

ASSESSMENT OF BIOSAFETY RISKS AND MANAGEMENT PRACTICES IN SELECTED MEDICAL LABORATORY SCIENCE SCHOOLS IN CALABARZON: BASIS FOR PROPOSED BIOSAFETY STANDARD PROCEDURES

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Abstract

Biosafety is vital in Medical Laboratory Science (MLS) programs to safeguard students, faculty members, and the community. This study assessed biosafety risks and management practices in MLS schools in CALABARZON as a basis for proposed standard procedures. A descriptive quantitative design utilizing a survey approach was conducted with 12 purposively selected MLS schools using a self-developed questionnaire to assess current practices and identify gaps. Data were analyzed through frequency counts, percentages, means, standard deviations, and analysis of variance (ANOVA). A proposed model of procedures was developed based on the findings of this assessment. The overall mean biosafety practice score was 3.98 (SD = 0.499), indicating moderately practiced biosafety practices. Out of 12 schools, 11 showed moderate biosafety implementation. ANOVA results revealed significant differences among schools, $F(11,29) = 5.934$, $p < 0.001$, indicating inconsistencies in adherence to protocols despite similar program requirements. Biosafety practices varied significantly, highlighting the need for standardized guidelines in academic laboratories to ensure safety and compliance. Further research using qualitative methods was recommended to gain a deeper understanding.

Keywords: biosafety risks, management practices, Medical Laboratory Science School

Research Highlights

What is the current knowledge?

- Biosafety is recognized as a critical component of Medical Laboratory Science (MLS) programs, serving to protect students, faculty, and the broader community from laboratory-associated risks.
- National and international guidelines underscore the importance of biosafety, yet evidence indicates that adherence and implementation across academic laboratories are often inconsistent.
- Studies have shown that inadequate biosafety practices may increase the likelihood of laboratory-acquired infections and compromise institutional safety cultures.
- Despite its relevance, there is a scarcity of region-specific data documenting the actual level of biosafety implementation in Philippine MLS schools, particularly in CALABARZON.
- The lack of localized evidence hinders the formulation of targeted strategies to strengthen biosafety in educational settings.

What is new in this study?

- This study provides empirical evidence from MLS schools in CALABARZON, demonstrating that biosafety practices are only moderately implemented and vary considerably across institutions.
- It proposes a standardized model of biosafety procedures to address observed inconsistencies and provide a framework for more uniform implementation in academic laboratories.
- Findings highlight the need for systematic capacity building, regular faculty and student training, and strengthened monitoring mechanisms to ensure compliance.
- The study underscores the importance of institutional policy reinforcement and collaborative initiatives among MLS schools to foster a stronger culture of biosafety.
- Recommendations are offered for future qualitative research to explore contextual barriers and enablers, thereby informing more responsive and evidence-based policies.

INTRODUCTION

Biosafety and biosecurity were essential frameworks that safeguard laboratory personnel, the environment, and the community. Biosafety focuses on practices and containment measures against infectious agents, while biosecurity prevents the misuse or intentional release of hazardous materials. Central to both is the use of Standard Operating Procedures (SOPs), which are written, standardized instructions designed to ensure that laboratory activities are carried out safely, consistently, and in compliance with established guidelines. Despite these measures, laboratory-acquired infections (LAIs) continue to be a significant occupational hazard. LAIs are infections contracted through laboratory-related activities such as inhalation, ingestion, direct contact, or accidental inoculation. Reported cases often involve pathogens such as *Brucella* spp., *Shigella* spp., *Salmonella* spp., *Mycobacterium tuberculosis*, and *Neisseria meningitidis*. A notable incident was the 2003 SARS coronavirus infection in a Singapore laboratory, which occurred despite

containment measures and highlighted the persistent risks of laboratory work (Shobowale et al., 2015). To address these challenges, global frameworks like the CEN Workshop Agreement (CWA 15793) and national policies of the National Committee on Biosafety of the Philippines (NCBP) guide biosafety risk management. Locally, the Research Institute for Tropical Medicine (RITM) introduced a WHO-based ladderized biosafety training program in 2016.

In higher education, the Commission on Higher Education (CHED) promotes quality assurance in academic laboratories through the Medical Laboratory Science (MLS) program, governed by CMO No. 14 s. 2006. However, reporting of LAIs and accidents still varies across institutions, as CHED has yet to establish specific biosafety standards for academic laboratories. Strengthening evidence-based biosafety management in MLS schools is therefore vital, not only to ensure safer academic environments but also to enhance educational quality and protect public health.

This study investigated the extent and consistency of biosafety practices among MLS schools in CALABARZON, contributing to the limited body of literature on biosafety in Philippine academic laboratories and providing evidence that may inform policy development in higher education.

LITERATURE REVIEW

Research on biosafety practices has consistently underscored the importance of structured management systems in laboratory environments. International and local guidelines provide a foundation for understanding and implementing biosafety, yet significant gaps remain in their application, particularly in academic institutions.

Importance of Biosafety Management Practices

Biosafety management systems are critical in safeguarding laboratory personnel, students, and the wider community from biological risks. Well-structured programs not only minimize laboratory-acquired infections (LAIs) but also foster a strong culture of safety and ensure compliance with national and international standards (Caskey et al., 2010; Cook et al., 2005; Emmert, 2013). More recent studies emphasized that biosafety management should be understood as a comprehensive system, integrating administrative policies, engineering controls, and ongoing education in order to achieve sustainable safety outcomes (Nkengasong & Djoudalbaye, 2017; World Health Organization [WHO], 2020).

While these principles were well-established in research and clinical laboratories, academic teaching laboratories presented distinct challenges. Students often have limited technical skills and may underestimate risks, making them more prone to errors (Kelly & Alper, 2020). Furthermore, teaching environments involve large groups of trainees simultaneously handling microorganisms under constrained supervision, which increases the likelihood of safety lapses (Markham & Alper, 2018). These factors point to the need for tailored biosafety management approaches that balance risk reduction with pedagogical objectives.

Importantly, biosafety management is not only a mechanism to prevent LAIs but also an essential component of institutional accountability. Evidence suggests that institutions with robust biosafety frameworks demonstrate higher levels of preparedness, more consistent reporting of incidents, and greater public trust (Salerno & Gaudioso, 2015; WHO, 2020). Embedding such systems in

academic settings contributes not only to safer laboratory environments but also to the professional formation of future health workers, ensuring that graduates are both competent and safety-conscious.

