

Article

Chemical Risk Perception, Safety Practices, Exposure Events, and Self-Reported Health Symptoms Among Laboratory Technicians at Two Universities in Southern Ecuador: A Cross-Sectional Study

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Abstract

Little is known about the risk perception and working conditions of university chemistry laboratory technicians in Latin America. This census-based cross-sectional study aimed to characterize chemical risk perception, safety practices, self-reported chemical incidents and exposure events, and self-reported health symptoms among laboratory technicians at two universities in southern Ecuador, and to explore institutional differences and selected associations. An anonymous questionnaire based partly on the Spanish technical note NTP 578 was completed by 29 of 30 eligible technicians (96.7%). Data were analyzed descriptively and with exploratory tests. In the previous 12 months, 65.5% reported at least one incident or exposure event (inhalation: 58.6%) and 55.2% at least one symptom, most frequently headaches (41.4%). The number of reported events correlated with the number of symptoms ($\rho = 0.57$; $p = 0.001$). No significant differences in reported events or symptoms were detected by institution or sex, and training was not significantly associated with reported events; however, training provision differed markedly between institutions (Cramér's $V = 0.75$), so this cannot be interpreted as an independent effect of training. Technicians reported high self-perceived risk awareness, whereas fewer than half reported a fume hood that was available and functioning well. These exploratory findings are specific to the two participating institutions.

Keywords: risk perception; workplace safety; chemical exposure; laboratory safety; chemical incidents; exposure events; self-reported symptoms; safety culture



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1. Introduction

Safety management in academic laboratories is a recognized international concern, as these environments combine a wide range of hazardous chemicals, equipment and procedures with frequent turnover of students and early-career researchers [1,2]. Besides chemical agents, university research laboratories can expose staff to physical and other hazards, such as ionizing and non-ionizing radiation, electromagnetic fields, temperature extremes, and carcinogenic or mutagenic substances; the present study, however, focuses specifically on chemical hazards. Serious events, such as the 2010 explosion at Texas Tech University investigated by the U.S. Chemical Safety and Hazard Investigation Board, have

drawn attention to gaps in the management of safety in academic research [3]. Survey evidence also suggests important differences in safety management conditions between academic and industrial laboratories [4].

Another factor is staff turnover, which includes students and temporary young researchers with varying levels of experience and training [5,6]. Researchers in industry tend to report more standardized safety practices and training than those in academia, a difference often attributed to stronger regulatory and financial accountability in industrial settings [4]. Academic laboratories are nonetheless expected to follow internationally recognized standards and guidance, such as the OSHA Laboratory Standard (29 CFR 1910.1450) in the United States [7], Directive 98/24/EC on chemical agents at work in the European Union [8], and reference works such as *Prudent Practices in the Laboratory* [9], the *CRC Handbook of Laboratory Safety* [10] and the American Chemical Society's *Safety in Academic Chemistry Laboratories* [11]; many universities worldwide have adopted institutional safety rules based on these documents. In Ecuador, occupational safety and health is governed by the Andean Instrument on Occupational Safety and Health (Decision 584 of the Andean Community) [12], Executive Decree 255 of 2024, which issued the Occupational Safety and Health Regulations and replaced Executive Decree 2393 [13], and technical standards such as NTE INEN 2266:2013 on the transport, storage and handling of hazardous materials [14]. These instruments apply to public and private employers, including universities, but they are oriented mainly to industrial settings and contain no specific provisions for teaching and research laboratories. In addition, academic institutions may face budgetary constraints on safety equipment and training [15–17].

The health effects of chemical exposure depend on the specific agent, its toxicity and the dose absorbed, and are influenced by factors such as composition, properties, concentration, duration of exposure and route of entry into the body [17,18]. Because a very large number of substances is used in teaching and research laboratories, laboratory exposures are typically intermittent, low-level and mixed, which makes them difficult to characterize and to link to specific health outcomes [9,17]. Reported effects range from acute irritation of the skin, eyes and respiratory tract to chronic effects associated with particular agents, such as sensitizers, carcinogens and reproductive toxicants [17–19]. The present study did not measure specific agents, doses or biological indicators of exposure; it focuses on technicians' self-reported exposure events and symptoms, which can serve as practical indicators for prioritizing preventive action.

At one university in the United States, analysis of injury records from 2001 to 2014 showed that about 18% of reported incidents were laboratory-related and that students (graduate assistants and student employees) accounted for about one-third of those involved in laboratory injuries [20]. Although such data mainly concern students, they illustrate that laboratory work concentrates a substantial share of injuries in higher education. Understanding how laboratory staff perceive risks is essential for developing effective safety interventions tailored to their needs. A textual analysis of contemporary notes identified six interrelated themes associated with risk in chemical handling: lack of knowledge, which leads to uncertainty and unrecognized risks; practical difficulties in implementing structural changes in laboratories; limited involvement of some key individuals; a perceived lack of support from safety officers; and work pressure, leading to poor decision-making [21].

However, while students have temporary exposure, laboratory technicians represent the permanent frontline workforce. Technicians may face continuous, cumulative exposure over many years and often bear day-to-day responsibility for laboratory management, so their risk perception and safety practices are an important component of institutional safety culture. In this study, the term “laboratory technician” refers to permanent university

staff who prepare reagents and solutions, support teaching practicals, perform analyses, participate in research and manage chemical waste within university chemistry laboratories; activities performed outside the university, such as sampling at industrial or construction sites, were outside the scope of the study.

