CHALLENGES AND PATHWAYS FOR BRAZILIAN MINING SUSTAINABILITY

Wellington Alves, Paula Ferreira, Madalena Araújo
ALGORITMI Research Centre, University of Minho, School of Engineering, Campus de Azurem, Guimarães, Portugal

ABSTRACT

Brazil is one of the world key players in the mining industry. This sector has also a remarkable role on the Brazilian economic and social development. Nonetheless, the economic, social and environmental impacts of the sector have not yet been fully documented, debated or understood in reports presented by companies and public organizations in the country. In this context, this research aims to contribute to this debate by analysing sustainability in the Brazilian mining sector. For this research, the approach has used mostly a qualitative method, interviews, coupled with content analysis of reports of public mining agencies. Results showed that sustainability assessment and communication is still an emergent process in Brazilian mining, since only a few large companies have been reporting their sustainability initiatives. The results provide also evidence of the existing gap between large and small companies, with the latter showing lower levels of awareness of the impact of their activities. Based on these findings, this research has concluded on the need for closer cooperation between government, public mining agencies and companies to raise levels of knowledge and awareness within companies, towards sustainability practices and communication initiatives.

KEYWORDS: Sustainability concept; Mining impact; Sustainability communication; Interviews.

1. Introduction

Over the past two decades, debates and research about impacts of the mining industries have pointed to two different approaches, the first one is centred on the negative effects originated from mining activities, including environmental and social aspects, and the second one on the positive effects, namely the contribution to economic growth through mining activities in many economic depressed regions.

The mining sector relies on extractive activities, which can be highly intrusive. However, these activities play also a fundamental role to society providing minerals which are essential to everyday life and support many other industries which depend on raw materials for their activities and for technological progress. Mining sector is then vital for sustaining population wellbeing and the function of global economies (Gomes et al., 2013, Mancini and Sala, 2018). As Endl et al., (2019) highlighted, primary raw materials are part of the solution and the problem towards achieving the United Nations Sustainable Development Goals.

From a manufacturing perspective, the economic and technological development brings positive consequences for the society and environment. The economic and technological growth has been creating new demands and constraints for industrial activities due to the challenge to manage companies' activities in a sustainable manner (Henckens et al., 2016). However, fundamental mining activities are directly associated to several environmental and social impacts originated by their operational activities. The contribution of mining activities to economic and social development is then a key discussion in mining worldwide with direct consequences on other industrial sectors and even on policy decisions towards sustainable development. Over the years these activities have faced the most difficult challenges to achieving sustainability in this sector (Bui et al., 2017).

The potential impact of a mining operation is dependent on a wide range of local factors, such as the nature of the mineral, the geological and geotechnical parameters, the extraction method, the nature and amount of waste generated (solid, liquid or gases) and the nature and the vulnerability of the environmental component (Castilla-Gómez and Herrera-Herbert, 2015). On regards to social effects, fear over land dispossession, economic marginalization, imperilment of cultural practices and traditional livelihoods, and also the inability to oppose the extractive modes are some of the impacts faced by local communities where mines operate (Peterson St-Laurent and Billon, 2015). Moreover, Hilson (2002) supports that the most

pressing social problems in the mining activities are related with safety and health to both local community and workers. Problems such as overexposure to dust, side effects from excessive noise and vibration, waterborne disease, over exertion and inhalation of noxious gases and habitat destruction are then considered as significant social impacts from mining activities.

Mining companies perform essential activities on regards to the contribution to regions' development, economic growth and poverty reduction (Bansah, 2019) at local and regional level. According to Gamu, Le Billon and Spiegel (2015), in theory, mineral extraction should contribute to development by increasing employment, economic growth and public services, and thus reduce poverty. However, as discussed by Gomes et al., (2013) and Castilla-Gómez and Herrera-Herbert (2015), social impacts of mining are diverse and they can prevail last long after the end of all mining activities where mines are located. For instance, occupational diseases of workers acquired through mining, impacts on the landscape, modification in watercourses and unemployment are some of the most serious social consequences after mines' closure.

The development of strategies addressing key aspects in the fundamental areas related to environment and society, and therefore, their use in establishing the foundations for sustainable mining should be an important step to mitigate the potential impacts originated from mining activities (Castilla-Gómez and Herrera-Herbert, 2015). In order to achieve sustainability in mining companies Hallstedt et al., (2013) suggest a four stage methodology: firstly, to have a common view on sustainability; secondly, to coordinate and integrate tools and methods for sustainable product development in the overall decision-making process; thirdly, to combine widely used initiatives to support corporations in their sustainability efforts, and fourthly, to emphasize the importance of effective communication.

In light of the many challenges faced by mining industries and based on Hallstedt et al., (2013) approach this research investigates various aspects related to sustainability in the mining sector in Brazil including: the sustainability concept and the existence of a common view; the positive and negative impacts originated by this sector and the methods and tools for sustainable product development including the possible use of BAT (Best Available Techniques); the sustainability communication strategies including reporting; and the required routes and initiatives to drive the sector towards sustainability objectives. As such this work aims to assess how sustainability is perceived and considered, by mining companies in Brazil and, with this information, highlight the main challenges and present possible pathways to tackle them.

For this research, qualitative in-depth interviews with experts from the mining sector in Brazil were conducted. The interviews followed a semi-structured guide designed according to a previous literature review on sustainability concept and assessment and on the Brazilian mining sector characterization. Although it was applied to Brazil, the proposed methodology may be used in other regions or countries if adapted to the specific features of each individual mining industry under analysis and the conclusions can offer import implications to support mining companies and policy makers.

The remainder of this paper is organized as follows: section 2 aims to justify the target country of the research by highlighting the importance of the mining sector in Brazil, section 3 presents the context of the research and introduces main aspects related to sustainability in the mining sector such as sustainability concept and the use of sustainability practices including BATs. Section 4 outlines the research design, including construction of the interview guide used as instrument in this research, experts' selection and interviews. Section 5 presents the results from interviews with experts and findings of this research. The paper ends with conclusions and policy implications of this research in section 6.

2. The Brazilian mining sector

The main motivation for this section comes from the recognition of the importance of the mining sector in Brazil and also the significant environmental, social and economic impacts attributed to the mining extraction process. The research published in this particular sector is still scarce. To the best of the researcher's knowledge, frameworks and tools for sustainability performance evaluation especially suited to the mining sector and which take into account the socio-economic conditions of Brazilians are yet far from being fully explored.

From the perspective of mining, Brazil is recognized worldwide for its wealth of geo-diversity and mine deposits. Brazil's geographical area of 8,514,877 Km^2 accounts for its great reserves of minerals, allowing for mines of international quality which position Brazil between Australia, Canada, China and South Africa as among the most important countries in the international market for mineral commodities (DNPM, 2016).

As one of the largest mineral repositories in the world as well as being an important producer and exporter of minerals with high quality ore, the mining sector is one of the mainstays of the Brazilian economy. According to IBRAM, (2012), the Brazilian mining industry has contributed to the country's positive balance of trade, and the outlook for economic activity has been extremely optimistic for the coming decades.

Brazil occupies an enviable position in the worldwide production of raw materials of mineral origin, particularly minerals such as copper, niobium, iron ore, gold, manganese and aluminium; all metallic minerals to strategic Brazilian mineral production. Iron ore deserves special attention owing to the country's position as leading exporter of this mineral.

The Brazilian mining sector is a cross-section present in three sectors of the economy: Primary (mineral research and mining), secondary (mineral transformation) and tertiary (the market, trade) (DNPM, 2017). It covers a wide scope and is highly heterogeneous in terms of segment, ranging from artisanal mining to mining companies with technical excellence in geology, both of which contribute to Brazilian economic growth.

According to IBRAM, (2015), over recent decades, this sector in Brazil has experienced a period of vigorous growth, contributing positively to structural changes in the social and economic sphere. This growth is driven by increased demand for minerals generated by the urbanisation process, not only in Brazil but in emerging countries, where large territorial areas make these countries important players in the global mining picture. According to the International Council on Mining and Metal, the contributions of the mining sector to Brazil's macroeconomics are increasingly significant. Data provided by IBRAM, the Brazilian Mining Institute (2017a), indicate that this sector increased from less than US$ 10 billion in product value in 2000 to around US$ 53.6 billion by 2014 (estimated value) representing 5% of the Brazil's industrial GDP.

