RESPIRATORY HAZARDS

An Exploratory Study Analyzing Risk in Nonbiochemical Academic Laboratories

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LABORATORIES ARE CENTRAL to practically every research-based university. Typically, academic laboratories are closed, crowded spaces with various hazards including dangerous equipment and chemical agents to which staff and students are exposed daily (Ali et al., 2015; AlShammari et al., 2021; Ozdemir et al., 2017; Salazar et al., 2020). In addition, students in academic laboratories often work alone with little or no safety and health training (Abu-Siniyeh & Al-Shehri, 2021; AlShammari et al., 2021; Cook et al., 2020; Groso et al., 2012; Ozdemir et al., 2017). It is therefore not surprising that studies have found a general lack of awareness among students about the hazards and associated risks that may be found in the labs where they work (Abu-Siniyeh & Al-Shehri, 2021; AlShammari et al., 2021; Groso et al., 2012; Ozdemir et al., 2017). Furthermore, studies have concluded that most academic laboratories lack a positive safety culture, which is the shared beliefs, attitudes and behavioral norms concerning safety in the workplace; therefore, safety and health is not necessarily a priority (Gutiérrez et al., 2013; Schröder et al., 2016). Consequently, students and staff who work in academic laboratories are at risk of experiencing incidents, injuries or, in some extreme cases, death (Ali et al., 2015; Salazar et al., 2020).

Over the past decade, the prevalence and severity of incidents that have occurred in academic laboratories have drastically increased (Zhang et al., 2021). In fact, incident rates in academic laboratories are believed to be 10 to 50 times greater than in similar industrial laboratories (Ali et al., 2015; Salazar et al., 2020). According to the U.S. Chemical Safety and Hazard Investigation Board, between 2001 and 2011, a total of 120 academic laboratory incidents were reported in the U.S. (Salazar et al., 2020). The most notable of these resulted in fatalities at University of California, Los Angeles, University of Chicago and Yale University (Huising & Silbey, 2013; Ménard et al., 2022; Salazar et al., 2020). Besides in the U.S., numerous cases of academic laboratory injuries and fatalities have been reported worldwide (Salazar et al., 2020). Many documented academic laboratory incidents have common underlying causes including inadequate training, lack of adherence to PPE and poor safety culture (Cook-Shimanek et al., 2020; Groso et al., 2012; Huising & Silbey, 2013; Juba et al., 2021).

Overall, exposure to respiratory hazards is the second most common type of incident in academic laboratories (Sieloff et al., 2013) because inhalation of toxic or irritating airborne contaminants is a common route of exposure (Ménard et al., 2022; Nasrallah et al., 2022). However, based on the authors' literature review, these studies have only been conducted in academic biochemistry labs; yet respiratory hazards such as gases, fumes and particulates are also generated by equipment and processes found in nonbiochemical labs, studios and workshops (Ozdemir et al., 2017). To the best of the authors' knowledge, no study has evaluated the respiratory hazard risks found in nonbiochemical academic laboratories.

Therefore, the present study sought to identify and assess the risks associated with respiratory hazards generated by equipment and processes used in nonbiochemical science labs, studios and workshops. This exploratory study was conducted to better understand the extent and severity of this hazard in academic workspaces as well as identify where improvements could be made to protect the respiratory health of staff and students.

KEY TAKEAWAYS

- **Respiratory hazards in nonbiochemical academic laboratories, studios and workshops are varied and can pose risks to staff and students.**
- **Local exhaust ventilation or respiratory protection usage and maintenance are lacking or insufficient in these settings. As with biochemical academic laboratories, there are opportunities to improve the safety culture in nonbiochemical academic workspaces.**
- **This exploratory study sought to identify and assess the risks associated with respiratory hazards generated by equipment and processes in nonbiochemical academic laboratories, studios and workshops.**

Methods

This cross-sectional study was conducted at a mid-sized public university in Toronto, Canada. The eligibility criteria for this study were any nonbiochemical laboratory, workshop or studio where there is a potential for exposure to respiratory hazards. Institutional ethics approval was obtained prior to the start of the study (REB 2022-465). Recruitment was conducted through emails sent on behalf of the research team by the university's environmental health and safety department. Lab managers or safety officers who consented to participate in the study arranged a mutually convenient time for a member of the research team to make an in-person visit to collect data.

Data Collection Tools

To understand the type of respiratory hazards that are generated from within the participating nonbiochemical laboratories, two types of data were collected:

- passive observations of equipment or processes that generate airborne hazards documented using a checklist, and
- video recordings of these same equipment or processes.

The observational checklist was based on existing laboratory inspection guidelines published by the Government of Canada, WorkSafeBC and NIOSH (Karpinski, 2018; NIOSH, 2003, 2020a; WorkSafeBC, 2014). The final checklist consisted of four sections:

1) types of respiratory hazards potentially generated and how often exposure occurs,

2) general safety information including student and staff training, ventilation (both local and general), safety data sheets (SDS), and chemical labeling and storage,

3) respiratory protection availability and usage, and

4) information about the cleaning, collection, and containment of airborne contaminants generated in the lab or workshop.

