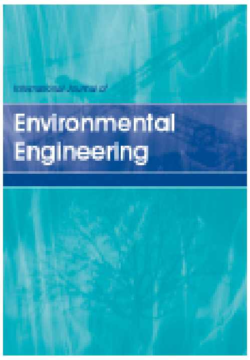

International Journal of Environmental Engineering

ISSN online: 1756-8471 - ISSN print: 1756-8463
https://www.inderscience.com/ijee

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DOI: 10.1504/IJEE.2024.10061840

Article History:

Received:	17 July 2023
Last revised:	09 October 2023
Accepted:	16 October 2023
Published online:	13 March 2024

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Abstract: The objective of this article is to analyse the activities in the confined spaces of several industries to verify the state-of-the-art and identify the factors that contribute to the occurrence of accidents, as well as the tools, methods and technologies used in the management and control of the risks. The research used the systematic literature review (SLR). Of the 21 accepted papers, eight explored risk management and control in confined spaces (33.3%). The use of technologies appeared in six articles (28.6%) and the monitoring of environmental agents in five articles (23.8%). The main contributing factors for accidents were failures in the management process, lack of safe procedures, unsafe operations, financial restriction and training deficiencies. The studies showed the development of risk management and monitoring tools, and the use of technology as a way to improve worker safety.

Keywords: confined space; construction site; hazardous atmospheres; risk management; accidents; management tools; technologies.

Reference to this paper should be made as follows: de Lima Eustáquio, C.C., da Cruz, F.M., de Araújo, R.P. and Santos, A.C.C. (2024) 'Confined spaces at construction sites', *Int. J. Environmental Engineering*, Vol. 12, No. 3, pp.271–286.

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Augusto César Cabral Santos is the Director Máximo SMS and Coordinator of the Technical Project of Work Safety and graduated in Marketing. His specialty/activities to be developed in the project are extensive professional experience in work safety, with emphasis on activities in confined space and respiratory protection.

1 Introduction

Industries face challenges when working in confined spaces as they can put their workers at risk despite existing national and international laws. Selman et al. (2018) noted that the definition of confined space varies according to legislation, jurisdiction, and, in some cases also with industrial group, but usually involves hazards related to entry and work in spaces with limited ventilation and entry/exit.

Regulatory Standard 33 (NR 33) defines confined space as any environment not designed for continuous human occupation, which has limited means of entry and exit, whose existing ventilation is insufficient to remove contaminants or where oxygen deficiency or enrichment may exist (Ministry of Labor and Social Security, 2019), while the Occupational Safety and Health Administration (OSHA, 2014) of the USA, defines confined space as being large enough for entry and work of workers, but with restrictions on entry/exit and not designed for continuous occupation.

According to National Institute for Occupational Safety and Health (NIOSH, 1979), confined space is defined as one with limited entry and exit openings, unfavourable natural ventilation, which may contain or produce dangerous contaminants, not intended for continuous occupation. It also informs that this space is divided into Class A, Class B and Class C, with criteria that establish a standard for work in confined spaces, whose purpose is to make the confined space safe for the worker, as well as make him aware of the dangers existing ones, inducing him to safe working practices.

However, employers have difficulty distinguishing between workspaces, which fall under the definition of confined spaces, despite worldwide regulations. Lack of situational awareness is a causal factor in many accidents in these spaces (Botti et al., 2017). The regulation establishes the requirements to identify, characterise and recognise confined spaces, as well as to implement the management system in order to permanently guarantee the safety and health of workers who interact, directly or indirectly, in these spaces while carrying out work, inside it (ABNT, 2017).

Potentially hazardous atmospheres are an aggravating factor in confined spaces. The Brazilian Standard (NBR 16.577:2017) defines a hazardous atmosphere as one that may expose workers to risk of death, disability, injury, or acute illness caused by flammable gases, vapours, dust above the explosivity limit, oxygen-poor atmosphere (concentration below 19.5%) or oxygen-rich atmosphere (concentration above 23%) (ABNT, 2017). NR 33 states that if there is an immediately, hazardous to life or health (HLH atmosphere), the space can only be accessed with the use of autonomous demand mask with positive pressure or compressed air line respirator with auxiliary cylinder for exhaust (Ministry of Labor and Social Security, 2019). According to Selman et al. (2018), atmospheric condition is the main cause of accidents involving rescue teams in confined spaces, and recent data indicate that 17% of these accidents involve rescuers.

