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Original Article

Assessment of Biosafety Practices and Occupational Risks in Biomedical Laboratories in Kinshasa, Democratic Republic of Congo.

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Abstract

Background:
Biosafety is a critical component in protecting human, animal, and environmental health. However, its implementation in biomedical laboratories across low-resource countries remains limited. This study aimed to assess the current state of biosafety practices in biomedical laboratories in Kinshasa and to identify factors associated with occupational exposure to blood-borne pathogens.
Methodology:
An analytical cross-sectional survey was conducted between 1st February and 30th May 2025 in 51 biomedical laboratories across the four districts of Kinshasa. Data were collected through direct observations, semi-structured interviews, and structured questionnaires administered to 290 laboratory staff. Variables assessed included laboratory infrastructure, biosafety measures, staff training, and occupational exposure history.
Results:
The majority of laboratories were peripheral (80.4%) and public sector facilities (66.7%). Only 33.3% of laboratories met the defined biosafety quality criteria, with handwashing stations being the most common element (98%) and staff vaccination the least (11.8%). Among the 290 participants, most were male (57.2%), aged 30–39 years (34.5%), and university educated (98.3%). Nearly half (47.9%) reported occupational exposure to blood, yet only 20.3% underwent testing and 18.8% sought medical consultation. Logistic regression identified age ≥30 years (aOR 1.85–2.81), professional experience >10 years (aOR 2.24–2.85), and lack of biosafety training (aOR 3.19, 95% CI: 2.27–5.96) as independent predictors of exposure.
Conclusion:
Biosafety in Kinshasa biomedical laboratories remains inadequate, with major deficiencies in training, infrastructure, and post-exposure management. Strengthening biosafety systems through regular audits, continuous training, and policy enforcement is urgently required to reduce occupational risks and improve laboratory safety.
Keywords:
Hand Biosafety, Biomedical Laboratories, Occupational Exposure, Kinshasa, Laboratory Safety, Face Masks, Gender Differences, Non-Pharmaceutical Interventions.

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Introduction

Biomedical laboratories play an essential role in the diagnosis, management, and surveillance of diseases by analyzing human samples and providing critical information for both patient care and public health interventions [1]. Despite their importance, laboratories inherently pose risks to personnel and the environment due to potential exposure to infectious agents, hazardous chemicals, and unsafe equipment [2].

The incidence of laboratory-acquired infections varies across institutions and countries, often influenced by the robustness of reporting systems and biosafety practices [3]. For example, in the United States, Henkel et al. reported multiple laboratory-acquired infections associated with biological agents and toxins from 2004 to 2010, involving an annual population of approximately 10,000 individuals with approved access to these pathogens [3]. Similarly, in Canada, the national laboratory incident reporting surveillance system recorded 43 exposure incidents involving 72 individuals in 2021, corresponding to an estimated exposure rate of 4.2% [4]. Beyond infectious hazards, biomedical laboratories also pose chemical and physical risks from reagents, equipment, and electrical installations [5].

Globally, the rise of emerging pathogens, exemplified by SARS-CoV-2, has underscored the urgency of strengthening biosafety systems [6]. Biosafety is defined as a strategic and integrated approach to analyzing and managing risks that threaten human, animal, and plant life as well as the environment [7]. Core components include risk assessment, codes of practice, laboratory infrastructure, equipment maintenance, medical surveillance, staff training, waste management, and emergency preparedness [8].

Despite international guidelines, many laboratories in low-resource countries face challenges in implementing biosafety measures, including limited funding, inadequate infrastructure, insufficient training, and weak regulatory frameworks [9–11]. The Democratic Republic of Congo (DRC) has made commitments to biosafety by joining the Cartagena Protocol in 2005 and aligning with the Convention on Biological Diversity [12]. However, the country still lacks a specialized national coordinating structure for biosafety in medical laboratories, and there is limited availability of advanced containment facilities such as BSL-4 laboratories.

Kinshasa, the capital city, represents a critical hub for healthcare and biomedical research. Yet, publications assessing biosafety practices in local laboratories remain scarce [13]. Given the rising demand for disease diagnostics, coupled with the persistent threat of occupational hazards and weak biosafety systems, it is essential to evaluate the current state of biosafety practices in Kinshasa. This study was therefore undertaken to assess laboratory biosafety conditions, determine the prevalence of occupational exposures, and identify factors associated with increased risk among laboratory personnel.

Methodology

Study Design

This investigation was carried out as an analytical cross-sectional survey aimed at assessing biosafety practices in biomedical laboratories. The study combined both quantitative and qualitative approaches, including direct observation, semi-structured interviews, and structured questionnaires, to provide a comprehensive understanding of biosafety conditions and occupational exposures. The study period extended from 1st February to 30th May 2025.

