Accident Experiences and Reporting Practices in Canadian Chemistry and Biochemistry Laboratories: A Pilot Investigation
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ABSTRACT: Accidents in chemistry and biochemistry laboratories are a regular occurrence and have been associated with injuries, property damage, and deaths. However, despite a high prevalence rate of accident involvement reported in previous investigations of academic lab personnel (approximately 30%), little is known about the context in which academic lab accidents occur. Previous findings also suggest a high degree of accident underreporting (25−40%), but again, little is known about this phenomenon. Pilot data was gathered from a convenience sample of 104 students and postdoctoral fellows in chemistry-related fields through an online survey. Results showed a high level of accident involvement (56.7%); of that number, most of those (65.9%) had been involved in multiple accidents. Most accidents involved only personal injuries and happened on a weekday afternoon with other lab members present. The majority of participants reported wearing multiple types of PPE at the time; however, adherence rates for any one type of equipment (e.g., goggles, gloves, coat) was less than 50%. Most (69.6%) reported their accidents to multiple individuals and were at least somewhat or very satisfied (81.2%) with their decision to report. Participants who chose not to report their accidents reported barriers such as beliefs that the accident was not severe, concerns about judgment, self-blame, and not knowing they had to report the accident or how. Implications for safety training and reporting practices are considered.

KEYWORDS: lab safety, underreporting, PPE use, accident involvement, lab accidents

Academic lab accidents represent a serious threat to the ongoing conduct of research in chemistry and biochemistry; many have resulted in damage to equipment, laboratories, and buildings, injuries to lab personnel, and, on a near-annual basis, deaths. Although a few studies have attempted to determine the prevalence rate of accident involvement among chemistry/biochemistry researchers, which is quite high,1 there is limited data about accident context and correlates. Reporting practices related to academic lab accidents have not been the subject of previous investigations, but anecdotal evidence suggests that many minor accidents go unreported to PIs or safety personnel. This is a serious omission as our understanding of the nature and causes of lab accidents will remain incomplete if incident data is recorded from only a fraction of overall accident occurrences. The goal of this study was to gather pilot data from a sample of research personnel working in a Canadian chemistry/biochemistry lab about accident experiences and reporting practices.

Accidents in Academic Laboratories. Despite the prevalence and severity of laboratory accidents in academic settings, minimal research in this area has been conducted. The largest study done to date on the subject (n = 2400 respondents) found a prevalence rate of 30% for involvement in or witnessing a lab accident.1,2 Data on demographic correlates of accident occurrence is scarce. Lab personnel who may be most vulnerable to accident involvement appear to be men under 30 years old;3 however, this data is extremely dated and may no longer be relevant based on changes in the demographic composition of modern chemistry/biochemistry laboratories. In terms of environmental context, accidents may occur more commonly on weekday afternoons and involve spills, fires or explosions, or equipment failures.3−5 Common injuries include lacerations, thermal or chemical burns, and chemical inhalation.1,6,7 The use of Personal Protective Equipment (PPE) to mitigate the danger of research work in academic chemistry/biochemistry laboratories is inconsistent at best. In one investigation, more than 65% of undergraduate chemistry students reported never wearing gloves.6 Similarly, less than half of Canadian academic lab workers and trainees in
another study reported always wearing appropriate PPE. An investigation by Schröder et al. found that PPE compliance was lowest among academic participants (compared to industry or government); 95% of participants endorsed consistent glove use but only 66% wore their lab coats consistently and 61% used eye protection. No prior research could be located related to the use of laboratory engineering controls (e.g., fume hoods, blast shields), although their use is likely to mitigate the impact of adverse events.

**Accident Reporting Practices.** Existing data on the prevalence of lab accident occurrence is likely to represent an underestimate of the frequency with which accidents occur: Several studies have suggested that 25–40% of laboratory accidents are not reported. No research has been done on the characteristics of individuals or of the accidents themselves that are associated with underreporting; given this deficit, findings from research on underreporting of accidents in other occupations and settings may be relevant. High occurrences of underreporting have been found in numerous other occupations and fields of work, such as health care, hospitality/service, manufacturing, and construction. Younger people in the work force (i.e., the same age as most lab personnel), and especially young men, are particularly likely to under-report occupational accidents, reportedly due to perceived power differentials and job insecurity. Common reasons identified for underreporting include perceived low injury severity, high levels of production pressure,
emotional exhaustion, poor safety climate, and physical or verbal workplace aggression.