The implementation of chemical safety in Latin American academia faces unique regulatory challenges, with regulatory frameworks often geared toward the industrial sector and lacking specific adaptations for teaching and research; safety deficiencies have been identified where academic staff use significantly less personal protective equipment (PPE) compared to the industrial sector, increasing vulnerability to chronic exposures [22,23]. A bibliometric study on safety culture has identified significant geographical differences, particularly in South America, and it was observed that current simplified methodologies for assessing risks in laboratories are often incomplete, as they do not take into account factors such as ventilation systems, storage, or implemented control measures, which creates uncertainty in this area [24,25]. There is limited empirical evidence specifically addressing chemical risk perception, exposure incidents and safety practices among permanent laboratory technicians in Latin American universities [2,24].

Numerous problems have been described in university chemistry laboratories, including inadequate hazard identification, limited risk awareness and insufficient safety management [26,27]. Risk perception has been studied mainly within the psychometric paradigm, in which perceived risk depends on attributes of the hazard such as knowledge, dread, controllability, catastrophic potential and delay of consequences [28]; this framework underlies the NTP 578 procedure for evaluating perceived occupational risk used in the present study [29]. People perceive risk through direct, intuitive judgment influenced by risk characteristics, personal variables and cultural and socioeconomic context [30], and external cues may be needed to activate risk awareness [31]. However, risk perception is not always a direct predictor of safe behavior: even when workers are aware of hazards, their use of PPE may be influenced by subjective assessments of the immediate danger of the task or the perceived discomfort of the equipment [32], and risk perception has been reported to mediate the relationship between chemical safety knowledge and safety behavior [33]. Daily and prolonged exposure to hazardous substances may also lead to habituation, which reduces vigilance toward latent dangers, especially when the effects are chronic rather than immediate [17]. Greater knowledge, therefore, does not necessarily translate into safer behavior; optimism bias may lead trained personnel to underestimate their personal vulnerability [25].

Based on the problem described above, the primary objective of this study was to characterize chemical risk perception, safety practices, self-reported chemical incidents and exposure events, and self-reported health symptoms among laboratory technicians at two universities in southern Ecuador. The secondary, exploratory objective was to explore differences between the two institutions and associations between these outcomes and selected occupational characteristics, including training and sex.

2. Materials and Methods

A quantitative, census-based, descriptive cross-sectional study was conducted in two purposively selected universities in southern Ecuador. Data were collected during the first quarter of 2026, yielding a sample of $n = 29$ participants. Participation was voluntary and anonymous, and informed consent was obtained from all subjects. The sample comprised all technical staff regularly exposed to chemical hazards at the two participating universities, corresponding to a census of the eligible workforce rather than a probabilistic sample. Recruitment followed a complete-enumeration (census) approach: the 30 technicians who met the eligibility criteria constituted the entire exposed workforce across the

two institutions in the study, and 29 of them completed the questionnaire, corresponding to a participation rate of 96.7%. Because both universities requested institutional anonymity and the numbers involved are small, the eligible workforce is reported as a combined total rather than disaggregated by institution. Eligibility was defined by the following inclusion criteria: (i) being currently employed as a technician at the participating institution; (ii) having job duties that involve the direct handling of chemical substances (e.g., reagent preparation, performing analyses, practical teaching involving chemicals, or chemical-waste management); and (iii) having worked in this role, or a similar laboratory role involving chemical handling, for at least the 12 months preceding the study. The exclusion criteria were: (i) not providing informed consent to participate; (ii) holding a role that did not involve the direct handling of chemical substances (e.g., exclusively administrative or non-laboratory positions); (iii) having less than 12 months of experience in a chemical-handling laboratory role at the time of the study; and (iv) not being actively employed at the participating institutions during the data-collection period (e.g., extended leave or no longer in post). Because the two institutions were purposively selected and participation was voluntary, the results describe this specific group of technicians and are not intended to be generalized to laboratory technicians at other universities in Ecuador or Latin America, or to academic laboratories in general.

Site selection was purposive: the two participating universities were selected because they operate chemistry laboratories with permanent technical staff who handle chemicals, matching the focus of the study. Both share the same regional context but differ in their administrative and organizational models. In line with the confidentiality conditions agreed with both institutions, which requested that neither the institutions nor their staff be identifiable, the institutions are not named and no further institutional characteristics are reported; they are referred to as Institution 1 and Institution 2.

