defined hazards as “the source such as substance, condition, process, practice, and material that can induce potential damage, harm, or negative impact on people's health or things”. Risk is also introduced as the probability of injury or damage while exposing to a potential hazard. In the same context, risk assessment is the overall process of identifying hazards, analyzing associated risks, and controlling them [16]. Risk probability refers to an event or threat occurring chance. Also, risk severity illustrates the highest damage level when an accident or hazard happens. Generally, the hazard classifies into physical, chemical, biological, ergonomic, safety, and psychosocial. And the risk is mainly categorized into low, medium, high levels.

According to Occupational Safety and Health Administration (OSHA), the defined hazards can be prevented or controlled to eliminate the threat, provide safe work conditions, protect people, and avoid induced injuries or incidents [17]. National Institute for Occupational Safety and Health (NIOSH) has developed a hierarchy of controls to be a method used to determine how control solutions are implemented effectively. Five rungs under the hierarchy of controls have been clearly defined by NIOSH, starting from the most effective and protective to the least effective control. The five levels of control are elimination, substitution, engineering, administrative controls, and personal protective equipment (PPE) **Figure 2** [18].

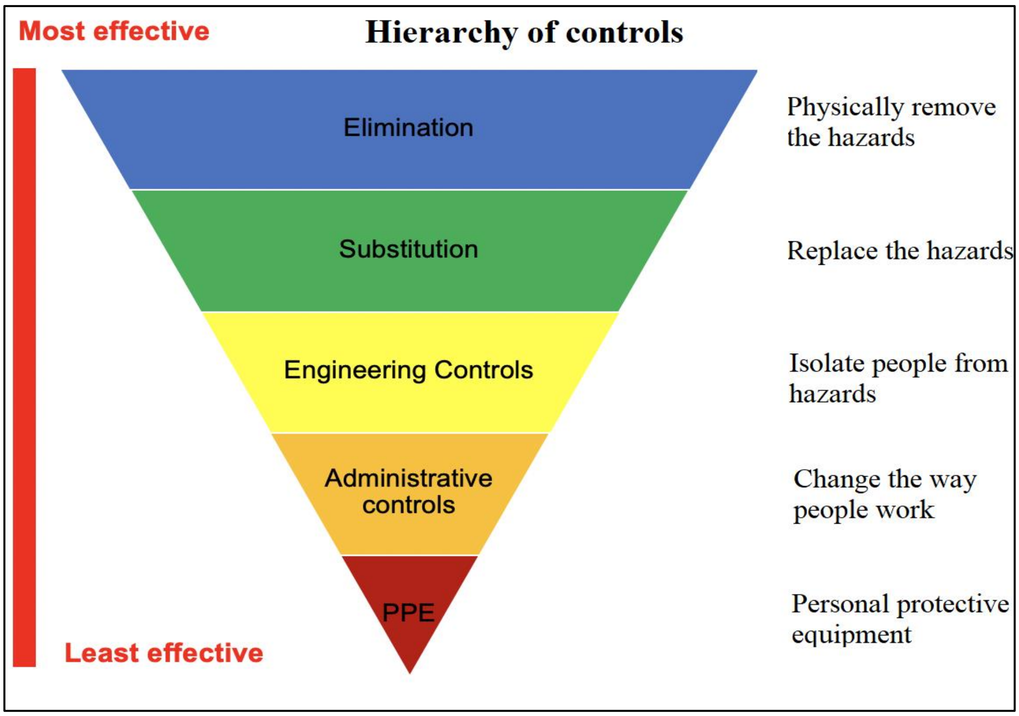

Figure 2. The five levels of hazards control developed by NIOSH [18].

3. Hazards Identification in Mining Industry

Hazard identification through analyzing undesirable events is a first step to assessing associated risks and achieving the acceptable level. Hazard identification is almost followed by investigation tasks to perform overall risk assessment [19]. On the industry scale, accidents cause many injuries, fatalities, economic issues, and work interruption, in addition to the accompanying environmental damages [20].

Mining is a significant industry and considerable sector that controls many economies worldwide [21–23]. At the same time, this sector faces many occupational safety and health challenges (**Figure 3**); that keep mining engineers and safety officers under stress to meet the safety standards and regulations **Tables 2**. For example, significant mining safety challenges induced during conventional rock blasting include flyrock, gas emissions, and ground vibration [24].

