Global Journal of Advanced
Research and Reviews
Journal homepage: https://gsjournals.com/gjarr/
ISSN: 2980-423X (Online)

(REVIEW ARTICLE)

Check for updates

Improving worker safety in confined space entry and hot work operations: Best practices for high-risk industries

Oluwaseyi Ayotunde Akano [1,*], Enobong Hanson [2], Chukwuebuka Nwakile [2] and Andrew Emuobosa Esiri [3]

[1] *Chevron Nigeria Limited, Nigeria.*
[2] *Independent Researcher, Nigeria.*
[3] *Independent Researcher, Houston Texas, USA.*

Global Journal of Advanced Research and Reviews, 2024, 02(02), 031–039

Publication history: Received 03 September 2024; revised on 16 October 2024; accepted on 19 October 2024

Article DOI: https://doi.org/10.58175/gjarr.2024.2.2.0056

Abstract

This paper explores best practices for improving worker safety in confined space entry and hot work operations within high-risk industries, such as oil and gas, manufacturing, and construction. Confined spaces present significant dangers due to limited access, poor ventilation, and the potential presence of toxic gases, while hot work carries the risk of fire, explosions, and harmful fumes. The paper examines the current regulatory frameworks, including OSHA and international standards, and the challenges industries face in achieving compliance. Key case studies highlight the consequences of non-compliance and the benefits of adhering to safety protocols. The paper also outlines best practices, including thorough risk assessments, regular training programs, the use of advanced safety technologies, and emergency preparedness measures. Ultimately, this research underscores the importance of strict safety adherence to prevent accidents and protect workers in hazardous environments.

Keywords: Confined space safety; Hot work hazards; OSHA regulations; Risk assessment; Worker safety; Emergency preparedness

1 Introduction

A confined space is any area large enough for a worker to enter, has limited entry or exit points, and is not designed for continuous occupancy. Common examples include tanks, vessels, silos, and underground vaults. What makes confined spaces particularly dangerous is that they often have poor ventilation, which can lead to the accumulation of toxic gases, a lack of oxygen, or the risk of engulfment. Workers operating in these environments face the threat of asphyxiation, poisoning, and other life-threatening conditions (J. Selman, Spickett, Jansz, & Mullins, 2019). On the other hand, hot work refers to any work involving open flames, sparks, or heat that could ignite flammable materials. Welding, cutting, and brazing are typical examples of hot work. These operations present substantial fire and explosion hazards, particularly in environments with flammable gases or liquids. Hot work also exposes workers to burns, harmful fumes, and excessive heat, which can result in immediate and long-term health issues (Wang, 2023).

The relevance of confined spaces and hot work to hazardous environments cannot be overstated. These types of environments are common in high-risk industries like oil refineries, chemical plants, shipyards, and construction sites. Workers in these sectors often have to perform tasks that put them in confined or combustible spaces, where a single mistake or oversight can lead to catastrophic consequences. The combination of limited mobility, difficult working conditions, and the presence of hazardous materials underscores the need for stringent safety measures (Groysman, 2024).

* Corresponding author: Oluwaseyi Ayotunde Akano

Worker safety is a priority in any industry, but it is especially critical in high-risk industries where the potential for accidents is elevated. The importance of safeguarding workers who perform confined space entry and hot work cannot be overstated. Accidents in these environments are not only life-threatening but can also cause significant financial losses and legal liabilities for companies. In addition to the immediate impact on workers and their families, industrial accidents can tarnish an organization's reputation and disrupt production. Therefore, developing and implementing effective safety measures to mitigate the risks associated with confined space and hot work operations is essential (Domínguez, Guadian, Lona, & Mares, 2023).

Confined space entry and hot work accidents often occur due to inadequate training, improper use of personal protective equipment (PPE), or failure to identify and mitigate hazards. In confined spaces, the primary risks include oxygen deficiency, exposure to hazardous substances, and physical hazards like entrapment or falling objects. In hot work environments, the risks are primarily related to fire, explosions, and burns. Despite existing regulations and safety standards, accidents continue to occur, often because of lapses in safety protocols or lack of awareness (Song & Awolusi, 2020).

For high-risk industries, a robust safety culture that prioritizes worker training, hazard identification, and emergency preparedness is essential. Worker safety should be seen as a compliance issue and a moral and operational imperative. Employers must take proactive steps to prevent accidents, from designing workspaces to providing appropriate safety gear and training. Ensuring that workers understand the hazards they face and are equipped to deal with them is critical to reducing the incidence of accidents (Derdowski & Mathisen, 2023).

