

Risk assessment of biological exposure in health workers of West Walenrang Health Center

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ABSTRACT

Introduction: Biological hazards remain a primary occupational health concern for healthcare workers, particularly in primary healthcare centers where frequent contact with patients, biological specimens, and infectious medical waste occurs. Limited infrastructure and suboptimal occupational safety and health (OSH) implementation further increase the risk of biological exposure among healthcare workers at the primary care level.

Research Methodology: This study employed a mixed-methods, sequential explanatory design at the West Walenrang Health Center. Quantitative data were collected through field observations and structured questionnaires administered to all 48 healthcare workers, using total sampling. Biological risks were identified and assessed using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method with a risk matrix. Qualitative data were obtained through in-depth interviews with selected healthcare workers from high-risk units to explore contextual factors influencing biological risk exposure and control practices.

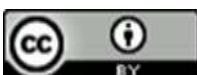
Results: The findings indicated that biological hazards were the most dominant occupational risks. High-risk exposures were primarily associated with contact with blood and body fluids, needlestick and sharps injuries, and improper management of infectious medical waste, each scoring 12 on the HIRADC risk matrix. Moderate risks were identified in relation to direct contact with infectious patients and aerosol-generating medical procedures. Existing control measures were largely limited to personal protective equipment and administrative controls, while higher-level controls, such as engineering interventions, were insufficient. Qualitative findings supported these results, highlighting inconsistent use of protective equipment, inadequate waste management, limited training, and weak supervision.

Conclusion: Biological risk management at the primary healthcare level remains inadequate. It is recommended that comprehensive HIRADC implementation, improved medical waste management systems, regular occupational safety training, and the integration of higher-level control measures be strengthened to reduce biological exposure among healthcare workers effectively.

Keywords: Biological risk; HIRADC; Occupational safety and health; Primary healthcare; Risk assessment.



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INTRODUCTION

Healthcare facilities are inherently high-risk work environments due to continuous interactions between healthcare workers, patients, biological specimens, and infectious waste. Primary healthcare centers play a particularly critical role in disease prevention and treatment at the community level (Hong *et al.*, 2025). Yet, they often operate with limited infrastructure, high patient volumes, and constrained occupational safety resources. These conditions significantly increase the likelihood of biological exposure among healthcare workers, including exposure to pathogenic microorganisms such as viruses, bacteria, fungi, and parasites (Abidin *et al.*, 2024). Globally, the World Health Organization has consistently reported that healthcare workers face a substantially higher risk of occupational exposure to blood-borne and airborne pathogens, including hepatitis B, hepatitis C, HIV, and tuberculosis, especially in settings where invasive procedures and specimen handling are routine. Such exposures not only threaten worker safety but also compromise service quality and patient safety (Andrup, Hadrup and Mette Madsen, 2025).

In Indonesia, biological hazards remain a major contributor to occupational diseases in the healthcare sector, particularly at the primary care level (Serli, Mayasari and Yulis, 2025). Health Center serve diverse patient populations, including individuals with communicable diseases, within confined clinical spaces that frequently lack optimal ventilation and engineering controls (Arhouné *et al.*, 2025). As a result, healthcare workers are regularly exposed to blood, body fluids, droplets, aerosols, and infectious medical waste during daily clinical activities (Baubhom, Buckley and Norkaew, 2025). Reports from the Ministry of Health indicate that needlestick injuries and unsafe waste handling remain recurrent incidents, reflecting persistent weaknesses in occupational safety and health (OSH) implementation. Despite regulatory frameworks mandating OSH practices in healthcare facilities, biological risk control at the Health Center level is often limited to basic personal protective equipment (PPE) use, with minimal integration of systematic risk assessment and higher-level control measures (Ashar, Santi and Naria, 2025).