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Table 2. Mining occupational safety regulations and standards.

Organization	Occupational safety standard	Reference
International Organization for Standardization (**ISO**)	ISO 19434:2017 & ISO/TC 82	[25]
Occupational Safety and Health Administration (**OSHA**)	SIC Manual/Division B: Mining	[26]
Mine Safety and Health Administration (**MSHA**)	30 CFR Parts 1 – 199	[27]
Health and Safety Executive (**HSE**)	Mines Regulations/ MR2014	[28]

Paithankar (2010), through extensive study, has been identified hazards and then analyzed the associated risk in the mining industry [29]. The identified hazards were considered for different mining activities in surface and underground mines, including surveying, drilling, explosives, face stability, loading, transporting, crushing, grinding, and screening. While the significant identified hazards involve falling, dust, noise, poor design blast, rock falling, fire, hydraulic and mechanical failure of equipment, vibration, lack of visibility, confined space, chemical additive, air blast, electrical hazards, volatile gases, cooling, and illumination systems breakdown. Utembe et al. (2015) examined the chemical hazards in the mining industry [30]. The conducted study highlighted the exposure to dust, toxic, diesel which can cause various pathological effects like respiratory diseases. As well stated, the contamination induced by the mining industry has a significant negative impact on the surrounding environment.

Donoghue (2004), through a review article, outlined a set of occupational health hazards associated with the mining operations [31]. Crystalline silica was introduced in the study as a severe chemical hazard in the mining industry. While rockfall, explosion, fires, and heavy equipment accidents were mentioned as main physical hazards. Moreover, work in remote areas and some dangerous diseases demonstrated in detail as psychosocial and biological hazards related to mining. Finally, the review article discussed overhead work, long duty shifts, sleep deficits, and ergonomic hazards resulting from the mining operation.

4. Importance of Laboratories Safety

Maintaining the safety of lab visitors and the equipment used is the primary step that prevents accidents in university laboratories [32]. Fishwick (2014) has listed some general precautions that apply to eliminate conventional accidents in labs [33]. Recommended guidelines include maintaining workplace cleanliness to avoid clutter, safely disposing of hazardous materials, ensuring electrical wiring safety, providing emergency exits, correct use of PPE, and providing adequate training for the laboratory team. The academic field comprises multi actors with different cultures and skills such as researchers, students, technical team, administration staff, and external visitors; hence, the needed safety requirements should consider these variations in the safety knowledge [34]. The mining lab holds a significant function starting from preparing the samples for chemical analysis in the exploration phase, resource estimation, processing, metallurgy up to rehabilitation in the mine closure phase, furthermore, conducting several geotechnical tests. Therefore, it is necessary to maintain occupational health and safety rules while utilizing laboratory equipment to reduce undesirable risks to the minimum levels. A mining laboratory has a wide range of equipment and devices used for education, research, and solving engineering problems. However, operating the lab equipment faces many challenges, including managing projects and people, employee training, workplace practices, and safety culture development [35]. Mining laboratories may contain much hazardous equipment used to prepare samples for further tests depending on the purpose of the sample study. Equipment and devices run for drilling, cutting, crushing, grinding, heating, testing, and other processing activities raise risks in the mining lab if used contrary to safety rules.

Figure 3. Summary of some significant hazards associated with the mining industry.

5. Method and Materials

Risk assessment improves workplace safety in university laboratories and creates a safer environment to implement the different experimental tests. Approaches used for conducting the risk assessment classify into quantitative, qualitative, semi-quantitative, dynamic, and generic methods. This paper will investigate the hazards and associated risks by conducting a semi-quantitative risk assessment for sixteen major equipment in two leading labs: rock mechanics and mineral processing in mining department laboratories at King Abdulaziz University, Jeddah, KSA.

The equipment available in these laboratories have different manufacturers with different operating procedures, generating various hazards and requiring additional precautions. Therefore, the risk assessment process will examine separately each piece of equipment utilized for multiple activities to identify potential hazards, analyze undesirable events, and control them to create a safe environment for the lab students, researchers, staff, and visitors. Generally, risk assessment involves defining potential hazards, analyzing the risks, controlling them, and monitoring **Figure 4**. The risk assessment will include risk severity which describes the damage amount that may create due to potential hazards, ranging between 5 (highest) to 1 (lowest) scale based on induced damage **Figure 5**. And the probability, which explains the occurring likelihood of the hazard. Mainly, the probability classifies into five levels: very likely (5), likely (4), possible (3), unlikely (2), and very unlikely (1). Multiplying the scores of severities and probability is often used to determine the values of risk scale level **Figure 6** [36].