As illustrated in Figure 1 **Error! Reference source not found.**, international prices of mineral commodities show a generalized decrease since 2011. This is particularly evident for the first semester of 2015 when compared with 2014. The average price index (US$) of fertilisers, metals/minerals, basic metals and precious metals in 2015 decreased respectively 4.2%, 13.9% and 12.2% comparatively to the second semester of 2014 (DNPM, 2015). Evidences from World Bank Group show that the decrease of prices of metals and fertilizers are explained by the low global demand for metals (especially in China), oversupply and high stock and also, influence of American dollar quotation.

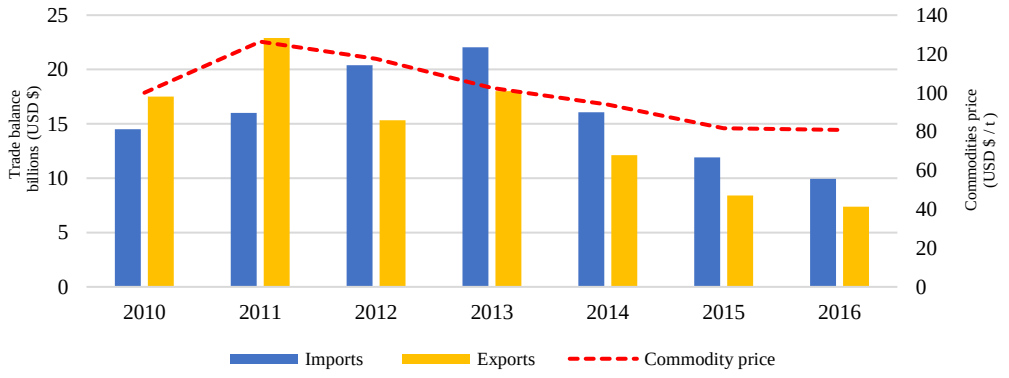

Figure 1: Trade balance of commerce for the mining industry (2010-2016). Source: DPNM, (2016) and World Bank (2016)

The combination of lower global demand and reduction of minerals prices largely contributed to a reduction of the exportation value of the Brazilian mining sector. According to IBRAM (2015) the main factor leading to this reduction is the price decrease of iron mineral in the international market. Also, the World Bank (2015) highlighted the impact of the increase of iron mineral offer, with new market operators and increasing production capacity in both Brazil and Australia, contributing to the decrease of iron mineral price which is one of the most important mineral commodities for Brazil.

Due to the global economic crisis since the second semester of 2013, jobs generated by the mining sector in Brazil have been decelerating. However, this sector remains an important job creator. Activities related to coal mineral extraction, non-metallic mineral extraction, metallic mineral extraction and activities to support minerals extraction in the extractive mineral industry, accounted for a total of 214,070 direct jobs

in the first trimester of 2015 and more than 2.7 millions of workers are involved in activities related to the mining sector in the country (IBRAM, 2015).

Brazil's mining social contribution is significant also on regards to HDI - the Human Development Index. Data from IBRAM show that the HDI of mining towns tends to be the highest one among all towns in each state. Even when mining projects are set up away from major urban areas or even in areas with low social support, it is perceived that these projects bring a tangible potential for regional sustainable development (IBRAM, 2012).

On the negative side, the mining sector in Brazil has been involved in some environmental disasters, with the most recent and mediatic one occurring in November 2015 (in Mariana) and in January 2019 (in Brumadinho) both in the state of Minas Gerais. According to Neves et al. (2016), at that time, Mariana disaster was the worst environmental disaster in the history of Brazilian mining sector. Sixty million m^3 of sludge overwhelmed houses and the historical, cultural and natural heritage of a village in a municipality of Mariana in this state sequence included nearly a million of people without tap water for days, fishing suspended in traditional fisher's village, universities and schools closed in two Brazilian states (Garcia et al., 2017). Additionally, Meira et al. (2016) underlined that there are hundreds of damns with mining waste and more than 40 of them are unstable and at full capacity only in this state. More recently, the Brumadinho disaster clearly demonstrated the relevance of these concerns, as the collapse of the iron ore tailings dam destroyed nearby communities, contaminated soil, water resources and forests and killed hundreds of people (Almeida et al., 2019; Munhoz, 2019; Owen et al., 2020).

Neves et. al. (2016) argued that in Brazil some of the most mining affected ecosystem services are those related to freshwater, such as water provisioning to agriculture, households and support to livelihoods, water filtration, control of erosion and flood. Also Enríquez and Drummond, (2007), highlighted that the interest of indigenous communities and the needs of communities where mining projects are established have not been properly considered. Matlaba et al. (2017) results showed a more positive vision towards mining development for local populations Eastern Amazonia –Brazil. This prevalent positive vision was mainly driven by the social and economic aspects, such as perceived opportunities for jobs, personal income and city development. However, environmental degradation remained as an important concern for the community.

Due to the economic importance of the mining sector to Brazil and its high environmental and social risks, achieving sustainability in all related activities represents one of the most important goals for the sector. However, information on sustainable practices and related reports from Brazilian mining companies are still scarce.

This research seeks to contribute to a better understanding of the Brazilian mining sector in fourfold: by analysing the evolution of the sustainability concept for the mining sector in Brazil; by contributing to a characterization of the current positive and negative impacts originated by this sector, by addressing communication strategies and finally by providing some insights on challenges faced by the sector and strategies to overcome them.

3. Literature review

Over the last decade sustainable development has become one of the most common concerns on the agenda of governments and companies. Almost all governments are committed to sustainable development by integrating economic, environmental and social issues on their policies and regulations.

According to Hami et al. (2015), the emergence of the concept of sustainability reflects a decisive change in global thinking, thus forcing firms to reconsider the way that their business is conducted. With the aim of boosting economic development, firms need to re-establish manufacturing practices, defined in terms of their intra- and inter- organizational practices that integrate environmental, economic and social aspects into operations and business activities.

Bui et al. (2017) support that sustainability can be defined as "an inspiration for a future situation", while the process by which industries and society move from the current *status quo* towards this future situation can be understood as sustainable development.

In this context, the debate about the methods used to evaluate sustainability in the industrial process is growing in academia and industry. The reports and indicators proposed by institutions such as GRI (Global Report Initiative), DJS (Dow Jones Sustainability Index), OECD (Organization for Economic Co-operation and Development), Environmental Indicators for European Union, and EPA (Environmental Protection

Agency), have played an important role in starting the discussion with regard to the need to develop methods that can help companies to evaluate their processes towards environmental sustainability and even social sustainability.

From this perspective and motivated by this fact, a few studies and projects have been conducted with the aim of developing frameworks, models and tools that can help minimize environmental impacts and reduce the consumption of natural resources in the production of goods and services (Avram et al., 2010). A few examples include EFORWOOD Sustainability Impact Assessment Approach (Rametsteiner et al., 2008), ToSIA- Tool for Sustainability Impact Assessment (Lindner, 2010; Werhahn-mees, Palosuo, Garcia-Gonzalo, Röser, & Lindner, 2011), SustainabilityA-Test (Kasperczyk and Knickel, 2006), ExternE - Externalities of Energy (Bachmann, 2012) or VAT- Reduction for environmentally friendly products and services (Oosterhuis, 2009).

According to Dubiński (2013) the concept of "sustainable development" applied to the mining sector has been gaining particular importance because the mining activity is connected with the acquisition of various kinds of exhaustible or non-renewable natural resources. As such, and based on the 1987 United Nations definition of sustainable development "development which meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, p.43), has been questioned if this concept could ever be applied to the mining sector since mining activities are directly associated to a large extraction of non-renewable minerals which compromise their availability for the future generations.

The mining industry plays a crucial role in ensuring an acceptable quality of life for the entire population across the globe. However, their activities have frequently been associated with the effects of extraction of natural resources, creating legacies of unacceptable long-term social and environmental impacts in many parts of the world (Moran et al., 2014). Nonetheless, over recent decades, the number of mining corporations sharing details on their sustainability initiatives in publicly available reports has grown rapidly (Böhling et al., 2017).