Ethics

All study procedures were conducted in compliance with the ethical principles of the Helsinki Declaration. Approval was granted by the National Health Ethics Committee of the Democratic Republic of Congo (Ref: 620/CNES/BN/PMMF/2025, dated 20 January 2025). Written informed consent was obtained from all participants, with assurances of confidentiality and anonymity throughout data collection and reporting.

Setting

The study was conducted in 51 biomedical laboratories distributed across the four administrative districts of Kinshasa. These facilities included both central and peripheral laboratories, and represented a mixture of public sector, faith-based, and privately owned laboratories, ensuring wide contextual representation of laboratory practices within the city.

Participants

Participants consisted of laboratory staff working in the selected biomedical laboratories, including laboratory technicians, medical biologists, laboratory physicians, and general physicians. Eligibility criteria included at least six months of professional experience and willingness to participate. Personnel with less than six months of service or those who declined consent were excluded. In total, 290 laboratory staff members participated, representing a balanced mix of demographic and professional categories.

Variables

Laboratory-related variables encompassed infrastructure and safety features such as workspace layout, security measures, signage, availability of biosafety manuals, waste management, sterilization facilities, fire safety equipment, audits, personal protective equipment (PPE), vaccination coverage, and biosafety training programs. Personnel-related variables included demographic characteristics (age, sex), education level, years of professional experience, biosafety training history, vaccination status, and history of occupational exposure to biological hazards. Outcome variables focused on biosafety quality scores and reported blood-borne pathogen exposures (BBPE).

Data Sources and Measurement

Data were collected through a triangulated approach. Direct observations by trained investigators documented laboratory facilities, infrastructure, and biosafety procedures. Semi-structured interviews with laboratory managers and staff provided qualitative insights into biosafety practices, while structured questionnaires captured individual knowledge, training, and experiences with biosafety and occupational exposure. A composite laboratory quality score was generated using 26 predefined criteria, coded dichotomously as “yes = 1” or “no = 0,” producing a scale from 0–26. Laboratories scoring ≥21 were classified as high quality, while those scoring ≤20 were categorized as low quality.

Bias

To minimize selection bias, laboratories were systematically chosen from all four districts, covering both central and peripheral levels. Observer bias was reduced through the use of standardized checklists and data collection forms. Recall bias in self-reported exposures was mitigated by cross-checking responses with laboratory records wherever available.

Study Size

The study assessed 51 laboratories and included 290 healthcare workers. This sample size was determined to provide adequate representation of both institutional and personnel factors across diverse laboratory settings in Kinshasa.

Quantitative Variables

Quantitative variables included age, years of experience, and laboratory quality scores. Categorical variables included gender, level of education, type of laboratory, training status, vaccination status, and occupational exposure history. These were analyzed using both descriptive and inferential statistics.

Statistical Methods

Data were first entered into Microsoft Excel (2010) and cleaned before being exported to IBM SPSS version 24 for analysis. Descriptive statistics were presented as means with standard deviations or medians with interquartile ranges for continuous variables, and as frequencies with percentages for categorical variables. Group comparisons were made using Student's t-test or Mann–Whitney U test for continuous data, and Pearson's chi-square or Fisher's exact test for categorical data. Logistic regression analyses were performed to determine independent predictors of occupational exposure to biological hazards, with adjusted odds ratios (aOR) and 95% confidence intervals (CI) reported. A p-value of less than 0.05 was considered statistically significant.

Results

Participants

A total of 290 laboratory staff members from 51 biomedical laboratories across the four administrative districts of Kinshasa participated in the study. All participants met the inclusion criteria of having at least six months of professional experience and providing informed consent. The mean age of respondents was 39.1 ± 10.2 years, with an age range of 19 to 70 years. The most represented age group was 30–39 years (34.5%). More than half of the participants were male (57.2%), and nearly all had attained higher or university-level education (98.3%).

Descriptive Data

In terms of professional background, 59.7% of participants were A1-level laboratory technicians, followed by medical biologists (30.7%), laboratory physicians (5.9%), and general physicians (2.1%). Work experience varied, with 27.2% reporting less than 5 years, 30.7% between 5 and 10 years, 15.2% between 11 and 15 years, and 26.9% more than 15 years. Regarding biosafety training, 55.5% of staff had received some form of training, although for 34.8% this occurred more than two years prior. Vaccination coverage and post-exposure prophylaxis policies were inconsistently reported, reflecting institutional variation.