The aim of this paper is to explore and develop best practices that can reduce worker injuries and accidents in confined space entry and hot work environments. These environments are known for their high-risk nature, and the consequences of failing to implement effective safety measures can be severe. The paper will examine the current regulatory framework, explore the main hazards associated with confined space entry and hot work, and suggest best practices for managing these risks. By addressing these key issues, the paper aims to contribute to the broader goal of improving safety standards in high-risk industries.

Specifically, the paper will focus on risk assessment and hazard identification as the foundation of any safety strategy. A thorough risk assessment helps identify the specific dangers associated with each job, allowing employers to implement appropriate control measures. The importance of regular worker training and competency certification will also be discussed, as well-trained workers are better equipped to handle the challenges posed by confined spaces and hot work. Furthermore, the role of advanced safety equipment, such as gas detectors, personal protective equipment (PPE), and remote monitoring technologies, will be explored as critical tools in mitigating risk. Finally, the paper will outline the importance of robust emergency preparedness plans to ensure that workers can be safely evacuated or rescued in an accident.

2 Risk Factors in Confined Space Entry and Hot Work

2.1 Confined Spaces: Key Hazards

Confined spaces are work areas that are not designed for continuous human occupancy and typically have limited access points, making it difficult for workers to enter and exit safely. One of the most significant hazards associated with confined spaces is poor ventilation. These spaces often have limited airflow, which can lead to the buildup of toxic gases or a lack of oxygen. In an oxygen-deficient atmosphere, workers can suffer from asphyxiation, which can occur within minutes if they are not properly equipped with respiratory protection or air supply systems (Pupulidy, 2020).

Toxic gases, such as hydrogen sulfide, methane, and carbon monoxide, pose another major risk in confined spaces. These gases can accumulate without detection, especially in areas like tanks, sewers, or pipelines. Hydrogen sulfide, for instance, is a colorless gas that is highly toxic and can cause unconsciousness and death at high concentrations. Carbon monoxide, produced by incomplete combustion processes, is also a silent killer, as it is odorless and can displace oxygen in the blood, leading to suffocation (Namour, 2022).

In addition to atmospheric hazards, confined spaces may present physical dangers such as engulfment, where workers can be trapped or buried by materials like sand, grain, or liquids. Entrapment due to equipment failure or structural collapse is another risk, as confined spaces often have restricted access, which can delay rescue operations in emergencies. Workers in confined spaces risk falling from heights, as these areas may include vertical shafts, elevated platforms, or unstable surfaces (J. Selman et al., 2019).

Given the unique challenges of confined spaces, it is crucial for employers to conduct thorough risk assessments before allowing workers to enter. Hazard identification and control measures, such as continuous atmospheric monitoring and the use of ventilation systems, are essential to prevent accidents. Additionally, proper training and the implementation of a confined space entry permit system ensure that only qualified personnel enter these hazardous environments, equipped with the necessary tools and safety gear (J. S. Selman, 2019).

2.2 Hot Work: Risks of Fire, Explosions, and Harmful Fumes

Hot work refers to activities that involve open flames, sparks, or high temperatures, such as welding, cutting, and grinding. These operations are widely used in industrial settings but are associated with several significant risks, the most common being fire and explosions. Hot work often occurs in environments with flammable materials, gases, or vapors. Even a small spark can ignite these substances, leading to devastating consequences (Wang, 2023).

One of the primary risks during hot work is the accidental ignition of flammable gases or liquids. For example, hot work near storage tanks or pipelines can trigger explosions in oil and gas refineries if combustible vapors are present. The heat generated by welding or cutting can also cause flammable surfaces to ignite, particularly in areas where combustible dust or materials like insulation are prevalent (Berlinger, Skogen, Meijer, & Thomassen, 2019).

Workers engaged in hot work are also exposed to harmful fumes, which can have immediate and long-term health effects. Welding, for instance, generates metal fumes that contain hazardous substances such as lead, chromium, and cadmium. Inhalation of these fumes can lead to respiratory issues, metal fume fever, and, over time, even lung cancer. Without proper ventilation and respiratory protection, workers are at significant risk of chronic health problems caused by prolonged exposure to toxic substances (Danzi & Marmo, 2019).