2.1. Data Collection

The data collection instrument was a structured web-based questionnaire administered in Spanish and organized into four main thematic sections that collected information on: (1) sociodemographic and occupational characteristics; (2) risk perception, assessed using the attributes of the NTP 578 procedure; (3) safety practices, culture and environment, including the use of personal protective equipment (PPE); and (4) self-reported chemical incidents, exposure events and health symptoms in the previous 12 months (Supplementary Material file; English translation). Incidents were assessed with the question “In the past 12 months, have you experienced any of the following incidents directly related to handling chemicals in your laboratory?”, with Yes/No responses for six items: accidental spill of a chemical on the skin or clothing; accidental splash of a chemical into the eyes or face; accidental inhalation of chemical vapours, dust or gases that caused immediate discomfort (e.g., coughing, dizziness, throat irritation); cuts or punctures from glassware or sharp objects contaminated with chemicals; a fire outbreak or a small explosion involving chemicals; and another type of chemical incident (open text). Respondents were then asked whether the event they considered most significant had required first aid in the laboratory or formal medical care, and whether it had been officially reported. Symptoms were assessed with the question “In the past 12 months, have you experienced any of the following health symptoms that you believe might be related to your work or exposure to chemicals in the laboratory?”, with Yes/No responses for skin irritation, rash or dermatitis; eye irritation not caused by a direct splash; frequent or severe headaches associated with the laboratory; dizziness, vertigo or lightheadedness; nausea; respiratory problems (persistent cough, wheezing, difficulty breathing or frequent nasal congestion); and another symptom (open text). Given the heterogeneity of these events, the term “accident” is not used for the

study outcomes. Inhalation of vapors or gases is classified as a self-reported exposure event, whereas spillage on the skin or clothing, splashes to the eyes or face, fires or explosions, cuts or punctures, and other chemical incidents are classified as self-reported chemical incidents; “any reported event” refers to at least one event of any of the six types. None of these events was verified against incident registers; severity was assessed only indirectly, through the questions on first aid and medical care for the most significant event, and the cause of each event was not recorded. Symptoms were self-reported health complaints that respondents believed might be related to their work; they were not verified against clinical diagnoses or occupational health records, and respondents were not asked to attribute them to specific events.

The variables in this study were assessed using structured scales tailored to each construct. Safety practices and environment were assessed using a 5-point Likert scale (1 = Strongly disagree to 5 = Strongly agree). PPE usage frequency was measured on a 5-point scale (1 = Never to 5 = Whenever necessary), referring to the use of each item when the procedure or chemical required it. Because this anchor relies on the respondent’s own judgment of when protection is required, and the questionnaire did not record which procedures formally required each item, lower scores cannot be interpreted as non-compliance with a specific protocol. Chemical risk perception dimensions were evaluated using 7-point scales with specific anchors (e.g., 1 = Very low to 7 = Very high), and the global risk rating on a 0–100 scale.

The questionnaire combined items from three sources. (i) The risk-perception section reproduced the nine attributes and the global risk rating of the perceived-risk questionnaire described in the Spanish technical note NTP 578 of the National Institute for Safety and Hygiene at Work [29], which is grounded in the psychometric paradigm [28]: knowledge of the risk by the worker and by those responsible for prevention, fear of damage, vulnerability, severity, avoidability, controllability of damage, catastrophic potential and delay of consequences, each rated on a 7-point scale, plus a global 0–100 rating; chemical risk in the laboratory was used as the risk factor. (ii) Items on PPE use and availability, fume hoods, emergency showers and eyewash stations, safety data sheets, training, and incidents, exposure events and symptoms were adapted from previous laboratory surveys [17,25,26] and from the requirements of Executive Decree 255 [13]. (iii) Sociodemographic and occupational items and the four safety-culture items (supervision, reporting, priority of safety over speed, and omission of safety measures) were developed by the authors on the basis of the safety-culture literature [11,24,30]. Because NTP 578 was originally published in Spanish, no translation was required; adaptation consisted of specifying chemical risk in the laboratory as the risk factor, as foreseen by the NTP 578 procedure. Content validity and clarity were reviewed by three occupational safety experts, all holding a master’s degree in occupational safety and health, who independently reviewed the complete instrument and provided open-ended comments on the relevance and clarity of the items; their comments focused on grouping some response options to improve the structure of the instrument. Retrospective cognitive debriefing interviews were then conducted with five technicians from the eligible population immediately after they completed the questionnaire, to confirm item comprehension; these five technicians were selected according to their availability, included staff from both institutions, and were interviewed online. Neither the expert review nor the cognitive debriefing required changes to item content or wording, and no items were added or removed; the responses of the five debriefing participants were therefore retained in the final sample.

The internal consistency of the four-item “Safety practices and environment” construct (supervision, reporting, priority, and the reverse-coded item on omission of safety measures) was evaluated using Cronbach’s alpha in Stata (version 17; StataCorp LLC, College Station,

TX, USA) [34]; the resulting coefficient is reported in the Results. Construct validity (e.g., factor analysis) was not assessed, as this was not feasible with 29 respondents; the four items are therefore analyzed individually rather than as a summed scale.

2.2. Data Preparation

The data were exported and compiled into a structured database. A data curation and cleaning process was carried out, which included verifying the consistency of the responses, validating the ranges of the variables, and treating missing values, which were appropriately coded for correct exclusion in the analyses. Missing data were minimal. All variables were complete except age, three risk-perception items (avoidability, delay of consequences and the global risk rating), fume-hood availability, eye irritation and the questions on the most significant event (1 missing each, 3.4%), and respiratory problems, dizziness/vertigo and nausea (2 missing each, 6.9%). Missing values were handled by available-case analysis, with the corresponding denominators reported in the table footnotes; given the very small number of missing responses no imputation was performed, and formal testing of whether missingness was random was not feasible owing to the sample size. Consequently, denominators vary slightly across items ($n = 27\text{--}29$). In addition, the items on the quality and duration of training applied only to the 19 technicians who reported having received training, and these percentages are therefore calculated over $n = 19$ by design, not because of missing data. Each item in the questionnaire was assigned a short, unique variable name to facilitate computer handling and analysis (e.g., EXP_QUI for years of experience). This process culminated in the creation of the final, cleaned database, which was imported into Stata software to perform the statistical analysis described below.