**Research Questions.** Preliminary findings suggest that lab accidents are common, and mitigating control systems (such as PPE) are inconsistently employed; furthermore, due to underreporting, accidents may be happening far more frequently than officially reported. Likewise, there is little understanding about the types, correlates, and context of academic accidents.

The objectives of this investigation were (1) to gather information about the occurrence and characteristics of academic lab accidents in chemistry/biochemistry settings and (2) to collect data on accident reporting practices. Given that very few studies have focused on these issues, a cross-sectional descriptive survey was administered to a convenient sample of participants; the intention was for this investigation to serve as a pilot study for a larger, more representative study.

**METHODS**

**Participants.** Completed surveys were obtained from 104 Canadian students and postdoctoral fellows; 39.4% of participants identified as male and 59.6% as female. The primary fields of study reported by participants were chemistry (83.7%), biochemistry (9.6%), and chemical engineering (6.7%). Participant age ranged from 20 to 56 years old (M = 27.34, SD = 6.70). Most participants were domestic (81.6%), Ph.D. students (52.0%), of European ethnic origins (49.0%; Figure 1), and did not identify as a visible minority group member (75.0%).

Participants were also asked to provide details about their experience in the lab (Figure 2). Most participants had two–five years (45.6%) or over five years (44.7%) years of lab experience, had been with their current group for one–two years (20.6%) or two–three years (19.6%), had worked in three or more laboratories throughout their careers (68.0%), and usually put in 30–40 (27.5%) or 40–50 hours per week in the lab (29.4%).

**Survey Instrument.** Survey respondents were first asked a series of demographic questions, including their age, sex, sexual orientation, ethnicity, level of study, and study status (i.e., domestic or international). As no validated measures are available focused on academic lab accidents, questions in this study were designed by the authors, which included a chemistry professor and two psychology professors (the survey instrument is available upon request to the authors). Participants were asked if they had personally been involved in or had witnessed an accident. Follow-up questions related to the level of damage involved (i.e., details of personal injuries or damage to lab equipment), when the incident occurred (i.e., time and day of the week), who else was present, and what PPE or engineering controls, if any, were in use at the time of the accident. Those who reported having been involved in an accident were asked a series of follow-up questions related to their experiences of reporting the accident. They were asked if they had reported the accident and, if so, to whom and how (i.e., email, phone, paperwork filing). They were also asked why they decided to report or not report the incident and how satisfied they were with their decision. Answer stems provided for reasons not to report were based on previous research by Tucker and co-workers and used with the author’s permission. Finally, the survey included questions related to their sense of the overall safety environment and culture of their lab. The measure was pilot-tested by students and postdoctoral fellows in chemistry/biochemistry; adjustments were made to questions based on their feedback.

**Procedure.** This study was cleared by the Research Ethics Board of the authors’ institution (REB #20-054). A convenience sample was recruited though a partnership with a professional chemistry organization (details withheld to
protect participants’ confidentiality) and social media platforms (e.g., Twitter). An email that included the link to the survey was sent out by the organization to leaders of affiliated student chemistry/biochemistry campus groups requesting completion of the study. One email was sent the day the survey became available with a reminder email sent weekly for a total of three communications. The organization also included a link to the survey in their monthly newsletter and on their Web site for the duration of the study. The survey was hosted on Qualtrics, and completion of the survey took approximately 15 to 20 minutes. Individuals who completed the survey could choose to enter a draw for a $10 Tim Horton’s gift card.

Data Analysis. The study initially received 150 responses from academic trainees, collectively designated highly qualified personnel (HQPs). Two of the entries were eliminated as the respondents identified their field of study as biology; four additional entries were removed as the respondents did not answer the question about their involvement in lab accidents; and an additional 40 surveys were eliminated as the questionnaire was initiated but was otherwise blank. Analysis of results was based on the remaining 104 surveys. Results were analyzed primarily through percentages as the primary goal of this study was descriptive rather than inferential; demographic group differences related to accident involvement were evaluated using chi squares and logistic regression.

Participants were asked a series of demographic questions (Figure 1), questions about their laboratory experience (Figure 2), and to describe the accidents in which they were involved and were provided up to 20,000 characters (roughly 3200 words). A panel of evaluators comprising a graduate student, postdoctoral fellow, and an undergraduate student in chemistry were provided with the accident descriptions and asked to identify commonalities across these descriptions. These categories were then independently verified by a chemistry professor and a psychology professor with the goal of achieving consensus.