The mining sector is often shown in the literature as an example of the way in which negative impacts arise from the production process. These impacts include geographically and culturally negative effects such as air and land pollution resulting from toxics released during extraction and other related processes and water contamination, among others. Suopajärvi et al. (2016) highlighted that social impacts from mining activities are also particularly significant among those living in close proximity to mines. In fact, in spite of the sector's recognized importance at a global level, the negative impacts (especially, on the social and environmental) are mostly concentrated at the local or regional level. On the other hand, mineral extraction activities have been also fostering local development and materialised into economic benefits in different countries, although local benefits still remain ambiguous (Arellano-Yanguas, 2019; Loayza and Rigolini, 2016).

Kogel (2015) supports that minerals are relevant for sustaining the built environmental and modern economics. A key element of sustainable development within the scope of acquisition and the use of natural resources is then the rational and cost-effective extraction of minerals. Minerals provide the basic raw materials for many arrays of manufactured consumer goods and services. In spite of all concerns, mining companies have been an imperative economic activity for many countries and their value and importance to society welfare is undeniable (Leena et al., 2019). People accustomed to the availability of mineral resources forget a most important fact, which is the inevitable depletion of non-renewable resources of raw materials through mineral extraction (Dubiński, 2013). With the high rates of population growth, the demand for minerals is even expected to grow, intensifying the minerals extraction, which reinforces the idea that mining activities are not sustainable.

Despite this, the concept of sustainable development continues to be discussed at length in the current literature. In the mining sector, sustainable mining requires the "evaluation and management of uncertainties and risks which are associated with natural resource development" (Horowitz, 2006). The need for sustainability of mineral resources refers to all stages – from the phase of gathering all documents, through and up to the stage of exploitation, for instance, strategies related with safety of the workers, mineral processing, use of finished raw materials or recycling of raw materials not used (Bluszcz and Kijewska, 2015). Thus, one of the main challenges to sustainable development in the mining sector remains as how to apply this concept on their activities, contributing positively to environmental, social and economic societal aspects, given two major factors intrinsically linked to the sector- firstly minerals deposits are finite, and secondly activities of mining companies are considered to be responsible for several socio-environmental negative impacts.

3.1 Sustainability practices in the mining sector

The implementation of sustainability practices in the mining companies need to address social, environmental and economic aspects. These sustainable practices can be accomplished in different ways.

On regards to economic aspects, in many countries where mines are operated these activities are considered as a major contributor to the economic development. This sector covers broad different activities in in their operations contributing to jobs creation and community development in many regions. Activities such as financing, labour relation on the soft side, exploration, excavation, planning, production, materials handling, management, among others are all activities which contribute to generate jobs and support the social and economic development where mines operate (Sivakumar, Kannan and Murugesan, 2015).

Under an environmental perspective, activities such as recycling and reuse are good examples of sustainable practices towards a more efficient use of the resources through improving mining methods processing methods. (Kogel, 2015).

On regards to the social perspective, mining presents a high occupational risk to workers. As such, health and safety practices have to be considered and are required to overcome these challenges (Kogel, 2015).

Over time these practices should be integrated into a strategic perspective together with decision-makers of mining companies, in order to effectively contribute to sustainable activities. According to Lins and Horwitz, (2007), the creation and or introduction of sustainability practices in the mining sector have to address key issues as summarized in Table 1.

Table 1: Key issues towards sustainability practices in mining (source: Lins and Horwitz, 2007)

Environmental sphere	**Social sphere**	**Economic sphere**
To seek to reduce the emission of toxic substances	*To seek to meet challenges regarding work and community safety*	*To contribute to sustainable growth of the local community*
To promote a better use of water	*To achieve stakeholders' engagement*	*To increase the communities' infrastructures beyond the life cycle of mines*
To manage waste produced during the mining process	*To implement good policies for the life cycles of mining operations*	*To reduce illegal payments in terms of land concessions or taxes.*
To minimize impacts of mining activities on biodiversity	*To create education and advancement of workers*	
To manage the energy used across operations		

According to Table 1, various factors must be taken into account, in order to implement sustainability practices for mining companies. It is expected that if the practices suggested are followed, this should drive mining companies towards sustainable development and the identified key issues could constitute a guide to sustainable mining actions. Other authors present sustainability practices in different forms, trying to attain similar objectives. For instance Bluszcz and Kijewska (2015) suggested that sustainability practices in the mining sector should be developed considering aspects such as (1) reduction of the negative effects of the exploitation of minerals, (2) rational use of resources deposits, (3) security for possible use of mineral resources left in abandoned fields, (4) optimal usage of land and consistency with the preferences of local community and the requirements of post mining environmental protection and (5) protection of biodiversity.

In spite of the efforts made, the translation of the sustainable development concept to the mining sector into sustainable practices is still incipient. These efforts are presented in the literature, addressing efforts and initiatives to support sustainability in mining companies, seeking to guide these companies to become sustainable, by integrating the three pillars of sustainable development in their activities. However, Pimentel et al., (2016) and Lechner et al., (2017) defend that significant challenges for advancing research and practice to ensure sustainable development in the sector still persist. Moreover, it is important to highlight that innovations in mining require a careful analysis under a sustainable development perspective as trade-offs or imbalances between individual sustainable development goals may exist (Endl et al., 2019).

3.2 BATs – Best Available Techniques in the mining sector

As previously discussed in section 3.1, despite its positive impact mining also create negative impacts, it has been drawing attention for a growing demand for the development of more sustainable practices within mining activities (Milanez and Puppim de Oliveira, 2013).

Due to the intrinsic characteristics of mining activities, the adoption of techniques and practices towards environmental protection has become imperative to this sector. To this end, the implementation of best available practices (techniques) can be an important methodology to improve the environmental performance in these companies. BATs (Best Available Techniques) are supported on technology development resulting in practices adequate for an effective environmental protection without compromising the economic viability of the companies.

In order to contribute to the reduction of environmental burdens caused by industrial activities without compromising the economic performance and ensuring the minimum environmental impact, environmental protection and development sustainable strategies are required. For this aim, BATs have been focusing on the adoption of regulatory measures, often in combination with economic incentives to promote sustainable activities (Georgopoulou et al., 2008).

In Europe, Directive 96/61 (OJ L 257 -10/10/1996) from IPPC (Integrated Pollution Prevention and Control) defines BATs by clarifying each of the three terms composing its name:

- *'Best'* – in relation to techniques, mean most effective in achieving a high general level of protection of the environment as a whole.
- *'Available'*- available techniques mean those developed on a scale which allows the implementation in the relevant industrial sector, under economically and technically viable conditions, taking into account the cost and advantages, as long as they are reasonably accessible to the operator.
- *'Techniques'* – includes both, the technology used and the way which the installation is designed, built, maintained, operated and decommissioned.

Evrard et al. (2016), argue that BATs comprehend environmental, economic and technical features which would have to be considered as precisely as possible. The selection of criteria to choose BATs raises the question of how to define the performance of an installation or a technique. According to Ibáñez-Forés et al. (2013), the use of BAT is an important driver to improve industrial sustainability through higher energy efficiency, reduced pollution and related environmental and economic benefits. These authors argue that in order to select a BAT some criteria have to be established namely, consumption of raw materials, energy efficiency, the use of low-waste technology and less hazardous substances as well as the cost of its implementation.

BATs reference documents cover several sectors, each comprising its own process, as well as giving rise to different impacts on the local, regional and national scale (European Commission, 2009). As previously mentioned, each sector is related to its own manufacturing process and the impacts generated by this process, for which it is mandatory to take into account the objective of the BAT and its use to allow a comprehensive use of the reference document.

Focusing on mining activities and due to their own characteristics, the adoption of techniques and practices towards environmental protection has become imperative to this sector. To this end, the implementation of best available practices (techniques) can be an important methodology towards the improvement of environmental performance in these companies. BAT involve technological development resulting in adequate practices for effective environmental protection, while being economically advantageous.

