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WORKER SAFETY AND OCCUPATIONAL HEALTH IN THE DECOMMISSIONING OF OIL AND GAS PRODUCTION SYSTEMS: A SYSTEMATIC REVIEW

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Abstract

The operational lifespan of many offshore oil and gas production facilities is reaching its end, and the decommissioning of production systems faces challenges related to the safe and efficient deactivation of industrial installations, considering the inherent risks to occupational health and worker safety. This study conducted a systematic literature review across the Web of Science, Scopus, Springer, and Wiley Online Library databases, aiming to identify what the literature reveals about Health and Safety in offshore oil and gas decommissioning. A total of 11 articles were selected from an initial pool of 270 and categorized into three analytical groups: risk exposure, regulatory bodies and legislation, and safety planning. The literature still lacks detailed information on worker health and safety in offshore decommissioning, with most reviewed articles focusing on other aspects. In this context, activity ergonomics emerges as significant for understanding the work, aiming to enhance analysis methodologies and mitigate risks.

Keywords: Decommissioning; Occupational Health; Worker Safety; Oil and Gas; Ergonomics.

1. INTRODUCTION

The process of decommissioning offshore facilities gains relevance in the face of the fall in oil prices, driving the need to evaluate the termination of lease contracts, the useful life of the wells, and the financial relationship after the end of exploration (Nicolosi et al., 2018).

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Petrobras (2023) defines decommissioning as the definitive interruption of operations, encompassing activities related to the platform and its equipment when opportunities for extension or maintenance of production are exhausted. From this perspective, there are different methods of decommissioning subsea equipment, including complete removal with disposal on land or on the seabed, partial removal, tipping over in place and permanence of the structure in place for alternative use (Ruivo, 2001; Petrobras, 2022).

This variety of alternatives requires complex decisions, demands numerous activities and exposes workers to different operational risks. Understanding work as a dynamic and constantly changing process allows us to analyze its impacts and seek solutions that consider complexity and the human dimension (Queiroz & Souza, 2020). The main challenge is to promote changes and reflections in the activities during the decommissioning project, aiming to create collaborative work systems that are closer to reality (Bittencourt et al., 2017).

2. MATERIALS AND METHODS

To complement the methodological approach of the case study, a systematic review of the literature on the state of the art of health and safety in the context of the decommissioning of offshore oil and gas installations was made. The present study was guided by the *Preferred Reporting Items for Systematic Reviews and Meta-Analysis* (PRISMA) guidelines, which according to *the National Library of Medicine* (2022) provide updated reporting guidelines for systematic reviews, which reflect advances in methods for identifying, selecting, evaluating, and synthesizing studies. A systematic review serves as an essential resource for compiling, analyzing, and conveying the findings and implications of a vast body of research and data. Its importance lies in its ability to integrate the results of several independent studies that investigate the same issue, especially when these studies present divergent conclusions (UFRRJ, 2020).

2.1. Positionality

The present review was based on the following guiding question: "what does the literature report on worker health and safety in the decommissioning activities of offshore oil and gas installations?". Thus, the methodology adopted comprises four stages (Levac et al., 2010):

1. Identification of the research question;

2. Decision making about the studies to be included, analysis of which terms and sources are used, as well as the choice of language;

3. Selection of studies based on inclusion and exclusion criteria under the supervision of two reviewers;

4. Content analysis and reporting of results.

2.2 Eligibility Criteria

The eligibility criteria were defined by: articles dealing with worker health and safety in offshore oil and gas decommissioning; in Portuguese and English; and original documents, freely accessible in full, recovered via the Federated Academic Community (CAF).

Duplicate papers, those that did not have full access, those that were not in the language determined by the eligibility criteria, as well as those that were not related to the review question were excluded.

2.3 Sources of information

The searches were carried out in April and May 2024 in the *Web of Science, Scopus, Springer, and Wiley Online Library databases*, following the search strategies presented in Chart 1.