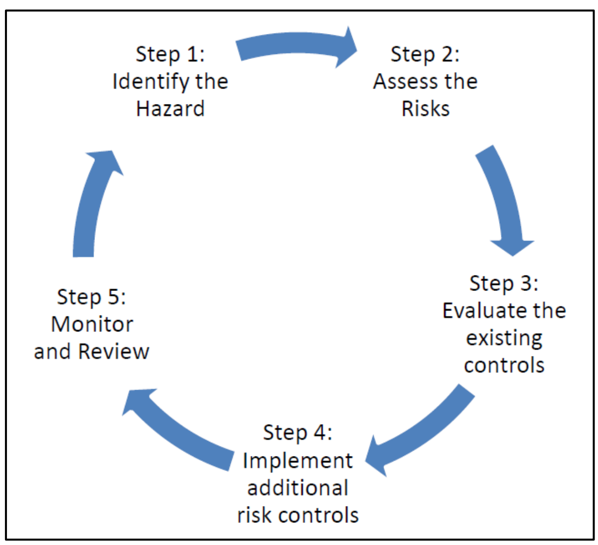

Figure 4. Risk assessment main steps [29].

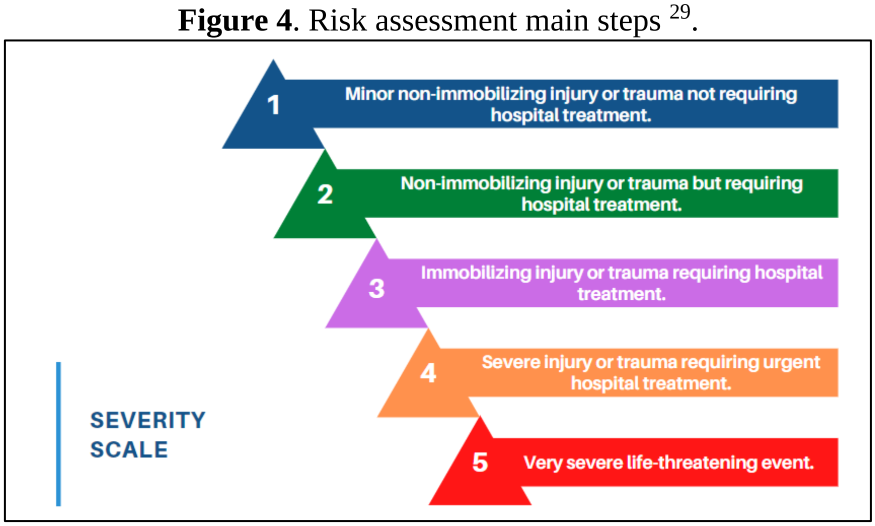

Figure 5. Five scales of induced severity.

RISK MATRIX

PROBABILITY ↑					
Very Likely - 5	5	10	15	20	25
Likely - 4	4	8	12	16	20
Possible - 3	3	6	9	12	15
Unlikely - 2	2	4	6	8	10
Very Unlikely - 1	1	2	3	4	5
	1	*2*	*3*	*4*	*5*
	Negligible	*Slight*	*Moderate*	*High*	*Very High*
	SEVERITY →				

Risk	Risk Level	Action
1 to 6	Low Risk	May be acceptable but review task to see if risk can be reduced further
8 to 12	Medium Risk	Task should only be undertaken with appropriate management authorization after consultation with specialist personnel and
15 to 25	High Risk	Task must not proceed. It should be redefined or further control measures put in place to reduce risk. The controls should be

Figure 6. Risk assessment matrix [36].