On regards to the mining sector, the reference document MWEI BREF (Management of waste from the extractive industries) was developed under directive from IPCC contain BATs which are specific to be adopted by mining companies for tailings and waste-rock management or sectors related to mining and raw-materials usage. They were established taking into account the characteristics of this sector and key environmental issues.

Due to the potential for significant waste generation of mining activities, the need for good practices towards a better waste management as well as fostering awareness on promoting such practices intending to reuse the waste across activities in the sector, are required. For instance, the BAT document developed for management of tailings and waste-rock (European Commission, 2009), suggests good practices to be adopted by mining companies in order to manage the residues generated at mining operations. Thus, the selection of relevant criteria to mining sector concerns both the determination of BATs and assessment of their performance on site.

Also Yilmaz, Anctil and Karanfil (2015) highlight that in the mining sector, the implementation of BATs is important in threefold: (1) to contribute with environmental benefits through the improvement of raw materials utilization, energy consumption, emission to air and minimization of solid waste generation, (2) to reduce environmental impacts for mining activities as global warming, biodiversity loss and human ecotoxicity, and (3) to analyse the cost of implementation of each technique, choosing the better to be implemented. Nonetheless, as BATs were created under the European Union context, they have been implemented in EU countries' industries, not really being significantly spread in other countries.

4. Research methodology

The methodology used in this research was based on a qualitative method with the participation of key stakeholders from the Brazilian mining sector. Face to face interviews were privileged. Only in a few cases virtual interviews were conducted to ensure the effective participation of the adequate experts due to their geographical location in Brazil.

A semi-structured interview guide with open-ended questions was prepared and implemented. Figure 2 summarizes the methodological approach adopted for this research which can be summarized in five main stages: the literature review which provided the fundamentals of the research; the expert's selection; the interviews implementation according to the interview guide previously designed; the qualitative analysis of these interviews and the presentation of conclusions and policy implications.

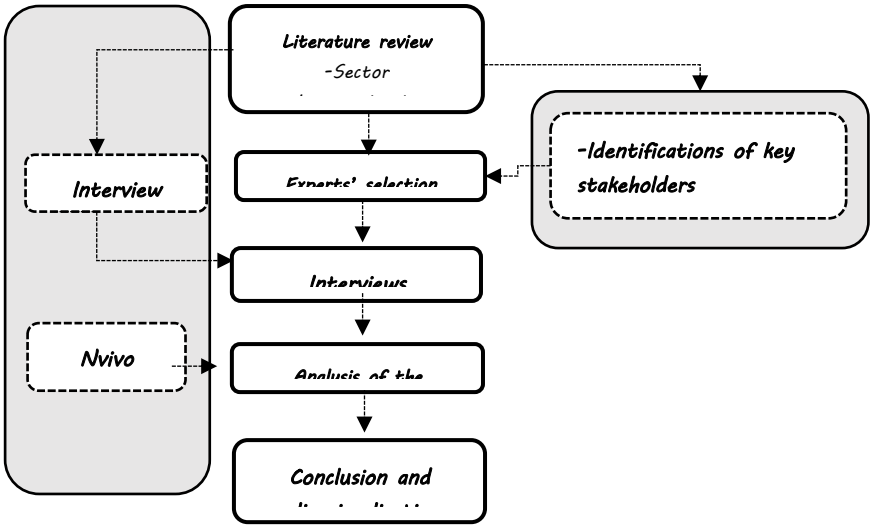

Figure 2: Methodological approach of the research

In order to collect data for this research, a semi-structured interview guide was prepared and used (see Appendix A). The interview guide was organised into five (5) sections, composed of a mix of closed and open-ended questions. *Section 01* focused on the characterization of the experts selected for respondents. On *Section 02* the respondents were given freedom to express their understanding about the sustainability concept and the related advancements in the Brazilian mining sector. *Section 03* focused on sustainability strategies and the use of BATs in the Brazilian mining sector. *Section 04* targeted the social dimension, addressing positive and negative impacts originated by the mining activities. In the *Section 05* the interview guide was designed to allow the experts to describe tools or methodologies used by Brazilian mining companies to evaluate and communicate sustainability. The interview guide comprised nineteen questions designed to be aligned with the objectives of this research.

The identification of relevant key experts was a pre-requisite to ensure an appropriate overview of the sustainability concept in the Brazilian mining sector as proposed in this research. These included professionals who have large work experience, know-how and high recognition in the mining sector. The group included experts from important mining associations/organizations in Brazil, namely public mining agencies, academy, research institutions and mineral sector labour unions. A total of 25 experts were contacted and 11 agreed to participate on the study. Table 2 presents these 11 experts' work experience.

Table 2: Overview of the experts consulted for this research

WORK EXPERIENCE	EXPERT										
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Public mining agency								*x*			*x*
Academic	*x*	*x*				*x*	*x*			*x*	
Research institution									*x*		
Labour Union				*x*							
Private institution			*x*								
Environmental agency					*x*						

The experts were interviewed in their native language, and audio recording and notes were used for each interview. In addition to the interviews, some documents from the National Department of Mineral Production (DNPM), the Brazilian Mining Institute (IBRAM) and the Ministry of Mines and Energy (MME), mainly related to the importance of the mining sector in Brazil and its characterization, were also consulted to provide secondary data.

The interviews lasted about seventy minutes each and were transcribed into a word document and coded according to each stage of the designed interview guide. The full transcription of each interview resulted in documents with fifteen to forty-eight pages, which called for the use of formal software tools for the analysis. This was not unexpected as according to Richards, (1999), qualitative analysis usually deals with complexity and large volumes of information. NVivo is a software application package for qualitative text-based data analysis, and its version 10 was then used for this discourse analysis task.

The NVivo software package was used to carry out the analysis of this research in five main phases, namely (i) to build the project database from the experts' interviews, (ii) to code and classify concepts (iii) to support chaining of nodes (iii) to identify the main characteristics which led to identify concepts and expressions related to sustainability (iv) to find out the similarities between interviews carried out and (v) to build an overview of the main outcomes of the research.

Then, the results achieved through NVivo software package were used to support the interview analysis as well as to identify the main characteristics related to sustainability in the Brazilian mining sector. These data were relevant to reach goal of assessing challenges and pathways to mining companies integrate sustainability for future developments.

5. Results from interviews

Although different experts from different professional backgrounds were involved in the interviews, some similarities on their answers could be identified. The results presented here are based on the outcomes from the NVivo software. Figure 3 shows the summary model of coded statements with the key challenges and pathways pointed out by the interviews and resulted from the NVivo analysis. The figure is also based on the principles of inductive thematic analysis developed by Gioia et al. (2013) where in a first stage concepts related to topic of the research are analysed; secondly, the similarity of themes related to the outlined concepts which are called second order themes were identified; thirdly an ultimate construct is devised based on pieces of data from first order concept and second theme.

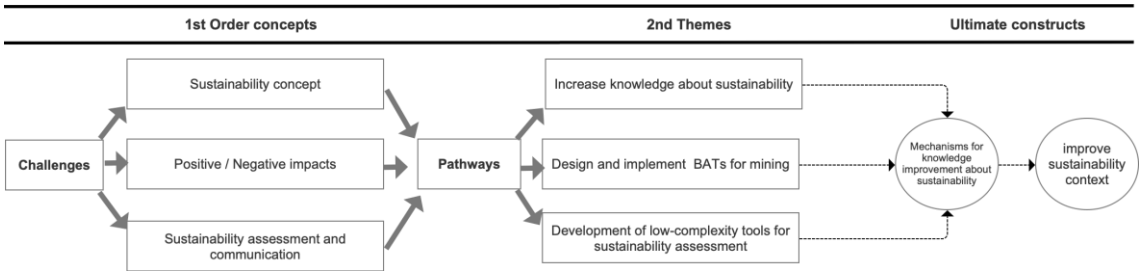

Figure 3: Outcome structure of the interviews

As presented in Figure 2, data analysis of the transcripts from the eleven interviews with experts coded in the NVivo yields overarching three main concepts related to sustainability concept, positive and negative impacts, BATs and sustainability assessment and communication. From these concepts, themes related to

increase knowledge about sustainability design and implementation of BATs from mining, and development of low-complexity tools for sustainability assessment, emerge as pathways to support mining industry towards sustainability. This analysis results then on the proposal of mechanisms for knowledge improvement about sustainability in the view of changing sustainability context. In addition, Table 3 presents a summary of key words related to theme heading pointed out during the interviews and listed by the NVivo analysis.