The questions were dichotomous in nature (yes/no) with options for additional comments if needed. The checklist was completed by a member of the research team in conjunction with informal questioning of the lab manager or safety officer.

To visually identify how airborne hazards are generated and the resulting amount, video recordings of equipment

TABLE 1
RESPONSE FREQUENCY OF PARTICIPATING LABS

Response frequency of participating labs, workshops and studios (*n* = 7) to Sections 2, 3 and 4 of the observational checklist.

Question	Yes	No	N/A
Section 2: Housekeeping and general safety			
Are safety data sheets updated and readily available (hard copy or digital)?	100%	0%	0%
Are lab users informed of the university's digital database, Chemwatch, for accessing safety data sheets?	100%	0%	0%
Are hazardous chemicals stored properly and safely?	100%	0%	0%
Are hazardous chemicals labelled correctly (e.g., WHMIS)?	100%	0%	0%
Are lab or workshop doors always closed?	46%	54%	0%
Section 3: Respiratory protection use			
Based on observations of the tasks and interviewing the lab representative, should respiratory protection be used in this space?	85%	15%	0%
Is respiratory protection being used in this lab?	31%	69%	0%
Is the respirator used appropriate for the work done in the lab?	31%	69%	0%
Are there clear and visible signs reminding people to use respirators?	0%	23%	77%
Is there a written respiratory protection program?	0%	100%	0%
Required respiratory protection is available and in stock?	85%	0%	15%
Do students and lab staff know where required respirators are located or stored?	69%	15%	15%
Are students and lab staff trained on how to correctly use the respirator?	69%	8%	23%
Is the respirator used for the full duration of the experiment or class?	0%	31%	69%
Are respirator users fit tested?	23%	8%	69%
Are the respirators that are used in good condition (e.g., no wear and tear, filters changed)	77%	0%	23%
Does the required respirator interfere with user's ability to safely complete experiments or work?	8%	23%	69%
Section 4: Other controls or safety practices			
Are airborne chemical generating procedures done in an enclosed space?	0%	77%	23%
Are all work surfaces cleaned using a wet method to not generate airborne particles?	8%	92%	0%
Are there any written strategies for containment and collection of released airborne chemicals?	0%	85%	15%
Is a dust collector, extractor or dust removal machine used in the lab?	69%	31%	0%
Is the dust collector, extractor or dust removal machine in good working condition?	38%	23%	31%
Are students and staff trained on how to use the dust collector, extractor or dust removal machine?	38%	23%	31%
Is the dust collector, extractor or dust removal machine properly maintained and repaired (e.g., are filters being changed according to manufacturer frequencies)?	38%	23%	31%

TABLE 2
FIVE-POINT SCALE DESCRIPTIONS

Level	Consequence	Likelihood
1	Insignificant	Rare
2	Minor	Unlikely
3	Significant	Moderate
4	Major	Likely
5	Severe	Almost certain

or processes were collected using a Canon EOS Rebel T4i digital video recorder. The length of each video represented the duration of each particular task, which ranged from 10 seconds to 13 minutes.

Data Analysis

Data from Sections 2 to 4 of the checklists were combined and summarized via frequency distributions (Table 1). For each respiratory hazard identified, data from the checklists and the video recordings were used to determine the consequence as well as the likelihood of exposure. Consequence values were assigned according to the potential adverse health effects associated with each identified respiratory hazard based on the corresponding SDS as well as referring to the NIOSH Pocket Guide to Chemical Hazards (NIOSH, 2020b). Likelihood values were established based on the amount of airborne hazard generated by the equipment or process as well as the frequency of exposure. In addition, to assign appropriate likelihood values, the existence and adequacy of the types of controls associated with each piece of equipment or process was assessed using the data documented on the observational checklist.

As there is no standardized approach for classifying the consequences and likelihood values, the research team assigned values based on consensus using the five-point scale descriptions from SafetyCulture.com, which are summarized in Table 2 (Guevara, 2024). Various factors influenced the consequence and likelihood values assigned to each machine; for example, machines used more frequently by staff or students were assigned a higher probability value. This is because there is a greater chance of exposure to respiratory hazards generated by a machine when it is used more often (OSHA, n.d). Likewise, factors such as the amount of the generated respiratory hazard and the degree of harm that exposure to the hazard would cause were used in determining consequence values.

Subsequently, the consequences and likelihood values were input into a 5x5 qualitative risk matrix. This type of matrix was chosen because it is more accurate than 3x3 or 4x4 matrixes (Guevara, 2024) and results in a sufficient but reasonable number of risk rating levels to allow for decision-making (Baybutt, 2018). The final risk rating for each hazard was then calculated using the formula *risk rating = consequence x likelihood*. Overall, the possible risk rating categories were: "acceptable" (risk ratings of 1 to 4), adequate (risk ratings of 5 to 9), tolerable (risk ratings of 10 to 16), or unacceptable (risk ratings of 17 to 25). The color-coded risk matrix allows the categories to be easily distilled for those who have little or no OSH knowledge (Duijm, 2015). Figure 1 provides additional information (Baybutt, 2018; Guevara, 2024; Peace, 2017).