2.3. Statistical Analysis

This was performed in two stages. First, a descriptive statistical analysis of the sample characteristics was performed. Continuous variables (age, years of experience) are presented using the mean and standard deviation (SD) as a measure of central tendency, and the median with its interquartile range (IQR) as a robust measure given the asymmetry of the data. Categorical and ordinal variables, ranging from sociodemographic data (such as sex) to perception scales (such as risk severity) and safety practices (such as frequency of PPE use), are described using absolute frequencies (n) and relative percentages (%).

Second, an exploratory inferential analysis was conducted on a limited set of variables preselected on theoretical grounds [24–26,30] and on the variability observed in the descriptive phase. A nonparametric approach was adopted because most variables are ordinal by construction, so that distances between response categories cannot be assumed equal, and because the count outcomes are heavily tied (the modal value accounts for 34% of cases in the number of reported events and 45% in the number of symptoms); in addition, years of experience departed from normality (Shapiro–Wilk $p = 0.024$), and the small sample limits the power of normality tests. The Mann–Whitney U test was used for group comparisons, Fisher’s exact test for contingency tables and Spearman’s correlation (ρ) for associations. Effect sizes are reported alongside p -values: the rank-biserial correlation (r) for Mann–Whitney tests, Cramér’s V for Fisher’s exact tests, and ρ for correlations. Exact two-sided p -values are reported, and statistical significance was set at $\alpha = 0.05$. To account for multiple testing, p -values were additionally adjusted within each table using the Benjamini–Hochberg false discovery rate (FDR) procedure [35] (12 tests in Table 4 and 28 correlations in Table 5), and results are described as statistically significant only when they remained significant after this adjustment. Results with p -values between 0.05 and 0.10 are not described as significant or marginally significant; where mentioned, they are reported only as exploratory observations for future research. In addition, three pre-specified

exposure–symptom pairs (inhalation events and respiratory problems, inhalation events and headaches, and spills and skin irritation) were examined at the individual level using Fisher’s exact test, with FDR adjustment across the three tests. Given the census design and the small number of participants, all inferential results are exploratory and refer only to the participating technicians. All analyses were performed using Stata software.

3. Results

3.1. Descriptive Analysis

3.1.1. Characteristics of the Participants

The sociodemographic and occupational characteristics of the sample are detailed in Table 1. The workforce was predominantly female, had a median age of 36 years and was predominantly postgraduate educated, with a median of 6 years of experience working directly with chemicals.

Table 1. Sociodemographic and Occupational Characteristics.

Characteristic	Value
Age (years) ¹	
Mean (SD)	38 (9.4)
Median [IQR]	36 [12]
Years of experience	
Mean (SD)	7.7 (5.3)
Median [IQR]	6 [9]
Sex, <i>n</i> (%)	
Female	19 (65.5%)
Male	10 (34.5%)
Level of Education, <i>n</i> (%)	
Tertiary	5 (17.2%)
Postgraduate (Master’s/Specialization)	20 (69.0%)
Doctorate (PhD)	4 (13.8%)
University, <i>n</i> (%)	
Institution 1	15 (51.7%)
Institution 2	14 (48.3%)
Hours/week with chemicals, <i>n</i> (%)	
≤10 h	20 (69.0%)
>10 h	9 (31.0%)
Main activities, <i>n</i> (%) *	
Teaching support	22 (75.9%)
Preparation of reagents and solutions	22 (75.9%)
Scientific research	18 (62.1%)
Sample analysis	18 (62.1%)
Waste management	8 (27.6%)
Equipment maintenance	8 (27.6%)

Source: Information survey, 2026. Notes: SD: standard deviation; IQR: interquartile range.

* Participants could select multiple activities. ¹ sample *n* = 28.

The nearly balanced number of participants from each institution facilitates descriptive comparison between them, although it neither removes institutional differences nor compensates for the small sample size. Most technicians reported handling chemicals for 10 h per week or less; however, weekly handling time is only a crude proxy for exposure, because actual exposure also depends on the substances handled, their volatility and toxicity, the quantities used and the containment measures available, none of which were measured. The technicians’ tasks were diverse, most commonly teaching support and reagent preparation, followed by scientific research and sample analysis.

3.1.2. Risk Perception and Safety Practices

The descriptive statistics for risk perception, safety practices, and culture are presented in Table 2. Overall, participants reported high levels of self-perceived risk awareness and perceived damage severity. In contrast, self-reported confidence in their ability to control an adverse event was comparatively lower and showed wider variability among the staff.

Table 2. Risk Perception, Practices, and Safety Culture.

