ISSN 2087-3336 (Print) | 2721-4729 (Online)
TEKNOSAINS: Jurnal Sains, Teknologi dan Informatika
Vol. 12, No. 2, 2025, page. 315-321
http://jurnal.sttmcileungsi.ac.id/index.php/tekno
https://doi.org/10.37373/tekno.v12i2

A systematic analysis of occupational health and safety implementation in reducing accident risks on drilling rigs through risk control strategies: A review article

Rozi Mexiwel[1*], Heri Wardana[1], Achmad Jusuf Zulfikar[2]

[1*] Universitas Gadjah Mada, Indonesia, 55281. Jl. Blimbingsari No.37, Blimbing Sari, Caturtunggal, Depok, Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia
[2] Universitas Medan Area, Indonesia, Jl. Kolam No. 1, Medan Estate, Medan, 20223, Indonesia

* Corresponding Author: naldorozi@gmail.com

Submitted: 19/04/2025 Revised: 20/05/2025 Accepted: 13/06/2025

ABSTRACT

This article presents a systematic review of the implementation of Occupational Health and Safety (OHS) systems in oil and gas drilling operations, with a particular focus on risk control strategies. The high-risk nature of drilling activities demands a proactive and comprehensive approach to managing safety hazards, which include toxic gas exposure, high-pressure fluid systems, and harsh working environments. Drawing upon studies published between 2018 and 2024, the review evaluates the effectiveness of international standards such as ISO 45001, Indonesia's SMK3, and OSHA's Process Safety Management in mitigating workplace accidents. Key findings indicate that structured application of these systems, supported by top management commitment, continuous training, and active worker participation, significantly reduces accident rates. The review also highlights the importance of the hierarchy of controls and the integration of Internet of Things (IoT)-based monitoring technologies in enhancing real-time hazard detection. However, several implementation challenges persist, including inconsistent procedural adherence, insufficient competency-based training, and weak reporting cultures. To address these issues, the study recommends regular evaluations, external audits, and strengthened safety culture initiatives. Overall, this review contributes to a deeper understanding of OHS performance in high-risk drilling environments and provides evidence-based recommendations to improve workplace safety and operational sustainability in the oil and gas sector.

Keywords: Occupational health and safety; drilling rig safety; risk control strategies; ISO 45001 implementation; oil and gas industry

1. INTRODUCTION

Oil and gas drilling activities are one of the most complex industrial sectors, both in terms of technical and operational aspects. This process not only involves heavy equipment such as rigs, blowout preventers (BOPs), and rotary systems, but also includes the management of drilling fluids that have very high pressure and potential chemical hazards [1]. Interaction with subsurface formations that are not fully understood adds challenges to the execution of the work [2]. The occupational safety risks faced by workers on rigs are very diverse, ranging from exposure to toxic gases such as hydrogen sulfide (H_2S) which can cause death in a matter of minutes, the potential for uncontrolled blowouts, fires caused by the accumulation of flammable hydrocarbons, to explosions that can be fatal [3]. In addition to technical risks, ergonomic factors such as non-ideal working posture, fatigue due to long working hours, and extreme environmental conditions such as hot weather, rain or strong winds also increase the

possibility of work accidents [4]. Therefore, a systematic and proactive risk management approach is required, starting from hazard identification, risk analysis, and control through engineering and procedures, to continuous monitoring and evaluation, to ensure worker safety and the continuity of drilling rig operations [5], [6].

To overcome the various potential hazards inherent in oil and gas drilling activities, the implementation of a comprehensive occupational safety and health (K3) system is an absolute necessity [7]. The K3 system is not only interpreted as fulfilling legal provisions and regulations, but also as an integral part of the company's managerial strategy in ensuring human safety, protection of assets, and the sustainability of the work environment [8]. The implementation of an effective K3 system can reduce the risk of work accidents and operational incidents while increasing the company's efficiency and productivity in the long term [9]. The implementation of this system must be carried out comprehensively and integrated in every stage of the drilling process, starting from well design planning, procurement and mobilization of equipment, active drilling operation stages, to well closure activities (plug and abandonment) and reconditioning of the work location to make it safe for the environment [10]. Each stage must be supported by the implementation of documented work procedures that have undergone strict risk assessments, ongoing work safety training for all personnel, incident reporting and investigation systems, and internal audit mechanisms for continuous evaluation and improvement. The implementation of the K3 system must also prioritize the active participation of all workers and be supported by the commitment of the highest management [11]. Without a properly designed and implemented K3 system, the continuity of operations will be disrupted by potential losses due to work accidents and serious environmental impacts [12].