However, it appears that the high rate of fatal accidents does not only occur with rescuers. Recent annual data show that 2016 and 2017 were the deadliest years of the last decade, in interventions in confined spaces, in Quebec and in the USA (Gonzalez-Cortes et al., 2022). Furthermore, a fatality rate of 1.3 fatalities per 100,000 workers in the USA, 0.06 for Quebec, 1.55 for Jamaica and 2.25 for Italy shows that accidents in confined spaces can result in multiple fatalities (Botti et al., 2015; Selman et al., 2019; Xia et al., 2021). This rate is 0.08 in Singapore and 0.05 in Australia, with 17% of these deaths involving first responders and would-be rescuers (Selman et al., 2018). Between 1992 and 2005, an average of 38 deaths per year occurred in the USA due to poisoning or asphyxiation (Wilson et al., 2012). According to Burlet-Vienney et al. (2014), moving parts of machines are responsible for 20% of fatalities in Quebec; engulfment, by 15%; falls from heights and falling objects by 12.5% each, and are considered as situations that increase the occurrence of accidents in confined spaces.

The dangers of an unsafe atmosphere may not be evident to a rescuer, i.e., a rescuer attempts a rescue if he is unaware of the entry hazards (Selman et al., 2018). According to Burlet-Vienney et al. (2014, 2015), this reveals the lack of awareness of the real situation about the presence of risks, existing in these activities. According to the Brazilian Standard (NBR 16.577:2017), dangerous atmospheres include those deficient in oxygen, which cause death by asphyxiation, as well as toxic ones, which present concentrations above the tolerance limit, the maximum value of which is determined in Regulatory Standard 15, from the Ministry of Labor and Employment. Also included as toxic are those carried by the air, in vapours, gases, dust and fumes, causing death after inhaling them.

Studies have investigated the presence of hazardous substances in atmospheric conditions associated with detonations and explosions in confined spaces (Chettouh et al., 2016; Kolbe et al., 2017). It was proposed by Salvado et al. (2017), a mathematical model to support the analysis of the destructive effects of detonations in confined industrial spaces. Other studies have focused on oxygen deficiency and the consequent danger and exposure of workers to the risk of asphyxia (Lunn, 2016; Mejías et al., 2014; Stefana et al., 2015; Sundal et al., 2017). According to Burlet-Vienney et al. (2014), the most common toxic atmosphere responsible for deaths in confined spaces, in the period from 1998 to 2011, was hydrogen sulphide, corresponding to 19.5% of all deaths.

Accidents in confined spaces occur in several industries and are related to several factors. According to Hamid et al. (2019), one of the main contributing factors is management. In addition, unsafe behaviours of workers are responsible for about 80% of construction accidents, 90.91% of which are caused by unsafe actions (Li et al., 2015; Han et al., 2013). According to Wong et al. (2016), individual characteristics, failures in the use of PPE and inadequate judgement of dangerous scenarios also contribute to the occurrence of accidents.

According to the International Labor Organization (ILO, 2011), the safety management system aims to provide a method to evaluate and improve behaviour regarding the prevention of incidents and accidents, through the effective management of risks, at the workplace and work. With regard to management, Reinhold et al. (2015) suggest that using a support tool to assess hazards and following the hierarchy of safety control measures can be an element for success. Caputo et al. (2013) and Blaise et al. (2014) are recent examples of the development of a supportive approach, to select industrial machine safety devices and safe maintenance operation, respectively.

Burlet-Vienney et al. (2015) propose the creation of a risk assessment tool in confined spaces capable of meeting the needs observed in the literature and in the field. The tool obeys the basic stages of risk management systems, namely: characterisation of the situation (describing the configuration of spaces, through questionnaires); hazard identification (describing risk components); risk estimation (using risk-adapted matrix); risk assessment (determining interventions by class and level); and risk reduction (feedback provided after the adoption of corrective measures). In most of the fatal accidents analysed, risk identification and estimation were not carried out, pointing to flaws in the risk assessment process. For example, in most fatal confined space accidents in Quebec between 1998 and 2011, the investigation report clearly mentioned failure to identify hazards or underestimation of risks.

Botti et al. (2018), when analysing fatal accidents that occurred in the USA and Italy, propose a procedure for safe work through the analysis of the characteristics of the confined area, task and requirements of the emergency response plan. Then, it analyses the risks that can affect the activity in a confined space, and finally, the analysis of the engineering and administrative controls to eliminate the risks.