Mining Laboratory consists of many equipment and machinery employed to perform different types of jobs. Equipment of mineral processing and rock mechanics laboratories are involved in crushing, milling, separating, heating, cutting, drilling, grinding, and high-pressure compression type activities. The list and figures of equipment in both labs are shown in **Table 3**. This equipment has the potential to cause accidents and injuries during laboratory activities and operations. Some high-speed rotating equipment exists in the mineral processing lab used for material size reduction when being operated, such as Tube Rod Mill, Mini Ball/Rod Mill Roller, Ball Mill, Disc Mill, Multi Rolling Jar, Bond Mill, Los Angeles Abrasion, etc. Also, crushing equipment, including Hammer Crusher, Bell Shaped Crusher, and Jaw Crusher, comprises mechanical crushing pieces, rotating motor, and strength driving. Moreover, equipment used for separation purposes, e.g., Column Flotation, Humphrey Spiral, Shaking Tables, Cyclone Demonstration Units, Mozley Cyclone, Falcon Concentrator, Rare Earth Magnetic Separator, and Outotec et Electro Magnetic Separator. In addition to equipment generate heat such Water Distillers, Furnace 2400 C, and dryer. The working mechanism for all the previous machines is different, which contributes to creating unsafe conditions and causes different types of accidents. They are considered a source of the risk of wringing, colliding, grinding, extrusion, entangle, incision, etc.

The rock mechanics lab's cutting and drilling equipment are Diamond Core Drill, Manual Drill, Saw Cutter of Core Specimen, Petrographic Rock Cutter, Core Specimen Grinder. High-speed cutting and drilling equipment can generate fly fragments due to high operating energy, thus inducing damage to surrounding people or equipment. Moreover, they almost generate airborne dust particles while cutting or rubs the material during processing; those particles can stay in the ambient air for a long time and may cause chronic diseases to lab staff and students.

Table 3. List of all equipment in mineral processing and rock mechanics labs.

Mineral Processing Lab (1st Lab)	Mineral Processing Lab (2nd Lab)	Rock Mechanics Lab
Hammer Crusher	Shaking Table	Diamond Core Drill
Column Flotation	Cyclones Demonstration Units	Manual Drill
Humphrey Spiral	Mozley Cyclone	Core Specimen Saw Cutter
Water Distiller	Falcon Concentrator	Core Specimen Grinder
Cone Crusher	Lab Eccentric Jig	Slake Durability Testing Machine
Ball Mill	Rare Earth Magnetic Separator	Direct Shear Testing System
Rod Mill Roller	Furnace 2400 C	Compression Testing Machine
Tube Rod Mill	Outotec et Electro-Magnetic Separator	Uniaxial Testing System Servo Controlled
Disc Mill	Los Angeles Abrasion	Dryer
Jaw Crusher		Triaxial Testing System Servo Controlled
Multi Rolling Jar		Point Load Tester
F.C Bond Mill		

Risk Assessment of Mining Laboratory

The main objective of this risk assessment in mining department laboratories is to help laboratory staff, researchers, and students identify the hazards induced by the main piece of equipment and check existing controls. Thus, minimizing the associated risks level by providing additional control measures **Figures 9-24**. In addition to risks prioritizing and safety improvements purposes for mining laboratories due to the significant lack of research published in this field, the literature revealed.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
1	Mills	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1-Cover for feeding Hopper during operation. 2-Safe guard for moving parts. 3-Barricading of 1m around the equipment. 4-Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	3	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 7. Risk assessment of mining department laboratory Mills.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
2	Crushers	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1-Cover for feeding Hopper during operation. 2-Safe guard for moving parts. 3-Barricading of 1m around the equipment. 4-Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	4	Medium	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 8. Risk assessment of mining department laboratory Crushers.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
3	Shaking Tables	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1-Cover for feeding Hopper during operation. 2-Safe guard for moving parts. 3-Barricading of 1m around the equipment. 4-Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	2	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 9. Risk assessment of mining department laboratory Shaking Tables.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
4	Cyclones and Jig	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1-Cover for feeding Hopper during operation. 2-Safe guard for moving parts. 3-Barricading of 1m around the equipment. 4-Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 10. Risk assessment of mining department laboratory Cyclones and Jig.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
5	Magnetic Separators	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1-Cover for feeding Hopper during operation. 2-Safe guard for moving parts. 3-Barricading of 1m around the equipment. 4-Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Radiation)	Headaches, anxiety, affect nervous system function and cause damage to cells	5	3	High	1-Limit the exposure time. 2-Exposure monitoring radiation badges and handheld monitor to ensure it is within limits (WHO: time-weighted average of 200 mT during the working day for occupational exposure) [34].