Additionally, the physical risks of hot work include burns, eye damage, and heat stress. Welding arcs produce intense ultraviolet and infrared radiation, which can cause severe burns to unprotected skin and damage to the eyes. Suppose workers are not equipped with proper personal protective equipment (PPE), such as flame-resistant clothing, welding shields, and goggles. In that case, they face an increased likelihood of injury (Abikenova, Issamadiyeva, Kulmagambetova, Daumova, & Abdrakhmanova, 2023). The risk of fire and explosions in hot work operations is so great that many industries require strict permitting procedures before any hot work can be performed. The implementation of a hot work permit system ensures that all potential hazards are identified and mitigated before the work begins. This may involve isolating flammable materials, using fire-resistant barriers, or continuously monitoring the work area for the presence of flammable gases (Xu et al., 2022).

2.3 Industry Examples: Oil and Gas, Manufacturing, and Construction

Several high-risk industries are particularly vulnerable to the dangers of confined space entry and hot work. In the oil and gas industry, confined space entry is common during maintenance activities such as cleaning storage tanks, inspecting pipelines, or repairing offshore platforms. Workers are frequently exposed to hazardous substances like hydrogen sulfide, and poor ventilation in confined spaces can result in oxygen deficiency or toxic gas accumulation. In 2010, a tragic incident at a Texas oil refinery resulted in multiple fatalities when workers entered a confined space without proper atmospheric testing, leading to a deadly exposure to hydrogen sulfide gas (Naghavi, Mortazavi, & Hajizadeh, 2019).

Similarly, hot work is a regular part of refinery operations, especially during maintenance and construction activities. In 2005, a fire and explosion at the BP Texas City refinery, caused by sparks from hot work, resulted in 15 deaths and over 170 injuries. The incident highlighted the catastrophic potential of hot work accidents in environments where flammable gases are present (Abbasi, Khourdustan, Sayyadi, Jalilpour, & Alizadeh, 2020).

In the construction industry, workers often perform hot work such as welding and cutting in environments where flammable materials are abundant. In 2014, a fire at a Boston construction site was ignited by sparks from welding, which caused an explosion when they came into contact with nearby flammable materials. This incident, which resulted in multiple fatalities, underscored the need for strict safety measures and fire prevention protocols during hot work activities (Kim, 2022).

Manufacturing facilities also pose significant risks for confined space entry and hot work. In food processing plants, for example, workers may enter confined spaces like silos or grain bins to perform cleaning or maintenance tasks. The buildup of combustible dust in these areas can lead to explosions, while poor ventilation and the presence of mold or chemicals can cause respiratory issues. In 2008, an explosion at a sugar refinery in Georgia killed 14 workers and injured

dozens more. The explosion was caused by combustible sugar dust, which ignited during hot work operations, leading to a massive fire (Fishwick, 2019).

3 Current Regulatory Framework and Standards

3.1 OSHA and International Standards

The Occupational Safety and Health Administration (OSHA) is the primary regulatory body responsible for ensuring workplace safety in the United States. OSHA has developed specific regulations that govern confined space entry and hot work operations to reduce risks and prevent accidents. For confined space entry, OSHA's standard 29 CFR 1910.146 outlines the procedures and safety measures that must be followed. This standard defines what constitutes a permit-required confined space, which includes spaces with the potential for hazardous atmospheres, engulfment, or entrapment hazards (Rosner & Markowitz, 2020). OSHA mandates that employers assess confined spaces, identify hazards, and implement control measures such as atmospheric monitoring, ventilation, and emergency rescue procedures. Workers must be properly trained and authorized to enter confined spaces, and a permit system must be used to ensure that all safety requirements are met before entry (Tupper & Doyal, 2023).

For hot work, OSHA's regulation 29 CFR 1910.252, part of its broader welding, cutting, and brazing standards, outlines the safety requirements for performing operations that involve open flames or heat sources. The regulation requires employers to conduct hazard assessments, implement fire prevention measures, and use appropriate personal protective equipment (PPE). In addition, OSHA mandates the use of hot work permits in environments where flammable materials or gases are present to ensure that necessary precautions are taken (Spellman, 2023).

Internationally, the International Labour Organization (ILO) and other bodies such as the International Organization for Standardization (ISO) provide guidelines and standards for worker safety that align with OSHA's framework. For example, ISO 45001:2018, an international standard for occupational health and safety management systems, outlines best practices for identifying workplace hazards and implementing control measures. This standard encourages a proactive approach to risk management, including regular safety audits, worker training, and continuous improvement of safety protocols (Servais, 2024). In many countries, national safety regulations are modeled after these international frameworks, ensuring that the fundamental principles of worker protection are upheld globally. However, enforcement and compliance can vary depending on local contexts, resources, and the specific hazards associated with different industries (Gupta, Saksena, & Baris, 2019).