FIGURE 1

RISK ANALYSIS MATRIX

Risk analysis matrix that was used with risk rating categories of acceptable (green), "adequate" (yellow), tolerable (orange) and unacceptable (red).

		Likelihood				
Consequence		1 Rare	2 Unlikely	3 Moderate	4 Likely	5 Almost certain
	5 Severe	5	10	15	20	25
	4 Major	4	8	12	16	20
	3 Significant	3	6	9	12	15
	2 Minor	2	4	6	8	10
	1 Insignificant	1	2	3	4	5

Results

All site visits were conducted in February 2023, and seven nonbiochemical laboratories, studios or workshops participated, with observations and video recordings collected from 13 pieces of equipment or processes overall. Based on the observational checklist data, the lab doors were always closed in less than 50% of the participating workspaces, and none of the workspaces had written procedures for the containment of airborne hazards. Only 69% of these workspaces employed any type of local exhaust ventilation system. Also, only 38% of participating labs, studios and workshops reported that the existing dust extractors were properly maintained and in good working condition. In some instances, students or staff were not trained on how to use the dust collector, extractor or dust removal machine found in the workspace (see Figure 2, p. 24).

With respect to respiratory protection, only 31% of the workspaces reported using respirators; however, based on the authors' observations, 85% of them should be using respiratory protection. None of the participating workspaces displayed signs indicating that respiratory protection was required. In addition, none of these workspaces reported having a written respiratory protection program. In some instances, neither training nor respirator fit testing was offered (see Figure 2, p. 24).

Regarding the qualitative risk ratings, of the 13 pieces of equipment and processes observed in the participating workspaces, the highest risk rating was 16 (tolerable) and was attributed to two pieces of equipment—the Los Angeles abrasion machine and milling machine. Other machines, such as the lathe, pedestal grinder, edge sander, band saw and table saw, also received risk ratings deemed tolerable but had a slightly lower calculated risk rating value of 12. All remaining evaluated equipment or processes had risk ratings of 9 (adequate) or less (see Table 3, p. 25). Photos 1 to 13 (p. 26) depict all tested equipment or processes, and the captions explain respiratory hazards associated with each.

Discussion

To the authors' knowledge, this is the first study to assess the risk of respiratory hazard exposure in nonbiochemical academic laboratories. This exploratory study was conducted in seven nonbiochemical science labs, studios and workshops at an urban Canadian university, and a total of 13 pieces of equipment or processes were observed. Various respiratory hazards such as aggregate dust, wood, metal, plaster and acrylic dust, adhesive fumes, smoke, and solvents were identified. Overall, based on the 5x5 risk matrix, a slight majority of the equipment or processes (7 of 13, or 54%) were deemed tolerable whereby additional control measures are suggested to lower the risk.

The findings also indicate that there was a great deal of reliance on general exhaust ventilation systems, as very few spaces were equipped with local exhaust ventilation. Ideally, local exhaust ventilation, a form of engineering control, is employed for equipment and work processes that generate large amounts of dust, fumes and air contaminants that pose serious health risks (CCOHS, 2016). Academic laboratories, regardless of type, should be designed and equipped with devices and equipment essential to lowering the risks associated with the potential airborne hazards found in the workspace (AlShammari et al., 2021). However, it is not sufficient to simply have a local exhaust ventilation system installed; it is also important to ensure frequent inspection and maintenance of these control measures as they age over time (Al-Dahhan et al., 2017; Wei, 2020).

In addition, it was found that in spaces where respiratory protection should have been used, no respiratory protection program or visible signs were present to remind users; as such, respirators were not used for the full duration of task or process. This aligns with numerous studies conducted in many biochemistry laboratories, as lack of adherence to PPE usage is known to be an issue in many academic laboratories (Schröder et al., 2016). Generally, control methods that ask an individual to comply with their use should not be relied upon as a primary method of control, as studies have found that individuals often have a misconstrued perception of risk and, unfortunately, human error is inevitable (Brown et al., 2022; Schröder et al., 2016). If respiratory protection is to be used in the workplace, a written respiratory protection program must be implemented as per requirements established by the governing body where the university is located (Government of Ontario, 2022; Juba et al., 2021).