Figure 11. Risk assessment of mining department laboratory Magnetic Separators.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
6	Furnaces	Physical (Temperature)	Skin burns, Heat stress, and Heat stroke	3	3	Medium	1- Sign for hot surface and do not touch. 2- Gloves (cut and pinch-resistant). 3- Transfer to a separate room. 4- Barrication of 1m around the equipment. 5- Using a lab coat, safety goggles, safety shoes, face protection shield, and heat-resistant gloves.

Figure 12. Risk assessment of mining department laboratory Furnaces.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
7	Electro-magnetic Separator	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Radiation)	Headaches, anxiety, affect nervous system function and cause damage to cells	5	3	High	1-Limit the exposure time. 2-Exposure monitoring radiation badges and handheld monitor to ensure it is within limits (WHO: time-weighted average of 200 mT during the working day for occupational exposure) [34].

Figure 13. Risk assessment of mining department laboratory Electro-magnetic Separator.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
8	Los-Angeles	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	3	Low	1- Cover for feeding Hopper during operation. 2- Safe guard for moving parts. 3- Barricading of 1m around the equipment. 4- Safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1- Suction fan to minimize dust. 2- Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1- Breaking down tasks and weight loads. 2- Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1- Limit exposure time. 2- Noise monitoring. 3- Ear muffs. 4- Sound proof cabinet for equipment.

Figure 14. Risk assessment of mining department laboratory Los Angeles.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
9	Column Flotation	Physical (Fall)	Broken Bones (Fracture)	3	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Health (Dust)	Respiratory disorders	2	1	Low	1- Suction fan to minimize dust. 2- Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1- Breaking down tasks and weight loads. 2- Using equipment for heavy lifting.

Figure 15. Risk assessment of mining department laboratory Column Flotation.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
10	RCD-250 Pressure Controlled Coring Machine	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	3	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	3	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 16. Risk assessment of mining department laboratory RCD-250 Pressure Controlled Coring Machine.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
11	Petrographic Rock Cutter and Diamond slap Saw (Diamond pacific tool CORP)	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	3	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	3	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 17. Risk assessment of mining department laboratory Petrographic Rock Cutter and Diamond slap Saw.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
12	Direct Shear Test Machine	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2-Emergency stop. 3-Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	3	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1-Limit exposure time. 2- Noise monitoring. 3-Ear muffs.

Figure 18. Risk assessment of mining department laboratory Direct Shear Test Machine.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
13	Manual Drill	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	4	Medium	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	3	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1- Limit exposure time. 2- Noise monitoring. 3- Ear muffs.

Figure 19. Risk assessment of mining department laboratory Manual Drill Machine.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
14	Rock Surface Grinder	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	2	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1- Limit exposure time. 2- Noise monitoring. 3- Ear muffs.

Figure 20. Risk assessment of mining department laboratory Rock Surface Grinder.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
15	Slake Durability Testing system	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	1	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1- Limit exposure time. 2- Noise monitoring. 3- Ear muffs.

Figure 21. Risk assessment of mining department laboratory Slake Durability Testing system.

Sr.	Equipment	Hazard	Hazard Effect	Severity	Probability	Risk Scale	Control Measure
16	Compression Machine	Physical (Electrical)	Electric Shock	5	1	Low	1- Electric cables and circuit breaker must be covered. 2- Emergency stop. 3- Gloves.
		Physical (Mechanical)	Wounds and Skin cuts	2	3	Low	1- Safety shield around the moving part. 2- Using safety goggles, safety shoes, and gloves (cut and pinch resistant).
		Health (Dust)	Respiratory disorders	2	1	Low	1-Suction fan to minimize dust. 2-Respirator.
		Health (Ergonomics)	Muscle strain	1	3	Low	1-Breaking down tasks and weight loads. 2-Using equipment for heavy lifting.
		Health (Noise)	Hearing loss or tinnitus	1	3	Low	1- Limit exposure time. 2- Noise monitoring. 3- Ear muffs.

Figure 22. Risk assessment of mining department laboratory Compression Machine.

6. Results and Discussion

The risk assessment was conducted in the rock mechanics and mineral processing laboratories of the Mining Engineering Department. The investigation study covered 16 significant pieces of equipment. It assessed the physical hazards, which can induce electric shocks, wounds, skin cuts, as well as the health risks such as ergonomics, temperature, noise, dust, and radiation.