Characteristic	Median [IQR] or <i>n</i> (%)
I. Risk perception, NTP 578 attributes (Scale 1 to 7; 1 = Very Low, 7 = Very High)	
Own Knowledge of Risk	6 [1]
Knowledge of Risk by Those Responsible for Prevention	4 [4]
Degree of Fear of Damage	6 [2]
Possibility of Experiencing Damage	5 [3]
Severity of Damage Should a Risk Situation Occur	6 [1]
Degree to Which Risk Can Be Avoided ¹	5 [2]
Degree to Which Damage Can Be Controlled	5 [2]
Degree to Which It Can Harm Many People	3 [3]
When Consequences are Experienced (1 = Immediate, 7 = Very Long Term) ¹	4 [2.5]
Global Risk Rating (Scale 0 to 100) ¹	60 [27.5]
II. Safety practices and equipment	
Personal Protective Equipment Use (Scale 1 to 5; 1 = Never, 5 = Whenever necessary) ³	
Lab coat/protective apron	5 [0]
Gloves appropriate for the chemical	5 [0]
Mask/respirator	5 [1]
Safety goggles/face shield	4 [2]
Availability, Infrastructure, Knowledge and Hazard Information (Categorical)	
Availability: General PPE Availability (Always / Almost always available)	13 (44.8%)
Infrastructure: Extractor Hood (Available and functioning well) ¹	13 (46.4%)
Knowledge: Showers/Eye Wash Stations (Knows perfectly how to use)	12 (41.4%)
Hazard information: Safety Data Sheets (SDS) (Always knows where to find them)	23 (79.3%)
III. Training and preparedness (Categorical)	
Has received training in the last 2 years	19 (65.5%)
Quality of training (Good/Very good) ²	16 (84.2%)
Duration of training (>8 h) ²	14 (73.7%)
IV. Safety culture items (Scale 1 to 5; 1 = Strongly Disagree, 5 = Strongly Agree)	
Supervisor actively promotes safety	4 [1]
Feels comfortable reporting incidents or concerns	4 [1]
Safety takes priority over speed	4 [1]
Sometimes safety measures are omitted for the sake of speed	2 [1]

Source: Information survey, 2026. Notes: Likert scale data are presented as Median [Interquartile Range]. The numerical direction and anchors for each scale are specified in the section headers to ensure precise interpretation. Categorical data are presented as frequencies (percentages). ¹ sample *n* = 28. ² percentages calculated based on those who received training (*n* = 19). ³ Frequency of use of each item when required by the procedure or chemical, as judged by the respondent; lower scores do not necessarily indicate non-compliance. IQR: interquartile range; NTP: Nota Técnica de Prevención (technical note of the Spanish National Institute for Safety and Hygiene at Work); PPE: personal protective equipment; SDS: safety data sheets.

Regarding safety practices, reported use of personal protective equipment (PPE) varied by item. Reported use of lab coats, gloves and masks/respirators was near-universal, whereas reported use of safety goggles/face shields was lower and more heterogeneous. Fewer than half of the respondents reported always or almost always having PPE available, having a fume hood that was available and functioning well, or knowing perfectly how to use emergency showers and eyewash stations, whereas most knew where to find safety

data sheets. Most staff had received formal safety training in the previous two years, which was generally rated as good or very good and lasted more than 8 h.

Finally, responses to the selected safety-culture items were generally favorable: respondents indicated that supervisors actively promote safety and that safety takes priority over speed, and reported a low tendency to omit safety measures for the sake of speed. The internal consistency of these four items (the “Safety practices and environment” construct) was modest (Cronbach’s $\alpha = 0.66$), supporting cautious interpretation of this construct.

3.1.3. Analysis of Self-Reported Incidents, Exposure Events and Symptoms

The frequency of self-reported chemical incidents, exposure events and health symptoms is detailed in Table 3.

Table 3. Frequency of Self-Reported Chemical Incidents, Exposure Events and Self-Reported Health Symptoms.

Characteristic	n (%)
I. Self-reported chemical incidents and exposure events *	
Exposure event: inhalation of vapors/gases	17 (58.6%)
Incident: spillage on skin or clothing	9 (31.0%)
Incident: fire or explosion ³	5 (17.2%)
Incident: splash in eyes or face	3 (10.3%)
Incident: cuts or punctures	2 (6.9%)
Incident: other chemical incident ⁴	3 (10.3%)
At least one incident or exposure event of any type	19 (65.5%)
At least one incident other than inhalation	15 (51.7%)
Number of event types reported, median [IQR]	1 [2]
II. Self-reported health symptoms *	
Frequent headaches	12 (41.4%)
Respiratory problems ¹	10 (37.0%)
Skin irritation, dermatitis	9 (31.0%)
Dizziness or vertigo ¹	5 (18.5%)
Nausea ¹	5 (18.5%)
Eye irritation ²	3 (10.7%)
At least one symptom reported	16 (55.2%)
Number of symptoms reported, median [IQR]	1 [3]

Source: Information survey, 2026. * The frequencies of specific events refer to those who answered “Yes”. Events refer to the previous 12 months and were not independently verified; inhalation of vapors/gases is classified as an exposure event and the remaining categories as incidents. Symptom frequencies are group-level and were not linked to specific events. ¹ $n = 27$; ² $n = 28$. ³ Single Yes/No item (“a fire outbreak or a small explosion involving chemicals”); counts refer to respondents, not to distinct occurrences. ⁴ Open-text item (“another type of chemical incident”); the three respondents who reported it also reported other events. IQR: interquartile range.