It has been demonstrated that workers in most industries, including academia, lack knowledge and awareness of the hazards to which they are exposed in their jobs, contributing to 80% to 90% of most industrial incidents (Khoso et al., 2017; Musonda & Smallwood, 2008). This lack of awareness and low priority of safety and health suggests a poor safety culture. In fact, Ayi and Hon (2018) concluded that biochemical labs at the same institution where the present study was conducted "not only has issues with safety compliance but also lacks a strong and positive safety culture." The existence of a robust safety culture in academic labs improves productivity and efficiency, and ultimately lowers the risk of incidents and

FIGURE 2
OBSERVATIONAL CHECKLIST RESPONSES

Select findings and responses from Sections 2 to 4 of the observational checklist (*n* = 7 participating workspaces). In those instances where the total does not equal 100%, the remainder is not applicable. Response frequencies for all observation checklist questions are found in Table 1 (p. 22).

Table 1 (p. 22)

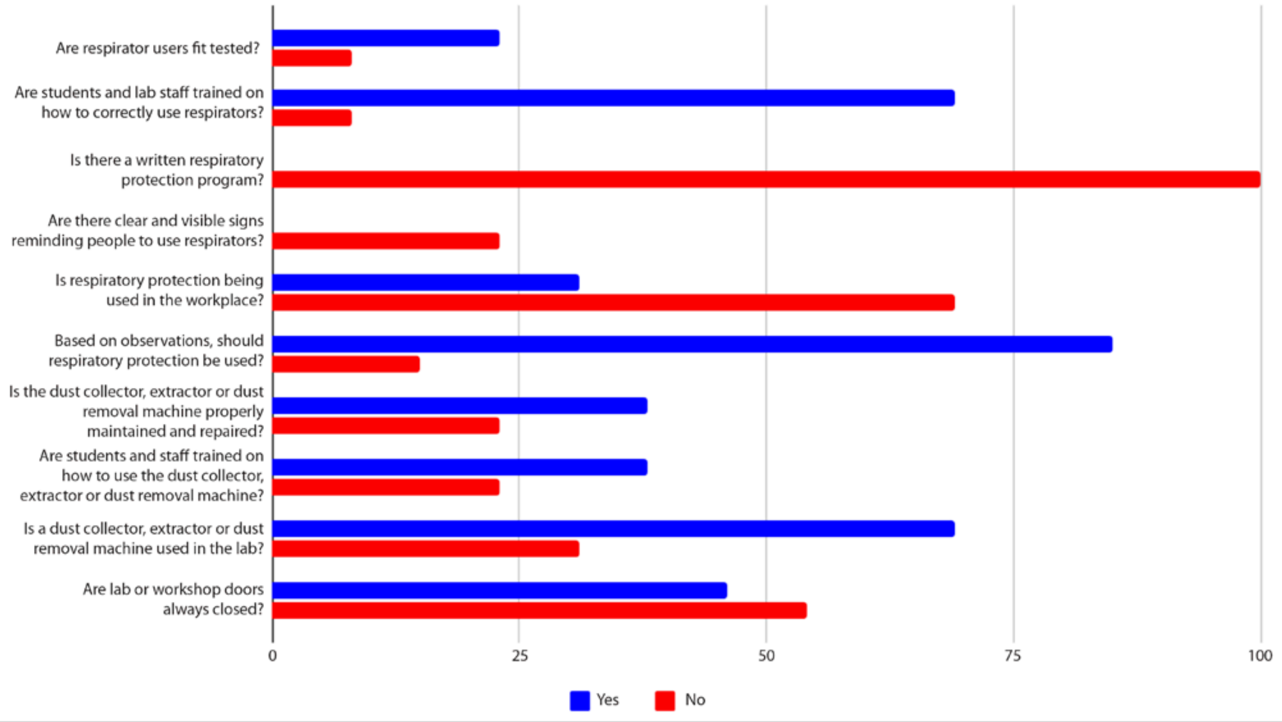

TABLE 3
RESPIRATORY HAZARD RISK RATING

Qualitative risk rating of respiratory hazards generated from various equipment and processes [see Photos 1 to 13 (p. 26) for equipment and procedure images].