In this study, around seventy-two hazards have been identified and then analyzed. The risk assessment results showed that types of equipment such as Electro-magnetic Separator and Magnetic Separator might negatively impact health through the emitted radiation and cause headaches, anxiety, disturb nervous system function, and cell damage. They fall into a high-risk scale, which requires strict control measures in addition to existing control measures to reduce risk and prevent any negative impact. The highly recommended additional control measures are limiting the exposure time, monitoring radiation exposure badges and handheld monitors to ensure it is within allowed limits (average: 200 mT per working day).

Likewise, the risk assessment results showed that a medium risk scale might be associated with operating the manual drilling equipment and the crusher, which may cause wounds or skin cuts and respiratory disorders. The required additional control measures include providing a suction fan to minimize dust and respirator for the crusher area. And safety shield around the moving part of manual drilling equipment. Moreover, it is necessary to use safety goggles, safety shoes, and gloves (cut and pinch-resistant) while operating them.

Medium risk scale is also associated with furnaces equipment operation. It can induce a high temperature while operating and cause skin burns, heat stress, and heatstroke. Providing a sign for hot surface and do not touch, heat-resistant gloves, and using a lab coat, safety goggles, safety shoes, and face protection shield are recommended control measures. Equipment falling into the low-risk scale may be acceptable but simultaneously require additional tasks depending on the type of equipment and the identified hazard as recommended in the risk assessment of each equipment to reduce the level of risk as much as possible.

Conclusion

Since the prominent role of the university laboratories in the educational and academic field, it is necessary to conduct a risk assessment for their equipment before operating to identify the potential induced hazards. It also helps evaluate existing controls, minimize the associated risks, prioritize them, and create a safe work area with additional control measures if required. The mining laboratory consists of many equipment and machinery employed to perform different types of jobs. Equipment of mineral processing and rock mechanics laboratories are involved in crushing, milling, separating, heating, cutting, drilling, grinding, and high-pressure compression type activities. The working mechanism is different, which may create unsafe conditions and cause different types of accidents while operating.

The risk assessment task was carried out for sixteen significant pieces of equipment in the mining laboratory, including around seventy-two identified hazards. The results revealed that Electro-magnetic Separator and Magnetic Separator are considered high-risk equipment. Both required strict additional control measures such as limiting the exposure time, monitoring radiation exposure badges, and handheld monitors to ensure it is within allowed limits. A warning sign "Only or Authorized Personnel" should be posted near the equipment to minimize potential exposure to other personnel. In addition, outcomes showed some medium-risk scale might be associated with operating the manual drilling equipment and the crusher. That requires providing a suction fan, respirator, and safety shield around the moving part. The acceptable levels of risk scale were achieved in most laboratory equipment; however, some additional control measures have been recommended to reach the minimum levels of risks.

The overall outcomes showed that university laboratories contain many sources of occupational hazards. Therefore, it is necessary to carry out risk assessments periodically and evaluate the existing control measures on an ongoing basis to avoid any accidents or negative impacts on safety or health. However, among the literature, there was a significant lack of research conducted to examine the university laboratories' risk except for labs used for chemical studies. Accordingly, more studies are recommended to investigate the occupational hazards and associated risks in university laboratories.

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References

[1] **Forcino, F. L.,** The importance of a laboratory section on student learning outcomes in a university introductory earth science course. *J. Geosci. Educ.* **61**, 213–221 (2013).

[2] **Reid, N.** and **Shah, I.,** The role of laboratory work in university chemistry. *Chem. Educ. Res. Pract.* **8**,

172–185 (2007).

[3] **Al-Zyoud, W.**, **Qunies, A. M.**, **Walters, A. U. C.** and **Jalsa, N. K.,** Perceptions of chemical safety in laboratories. *Safety* **5**, (2019).

[4] **Ozdemir, Y., Gul, M.** and **Celik, E.,** Assessment of occupational hazards and associated risks in fuzzy environment: A case study of a university chemical laboratory. *Hum. Ecol. Risk Assess. An Int. J.* **23**, 895–924 (2017).

[5] **Donaldson, T.,** University laboratory hazards - some key lessons from LPB IChemE IChemE. *Loss Prev. Bull.* **271**, 9–13 (2020).

