Integrating Robotics and AI into Workplace Biorisk Management

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ABSTRACT

Work-related illnesses and injuries affect over 2.3 million people annually. Biological hazards are often underreported and poorly managed. Biorisk Management (BRM) aims to assess and reduce these risks. Emerging technologies like AI and robotics offer new tools for predictive analytics, real-time monitoring, and hazard detection. This chapter explores how AI can enhance BRM, particularly in under-resourced settings, to improve workplace health and safety. This chapter explores how AI can support effective, adaptive, and ethical BRM systems, especially in under-resourced settings.

INTRODUCTION

Work-related injuries and illnesses remain a major global health concern, affecting approximately 2.3 million people annually and resulting in over 6,000 deaths every day. In total, around 340 million occupational accidents occur each year, impacting nearly 160 million workers. These statistics highlight the urgent need for comprehensive strategies to manage workplace hazards and promote worker health and safety. Occupational health is a critical pillar of public health, dedicated to improving the physical, mental, and social well-being of workers across all occupations (Shah & Mishra, 2024). To ensure safe and productive work environments, risks from various hazard categories, including physical, chemical, ergonomic, psychosocial, and particularly biological, must be effectively managed. This chapter focuses on the management of biological risks in occupational settings and the transformative role of artificial intelligence (AI) and robotics.

Biorisks refer to potential exposures to biological agents such as bacteria, viruses, fungi, parasites, their by-products, and other organic matter that may adversely affect workers, visitors, and surrounding communities (Singh & Matuka, 2013, Juan José, María Renée, Tesifón et al., 2022, ILO, 2023). Managing these hazards requires a structured, evidence-based approach known as Biorisk Management (BRM), a process that encompasses risk identification, assessment, control, and mitigation (Fernando & Antonio, 2013, Burzoni, Duquenne, Mater et al., 2020). Failure to adequately manage biorisks can lead to devastating consequences for organisations, including operational disruption, reputational damage, and, in extreme cases, as seen during the COVID-19 pandemic, widespread economic and societal collapse. Despite the existence of global frameworks such as ISO 45001:2018, BRM remains under-prioritised, especially in high-risk or emerging sectors like biotechnology, waste management, and the green economy (Anna, 2022, Rittick, Sachin, Mandar Bhalchandra et al., 2023).

Persistent challenges, such as the underreporting of biohazard-related incidents, limited awareness among workers, and inconsistent implementation of control strategies like personal protective equipment (PPE) usage, immunisation, and post-exposure prophylaxis, continue to undermine BRM efforts. Additionally, the psychosocial impact of biological threats is often overlooked in occupational health discourse. While legal instruments such as the EU Directive 2000/54/EC provide infection control guidance, effective implementation requires a holistic, systems-level approach that integrates prevention, mental health support, compliance monitoring, and workforce education (Lemos, Gaspar & Lima, 2022).

Risk analysis is central to BRM, enabling the systematic assessment and mitigation of risks from local incidents to global outbreaks. As the world becomes increasingly interconnected, due to climate change, globalisation, and technological convergence, the complexity and urgency of managing biorisks have intensified. In this evolving landscape, AI and robotics offer powerful tools for forecasting, probabilistic modelling, early detection, and real-time hazard response (Tessandra, Jon & Seth, 2022).

AI is particularly valuable in scenarios where data is large, complex, or incomplete. It complements traditional approaches such as Bayesian inference by offering dynamic models for risk prediction and decision-making. Digital tools, including simulation software, spatial layout planning, and real-time statistics, can be enhanced with AI to assess both physical and psychological risks that are often difficult to quantify (Westhoven & Herrmann, 2023). As biological threats grow in complexity and frequency, organisations must shift from reactive to adaptive risk management systems that identify and respond to threats in real time (Janssen, Cski, Lindgren et al., 2022, Leyma, 2024). In this context, AI and robotics emerge as transformative enablers for BRM, offering scalable and responsive solutions that can improve workplace safety across industries (Janaína, Vanessa Borba de, Frederico Soares et al., 2024, John & Paul, 2024).

AI technologies have been increasingly employed for epidemic management, particularly in under-resourced and rural environments (Ejike Innocent, Ebube Victor, Mojeed Dayo et al., 2024). Although still in the early stages of integration into Occupational Health and Safety (OHS), AI has demonstrated significant potential for hazard detection, predictive analytics, and emergency preparedness. These systems use algorithms to mimic human intelligence for tasks such as decision-making, language processing, visual recognition, and real-time monitoring. In high-risk environments, such as mining, energy production, and construction, AI is already being used to automate safety inspections and identify psychosocial risks like fatigue and burnout (El-Helaly, 2024). When paired with sensor technologies that measure air quality, noise levels, humidity, and temperature, AI enables advanced environmental monitoring and health surveillance (Nathavitharana, Mishra, Sullivan et al., 2022, Lee, Miao, Chau et al., 2023). These systems also synthesise diverse data sources, including health records, biometric data, and mobility patterns, to support outbreak forecasting and early intervention (Wenqiang, Chenrui, Meng et al., 2023, Ejike Innocent, Ebube Victor, Mojeed Dayo et al., 2024).

Advanced analytical techniques such as neural networks, decision trees, Bayesian models, and multivariate regression are increasingly utilised in occupational safety applications (Ria, WeiHuang, Anélie et al., 2023). These are enabled through various machine learning (ML) approaches, supervised, unsupervised, semi-supervised, and reinforcement learning, which allow organisations to extract actionable insights from occupational health data (Table 1) (Goodfellow, Pouget-Abadie, Mirza et al., 2020). The

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