Table 3:Overarching research theme

Sustainability concept	**Positive (P) / Negative (N) impacts**	**BATs**	**Sustainability Assessment and Communication**
Concept is not clear	Environmental (N)	Valuable option towards sustainability	Translated into reports
Abstract concept	Social (N)	Mostly implemented by European countries	Reports published by public mining agencies
Associated with environmental concerns	Economic Development (P)	Never addressed by Brazilian mining companies	Growing concern in this field
Addressed by large companies	Creation of Jobs (P)	Lack of involvement of government	Not published in a systematically manner
Lack of consensus across mining companies	Local Development (P)		Lack of knowledge by managers
Lack of knowledge by managers	Loss of biodiversity (N)		Poor quality of reports
			It is not mandatory

For the sake of simplicity most of the research themes were analysed by topic. In order to achieve an in-depth analysis, the results are divided into three main topics as described in the remainder of this section, with the overall goal of concluding on possible policies and initiatives towards sustainable mining.

5.1 Sustainability concept in the Brazilian mining sector

The current literature devoted to sustainability has been showing that the term "sustainability" has different meanings for many authors. Almost all interviewees agreed that sustainability in the mining sector is still a very abstract concept, no consensual definition exists, and it is usually associated only to environmental concerns. Nonetheless, the notion of sustainability has emerged in several mining sectors and companies, and the last decades have been decisive on regards to governments and companies fostering the development of new strategies towards sustainability.

For this research, results from the interviews showed that, in the Brazilian case, sustainability issues have attracted increasing attention over recent decades, but that the concept is still not completely clear in the mining sector. This perception seems to derive from two aspects: mining activities are considered unsustainable by nature; and many stakeholders, including top level company decision makers and mining operators, seem to be unfamiliar with the meaning of sustainability, thus are incapable of addressing the issue within their mining companies. Table 4 summarizes findings from experts' interviews regarding sustainability concept in the Brazilian mining sector.

Table 4: Illustrative quotes regarding sustainability concept

Knowledge source	**Research theme**	**Illustrative quote**
Academic	Sustainability concept	*"We have many people which believe that mining cannot be sustainable by itself, just for a simple reason: mining industries remove natural resources of the planet and do not provide anything back. Mining just has been creating an environmental liability. It is common in the extraction of the natural resources. In their nature mining sector is not sustainable."*
Public mining agency	Sustainability concept	*"How can we call the mining sector as sustainable? It is sustainable for companies with profits and as such only for their shareholders; usually the mining companies are foreign companies and not Brazilian companies, the main impacts are kept at the local level here in Brazil."*

Research institution	Sustainability concept	*"I think mines remove mineral resources and theoretically do not return nothing else meaning that they are not sustainable. Mining companies do not want to create (negative) impacts to the environment; they want to keep the environment as it is. However, society demands for resources that are just provided by mining activities."*

As noted in Table 4, and discussed during the interviews, the majority of the experts highlighted that most efforts towards sustainability were addressed by large and multinational mining companies, as a result of their internal policies. As one of the experts stated, the concept of sustainability has been addressed by only a few mining companies in Brazil, thus the evolution of the concept cannot be considered consensual across the overall mining sector. Related to this, the interviews addressed the barriers to sustainability faced by the Brazilian mining sector in their attempts to incorporate the concept in the companies' practices. Lack of knowledge of sustainability on the part of managers and workers, low levels of engagement on the part of government agencies and a poorly informed local community are the main barriers highlighted during the interviews

In summary, the interviews clearly showed that this concept has mostly been discussed by large mining companies and is usually related to environmental concerns. Social and economic aspects have not been fully addressed in this field. This also means that few mining companies in Brazil have a comprehensive understanding of the meaning of sustainability, which is intricately linked to low levels of knowledge and awareness in both companies and local stakeholders.

5.2 Brazilian mining sector: positive x negative impacts

Despite mining activities being predominantly characterized by their environmentally and socially negative impacts, the importance of this sector to economic development in the many regions where mines are located is well recognized.

Results from the interviewees showed that this sector in Brazil enables the supply of a diversity of products to society, sharing the resources generated from mineral extraction, products such as iron, coal, silver, copper and zinc, among others, all of which are essential to the life of any modern society. Considering findings from interviews, Table 5 brings an illustration regarding impacts from mining activities.

Table 5: Illustrative quotes regarding impacts from mining activities

Knowledge source	**Research theme**	**Illustrative quote**
Research institution	Positive / Negative impacts	*"…in Brazil, every place where mines are operating grow up significantly in terms of social, economic and politic aspects. In these places, the main way for the people's survival is through mining."*
Academic	Positive / Negative impacts	*"… mining sector is an important player to generate income in Brazil, distributed to the municipalities where mines are located, through local taxes such as CFEM (Financial Compensation for the Mineral Exploration). CFEM for example is calculated taking into account the net income of minerals sales by companies and frequently represents the main tax and source of income received by cities to support the community."*
Academic		*"To communities located closely to mines, the negative impacts are greater than the positive ones. Depending on the social vulnerability of the community, when mining companies arrive, they change (worsening) the quality of life of the surrounding area..."*

	Positive / Negative impacts	
Academic	Positive / Negative impacts	*"…Mines have a particular characteristic: when they arrive at a place, they disassemble all the way of life of locals. As they impose a new approach to people's lives and work, a new logic to life is imposed changing all the area and population…"*

Regarding positive impacts, the experts agreed that economic development represents a significant positive impact, and they highlighted the threefold economic development: in the country as a whole, in the state where mines are located and in local communities.

Experts highlighted employment as the greatest positive impact resulting from mining activities in Brazil. The high number of jobs created and the overall reduction in unemployment levels were thought to be a direct positive impact of the mining activities in the regions where they operate. The mining sector is a driver for local development, and numerous communities have benefited from these activities in Brazil, which have resulted in economic development and consequently in improvements in the quality of life of local residents. This positive aspects are clearly in line with Matlaba et al. (2017) outcomes also for Brazil showing the relevance of theses aspects across different local communities.

Experts then highlighted the importance of Brazil's mining activities in terms HDI - the Human Development Index and its three indicators: 1- Long healthy life (life expectancy from birth), 2- Knowledge (average years of schooling) and 3- A decent standard of living (GNI per capita). Experts recalled that according to data from IBRAM (2012), the HDI of mining towns tends to be the highest one among all towns in each state. Even when mining projects are set up away from major urban areas or even in areas with low social support, it is perceived that these projects bring a tangible potential for regional sustainable development.

Nonetheless, the negative impacts of mining were also a recurring theme mentioned by almost all the experts consulted. They argue that, despite these activities making a significant contribution to the Brazilian economy, several negative impacts on the environment and the local community are also intrinsic characteristics of the sector. One of the experts illustrated these negative impacts with the most recent major environmental disaster resulting from mining activity in Brazil in November 2015, in the state of Minas Gerais.

According to the experts interviewed, Brazil's many mining intensive regions have suffered tremendous losses in biodiversity, air pollution and erosion of soils. Also, the experts highlighted that indigenous communities are negatively affected. Water pollution, loss of access to natural resources, noise, traffic growth, landscape deterioration and dust are the most negative impacts of mining activities on the local population

In summary, the interviewees' opinions were uniform on the question of impacts resulting from mining activities in Brazil. Almost all recognized the positive economic impacts, but they also highlighted the negative impacts of mining activities in some regions in Brazil, both on the environmental ecosystem and on the local communities, which illustrates the importance of tackling these challenges and mitigating these impacts without delay.