Outcome Data

Laboratory quality assessment revealed that only 17 laboratories (33.3%) met the predefined quality standards, while the majority (66.7%) were categorized as low quality. Among the biosafety elements assessed, handwashing stations were the most widely available (98%), followed by safe sharps disposal, covered centrifuges, and chemical storage facilities (each >80%). Conversely, the least observed elements included the presence of a biosafety manual (19.6%), availability of first-aid kits (21.6%), operational alarm systems (21.6%), and vaccination of laboratory personnel (11.8%). Concerning occupational exposure, 139 participants (47.9%) reported a history of blood-borne pathogen exposure. Immediate responses varied: 48.6% washed with soap and water, 35.5% used bleach, while fewer than one in five sought medical consultation (18.8%) or testing (20.3%).

Main Results

The findings highlight significant gaps in biosafety practices and preparedness across Kinshasa laboratories. Older staff (≥40 years) and those with more than 15 years of professional experience were significantly more likely to report occupational blood exposures compared to younger or less experienced staff. Logistic regression analysis showed that age ≥30 years (aOR 1.85–2.81), professional experience >10 years (aOR 2.24–2.85), and lack of biosafety training (aOR 3.19; 95% CI: 2.27–5.96) were the strongest predictors of occupational exposure. While a majority of staff demonstrated relatively high educational qualifications, deficiencies in biosafety infrastructure, inadequate refresher training, and limited adherence to recommended post-exposure protocols collectively undermined laboratory safety. Overall, these results emphasize the urgent need for strengthened biosafety infrastructure, systematic training programs, and policy enforcement to reduce occupational risks in biomedical laboratories in Kinshasa.

Table 1: Characteristics of Biomedical Laboratories Surveyed in Kinshasa (n = 51)

Variables	Frequency	Percentage
Laboratory level		
Central	10	19.6
Peripheral	41	80.4
Ownership		
Public	34	66.7
Private	17	33.3
Type of laboratory		
Medical laboratory	48	94.1
Research laboratory	3	5.9

Table 2: Distribution of biosafety quality components across low- and high-quality laboratories in Kinshasa.

Variable	Non-quality laboratory (n=34)	Quality laboratory (n=17)	Total (n=51)
Handwashing station	33 (97.1)	17 (100.0)	50 (98.0)
Sharp waste disposal	26 (76.5)	17 (100.0)	43 (84.3)
Use of electric cords	26 (76.5)	17 (100.0)	43 (84.3)
Centrifuge cover	27 (79.4)	16 (94.1)	43 (84.3)
Chemical product storage	26 (76.5)	15 (88.2)	41 (80.4)
Separation of work areas	19 (55.9)	17 (100.0)	36 (70.6)
Biosafety training	20 (58.8)	15 (88.2)	35 (68.6)
Sample storage	14 (41.2)	16 (94.1)	30 (58.8)
Signage	12 (35.3)	16 (94.1)	28 (54.9)
Workspace free of clutter	10 (29.4)	17 (100.0)	27 (52.9)
Sterilization room	10 (29.4)	12 (70.6)	22 (43.1)
Maintained fire extinguisher	6 (17.6)	15 (88.2)	21 (41.2)
Presence of qualified quality auditor	11 (32.4)	10 (58.8)	21 (41.2)
Conduct of internal quality audit	10 (29.4)	11 (64.7)	21 (41.2)
Root cause analysis of non-conformities	8 (23.5)	13 (76.5)	21 (41.2)
Safety training	8 (23.5)	11 (64.7)	19 (37.3)
Audit evidence	7 (20.6)	9 (52.9)	16 (31.4)
Audit program	6 (17.6)	9 (52.9)	15 (29.4)
Eye-wash station	5 (14.7)	10 (58.8)	15 (29.4)
Alarm system	2 (5.9)	9 (52.9)	11 (21.6)
Liquid waste disposal	2 (5.9)	9 (52.9)	11 (21.6)
First-aid kit available at workstation	1 (2.9)	10 (58.8)	11 (21.6)
Safety manual	0 (0.0)	10 (58.8)	10 (19.6)
Microbiology safety cabinet	2 (5.9)	7 (41.2)	9 (17.6)
Staff vaccination	1 (2.9)	5 (29.4)	6 (11.8)

Table 3: Sociodemographic and Professional Characteristics of Laboratory Personnel (n = 290).