Equipment/ process	Respiratory hazards	Existing controls[a]	Frequency and exposure duration	Consequence of exposure[b]	Overall risk rating
Los Angeles machine (Photo 1)	Aggregate dust, solvent cleaners	GEV system and LEV (dust extractor), N95 or cartridge mask respirators, SDS and WHMIS labeling available for solvents used	*Graduate students/staff:* 2 to 4 hr per day, 4 days per week *Undergraduate students:* 2 to 4 hr per day, 1 to 2 times per year	Silicosis or lung damage, eye, nose, throat irritation, nausea, dizziness, headache (4)	16
	Likelihood (4)				
Milling machine (Photo 2)	Metal dust, smoke/fumes	GEV, Plexiglass shield in front of machine, optional respirator use	*Staff:* 2 to 5 hr per day for about 3 times per week	Metal Fume Fever, lung, kidney and CNS damage (4)	16
	Likelihood (4)				
Band saw (Photo 3)	Wood or acrylic dust, solvent cleaners	GEV, LEV (dust extractor), optional respirator use, vacuum used to clean dust generated after use	*Students:* 30 min per day, weekly *Staff:* 7 hr per day, weekly	Eye, nose, throat irritation, dermatitis, occupational asthma, hypersensitivity pneumonitis (4)	12
	Likelihood (3)				
Table saw (Photo 4)	Wood or acrylic dust, solvent cleaners	GEV, LEV (dust extractor), optional respirator use, vacuum used to clean dust generated	*Students:* 30 min per day, weekly *Staff:* 7 hr per day, weekly	Eye, nose, throat irritation, dermatitis, occupational asthma, hypersensitivity pneumonitis (4)	12
	Likelihood (3)				
Edge sander (Photo 5)	Wood dust	GEV, LEV (dust extractor), optional respirator use, vacuum used to clean dust generated	*Students:* 30 min per day, weekly *Staff:* 7 hr per day, weekly	Eye, nose, throat irritation, dermatitis, occupational asthma, hypersensitivity pneumonitis (4)	12
	Likelihood (3)				
Pedestal grinder (Photo 6)	Metal dust smoke/fume	GEV, Plexiglass shield in front of machine, optional respirator use, HEPA vacuum used to clean surfaces after machine use	*Staff:* 10 to 45 min per day, twice per day	Metal Fume Fever, lung, kidney and CNS damage (4)	12
	Likelihood (3)				
Lathe (Photo 7)	Smoke/fumes	GEV, optional respirator use	*Staff:* 15 min to 3 hr per day for about once per week	Metal Fume Fever, lung, kidney and CNS damage (4)	12
	Likelihood (3)				
Surface grinder (Photo 8)	Metal dust smoke/fumes solvent cleaners	GEV, optional respirator use, Plexiglass shield, wet cloth used to clean dust after machine use, SDS and WHMIS labeling available for solvents used	*Staff:* 2 to 4 hr per day, every 2 to 3 months	Metal Fume Fever, lung, kidney and CNS damage, eye, nose, throat irritation, nausea, dizziness, headache (3)	9
	Likelihood (3)				
Jaw crusher (Photo 9)	Aggregate dust solvent cleaners	GEV and LEV (dust extractor), N-95 or cartridge mask respirators, SDS and WHMIS labeling available for solvents used	*Graduate students/staff:* 2 to 4 hr per day, 4 days per week *Undergraduate students:* 2 to 4 hr per day, 1 to 2 times per year	Silicosis or lung damage, eye, nose, throat irritation, nausea, dizziness, headache (4)	8
	Likelihood (2)				
Plaster casting powder pouring (Photo 10)	Plaster dust	GEV, LEV (dust extractor), Optional respirator use	*Students/staff:* 2 hours per day, once a year	Silicosis, lung damage/disease (3)	6
	Likelihood (2)				
Coarse aggregate shaker (Photo 11)	Aggregate dust solvent cleaners	GEV and LEV (dust extractor), N-95 or cartridge mask respirators, SDS and WHMIS labeling available for solvents used	*Graduate students/staff:* 15 min to 1 hr per day, 4 days per week *Undergraduate students:* 15 min to 1 hr per day, 1 to 2 times per year	Silicosis or lung damage, eye, nose, throat irritation, nausea, dizziness, headache (4)	4
	Likelihood (1)				
Hand sanding (Photo 12)	Wood dust	GEV, optional respirator use	*Students:* 30 min per day once a week *Staff:* 7 hr per day for about 7 days per week	Eye, nose, throat irritation, dermatitis, occupational asthma, hypersensitivity pneumonitis (2)	4
	Likelihood (2)				
Adhesives (acrylic glue or adhesive spray used to stick acrylics; Photo 13)	Adhesives fumes	GEV, optional respirator use, SDS and WHMIS labeling available for solvents used	*Students/staff:* 5 min per day, 1 time per year	Eye, nose, throat irritation, nausea, dizziness, headache (2)	2
	Likelihood (1)				

Note. [a]General exhaust ventilation (GEV) system, local exhaust ventilation (LEV) system, safety data sheets (SDSs) and Workplace Hazardous Materials Information System (WHMIS; a legislated system of communicating safety and health information for the safe handling, use and storage of hazardous chemicals in Canada; CCOHS, 2021)
[b]central nervous system (CNS)

Photo 1: Los Angeles abrasion machine used to study the quality of coarse aggregate. The machine generates a great amount of visible aggregate dust despite the use of a dust extractor.

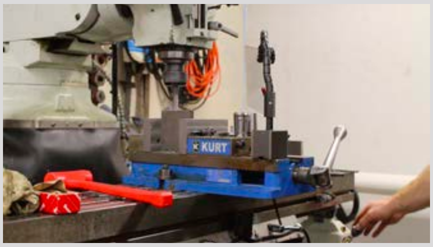

Photo 2: Milling machine used to create grooves, holes and irregular surfaces on metals. The machine generates a great amount of metal dust, and no local exhaust ventilation system is used.