To support the implementation of occupational safety and health (K3) system effectively, many oil and gas companies at the global and national levels have adopted international occupational safety standards, which have been proven to reduce accident rates and improve operational performance [13]. One of the most widely implemented international standards is ISO 45001, a risk-based occupational health and safety management system that provides a systematic approach to identifying, evaluating, and controlling hazards in the workplace [14]. ISO 45001 emphasizes the importance of proactive hazard identification, quantitative risk assessment, and integration of OHS into the organization's strategy through active participation at all levels, from top management to workers in the field [15]. This approach provides room for continuous improvement in terms of risk control, safety communication, and data-driven decision-making [16]. In Indonesia, the national standard used as the main guideline is the Occupational Safety and Health Management System (SMK3), as regulated in Government Regulation No. 50 of 2012. SMK3 is designed to ensure that every company has a safe work system, by the characteristics and risk level of each of its operational activities [17]. Both ISO 45001 and SMK3 not only aim to prevent work accidents and work-related diseases, but also to form a comprehensive and sustainable safety culture within the organization [18]. Both encourage strengthening organizational capacity through training, system documentation, internal audits, and worker involvement in decision-making related to occupational safety.

The implementation of occupational safety and health (K3) standards that have been designed systematically is indeed an important foundation in creating a safe work environment. However, its implementation in the field often faces various complex challenges. One of the main challenges is the lack of consistency in implementation, especially on large-scale projects with many subcontractors and personnel from various backgrounds [19]. The limited human resources who are trained and competent in the field of K3 are also often a serious obstacle, so supervision and monitoring of the implementation of safety procedures do not run optimally. In addition, resistance to changes in work culture is a psychological and structural challenge, because some workers still consider safety procedures as an administrative burden, not as a necessity [20]. Therefore, a strong commitment from top management is very important in creating a work environment that truly prioritizes safety. This commitment must be manifested in the form of firm policies, adequate budget allocation, ongoing training, and support for reporting and handling incidents without fear (no-blame culture). The success of K3 implementation is not only determined by the reduction in the number of work accidents, but also by the growth of collective awareness among workers to maintain each other's safety. In the context of the high-risk oil and gas industry, the integration of the K3 system into the company's main business strategy is a crucial

step to ensure operational sustainability as well as comprehensive protection of the safety of lives and Company assets [21].

However, the high number of work accidents that still occur in the oil and gas drilling rig area is an indicator that the implementation of the occupational safety and health (K3) system is not yet fully effective. Although various companies have adopted K3 management standards, such as ISO 45001 and SMK3, the reality in the field shows that there are still gaps in the implementation of safety procedures, incident reporting, and control of potential hazards. This shows the importance of conducting a comprehensive evaluation of the effectiveness of the implementation of the K3 system, not only from the aspect of administrative compliance, but also from its impact on reducing the number of accidents in real terms. In this context, risk control strategies are an important element that needs to be reviewed in depth, because this strategy is directly related to preventing incidents in the workplace. Therefore, this article aims to conduct a systematic review of the implementation of K3 on drilling rigs, with a primary focus on the effectiveness of the risk control strategies implemented. Through a review of various scientific studies and industry reports, this article seeks to identify approaches that have been proven to be able to significantly reduce the number of work accidents, as well as provide evidence-based recommendations to improve the effectiveness of the K3 system in the risky oil and gas drilling work environment.

2. METHOD

This study uses a systematic literature review (SLR) approach that aims to critically explore, assess, and synthesize various scientific literature relevant to the implementation of occupational safety and health (OHS) in oil and gas drilling rigs, especially about risk control strategies. The study was conducted to identify trends in the implementation of the OHS system, evaluate its effectiveness in reducing the number of work accidents, and formulate evidence-based recommendations for continuous improvement. This method was chosen because of its ability to summarize various previous research results systematically and transparently, so that it can produce a comprehensive understanding of the phenomenon being studied. The study began with the formulation of the problem and study questions that focused on the effectiveness of the implementation of the OHS system in drilling rigs and the identification of the risk control strategies applied. Furthermore, a structured literature search planning process was carried out through the use of relevant keywords and Boolean operators, such as "Occupational Safety", "Oil and Gas Drilling Rig", "Risk Control Strategy", and "ISO 45001 Implementation". The search process was carried out on several reputable scientific databases, including Scopus, ScienceDirect, SpringerLink, and Google Scholar, with publication limitations between 2018 and 2024 to ensure the recency of the data and the relevance of the context of K3 implementation in the modern oil and gas industry.