A critical gap in current practice lies in the incomplete application of structured risk management approaches for biological hazards. Although national regulations require healthcare facilities to conduct hazard identification, risk assessment, and determine control (HIRADC), many primary health centers have not fully developed or operationalized comprehensive HIRADC documentation (Babigumira *et al.*, 2025). Consequently, biological risks are not consistently identified, quantified, or prioritized, leading to reactive rather than preventive safety measures (Fang *et al.*, 2025). Previous studies have largely focused on hospital settings, leaving primary healthcare facilities underrepresented in empirical evidence related to biological risk profiling and control effectiveness (Cai *et al.*, 2025). This gap is particularly concerning given that Puskesmas often function as the first point of contact for patients with infectious diseases, thereby placing frontline workers at sustained risk (Dang *et al.*, 2026).

Furthermore, existing research has tended to emphasize single aspects of biological exposure, such as needlestick injuries or PPE compliance, without integrating environmental, organizational, and behavioral determinants within a unified risk assessment framework (Kirman *et al.*, 2025). Limited attention has been paid to how deficiencies in waste management systems, training coverage, supervision, and engineering controls collectively amplify biological risk. In many cases, administrative controls and PPE are implemented inconsistently, while higher-order controls such as elimination, substitution, and engineering interventions receive insufficient prioritization. This imbalance underscores a structural weakness in OSH management systems at the primary care level.

Against this backdrop, there is a pressing need for context-specific, systematic biological risk assessments that reflect the operational realities of Puskesmas. This study addresses this gap by applying the HIRADC method to comprehensively identify biological hazards, assess their risk levels, and evaluate existing control measures at Puskesmas Walenrang Barat. By integrating quantitative risk scoring with qualitative insights from healthcare workers, the study offers a more holistic understanding of biological exposure pathways and control challenges. The novelty of this research lies in its focused application of HIRADC within a primary healthcare setting in a rural Indonesian context, where empirical evidence remains limited. The findings are expected to provide practical evidence to strengthen OSH management, improve infection prevention strategies, and inform policy-oriented interventions tailored to primary healthcare facilities.

RESEARCH METHODOLOGY

Study Design

This study employed a mixed-methods, sequential explanatory design to comprehensively assess biological risks among healthcare workers at Puskesmas Walenrang Barat. The research was conducted in two consecutive phases. The first phase consisted of a quantitative assessment using the Hazard Identification, Risk Assessment, and Determining Control (HIRADC) method to systematically identify biological hazards and determine their risk levels. The second phase involved a qualitative inquiry through in-depth interviews to explore contextual factors, perceptions, and implementation challenges related to biological risk control, thereby strengthening and explaining the quantitative findings.

Study Setting and Population

The study was conducted at Puskesmas Walenrang Barat, a primary healthcare center that provides outpatient, emergency, maternal, laboratory, and public health services. The study population comprised all healthcare workers employed at the facility, including physicians, nurses, midwives, laboratory personnel, pharmacists, and public health officers. Given the relatively small population, total sampling was used in the quantitative phase, including all 48 eligible healthcare workers. For the qualitative phase, purposive sampling was used to select key informants from service units with high biological exposure, including emergency care, outpatient services, and the laboratory.

Quantitative Data Collection and Risk Assessment

Quantitative data were collected through direct field observation and structured questionnaires. Observations focused on identifying sources of biological hazards during routine clinical activities, including patient contact, invasive procedures, specimen handling, and medical waste management. The structured questionnaire was used to collect information on respondents' characteristics and biological exposure experiences. The HIRADC method was applied to assess biological risks through three systematic steps: hazard identification, risk analysis, and determination of control measures. Identified biological hazards included exposure to blood and body fluids, infectious patients, aerosols generated during medical procedures, and infectious medical waste. Risk analysis was conducted using a risk matrix that combined the likelihood of exposure and the severity of potential health impacts. Each hazard was assigned a risk score, which was then categorized into low, moderate, or high-risk levels. Existing control measures were documented and classified according to the hierarchy of controls, including elimination, substitution, engineering controls, administrative controls, and personal protective equipment (PPE).