Database	Search strategy	Findings
Web of science	((ALL=decommissioning)) NA ALL=(*oil and gas*)) AND ALL=(*safety*).	72
Scopus	*Decommissioning* AND *oil* AND *gas* AND *risks* AND *worker*	7
Springer	*Decommissioning offshore* AND *worker safety* *Filters: Article, research article, review article, conference paper, english*	17
Wiley Online Library	*"Decommissioning" anywhere and "oil and gas" anywhere* *filter: open access*	174
Total		270

Chart 1 – Search strategies

2.4 Data Graphing Process

All recovered records were imported into the *Mendeley* reference manager, which automatically eliminated duplicate articles. Next, a process of selection of documents was carried out by reading the title and abstracts and by reading the texts in full. From the formation of the body of this review, a data extraction protocol was developed to collect the following information: authors' names, journal, method, and the findings signed.

2.5 Summary of Results

The process of selecting the documents was carried out by reading titles and abstracts and by reading the texts in full. In the next stage, the organization of findings related to workers' health and safety was structured to facilitate the analysis of results, enhance the interpretation of data and formulate reflections and propositions for future research on the subject.

3. FINDINGS

The research retrieved 270 articles, of which after using the eligibility criteria, articles were excluded due to title and abstract reading, articles that were not possible to be accessed in full, those that were duplicated, as well as articles that, after reading in full, did not address the health and safety of workers in the decommissioning activities of offshore oil and gas facilities. Based on these constraints, 11 articles were selected and 259 were excluded. Of those selected, 10 were written in English and 1 in Portuguese. Regarding the included studies, 5 articles were from the *Web of Science*, 5 from *Scopus*, and 1 from the *Wiley Online Library*. The details of the selection of the articles can be seen in Figure 1.