Local Initiatives and Professional Advocacy

In the Philippine context, the works of Guerrero and Serrano (2017) and the initiatives of the Philippine Association of Schools of Medical Technology (PASMETH) (C&E Bookstore, 2019) reflect growing efforts to standardize biosafety training in natural science and medical technology laboratories. The Research Institute for Tropical Medicine (RITM) further contributed by establishing a ladderized biosafety training program in 2016 (Medina, 2017) aligned with the WHO's Laboratory Biosafety Manual. Despite these advances, implementation has been uneven, with no unified framework from the Commission on Higher Education (CHED). Consequently, compliance varies across institutions, leaving biosafety practices dependent on institutional priorities and resources rather than national mandates.

This lack of a regulatory backbone creates inconsistencies in laboratory safety culture. While some institutions adopt best practices, others operate without structured risk management protocols. Professional organizations such as PASMETH continue to advocate for stronger biosafety integration into medical laboratory science curricula, but without CHED-issued guidelines, academic institutions face challenges in harmonizing standards (Guerrero & Serrano, 2017).

Facility Safety and Operational Practices

A wide body of literature highlights facility-related factors as integral to biosafety. Studies by Nasim et al. (2012), Elduma (2014), Sewunet et al. (2014), Oladeinde et al. (2013), Shobowale et al. (2015), Qasmi et al. (2012), and Fahmida et al. (2017) addressed operational practices such as fire safety, waste management, and the use of personal protective equipment (PPE). These works emphasize that technical measures are indispensable for minimizing occupational hazards.

However, most of these studies focus on general laboratory safety without situating facility safety within a broader biosafety management framework. For example, while the proper disposal of infectious waste is universally acknowledged as critical, its successful implementation depends on institutional support, availability of resources, and trained personnel (Elduma, 2014). In academic laboratories, where budgets may be limited and student turnover is high, sustaining such practices poses additional challenges. Thus, operational practices, though essential, cannot substitute for comprehensive biosafety systems that address both physical infrastructure and behavioral compliance.

Biological Safety Concepts and Laboratory Equipment

Research has also examined biological safety practices and the role of equipment in mitigating risks. Kozajda et al. (2013), Coelho and Diez (2015), Elduma (2012), and Shekhar (2014) emphasized safe handling practices as the primary line of defense against exposure to infectious agents. Complementarily, Kimman et al. (2008), Nasim et al. (2012), and Oladeinde et al. (2013) highlighted the importance of laboratory equipment such as biosafety cabinets, autoclaves, and proper ventilation systems in ensuring containment.

Nevertheless, many of these studies assume the availability of adequate resources and trained personnel, conditions not always present in developing countries. Academic institutions, in particular, may lack the financial and technical capacity to maintain advanced biosafety equipment, thereby increasing reliance on basic safety behaviors and institutional monitoring. This gap underscores the need for adaptable biosafety frameworks that reflect resource constraints while upholding safety standards.

Identified Gaps and Relevance to the Current Study

The reviewed literature converges on the need for strong biosafety management, yet few studies focus specifically on teaching laboratories in higher education. One pressing concern is the safe handling of microorganisms by students without a uniform, accessible, and enforceable set of biosafety guidelines. The absence of CHED-issued standards for microbiological experiments exacerbates inconsistencies and leaves protocols largely to institutional discretion.

By situating the present study within both global and local discourses on biosafety, it becomes clear that while international frameworks and local initiatives exist, their adaptation to academic teaching laboratories remains underexplored. This research contributes to the literature by systematically examining biosafety management practices in MLS schools in CALABARZON, thereby providing empirical evidence that can inform the development of standardized guidelines. In doing so, it bridges a critical gap between policy and practice and strengthens the foundation for creating safe, sustainable, and pedagogically sound laboratory environments for future health professionals.

METHODOLOGY

Design

This study utilized a descriptive quantitative design, which systematically described and quantified phenomena without manipulating variables. As Polit and Beck (2004) noted, this approach was effective for identifying issues, justifying current practices, and determining what was being done in similar contexts. The design was chosen to assess biosafety management practices in their natural, uncontrolled laboratory settings, ensuring that observations reflected authentic operational conditions. No variables were altered, allowing the study to capture accurate and context-specific data. This method was appropriate for generating measurable insights into biosafety performance, identifying gaps, and informing the development of standardized protocols for academic laboratories.

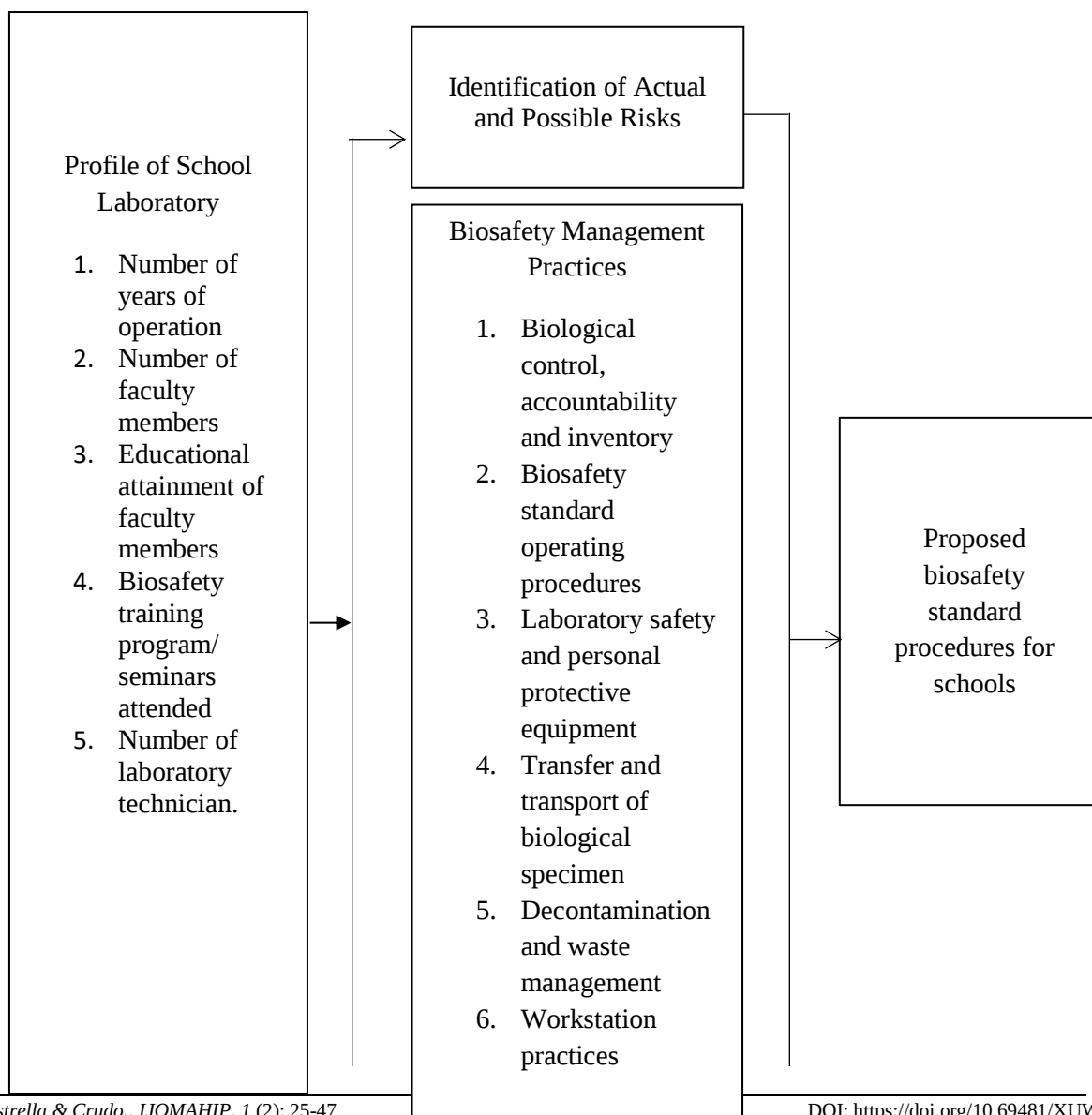
The concept presented could be best understood in the paradigm of the study presented in Figure 1.

