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Social aspects in the process of mine closure: evolution and avenues for future research agenda

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Abstract

Historically, the undertaking of mine closure has emphasised facility decommissioning, environmental recovery and remediation, and the adoption of measures and programs that promote the physical and chemical stability of the mining area. This fundamental concern with the physical and environmental aspects of closure allowed for the development of deep knowledge of the technical environmental issues involved. However, the integration of social aspects into the process of mine closure is a more recent theme. The effects of a mine closure on the community can persist for many years after a mine ceases operations, which causes several negative socio-economic impacts on the physical and mental wellbeing of residents. This paper mainly discusses the theoretical evolution of the integration of social impacts into mine closure studies. Based on a systematic literature review on mine closure, the results show a recent trend, although still incipient, of valuing social aspects. Against this backdrop, three main analytical categories emerge from the literature when considering the social dimension of mine closure and the post-mining period: the social licence to operate, engagement and participation, and vulnerability.

Keywords: *social aspects, mine closure, engagement, social licence to operate, vulnerability*

1 Introduction

Historically, mine closure activities have prioritised facility decommissioning, environmental remediation, and rehabilitation. Furthermore, they have implemented programs and activities that promote the physical and chemical stability of the mining area (Beckett & Keeling 2019; Unger et al. 2020; Vivoda et al. 2019). This necessary concern with the physical and environmental aspects of mine closure consequently allowed for the development of deep knowledge of the technical and environmental issues involved. However, the integration of social aspects into the process of mine closure is a more recent theme (Beckett & Keeling 2019; Xavier 2014). This assertion is supported by the evolution of the theoretical construction of the subject of mine closure in the Web-of-Science (WoS) database. From 1968 to 2020, 1,851 articles were published on mine closure, of which 217 discussed the process of mine closure from the perspective of its social impacts on territories. Although the social aspects emerge as evolving knowledge, increasingly drawing the attention of mining researchers, the small number of publications on social issues suggests a lesser emphasis on these aspects within the literature (Bainton & Holcombe 2018). The effects of a mine closure on a community can persist for many years after a mine ceases operations, which causes several negative socio-economic impacts on the physical and mental wellbeing of residents (Xavier et al. 2015). In such a scenario, two main questions arise: What are the implications of the mine closure process for the sustainable development of the territory? How are these social impacts anticipated and mitigated to ensure a post-mining transition path that is aligned with sustainable development principles? This paper discusses the theoretical evolution of the integration of social impacts into mine closure studies. The objective of this research is to discuss the theoretical evolution of the subject of mine closure while identifying future pathways for the integration of social impacts. The chosen methodology was a systematic literature review of articles published in the WoS, supported by content analysis using VOSviewer and NVivo software.

2 Selection of the articles analysed

This study analyses the evolution of social aspects with respect to mine closure in academic literature, based on a systematic review of the literature and content analysis supported by NVivo and VOSviewer software. The database chosen was the WoS, a reference and citation platform for accessing and supporting scientific research. WoS is a platform that provides access to a large pool of databases, offering comprehensive citation data for a wide range of academic disciplines. It is regarded as one of the most complete platforms for accessing academic content. Initially, we sought to identify studies that had the following terms in English among their main topics, in relation to the process of mine closing operations: 'Mining Closure', 'Post-Mining Transition', 'Closure Relinquishment', 'Mining Downscaling', 'Decommissioning'. In this first stage, 1,851 articles were selected. Two tests were then run: first, the frequency of synonym words and literature auto-code in NVivo and, second, a cluster/dendrogram in VOSviewer/NVivo. The terms 'social' and 'local development' were identified within 217 articles in the second stage. This batch of 217 articles, or 12% of the papers, indicated the following theme: environment related to local development and social issues. Finally, in the third stage of the study, 35 articles were selected whose themes presented units of analysis with a social focus. To achieve the identification in the third stage, the abstracts and keywords of the 217 articles were organised in NVivo in order to select the articles with the highest volume of discussion on social issues.

3 Theoretical evolution in the subject of mine closure

3.1 Quantitative evolution of theoretical work

Regarding the base of 1,851 articles with the terms related to the ending of mining operations, the first publication was in the late 1960s, but until the 1990s, less than 10 publications had been made on this topic. Figure 1 shows that, from the beginning of the 1990s, publications began to increase gradually until 2010.