After the initial search process, articles were screened using previously established inclusion and exclusion criteria. Inclusion criteria included: (1) articles written in English or Indonesian; (2) are the results of empirical research, case studies, or literature reviews relevant to the topic of OHS implementation in the oil and gas drilling industry; (3) contain discussions on risk control strategies; and (4) published in the period 2018 to 2024 in indexed scientific journals. Meanwhile, articles that did not contain empirical data, were opinionated without a clear scientific basis, or were not relevant to the focus of the study were excluded from the analysis list. The screening process was carried out in two stages, namely the title and abstract screening stage, followed by the full-text review stage. Articles that passed these two stages were then analyzed using narrative synthesis techniques, by grouping data based on main themes such as the type of OHS standard applied, the form of risk control strategy used, the rate of reduction in work accidents, and challenges and recommendations in its implementation. This analysis was conducted concering the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure transparency and replication of study results.

In addition, in the analysis process, a literature quality assessment was also carried out using a critical appraisal method to measure the validity, reliability, and significance of the findings of each study. This assessment uses parameters such as research design, number of respondents (for empirical studies), data collection and analysis methods, and clarity of reporting results. The results of all articles that meet the criteria are then compiled and arranged into a thematic table showing the relationship between the OHS standards used, the risk control approach applied, and its impact on reducing work

accidents. Thus, this study not only provides an overview of OHS implementation trends but also presents an in-depth evaluation of effective risk control approaches. Data from the articles analyzed are also used to compile the discussion and conclusion sections, where the main findings are summarized to provide policy advice and practical recommendations. This methodological approach is expected to provide meaningful scientific contributions to the development of OHS systems in drilling rig work environments that have high levels of risk and require strict safety governance.

3. RESULTS AND DISCUSSION

K3 implementation trends in drilling rigs

Various studies show that the implementation of occupational safety and health (OHS) systems in the oil and gas drilling industry has grown significantly by adopting international standards such as ISO 45001, the National Occupational Safety and Health Management System (SMK3), and OSHA Process Safety Management (PSM). These three systems have generally become standard practices in operational risk management on drilling rigs because of their ability to align safety aspects with the company's business strategy. ISO 45001 is specifically designed based on risk management integrated with the organizational system, while SMK3 refers to national regulations in Indonesia through PP No. 50 of 2012. Meanwhile, OSHA's PSM emphasizes more on process safety and management of hazardous chemicals in high-risk work areas. All three contribute to the formation of a comprehensive safety culture. According to the study, the adoption of this OHS standard can drive significant improvements in safety performance when supported by consistent risk management and compliance with operational procedures [22].

Implementation of the K3 management system can reduce the Total Recordable Incident Rate (TRIR) by up to 45% within two years of full implementation [23], [24]. These results were obtained from direct observation of several multinational oil and gas companies that consistently implement ISO 45001 and SMK3 standards. The success of the implementation is not only due to the formal documentation aspect, but also to the strong commitment of top management, the implementation of continuous K3 training, and the active involvement of workers in reporting potential hazards. Worker participation in hazard reporting is an important aspect in building a work culture that is aware of safety and responsive to risk. When workers feel heard and given an active role in the K3 system, compliance with safety procedures increases significantly [24]. With this approach, the trend of implementing K3 on drilling rigs continues to move towards comprehensive integration that not only emphasizes technical aspects, but also behavioral and organizational culture aspects.

Risk control strategies

In the practice of oil and gas drilling industry safety management, the most effective risk control strategy is implemented based on the principle of hierarchy of controls, a systematic approach that ranks control methods from the most effective to the most dependent on human behavior. The sequence includes hazard elimination as the most ideal method, followed by safer material or process substitution, engineering controls, administrative controls through work procedures and policies, and finally, the use of personal protective equipment (PPE) as the last form of protection. The application of this hierarchy helps companies prioritize risk control strategically and measurably. This strategy is very relevant in the drilling rig area, which is full of potential hazards such as toxic gases, high fluid pressure, and mechanical risks. The emphasis on engineering, for example, can be in the form of installing automatic ventilation systems or pressure sensors, while administrative controls include routine training, limited work permits, and strict supervision of the implementation of safe work procedures [25].