■ RESULTS

Accident Characteristics and Mitigation Strategies. Most participants (56.7%) had been involved in a lab accident; one-third reported witnessing an accident, and the other two-thirds were directly involved (Figure 3). The largest group of respondents said they had only been involved in one accident (34.0%), but a total of 40.4% had been involved in either two or three accidents and 25.5% had been involved in four or more accidents. Most accidents involved personal injuries only (65.2%) for which participants did not seek medical attention (53.1%) and occurred while other lab members were present (72.3%; Figure 3). Male respondents were more likely to report accident involvement than female respondents \(\chi^2 (1, N = 103) = 3.97, p < 0.05; \phi = -0.196\); 28 of the 41 male respondents had been involved in an accident compared to 30 of the 62 female respondents. No group differences emerged related to age, ethnicity, identification as a visible minority, level of study, sexual orientation, or domestic/international status. Accidents tended to occur in the afternoon, with more than half occurring between noon and 6:00 pm (Figure 4), and on weekdays (95.7%).

Accidents were categorized based on the hazard associated with the accident and the proximate cause of the accident. Fires and explosions were involved in 17.1% of the reported accidents, 48.8% involved chemical spills or toxic materials (e.g., spilling strong acids, inhaling powdered strong bases, being splashed with solvent), sharp materials were involved in 24.4%, and electricity was involved in 4.9% (note: percentages do not add up to 100 as some accidents involved multiple types of hazards). Accidents were also classified based on contributing factors. Unexpected or unavoidable accidents were the most common theme (35.9% of accidents); this included equipment failure, flaws in PPE, slips in hand-eye coordination, human error, or possible contaminants in
chemicals used. Several of the accidents resulted from personnel (rarely the respondent) explicitly not following established protocol or procedures or being negligent (17.9%); in these cases, the accident was deemed to have been preventable if the proper procedures had been observed. This category label was only applied if the respondents explicitly state that the protocols were not obeyed, as protocols often vary between institutions. These incidents often involved improper storage or transportation of reagents or the improper use, or lack of use, of PPE. Improper equipment use (19.5% of accidents described) included both the catastrophic failure of research tools and/or glassware (not accompanied by a clear aggravating external source of damage like a fire or explosion) or the use of inappropriate equipment for a chemical operation. Finally, some accidents were the result of a lack of knowledge on the part of the respondent (9.8%).

Most participants reported wearing multiple forms of PPE at the time of their accident (70.2%), but usage of each individual item was much lower (i.e., lab coats, 42.4%; gloves, 50.8%; safety goggles, 54.2%; Figure 4). Engineering controls were less commonly endorsed: fume hoods were employed in 39% of accidents, 18.2% reported multiple types of engineering controls (i.e., blast shields, other secondary containment), and 25% reported that no engineering controls were in use when the accident occurred.

**Accident Reporting.** The majority of respondents (74.0%) knew the name of the safety officer for their department; the rest did not or were unsure. Of those involved in an accident, 70% said they had reported the incident and 30% did not (Figure 5). No demographic group differences emerged with respect to decisions to report. Most of those who decided to report were at least somewhat satisfied with that decision (81.2%), whereas most who chose not to report expressed some degree of dissatisfaction with that choice (64.3%). The majority of those who reported did so on the day of the accident (68.8%), reported it to multiple individuals (i.e., PI, safety officer, other students) (56.3%), and reported through a variety of methods (i.e., in person, by email, form completion) (50.0%). Among accident reporters, the majority rated the response of the person to whom they reported the accident as “somewhat” or “very” helpful (56.3%). Respondents who did not report the accident shared various reasons for their decision. 20.3% believed that the accident was not severe enough to warrant a report; 11.9% were concerned about the reaction of their PI or of others; 13.6% had concerns about being judged by others for the accident; 15.3% either were unaware that they should report the accident or did not know how to report the accident; and 13.6% blamed themselves for the accident. Respondents who opted to share additional details provided reasons such as “It was not serious enough to report,” “Nobody was injured and lab mate learned their lesson,” and “Shame.”

A few of those who did not report accidents provided additional details about what would need to change for them to report a future incident. Some said they would report an accident of greater severity or danger or an accident associated with greater injuries and physical pain.

Others were concerned about the administrative burden of reporting, stating that they would need accidents to require less paperwork and fewer repercussions. Others had little faith in the institutional response to accident reports and believed the focus to be more on legal protections and punishment than on furthering safety culture and protecting HQP.