Qualitative Data Collection

The qualitative phase involved in-depth, semi-structured interviews with selected healthcare workers. The interview guide explored experiences of biological exposure, compliance with standard precautions, availability and use of PPE, waste management practices, training and supervision related to occupational safety and health, and barriers to effective biological risk control. Interviews were conducted in a private setting, audio-recorded with participant consent, and transcribed verbatim to ensure data accuracy.

Data Analysis

Quantitative data were analyzed using descriptive statistics to summarize respondent characteristics, types of biological hazards, and the distribution of risk levels based on HIRADC scores. The results were presented in tables and narrative descriptions. Qualitative data were analyzed using thematic analysis, which involved transcription, initial coding, categorization of codes into themes, and interpretation of patterns related to biological risk exposure and control practices. Quantitative and qualitative findings were integrated during the interpretation stage to provide a comprehensive understanding of biological risk conditions at the study site.

Ethical Considerations

Ethical approval was obtained from the relevant institutional ethics committee before data collection. All participants received clear information regarding the study objectives and procedures and provided informed consent before participation. Confidentiality and anonymity of respondents were strictly maintained throughout the research process, and data were used solely for academic and research purposes.

RESULT

This study assessed biological risks among healthcare workers at Puskesmas Walenrang Barat using the HIRADC method. The results are presented in two main sections: respondent characteristics and biological risk assessment outcomes. Quantitative findings from hazard identification and risk assessment were complemented by qualitative insights to support the interpretation of risk levels and control measures. Overall, biological hazards were identified as the most dominant occupational risks, with several activities classified as high-risk, indicating the need for strengthened occupational safety and health interventions.

Table 1. Characteristics of Respondents (n = 48)

Variable	Category	Frequency (n)	Percentage (%)
Sex	Male	9	18.8
	Female	39	81.3
Age (years)	20–30	9	18.8
	31–40	30	62.5
	41–50	8	16.7
	51–65	1	2.1
	Others	1	2.1
Occupation	Physician	1	2.1
	Midwife	19	39.6
	Nurse	16	33.3
	Pharmacy staff	2	4.2
	Public health officer	4	8.3
	Laboratory staff	3	6.3
	Others	3	6.3
Length of employment	1–10 years	32	66.7
	11–20 years	15	31.3
	21–30 years	1	2.1

The dominance of midwives and nurses, and the high proportion of staff in productive age groups, indicate frequent and direct involvement in patient care activities, increasing the likelihood of biological exposure during routine services.

Table 2. Biological Risk Assessment Based on HIRADC Method

Identified Hazard	Potential Impact	Existing Control Measures	Likelihood (L)	Severity (S)	Risk Score (R)	Risk Level
Direct contact with infectious patients (TB, hepatitis, HIV)	Occupational infection	PPE use, standard precautions	3	3	9	Moderate
Exposure to blood and body fluids	Blood-borne infections	PPE, administrative controls	4	3	12	High
Needlestick and sharps injuries	Transmission of infectious diseases	PPE, safety box availability	4	3	12	High
Improper medical waste management	Environmental contamination, infection	Administrative controls	4	3	12	High
Aerosol generation during medical procedures	Airborne infection	Mask use, ventilation	3	3	9	Moderate

The HIRADC analysis showed that exposure to blood and body fluids, needlestick injuries, and improper medical waste management were classified as high-risk hazards (risk score = 12). These findings indicate that current control measures are insufficient to reduce biological risk and require reinforcement through higher-level controls.

Table 3. Distribution of Biological Risk Levels

Risk Level	Frequency (n)	Percentage (%)
Low	0	0.0
Moderate	2	40.0
High	3	60.0

Most identified biological hazards fell into the high-risk category, emphasizing that healthcare workers at Puskesmas Walenrang Barat face significant occupational exposure to infectious agents during routine service activities.