The paradigm illustrated the variables in the study that included the biosafety risks and management practices of selected medical laboratory science schools in CALABARZON. Specifically, the researcher determined the demographic variables of the participating schools, such as: (a) number of years of operation; (b) number of faculty members; (c) educational attainment of faculty members; (d) biosafety training program/seminars attended; and (e) number of laboratory technicians.

The actual and possible risks encountered by the medical laboratory science schools during laboratory procedures performed by the students were also identified while the biosafety management practices of the medical laboratory science school laboratory in terms of: (a) biological control, accountability, and inventory; (b) biosafety SOPs; (c) laboratory safety and personal protective equipment; (d) transfer and transport of biological specimen; (e) decontamination and waste management; and (f) workstation practices were determined. Moreover, an analysis was performed to show whether there was a significant difference in the biosafety management practices in selected medical laboratory science schools. Consequently, a proposed strategy for addressing the identified gaps was formulated.

Figure 1

Conceptual Paradigm of the Assessment of Biosafety Risks and Management Practices: Basis for Proposed Biosafety Standard Procedures in School



Sampling Design and Sample Size

Table 1 shows the twelve institutions that were selected using purposive sampling based on the following inclusion criteria: (a) Commission on Higher Education (CHED) program recognition; (b) at least two professional course laboratories; and (c) at least two full-time faculty members. The total eligible population from these institutions comprised 89 full-time faculty members handling professional laboratory courses, 22 laboratory technicians, and 610 third-year students ($N=721$). The minimum required sample size was calculated using Slovin's formula:

$$n = \frac{N}{1 + Ne^2} \quad \text{with } N=721 \text{ and a 5\% margin of error } (e=0.05) \text{ yielding } n \approx 258.$$

During actual data collection, all respondents who met the inclusion criteria, were present, and gave informed consent were included, resulting in 28 faculty members, 13 laboratory technicians, and 553 students (total $n=594$). This corresponded to an overall response rate of 82.4% ($594/721$). The purposive sampling method was chosen to ensure inclusion of participants with direct involvement in professional laboratory courses and biosafety management practices, thereby increasing the relevance and validity of the findings.

Table 1

Population and Sample of the Study

School	Population			Sample					
	Faculty	Lab. Tech.	3 rd Year Students	Faculty		Laboratory Technicians		3 rd Year Students	
	F	F	F	F	%	F	%	F	%
A	9	1	67	2	22%	1	100%	67	100%
B	9	0	88	3	33%	0	-	85	97%
C	6	1	48	2	33%	1	100%	53	91%
D	4	1	50	2	50%	1	100%	16	32%
E	6	1	30	2	33%	2	200%	20	67%
F	4	5	78	2	50%	2	40%	78	100%
G	9	4	40	2	22%	0	0%	40	100%
H	3	1	18	2	67%	1	100%	18	100%
I	10	3	87	4	40%	1	33%	82	94%
J	10	3	48	2	20%	2	67%	48	100%

K	12	1	27	3	25%	1	100%	27	100%
L	7	1	19	2	29%	1	100%	19	100%
Total	89	22	610	28	31%	13	59%	553	91%

Legend: F=frequency count; %=percentage

Instrumentation

A researcher-made questionnaire, guided by the WHO Laboratory Biosafety Manual (2004), CEN guidelines, and other international standards, was used alongside ocular inspection to verify laboratory conditions. The tool comprised: (1) informed consent, (2) respondent profile, (3) identified laboratory risks, and (4) biosafety management practices in six areas such as biological control, SOPs, PPE use, specimen transport, decontamination/waste management, and workstation practices which were rated on a 5-point Likert scale (5 = Always to 1 = Never). Content validity was confirmed by three subject matter experts in biosafety, education, and laboratory sciences. A pilot test in a non-participating institution established clarity, and Cronbach's alpha values exceeded 0.70 across all sections. Purposive sampling was used to select participants. Surveys were administered in person, with ocular inspections conducted concurrently. Of the eligible population (89 faculty, 22 technicians, 610 students), responses were obtained from 28 faculty, 13 technicians, and 553 students, yielding an 82.4% response rate.