[6] **Li, Z., Zhao, S., Su, L.** and **Liao, C.,** Study on the operators' attention of different areas in university laboratories based on eye movement tracking technology. *IEEE Access* **8**, 8262–8267 (2020).

[7] **Ménard, A. D.** and **Trant, J. F.,** A review and critique of academic lab safety research. *Nat. Chem.* **12**, 17–25 (2020).

[8] **Institute, L. S.,** Memorial Wall - Killed in Lab Accident - Laboratory Safety Institute. https://www.labsafety.org/memorial wall (2021).

[9] **Asiry, S.** and **Ang, L. C.,** Laboratory safety: Chemical and physical hazards. *Methods Mol. Biol.* **1897**, 243–252 (2019).

[10] **Mugivhisa, L. L., Baloyi, K.** and **Olowoyo, J.,** Adherence to safety practices and risks associated with toxic chemicals in the research and postgraduate laboratories at Sefako Makgatho Health Sciences University, Pretoria, South Africa. *African J. Sci. Technol. Innov. Dev.* **13**, 747–756 (2021).

[11] **Halvani, G., Soltani, R., Alimohammadi, M.** and **Kiani, Z.,** Identification and evaluation laboratory hazards in Yazd University of Medical Sciences by standard checklists – DOAJ. *Occup. Med. (Chic. Ill).* **3**, 21–27 (2011).

[12] **Olewski, T.** and **Snakard, M.,** Challenges in applying process safety management at university laboratories. *J. Loss Prev. Process Ind.* **49**, 209–214 (2017).

[13] **Schröder, I., Huang, D. Y. Q., Ellis, O., Gibson, J. H.** and **Wayne, N. L.,** Laboratory safety attitudes and practices: A comparison of academic, government, and industry researchers. *J. Chem. Heal. Saf.* **23**, 12–23 (2016).

[14] **Shallcross, D. C.,** Safety shares in the chemical engineering class room. *Educ. Chem. Eng.* **9**, e94–e105 (2014).

[15] **Véchot, L. N., Casson, V.** and **Olewski, T.**, Training future engineers to be committed to safety. in *QScience Proceedings* vol. 2014 28 (Hamad bin Khalifa University Press (2014).

[16] **Canadian C. for O. H.** and **S.,** OSH Answers. *Hazard and Risk* https://www.ccohs.ca/oshanswers/hsprograms/hazard_risk.html (2021).

[17] **OSHA,** Safety Management - Hazard Prevention and Control | Occupational Safety and Health Administration. *Recommended Practices for Safety and Health Programs* 2021 https://www.osha.gov/safety-management/hazard-prevention.

[18] **NIOSH**, Hierarchy of Controls | NIOSH | CDC. *Workplace Safety & Health* https://www.cdc.gov/niosh/topics/hierarchy/default.html (2021).

[19] **Akhtar, R., Azim, S., Nawaz, R.** and **Ahmad, I.**, Identification And Evaluation Of Risk Assesment In Cement Industry. *Int. J. Sci. Technol. Res.* **10**, 94–103 (2021).

[20] **Casson, V., Olewski, T.** and **Ve, L. N.,** Training future engineers to be committed to safety. in *QScience Proceedings (World Congress on Engineering Education 2013) 2014:28* 1–8 (Hamad bin Khalifa University Press (HBKU Press), 2014).

[21] **Badri, A., Nadeau, S.** and **Gbodossou, A.,** A mining project is a field of risks: A systematic and preliminary portrait of mining risks. *Int. J. Saf. Secur. Eng.* **2**, 145–166 (2012).

[22] **Ivanova, G.,**The mining industry in Queensland, Australia: Some regional development issues. *Resour. Policy* **39**, 101–114 (2014).

[23] **Al-Bakri, A. Y., Ahmed, H. A. M., Ahmed, H. M.** and **Hefni, M. A.,** Evaluation studies of the new mining projects. *Open Geosci.* **15**, 20220466 (2023).

[24] **Al-Bakri, A.** and **Hefni, M.,** A review of some nonexplosive alternative methods to conventional rock blasting. *Open Geosci.* **13**, 431–442 (2021).

[25] **ISO,** ISO/TC 82 - Mining. https://www.iso.org/committee/50164.html.

[26] **OSHA,** Division B: Mining | Occupational Safety and Health Administration. https://www.osha.gov/data/sic-manual/division-b.