Qualitative Findings Supporting Risk Assessment

Qualitative interviews revealed several contributing factors to high biological risk levels, including inconsistent use of PPE, limited availability of safety equipment, inadequate waste segregation practices, and insufficient training related to infection prevention and occupational safety. Informants reported that workload pressure and limited supervision further reduced compliance with standard precautions. These qualitative findings corroborate the quantitative risk assessment results, demonstrating that biological risk exposure is influenced not only by hazard presence but also by organizational and behavioral factors within the primary healthcare setting.

The qualitative findings revealed several factors that supported the biological risk assessment results. Healthcare workers reported frequent exposure to blood, body fluids, and infectious patients during routine service activities, particularly in outpatient, emergency, and

laboratory units. Inconsistent use of personal protective equipment was commonly attributed to limited availability, time constraints, and high workload.

Participants also highlighted shortcomings in medical waste management, including improper segregation of infectious waste and unsafe disposal of sharps, which increased the risk of needlestick injuries. In addition, informants noted limited occupational safety and health training, weak supervision, and the absence of comprehensive HIRADC documentation, resulting in variable compliance with standard precautions. Overall, these qualitative insights confirm that biological risks are influenced not only by clinical exposure but also by organizational and managerial factors within the primary healthcare setting.

DISCUSSION

This study demonstrates that biological hazards constitute the most significant occupational risks faced by healthcare workers at Puskesmas Walenrang Barat, as evidenced by the HIRADC assessment that categorized most identified biological hazards as high risk. These findings highlight the persistent vulnerability of healthcare workers in primary healthcare settings, where frequent patient contact, invasive procedures, and the handling of medical waste are integral to daily service delivery. The dominance of biological risk observed in this study aligns with global evidence indicating that healthcare workers remain disproportionately exposed to infectious agents compared to other occupational groups, particularly in resource-limited primary care facilities (Li *et al.*, 2024).

Exposure to blood and body fluids emerged as one of the highest-risk hazards, reflecting the routine nature of clinical activities such as injections, wound care, laboratory specimen handling, and emergency procedures (Li *et al.*, 2025). The high-risk scores associated with these exposures indicate that existing control measures have not sufficiently reduced the likelihood or severity of infection (Liu *et al.*, 2026). This finding is consistent with previous studies reporting that blood-borne pathogens, including hepatitis B, hepatitis C, and HIV, remain major occupational threats in healthcare environments where compliance with standard precautions is inconsistent. In the context of Health Center, where service demand is high and staffing levels may be limited, the probability of exposure increases further due to time pressure and workload intensity.

Needlestick and sharps injuries were also identified as high-risk hazards, underscoring ongoing deficiencies in sharps management and safe injection practices (Suprpto and Kadang, 2026). Despite the availability of safety boxes, qualitative findings revealed that improper disposal practices and unsafe handling behaviors persist. This result supports earlier research indicating that needlestick injuries remain a leading cause of occupational infection among healthcare workers, particularly in primary healthcare facilities, where training and supervision may be less structured than in hospital settings. The persistence of this risk suggests that safety equipment alone is insufficient without consistent enforcement, training, and monitoring (Y. Liu *et al.*, 2025).

Improper management of infectious medical waste was another critical contributor to elevated biological risk levels (Z. Liu *et al.*, 2025). Inadequate segregation, temporary storage, and disposal of medical waste increase the likelihood of environmental contamination and secondary exposure among healthcare workers and support staff (Noh, Lee and Kyung, 2025). These findings reflect systemic challenges in primary care waste management, including limited infrastructure, insufficient resources, and weak administrative oversight. Similar patterns have been reported in other studies, which emphasize that ineffective waste management significantly amplifies biological risk and undermines infection prevention efforts (Osimitz and Droegge, 2025).