Data Collection Procedure

The study commenced with securing an ethics clearance from the De La Salle University–Dasmariñas Research Office, ensuring that the research design, instruments, and methodology complied with ethical research standards. Following this, an endorsement letter was obtained from the Philippine Association of Schools of Medical Technology and Public Health (PASMETH) to formally authorize engagement with member institutions. Subsequently, the researcher sought written permission from the dean's office of each selected Medical Laboratory Science (MLS) school in the CALABARZON region to conduct the study within their institution. Upon institutional approval, faculty members, laboratory technicians, and students were briefed regarding the study's purpose, procedures, and scope. Purposive sampling was employed to select participating MLS schools. The questionnaire, designed to gather both demographic and technical data, was distributed to identified respondents: full-time faculty handling professional laboratory courses, laboratory technicians, and third-year MLS students. The researcher personally administered the questionnaires to ensure uniform instructions and to address any queries from the participants. For laboratory technicians, the researcher provided direct guidance during questionnaire completion to ensure clarity of interpretation. Additionally, interview data gathered during interactions were incorporated into Part 1 of the questionnaire for demographic profiling. Data were collected promptly and subjected to statistical analysis for interpretation at the earliest opportunity.

Ethical Considerations

All potential respondents were provided with a written informed consent form detailing the objectives of the study, the nature of their participation, the voluntary nature of their involvement,

and their right to withdraw at any point without repercussions. Consent was secured before participation, and only those who agreed were included in the study. Respondents' identities were kept strictly confidential. Personal identifiers were excluded from the data sets, and responses were coded to maintain anonymity. Data were stored in a password-protected electronic file accessible only to the researcher. The study followed a clear chain of approvals, such as ethics clearance from De La Salle University–Dasmariñas Research Office, endorsement from PASMETH, and written permission from the deans of selected MLS schools. These institutional approvals ensured compliance with both academic and organizational protocols. Care was taken to avoid any form of coercion. Respondents participated during their available time slots to prevent disruption of academic or work responsibilities. The questions were designed to avoid causing distress or discomfort. Data collection was done systematically under the direct supervision of the researcher to minimize errors, misinterpretations, and incomplete responses.

Data Analysis

The gathered data were analyzed using descriptive and inferential statistics. Frequency counts and percentages were used to summarize the respondents' demographic and institutional profiles, including years of operation, number of faculty members, educational attainment of faculty, number of laboratory technicians, attendance in biosafety training or seminars, and identified laboratory risks. To determine the level of biosafety management practices, the mean scores were computed for six key areas: (a) biological control, accountability, and inventory; (b) biosafety standard operating procedures (SOPs); (c) laboratory safety and personal protective equipment (PPE); (d) transfer and transport of biological specimens; (e) decontamination and waste management; and (f) workstation practices. The standard deviation was also calculated to assess the variability of responses within each area. For inferential analysis, analysis of variance (ANOVA) was conducted to examine whether significant differences existed in the level of biosafety management practices among the participating medical laboratory science schools.

RESULTS

Profile of Participating Medical Laboratory Science Schools

Table 2 presents the profile of participating medical laboratory science schools. The schools reflected a varied institutional profile in terms of years of operation, faculty composition, and laboratory staffing. Nearly half (42%) had been operating for 4–7 years, suggesting a relatively young yet established presence in the field, while a quarter (25%) had been in service for 12–15 years. A smaller portion was newly established with three years or less (17%) or had longer operational histories of 16–19 years (8%) and 20 years or more (8%). Interestingly, no institution fell within the 8–11-year range, indicating a possible gap in mid-aged programs. Faculty size showed moderate capacity, with two-thirds of schools employing between four and nine members (33% each for the 4–6 and 7–9 ranges), a quarter (25%) maintaining 10–12 members, and only one institution (9%) with fewer than four. Regarding qualifications, a significant majority of faculty held master's degrees (64%), followed by those with doctoral degrees (29%), while a small minority held either a Doctor of Medicine or bachelor's degree (4% each). Laboratory staffing patterns leaned toward minimal technical support, with most institutions (68%) employing only one laboratory technician. Others had two (16%) or three (8%), while one school (8%) reported having none. This relatively low technician-to-faculty ratio may have implications for laboratory

efficiency, quality of technical assistance, and the overall capacity to deliver extensive hands-on training.

Taken together, these findings suggested that while many institutions benefit from a qualified teaching workforce and a stable operational history, limitations in laboratory technical staffing could affect the depth and consistency of practical laboratory experiences, a point that warranted closer examination in the subsequent discussion.

Table 2

Profile of Participating Medical Laboratory Science Schools

Demographic Profile	F	%
Number of Years of Operation		
3 years and below	2	17
4-7	5	42
8-11	0	0
12-15	3	25
16-19	1	8
20 years and above	1	8
Total	12	100
Number of Faculty Members		
1-3	1	9
4-6	4	33
7-9	4	33
10-12	3	25
Total	12	100
Highest Educational Attainment of Faculty Members		
PhD degree	8	29
Master's degree	18	64
Doctor of Medicine	1	4
Bachelor's degree	1	4
Total	28	100
Number of Laboratory Technician(s)		
0	1	8
1	8	68
2	2	16
3	1	8
Total	12	100

Legend: F=frequency count; %=percentage

Biosafety Training Program/ Seminars Attended by the Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

The data in Table 3 revealed notable variations in the biosafety training received by faculty members and laboratory technicians in participating Medical Laboratory Science schools. Faculty members reported higher participation rates in most training areas, particularly Introduction to Biosafety and Biosecurity (71%), Biorisk Management (57%), and Risk Assessment (54%). In contrast, laboratory technicians showed comparatively lower engagement, with the highest attendance recorded in Introduction to Biosafety and Biosecurity (38%) and multiple topics such as Waste Management, Risk Assessment, and Handling of Infectious Substances, all at 31%.

Interestingly, General Laboratory Safety training was more common among technicians (31%) than faculty (14%), suggesting possible role-specific training priorities. These trends highlighted the need for more consistent and comprehensive biosafety training across both groups, with particular emphasis on strengthening technicians' competencies in Biorisk Management and ensuring faculty had broader exposure to fundamental safety practices. Addressing these gaps might enhance the overall laboratory safety culture, promote adherence to biosafety standards, and improve preparedness for handling infectious materials.