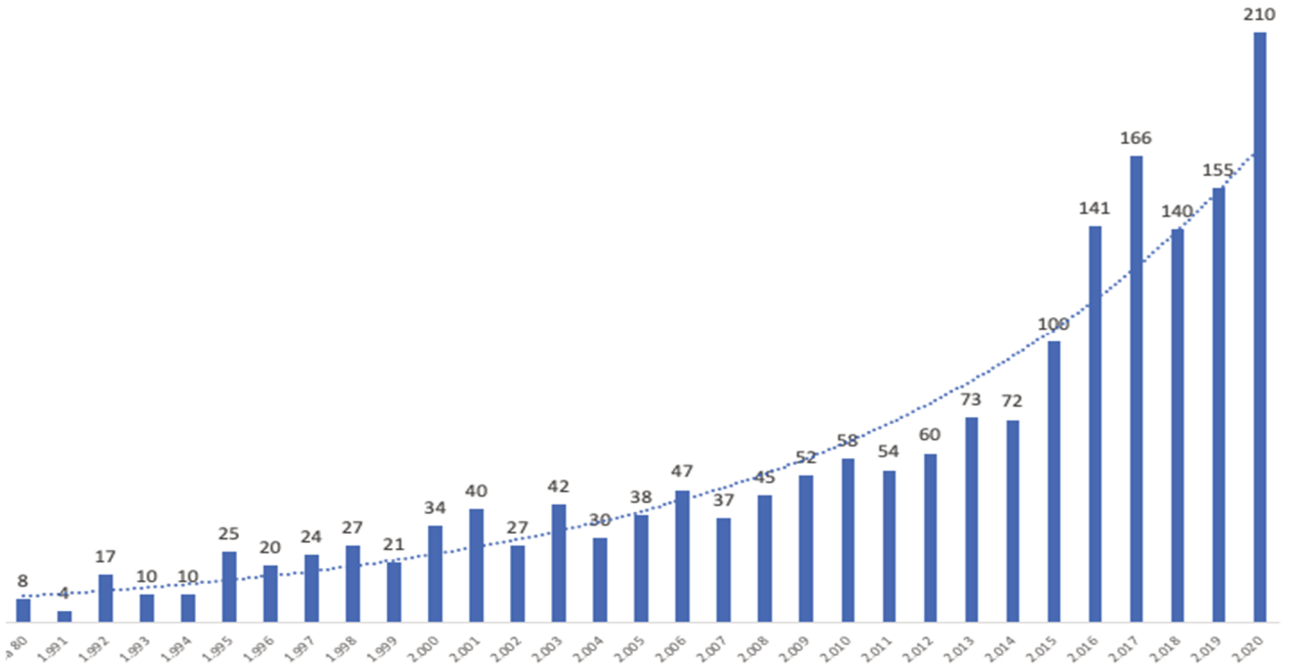

Figure 1 Evolution of publications on mine closure. Source: authors' own, based on Web-of-Science data

Yet only from 2015 had the theme grown in a more accelerated way. More than 50% of the articles were written from 2015 to 2020, with 210 articles being published in 2020 itself, indicating a strong trend of increasing interest within academic publications on the subject.

Countries with the most publications were noted: the United States (288), Canada (266), China (233), Australia (207), and South Africa (138). All these countries have significant mining activities. Germany, England, Spain, France, and Poland add to this group with a high number of publications on the subject. Brazil is 12th on this list, with 44 publications. One point that stands out is the fact that in the list of the 10 countries with the highest number of publications, only South Africa is considered a developing country. The universities to which the authors of these studies are affiliated were also surveyed, highlighting Australia, with three institutions, having the highest number of universities among those that most publish on mine closure, followed by China and Canada with two institutions each. Regarding the most frequent topics in the literature on mine closure, Figure 2 shows the most frequent words in two blocks of selected tags. NVivo's Auto-Code function identified themes by means of the most cited and grouped words in scientific papers.

Figure 2 Visualisation of the main words by block (keywords and abstracts). Source: authors' own, from NVivo and Web-of-Science data – word search and tag cloud

In the block to the left of Figure 2, with 1,851 articles analysed, tags were identified for themes related to operational and design aspects (a count of 1,230), control of mine operations (1,523), mine closure (5,191), protection and ongoing maintenance (316), environment (3,011), engineering (2,234), conflicts and those affected by them (984), evaluation (2,191), power of stakeholders (792), government (1,027), and complaints (685). The size and colour saturation of the tags relate to the frequency of these observations in this tag-cloud style representation. In the block to the right, with 217 articles analysed, we can observe the words affected (138), condition (124), design (129), mine closure (1,755), family (21), danger (21), poor (33), assessment (232), environment (534), regulation (52), complaint (46), positive (141), development (528), employment (21), agreement (40), decision (129), culture (64), dependent (110), faith (19), and economy (77).