Technological innovation has been a great ally in reducing risks at confined spaces, in construction. According to Li et al. (2015), unsafe behaviours of workers are responsible for about 80% of construction accidents in confined spaces. Hamid et al. (2019) also highlight management as one of the main contributing factors for accidents in these environments. In this sense, the use of technology, such as virtual reality (VR) can bring benefits in training and preparing workers for risky situations. As pointed out by Feng et al. (2020), VR can increase the efficiency of training simulation exercises through serious games, which bring greater realism and applicability. In addition, Burigat and Chittaro (2016) used VR to train effective evacuations in spacecraft, aiming to improve the spatial knowledge of participants. Thus, the use of this technology can contribute to a significant reduction of accidents in confined spaces in construction

Construction is an important sector of the Brazilian economy, and it is necessary to seek safe conditions for the performance of activities. This systematic literature review (SLR) analyses the activities carried out in confined spaces of several industries. The main challenge is to use the researched reports as important sources to characterise the atmospheres present in the confined spaces of construction sites, and to identify the possibility of developing an atmosphere immediately hazardous to workers. According to the scientific literature, the use of technologies such as VR, gas monitoring systems, and the adoption of administrative control measures are some of the possible solutions to minimise the risks in confined spaces.

Thus, the objective of this article is to analyse the activities performed in the confined spaces of several industries, based on SLR, to verify the state-of-the-art and identify the factors that contribute to the occurrence of accidents, as well as the tools, methods and technologies that are being used in the management and control of risks in these spaces.

2 Materials and methods

2.1 Research strategy

This article follows the guidelines of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) and aims to answer three research questions: What are the factors that contribute to the occurrence of accidents in confined spaces?; Which tools are used to manage and control the risks in these spaces?; and What are the technologies and monitoring methods available to control these risks?

For this purpose, several databases were used, selected by presenting the best results for the keywords, and inclusion and exclusion criteria were applied, in order to refine the results. The stages of the research consisted of planning, conducting, and documenting, following the methodology presented in Figure 1. The keywords used were 'confined space', 'hazardous atmosphere', 'construction industry', 'water tanks', 'sulphate reducing bacteria', combined with the Boolean descriptors (AND and OR). The terms found in the titles, abstracts and keywords of all articles searched in the selected databases were considered.

The stages of a review play a key role in ensuring the quality and relevance of the research, particularly in the context of a SLR. Are they:

1 Definition of the question: This step establishes the focus of the research. A clearly defined research question helps outline the scope of the study and guides all subsequent steps.

2 Selection of databases: The correct choice of databases is essential to access relevant sources of information. This allows for a comprehensive search that incorporates a wide variety of studies, increasing the validity and comprehensiveness of conclusions.

3 Wording of search strings: Precise wording of search terms ensures that results are relevant to the search question. This maximises search effectiveness, saving time and ensuring the relevance of articles found.

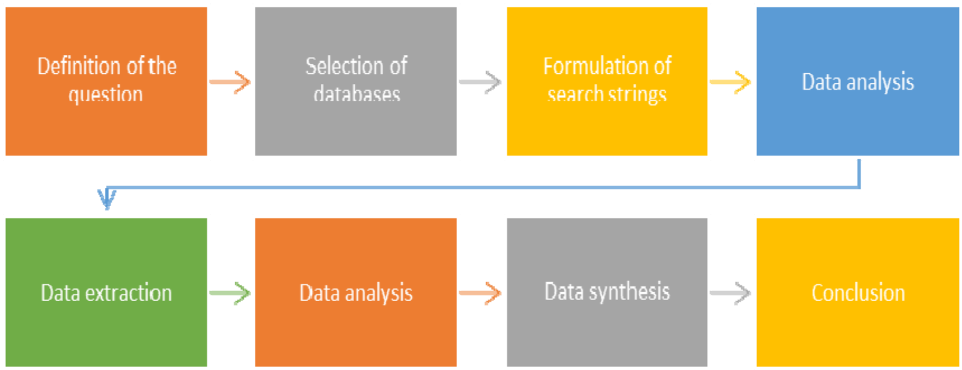
4 Data extraction: This step involves selecting relevant information from retrieved articles. This is done based on predefined criteria, which ensures that only high quality and relevant information is used in the study.