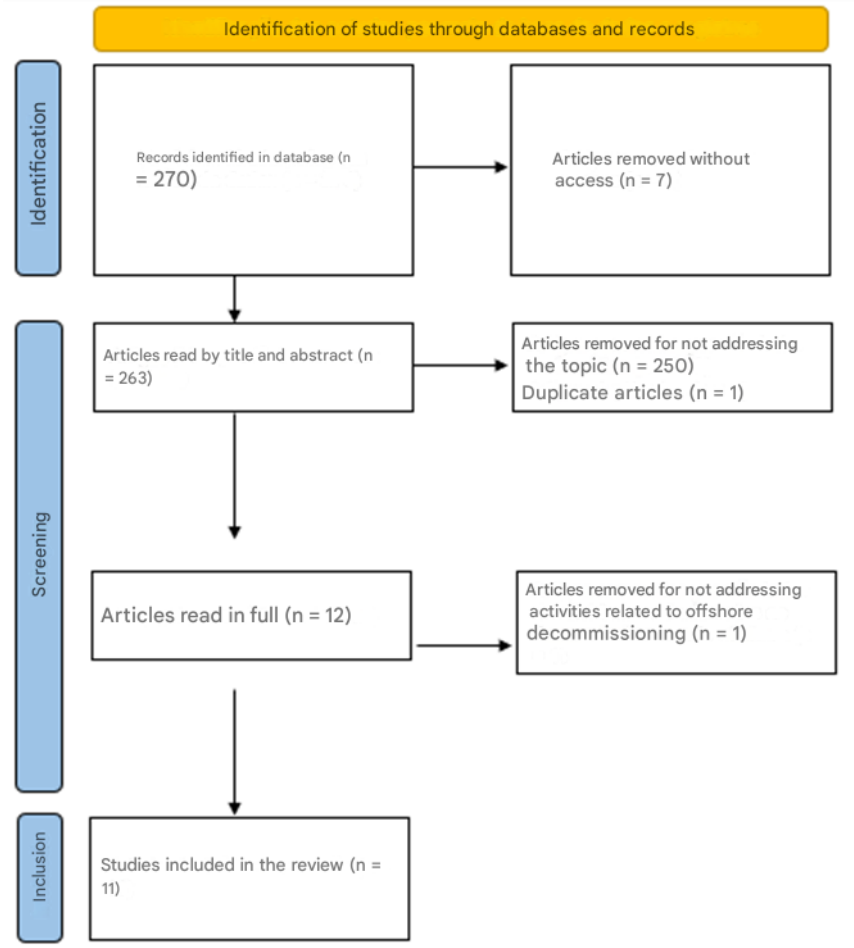


Figure 1 – PRISMA

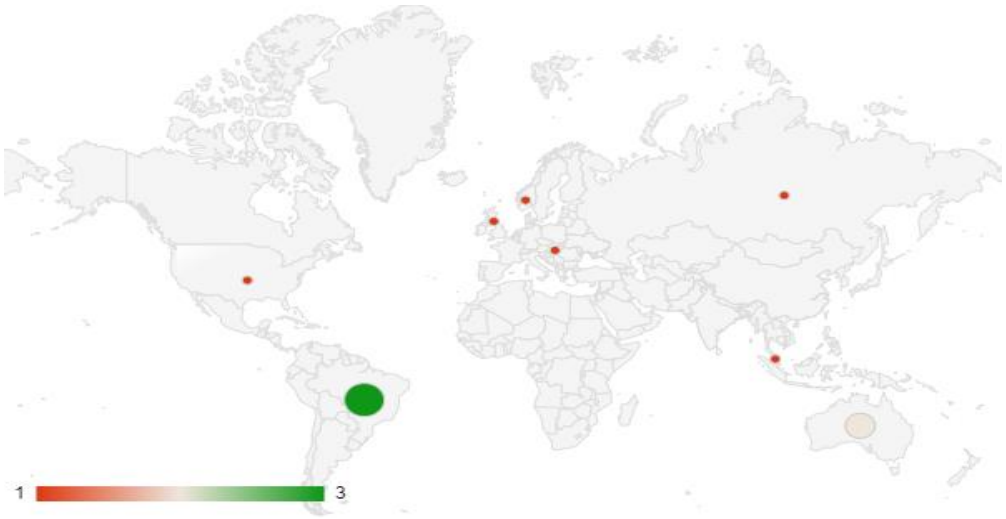
Chart 2 presents the main characteristics of the studies included in this review.

Author's name	Year	Periodic	Method	Health and Safety Findings
Robert Yanniello, Senior Member, IEEE, and Gabriel J. Paoletti	2009	*IEEE Transactions on Industry Applications*	Quantitative and qualitative research	The intent of this article is to highlight potential personal and environmental hazards associated with this same equipment when it is de-energized. This document is specifically targeted at switchgear and circuit breakers rated above 1000 V and is more specifically targeted at personnel performing maintenance and decommissioning.
A. M. Fowler a,*, P. I. Macreadie b, D. O. B. Jones c and D. J. Booth	2014	*Ocean and Coastal Management*	Multicriteria evaluation	Health and safety as a criterion within the decision-making process in decommissioning.
Al-Ghuribi T; Liew M; Zawawi, N. A. et. Al.	2016	*Civil, offshore and Environmental Engineering, ICCOEE*	Multicriteria evaluation	Importance of having the Health and Safety criterion in the decommissioning project.
Soheil Manouchehri	2017	*36th International Conference on Ocean, Offshore and Arctic Engineering*	Qualitative research	The safety risks of the different options should be compared and evaluated assuming that all tasks are being performed by competent personnel.

Róbert Soós, Bence Balogh, Gergely Dobos, Szabolcs Szávai*, and Judit Dudra	2019	*EPJ Nuclear Sciences & Technologies*	virtual training system - VR headset	Using this immersive virtual reality (AI) solution, the operator can experience realistic emergencies under psychological pressure and allows operators to be properly trained to make the right decisions, even in the real world.
Koroma, Sheik G., Animah, Isaac, Shafiee, Mahmood and Tee, Kong-Fah	2019	*International Journal of Oil, Gas and Coal Technology*	Qualitative and quantitative research	Health and safety regulatory issues.
Lima, Yarly Queiroz de Monteiro Gomes, Luiz Flávio Autran.	2021	Management and Projects Journal	Exploratory and descriptive research	Importance of the Health and Safety criterion in the decommissioning project.
Ibragim Khalidov a, Konstantin Milovidov A, Anzor Soltakhanov	2021	*Heliyon*	Overview of the Russian legislative and regulatory framework	Industrial and environmental safety management; safety regulations.
Jess Melbourne-Thomas; Keith R. Hayes; Alistair J. Hobday; Et. Al.	2021	*Frontiers in Marine Science*	Risk Support Research and Offshore Decommissioning Impact Assessment in Australia	Quantitative Risk Assessment, MCDA.
da Cunha Jácome Vidal P; Aguirre González M; Cassimiro de Melo D et.al.	2022	*Marine Structures*	Systematic review of the literature	Workers' unions; university (support); adequate technical procedures for the execution of the work; risks of fatal accidents, exposure to toxic materials; operational safety.
Karen Alves de Souza; Ludmyla Carolina Mariano Barbosa; Tiago Machado de Souza Jacques, et. Al.	2022	*ASCE-ASME Journal of Risk and Uncertainty in Engineering Systems, Part B: Mechanical Engineering*	Multicriteria evaluation	Thus, the removal of facilities involves large costs and technology to address these challenges that can generate operational safety problems and impact the environment.