Variables	Frequency	Percentage
Age Groups		
– 19 to 29 years	57	19.7
– 30 to 39 years	100	34.5
– 40 to 49 years	84	29.0
– 50 to 59 years	37	12.8
– ≥ 60 years	12	4.1
Sex		
– Male	166	57.2
– Female	124	42.8
Education Level		
– Secondary	5	1.7
– Higher/University	285	98.3
Field of Training		
– Medical Biologist	89	30.7
– Laboratory Physician	17	5.9
– General Physician	6	2.1
– Laboratory Technician A1	173	59.7
– Laboratory Technician A2	5	1.7
Work experience		
– <5 years	79	27.2
– 5–10 years	89	30.7
– 11–15 years	44	15.2
– >15 years	78	26.9

Table 4: Biosafety Training Status and Timing Among Laboratory Personnel (n = 290)

Variables	n(%)
Biosafety Training	
– No	129 (44.5)
– Yes	161 (55.5)
Date of Last Training (n=161)	
– 6 months	30 (18.6)
– 1 year	38 (23.6)
– 2 years	37 (23.0)
– >2 years	56 (34.8)

Table 5: Actions Taken by Laboratory Personnel Following Occupational Blood Exposure (n = 139)

Action Taken	Frequency	Percentage
Wash with running water and soap	67	48.6
Wash with bleach	49	35.5
Wash with alcohol	8	5.8
Performed a test	28	20.3
Medical consultation	26	18.8

Table 6: Factors Associated with Occupational Blood Exposure Among Laboratory Personnel (n = 290)

Variable	No OBE (n=151)	OBE (n=139)	p-value
Age (years); Mean ± SD	37.3 ± 10.2	41.0 ± 9.9	0.002*
Age Groups			0.006*
– 19 to 29 years	39 (25.8)	18 (12.9)	
– 30 to 39 years	57 (37.7)	43 (30.9)	
– 40 to 49 years	36 (23.8)	48 (34.5)	
– 50 to 59 years	13 (8.6)	24 (17.3)	
– ≥ 60 years	6 (4.0)	6 (4.3)	
Sex			0.243
– Male	83(55.0)	83(59.7)	
– Female	68(45.0)	56(40.3)	
Education Level			0.461
– Secondary	3 (1.3)	3 (2.2)	
– Higher/University	149 (98.7)	136 (97.8)	
Field of Training			0.310
– Medical Biologist	95 (62.9)	78 (56.1)	
– Laboratory Physician	42 (27.8)	47 (33.8)	
– General Physician	7 (4.6)	10 (7.2)	
– Laboratory Technician A1	5 (3.3)	1 (0.7)	
– Laboratory Technician A2	2 (1.3)	3 (2.2)	
Work experience			0.008*
– <5 years	49 (32.5)	30 (21.6)	
– 5–10 years	52 (34.4)	37 (26.6)	
– 11–15 years	21 (13.9)	23 (16.5)	
– >15 years	29 (19.2)	49 (35.3)	
Biosafety Training			0.001*
– No	42 (27.8)	87 (62.6)	
– Yes	109 (72.2)	52 (37.4)	

*$p < 0.05$, $p < 0.01$ indicate statistically significant differences.

Table 7: Independent Predictors of Occupational Blood Exposure Identified by Logistic Regression Analysis.

Variable	Univariate analysis		Multivariate analysis	
	p-value	OR (95%CI)	p-value	aOR (95%CI)
Sex				
– Male		1		1
– Female	0.415	1.21(0.76-1.94)	0.726	1.09(0.67-1.78)
Age Group				
– 19 to 29 years		1		1
– 30 to 39 years	0.016	1.64(1.24-3.24)	0.027*	1.85(1.31-3.22)
– ≥30 years	0.001*	3.07(1.59-5.92)	0.007*	2.81(1.49-5.68)
Education level				
–University		1		1
–Secondary	0.589	1.64(0.27-2.98)	0.559	1.77(0.26-3.92)
Work experience				
– <5 years		1		1
–5–10 years	0.635	1.16(0.63-2.16)	0.926	0.96(0.48-1.93)
–11–15 years	0.013*	1.79(1.48-3.77)	0.022*	2.24(1.51-2.99)
– >15 years	0.002*	2.76(1.48-5.26)	0.003*	2.85(1.72-4.71)
Training biosafety				
–Yes				1
–No	0.008*	3.09(1.63-5.61)	0.009*	3.19(2.27-5.96)

*p < 0.05 indicate statistically significant differences.