5 Data analysis: Here, the extracted data is evaluated and interpreted. This allows for the identification of trends, patterns and gaps in the data, which in turn can lead to meaningful conclusions.

6 Data synthesis: In this step, findings from different studies are combined to form a more complete picture of the research topic. This can provide insights that would not be available from individual studies.

7 Conclusions: This is the final phase of the research where the results are summarised and conclusions are drawn. This step may also include recommendations for further research based on gaps identified during data analysis. All steps can be seen in Figure 1.

Figure 1 Stages of the SLR adopted (see online version for colours)



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2.2 Selection criteria

Articles in English published in periodicals were searched, following inclusion criteria, which addressed confined spaces, activities performed in construction sites, hazardous atmospheres, services in reservoirs and water tanks of construction sites, and those published between 2012 and 2022. Studies published before 2012, with zero score (without the search terms in titles, abstracts or keywords) and those that did not address confined spaces were excluded.

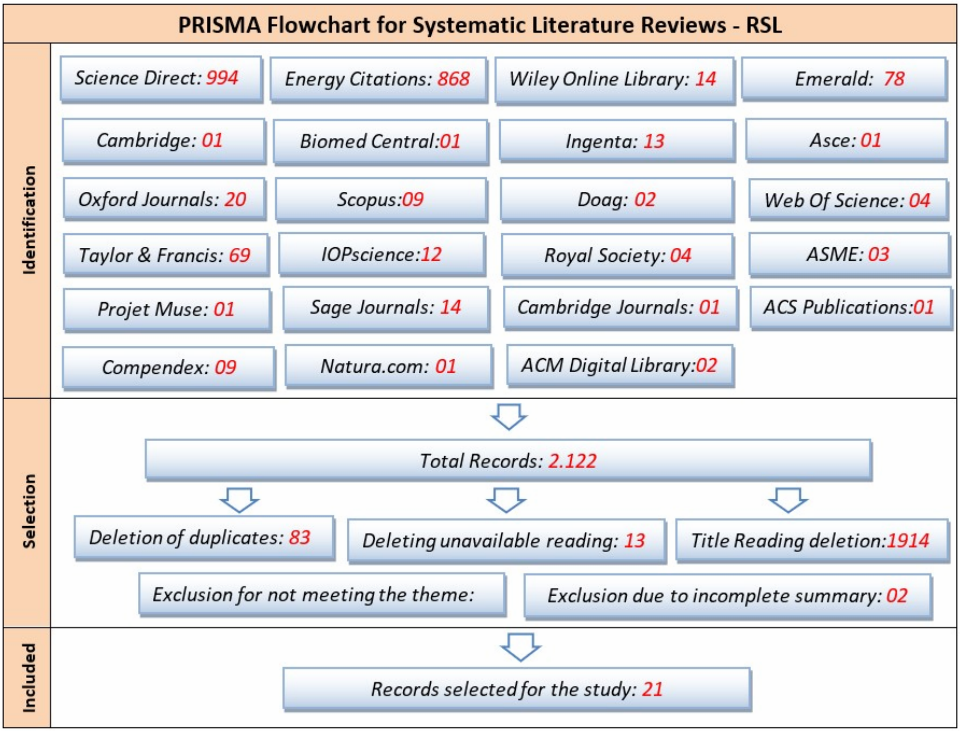
3 Results

3.1 Mapping results

The search found 2,122 articles, and after selection, 83 repeated articles were excluded, 1,914 rejected after reading the titles, two articles with incomplete abstracts, 89 articles that did not meet the proposed theme, and 13 articles unavailable for reading. The PRISMA flowchart in Figure 2 shows the databases searched and the identification, selection, and inclusion steps.