## DISCUSSION

**Summary and Comparison to Previous Literature.** Results from this pilot study showed a higher rate of accident involvement (56.7% of participants) compared to 15–30% in previous studies. Due to the size and nature of the sample, broader generalizations should not be made based on these findings, although this figure is still noteworthy and concerning. The true incidence of accident involvement should be assessed through larger investigations with more representative samples. This investigation also found that male respondents were more likely to report accident involvement, although no other demographic differences emerged. To our knowledge, this was the first investigation to ask participants about their experience of multiple accidents, and a significant proportion of respondents (66.0%) endorsed involvement in several accidents. This raises concern about individual-level propensity toward accidents. If a researcher is involved in a minor accident involving no injuries or property damage, might that person become more careless going forward, increasing their chances of being involved in a major accident? Or might they instead become sensitized to the dangers of lab work and take more precautions, thus decreasing their changes of being involved in a bigger accident? Further investigations, including longitudinal research, will be required to address this question.

Most accidents occurred on a weekday afternoon with other lab members present at the time, which supports much older findings by Hellman and co-workers. This likely reflects the workflow of a typical academic lab; it would be expected that the highest frequency of accidents and the greatest density of lab personnel present would overlap. Most accidents occur during the day and not at night, notwithstanding certain catastrophic exceptions, but the risk of being alone in a workspace could easily accentuate any negative outcomes.

Findings from this investigation corroborate those of earlier investigations that PPE usage among chemistry and biochemistry lab personnel is far from universal. Participants reported low adherence for any one type of PPE (just over half
reported goggles or gloves, under half reported lab coats), which confirms findings from previous studies.\textsuperscript{2,6} There is a significant and pressing need to investigate barriers to PPE adherence, which may be especially relevant given the possibility for post-COVID PPE fatigue. Some academic settings have instituted educational programming and promotional events to enhance PPE use; for example, a multi-intervention, student-led safety program has been initiated through the Dow-University of Minnesota partnership.\textsuperscript{24} However, this program, in common with many others, failed to collect the pre- and postintervention data that would demonstrate the utility of these types of interventions and their measurable impact on safety outcomes (e.g., accident occurrence, injury severity).\textsuperscript{25} As such, it is unclear if programs of this type actually lead to improvements in safety outcomes and further research is required.\textsuperscript{7}

A substantial minority of participants chose not to report their accident involvement (30%), again supporting previous findings by other investigators that found underreporting rates of 25–40%.\textsuperscript{7,8} Accident underreporting is a serious concern: If minor accidents are not reported, many laboratories may be the equivalent of time bombs. As Langerman has noted,\textsuperscript{26} important lessons are often not learned after reactive chemistry incidents and changes are not made; this becomes a certainty when accidents are not reported. Normalizing the reporting of “near-misses” should be implemented, and this will likely require close collaboration between PIs, HQP, and University safety professionals to minimize barriers, streamlining the process, and avoiding unnecessary administrative complications. This is potentially an area ripe for software innovation through a simple to-use autofilled institutional web application. Commonly reported reasons for not reporting accidents included beliefs the accident was not serious, concerns about shame or judgment from others, self-blame, and lack of knowledge or understanding on how to report. These results support reasons for not reporting accidents in shared by participants in other industries.\textsuperscript{13} Of those who reported, 25.0% described the response of the other person as neutral and 56.3% as somewhat or very helpful. This is certainly an encouraging finding, but there is obvious room for improvement. Lab personnel who encounter unhelpful or punitive responses when reporting accidents may be less likely themselves to report future accidents and may also discourage colleagues from doing so.

**Implications.** The findings of this investigation present a number of considerations for the training of laboratory personnel going forward. This study was the first, to our knowledge, to generate a typology of contributors to chemistry/biochemistry accidents. These categories should be validated and modified as needed based on larger investigations; however, sharing this information with trainees might be valuable. It may be important to investigate whether certain lab personnel are more vulnerable to certain types of accidents, or whether certain laboratories or departments are overreporting particular types of accidents. Such data could help refine chemical safety education.

This investigation, like others in the area, found that usage of PPE was inconsistent and not universal, and likewise we believe this is the first study to consider engineering controls. Many accidents did not involve a fume hood; however, this does not mean that chemical operations were performed inappropriately in the open as it is also possible that the engineering controls prevented accidents from being thought of as such—a minor spill in a fume hood may pose no danger while the exact same spill outside the fume hood would be considered an accident. Follow-up work will need to better clarify this question. Both PPE and engineering control usage are major avenues for intervention with regards to safety education. Further research is required to understand the root causes related to PPE noncompliance. It is clearly insufficient and naïve for PIs to simply direct research personnel to wear PPE and use available controls and consider their role satisfied. Is the issue related to personnel beliefs about the efficacy of PPE? Are researchers making cognitive errors about the safety of a reaction because they have done the procedure many times without incident? Are root causes related to systemic issue such as poor fit of equipment on women compared to men? (On this last point, anecdotally, all-cotton, extra-small labcoats appropriate for synthetic chemistry and required for one of the authors’ multiple HQP were not stocked (2020–2021) by any of the major suppliers of laboratory equipment, and had to be custom ordered.) A deeper understanding is required of the barriers to PPE use to address these directly and effectively, using empirical research.