Photo 3: Band saw used to cut pieces of wood, plaster molds and acrylic plastics. The machine generates a great amount of dust, but a local exhaust ventilation system is often used when in operation.

Photo 4: Table saw used to cut pieces of wood and acrylic plastics. The machine generates a great amount of dust, but a local exhaust ventilation system is often used when in operation.

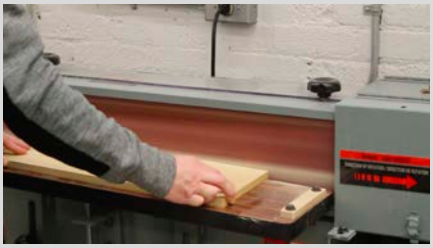

Photo 5: Edge sander used to sand down the edges of wooden material. The machine generates a great amount of wood dust, but a local exhaust ventilation system is often used when in operation.

Photo 6: Pedestal grinder used to sharpen and smoothen the surfaces of metals. The machine generates some metal dust, smoke and fumes. There is a small Plexiglass shield, but no local exhaust ventilation system is used.

Photo 7: Lathe used to shape metals by rotating it against a stationary cutting tool. The machine generates smoke when the cutting tool gets too hot or fumes if a coolant is used as well. Metal chips created by this machine are dusted off, but no local exhaust ventilation system is used for the airborne contaminants.

Photo 8: Surface grinder used to shave metal surfaces. The machine generates some metal dust, smoke and fumes. Solvent is released to control the temperature while shaving the metal. There is a small Plexiglass shield, but no local exhaust ventilation system is used.

Photo 9: Jaw crusher used to crush aggregate stone or rock. The machine generates aggregate that falls into a tray. Respirators are used and a local exhaust ventilation system is turned on when machine is operating.

Photo 10: Plaster-casting powder being poured into pail before use. The process generates plaster dust, and a local exhaust ventilation system is used.

Photo 11: Coarse aggregate shaker used to sieve aggregate stone or rock to different levels of fineness. The machine barely generates aggregate dust, as it is covered when in use.

Photo 12: Piece of wood being sanded using a manual hand sander. This process hardly generates any wood dust.

Photo 13: Process of gluing acrylic plates using acrylic or super glue. This process hardly generates any fumes, but on rare occasions an adhesive spray may be used.

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injuries by encouraging all lab workers to implement best practices and raise awareness about safety issues (McGarry et al., 2013; National Research Council, 2011, 2014; Olewski et al., 2016; Staehle et al., 2016).

Some limitations of this study bear mentioning. Observations and video recordings in each workspace were cross-sectional in nature; as such, the data collected are only representative of the time of collection and may not be representative of the amount of airborne hazard the equipment or processes in these workspaces typically generate. In addition, the small sample size means that it is difficult to generalize the findings of the study to other nonbiochemical labs, studios and workshops that may have different associated respiratory hazards. Therefore, it is recommended that future studies use a larger sample size and collect data over a longer period or multiple periods during a shift.

Conclusion

Overall, this exploratory study found that some of the equipment and processes used in the nonbiochemical academic labs, workshops and studios generated various respiratory hazards, with most having a tolerable risk rating. In addition, many of these spaces either improperly maintained or did not maintain local exhaust ventilation systems. Additional conditions noted in labs, workshops and studios were lack of adherence to PPE use and a lack of written respiratory protection program where respirators ought to be used. Lastly, action should be taken to strengthen the safety culture in these workspaces, as it is currently lacking and remains a common deficiency in most academic research facilities. Safety culture can be improved by academic leadership demonstrating commitment to workplace safety and health through policies and programs that encourage stakeholder participation and collaboration in safety and health initiatives, including routine evaluation for continuous improvement (Sorensen et al., 2018). Safety professionals in academia, department heads, lab safety managers and supervisors can further strengthen the safety culture by implementing a safety and health management system and performing routine safety inspections or audits to ensure effective implementation of control measures in every lab, studio and workshop (Hill & Finster, 2013; Salazar et al., 2020; Steward et al., 2016). In addition, fostering an environment that encourages reporting of near-miss incidents, as well as introducing routine safety training programs to educate staff and students about recognizing hazards and appropriate control measures would be beneficial (Benson et al., 2023). PSJ

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References

Abu-Siniyeh, A. & Al-Shehri, S.S. (2021). Safety in medical laboratories: Perception and practice of university students and laboratory workers. *Applied Biosafety, 26*(S1). https://doi.org/10.1089/apb.20.0050

Al-Dahhan, W.H., Ali, A.A. & Yousif, E. (2017). Lack of maintenance in a chemical laboratory has almost caused an accident. *Journal of Chemistry, 1*(1), 63-66. https://doi.org/10.22259/2637-5834.0101009

Ali, N., Goh, C.T., Zakaria, S., Mokhtar, M. & Halim, S.A. (2015). Chemical safety in school laboratories located in urban and rural areas: A case study in Cameron Highlands, Malaysia. *International Journal of Management and Applied Science, 1*(7), 70-73.