According to the self-reported data, most technicians reported at least one incident or exposure event in the previous year, most commonly inhalation of vapors or gases, followed by chemical spills on the skin or clothing; 15 technicians (51.7%) reported at least one incident other than inhalation, and 4 (13.8%) reported inhalation events only. Five technicians (17.2%) reported at least one fire outbreak or small explosion; because several technicians may have referred to the same occurrence, this figure indicates the number of technicians reporting such an event, not the number of distinct events. Of the 10 technicians who answered the questions on their most significant event, one reported that it had required both first aid and formal medical care, and this was the only event that had been officially reported; the remaining nine events required neither and were not reported. The other nine technicians who had reported at least one event answered that they had no accidents, including seven who reported in-

halation events, suggesting that many of these events were not perceived as accidents. Information on first aid, medical care and reporting was therefore available for only 10 of the 19 technicians who reported at least one event; most of the events described did not require first aid or formal medical care, but the severity of the remaining events is unknown. Nevertheless, any report of fire or explosion in a laboratory warrants attention from an occupational safety perspective.

Similarly, just over half of the sample reported at least one self-reported symptom, most commonly frequent headaches, respiratory problems and skin irritation. In the exploratory individual-level analysis, respiratory problems were more frequent among technicians who reported inhalation events than among those who did not (9/16 vs. 1/11; Fisher's exact test, $p = 0.018$), and headaches showed a similar but non-significant pattern (10/17 vs. 2/12; $p = 0.053$), whereas skin irritation was not associated with reported spills (3/9 vs. 6/20; $p = 1.000$). None of these associations remained statistically significant after FDR adjustment ($q = 0.054, 0.080$ and 1.000 , respectively).

3.2. Inferential Analysis

Moving beyond the descriptive data, an exploratory inferential analysis was conducted to examine whether the outcomes differed by institution, training or sex (Table 4).

Table 4. Exploratory Comparative Analysis of Variables.

Characteristic	Test Used	<i>p</i> -Value	Effect Size
1. Comparison between universities			
Number of reported events	Mann–Whitney U	0.749	$r = -0.07$
Number of reported symptoms	Mann–Whitney U	0.747	$r = 0.07$
Any reported event	Fisher's Exact Test	1.000	$V = 0.03$
Any reported symptom	Fisher's Exact Test	0.715	$V = 0.10$
Perceived severity	Mann–Whitney U	0.717	$r = -0.08$
Frequency of goggles/face shield use	Mann–Whitney U	0.139	$r = 0.31$
Safety priority	Mann–Whitney U	0.871	$r = -0.03$
2. Training vs. reported events			
Training Provision by University	Fisher's Exact Test	<0.001 ***	$V = 0.75$
Training vs. any reported event	Fisher's Exact Test	1.000	$V = 0.07$
3. Comparison by sex			
Number of reported events	Mann–Whitney U	0.280	$r = -0.24$
Number of reported symptoms	Mann–Whitney U	0.298	$r = -0.23$
Any reported event	Fisher's Exact Test	1.000	$V = 0.07$

Exact two-sided *p*-values are shown. *** $p < 0.01$; this result remained significant after Benjamini–Hochberg false discovery rate adjustment across the 12 tests in this table. Reported events: self-reported chemical incidents and exposure events. *r*: rank-biserial correlation; *V*: Cramér's *V*.

The nonparametric comparative analysis did not detect statistically significant differences ($p > 0.05$) between the two universities in the number or occurrence of reported events or symptoms, perceived severity, goggles/face shield use or safety priority, and effect sizes were small ($|r| \leq 0.31$; $V \leq 0.10$). Similarly, no statistically significant differences by sex were detected in the number or occurrence of reported events or in the number of symptoms. Given the small sample, these non-significant results do not demonstrate the absence of differences.

Furthermore, the provision of formal safety training differed markedly between the institutions ($p < 0.001$; $V = 0.75$), being concentrated almost entirely in one of them. Consequently, training status and institution are largely confounded, and the absence of a statistically significant association between training and reported events ($p = 1.000$) cannot

be interpreted as an independent effect, or lack of effect, of training; the sample was too small for a stratified or adjusted analysis.

Following the comparative analysis, an exploratory Spearman correlation analysis was performed among selected exposure, perception, safety-practice and outcome variables (Table 5).

Table 5. Spearman's Correlation Matrix (Exploratory).

Variable	1	2	3	4	5	6	7	8
1. Events	1.00							
2. Symptoms	0.57 ***†	1.00						
3. Experience	−0.15	−0.11	1.00					
4. Hours	0.35	0.34	0.06	1.00				
5. Severity	0.33	0.30	0.32	0.70 ***†	1.00			
6. Goggles/face shield	0.03	0.01	0.11	0.01	−0.06	1.00		
7. Priority	0.11	−0.26	0.03	0.07	−0.06	0.54 ***†	1.00	
8. Supervision	0.02	−0.30	−0.19	−0.06	−0.17	0.18	0.54 ***†	1.00

Unadjusted two-sided *p*-values: *** *p* < 0.01. † Remains significant after Benjamini–Hochberg false discovery rate adjustment across the 28 correlations (*q* < 0.05). Events: number of types of self-reported chemical incidents and exposure events; Hours: weekly hours of chemical handling; Goggles/face shield: frequency of use; Severity: perceived severity of damage in case of an adverse event (NTP 578).