The high proportion of participants who chose not report their accidents was a particularly troubling finding, as was learning that a significant percentage of those who chose to report were dissatisfied with their experience. This might make it less likely that they would report the next time. Of those who did not report, several identified concerns included a focus on regulations as opposed to safety, beliefs that the accident was not severe, concerns about shame/judgment, and lack of knowledge about how to report. To ensure the safety of lab personnel, accident reporting must be a guilt-free, nonpunitive, educative, and solution-focused practice. This must involve a culture change within lab groups, departments and administrations involving coordination with lab personnel, PIs, safety officers, and administrators to agree on the goals, processes, training, and outcomes of accident reporting. A change in reporting philosophy will also likely reduce barriers for people who decided not to report, many of whom expressed uncertainty with this decision. Future investigations should collect data on the factors associated with helpful and unhelpful responses. There is a need to install a culture of reporting all incidents, including those resulting in no or minimal injuries or property damage. This is already common required practice in many industrial settings,\textsuperscript{27} but public access to these databases is restricted and this limits their utility to individuals outside of the specific organizations.

**Limitations and Future Directions.** This study suffers from a number of methodological limitations which limit the generalizability of findings to the broader population of graduate students/postdoctoral fellows in this area. A convenience sample was sought; therefore, the composition of participants may not be representative of lab personnel across other academic laboratories in chemistry/biochemistry. The survey instrument has not been validated by previous studies. Although there are currently no validated options available to researchers, these will be important to create going forward to ensure the reliability, validity, and comparability of findings in this area. Participants reported significant heterogeneity in accident description and severity. Although the wording of the question clearly defined an accident as an event involving significant injury/property damage, a different approach may be required going forward to ensure comparability of findings within and between investigation.
Despite the regular occurrence of accidents in academic laboratories, results may have been subject to bias on the part of participants. This can be remedied going forward through prospective, longitudinal investigations involving regular check-ins with participants (e.g., monthly). Results may have been affected by social desirability bias (i.e., a tendency to respond to questions in a way that the participant would be seen favorably by others); given the experiences that participants did choose to share, this seems unlikely. However, we cannot rule out the possibility that prospective respondents chose not to participate due to a sense of shame.

Going forward, these findings need to be replicated on a wider scale, using a large, representative sample. Qualitative data, in the form of interviews and focus groups, could shed light on the nuances and complexities of lab members’ accident experiences, their decisions to report or not, and the impact on them afterward with regards to career decisions and mental health. Investigations are needed regarding the differential impacts of accident type (i.e., personal injury only, property damage) and of proximity (i.e., personal involvement vs witnessing) as well as the impact of involvement in multiple accidents and/or near-misses. The long-term goal of this data collection will be to make changes to education and training and to determine if those changes improve the incidence of accident involvement. Hazards are inevitable in chemistry and biochemistry laboratories. Accidents causing physical harm to personnel are not.

**CONCLUSION**

Despite the regular occurrence of accidents in academic chemistry and biochemistry laboratories resulting in significant property damage, serious injuries, and even deaths, research on academic lab safety has languished. Results from this pilot study of Canadian students and postdoctoral fellows showed a high rate of accident involvement and low adherence rates for specific PPE usage. Most participants had reported their accident involvement to someone and were at least somewhat satisfied with their decision to report; however, a sizable minority chose not to report their accidents due to self-blame, concerns about judgment, a belief that the accident was not severe, or confusion about how to report. Further research is required to verify these findings on a larger scale and to explore the impact of accident involvement and reporting decision in greater depth. The ability to develop empirically based training programs and implement academic reduction strategies will depend on an improved understanding of academic accident experiences.

**ASSOCIATED CONTENT**

*Supporting Information*

The Supporting Information is available free of charge at https://pubs.acs.org/doi/10.1021/acs.chas.1c00070.

Copy of the text of the questionnaire used by the authors in the study (PDF)

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**Notes**

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