Table 3

Biosafety Training Program/Seminars Attended by the Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

Biosafety Training Program/ Seminars Attended	Faculty Members		Laboratory Technicians	
	N = 28		N = 13	
	f	%	f	%
Introduction to biosafety and biosecurity	20	71	5	38
Risk assessment	15	54	4	31
Good microbiological practices	10	36	3	23
Bio risk management	16	57	2	15
Training on biosafety cabinet	13	46	4	31
Waste management	14	50	4	31
Handling, transfer, and transport of infectious substances	10	36	4	31
Others: general laboratory safety	4	14	4	31

Legend: N=total respondents; f=frequency count; %=percentage

Cross-tabulation of the Possible and Actual Risks Encountered by Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

The cross-tabulation in Table 4 revealed notable gaps between the risks perceived as possible and those actually experienced by faculty members and laboratory technicians in the participating Medical Laboratory Science schools. While infections were anticipated by only 17% of respondents, they emerged as one of the most common actual incidents (40%). Likewise, injury was identified by just 12% as a possible risk but was the most frequently reported actual occurrence (44%). Contamination was considered possible by only 9%, yet over a quarter (27%) reported experiencing it. Some risks, such as accidents (14% possible vs. 2% actual) and spills (14% possible vs. 17% actual), showed smaller gaps between perception and reality. However, several hazards including allergy, electrocution, erroneous results, inhalation, and tripping were not anticipated by any respondent but still occurred (5% each), indicating that certain occupational hazards were underestimated. When viewed alongside the earlier training participation data, the findings suggested that limited or selective participation in biosafety, biosecurity, and laboratory safety trainings might have contributed to the underestimation of specific hazards. This mismatch between perceived and actual risks pointed to the need for more comprehensive and proactive risk

awareness programs, ensuring that both anticipated and overlooked hazards were addressed in safety protocols.

These findings highlighted the uneven distribution of biosafety training between faculty and laboratory technicians, which might have implications for laboratory safety culture and operational efficiency. Addressing the identified gaps, particularly in Biorisk Management for technicians and general laboratory safety for faculty members, could strengthen institutional compliance with biosafety standards and improve preparedness for handling infectious materials.

Table 4

Cross-tabulation of the Possible and Actual Risks Encountered by Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

Risks	Possible		Actual	
	F	%	F	%
Infections	7	17	15	40
Accidents	6	14	1	2
Spills	6	14	7	17
Injury	5	12	18	44
Theft	5	12	2	5
Contamination	4	9	11	27
Dual use	3	7	0	0
Fire	3	7	2	5
Cuts	1	2	0	0
Explosion	1	2	0	0
Needle prick	1	2	1	2
Poisoning	1	2	0	0
Splashes	1	2	3	7
Allergy	0	0	2	5
Electrocution	0	0	2	5
Erroneous results	0	0	2	5
Inhalation	0	0	2	5
Tripping	0	0	2	5

Breakage	0	0	1	2
Dizziness	0	0	1	2
Vomiting	0	0	1	2

Total Number of Faculty Members and Laboratory Technicians=41

Legend: f=frequency count; %=percentage

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Biosafety Management Practices

Table 5 illustrates the biosafety management practices implemented by Medical Laboratory Science schools, as measured across key operational domains. The findings revealed an overall moderate level of adherence, with mean scores ranging from 3.80 to 4.35 on a five-point scale. Notably, the management of Biosafety Standard Operating Procedures (SOPs) received the highest mean score of 4.35 (SD = 0.745), indicating a high level of compliance and standardization in formal biosafety protocols. This underscored the schools' commitment to establishing clear and consistent procedural frameworks essential for laboratory safety. Other biosafety domains, including Biological Control, Accountability, and Inventory (mean = 4.00, SD = 0.539), Laboratory Safety and Use of Personal Protective Equipment (PPE) (mean = 4.02, SD = 0.536), and Laboratory Decontamination and Waste Management (mean = 3.96, SD = 0.662), demonstrated moderate practice levels. These results suggested effective but variable implementation across institutions, signaling areas where further reinforcement could enhance safety outcomes. The domain of Transfer and Transport of Biological Specimens exhibited the lowest average score at 3.80 (SD = 0.907), coupled with the highest variability among responses. This pointed to inconsistent practices in specimen handling, potentially reflecting disparities in resources, training, or procedural rigor across different schools. Aggregating the various dimensions, the overall biosafety management practices achieved a mean score of 3.98 (SD = 0.499), indicative of a moderate but foundational adherence to biosafety standards. These findings highlighted that while Medical Laboratory Science schools maintained essential biosafety measures, strategic interventions focusing on specimen transfer and transport protocols were warranted to elevate safety standards and reduce laboratory risks.

Table 5

Overall Biosafety Management Practices of Medical Laboratory Science Schools

Items	Mean	SD	VI
Biological control, accountability, and inventory	4.00	0.539	MP
Biosafety SOPs	4.35	0.745	HP
Laboratory safety and PPE	4.02	0.536	MP
Transfer and transport of biological specimen	3.80	0.907	MP
Laboratory decontamination and waste management	3.96	0.662	MP

Workstation practices	3.91	0.738	MP
<i>Overall biosafety management practices</i>	<i>3.98</i>	<i>0.499</i>	<i>MP</i>

4.21–5.00 Highly practiced (HP)
3.41–4.20 Moderately practiced (MP)
2.61–3.40 Less practiced (LP)
1.81–2.60 Least practiced (LTP)
1.00–1.80 Not practiced (NP)
SD-Standard deviation
VI-Verbal Interpretation

The results presented in Table 5 provide valuable insights into the current state of biosafety management practices within Medical Laboratory Science schools. While the overall moderate adherence reflects a commendable foundation of biosafety awareness and implementation, the observed variability, particularly in the handling and transport of biological specimens, raises important considerations. These findings warranted further exploration to understand the underlying factors influencing these practices, their implications for laboratory safety, and opportunities for targeted improvements. The following discussion delved into these aspects, contextualizing the results within existing literature and identifying actionable strategies to enhance biosafety protocols across institutions.

Comparison of Current Biosafety Practices of MLS Schools in CALABARZON and Recommended Standards

Table 6 showed that the overall biosafety practice among MLS schools in CALABARZON was rated as moderately practiced with a composite mean of 3.98 (SD = 0.499). Eleven of the twelve participating schools fell within this category, reflecting that while foundational biosafety measures were in place, their implementation was inconsistent. Among the biosafety practices assessed, biosafety SOPs and laboratory safety and PPE use scored relatively higher, whereas transfer and transport of biological specimens obtained the lowest mean (≈ 3.80).