3.2 Compliance Challenges

Despite the comprehensive nature of OSHA and international standards, industries often face challenges in achieving full compliance. One common challenge is the complexity of the regulations themselves. Confined space entry and hot work standards require detailed assessments, permits, and specific control measures, which can be difficult to implement in environments with limited time and resources. Small and medium-sized enterprises (SMEs), in particular, may lack the infrastructure and expertise needed to fully comply with these standards, leading to gaps in safety practices (Dugolli, 2021).

Another challenge is the issue of training and competency. OSHA requires that workers involved in confined space entry and hot work operations receive adequate training to understand the risks and know how to mitigate them. However, many companies struggle to maintain consistent training programs, particularly when there is high employee turnover or when subcontractors are used for specialized tasks. Inadequate training can result in workers being unaware of critical hazards, such as the presence of toxic gases or the potential for fire and explosions.

Cost is also a significant factor that affects compliance. Implementing the necessary safety equipment, such as gas detectors, ventilation systems, and fire suppression tools, can be expensive, especially for smaller businesses. Some companies may attempt to cut corners on safety investments to save costs or to underestimate the risks. This can lead to non-compliance with OSHA standards and increase the likelihood of accidents (Kodur, Kumar, & Rafi, 2020).

Moreover, maintaining compliance in industries with dynamic and hazardous environments, such as oil and gas, construction, and manufacturing, can be particularly challenging. These industries often involve changing work conditions, multiple contractors, and high-pressure deadlines, which can lead to lapses in safety oversight. The complexity of managing confined spaces and hot work in such settings makes it difficult to ensure that all regulations are consistently followed (Agus Salim et al., 2023).

3.3 Industry Case Studies

Numerous case studies highlight the consequences of failing to comply with OSHA and international safety standards and the benefits of compliance in improving worker safety. One notable example of regulatory non-compliance leading to disaster is the accident at the DuPont chemical plant in La Porte, Texas 2014. Four workers were killed after being exposed to a deadly release of methyl mercaptan in a confined space. An investigation by OSHA revealed multiple safety violations, including failure to conduct proper atmospheric testing, inadequate training, and the absence of emergency rescue plans. The accident underscored the importance of adhering to confined space entry protocols and highlighted how non-compliance can have fatal consequences (Gonyora & Ventura-Medina, 2024).

Another significant case occurred in 2005 at the BP Texas City refinery, where a fire and explosion during hot work operations resulted in 15 deaths and over 170 injuries. The explosion was caused by the ignition of hydrocarbon vapors that had accumulated due to equipment malfunctions. An investigation revealed that BP failed to implement adequate safety measures, including hazard assessments and fire prevention protocols. This tragedy led to increased scrutiny of hot work practices in the oil and gas industry, and OSHA subsequently tightened its regulations regarding hot work permits and fire prevention (Abbasi et al., 2020).

On the other hand, compliance with safety regulations has been shown to significantly reduce the risk of accidents. One success story is the implementation of confined space safety programs in the water and wastewater treatment industry. These facilities often involve confined spaces such as tanks, manholes, and sewer systems, which pose significant hazards to workers. By following OSHA's permit-required confined space standard, many municipalities and companies have successfully reduced the number of confined space accidents. For example, Houston implemented a rigorous confined space safety program, which included regular training, atmospheric monitoring, and rescue equipment. As a result, the city saw a marked decrease in accidents and improved worker safety outcomes (Yazdi, Adesina, Korhan, & Nikfar, 2019).

Similarly, the construction industry has seen improvements in safety outcomes through compliance with hot work standards. Construction companies that enforce strict hot work permit systems, combined with fire prevention measures such as fire watches and continuous monitoring for flammable gases, have been able to reduce the incidence of fires and explosions on job sites. By adhering to OSHA's regulations, these companies protect their workers and avoid costly accidents and downtime (Maliha, Abu Aisheh, Tayeh, & Almalki, 2021).

4 Best Practices for Managing Confined Space Entry and Hot Work

4.1 Risk Assessment and Hazard Identification

One of the foundational elements of safety management for confined space entry and hot work operations is conducting thorough risk assessments. A risk assessment involves identifying, evaluating, and controlling potential hazards before any work begins. This process is particularly important in environments involving confined spaces and hot work, as the risks are often hidden or not immediately obvious.