[27] **MSHA,** Regulations | Mine Safety and Health Administration (MSHA). https://www.msha.gov/regulations.

[28] **HSE,** Mining: Mines Regulations 2014. https://www.hse.gov.uk/mining/mlr.htm.

[29] **Paithankar, A.,** Hazard identification and risk analysis in mining industry. (National Institute of Technology, 2010).

[30] **Utembe, W., Faustman, E. M., Matatiele, P.** and **Gulumian, M.,** Hazards identified and the need for health risk assessment in the South African mining industry. *Hum. Exp. Toxicol.* **34**, 1212–1221 (2015).

[31] **Donoghue, A. M.,** Occupational health hazards in mining: An overview. *Occup. Med. (Chic. Ill).* **54**, 283–289 (2004).

[32] **Wei, C.,** Research on university laboratory management and maintenance framework based on computer aided technology. *Microprocess. Microsyst.* (2020) doi:10.1016/j.micpro.2020.103617.

[33] **Fishwick, T.,** Conventional safety management in a modern university laboratory. *Loss Prev. Bull.* 8–11 (2014).

[34] **Meyer, T.,** How about safety and risk management in research and education. *Procedia Eng.* **42**, 854–864 (2012).

[35] **Aydar, E.,** Laboratories in Geosciences : Some Tips for Management. *Int. J. Progress. Sci. Technol.* **22**, 232–239 (2020).

[36] **HSSE WORLD,** TPL Risk assessment Matrix. *Safety* https://hsseworld.com/hira-hse-hazards-effects-management-process-hemp-risk-register-template/tpl-risk-assessment-matrix/ (2021).

المخاطر المهنية في المعامل الجامعية والتأثيرات السلبية المحتملة المرتبطة بها: دراسة تفصيلية لمعامل قسم هندسة التعدين

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مستخلص. تلعب المعامل دوراً بارزاً في المجال الأكاديمي من خلال البحث والتجارب وتعزيز الممارسات التعليمية للطلاب. ومن ناحية أخرى، يصاحب العمل في المعامل الجامعية بعض المخاطر التي قد تؤثر سلباً على سلامة الباحثين والطلاب والفنيين والزوار. قامت هذه الدراسة ومن خلال معامل قسم هندسة التعدين، بدارسة مصادر تلك المخاطر من منظور السلامة المهنية. وذلك بهدف تقييم التأثيرات السلبيه المحتملة الناتجة عن استخدام مختلف المعدات المعملية من خلال تحديد مصادر الخطر، ومراجعة ضوابط السلامة الحالية، ومن ثم تقليل التأثيرات السلبية المحتملة المرتبطة بها، وكذلك ترتيب أولوياتها واهميتها، ثم بالتالي تقديم منطقة عمل آمنة مع تدابير تحكم إضافية. غطت الدراسة ستة عشر معدّة من الآلات المستخدمة في معملي معالجة المعادن وميكانيكا الصخور. وقد أشارت النتائج التي تم الحصول عليها إلى تحديد قرابة اثنين وسبعين مصدر خطر. حيث تم تحديد مقياس خطورة عالية في كلاً من معدّة الفصل الكهرومغناطيسي ومعدّة الفصل المغناطيسي. وكلاهما يتطلب تدابير وقائية إضافية صارمة على النحو الموصى به في هذه الدراسة. بالإضافة إلى ذلك، أظهرت النتائج أن بعض المخاطر ذات التقييم المتوسط قد تكون مرتبطة بتشغيل معدات الحفر اليدوية وكسارات الصخور. كما انه تم تحقيق المستويات المقبولة من المخاطر في معظم الأجهزة المعملية؛ ومع ذلك، تقترح هذه الدراسة بعض التدابير الرقابية الإضافية للوصول إلى الحد الأدنى من مستويات المخاطر. كما أنه كشفت مراجعة الدراسات السابقة عن وجود نقص كبير في الأبحاث التي تم اجراؤها لتحديد وتقييم مخاطر المعامل الجامعية باستثناء المعامل التي تستخدم في التجارب الكيميائية. ولذلك، فإنه يُوصى وبشدة بإجراء المزيد من الدراسات للبحث في المخاطر المهنية والتأثيرات السلبية المرتبطة بها في مختلف المعامل الجامعية.

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