AlShammari, W., Alhussain, H. & Rizk, N.M. (2021). Risk management assessments and recommendations among students, staffs, and health care workers in educational biomedical laboratories. *Risk Management and Healthcare Policy, 14*, 185-198. https://doi.org/10.2147/RMHP.S278162

Ayi, H.-R. & Hon, C.-Y. (2018). Safety culture and safety compliance in academic laboratories: A Canadian perspective. *Journal of Chemical Health and Safety, 25*(6), 6-12. https://doi.org/10.1016/j.jchas.2018.05.002

Baybutt, P. (2018). Guidelines for designing risk matrices. *Process Safety Progress, 37*(1), 49-55. https://doi.org/10.1002/prs.11905

Benson, C., Obasi, I.C., Akinwande, D.V. & Ile, C. (2023). The impact of interventions on health, safety and environment in the process industry. *Heliyon, 10*(1), Article e23604. https://doi.org/10.1016/j.heliyon.2023.e23604

Brown, K.J., Smith, A.B., III & Nguyen, M. (2022). Lessons learned from laboratory vacuum pump exhaust explosion: Discussion and preventative strategies. *ACS Chemical Health and Safety, 29*(1), 87-90. https://doi.org/10.1021/acs.chas.1c00060

Canadian Centre for Occupational Health and Safety (CCOHS). (2016). Industrial ventilation: Introduction. https://bit.ly/4l0H9Cz

CCOHS. (2021). WHMIS—WHMIS program. www.ccohs.ca/oshanswers/chemicals/whmis_ghs/program.html

Cook-Shimanek, M., McGrath, A. & Pacheco, K.A. (2020). Isocyanate induced allergic contact dermatitis in a university undergraduate student: An occupational dermatitis case report, review of laboratory safety regulations, and implications for campus research. *American Journal of Industrial Medicine, 63*(8), 726-732. https://doi.org/10.1002/ajim.23140

Duijm, N.J. (2015). Recommendations on the use and design of risk matrices. *Safety Science, 76*, 21-31. https://doi.org/10.1016/j.ssci.2015.02.014

Government of Ontario. (2022, June 29). Guide to the Occupational Health and Safety Act. www.ontario.ca/document/guide-occupational-health-and-safety-act

Groso, A., Ouedraogo, A. & Meyer, T. (2012). Risk analysis in research environment. *Journal of Risk Research, 15*(2), 187-208. https://doi.org/10.1080/13669877.2011.634513

Guevara, P. (2024, July 12). A guide to understanding 5x5 risk management matrix. Safety Culture. https://safetyculture.com/topics/risk-assessment/5x5-risk-matrix

Gutiérrez, J.M., Emery, R.J., Whitehead, L.W. & Felknor, S.A. (2013). A means for measuring safety climate in the university work setting. *Journal of Chemical Health and Safety, 20*(6), 2-11. https://doi.org/10.1016/j.jchas.2013.07.001

Hill, R.H., Jr. & Finster, D.C. (2013). Academic leaders create strong safety cultures in colleges and universities. *Journal of Chemical Health and Safety, 20*(5), 27-34. https://doi.org/10.1016/j.jchas.2013.06.011

Huising, R. & Silbey, S.S. (2013). Constructing consequences for noncompliance. *The ANNALS of the American Academy of Political and Social Science, 649*(1), 157-177. https://doi.org/10.1177/0002716213492633

Juba, B.W., Mowry, C.D., Fuentes, R.S., Pimentel, A.S. & Román-Kustas, J.K. (2021). Lessons learned—Fluoride exposure and response. *ACS Chemical Health and Safety, 28*(2), 129-133. https://doi.org/10.1021/acs.chas.0c00108