Table 2 – Characteristics of the included studies

Geographic graph 1 refers to the countries where the surveys included in this review were conducted. It was possible to observe a greater concentration of research developed in the following countries: Brazil, Australia, the United States, the United Kingdom, Norway, Malaysia, Russia and Hungary.



Graph 1 – Distribution of searches by country

Regarding the number of searches per year, Figure 2 shows a large concentration from 2019 onwards, increasing considerably in 2023. There is also stability in the production of studies from 2009 to 2017.

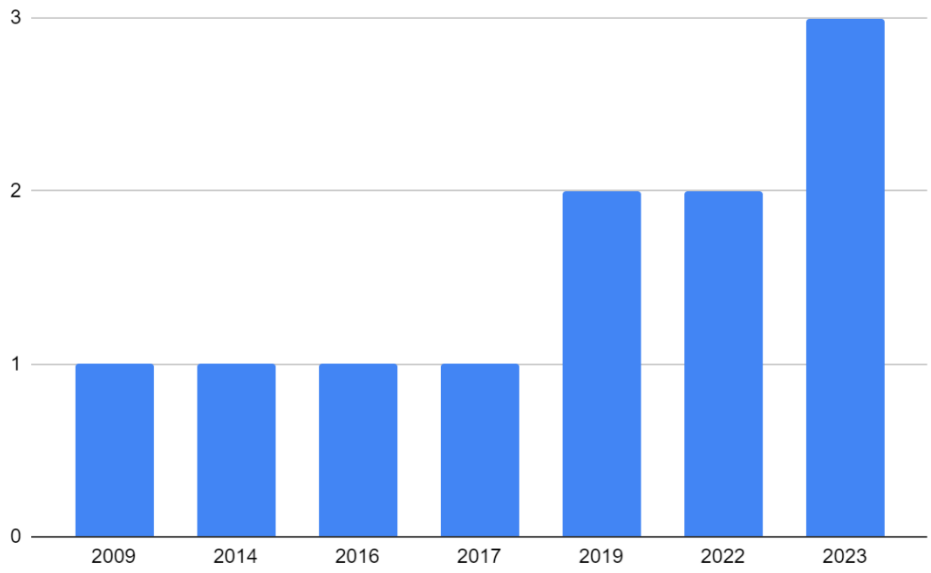


Figure 2 – Number of searches per year

3.1 Thematic analysis

The main focus of the selected works is on the health and safety of the worker in the decommissioning activities of *offshore* oil and gas installations. The analysis of the extracted results will be presented according to the objective and the research question. Based on the data collected, it was possible to categorize the findings into seven groups: use of artificial intelligence in the training of workers; exposure to risk; multicriteria evaluation; quantitative

impact matrix; regulatory bodies and legislation; unions and universities; and security plan, which will be presented below:

3.2 Use of artificial intelligence in worker training:

Only one article mentioned the interactive training of maintenance workers through artificial intelligence (AI), which simulates a real operating scenario; encompassing the environment and the activities/equipment used in the actual work (Soós et al., 2019). The training platform mentioned was the virtual reality platform developed by Bay Zoltán Nonprofit Ltd. The aim is to decrease the human factor and ensure safer working conditions and operations, taking into account the replacement of expensive training centers. However, the platform also has some negative aspects, such as the lack of step detection by optical sensors (Soós et al., 2019).