Complementing the previous analysis, VOSviewer software was used in 'text data mining' to create, visualise, and explore scientific maps (Van Eck & Waltman 2019). Figure 3 shows the density visualisation of the co-occurrence of the keywords within the 1,851 articles.

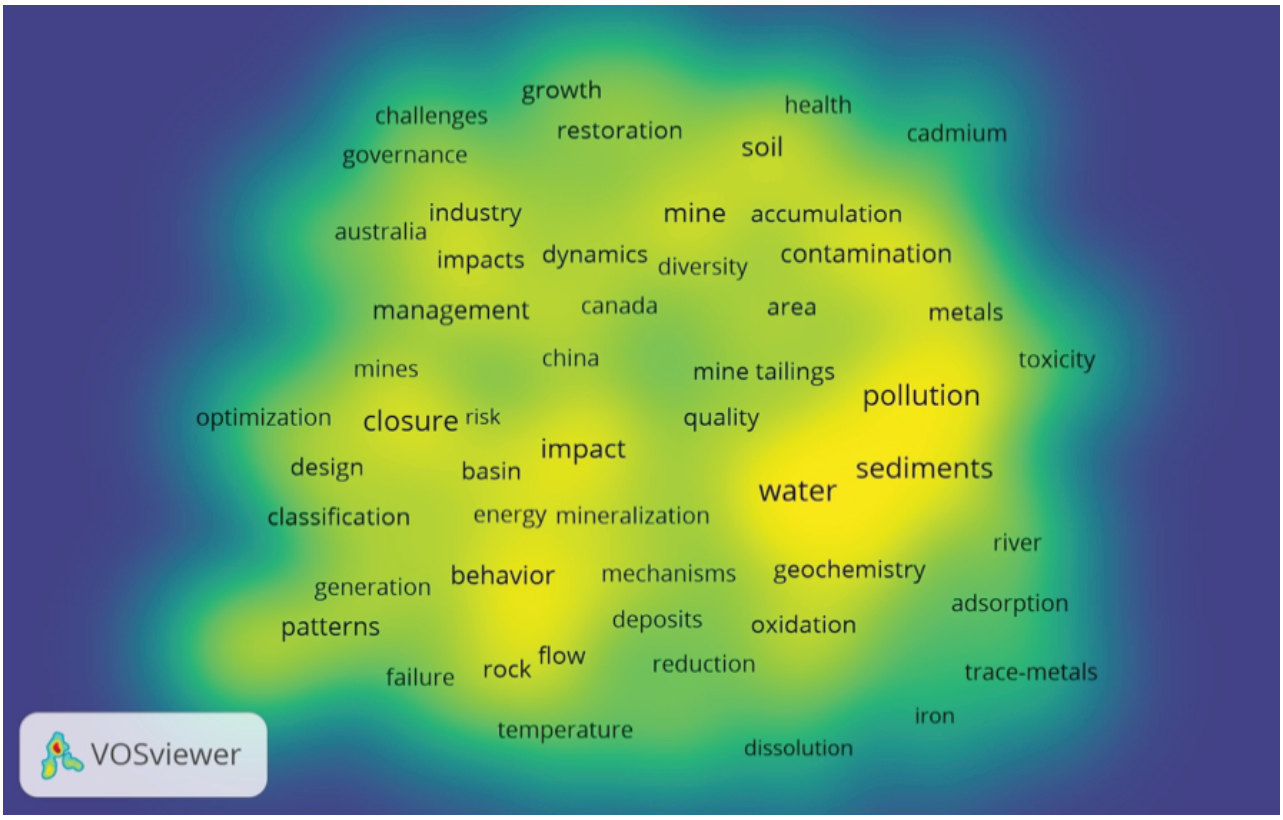

Figure 3 'Density visualisation' (keyword incidence) (Source: authors' own, using VOSviewer and WoS data)

The word cloud presentation given by VOSviewer corroborates the findings of the NVivo algorithm, despite its use of a different algorithm altogether. Such inference is not invalid considering that the database is the same, using a large enough '*n*' (*n* = 1,851) to conclude that there is statistical significance to this comparison (Chung & Zhong 2001), even if for mere graphical representation. There is a dense region of studies focused on contamination, pollution, sediments, water, and geochemistry; a second region concentrating on risks, impacts, and water basins; and a third region grouping the management of impacts and ecosystems. In other words, there is a strengthening of the argument that when it comes to the subject of mine closure, the environmental perspective is emphasised. In the second stage of the study, which considered a base of 217 articles, an author co-citation analysis was performed using the data exports generated by the VOSviewer algorithm and consolidating them into tables in MS Excel. This made it possible to organise the articles by considering the numbers of citations within the set of 217 papers. The algorithm identified 10,692 references cited among the 217 articles, and presented a ranking based on the number of times each is cited, allowing for the identification of studies of greater relevance and influence, which can be considered as seminal. When investigating the top 10 in the ranking, case studies are seen that contemplate the sustainable development and mine closure nexus in Australia, Africa, and China. For example, the works of Andrews-Speed et al. (2005) and Neil et al. (1992) support several case studies of the 217 base: Babi et al. (2016); Nel & Binns (2002); Pehoiu et al. (2019); Zobrist et al. (2009). In the other portion investigated, it was possible to select important themes to be explored that are not exclusively restricted to the keywords that generated the base of 217 documents. Such themes point to several issues: engagement (Hamann 2004), social conflicts (Bebbington et al. 2008), vulnerability, community participation, the social licence to operate (SLO), and the acceptance of the mining process and risk management (Laurence 2006).