Table 6

Comparison of Current Biosafety Practices of MLS Schools in CALABARZON and Recommended Standards

Biosafety Practices	Current Practice (Survey Findings)	Recommended Standard / Practice
Biological Control, Accountability, and Inventory	Moderately practiced (Mean ≈ 4.0); inconsistencies in inventory records and control measures	Comprehensive inventory management system; strict accountability for reagents and specimens (World Health Organization [WHO], 2020; Centers for Disease Control and Prevention [CDC] & National Institutes of Health [NIH], 2020)
Biosafety Standard Operating Procedures (SOPs)	Practiced at a high level; SOPs exist but vary across schools	Uniform, documented SOPs aligned with national and WHO biosafety guidelines; periodic reviews and updates (WHO, 2020; Department of Health [DOH], 2010)
Laboratory Safety and PPE Use	Moderately practiced (Mean ≈ 4.02); PPE available but inconsistently used	Mandatory use of PPE at all times; compliance monitoring and reinforcement (International Organization for Standardization [ISO], 2020; CDC & NIH, 2020)

Biosafety Practices	Current Practice (Survey Findings)	Recommended Standard / Practice
Transfer and Transport of Biological Specimens	Lower practice levels (Mean $\approx$ 3.80); limited standardization in transport protocols	Adoption of international guidelines for safe transport; staff/student training (WHO, 2020; DOH, 2010)
Laboratory Decontamination and Waste Management	Moderate adherence; practices differ depending on resources	Centralized waste management systems; use of autoclaving and proper segregation (WHO, 2020; ISO 2020)
Workstation Safety	Moderate practice; some workstations remain cluttered	Ergonomic, hazard-free workstation layouts; routine inspection and hazard identification (ISO 2020)
Overall Biosafety Practices	Overall Mean = 3.98 (SD = 0.499) interpreted as <i>Moderately Practiced</i>	Development of standardized institutional biosafety manuals and mandatory training programs (WHO, 2020; CDC/NIH, 2020; DOH, 2010)

WHO-World Health Organization; CDC/NIH-Center for Disease Control and Prevention /National Institutes of Health; DOH-Department of Health (Philippines); ISO-International Organization for Standardization.

As shown, variations were also observed in inventory management, waste disposal, and workstation safety, indicating gaps in uniformity across schools. These results suggested that MLS programs follow baseline biosafety measures but fell short of fully aligning with international and national standards such as those outlined by WHO (2020), CDC and NIH (2020), DOH (2010), and ISO (2020).

Biosafety Risk and Management Practices of Medical Laboratory Schools in terms of Demographic Profiles

The data presented in Table 7 indicated that most of the participating MLS schools moderately practiced various aspects of biosafety risk and management. This moderate level of practice appeared to be strongly influenced by the generally high educational attainment of faculty members, as well as their active participation in biosafety-related training and seminars.

Table 7

Biosafety Risk and Management Practices of Medical Laboratory Schools in terms of Demographic Profiles

School	NYO	NFM	HEAFM	NLT	Biosafety Training/Seminars Attended by Faculty Members								Biosafety Training/Seminars Attended by Laboratory Technicians								Areas of Biosafety Risk and Management						Over-all Biosafety Management Practices
					IBB	RA	GMP	BM	TBC	WM	HTTIS	O	IBB	RA	GMP	BM	TBC	WM	HTTIS	O	A	B	C	D	E	F	
A	3	9	MS	1	✓	x	x	x	✓	✓	x	✓	x	x	x	x	x	x	x	MP	MP	MP	MP	MP	MP	MP	MP
B	7	9	MD	0	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	x	MP	HP	MP	MP	MP	MP	MP	MP
C	7	6	PhD	1	✓	✓	✓	✓	✓	✓	✓	x	✓	x	x	x	x	x	✓	✓	MP	HP	MP	MP	MP	MP	MP
D	4	4	MS	1	✓	✓	✓	✓	x	✓	✓	x	x	x	x	x	x	x	x	LP	MP	LP	MP	LP	LP	LP	LP
E	14	6	MS	1	x	x	x	x	x	x	x	x	✓	x	x	x	x	x	✓	MP	HP	MP	MP	MP	MP	MP	MP
F	16	4	PhD	5	✓	✓	x	x	✓	✓	x	x	✓	✓	x	x	✓	✓	✓	✓	MP	MP	MP	MP	MP	MP	MP
G	30	9	PhD	4	x	✓	✓	x	✓	✓	x	x	x	x	x	x	x	x	x	MP	MP	MP	MP	MP	MP	MP	MP
H	5	3	PhD	1	✓	✓	✓	✓	✓	✓	✓	✓	x	x	x	x	x	x	x	MP	MP	MP	MP	MP	MP	MP	MP
I	3	10	MS	3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	x	MP	MP	MP	MP	MP	MP	MP
J	14	10	MS	3	✓	x	x	x	x	x	x	x	x	x	x	x	x	x	x	MP	HP	MP	MP	MP	MP	MP	MP
K	15	12	PhD	1	✓	x	x	✓	✓	x	x	x	✓	✓	✓	✓	✓	✓	✓	✓	MP	HP	MP	MP	MP	MP	MP
L	5	7	MS	1	✓	✓	✓	✓	✓	✓	✓	x	x	x	✓	x	x	x	x	MP	HP	MP	MP	MP	MP	MP	MP

Legend:

NYO - Number of Years Operation
NFM - Number of Faculty Members
HEAFM - Highest Educational Attainment of Faculty Members
NLT - Number of Laboratory Technicians

Biosafety Training/Seminars Attended
IBB - Introduction to Biosafety and Biosecurity
RA - Risk Assessment
GMP - Good Microbiological Practices
BM - Bio-risk Management

TBC - Training on Biosafety Cabinet
WM - Waste Management
HTTIS - Handling, Transport, Transfer of Infectious Substances
O - Others

Areas of Biosafety Risk and Management
A - Biological control, accountability, and inventory
B - Biosafety standard operating procedures
C - Laboratory safety and personal protective equipment
D - Transfer and transport of biological specimen
E - Decontamination and waste management
F - Workstation practices

Biosafety Risk and Management Practices (Verbal Interpretation)
HP - Highly Practiced
MP - Moderately Practiced
LP - Less Practiced
LTP - Least Practiced
NP - Not Practiced

Interestingly, the presence or absence of laboratory technicians, as well as their numbers, did not significantly affect the overall trends observed. Notably, schools with more than six faculty members demonstrated a higher adherence to biosafety standard operating procedures (SOPs), which may be attributed to the larger workforce enabling better collaboration in developing and implementing these protocols. While faculty attendance at biosafety seminars likely enhanced their competencies, the involvement of laboratory technicians could potentially further improve biosafety practices across schools. However, one outlier, School D, showed consistently lower levels of biosafety risk management practices across most areas. This may be due to the relative infancy of the school, which could impact factors such as budget allocation, prioritization of biosafety measures, and staff capability. These unique contextual challenges underscored that each school's biosafety implementation was shaped by its specific circumstances. In summary, while the profile of each school, including faculty size and training participation, provided some indication of their biosafety risk and management practices, it could not fully explain the variations observed. The findings highlighted the need to consider individual institutional contexts when assessing and enhancing biosafety protocols.