3.3 Risk exposure

Six articles mentioned the topic of exposure to risk (Yanniello, Paoletti, 2009; Manouchehri, 2017; Fowler et al., 2014; Cunha et al., 2022; Koroma et al., 2019; Melbourne et al., 2021). The importance of spill containment measures before handling any oil was mentioned (Manouchehri, 2017); need to reduce risks both in the long term for benefactors of the sea and in the short term for those responsible for decommissioning operations, taking into account Safety, Environment and Health (HSE) recommendations. The safety risks of the different decommissioning options must be evaluated and compared in view of the risks to *offshore* workers, such as: injuries, modified work, operating time and fatalities (Fowler et al., 2014).

Other risks were mentioned regarding navigation, fishing hazards, diving activities, exposure to drilling mud, and exposure to toxic materials (Koroma et al., 2019). It was evidenced that each decommissioning alternative generates different risks for the health and safety of workers because they are extremely complex processes, with the potential to trigger fatal accidents due to the handling of heavy structures and contact with toxic products. The highest occurrences of serious accidents are due to lifting heavy structures and lifting activities; cutting activities with the help of a diver; communication problems; and risks of collisions in the transport of these structures (Cunha et al., 2022; Koroma et al., 2019; Melbourne et al.,

2021). One of the major problems highlighted is the fact that operators are faced with the task of not being able to determine the scope of their operations (Koroma et al., 2019).

3.4 Multicriteria evaluation

Six articles mentioned the importance of multicriteria evaluation within decommissioning projects (Manouchehri, 2017; Souza et al., 2022; Fowler et al., 2014; Al-Ghuribi, et al., 2015; Lima, Monteiro, 2021; Melbourne et al., 2021). An evaluation of the scenarios and evaluation criteria in decommissioning by the operators that formulate the PDI is necessary, in order to encompass, in its scope, an assessment of risks to the health and safety of the worker.

3.5 Quantitative impact matrix

Two articles mentioned the importance of the quantitative impact matrix (Manouchehri, 2017; Melbourne et al., 2021). In the UK and Europe between 1990 and 2002 a QRA (Quantitative Risk Assessment) was used for accident statistics, with the aim of adjusting the density function to the rate of serious injuries and the rate of fatal accidents in four categories of decommissioning activities: *onshore*, *offshore* above water, aerial diving and saturated diving. Estimates of task hours in each category for different decommissioning options were analyzed (Melbourne et al., 2021).

3.6 Regulatory bodies and legislation

Seven articles mentioned the importance of regulatory bodies and the performance of legislation with regard to the health and safety of workers (Souza, et al., 2022; Al-Ghuribi et al., 2016; Lima, Monteiro, 2021; Cunha et al., 2022; Khalidov et al., 2021; Koroma et al., 2019; Melbourne et al., 2021). Some resolutions were cited about risk management, operational safety management on the platform, and safety management of subsea systems (Souza, et al., 2022; Al-Ghuribi et al., 2016; Khalidov et al., 2021) as decisive within the scope of the criterion of worker safety and protection; which are influenced by some agencies such as the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), the National Petroleum Agency (ANP) and the Brazilian Navy, within the offshore platform decommissioning projects (Al-Ghuribi et al., 2016; Lima, Monteiro, 2021; Cunha et al., 2022).

The experience of the United Kingdom and Norway, on the other hand, reflects the institution of a definition of goals, where operators must create their own objectives and the regulator analyzes the entire process in order to manage safety. In the United States, the regulator establishes several requirements that must be met by the operator (Cunha et al., 2022). These aspects reflect the need for an adequate legal framework for decommissioning in the context of worker health and safety in oil and gas operations (Koroma et al., 2019; Melbourne et al., 2021).

3.7 Unions and universities

One article mentioned the influence of workers' unions and universities in choosing appropriate methods for carrying out work in activities involving health and safety, while minimizing risks. The university is seen as the one that favors the creation of technologies and methods in proposing research to optimize the decommissioning processes (Cunha et al., 2022).