The same exercise was done for the base of 35 articles obtained in the third stage, and with the results, a comparison of both stage rankings was made. It was noted that seven out of the first 10 seminal articles of stage 3 were also among the first 10 of stage 2 (base of 217), which shows the consistency in the filter used in the transition from stage 2 to 3, an exercise conducted under the observation of experts. Based on the

35 articles of the third stage, the co-occurrence analysis of keywords was performed with VOSviewer software and is shown in Figure 4.

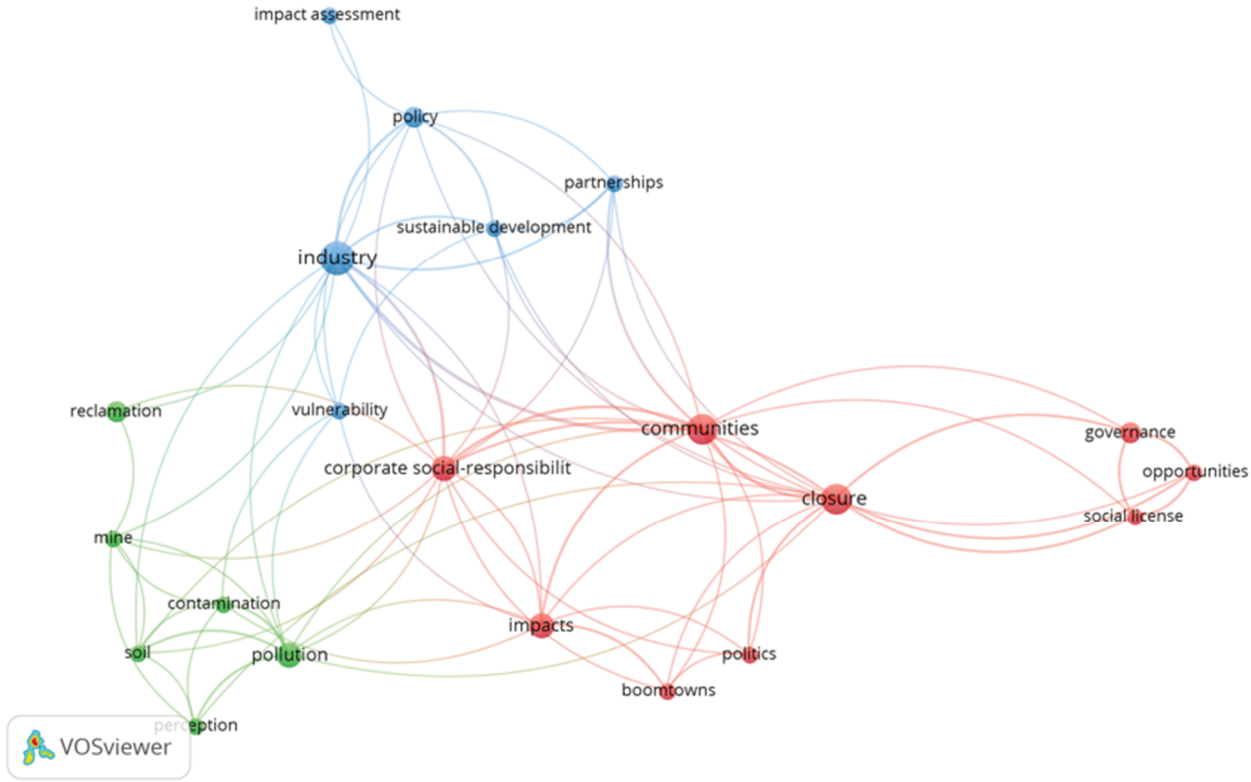

Figure 4 Map of the co-occurrence relationships of keywords. Source: authors' own, using VOSviewer and WoS data