For confined spaces, a comprehensive risk assessment should consider factors such as the presence of toxic gases, oxygen deficiency, physical hazards (e.g., the risk of engulfment), and the potential for fires or explosions. Before any worker is permitted to enter a confined space, atmospheric testing must be conducted to ensure that the air quality is safe. This testing should include measurements of oxygen levels, flammable gases, and toxic substances. If hazardous conditions are detected, control measures such as ventilation or the use of breathing apparatuses must be implemented (Stefana, Marciano, Cocca, Rossi, & Tomasoni, 2021).

In the case of hot work, risk assessments focus on identifying the potential sources of ignition and the presence of flammable materials. The risk of fire or explosions during hot work can be significantly reduced by ensuring that the work area is free of combustible materials and that fire prevention measures, such as fire-resistant barriers, are in place. Hazard identification also includes evaluating the proximity of hot work to other processes that may produce flammable gases or dust, which could ignite due to the heat or sparks generated by welding or cutting (Arifin, Ahmad, Abas, & Ali, 2023).

By conducting detailed risk assessments, employers can implement appropriate control measures to minimize hazards, such as isolating confined spaces, using atmospheric monitoring devices, and ensuring the availability of fire extinguishing equipment during hot work. Regular re-evaluations of the risks should be conducted, especially when there are changes to the work environment or new hazards are identified.

4.2 Training and Competency Programs

Another critical aspect of managing confined space entry and hot work operations is ensuring that workers are properly trained and competent to perform these tasks safely. Lack of adequate training is a common cause of accidents, as workers may not fully understand the risks or how to mitigate them. Training programs for confined space entry should cover a wide range of topics, including hazard identification, personal protective equipment (PPE) use, and emergency rescue procedures. Workers must be trained to recognize the signs of dangerous conditions, such as a sudden drop in oxygen levels or the presence of toxic gases, and know how to respond appropriately. Training should also focus on the proper use of equipment, such as gas detectors and ventilation systems, to ensure that workers can operate them correctly in confined spaces (J. Selman et al., 2019).

Similarly, hot work training programs must emphasize the risks of fire, explosions, and exposure to harmful fumes. Workers should be educated on the importance of conducting pre-work hazard assessments, using fire-resistant PPE, and adhering to hot work permit systems. In addition, training should include fire prevention techniques, such as maintaining fire watches during hot work and ensuring that flammable materials are removed or shielded from the work area (Adebayo, Ikevuje, Kwakye, & Emuobosa, 2024; Olajiga, Olu-lawal, Usman, & Ninduwezuor-Ehiobu, 2024).

Competency certification is essential for both confined space entry and hot work operations. Workers who have received proper training should undergo competency assessments to ensure that they can apply their knowledge in real-world scenarios. Regular refresher training is also necessary to keep workers up-to-date with the latest safety standards and best practices, particularly in industries where conditions and risks may evolve over time (Schroth, St Pierre, & Hody, 2023).

4.3 Use of Safety Equipment and Technologies

Advanced safety equipment and technologies play a vital role in managing the risks associated with confined space entry and hot work. Innovations in gas detection devices, personal protective equipment (PPE), and remote monitoring systems have greatly improved worker safety in hazardous environments. Gas detection devices are essential tools for confined space entry. These devices continuously monitor the air quality in confined spaces and alert workers to the presence of dangerous gases, such as hydrogen sulfide or methane, and oxygen-deficient atmospheres. Modern gas detectors are highly sensitive and can be configured to detect multiple gases simultaneously. In addition to handheld detectors, fixed gas monitoring systems can be installed in confined spaces to provide continuous, real-time data on atmospheric conditions (Adebayo, Ikevuje, Kwakye, & Esiri, 2024; Aderamo, Olisakwe, Adebayo, & Esiri, 2024a, 2024b).

Personal protective equipment (PPE) is another crucial component of worker safety. Workers may require specialized PPE for confined space entry, such as full-body harnesses, respirators, and helmets, depending on the hazards identified during the risk assessment. In hot work operations, flame-resistant clothing, welding helmets, gloves, and respiratory protection are critical for protecting workers from burns, sparks, and harmful fumes. Ensuring workers are equipped with the right PPE for their specific hazards is key to minimizing injuries (Samira, Weldegeorgise, Osundare, Ekpobimi, & Kandekere, 2024).