Although personal protective equipment and administrative controls were in place, the HIRADC analysis revealed that higher-level control measures such as engineering controls, elimination, and substitution were largely absent (Portilha-Cunha *et al.*, 2025). This imbalance in the hierarchy of controls represents a structural weakness in occupational safety and health

management at Puskesmas Walenrang Barat. Engineering controls, including adequate ventilation, physical barriers, and designated waste handling areas, play a crucial role in reducing exposure to airborne and contact-transmitted pathogens. Their limited implementation suggests that biological risk reduction strategies remain reactive rather than preventive (Rehman *et al.*, 2026).

Qualitative findings further illuminated organizational and behavioral factors that contribute to sustained biological risk. Healthcare workers reported limited access to regular occupational safety and health training, inconsistent supervision, and the absence of comprehensive HIRADC documentation. These gaps reduce awareness of potential hazards and weaken compliance with standard precautions (Salari *et al.*, 2025). The lack of formalized risk documentation also limits management's ability to prioritize and address high-risk activities systematically. This finding underscores the importance of integrating risk assessment tools such as HIRADC into routine management practices to support evidence-based decision-making (Salles *et al.*, 2025).

The predominance of nurses and midwives among respondents may also influence the overall risk profile observed in this study. These professional groups are directly involved in patient care activities that carry a high potential for biological exposure (Sellaro, Perneti and Oddone, 2024). Their central role in service delivery at the primary healthcare level underscores the need for targeted interventions focused on frontline workers who bear the greatest risk burden (Abedin *et al.*, 2025). Ensuring adequate staffing, workload distribution, and access to protective resources is essential to mitigating biological hazards in this context (Yin *et al.*, 2025).

Overall, the findings of this study reinforce the notion that biological risk in primary healthcare facilities is multifactorial, arising from the interaction of clinical exposure, environmental conditions, organizational practices, and behavioral factors. Addressing these risks requires a comprehensive approach that extends beyond PPE provision to include strengthened waste management systems, improved training and supervision, and the integration of higher-level controls within the hierarchy of occupational safety and health. By applying the HIRADC framework in a primary healthcare setting, this study provides context-specific evidence that can inform more effective biological risk management strategies and contribute to protecting healthcare workers and improving the quality-of-service delivery.

CONCLUSION

This study concludes that biological hazards represent the highest occupational risk for healthcare workers at Puskesmas Walenrang Barat. The HIRADC assessment identified high-risk exposures primarily related to contact with blood and body fluids, needlestick and sharps injuries, and inadequate management of infectious medical waste. Existing control measures were largely limited to personal protective equipment and administrative actions, which have not been sufficient to reduce biological risk significantly. These findings indicate that biological risk management at the primary healthcare level remains suboptimal and requires systematic improvement.

It is recommended that Puskesmas Walenrang Barat strengthen occupational safety and health management by fully integrating the HIRADC framework into routine operations. Priority actions should include improving medical waste segregation and disposal systems, ensuring consistent availability and proper use of personal protective equipment, and conducting regular occupational safety and infection prevention training for healthcare workers. In addition, adopting higher-level control measures, such as engineering controls and strengthened supervision, is essential to effectively reduce biological risk and protect healthcare workers in primary healthcare settings.

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Conflict of Interest

There are no potential conflicts of interest relevant to this article.

Ethical Approval

This study was conducted in accordance with ethical standards for research involving human participants. All participants were informed of the study objectives and procedures, and written informed consent was obtained before participation. Confidentiality and anonymity of respondents were strictly maintained throughout the research process.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to ethical considerations and the need to protect participant confidentiality.

Authors' Contributions

Nur Al Mughnia contributed to the study conception, design, data analysis, and manuscript drafting. Lusia Salmawatia and Vidyantoa were responsible for data collection and preliminary analysis. Musjaya M Gulia contributed to data interpretation and methodological review. Sumarnia reviewed the manuscript critically and approved the final version. All authors read and approved the final manuscript.

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