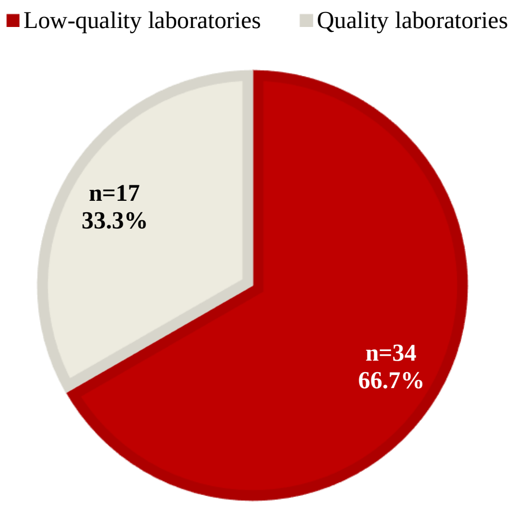

Figure 1: Proportion of biomedical laboratories in Kinshasa meeting defined biosafety quality standards (n = 51).

Discussion

This study provides one of the few systematic assessments of biosafety practices in biomedical laboratories in Kinshasa. Our findings reveal significant deficiencies in infrastructure, training, and occupational safety, with only one-third of laboratories meeting established biosafety quality criteria. These results align with reports from other African countries, where inadequate biosafety practices remain a persistent challenge due to resource constraints, limited training, and weak regulatory enforcement [13–15].

The predominance of public laboratories (66.7%) observed in this study is consistent with findings from Kinshasa and other African contexts, such as Togo, where public facilities represented the majority of laboratory infrastructure [13,14]. While public laboratories expand access to services, they may face greater budgetary and operational constraints, limiting their ability to invest in biosafety measures.

Only 33.3% of laboratories in our study achieved the defined quality standards, highlighting critical gaps in safety measures such as sterilization facilities, fire preparedness, biosafety manuals, and vaccination of staff. Similar findings were reported in Burkina Faso, where fewer than 10% of laboratories complied with WHO biosafety standards [15]. These observations emphasize the urgent need for policy interventions to strengthen laboratory safety systems.

The study population was relatively young, with more than half of participants under 40 years of age, and highly educated, with nearly all holding university degrees. This suggests that human resources are available to implement biosafety practices, but systemic barriers such as limited training opportunities and inadequate supervision undermine their effectiveness. Indeed, although 55.5% of staff reported receiving biosafety training, over one-third had not received training in the past two years. This gap in continuous education is problematic, given evidence that regular refresher training improves compliance and reduces occupational risk [14,16].

Occupational exposure to blood was reported by 47.9% of participants, reflecting a substantial burden of risk. However, post-exposure practices were inconsistent and often inappropriate, with many staff using bleach or alcohol instead of following recommended protocols. According to WHO guidelines, proper management of occupational blood exposure should include immediate washing with soap and water, prompt medical consultation, diagnostic testing, and post-exposure prophylaxis where indicated. Yet, in our study, fewer than one in five participants sought medical evaluation [5]. This inadequate response increases the risk of transmission of blood-borne pathogens such as HIV, HBV, and HCV.

Logistic regression analysis identified age, professional experience, and lack of biosafety training as independent predictors of occupational exposure. Older staff and those with more years of service were at higher risk, likely due to cumulative exposure and, in some cases, reduced vigilance in routine tasks. These findings are consistent with studies in Ethiopia, Saudi Arabia, and Egypt, which reported higher exposure risks among experienced staff and those lacking training [17–20]. Lack of biosafety training was the strongest predictor in our study, tripling the risk of exposure, reinforcing the importance of systematic, updated, and mandatory training programs.

Our findings highlight structural, organizational, and behavioral deficiencies that undermine laboratory biosafety in Kinshasa. While human resources are adequately trained academically, weak biosafety systems and insufficient institutional support compromise both staff safety and the reliability of laboratory services.

Limitations

This study has several limitations that should be considered when interpreting the findings. First, its cross-sectional design prevents the establishment of causal relationships between biosafety practices and occupational exposures. Second, reliance on self-reported data may have introduced recall bias or underreporting of exposure incidents. Third, the study was restricted to laboratories within Kinshasa, limiting the generalizability of results to other regions of the Democratic Republic of Congo. Finally, while the mixed-methods approach strengthened data validity, qualitative exploration of structural barriers was limited, and future studies incorporating longitudinal designs and broader geographic coverage are recommended.

Conclusion

This study demonstrates that biosafety practices in biomedical laboratories in Kinshasa remain largely inadequate, with only one-third of laboratories meeting quality standards and nearly half of staff reporting occupational exposure to blood. Deficiencies in infrastructure, limited refresher training, and poor adherence to post-exposure protocols contribute to elevated risks, particularly among older and more experienced personnel. Strengthening laboratory biosafety therefore requires urgent investment in infrastructure, implementation of mandatory and continuous training programs, regular quality audits, and enforcement of standardized post-exposure management to safeguard healthcare workers and improve the reliability of laboratory services.

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