3.8 Security plan

Two articles mentioned the creation of safety plans as a decisive factor for the health and safety of workers in *offshore* activities (Cunha et al., 2022; Khalidov et al., 2021). It was discussed that safety depends on aspects such as: weather conditions, location; technical details of the project; material strength; technical training of the team and level of experience of the work team (Cunha et al., 2022). Therefore, it is necessary to have a decommissioning preparation plan that indicates proposals for industrial safety risk management, based on risk assessment for compliance with safety measures in the engineering support phase and during operations. The following should be considered: changes in hazard characteristics in the stages of the decommissioning project; detailed information on the hazards and risks; effective change management; application, monitoring and analysis of safe working methods; relations and interaction with regulatory authorities and stakeholders (Khalidov et al., 2021).

4. DISCUSSION

The objective of this systematic review of the literature was to investigate what has been reported about Worker Health and Safety in offshore decommissioning activities for oil and gas production. The discussion of the results will be constituted from the interaction between

the characteristics of the studies with the thematic categories; interpreting and discussing the limitations and implications for future practice and research.

As noted, the included studies focus primarily on Europe and Brazil, followed by Asia, Oceania, and North America. According to the Brazilian Institute of Oil, Gas and Biofuels [IBP] (2017), in recent years the number of offshore decommissioning projects has grown, mainly due to the end of the useful life of several fields that started their operations in the 1970s, especially the North Sea. Given this scenario, the increase in assets destined for decommissioning, combined with increasingly stringent environmental and regulatory rules for offshore activities, has made the demobilization of production infrastructures a priority for *offshore companies. Thus, the deactivation of these fields will soon require a significant effort.*

Brazil, being a major *player* in the energy sector, is widely recognized for its predominantly renewable energy matrix and for its active role in formulating the global energy transition agenda. In this context, the debate on the fate of oil and gas facilities, both nationally and internationally, needs to be among the main priorities of energy planning and the country's positioning strategy (FGV Energia, 2024). In view of the different realities of the countries with the theme, offshore decommissioning varies greatly, reflecting the particularities of each market and the stage of development of their oil and gas industries; which consequently affects the stability of research demonstrated in the systematic review in the period from 2009 to 2017 and growth from 2019 onwards on the subject in question (FGV Energia, 2022).

Based on the analysis of the findings on worker health and safety, the management and assessment of risks, in the activities present in each offshore decommissioning alternative, have been widely recognized and debated within the conventions in order to ensure, with more knowledge and efficiency, the safety of operations (Khalidov et al., 2021). It is necessary to develop plans that present clear proposals for the management of industrial safety risks, based on detailed risk assessment and the implementation of safety measures during the engineering support and execution phases of the works. It is necessary to consider several factors, such as: the variation of hazard characteristics at each stage of decommissioning; the provision of more accurate information on the risks and dangers involved; the proper management of changes; the implementation, monitoring and evaluation of safe working methods; and interaction with regulatory authorities and stakeholders. However, there are still significant gaps in the literature regarding the mapping of these specific risks in each phase of these activities. Thus, the lack of data has a direct impact on the difficulty of developing adequate procedures to ensure the health and safety of the workers involved (Cunha et al., 2022; Khalidov et al., 2021).

On the other hand, the adoption of methodologies such as multicriteria evaluation and the quantitative impact matrix open up new possibilities for the advancement of research in this area, since they provide a more detailed and structured approach to the identification and analysis of risks, taking into account the execution of safer and more sustainable activities; prioritizing control measures based on a more integrated and quantitative view (Caprace et al., 2023; Souza et al., 2022). In this approach, the use of multicriteria methodologies allows the different alternatives to be evaluated based on multiple variables, such as health and safety, socioeconomic, technical, environmental, and waste management aspects, allowing both the criteria and their weights to be adjusted flexibly, according to the particularities of each reality (Borges, 2018). However, although these methodologies - Multicriteria Analysis and Quantitative Impact Matrix - represent a promising path, there is still a significant lack of research and concrete data on the part of operators that formulate the Facility Decommissioning Program (PDI) that can support their practical application in real scenarios of decommissioning offshore production systems oil and gas, to deepen the criterion of workers' health and safety (Fowler et al., 2014; Al-Ghuribi et al., 2016).