VOSviewer assists in surveying the most frequent words and presents a visualisation with an array of nodes and clusters, as in Figure 4. A node signals that there is some relationship between the terms. The proximity of nodes indicates the intensity of relationships between them. The grouping of nodes by affinity and intensity is called a cluster (Van Eck & Waltman 2019). The key terms were identified using the Keywords Plus function – WoS technology that maps words from titles and not only from those registered by the authors. A total of 122 keywords were identified (considering aggregations of synonyms) for which the following filters were applied: minimum of two occurrences of the keyword (n = 26) and exclusion of words outside the scope of this research, such as framework, free state goldfields, land use, resource-management, and management (n = 21). The algorithm grouped the nodes identified with close relationship intensities into three clusters. Therefore, Figure 4 shows the co-occurrence relations aggregated into three clusters, with red indicating relations with communities, blue indicating issues related to the mining industry, and green indicating environmental issues. In the red cluster, the terms 'closure' and 'communities' are at the centre of the entire network, with the issue of 'closure' being the central theme of this paper. It is noteworthy that 'communities' presented itself as an issue with greater representativeness due to the diameter of its circumference and its links to all the nodes of the interaction chain. Furthermore, in the red cluster, there is an interconnection between SLO, closing, and corporate social responsibility. With that said, it can be seen that mine closure is related to impacts on communities, the issue of social responsibility and SLO, as well as governance. The other cluster, in blue, shows the mining industry itself as the major node, directly related to issues of vulnerability, sustainable development, and partnership. These issues still relate to 'communities' and environmental issues. From Figure 4 it can be inferred that there is a trend towards discussions on the role of industry in sustainable development, as well as issues associated with partnerships. Vulnerability and impact assessment are also highlighted as important elements in this cluster. The third group, in green, is highlighted by pollution and other terms linked to the physical-environmental context, showing that even

after the effort to delineate the database on mine closure by seeking a base of observations with a social focus, the environmental perspective remains prominent.

4 Qualitative evolution of theoretical work

From 1968 to 1982, most studies investigated the methods of engineering and of chemistry or physics regarding mine operations and their closure or decommissioning (Pariseau & Eitani 1981). During this period, only two articles with social indications and a legal slant were identified. The first study was on socio-economic policies in mine closures, through a case study in Ontario, Canada (Hegadoren & Day 1981). The other study aimed to analyse the use of federal force and the development of laws and regulations for mine closure. This reflects the aftermath of the coal mine explosion in which 78 workers died in December 1972, in Farmington, West Virginia, USA. This new research agenda was reinforced by the Chernobyl disaster in the former Soviet Union in 1986 (Maul et al. 1993). From 1991 to 1995, research on radioactive mines, uranium mine operations, waste management at the closing of operations, and environmental impacts on communities was expanded (Maul et al. 1993; Xu & Genin 1994).

The regulatory agenda has become an important driver for mining stakeholders: government, business, and society. Countries such as Germany, the United States, Australia, and Canada have increased their publications on mining industry laws and regulations. This focus of studies lasted until 2000, when a new phase of the discussion on mine closure and its social aspects began, fostering a critical deepening of this phenomenon. To understand this process, the third methodological step focused on the content analysis of the 35 selected articles. First, a concern with the issue of employment is observed in these articles, influenced by the participation of trade unions in the debate (Rhee et al. 2018; Spence 1998), as well as a look at the issue of environmental and social justice.

These articles also show an increase in studies focused on the decline of the global coal market, and the pressure for economic transition is seen, as themes such as unemployment, coal-producing mining communities, environmental regulation, and ecological revitalisation to benefit local communities are expanded. Interest also grows in the socio-economic impact of fossil fuel substitution and investments in renewable energy, alongside the impact on job losses. Therefore, it is a period marked by diverse themes: coal mine closures and the post-closure impact, community tensions and wellbeing, including social and legal aspects, carbon emission reduction/climate change and jobs in the fossil fuel sector, workers' family life, food security, health, and migration. The participation of the State also gains relevance, highlighting the importance of seeking a new social discourse in mining areas involving public authorities, mining companies, and communities. Finally, the matter of an operation's plan for mine closure presents elements about mining culture and a sense of identity. In this regard, the subject paves the way for the analytical dimensions of the SLO, engagement, participation, and vulnerability. Based on the final cut of the 35 scientific articles, these analytical dimensions are presented and discussed in the following sections, for the purpose of contributing to a future research agenda on mine closure operations.