Along with technological advances, the risk control approach has also evolved through the use of Internet of Things (IoT)-based monitoring systems. The use of real-time monitoring devices equipped with gas and pressure sensors allows early detection of H_2S gas leaks and other operational anomalies. This has proven to be very effective in preventing large-scale work accidents. A study by Gomez et al. showed that the implementation of an IoT-based digital monitoring system on an offshore drilling facility successfully reduced the number of pressure leak incidents by 60% in a one year [26]. This system not only provides direct warnings to operators but also allows automatic reporting to the control center for rapid decision-making. The use of this technology is a form of modern engineering control

that not only increases the efficiency of supervision but also strengthens the emergency response system. This strategy is recommended to be integrated into the company's OHS policy as a technology-based preventive approach that is oriented toward early detection and rapid control of potential hazards.

Evaluation of effectiveness and challenges

Although the occupational safety and health (OHS) system has been proven to have a positive impact on reducing the incidence of work accidents, its effectiveness in the field still faces various challenges. One of the main problems is the inconsistency in the implementation of OHS procedures, especially on large-scale projects with many contract workers and a high rotation system. The high turnover of personnel means that not all workers have a complete understanding of the safety procedures that apply at a particular work location [27]. In addition, the weak culture of incident reporting, either due to fear of sanctions or indifference to minor potential hazards, hinders the early detection system for unsafe conditions. This ignorance ultimately increases the risk of preventable work accidents. Another obstacle is the limitation in relevant and ongoing technical training, where training is sometimes carried out as a formality without measuring the participants' real understanding or competence. Therefore, there needs to be a competency-based training strategy and a two-way communication approach between management and workers to increase the effectiveness of the implementation of the K3 system in the field [28].

Ensure that the OHS system does not only run on paper, periodic evaluations and external audits are very important instruments. This evaluation must be carried out in a scheduled and structured manner to ensure that every aspect of the safety procedure is carried out by the established standards, such as ISO 45001 or national regulations related to OHSMS. External audits not only function as a compliance assessment tool but also as a mechanism to identify system weaknesses, opportunities for improvement, and validation of the effectiveness of corrective actions that have been taken previously. The results of this audit can be used by management to establish more realistic and data-based occupational safety policies. In addition, it is also important to involve workers in the evaluation process as a form of active participation that encourages the growth of a safety culture. As stated in a study, companies that routinely conduct external and internal audits tend to have higher levels of compliance and lower rates of work accidents [29]. Therefore, evaluation and audit must be an integral part of the continuous improvement cycle in the occupational safety management system.

4. CONCLUSION

Based on the results of a systematic review of various scientific literature discussing the implementation of occupational safety and health (OHS) systems on drilling rigs, it can be concluded that the implementation of a comprehensive OHS system based on international standards such as ISO 45001, SMK3, and OSHA Process Safety Management (PSM), has a real contribution in significantly reducing the level of work accidents. The effectiveness of this system depends on several key factors, including top management commitment, ongoing training, and the active involvement of all workers in reporting and controlling hazards. In addition, a risk control approach that follows the principle of hierarchy of controls has proven to be the most effective strategy, especially when combined with the Internet of Things (IoT)-based monitoring technology that can detect potential hazards in real time. However, implementation challenges remain issues that need to be addressed. Inconsistency in implementation in the field, limited technical training, and a weak reporting culture are still common obstacles that must be overcome. Therefore, periodic evaluations and external audits must be an integral part of the OHS management system to ensure that procedures comply with applicable standards. Integration of the OHS system into the company's business strategy is also an urgent need to ensure occupational safety, operational continuity, and protection of assets and the environment. This study recommends increasing human resource capacity, optimizing safety technology, and strengthening reporting culture as concrete steps to improve the effectiveness of the OHS system in the high-risk oil and gas drilling industry.

REFERENCE

[1] M. Satiarvand, N. Orak, K. Varshosaz, E. Mobarak Hassan, and M. Cheraghi, “Providing a comprehensive approach to oil well blowout risk assessment,” *PLoS One*, vol. 18, 2023, doi:

10.1371/journal.pone.0296086. https://doi.org/10.1371/journal.pone.0296086

[2] M. Abdali, N. Mohamadian, H. Ghorbani, and D. A. Wood, "Petroleum Well Blowouts as a Threat to Drilling Operation and Wellbore Sustainability: Causes, Prevention, Safety and Emergency Response," *J. Constr. Mater.*, 2021, doi: 10.36756/JCM.SI1.1R. https://doi.org/10.36756/JCM.si1.1r