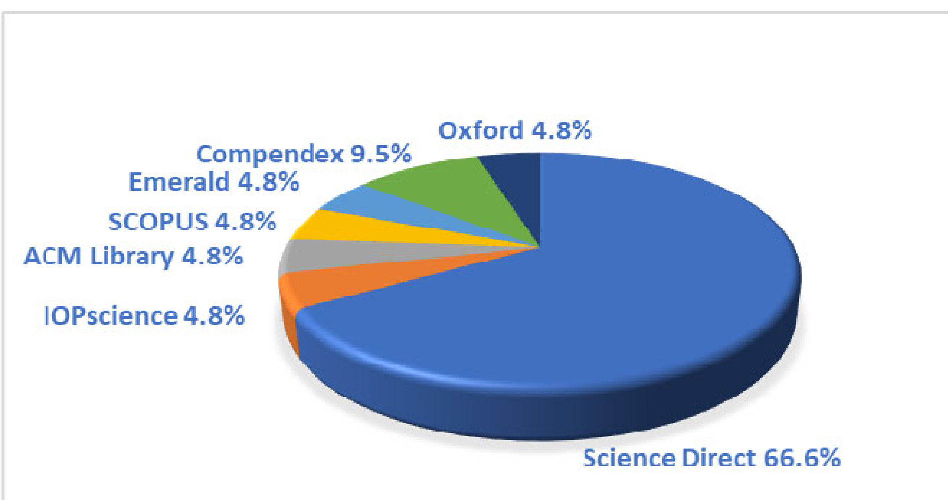
After applying the selection criteria, 21 articles were selected for the study, of which 14 were obtained from Science Direct (66.6%), 1 from IOPscience (4.8%), 1 from ACM Digital Library (4.8%), 1 from SCOPUS (4.8%), 1 from Emerald (4.8%), 2 from Compendex (9.5%), and 1 from Oxford (4.8%). The distribution of articles by database can be seen in Figure 3.

Figure 2 PRISMA flowchart (see online version for colours)



Source: Authors

Figure 3 Distribution of articles by databases (see online version for colours)

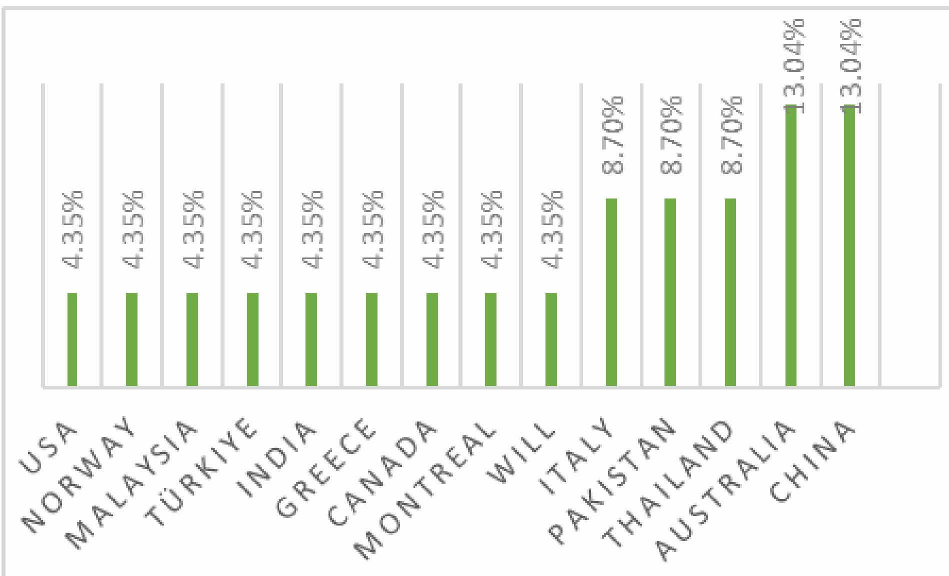


Source: Authors

3.2 Bibliometric results and discussion

According to Figure 4, the geographical distribution of the articles can provide information about the countries that had more interest or stood out in relation to the studied subject. For example, China and Australia were the countries with the highest number of publications in the area of confined spaces, which may suggest that these countries have a greater number of works, projects or activities related to this theme. In addition, the presence of publications from countries such as Canada, Iran, Montreal, Norway, Malaysia, Turkey, India and Greece show that the subject is studied in different parts of the world. However, it is important to remember that this analysis may not reflect the complete reality, because it is limited to the articles found in the research.

Figure 4 Percentages of productions by countries (see online version for colours)



Source: Authors

3.2.1 Risk management

Eight of the 21 articles in the survey presented management tools for monitoring and controlling risks in confined spaces. Methods used included interviews, reports, procedures, numerical simulation studies and digital tools. The risk assessment tool created by Burlet-Vienney et al. (2015) was tested through accident analysis and interviews with risk management specialists and workers with experience in confined spaces. The lack of identification and prior risk estimation was observed in many fatal accidents analysed. Naghavi et al. (2019) also adopted accident analysis and semi-structured interviews with specialists to identify causes and contributory factors for accidents in confined spaces. They established a five-level hierarchy of influence, considering external interference (lack of laws, regulations and government policies), which appeared as the fifth level of influence. Intoxication by gases, explosion, atmospheric poisoning and risk of accidents were indicated as causes of accidents.