Comparison of the Biosafety Management Practices among General Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

Table 8 illustrates the comparative biosafety management practices of faculty members and laboratory technicians across the twelve participating Medical Laboratory Science schools. The data showed that the majority of schools demonstrated moderate adherence to biosafety protocols, with mean scores predominantly ranging from 3.34 to 4.16, corresponding to a verbal interpretation of "Moderately Practiced." Schools G and K were exceptions, exhibiting mean scores of 4.71 and 4.36, respectively, which indicate a "Highly Practiced" level of biosafety management. This suggested a stronger institutional commitment to biosafety standards in these schools, potentially attributable to more robust training programs, resource allocation, or enforcement of protocols. In contrast, Schools B and D recorded the lowest mean scores of 2.85 and 3.34, respectively, classified as "Less Practiced." The minimal variability in responses for School D (SD = 0.000) reflected a uniform perception of limited biosafety practices, indicating potential systemic challenges within this institution. The remaining schools, A, C, E, F, H, I, J, and L, consistently fell into the moderate practice category, suggesting acceptable but improvable implementation of biosafety measures. This pattern revealed variability in biosafety management across institutions, underscoring the necessity for targeted strategies to enhance compliance, particularly in schools identified as less compliant. Overall, the findings highlighted significant disparities in biosafety management practices among MLS schools, emphasizing the importance of contextualized interventions to standardize and elevate biosafety standards across all institutions.

Table 8

Comparison of the Biosafety Management Practices among General Faculty Members and Laboratory Technicians of the Participating Medical Laboratory Science Schools

Schools	Mean	Standard Deviation	Verbal Interpretation
School A	3.63 ^{bc}	0.497	Moderately Practiced
School B	2.85 ^a	0.395	Less Practiced
School C	3.91 ^{bcd}	0.129	Moderately Practiced
School D	3.34 ^{ab}	0.000	Less Practiced

School E	3.98 ^{cd}	0.211	Moderately Practiced
School F	4.08 ^{cd}	0.363	Moderately Practiced
School G	4.71 ^e	0.156	Highly Practiced
School H	4.10 ^{cd}	0.659	Moderately Practiced
School I	4.16 ^{cde}	0.201	Moderately Practiced
School J	3.82 ^{bcd}	0.165	Moderately Practiced
School K	4.36 ^{de}	0.381	Highly Practiced
School L	4.00 ^{cd}	0.246	Moderately Practiced

Computed F -ratio=5.934. P -value is less than 0.001. Degrees of freedom=11 and 29. Significant at the 0.05 level.
Note: Means followed by the same letter are not significantly different from each other.

BioMaps: Proposed Model of Biosafety Management Procedures for Schools

Figure 2 illustrates the BioMaPS (Biosafety Management Procedures for Schools), a proposed model for biosafety standard procedures in educational institutions, depicted as a circle of mutually influencing dynamic processes. The model encompassed key variables, including risk assessment, evaluation of biosafety management practices, existing mitigation measures, implementation strategies, performance evaluation protocols, and feedback mechanisms, which were interconnected cyclically. Central to the model were biosafety concepts that served as the foundation guiding these processes. This framework captured the continuous interplay among advancements and changes in education, science, and technology. Each dynamic process within the model exerted reciprocal influence, thereby inspiring, refining, and complementing one another to promote an adaptive and robust biosafety system.

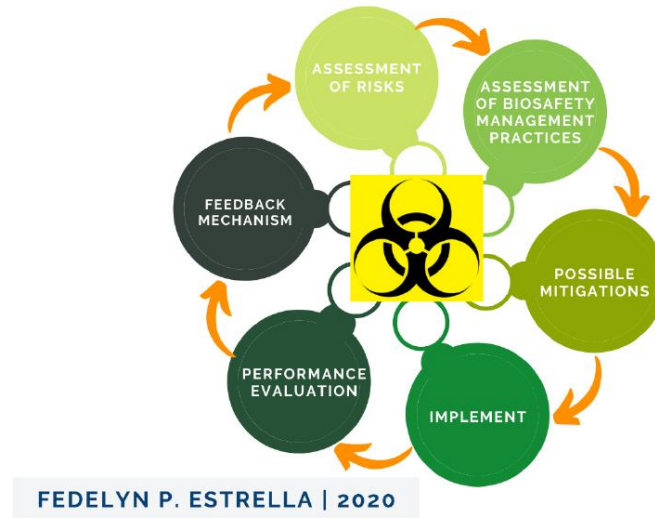
Figure 2

BioMaps: Proposed Model of Biosafety Management Procedures for Schools

BioMaPS Model

BIOSAFETY MANAGEMENT PROCEDURES FOR SCHOOLS

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DISCUSSION

The findings of this study corroborated and extended previous research on biosafety practices in laboratory settings. Consistent with Fahmida et al. (2017), who reported suboptimal biosafety performance among hospital laboratories in Karachi, Pakistan, our results revealed moderate to low adherence to biosafety protocols across several critical domains, including administrative controls, microbiological practices, and facility design. Similarly, the major gaps identified by Qasmi et al. (2012), such as the absence of protocols for reporting laboratory-acquired infections (LAIs), inadequate continuous training, and lack of regulatory oversight, paralleled the deficiencies observed in the participating schools. This convergence highlighted the persistent and global challenges faced by laboratory institutions in maintaining comprehensive biosafety standards. From a policy perspective, these findings underscore the urgent need for intervention by governing bodies such as the Commission on Higher Education (CHED) and institutional administrators. CHED could strengthen biosafety by implementing standardized policies mandating regular training, audits, and compliance monitoring. School administrators should prioritize the allocation of resources to biosafety infrastructure and embed biosafety education into curricula and staff development programs to mitigate risks to students, personnel, and the broader community. However, practical challenges remained evident. Limited budget allocations, insufficient access to continuous professional development, and the absence of clear regulatory frameworks hindered

effective biosafety management in many schools. The findings of this study revealed that biosafety practices in MLS schools in CALABARZON were generally moderately practiced ($M = 3.98$, $SD = 0.499$). Although baseline safety measures were in place, the ANOVA results ($F(11,29) = 5.934$, $p < .001$) indicated significant differences across institutions, underscoring inconsistencies in the implementation of biosafety protocols despite similar curricular and regulatory requirements. These variations highlight the uneven integration of biosafety principles in academic laboratories and the need for harmonization of standards.