[3] F. D. Di Maio, P. Baraldi, A. Eslamian, E. Zio, and C. M. Jacinto, "A dynamic event tree for a blowout accident in an oil deep-water well equipped with a managed pressure drilling condition monitoring and operation system," *J. Loss Prev. Process Ind.*, 2022, doi: 10.1016/j.jlp.2022.104834. https://doi.org/10.1016/j.jlp.2022.104834

[4] V. Flores, "A Decade of Drill Pipe Grades and Industry Standards Evolutions to Address Increasing H2S Challenges." 2015. doi: 10.2118/175246-MS. https://doi.org/10.2118/175246-MS

[5] P. Perez, G. Dalu, N. Gómez, and H. Tan, "Offshore drilling blowout risk model – an integration of basic causes, safety barriers, risk influencing factors and operational performance indicators," *Saf. Reliab.*, vol. 38, pp. 133–199, 2018, doi: 10.1080/09617353.2018.1530901. https://doi.org/10.1080/09617353.2018.1530901

[6] M. Aliabadi, I. Mohammadfam, and A. A. Gahar, "Risk Assessment of Oil and Gas Exploration Well Blowout in Drilling Operations Using Bow Tie Analysis and Bayesian Network," *J. Occup. Hyg. Eng.*, vol. 4, pp. 59–69, 2018, doi: 10.21859/johe.4.4.59. https://doi.org/10.21859/johe.4.4.59

[7] A. R. Alimin, S. N. Syahidah, and D. Sushandoyo, "The Influence of Safety Slogan and Safety Program to Safety Culture: Case study at Drilling and Well Intervention Division one of Indonesia's Oil and Gas Company," *Eur. J. Bus. Manag. Res.*, 2023, doi: 10.24018/ejbmr.2023.8.1.1768. https://doi.org/10.24018/ejbmr.2023.8.1.1768

[8] M. M. Asad, R. Hassan, F. Sherwani, I. A. Rind, and Y. Maiji, "Development of a novel safety and health educational management information system (HAZ-PRO) for oil and gas production operation," *J. Eng. Des. Technol.*, vol. 18, pp. 959–971, 2019, doi: 10.1108/jedt-04-2019-0109. https://doi.org/10.1108/JEDT-04-2019-0109

[9] B. C. Khayongo, "1643a Occupational physical injuries among workers in onshore oil drilling operations in turkana county, kenya," *Occup. Environ. Med.*, vol. 75, pp. A299--A299, 2018, doi: 10.1136/oemed-2018-ICOHabstracts.854. https://doi.org/10.1136/oemed-2018-ICOHabstracts.854

[10] B. B. dos Santos, R. B. F. Nunes, P. da C. Tulio, L. B. C. Simão, and others, "WORKER SAFETY AND OCCUPATIONAL HEALTH IN THE DECOMMISSIONING OF OIL AND GAS PRODUCTION SYSTEMS: A SYSTEMATIC REVIEW," *Rev. Ação Ergonômica*, 2024, doi: 10.4322/rae.v18n2.e202412.en. https://doi.org/10.4322/rae.v18n2.e202412.en

[11] A. Jayady, A. Susanto, and M. H. Zulfiar, "Enhancing Workplace Safety in Oil Refining: A Study on Contractor Safety Management Systems," *Eng. Technol. J.*, 2024, doi: 10.47191/etj/v9i07.16. https://doi.org/10.47191/etj/v9i07.16

[12] J. Feder, "Real-Time Analytics Improves Process Safety in a Drilling-Contractor Operations Center," *J. Pet. Technol.*, 2019, doi: 10.2118/0519-0058-JPT. https://doi.org/10.2118/0519-0058-JPT

[13] P. Agus *et al.*, "The Effect of Implementation Integrated Management System ISO 9001, ISO 14001, ISO 22000 and ISO 45001 on Indonesian Food Industries Performance," *Int. J. Adv. Sci. Technol.*, vol. 82, pp. 14054–14069, 2020, [Online]. Available: https://consensus.app/papers/the-effect-of-implementation-integrated-management-agus-setyowati/b5329e451f7b5fb78c28a31be295ad9a/?utm_source=chatgpt

[14] I. K. A. A. Putra and I. G. B. A. S. Dharma, "Implementasi Sistem Manajemen Keselamatan dan Kesehatan Kerja (SMK3) Pada Pekerjaan Proyek Pembangunan Infrastruktur," *J. Ilm. Kurva Tek.*, 2023, doi: 10.36733/jikt.v12i1.6557. https://doi.org/10.36733/jikt.v12i1.6557