5.3 The use of Best Available Techniques (BAT) in the Brazilian mining sector.

As previously stated in the section of the literature review, the use of BATs in Europe has been an important driver towards increasing sustainability in many industries. For instance, the IPCC developed BATs for activities related to the mining sector including ceramic manufacturing industries, the ferrous-metals processing industry, non-ferrous metals industries and the refining of minerals oil and gas. The BATs developed for these sectors aim to reduce certain direct and indirect emissions related to an industrial plant and as such to improve sustainability through energy efficiency, reduced pollution and economic benefits.

Due to the expected contribution of BATs to sustainability improvement in mining and related sectors, the section of the interviews addressing this issue aimed at understanding the experts' awareness on this topic and the extent of BAT implementation in sectors related to mining activities in Brazil. However, as presented in Table 6, only one interviewee was familiar with these techniques. This interviewee pointed

out the importance of the adoption of techniques and strategies towards sustainability in the mining sector and considered that the use of BATs is a valuable option to be considered. The expert recognises that while these BATs are mostly implemented in Europe, the increase of their use in other countries could contribute to improving the sustainability performance of the mining sector and related industry across the world.

Table 6: Illustrative quote regarding the use of BATs in the Brazilian mining activities

Knowledge source	Research theme	Illustrative quote
Private institution	BATs	*"These tools are mostly implemented in Europe; in Brazil this concept is well recognized by mining companies"*

The results show then, that these techniques are still at a very early stage of development in Brazil and are not recognized by companies or even organizations in the sector. Almost all the experts noted that they have worked in the sector for many years but have never addressed or explored the use of BATs in the Brazilian mining sector and related industry. For them, this would seem to be a new approach that should be considered in Brazil. According to the experts' opinion, successful implementation of these techniques requires the involvement of government in making an effective commitment to BAT and robust mineral legislation, but they argue that in Brazil these conditions are still very much at an embryonic stage.

5.4 Sustainability assessment and communication for mining companies in Brazil.

Drawing upon results from the experts' interviews, this section aims to understand how sustainability is reported and communicated by Brazilian mining companies. For that purpose, questions in this section of the interviews were focused on methodologies and tools adopted by companies and governmental agencies in Brazil for sustainability assessment and communication.

Sustainability assessment and communication, in Brazil, is usually translated into reports published by public mining agencies. Over recent decades, the number of reports published by certain large and multinational mining companies have increased, signalling a growing concern about the issue and the importance attached to publicly releasing related information (Alves, 2018). Mining companies are then expected to communicate and report their activities to a set of Brazilian governmental agencies. However, according to interviewees, in practice these agencies are only responsible for the regulation of the mining companies in terms of their license to operate, and as such, their environmental and social impacts and reporting initiatives tend to be overlooked.

Table 7 illustrates these main agencies and their assigned responsibilities. Almost all interviewees highlighted that the main role of these agencies in Brazil is only to formalize mining operations in terms of license to operate. For instance, local agencies and DNPM are responsible for licensing.

Table 7: Brazilian public mining agencies

PUBLIC AGENCY	RESPONSIBILITY
MME - Ministry of Mines and Energy	*To formulate public policies to mining*
DNPM - National Department of Research Mineral	*To regulate and to supervise mining activities*
MMA - Ministry of Environment	*To promote strategies to protect and recover the environment*
IBAMA - Brazilian Institute of Environment	*To issue license to mining operation. To issue environmental license, also to regulate and supervise mining.*
IBRAM - Brazilian Mining Institute	*To represent companies and institutions in mining industries*
Local Agencies	*To give environmental license, to regulate and supervise mining activities at local level.*

Table 8 presents some example quotes to illustrate the experts' view regarding sustainability and communication in the Brazilian mining sector. Results from the interviews also showed that sustainability assessment is still in its very early stages in mining companies because those companies face many challenges in the pursuit of such a practice. Only large and multinational mining companies are able to perform sustainability assessment in any regular way. For instance, in Small, Medium and Artisanal companies, most managers lack a knowledge of the meaning of sustainability, staff lack knowledge of how to develop sustainability initiatives, and, indeed, will even have difficulty in understanding the concept of sustainability, while the perception that any of these initiatives will add costs to these companies still

prevails. Also, the major barriers they face include the scarcity of low-complexity methodologies and user-friendly tools for sustainability assessment and communication to be used in mining companies in Brazil.

Table 8: Illustrative quotes regarding sustainability assessment and communication

Knowledge source	Research theme	Illustrative quote
Environmental agency	Sustainability assessment and communication	*"…sustainability assessment is only developed by large and international companies. For small and medium-sized enterprises is a challenge understand the benefits of it"*
Academic	Sustainability assessment and communication	*"most staff do not lack knowledge to develop sustainability actions, they have difficulty on understanding the benefits of sustainability assessment, for companies these actions will add costs to them"*

The experts argue that sustainability assessment in Brazilian mining companies needs to be extremely effective and sustainability initiatives require a huge increase in levels of application. A potential solution suggested by the experts for this, is to increase knowledge of the meaning of sustainability and to disseminate its benefits among mining companies.

In summary, the assessment and communication of sustainability in the Brazilian mining sector can be characterized by three main elements: difficulty in finding sustainability reports developed by most mining companies; poor quality of some of the reports found; and the near impossibility of these being developed by small-artisanal and medium size mining companies. It is interesting to note that the interviewees believe that as communicating sustainability is not an obligation to mining companies in Brazil, only few reports are available. Companies which are represented by IBRAM, for instance, have communicated their sustainability programs to this agency, thus one single report from that agency represents the aggregated results of several companies. However, the experts highlight that this does not represent the entire mining sector in Brazil, as small-artisanal and medium size companies are strongly under-represented in IBRAM

6. Conclusion and policy implications

This research has addressed sustainability in the Brazilian mining sector, including the perception of the concept, the perceived impacts of these activities, awareness towards best performing technologies and communication strategies. The work involved in-depth interviews with key experts from the mining sector in Brazil.

This research has allowed for the suggestion of important contributions and implications for coordinators of the Brazilian mining sector. Firstly, the research investigated how sustainability concept is understood by Brazilian mining companies, as well as the difficulties in defining sustainability for this sector. Results from interviews conducted showed that sustainability is mainly associated with environmental concerns and is acknowledged mostly by large and multinational mining companies operating in Brazil. The majority of mining companies face many barriers to understand the concept. Even if the company stakeholders' do acknowledge it, most companies do not have the required conditions to develop strategies towards sustainability due to the prevailing characteristics of the sector, namely the low academic level of managers and employees with limited knowledge and investment capacity. Therefore, almost all interviewees agreed that the best way to increase sustainability in the mining sector in Brazil is disseminating this concept and the routes to achieve its objectives amongst all companies, but with particular efforts directed towards small companies and cooperatives.

As regards to the importance of the mining sector in Brazil, results also showed that Brazil's mining activities have also contributed to social development in local communities with the creation of new jobs at all stages of operations, with considerable employment effects. Bearing in mind the increasing demand for minerals worldwide, the geological characteristics of Brazil show the sector to be a window of opportunity in the coming years

Also, taxes and royalties from mining have contributed to socio-economic development in many states and cities where mines are located. However, interviewees also agreed that, Brazilian mining, when compared with other industrial sectors, is frequently highlighted as increasingly responsible for higher levels of environmental damage.

The adoption of Best Available Techniques (BATs) has been playing a major role in several sectors including some related to mining activities, contributing to reduce their environmental impacts while keeping their competitiveness. Nonetheless, results from the interviews showed that the level of knowledge on these techniques is still extremely limited and its adoption in the mining sector and related activities is quite reduced in Brazil. In particular recommendations such as the ones from European Commission (2009), on the management of environmental impacts from tailings and waste-rock management facilities associated with the site location, relative land take and potential emissions of dust and effluents during operation or in the after-care phase, are not yet recognized.

Finally, this research also investigated how sustainability is reported and communicated by mining companies in Brazil. While some of the interviewees agreed that in the last decades' sustainability has been addressed by a small number of mining companies, results from interviews show that only large and multinational mining companies have been reporting and communicating their sustainability actions. In this case, these reports are available through public mining agencies or in the companies' webpage.