The biosafety practices results provided further insight into these disparities. While schools demonstrated stronger adherence to SOPs and laboratory safety and PPE use, lapses were evident in the transfer and transport of biological specimens, inventory management, and waste disposal practices. Such findings were consistent with earlier reports that biosafety compliance in educational laboratories was often resource-dependent and subjected to institutional priorities (WHO, 2020; CDC & NIH, 2020). The moderate implementation level suggested that schools were aware of biosafety requirements but faced challenges in sustaining consistent practices, which might be due to limited resources, lack of standardized manuals, or variations in administrative oversight. The observed gaps had important implications for both academic safety and public health. Inadequate inventory control, inconsistent PPE use, and weak transport protocols increased the risk of laboratory-associated infections and occupational hazards, which could extend beyond the laboratory and impact the broader community (DOH, 2010; ISO, 2020). To address these challenges, MLS schools must not only adopt but also operationalize internationally recognized standards by WHO (2020), CDC and NIH (2020), DOH (2010), and ISO (2020). This required institutional commitment to developing standardized biosafety manuals, enforcing regular compliance audits, and embedding biosafety training in curricula for both students and faculty.

Furthermore, the significant ANOVA results demonstrated that variability among schools was not random but systematic, suggesting that national-level policy interventions were warranted. Establishing a uniform set of academic biosafety guidelines, complemented by capacity-building programs and periodic monitoring, could help ensure equitable and consistent biosafety practices across MLS schools in the region. Such measures would align local practices with global biosafety frameworks while also safeguarding students, faculty, and the communities they serve. To address these issues, actionable recommendations included fostering partnerships with governmental and non-governmental organizations to secure training and resources, developing institution-specific standard operating procedures, and institutionalizing routine biosafety assessments. Strengthening regulatory oversight and promoting a culture of safety through leadership engagement were also critical. This study's limitations warrant consideration. The purposive sampling method limited the generalizability of results, and the reliance on self-reported data introduced potential social desirability bias, possibly inflating compliance levels. Additionally, the cross-sectional design precluded evaluation of biosafety practice trends over time. Future research should expand the sample size using randomized sampling and employ mixed methods to include observational verification of biosafety practices. Longitudinal studies would provide valuable insights into the sustainability of biosafety interventions. Investigating organizational culture and leadership's influence on biosafety adherence may further inform effective, context-specific strategies to enhance laboratory safety.

CONCLUSIONS AND RECOMMENDATIONS

This study advanced the knowledge on biosafety management practices in Medical Laboratory Science schools by demonstrating a moderate level of adherence to biosafety protocols across multiple domains. This study demonstrated that while MLS schools in CALABARZON exhibit a moderate level of biosafety practice and significant differences across institutions to inconsistencies in implementation. Domains such as specimen transport, inventory management, and waste disposal remain underdeveloped compared to international and national standards. These findings underscored the urgent need for standardized institutional biosafety manuals, consistent training, and compliance monitoring to ensure uniform application of protocols. Strengthening biosafety in academic laboratories was not only essential for student and faculty safety but also critical for public health protection and alignment with global best practices. The findings highlighted significant variability among institutions, suggesting that while school profiles might influence biosafety implementation, they are not solely determinative. This underscored the need for context-specific strategies to address gaps in biological control, standard operating procedures, laboratory safety, specimen handling, waste management, and workstation practices. Key recommendations included the development of sustained capacity-building programs involving training, certification, and continuing education for faculty members and laboratory technicians. The establishment of Institutional Biosafety Committees, staffed by qualified biosafety officers, was essential for effective oversight and enforcement of biosafety standards. Routine biorisk assessments integrated into accreditation processes were recommended to ensure ongoing compliance and continuous improvement.

Strong institutional commitment to biosafety was critical for fostering a culture of safety, supported by clear policies, comprehensive documentation, and adequate provision of personal protective equipment and related resources. The creation of a national regulatory body to standardize biosafety practices and enforce compliance was also imperative. Uniform adoption and implementation of biosafety procedures across schools would enhance consistency and safety in academic laboratory environments. Integrating biosafety education within the Medical Laboratory Science curriculum would further equip future professionals to mitigate laboratory risks effectively. Future efforts should focus on operationalizing these recommendations through coordinated institutional initiatives and policy support. Longitudinal research was warranted to assess the impact of these interventions on biosafety outcomes, thereby contributing to the sustained advancement of laboratory safety practices.

List of Abbreviations

ANOVA-Analysis of Variance
BioMaPS- Biosafety Management Procedures for Schools
CDC- Center for Disease Control and Prevention
CWA- CEN Workshop Agreement
CHED- Commission on Higher Education
DOH- Department of Health
ISO- International Organization for Standardization
MLS- Medical Laboratory Science
LAI- Laboratory-Acquired Infection
NCBP- National Committee on Biosafety of the Philippines
NIH- National Institutes of Health

PASMETH- Philippine Association of Schools of Medical Technology
PPE- Personal Protective Equipment
RITM- Research Institute for Tropical Medicine
SOPs- Standard Operating Procedures
WHO- World Health Organization

Declarations

Ethical approval and consent to participate

This study was reviewed and approved by the De La Salle University (DLSU) Dasmariñas Ethics Review Committee (DERC) with protocol code DLSU-DERC-2017-054H. The certification was provided by DLSU-DERC Coordinator, Dr. Norbel A. Tabo. Informed consent was obtained from all participants before their involvement in the study.

Consent for publication

The study did not contain any personal data requiring additional consent for publication. All participant data were anonymized, stored securely, and disposed of one year after the completion of the research.

Availability of data and materials

All data relevant to this study are presented within the article. Since no additional datasets were created or analyzed during this study, data sharing is not applicable.

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Competing Interests

The authors declare that they have no competing interests.

Author's contributions

This manuscript represents the sole authorship of the contributors, who independently conceptualized the study and the instrument, derived the protocol based on the study's own

results, and conducted quantitative data collection, interpreted findings, reviewed, and finished the manuscript.

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