4.1 Social licence to operate

Community support or opposition is a fundamental issue for establishing and successfully executing mining projects (Falck & Spangenberg 2014). In order to obtain the SLO, social acceptance of the activities developed by the industry must be obtained (Hall et al. 2015). The term, which has been gaining relevance in academic publications in recent years (Ford & Williams 2016), and represents a crucial factor for successful mining operations (Lacey et al. 2017; Santiago et al. 2021), also appears repeatedly in this base of analysed papers on mine closure. Some articles make only a single mention of SLO in the introduction, or when they talk about existing literature, but do not go deeper into the subject (Knierzinger & Sopelle 2019; Srikanth & Nathan 2018; Zvarivadza 2018). Cole & Broadhurst (2020), on the other hand, cite the social and labour plans that are a requirement of mining in South Africa, which plays an important role as part of the strategy to achieve an SLO; however, they limit themselves to only mentioning the concept. In a similar vein, other articles submit

that social and labour plans in South Africa have practically become the social licence itself (Marais 2013; Marais et al. 2017, 2018a).

Taking a more critical line on the SLO concept, Rhee et al. (2018) raise issues around the SLO, by showing the case of a company that, despite investments and efforts to include the local community in the socio-environmental agenda, suffers from a lack of approval, mainly because of perceptions related to soil erosion in local properties. A mining company also rarely has either complete approval or zero acceptance, being unlikely that either all or no stakeholders at all will approve of its mining activities (Kivinen et al. 2018). Marais et al. (2017) further point out questions and inconsistencies in the use of this term and the lack of SLO practices, especially in mine closure procedures. According to them, despite much talk about planning for closure, there is little evidence that social licence is being used to plan for a post-mining economy. However, if we consider that the closure of a mining operation or project also generates significant social and environmental impacts, and that in order to achieve the SLO it is necessary to obtain social acceptance of the activities developed by the industry (Hall et al. 2015), it is appropriate to consider that the SLO concept should also be extended to the process of decommissioning and closure of mines. It is vital to leave a legacy of development and positive impact for the community, and to that end, the concept of a social licence to close has recently emerged, which seeks to encompass a more holistic view of the impacts of mine closure on stakeholders. Better planning for closure would help local communities prepare and adapt accordingly. It would also allow practices to be implemented to sustain future socio-economic wellbeing and promote beneficial re-use of project assets (Kivinen et al. 2018). However, it is necessary that the construction of the concept of a social licence to close takes into consideration the inconsistencies and criticisms pointed out regarding the SLO. For example, the engagement and participation of communities is something fundamental to the acquisition of an SLO (Mayes et al. 2013), yet little attention has been paid to collaborative strategies in social licence processes (Marais et al. 2017). The lack of representation, engagement, and participation of local communities ends up being a determining factor of mining conflicts and resistance from certain groups (Kivinen et al. 2018), and therefore community participation is considered fundamental for planning a post-mining economy (Marais et al. 2017). The next topic assesses how engagement and participation appear in more detail within this base of studies, and how they should be considered in these mine closure procedures.

4.2 Engagement and participation

Participation is considered an indicator of the quality of the relationship between company and community, with Bowles et al. (2019) establishing a link between participation and just procedures, a concept supported by Zhao et al. (2020). For Moffat & Zhang (2014), procedural justice is a determining element for establishing trust and approval of a project, which is directly related to the foundations of the SLO. Cesare & Maxwell (2003) argue that the involvement of governments, communities, and other stakeholders can contribute to the development of a strong mineral policy, and further highlight the important role that communities have in the development of mine closure plans and activities, as also advocated by Odell et al. (2011). Giving the community a voice in this process, however, is not a trivial matter. Vivoda et al. (2019), analysed the regulatory tools of the main mineral jurisdictions in New South Wales, Queensland, and Western Australia, highlighting that while there is recognition of the importance of integrating the social dimension into mine closure, guidelines are generic and often without specific legislation or guiding policies. The authors also point out that regulatory agencies are satisfied with evidence that community engagement has occurred, and do not necessarily require the demonstration of evidence-based results and impact analyses.

Cesare & Maxwell (2003) point out that mining activities result in negative externalities for communities, and that growing scrutiny, demand, and expectations from communities, consumers, civil society, and authorities force mining companies to demonstrate their contribution to the development of communities, and the physical, social, and economic environment. Such expectation results in pressure for greater participation in decision-making processes about the future use of mined land. Thus, there seems to be a consensus among the reviewed authors on the importance of local community participation in mine closure procedures

(Bowles et al. 2019; Cesare & Maxwell 2003; Odell et al. 2011; Vivoda et al. 2019). Another point of consensus among the reviewed authors is that the process of effective and inclusive consultation should encompass the entire mine lifecycle, and not only during the phase of closure (Bowles et al. 2019; Cesare & Maxwell 2003; Everingham et al. 2018; Odell et al. 2011). Odell et al. (2011) argue that planning activities for mine closure should be expanded to include the concerns of local communities related to the wellbeing of the population. These elements must be monitored with the development of specific indicators that make sense at a local level and highlight the importance of participatory monitoring activities, in both environmental or socio-economic aspects.