Remote monitoring technologies are increasingly being used in high-risk industries to enhance safety during confined space and hot work operations. Remote monitoring systems allow supervisors to track the conditions in confined spaces and monitor worker movements in real-time. These systems can provide early warnings in case of dangerous gas levels or if a worker becomes incapacitated, enabling faster responses to potential emergencies. Drones and robotic inspection tools are also being used in some industries to assess confined spaces or hazardous areas before workers enter, reducing the need for human exposure to dangerous environments (Lemos, Gaspar, & Lima, 2022).

4.4 Emergency Preparedness

Despite the best efforts to mitigate risks, accidents can still happen during confined space entry and hot work operations, making emergency preparedness an essential aspect of safety management. Proper emergency response plans must be in place to ensure that workers can be rescued or evacuated quickly and safely in the event of an accident. For confined spaces, one of the most critical aspects of emergency preparedness is having a well-developed rescue plan. Confined spaces often have limited access points, making it difficult to extract workers in an emergency. Rescue personnel should be trained and equipped to enter confined spaces safely, and all necessary rescue equipment, such as harnesses, ropes, and retrieval systems, should be readily available. Communication systems that allow workers inside the confined space to maintain contact with rescue teams or supervisors are vital for coordinating emergency responses (Aderamo, Olisakwe, Adebayo, & Esiri; Ekpobimi, Kandekere, & Fasanmade, 2024; Hamdan, Al-Salaymeh, AlHamad, Ikemba, & Ewim, 2023).

Hot work emergencies, such as fires or explosions, require rapid response measures. Fire extinguishing equipment, such as fire blankets and portable fire extinguishers, should be located near the hot work area, and workers should be trained in their use. Fire watches, personnel assigned to monitor the hot work site for signs of fire, play a crucial role in detecting potential hazards early and preventing fires from spreading (Awonuga et al., 2024).

Having clear emergency evacuation procedures is essential in confined space and hot work operations. Workers should be trained on how to respond in the event of an emergency, including knowing the location of exit points, rescue equipment, and first aid supplies. Regular emergency drills should be conducted to ensure that all personnel are familiar with the evacuation routes and rescue procedures, improving their ability to react quickly and calmly in real-life situations (Shiwakoti, Tay, & Stasinopoulos, 2020).

5 Conclusion and Recommendations

In confined space entry and hot work operations, worker safety is paramount due to the significant risks posed by hazardous environments. These high-risk activities are prevalent in industries such as oil and gas, construction, and manufacturing, where the combination of limited access, poor ventilation, exposure to toxic gases, and the use of open flames or heat sources increases the likelihood of accidents. The regulatory framework, led by OSHA and international standards, offers comprehensive guidelines to manage these risks, but compliance challenges, such as inadequate training, high costs, and complex work environments, continue to impede safety improvements in many industries.

Key findings from the analysis reveal that confined spaces are particularly dangerous due to their enclosed nature, the presence of harmful gases, and potential physical hazards like engulfment. Hot work operations carry the risk of fires, explosions, and exposure to harmful fumes. A lack of proper risk assessments, insufficient worker training, and failure to use appropriate safety equipment are major contributors to accidents in these operations. However, case studies demonstrate that compliance with regulations, such as conducting risk assessments, implementing hot work permit systems, and ensuring proper ventilation, can significantly reduce accidents and save lives.

Industries must proactively address the identified challenges to improve safety in confined space entry and hot work. The following recommendations offer actionable steps:

- Industries must prioritize continuous training programs that focus on hazard recognition, proper personal protective equipment (PPE) use, and emergency rescue procedures. Workers should be regularly assessed for competency, and training should be updated to reflect new safety standards and technologies.
- Compliance with OSHA and international safety standards is non-negotiable. Companies must ensure that all safety protocols, including risk assessments, permit systems, and safety equipment, are consistently implemented. Stricter enforcement of these regulations, including penalties for non-compliance, will push industries to prioritize safety.
- The use of gas detection devices, remote monitoring systems, and drones for pre-entry inspections can significantly improve safety outcomes. These technologies offer real-time data on atmospheric conditions and help monitor worker safety, reducing the need for direct human exposure to hazardous environments.

By addressing these areas, industries can foster safer working conditions, reduce accidents, and protect workers' lives in confined space entry and hot work operations.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Abbasi, S., Khourdustan, P., Sayyadi, R., Jalilpour, S., & Alizadeh, S. S. (2020). BP Texas refinery incident causes: a literature review. *International Journal of Occupational Hygiene, 12*(3), 256-270.