The interviewees reported that mining companies in Brazil do not have any obligation to develop sustainability reports, and also highlighted the many challenges which these companies must face to develop their sustainability reports, namely the lack of inside specialized competencies and knowledge. Difficulties to identify methodologies, tools and support schemes to implement sustainability actions were highlighted.

In sum, in order to overcome all the challenges identified in this research, the combination of stakeholder engagement and the implementation of sustainability practices by companies should contribute to better and more sustainable mineral exploration in Brazil.

To increase sustainability in the Brazilian mining sector we strongly stress the need for sustainability assessment methodologies and tools, aiming for a higher level of understanding in the sector. This better and easier assessment will also allow decision-makers to design measures and strategies which can be easily adopted and addressed by companies of different sizes, taking into account the companies' characteristics.

In order to minimize problems related to difficulties in communication with the local community, mining companies should be encouraged by public mining agencies to develop initiatives to engage the community in their activities. In addition, sustainability reports are considered to be an effective mean to increase levels of communication with stakeholders, as well as to contribute to the effective implementation of impact assessment procedures and the minimization of environmental and social damage by these companies. Moreover, effective mechanisms to ensure compulsory but expeditious environmental and social licensing procedures along with their monitoring are key factors for guaranteeing sustainability in the sector to allow for its development without compromising the welfare of locals.

6.1 Challenges and pathways towards sustainability

This research offers insights to decision-makers of the Brazilian mining sector, through an overview of the current sustainability status of the Brazilian mining sector. Although the limited number of interviews does not allow generalizing the outcome or providing statistical implications, this approach can be central for scientific development. In fact, by relying on expert's knowledge and awareness, this research increases the understanding on the specific case under analysis which will be useful to derive policy implications and define pathways which can also be relevant for different cases, regions or countries dealing with closer situations and concerns for mining sustainability. As such, we recognize that the results may not be generalized but the proposed methods and results will bring important knowledge to scientific community, policy makers, companies, industrial organizations and local stakeholders.

Based on the literature review, interviews conducted with Brazilian experts and field work with mining companies the main challenges, related pathways and avenues for future research could be highlighted considering the socio-economic context of the country and of the sector.

Firstly, the importance of disseminating and evaluating the use of Best Available Techniques, not only to deal with tailings and waste-rock (see BAT- MTWR 07.2009) but also related to other sectors using minerals as raw materials to ensure lower impacts across the full value chain. Bringing BAT and innovations to the mining sector is fundamental to reach sustainability but results also on important challenges, as debated by Endl et al. (2019). The overall impact of innovations or adoption of different technologies to sustainable development goals is then an important field of research for the sector and for the country. However, for the development of new mining approaches, techniques and innovations governmental engagement is needed, as well as effective co-operation between companies, government and society. At this stage, the organization of the sector in Brazil and in particular this lack of a co-operative environment, constitute a barrier to the adoption of these practices.

Secondly, the challenges associated with the overall nature of the mining industry in Brazil, which is frequently characterized by small companies and an underqualified workforce, leading to low levels of awareness of the concept of sustainability and strategies to achieve it. The socio-cultural and economic context of the country, companies and communities should be considered to design effective mechanisms and incentives to ensure the compliance with sustainable practices for all companies. The case of small-artisanal and medium size mining companies is particularly worthily to be addressed in future research as they represent a major challenge for the sector but play also a major role on local employment. Future research addressing local communities to exploit the relative importance of local benefits comparatively to bared costs is then essential for the definition mitigating and compensating strategies.

Thirdly, sustainability reports are considered to be effective means to increasing communication with stakeholders, as well as contributing to the effective implementation of impact assessment procedures and the subsequent minimization of environmental and social damage caused by these companies. For better communication between stakeholders in the sector and external stakeholders, companies should communicate their sustainability appraisal by means of a report, made publicly available via the company website, or public agencies such as IBRAM and DNPM. As a result of the poor efforts at communication, governmental agencies do not have sufficient control over mining activities in Brazil and are even unaware of most initiatives related to sustainability developed by mining companies. Larger companies are already engaged on communication, but smaller companies still require organization and staff support which is related to the fourth and last aspect to be underlined.

Fourthly, the need to provide support schemes and incentives and to bring about qualified knowledge in mining companies through training and external specialized consulting. This will require not only cooperation between government, public mining agencies and companies, but also the involvement of local research and teaching institutions capable of supporting the implementation of sustainable practices in the short term and contributing to providing specialized staff and well-informed future decision makers in the long. The definition of new organizational models to promote cooperation among companies, government, agencies and academic agents to design and implement innovative pathways towards sustainability for the mining industry, represents a promising research field requiring an holistic and multidisciplinary approach to integrate social and environmental concerns on technical development and ensuring economic welfare at local, regional and country levels.

Acknowledgements

The authors would like to thank to CAPES and Without Borders scholarship (Brazil), BEX Process 10.190-13-9 for providing financial support to this research. This work has been also supported by national funds through FCT – Fundação para a Ciência e Tecnologia, Portugal, within the Project Scope: UID/CEC/00319/2019

Appendix A. Interview questions

A. *Sustainability concept*

What does sustainability mean to mining sector?
Do you think that sustainability concept has been advanced in the last two decades in the Brazilian mining industry?
Do you think that Brazilian mining sector has been advanced on regards to implementing sustainability practices?
Are sustainability policies well defined and taken into account for Brazilian mining industries?

B. *Positive x negatives impacts*

Which are the main positive and negative impacts to local community originated from mining activities in Brazil?
Till what extent does mining sector in Brazil contribute to the economic development of states and towns hosting these facilities?
How do local communities perceive the impacts of mining activities?
Till what extent do Brazilian mining companies take into account aspects related to health and safety of workers and locals during their operation?

C. BATs in the Brazilian mining sector

How could sustainability practices contribute to improve production processes in mining industries?
Do you think that Brazilian government enforces mining companies to adopt sustainability practices?
Do local community influence Brazilian mining companies to adopt sustainability practices? How?
Do you have any information about what Best- Available- Techniques (BATs)?
If yes, do you have any information about the use of BATs for Brazilian mining companies?
Do you know if public agencies in Brazil have been suggested some documents or methodologies to support sustainability in mining companies?

D. Sustainability assessment and communication

Do you know if in Brazil, methodologies or tools to support sustainability assessment in mining companies are available?
If yes, do you have any information how these methodologies or tools are disseminated between Brazilian mining companies?
How important are methodologies and tools to support sustainability assessment in the Brazilian mining companies?
Which strategies have been used to report and communicate sustainability in Brazilian mining companies?

E. Barriers to implementation to sustainability

Which are the main barriers faced by mining companies in Brazil to adopt sustainability policies?

References

Almeida, I.M. de, Jackson Filho, J.M., Vilela, R.A. de G., 2019. Razões para investigar a dimensão organizacional nas origens da catástrofe industrial da Vale em Brumadinho, Minas Gerais, Brasil. Cad. Saude Publica 35, e00027319. doi:10.1590/0102-311X00027319

Alves, W., 2018. Evaluation of sustainability in the mining sector in Brazil. University of Minho.

Arellano-Yanguas, J., 2019. Extractive industries and regional development: Lessons from Peru on the limitations of revenue devolution to producing regions. Reg. Fed. Stud. 29, 249–273. doi:10.1080/13597566.2018.1493461

Avram, O., Stroud, I., Xirouchakis, P., 2010. A multi-criteria decision method for sustainability assessment of the use phase of machine tool systems. Int. J. Adv. Manuf. Technol. 53, 811–828. doi:10.1007/s00170-010-2873-2

Bachmann, T.M., 2012. Towards life cycle sustainability assessment: drawing on the NEEDS project's total cost and multi-criteria decision analysis ranking methods. Int. J. Life Cycle Assess. 18, 1698–1709. doi:10.1007/s11367-012-0535-3

Bansah, K.J., 2019. From diurnal to nocturnal: Surviving in a chaotic artisanal and small-scale mining sector. Resour. Policy 64, 101475. doi:10.1016/j.resourpol.2019.101475

Bluszcz, A., Kijewska, A., 2015. Challenges of sustainable development in the mining and metallurgy sector in Poland. Metalurgija 54, 441–444.