The stakeholder identification process is considered a vital activity for the undertaking of mine closure (Cesare & Maxwell 2003). Everingham et al. (2018) suggest that individuals representing the diversity of local communities, potentially affected in some way by the closure and decisions about future land use, should participate in the decisions. The authors also point out that representatives of local communities have empirical knowledge that gives them unique perspectives and insights, which in turn becomes critical data and information for the management of the territory. While there is consensus on the importance of participation, still there does not seem to be much clarity on how to define how participation happens (Everingham et al. 2018), nor how to ensure that the right conditions exist for effective participation. A strong legal framework can force companies to involve communities and broaden the consultation processes but, on the other hand, it does not ensure effective participation (Cesare & Maxwell 2003). Weak participation of communities in the debate about the future of the territory can amplify the impacts post-closure. Kivinen et al. (2018) observed that even 20 years after of the closure of a mine in Finland, community members remain concerned about the flora, water quality, and soil contamination. They claim to lack information and knowledge about local environmental conditions, generating an ongoing sense of mistrust, and influencing their relationship with the local territory and landscape. In that regard, it is argued that the quality of the SLO and participation in the closure process are directly linked to the context of social vulnerability of the territory.

4.3 Vulnerability

Vulnerability of the local population in mining territories may occur at various stages within the lifecycle of mining projects. For example, in the operational phase, in addition to the obvious environmental impacts, more vulnerable populations have to face rising housing prices and the inadequacy of the public sector to provide a suitable housing infrastructure in order to compensate for increased housing costs, leading to the emergence of substandard housing (Feng et al. 2020; Marais et al. 2018b). Impacts do not stop once operations cease, however, as the process of closing mines can potentiate other risks. Siyongwana & Shabalala (2019) point to a set of risks inherent in mine closure, such as unemployment, crime, depression, substance abuse, and increased poverty. The situation is aggravated when local residents lack the knowledge and skills necessary to sustain their livelihood. As mentioned, a significant part of the literature produced focuses on physical and chemical stability and ecological restoration, limiting itself to the inclusion of biophysical indicators (Rosa et al. 2018). Yet, even considering the accumulated knowledge of ecosystem restoration in mining territories, the complexity of a closure process challenges the effectiveness of actions when combining economic, environmental, and ecological vulnerability. For Feng et al. (2020), problems of degradation of water resources are not limited to the reduction of water supply and its quality, but also include social problems, such as health issues, resulting from the process. This can have economic consequences, as in the case of communities that depend on fishing and agriculture for their livelihood. Using the example of the Hongshan mine, the authors point out that water contamination increased with the closure of the mine, significantly reducing the availability of water resources and negatively impacting human health and sustainable local socio-economic development. The authors conclude that environmental risks in relation to water resources were dynamic, even increasing in the post-mining period, with significant effects on health and on the performance of industrial and agricultural activities, harming the economic recovery of the territory. Therefore, if environmental challenges persist post-closure, understanding the risks and social impacts generated in this process is even more complex, as they tend to worsen in the context of the social, economic, and ecological vulnerability of local populations. It is also important to highlight that the set of

vulnerable actors is also dynamic in the process of mine closure. Actors not considered in the operation phase, such as former employees and service providers, as well as their families, expand the group of the vulnerable population affected when decisions regarding the future of the territory are not properly considered (Mayes et al. 2013).

In this respect, the debate on vulnerability reinforces the challenges of distributive justice, both during operations and post-closure. In the first case, the difficulty of distributing resources generated by mining in an equitable manner that benefits the local population as a whole is considered. In the second case, it is argued that the closure of mines in vulnerable areas can potentiate risks to the community in the post-operation period. To overcome the challenges of mine closures, as previously mentioned, researchers have valued dialogue with vulnerable populations as the most effective mechanism of corporate social responsibility (Mayes et al. 2013). For the authors, dialogue, understood as open and interactive communication, enables greater engagement of the local population. The company–community dialogue is highlighted in the literature as an important mechanism for crossing corporate boundaries and including the voice of the most vulnerable groups in the broader understanding of the consequences of companies' operational procedures. This dialogue can be considered efficient, in the sense that, unlike employees and suppliers, these groups would be free to express opinions that are not in line with what business representatives would necessarily like to hear. It is also important to highlight that this dialogue, in the case of the start-up and operation of a mineral project, is packaged in a set of terms referring to the community as the host and partner, responsible for granting the company an SLO in order to ensure a convergence of interests between community and company, constituting an ideal win-win scenario (Mayes et al. 2013).