In the context of decommissioning activities of oil and gas production systems, legislation and regulatory bodies play a key role in defining the criteria and procedures related to the health and safety of workers. Seven articles in this review address the importance of regulatory and inspection bodies in this process, and it is advised, as a central aspect of this regulatory diversity, the adaptation of standards to local geographical, environmental, and social conditions (Al-Ghuribi et al., 2016). For example, countries with a high number of *offshore* platforms may have stricter requirements in terms of monitoring and mitigating environmental risks, while nations with less developed sectors may focus on guidelines related to occupational safety due to the lack of advanced infrastructure. This creates a fragmented regulatory landscape, where safe and environmentally responsible decommissioning practices can vary significantly (Madi, 2018).

Contextualizing the current scenario in Brazil, in which some challenges prevail for regulatory agencies (ANP, IBAMA and the Brazilian Navy), the clash arises on multiple fronts: issues related to waste management and port infrastructure; service chain specialized in decommissioning and; the country's inexperience in this type of operation. Therefore, it is noted that, despite the regulatory advances, with the publication of ANP Resolution No. 817/2020, it is still possible to observe a fragmented normative scenario between different agencies. This results in a dispersed regulation, composed of standards that often lack coordination with other sectors and with industry (Steenhagen, 2020). Another additional aspect refers to the fact that

decision-making processes are still conducted independently, with different deadlines and procedures, which hinders the efficiency and articulation of regulatory activities in this context (Steenhagen, 2020).

Universities play a significant role in the evolution of decommissioning practices, especially when conducting research focused on the analysis of multiple criteria that influence these operations (Cunha et al., 2022). By analyzing the risks inherent to occupational health and worker safety in *offshore* environments focused on the removal of *subsea* equipment, academic institutions not only deepen scientific knowledge, but also offer technical subsidies for regulatory bodies to adjust their guidelines more effectively, based on evidence (DescomSub, 2024). This strengthens the authorities' ability to anticipate and mitigate potential risks during decommissioning, promoting a cycle of continuous improvements.

In this sense, the ergonomics of the activity can contribute significantly to health and safety in decommissioning projects, recognizing workers as active actors who build and modify their ways of working (Falzon, 2006). It is possible to understand work and build the conception of a project, bringing it closer to real work through the participation of workers in the processes of improvement and transformation; taking into account the Characteristic Action Situations (SAC) that can identify sources of diversity and variability and provide useful information about the situations of existing activities (Béguin, 2006; Nascimento & Rocha, 2021).

Another aspect to be analyzed is the issue of decommissioning confronting Ergonomics with a major challenge not mentioned in the literature review, which goes beyond the restructuring of working conditions. This process demands a deep reflection on the reuse of materials, the economic model of the enterprises and the creation of new development opportunities, with a view to the territory. The end-of-life processes of the means of production involve not only the closure of activities, but also the need to rethink waste management and the economic and social impact of these transformations. The Economy of Functionality and Cooperation (EFC) proposes a new way of thinking about economic development, integrating companies, communities and local managers in a cooperative way. In this model, decommissioning can be seen as an opportunity to reintegrate territories into more sustainable and resilient productive ecosystems (Du Tertre et al., 2019).

However, the implementation of this approach requires a more robust social and economic commitment, which takes into account local specificities and the public policies necessary to make its application viable. In Brazil, where policies aimed at sustainability are still solidifying, the Circular Economy can generate innovation, but its effectiveness depends on a more consistent integration of the economic and social dimensions and on a reflection on

new business models that respect the environment and meet the needs of the local community (Lima et al., 2022; Pereira & Messias, 2024).

5. Conclusion

The decommissioning of offshore installations faces complex challenges regarding the safety and health of workers. From the systematic review of the literature, a scarcity of detailed and specific information was evidenced that addresses the reality in this context. Although the studies analyzed contribute significantly, most research still focuses on other aspects, leaving a considerable gap in the approach to the risks faced by professionals. The limitations found refer to the lack of data on the subject, which promote a significant reflection on the reality of health and safety. It is necessary to recognize the limits of research and address them in a proactive manner. This may include investing in methodologies that seek to improve current methods; making them reflect the operational reality through the monitoring of work activities and the management models of work activities and waste use.

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