[2] Abikenova, S., Issamadiyeva, G., Kulmagambetova, E., Daumova, G., & Abdrakhmanova, N. (2023). Assessing Occupational Risk: A Classification of Harmful Factors in the Production Environment and Labor Process. *International Journal of Safety & Security Engineering, 13*(5).

[3] Adebayo, Y. A., Ikevuje, A. H., Kwakye, J. M., & Emuobosa, A. (2024). Corporate social responsibility in oil and gas: Balancing business growth and environmental sustainability.

[4] Adebayo, Y. A., Ikevuje, A. H., Kwakye, J. M., & Esiri, A. E. (2024). Circular economy practices in the oil and gas industry: A business perspective on sustainable resource management. *GSC Advanced Research and Reviews, 20*(3), 267-285.

[5] Aderamo, A. T., Olisakwe, H. C., Adebayo, Y. A., & Esiri, A. E. Leveraging AI for financial risk management in oil and gas safety investments.

[6] Aderamo, A. T., Olisakwe, H. C., Adebayo, Y. A., & Esiri, A. E. (2024a). AI-enabled predictive safeguards for offshore oil facilities: Enhancing safety and operational efficiency.

[7] Aderamo, A. T., Olisakwe, H. C., Adebayo, Y. A., & Esiri, A. E. (2024b). AI-powered pandemic response framework for offshore oil platforms: Ensuring safety during global health crises.

[8] Agus Salim, N. A., Salleh, N. M., Jaafar, M., Sulieman, M. Z., Ulang, N. M., & Ebekozien, A. (2023). Fire safety management in public health-care buildings: issues and possible solutions. *Journal of facilities management, 21*(1), 69-83.

[9] Arifin, K., Ahmad, M. A., Abas, A., & Ali, M. X. M. (2023). Systematic literature review: Characteristics of confined space hazards in the construction sector. *Results in Engineering, 18*, 101188.

[10] Awonuga, K. F., Nwankwo, E. E., Oladapo, J. O., Okoye, C. C., Odunaiya, O. G., & Scholastica, U. C. (2024). Driving sustainable growth in SME manufacturing: The role of digital transformation, project, and capture management. *International Journal of Science and Research Archive, 11*(1), 2012-2021.

[11] Berlinger, B., Skogen, U., Meijer, C., & Thomassen, Y. (2019). Workplace exposure to particulate matter, bio-accessible, and non-soluble metal compounds during hot work processes. *Journal of occupational and environmental hygiene, 16*(6), 378-386.

[12] Danzi, E., & Marmo, L. (2019). Dust explosion risk in metal workings. *Journal of Loss Prevention in the Process Industries, 61*, 195-205.

[13] Derdowski, L. A., & Mathisen, G. E. (2023). Psychosocial factors and safety in high-risk industries: A systematic literature review. *Safety science, 157*, 105948.

[14] Domínguez, C. R., Guadian, J. E. R., Lona, J. G., & Mares, J. I. P. (2023). Hazard identification for risk assessment using the PRA technique in the automotive industry. *Safety science, 160*, 106041.

[15] Dugolli, M. (2021). Occupational, health and safety situation at small and medium enterprises in Kosovo, contextual factors, barriers, drivers and intervention process. *International Review of Applied Sciences and Engineering, 12*(1), 19-28.

[16] Ekpobimi, H. O., Kandekere, R. C., & Fasanmade, A. A. (2024). Software entrepreneurship in the digital age: Leveraging front-end innovations to drive business growth. *International Journal of Engineering Research and Development, 20*(09).

[17] Fishwick, T. (2019). The sugar dust explosions and fire at Imperial Sugar Company, Georgia. *Loss Prev. Bull, 266*(5).

[18] Gonyora, M., & Ventura-Medina, E. (2024). Investigating the relationship between human and organisational factors, maintenance, and accidents. The case of chemical process industry in South Africa. *Safety science, 176*, 106530.

[19] Groysman, A. (2024). Corrosion Risk for Process Safety in the Chemical Industry. *Afinidad, 81*(601), 10-24.

[20] Gupta, S., Saksena, S., & Baris, O. F. (2019). Environmental enforcement and compliance in developing countries: Evidence from India. *World Development, 117*, 313-327.