The number of reported events and the number of reported symptoms were positively correlated ($\rho = 0.57$; $p = 0.001$), and this association remained significant after FDR adjustment. Weekly hours of chemical handling correlated strongly with the perceived severity of damage ($\rho = 0.70$; $p < 0.001$), and the perception of safety as a priority over speed correlated with both active safety supervision and the reported frequency of goggles/face shield use ($\rho = 0.54$; $p = 0.003$ for both); these associations also remained significant after adjustment.

Weaker positive correlations of weekly hours of chemical handling with the number of reported events ($\rho = 0.35$; $p = 0.06$) and symptoms ($\rho = 0.34$; $p = 0.07$), and of perceived severity with the number of reported events ($\rho = 0.33$; $p = 0.08$), did not reach statistical significance and are reported only as exploratory observations.

4. Discussion

This study describes an apparent contrast in the two participating institutions: although the technical staff were highly qualified and reported high self-perceived risk awareness, most reported at least one chemical incident or exposure event, and just over half reported health symptoms, in the previous year. Because risk awareness was self-rated rather than objectively tested, and all events were self-reported, this contrast should be regarded as descriptive rather than as evidence that knowledge fails to translate into lower risk. While technicians reported high median scores for both risk awareness and perceived severity, their confidence in their ability to control an adverse event was lower and more variable. This gap may reflect a perception that some risk factors, such as infrastructure limitations and administrative controls, lie beyond their individual capacity to manage; this interpretation was not directly tested.

A weak positive correlation between perceived severity of damage and the number of reported events was observed ($\rho = 0.33$; $p = 0.08$), which did not reach statistical significance and is reported only as an exploratory observation. If confirmed in larger studies, such a pattern would be compatible with the hypothesis that prior experience may influence

risk perception, that is, that experiencing incidents may heighten perceived severity, rather than high risk perception leading to incidents. Personal experience of a hazard has been identified as an influential factor in risk perception [36], and a laboratory-based study found that accurate knowledge of chemical hazards was more common among researchers who handled a greater number of chemicals [17]. However, the cross-sectional design cannot establish whether incidents influence risk perception or vice versa, and this interpretation remains hypothetical.

In this study, 65.5% of technicians reported at least one incident or exposure event of any type in the previous year (58.6% reported inhalation exposure events), and 55.2% reported at least one symptom. Comparisons with other studies must be made cautiously because of differences in populations, event definitions, recall periods, questionnaires and contexts. Among 220 laboratory workers at a public university in Lebanon, 45.0% reported having experienced accidents, most of them related to chemical exposure and predominantly by inhalation [25]; in a survey of 267 chemical laboratory employees in Sri Lanka, 40.1% reported laboratory injuries [37]; and at a Malaysian university, 34.4% of laboratory users reported formaldehyde-related symptoms, most often headache or dizziness [38]. The broader event definition used here, which includes inhalation exposure events, probably contributes to the higher figure observed. Studies of students, such as a survey of laboratory-science students that reported symptoms in 62.7% of frequently exposed participants [39], are not directly comparable with a workforce of permanent technicians. Underreporting of laboratory incidents has also been described [25,40] and may be related to the normalization of minor events, fear of punitive measures or the perceived bureaucracy of reporting; these mechanisms were not assessed here.

At the group level, inhalation exposure events (58.6%) and frequent headaches (41.4%) and respiratory problems (37.0%), as well as skin spills (31.0%) and skin irritation (31.0%), were among the most frequently reported items. In the exploratory individual-level analysis, respiratory problems were more frequent among technicians who reported inhalation events, but this association did not remain significant after adjustment for multiple testing, and no association was observed between spills and skin irritation; individual-level exposure–symptom relationships were therefore not demonstrated, and the temporal sequence between events and symptoms is unknown. The positive correlation between the number of reported events and the number of symptoms ($\rho = 0.57$) indicates that both outcomes tended to co-occur in the same individuals, but it may also partly reflect common-method bias or a general tendency of some respondents to report more adverse experiences [41]. Because the duration, severity and clinical diagnosis of symptoms were not measured, they cannot be characterized as a chronic or cumulative disease burden.

Fewer than half of the respondents reported having a fume hood that was available and functioning well (46.4%). According to the NIOSH hierarchy of controls, engineering controls such as local exhaust ventilation are more effective and reliable than personal protective equipment [9,42]. However, because ventilation performance, airborne contaminant concentrations and actual chemical exposure were not measured, the present data cannot establish that the reported symptoms result from deficiencies in engineering controls; this relationship remains a hypothesis to be tested with objective exposure assessment. From a preventive standpoint, verifying the availability, performance and maintenance of fume hoods, and scheduling procedures that generate vapors in adequately ventilated spaces, would be reasonable priorities for the participating institutions.

Regarding PPE, reported use of lab coats, gloves and masks/respirators was near-universal, whereas reported use of safety goggles/face shields was lower and more variable. Because the questionnaire asked how often each item was used when required by the procedure or chemical (“whenever necessary”), and did not record which procedures

formally required eye protection, lower scores for goggles/face shields do not necessarily indicate non-compliance or risk-taking; they may reflect differences in tasks, in local requirements, or in how respondents interpreted the scale anchor. Other studies have reported that discomfort, fogging and perceived inconvenience can hinder the consistent use of protective equipment [32,43,44], and low rates of correct PPE use have been reported among chemical laboratory employees elsewhere [37]; whether such factors operate in the participating laboratories was not assessed.