D'u et al. (2022) also investigated drowning/asphyxiation factors and subfactors in construction projects in Malaysia, using interviews, accident analysis, and developing a hierarchical process analysis (HPA) model. Hazardous worker behaviour, hazardous site conditions and management factors were identified as factors for fatal accidents. Although there are discrepancies in the percentages, the contributory factors pointed out by the authors converge in many respects. Based on the authors, it is possible to observe that several studies were carried out with the objective of identifying the risk factors associated with confined spaces and developing management tools to monitor and control these risks.

It was observed that most fatal accidents occurred in confined spaces could have been avoided if the identification and prior estimation of risks had been performed. The factors that most contributed to the occurrence of accidents in confined spaces were organisational factors, human factors, and to a lesser extent, external interferences.

The management tools developed by the studies include systems of analysis and classification of risk factors, models of HPA and risk assessment tools, which can help organisations to identify, monitor and control the risks associated with confined spaces, thus reducing the incidence of accidents and injuries.

3.2.2 Behaviour and perception of risks

Smith et al. (2018) used semi-structured interviews to evaluate the entry into confined spaces and the effectiveness of training of rescue and fire fighting teams of aircraft. Of the respondents, 74% stated that the training taught them to recognise the potential dangers of all permitted or representative spaces, 83.6% taught them to effectively recognise the signs, symptoms and consequences of exposure to any hazardous atmospheres present, 86.3% admitted that training taught them to select appropriate PPE for rescue, 76.7% learned to properly test the atmosphere, and finally 71.2% believed that training taught them to treat victims effectively during rescue operations. These results demonstrate that interviews are a very positive tool for training and awareness of workers.

Therefore, the semi-structured interviews were a very effective tool in this author's work to evaluate the entry into confined spaces and the effectiveness of the training of the rescue and fire fighting teams of the aircraft. Most respondents stated that the training taught them to recognise the potential hazards of all permitted or representative spaces, to effectively recognise the signs, symptoms, and consequences of exposure to any hazardous atmospheres present, to select the appropriate PPE for rescue, to properly test the atmosphere, and to effectively treat victims during rescue operations. These results indicate that semi-structured interviews are a valuable tool for worker training and awareness.

Botti et al. (2018) proposed a three-step procedure to ensure safe work in confined spaces, taking into account the characteristics of the site, the task, and the requirements of the emergency plan. When testing the procedure in fatal accidents occurred in the USA and Italy, they proved its effectiveness, because they identified that all stages of the procedure (analysis, evaluation and control of risks) were not followed, contributing to the occurrence of accidents, whose main causes were: asphyxiation, explosion, fire and electrocution, which caused fatalities. Selman et al. (2019) also tested a procedure to reduce risks in rescues in confined spaces and their results were similar to those of Botti et al. (2018), identifying the lack of risk analysis, detailed task procedures and entry permit. They also found that workers underestimated the risks at the site, converging with D'u et al. (2022) who estimated that the hazardous behaviour of workers in confined spaces was 80.98%. Mentes and Mollaahmetoglu (2022) used resilience engineering (RE) principles to identify risks on oil and gas platforms in confined spaces. They found that the current performance scores of the identified risks were below acceptable limits, but by applying RE skills the resilience performance scores (RPS) increased, reducing the risks.

Based on the information presented, it is possible to infer that the management and control of risks in confined spaces is a relevant and complex topic, which requires the application of specific procedures to ensure the safety of workers. The study by Botti et al. (2018) proposed a procedure for safe work divided into three stages that, when tested, showed its effectiveness in reducing risks in fatal accident analyses in the USA and Italy. However, failures were identified when noting that all steps of the procedure had not been complied with, which contributed to the fatalities that occurred, including asphyxiation, explosion, fire and electrocution. Selman et al. (2019) also tested a procedure to reduce the risks of rescues in confined spaces, which agreed with the results of Botti et al. (2018), identifying the absence of risk analysis, the lack of detailed task procedures and the lack of entry permission, as causes of the fatalities that occurred. In addition, they pointed out that workers underestimated the risks at the site. Mentes and Mollaahmetoglu (2022) used the principles of RE to identify the risks of confined space entry and operations on floating oil and gas platforms. The results showed that, when applied the RE skills, the RPS increased, reducing the identified risks. We can therefore infer that the application of specific procedures, such as those proposed by the mentioned studies, is essential to ensure the safety of workers in confined spaces.