Karpinski, E. (2018). Laboratory inspection guideline. Government of Canada. https://bit.ly/3FzyPtz
Khoso, A.R., Akhund, M.A., Memon, A. H., Siddiqui, F. & Khahro, S. H. (2019). Health and safety of Hyderabad Industries' labour: Causes and awareness. *Zenodo, 7*(6), 2334-2339. https://doi.org/10.5281/zenodo.1119012
McGarry, K.A., Hurley, K.R., Volp, K.A., Hill, I.M., Merritt, B.A., Peterson, K.L., Rudd, P.A., Erickson, N.C., Seiler, L.A., Gupta, P., Bates, F.S. & Tolman, W.B. (2013). Student involvement in improving the culture of safety in academic laboratories. *Journal of Chemical Education, 90*(11), 1414-1417. https://doi.org/10.1021/ed400305e
Ménard, A.D., Flynn, E., Soucie, K. & Trant, J.F. (2022). Accident experiences and reporting practices in Canadian chemistry and biochemistry laboratories: A pilot investigation. *ACS Chemical Health and Safety, 29*(1), 102-109. https://doi.org/10.1021/acs.chas.1c00070
Musonda, I. & Smallwood, J. (2008). Health and safety (H&S) awareness and implementation in Botswana's construction industry. *Journal of Engineering, Design and Technology, 6*(1), 81-90. https://doi.org/10.1108/17260530810863352
Nasrallah, I.M., El Kak, A.K., Ismaiil, L.A., Nasr, R.R. & Bawab, W.T. (2022). Prevalence of accident occurrence among scientific laboratory workers of the Public University in Lebanon and the impact of safety measures. *Safety and Health at Work, 13*(2), 155-162. https://doi.org/10.1016/j.shaw.2022.02.001
National Research Council. (2011). *Prudent practices in the laboratory: Handling and management of chemical hazards, updated version*. National Academies.
National Research Council (2014). *Safe science: Promoting a culture of safety in academic chemical research*. National Academies.
NIOSH. (2003). Respiratory protection: Safety checklist program for schools. www.cdc.gov/niosh/docs/2004-101/chklists/r1n57r~1.htm
NIOSH. (2020a). 3D printing safety at work. https://bit.ly/42dbDtG
NIOSH. (2020b). Pocket guide to chemical hazards. www.cdc.gov/niosh/npg/default.html
Olewski, T., Ahammad, M., Quraishy, S., Gan, N. & Vechot, L. (2016). Building process safety culture at Texas A&M University at Qatar: A case study on experimental research. *Journal of Loss Prevention in the Process Industries, 44*, 642-652. https://doi.org/10.1016/j.jlp.2016.08.022
OSHA. (n.d.). Prioritize hazards for control. www.osha.gov/sites/default/files/5_Prioritize_Hazards_For_Control.pdf
Ozdemir, Y., Gul, M. & Celik, E. (2017). Assessment of occupational hazards and associated risks in fuzzy environment: A case study of a university chemical laboratory. *Human and Ecological Risk Assessment: An International Journal, 23*(4), 895-924. https://doi.org/10.1080/10807039.2017.1292844
Peace, C. (2017). The risk matrix: Uncertain results? *Policy and Practice in Health and Safety, 15*(2), 131-144. https://doi.org/10.1080/14773996.2017.1348571
Salazar, M.A., Laborin-Alvarez, J.F., Alvarez-Chavez, C.R., Noriega-Orozco, L. & Borbon-Morales, C. (2020). Safety climate perceived by users of academic laboratories in higher education institutes. *Safety Science, 121*, 93-99. https://doi.org/10.1016/j.ssci.2019.09.003
Schröder, I., Huang, D.Y.Q., Ellis, O., Gibson, J.H. & Wayne, N.L. (2016). Laboratory safety attitudes and practices: A comparison of academic, government and industry researchers. *Journal of Chemical Health and Safety, 23*(1), 12-23. https://doi.org/10.1016/j.jchas.2015.03.001
Sieloff, A.C., Shendell, D.G., Marshall, E.G. & Ohman-Strickland, P. (2013). An examination of injuries and respiratory irritation symptoms among a sample of undergraduate chemistry students from a Public Northeastern University. *Journal of Chemical Health and Safety, 20*(5), 17-26. https://doi.org/10.1016/j.jchas.2013.04.011
Sorensen, G., Sparer, E., Williams, J.A.R., Gundersen, D., Boden, L.I., Dennerlein, J.T., Hashimoto, D., Katz, J.N., McLellan, D.L., Okechukwu, C.A., Pronk, N., Revette, A. & Wagner, G.R. (2018). Measuring best practices for workplace safety, health and well-being: The workplace integrated safety and health assessment. *Journal of Occupational and Environmental Medicine, 60*(5), 430-439. https://doi.org/10.1097/JOM.0000000000001286
Staehle, I.O., Chung, T.S., Stopin, A., Vadehra, G.S., Hsieh, S.I., Gibson, J.H. & Garcia-Garibay, M.A. (2016). An approach to enhance the safety culture of an academic chemistry research laboratory by addressing behavioral factors. *Journal of Chemical Education, 93*(2), 217-222. https://doi.org/10.1021/acs.jchemed.5b00299
Steward, J.E., Wilson, V.L., & Wang, W.-H. (2016). Evaluation of safety climate at a major public university. *Journal of Chemical Health and Safety, 23*(4), 4-12. https://doi.org/10.1016/j.jchas.2015.10.016
Wei, C. (in press). Research on university laboratory management and maintenance framework based on computer aided technology. *Microprocessors and Microsystems*, 103617. https://doi.org/10.1016/j.micpro.2020.103617
WorkSafeBC. (2014). Combustible wood dust mitigation and control checklist. https://bit.ly/42dbLcE
Zhang, B., Zhang, L., Wang, H. & Wang, X. (2021). Lessons learned from the explosion that occurred during the synthesis of Diaminomethanesulfonic acid: Discussion and preventative strategies. *ACS Chemical Health and Safety, 28*(4), 244-249. https://doi.org/10.1021/acs.chas.1c00021

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