No statistically significant association was detected between reported training and the occurrence of incidents or exposure events in this sample ($p = 1.000$), nor were statistically significant differences detected by sex or years of experience. Given the low statistical power, these non-significant results should not be interpreted as evidence that such differences are absent, and they do not indicate that training is ineffective. Moreover, training provision was strongly associated with institution ($V = 0.75$), so any comparison between trained and untrained technicians is confounded by other institutional differences such as infrastructure, workload and supervision, and the small sample did not allow stratified or adjusted analyses. Only the receipt, perceived quality and duration of training were recorded, not its content, practical component or timing relative to the reported events. Previous studies have reported inconsistent findings: among laboratory workers in Lebanon, lack of training was associated with accidents [25], whereas among clinical laboratory workers in Peru, good knowledge of biosafety rules was not associated with accident history [45]. The literature also emphasizes that safety is a shared responsibility that must be actively promoted by management and supervisors [46], and that organizational safety climate and culture contribute to safe behavior beyond individual knowledge [6,47,48].

Limitations

Several methodological limitations should be considered. First, the small number of participants ($n = 29$) results in low statistical power. Although the study covered 29 of the 30 eligible technicians (96.7%), which minimizes non-response bias within this workforce, non-significant results, such as the lack of association between training and reported events, should not be interpreted as evidence of no association, and the findings cannot be generalized to other institutions or to academic laboratories in general. Second, the cross-sectional design precludes causal inference and does not allow the temporal sequence between events, symptoms and risk perception to be established. Third, all outcomes were self-reported over a 12-month recall period and are susceptible to recall bias, social desirability and outcome misclassification; incidents and exposure events were not verified against incident registers, and their severity was assessed only indirectly, through the first-aid and medical-care questions on the most significant event. Fourth, because exposures, outcomes and perceptions were measured with the same questionnaire at the same time, associations among them may be inflated by common-method bias [41]. Fifth, the questionnaire was adapted rather than fully validated: content was reviewed by experts and comprehension was checked through cognitive debriefing, but the internal consistency of the safety-practices construct was modest and construct validity was not assessed. Sixth, the individual-level analysis of exposure events and symptoms was limited to three exploratory pairs, had low statistical power, and could not establish the temporal sequence between events and symptoms.

Seventh, no objective exposure assessment was performed: the specific chemical agents handled, their quantities, airborne concentrations, ventilation performance and biological indicators of exposure were not measured, and weekly hours of chemical handling are only a crude proxy for exposure. Moreover, the study examined only the perception of chemical risk: perceived risk was not compared with objectively assessed risk, and other

occupational hazards present in university laboratories, such as physical, biological or ergonomic hazards, were not examined. Reported symptoms were not corroborated by clinical examination or medical records and cannot be equated with diagnosed occupational diseases. Finally, formal safety training was almost entirely concentrated in one of the two institutions, so its association with the outcomes cannot be separated from other institutional differences such as infrastructure, workload or supervision; in addition, the severity of events was assessed only indirectly.

Given these limitations, several guidelines for future research are outlined. It is important to conduct longitudinal studies that can establish temporality and move toward causal inferences between safety practices and health outcomes, for example by recording when incidents occur relative to changes in risk perception, so that the hypothesized sequence can be tested directly. Replication in larger, multicenter cohorts with probabilistic sampling, verified incident records, individual-level linkage of exposure events and symptoms, objective exposure assessment and longitudinal follow-up would be needed to confirm these preliminary findings and increase statistical power. Additionally, the incorporation of qualitative methodologies, such as in-depth interviews, would allow for the exploration of contextual and cultural barriers underlying the observed behaviors, such as reluctance to report incidents.

5. Conclusions

In this exploratory census of chemistry laboratory technicians at two universities in southern Ecuador, self-reported chemical incidents and exposure events, mainly inhalation of vapors or gases, and health symptoms were common in the previous 12 months, and technicians who reported more events also tended to report more symptoms. Technicians rated their own risk awareness highly, whereas fewer than half reported having a fume hood that was available and functioning well or knowing perfectly how to use emergency showers and eyewash stations.

No statistically significant differences in reported events or symptoms were detected between the two institutions or by sex, and no statistically significant association between training and reported events was detected in this sample; given the small sample and the strong association between training and institution, these results do not indicate that training is ineffective. The findings are specific to the two participating institutions and to the perception of chemical risk, and should be interpreted in light of the limitations described above. They suggest that verifying the availability and performance of fume hoods, clarifying eye-protection requirements, strengthening incident reporting and complementing training with practical components are reasonable priorities for these laboratories, and that larger studies with objective exposure assessment and individual-level linkage of exposure events and symptoms are needed.

Supplementary Materials: The following supporting information can be downloaded at <https://www.mdpi.com/article/10.3390/hygiene6040072/s1>, Supplementary Material file: The full data-collection questionnaire: Survey on Chemical Risk Perception and Health and Safety Practices among University Laboratory Technicians.

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