3.2.3 Hazardous atmospheres

The research addressed the monitoring of environmental agents in confined spaces in various industrial sectors. Five of the articles accounted for 24% of the research and presented results on the presence or absence of toxic gases and altered oxygen levels in workplaces. Yenjai et al. (2012) and Wuthichotwanichgij and Geater (2015) performed measurements in six rice factories and 253 shallow wells, respectively, and concluded that although hazardous gases were detected in some places, none of the values exceeded the permitted levels. However, Selman et al. (2018) found highly toxic atmospheres in various workplaces, which were responsible for the death of rescuers, in unsuccessful rescue attempts. The lack of adequate training and awareness were pointed out as the main factor for these accidents. Li et al. (2018) analysed the thermal, physiological and acute health symptoms in 32 workers in an underground climate chamber in China, concluding that the combination of high concentrations of ambient temperature, relative humidity and carbon dioxide (CO_2) leads to different human responses and acute health symptoms. Bakke et al. (2014) conducted a study on exposure to contaminants in tunnel construction in Norway. The study involved 90 workers distributed across 11 construction sites and divided into different groups of activities. Each worker used individual sampling equipment and the results revealed that well drillers, injectors and shotcrete operators were exposed to higher thoracic aerosol mass concentrations compared to the other groups. In addition, well drillers were exposed to α-quartz concentrations, as were support workers. Ammonia (NH3) was the contaminant that was most exposed to sprayed concrete, drilling and blasting operators.

Therefore, the presence of environmental agents in confined spaces is a concern in several industries, including the agricultural industry, tunnel construction, and others. Monitoring these agents is important to ensure the safety of workers, allowing preventive measures to be taken in case of dangerous concentrations. In some cases, as in the studies by Yenjai et al. (2012) and Wuthichotwanichgij and Geater (2015), it was possible to detect the presence of hazardous gases in confined spaces, but the concentrations did not exceed the permissible limits, which posed no immediate risk to the life and health of workers. However, in other cases, as in the study by Selman et al. (2018), the detected atmospheres were considered highly toxic and were associated with fatal accidents in confined spaces. In addition to the presence of hazardous gases, other environmental factors, such as temperature and humidity, can also affect the health and well-being of workers. It is important for those entering confined spaces to have adequate training and knowledge of the risks involved in order to avoid accidents and fatalities.

3.2.4 Use of new technologies for safety in confined spaces

Of the 21 articles in this research, 6 of them, corresponding to 28.6%, addressed the use of technology in confined spaces. Among these articles, Lu et al. (2020) used VR in a serious game to simulate rescues in confined spaces and observed significant improvement in participants' knowledge after training. Riaz et al. (2014) proposed an integrated solution with wireless sensor networks and building information modelling (BIM) technology for worker safety in confined spaces, and in a new research, Riaz et al. (2017) reported a solution through a database to decrease the reading time of the sensors. Tiwari and Prabu (2018) created a prototype of a wall-climbing magnetic robot to transport materials in confined spaces in the naval industry, while Anyfantis et al. (2021) presented an electronic nose system for urban search and rescue operations. Botti et al. (2022) presented a digital tool for characterisation of confined spaces and awareness of workers, employers and security professionals about the risks present.

However, Dandan et al. (2016) recalls that devices such as drones and robots are expensive, require specialised technical knowledge and are not applicable in medium and small companies. Therefore, the evidence suggests that companies have rarely adopted new technologies in the field and continue to rely on classic risk reduction measures such as work permits, gas measurements, etc. (Burlet-Vienney et al., 2015).

Finally, the research also showed safe design principles, where Gonzalez-Cortes (2022) analysed 18 case studies on the decommissioning of confined spaces, based on the safe designer principle. Of the experts interviewed, 93.3% highlighted the importance of declassification as a solution to eliminate confined spaces, presenting three approaches:

1 total elimination, by reducing the size of the space to prevent entry

2 hazard-oriented decommissioning by installing permanent fixtures such as anchor points and continuous lighting

3 organisational decommissioning, designing or modernising structures that allow workers to enter and exit confined spaces without restriction, reducing the administrative burden of regulations.