This ideal scenario, however, seems hardly feasible when considering the reality in certain contexts where an asymmetry of power prevails between the parties involved. For Parent & Deephouse (2007), the relevance of a stakeholder is given by its legitimacy and its ability to affect the business from the company's perspective, added to the sense of urgency by managers in recognising the risk to the business. In this risk-oriented approach to business, populations with low social capital and limited ability to affect corporate and government decisions are unlikely to be considered an important factor of concern in the decision-making process by companies. Furthermore, knowledge on stakeholder engagement has focused much more on managing stakeholder behaviour than on understanding the social consequences of corporate actions for the community. In such cases, stakeholder theory proves to be much more effective in serving the interests of companies in shaping and controlling the behaviour of local representatives, especially when it comes to more vulnerable groups, ensuring that their interests are protected (Mayes et al. 2013). The authors' study focusing on BHP Billiton's sudden closure of a nickel mine in Australia in 2019 showed that the dialogue held with vulnerable groups not only solidified the company's interests but also succeeded in co-opting vulnerable groups in order to contribute to the process of securing those interests.

Another challenge identified in the post-closure stage is the choice of economic alternatives to be encouraged in the territory. Often, an option at this time can be the expansion of other industrial sectors, understood as being essential in reducing local vulnerability in the decline of production and during mine closure phases. However, environmental restrictions due to the process of environmental degradation can become a limiting factor. With that in mind, the focus could be on stimulating service activities as a way to contribute to the sustainable development of the territory (Marais & Nel 2016). This challenge is compounded by a number of characteristics observed in the closure process, where vulnerability is established long before the closure takes place. Ntema et al. (2017) show the difficulty for non-mineral activities to consolidate or perpetuate themselves in periods of mine operation in a survey conducted in Australia. They also found that there were few cases in which strategies for closure were considered at the planning stage of the enterprise. In addition, when operations begin, most investments are directed to infrastructure and leisure projects. Finally, they add that most of the mining municipalities were in remote regions, hindering the process of economic diversification and improvement of the population's quality of life. Rhee et al. (2018), meanwhile, complement the local vulnerability framework by discussing the weakness of mineral project ties to local reality. As such, most of the resources generated, in spite of the low efficiency of municipalities in investing in robust local development projects, are directed to the host country at the

expense of the local host region. Furthermore, it is possible to infer that the magnitude of investments in developing countries is primarily focused on the market of rich countries. These mega investments in regions such as Latin America, Africa, and Asia attract the interest of large international investors, who are a priority in the decision-making processes of organisations that are part of the open capital market. This, therefore, directs the commitment of local mineral projects to the profitability provided to large investment funds at the expense of risks to the local community during the period of operation and closure of mines.

5 Final considerations

This research shows that only in recent years have social issues gained more attention in the literature. The analysis of the results allows us to identify and further explore three analytical categories that stand out in recent literature that address the social aspects critical to the process of mine closure, highlighting community engagement and participation, vulnerability, and the SLO. Effective participation will only occur when the impacted communities participate in the discussions and decision-making procedures related to the present and future land use. In addition, it must be ensured that all stakeholders have the technical capacity to participate, and it is therefore essential to allocate resources and invest in training programs for communities to strengthen their capacity for dialogue and group decision-making, as well as training on technical aspects related to operation, closure, and post-closure. The reviewed literature also points out that the regulatory frameworks privilege environmental factors, while being limited in terms of social matters, indicating the need for the legal frameworks and public policies regarding mine closure to be reviewed promptly. Without adequate engagement, inclusive participation mechanisms, and the identification of and effective measures to prevent, reduce, and eliminate vulnerabilities and externalities, the reality of mine closure, even if integrating the environmental dimension, will still be incomplete, inadequate, and unjust. Local communities will continue to reside in the project area and will continue to experience the negative social and environmental consequences resulting from short-sighted closure processes.

As a future research agenda, this paper points to several avenues: the importance of developing a broad legal apparatus to integrate the social dimension into mine closure procedures, the deepening of strategies for empowering the local community in order to reduce the power asymmetry between companies and communities and enable a true process of participation, the incorporation of the SLO into the debate (a theme considered of great relevance in the mineral sector), and the proposal of the social licence to close. These are future research paths that could contribute to a socially just mining process – one that is committed to maintaining ecosystem services, and that puts alternatives for minimising the social, economic, and ecological vulnerability of populations in mining territories at the centre of the debate.

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