[21] Hamdan, A., Al-Salaymeh, A., AlHamad, I. M., Ikemba, S., & Ewim, D. R. E. (2023). Predicting future global temperature and greenhouse gas emissions via LSTM model. *Sustainable Energy Research, 10*(1), 21.

[22] Kim, J. (2022). *A Multimodal Approach to Improve Fire Safety on Construction Sites.* Oklahoma State University,

[23] Kodur, V., Kumar, P., & Rafi, M. M. (2020). Fire hazard in buildings: review, assessment and strategies for improving fire safety. *PSU research review, 4*(1), 1-23.

[24] Lemos, J., Gaspar, P. D., & Lima, T. M. (2022). Environmental risk assessment and management in industry 4.0: a review of technologies and trends. *Machines, 10*(8), 702.

[25] Maliha, M. N., Abu Aisheh, Y. I., Tayeh, B. A., & Almalki, A. (2021). Safety barriers identification, classification, and ways to improve safety performance in the architecture, engineering, and construction (AEC) industry: review study. *Sustainability, 13*(6), 3316.

[26] Naghavi, Z., Mortazavi, S. B., & Hajizadeh, E. (2019). Exploring the contributory factors of confined space accidents using accident investigation reports and semistructured interviews. *Safety and health at work, 10*(3), 305-313.

[27] Namour, P. (2022). The biogeochemical origin of sewage gases and control of their generation. *Journal of Hazardous Materials Advances, 7*, 100124.

[28] Olajiga, O. K., Olu-lawal, K. A., Usman, F. O., & Ninduwezuor-Ehiobu, N. (2024). Data analytics in energy corporations: Conceptual framework for strategic business outcomes. *World Journal of Advanced Research and Reviews, 21*(3), 952-963.

[29] Pupulidy, I. (2020). Self-designing safety culture: A case study in adaptive approaches to creating a safety culture. *ACS Chemical Health & Safety, 27*(1), 24-33.

[30] Rosner, D., & Markowitz, G. (2020). A short history of occupational safety and health in the United States. *American journal of public health, 110*(5), 622-628.

[31] Samira, Z., Weldegeorgise, Y. W., Osundare, O. S., Ekpobimi, H. O., & Kandekere, R. C. (2024). Comprehensive data security and compliance framework for SMEs. *Magna Scientia Advanced Research and Reviews, 12*(1), 043-055.

[32] Schroth, L. A., St Pierre, E. J., & Hody, B. J. (2023). Are my workers competent in EHS? Competency-based training to improve learning. *Professional Safety, 68*(12), 30-37.

[33] Selman, J., Spickett, J., Jansz, J., & Mullins, B. (2019). Confined space rescue: A proposed procedure to reduce the risks. *Safety science, 113*, 78-90.

[34] Selman, J. S. (2019). *Work-related traumatic fatal injuries involving confined spaces.* Curtin University,

[35] Servais, J.-M. (2024). International labour law.

[36] Shiwakoti, N., Tay, R., & Stasinopoulos, P. (2020). In an emergency evacuation situation what would you do? *Transportation research procedia, 48*, 860-869.

[37] Song, S., & Awolusi, I. (2020). Industrial safety management using innovative and proactive strategies. *Concepts, Applications and Emerging Opportunities in Industrial Engineering*.

[38] Spellman, F. R. (2023). *Physical hazard control: preventing injuries in the workplace*: Bernan Press.

[39] Stefana, E., Marciano, F., Cocca, P., Rossi, D., & Tomasoni, G. (2021). Oxygen deficiency hazard in confined spaces in the steel industry: Assessment through predictive models. *International journal of occupational safety and ergonomics, 27*(4), 990-1004.

[40] Tupper, C., & Doyal, A. (2023). OSHA Fire Safety. In *StatPearls [Internet]*: StatPearls Publishing.

[41] Wang, X. (2023). Analysis and improvement of hot work management in China. *Process Safety Progress, 42*(1), 72-78.

[42] Xu, H., Liu, Y., Shu, C.-M., Bai, M., Motalifu, M., He, Z., . . . Li, B. (2022). Cause analysis of hot work accidents based on text mining and deep learning. *Journal of Loss Prevention in the Process Industries, 76*, 104747.

[43] Yazdi, M., Adesina, K. A., Korhan, O., & Nikfar, F. (2019). Learning from fire accident at Bouali Sina petrochemical complex plant. *Journal of failure analysis and prevention, 19*, 1517-1536.