Research has indicated that prioritising the complete elimination of confined space provides better protection for workers, simplifies activities and reduces costs. The use of drones, robots, non-destructive testing, thermography, vibration sensors was recommended, as well as the installation of mirrors and windows to reduce the number of entries required by workers.

Based on the articles, it was possible to observe different technologies for monitoring and safety in confined spaces, such as VR, wireless sensor networks, BIM and robots. The proposed solutions aim to improve worker safety by reducing exposure to risks. In addition, the research also presents a digital tool (algorithm) for mobile devices as a proposal to make workers, employers and security professionals aware of the risks present. Finally, the research also highlights the importance of safe designer principles for decommissioning confined spaces in order to eliminate them or make them safer for workers.

4 Conclusions

The researched articles were written in several countries, including China and Australia which account for a large portion of the publications. The geographic distribution of the articles could provide information about which countries had the most interest or were most prominent in relation to the subject studied. The presence of publications in countries such as Canada, Iran, Montreal, Norway, Malaysia, Turkey, India, and Greece shows that the theme is studied in different parts of the world. It is important to remember that this analysis may not reflect the complete reality, since it is limited to the articles found in the research.

Based on SLR, it is possible to conclude that several studies were conducted to identify risk factors associated with confined spaces and develop management tools to monitor and control these risks. These studies used different methods, such as accident analysis, interviews with risk management specialists and workers with experience in confined spaces, numerical simulation studies and digital tools. The authors noted that many fatal accidents could have been avoided if identification and prior risk estimation had been performed. The factors that most contribute to the occurrence of accidents in confined spaces were organisational, human, and to a lesser extent, external interferences.

The management tools developed by the studies include systems of analysis and classification of risk factors, models of HPA and risk assessment tools. These tools can help organisations identify, monitor and control the risks associated with confined spaces, thus reducing the incidence of accidents and injuries.

The training and awareness of workers in confined spaces are fundamental to ensure safety and avoid accidents. The semi-structured interviews were an effective tool to evaluate the effectiveness of the training of the aircraft rescue and fire fighting teams. In addition, the studies by Botti et al. (2018) and Selman et al. (2019) highlighted the importance of detailed task procedures, risk analysis, and entry permission to reduce risks in confined space rescues. On the other hand, D'u et al. (2022) estimated that the hazardous behaviour of workers is high, reinforcing the importance of training and awareness. Mentes and Mollaahmetoglu (2022) showed that applying RE skills can help increase resilience performance and reduce risks on oil and gas platforms in confined spaces.

The presence of environmental agents in confined spaces is a concern in several industries, including the agricultural industry, tunnel construction, and others. Monitoring these environmental agents is important to ensure the safety of workers, allowing preventive measures to be taken in case of dangerous concentrations. The presence of hazardous gases was detectable in some cases, but concentrations generally did not exceed the permitted limits, which did not represent an immediate risk to the life and health of workers. However, in some cases, the atmospheres detected were highly toxic and were associated with fatal accidents. In addition to the presence of hazardous gases, other environmental factors such as temperature and humidity can also affect the health and well-being of workers in confined spaces. It is important that workers entering these locations are properly trained and aware of the risks involved to prevent accidents and deaths.

Of the 21 articles analysed in the SLR, 6 of them (28.6%) addressed the use of technology in confined spaces. The technologies mentioned in the articles included VR, wireless sensor networks, BIM and wall-climbing magnetic robots. The solutions proposed by the articles aim to improve the safety of workers in confined spaces, reducing exposure to risks. The research presented a digital tool for mobile devices, aiming to make workers, employers and security professionals aware of the risks present. The designer principles were presented as important solutions for the decommissioning of confined spaces in order to eliminate them or make them safer for workers.

The study of risks in confined spaces is a subject of great interest in industry and science. Many fatal accidents in confined spaces could have been avoided if identification and prior risk estimation had been performed. Therefore, it is essential that organisations identify, monitor and control the risks associated with these spaces to reduce the incidence of accidents and injuries. The management tools developed by the studies can help in this process, along with the training and awareness of workers. In addition, monitoring of these agents is important to ensure the safety of entrants and rescuers. The use of technology can also help improve worker safety by reducing exposure to risks. In summary, studying risks in confined spaces is a matter of great importance to ensure workers' safety and prevent accidents and injuries.

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