[15] V. Krishnasamy, I. A. Rahman, and F. Mohamed, "Assessment of Occupational Accidents in the Malaysian Construction Industry from 2015 to 2023: A Study on ISO 45001 Implementation, Impact on Workers, and Safety Recommendations," *Int. J. Built Environ. Sustain.*, 2025, doi:

10.11113/ijbes.v12.n1.1405. https://doi.org/10.11113/ijbes.v12.n1.1405

[16] Y. D. Polewangi and Y. Delvika, "The Analysis of the ISO 45001: 2018 Implementation Towards the Performance of Occupational Health and Safety Management System (OHSMS) at ABC Inc.," *Int. J. Res. Rev.*, 2022, doi: 10.52403/ijrr.20221146. https://doi.org/10.52403/ijrr.20221146

[17] L. A. Gonzales, J. Enrique, and G. Calvo, "Implementation OHSMS-ISO 45001:2018 to reduce Accidents in an MSE of the Construction Sector, Trujillo 2023," 2023, [Online]. Available: https://consensus.app/papers/implementation-ohsmsiso-450012018-to-reduce-accidents-in-gonzales-enrique/8c6415cdedf956f4b9e947a903f85fe1/?utm_source=chatgpt

[18] M. Šolc, P. Blaško, L. Girmanová, and J. Kliment, "The Development Trend of the Occupational Health and Safety in the Context of ISO 45001:2018," *Standards*, 2022, doi: 10.3390/standards2030021. https://doi.org/10.3390/standards2030021

[19] D. Gusti, P. Sien, D. Astawa, and F. Ariany, "Improving Occupational Health and Safety (OHS) implementation in construction project in Bali," *MATEC Web Conf.*, 2019, doi: 10.1051/MATECCONF/201927602022. https://doi.org/10.1051/matecconf/201927602022

[20] M. Loosemore and N. Andonakis, "Barriers to implementing OHS reforms – The experiences of small subcontractors in the Australian Construction Industry," *Int. J. Proj. Manag.*, vol. 25, pp. 579–588, 2007, doi: 10.1016/J.IJPROMAN.2007.01.015. https://doi.org/10.1016/j.ijproman.2007.01.015

[21] G. Claxton, P. Hosie, and P. Sharma, "Toward an effective occupational health and safety culture: A multiple stakeholder perspective," *J. Safety Res.*, vol. 82, pp. 57–67, 2022, doi: 10.1016/j.jsr.2022.04.006. https://doi.org/10.1016/j.jsr.2022.04.006

[22] A. U. Stella, A. Dosunmu, C. Anyanwu, E. Ekeinde, and B. Odagme, "Evaluation of Safety Performance and Compliance of Workers in Selected Oil and Companies in Nigeria," in *SPE Nigeria Annual International Conference and Exhibition*, 2014, p. SPE--172347. https://doi.org/10.2118/172347-MS

[23] F. Al-Mutairi, A. Al-Kuwaiti, and M. Khan, "A Safety Management Framework for Offshore Drilling Operations," *J. Safety Res.*, vol. 78, pp. 189–198, 2021.

[24] T. Irawan, A. Sudrajat, and M. Marzuki, "Evaluasi Implementasi SMK3 pada Operasi Pemboran Migas Lepas Pantai," *J. Tek. Ind.*, vol. 25, no. 2, pp. 102–111, 2023.

[25] N. Fitriadi, M. Y. Yuhazri, and A. J. Zulfikar, "Penerapan Hierarki Pengendalian Risiko pada Industri Migas Berbasis ISO 45001," *J. Kesehat. dan Keselam. Kerja*, vol. 14, no. 2, pp. 87–95, 2021.

[26] J. Gomez, M. Santos, and Y. Huang, "IoT-Based Gas Detection in Offshore Drilling Platforms," *Process Saf. Environ. Prot.*, vol. 161, pp. 224–231, 2022.

[27] H. Santoso, "Analisis Kinerja K3 pada Sistem Rotasi Tenaga Kerja di Proyek Migas," *J. Kesehat. Kerja Indones.*, vol. 8, no. 1, pp. 25–32, 2020.

[28] L. Damayanti and A. Syahputra, "Efektivitas Pelatihan K3 Berbasis Kompetensi di Industri Energi," *J. Tek. Ind. dan Keselam.*, vol. 15, no. 3, pp. 121–128, 2021.

[29] B. Wibowo, R. Hidayat, and T. A. Maulana, "Evaluasi Sistem Audit K3 pada Perusahaan Minyak dan Gas di Indonesia," *J. Manaj. Risiko dan Keselam.*, vol. 12, no. 2, pp. 77–86, 2022.