Böhling, K., Murguía, D.I., Godfrid, J., 2017. Sustainability Reporting in the Mining Sector: Exploring Its Symbolic Nature. Bus. Soc. 58, 191–225. doi:10.1177/0007650317703658

Bui, N.T., Kawamura, A., Kim, K.W., Prathumratana, L., Kim, T.H., Yoon, S.H., Jang, M., Amaguchi, H., Bui, D. Du, Truong, N.T., 2017. Proposal of an indicator-based sustainability assessment framework for the mining sector of APEC economies. Resour. Policy 52, 405–417. doi:10.1016/j.resourpol.2017.05.005

Castilla-Gómez, J., Herrera-Herbert, J., 2015. Environmental analysis of mining operations: Dynamic tools for impact assessment. Miner. Eng. 76, 87–96. doi:10.1016/j.mineng.2014.10.024

DNPM, 2017. Anuário estatístico do setor de transformação de não metálicos. Brasília.

DNPM, 2016. Departamento Nacional de Produção Mineral. Anuário Mineral Brasileiro: Principais subsrâncias metálicas. Brasilia.

DNPM, 2015. Sumário Mineral-2015. Brasília.

DNPM, 2006. Mineral Business. Brasília.

Dubiński, J., 2013. Sustainable Development of Mining Mineral Resources. J. Sustain. Min. 12, 1–6. doi:10.7424/jsm130102

828 Endl, A., Tost, M., Hitch, M., Moser, P., Feiel, S., 2019. Europe's mining innovation trends and their
829 contribution to the sustainable development goals: Blind spots and strong points. Resour. Policy
830 101440. doi:10.1016/j.resourpol.2019.101440
831 Enríquez, M.A., Drummond, J., 2007. Social-environmental certification: Sustainable development and
832 competitiveness in the mineral industry of the Brazilian Amazon. Nat. Resour. Forum 31, 71–86.
833 doi:10.1111/j.1477-8947.2007.00127.x
834 European Commission, 2009. Reference Document on Best Available Techniques for Management
835 Management of Tailings and Waste-Rock in Mining Activities, Reference Documents on Best
836 Available Techniques.
837 Evrard, D., Laforest, V., Villot, J., Gaucher, R., 2016. Best Available Technique assessment methods: a
838 literature review from sector to installation level. J. Clean. Prod. 121, 72–83.
839 doi:10.1016/j.jclepro.2016.01.096
840 Gamu, J., Le Billon, P., Spiegel, S., 2015. Extractive industries and poverty: A review of recent findings
841 and linkage mechanisms. Extr. Ind. Soc. 2, 162–176. doi:10.1016/j.exis.2014.11.001
842 Garcia, L.C., Ribeiro, D.B., de Oliveira Roque, F., Ochoa-Quintero, J.M., Laurance, W.F., 2017. Brazil's
843 worst mining disaster: Corporations must be compelled to pay the actual environmental costs. Ecol.
844 Appl. 27, 5–9. doi:10.1002/eap.1461
845 Georgopoulou, E., Hontou, V., Gakis, N., Sarafidis, Y., Mirasgedis, S., Lalas, D.P., Loukatos, A.,
846 Gargoulas, N., Mentzis, A., Economidis, D., Triantafilopoulos, T., Korizi, K., 2008. BEAsT: a
847 decision-support tool for assessing the environmental benefits and the economic attractiveness of best
848 available techniques in industry. J. Clean. Prod. 16, 359–373. doi:10.1016/j.jclepro.2006.12.002
849 Gioia, D.A., Corley, K.G., Hamilton, A.L., 2013. Seeking Qualitative Rigor in Inductive Research: Notes
850 on the Gioia Methodology. Organ. Res. Methods 16, 15–31. doi:10.1177/1094428112452151
851 Gomes, C.M., Kneipp, J.M., Kruglianskas, I., da Rosa, L.A.B., Bichueti, R.S., 2013a. Management for
852 sustainability in companies of the mining sector: an analysis of the main factors related with the
853 business performance. J. Clean. Prod. 84, 1–10. doi:10.1016/j.jclepro.2013.08.030
854 Gomes, C.M., Kneipp, J.M., Kruglianskas, I., da Rosa, L.A.B., Bichueti, R.S., 2013b. Management for
855 sustainability in companies of the mining sector: an analysis of the main factors related with the
856 business performance. J. Clean. Prod. 84, 1–10. doi:10.1016/j.jclepro.2013.08.030
857 Hallstedt, S.I., Thompson, A.W., Lindahl, P., 2013. Key elements for implementing a strategic
858 sustainability perspective in the product innovation process. J. Clean. Prod. 51, 277–288.
859 doi:10.1016/j.jclepro.2013.01.043
860 Hami, N., Muhamad, M.R., Ebrahim, Z., 2012. The Impact of Sustainable Manufacturing Practices on
861 Sustainability Performance. J. Teknol. (Sciences Eng. 58, 85–88. doi:10.1016/j.procir.2014.07.167
862 Henckens, M.L.C.M., van Ierland, E.C., Driessen, P.P.J., Worrell, E., 2016. Mineral resources: Geological
863 scarcity, market price trends, and future generations. Resour. Policy 49, 102–111.
864 doi:10.1016/j.resourpol.2016.04.012
865 Hilson, G., 2002. Small-scale mining and its socio-economic impact in developing countries. Nat. Resour.
866 Forum 26i don, 3–13. doi:10.1111/1477-8947.00002
867 Horowitz, L., 2006. Section 2: mining and sustainable development. J. Clean. Prod. 14, 307–308.
868 doi:10.1016/j.jclepro.2005.03.005
869 Horsley, J., Prout, S., Tonts, M., Ali, S.H., 2015. Sustainable livelihoods and indicators for regional
870 development in mining economies. Extr. Ind. Soc. 2, 368–380. doi:10.1016/j.exis.2014.12.001
871 Ibáñez-Forés, V., Bovea, M.D., Azapagic, A., 2013. Assessing the sustainability of Best Available
872 Techniques (BAT): Methodology and application in the ceramic tiles industry. J. Clean. Prod. 51,
873 162–176. doi:10.1016/j.jclepro.2013.01.020
874 IBRAM, 2015. Informações sobre a economia mineral brasileira 2015. Brasília.
875 IBRAM, 2012. The Strength of Brazilian Mining 2012.
876 Kasperczyk, N; Knickel, K., 2006. Advanced Techniques for Evaluation of Sustainability Assesment Tools.
877 Kogel, J.E., 2015. Sustainable Development and the Minerals Industry, in: Engineering Solutions for
878 Sustainability. John Wiley & Sons, Inc., Hoboken, NJ, USA, pp. 23–34.
879 doi:10.1002/9781119179856.ch2
880 Lechner, A.M., McIntyre, N., Witt, K., Raymond, C.M., Arnold, S., Scott, M., Rifkin, W., 2017. Challenges
881 of integrated modelling in mining regions to address social, environmental and economic impacts.
882 Environ. Model. Softw. 93, 268–281. doi:10.1016/j.envsoft.2017.03.020
883 Lieder, M., Rashid, A., 2016. Towards circular economy implementation: A comprehensive review in
884 context of manufacturing industry. J. Clean. Prod. 115, 36–51. doi:10.1016/j.jclepro.2015.12.042
885 Leena, S., Karina, U., Jungsberg, L., 2019. Social license to operate in the frame of social capital exploring
886 local acceptance of mining in two rural municipalities in the European North. Resour. Policy 64,
887 101498. doi:10.1016/j.resourpol.2019.101498

Lindner, M., 2010. Northern ToSIA – Sustainable forest resource management in the Northern Periphery Northern ToSIA project objectives Sustainability challenges in the Northern Periphery Assessing sustainability impacts with ToSIA.
Lins, C., Horwitz, E., 2007. Sustainability in the Mining Sector. Rio de Janeiro.
Loayza, N., Rigolini, J., 2016. The Local Impact of Mining on Poverty and Inequality: Evidence from the Commodity Boom in Peru. World Dev. 84, 219–234. doi:10.1016/j.worlddev.2016.03.005
Mancini, L., Sala, S., 2018. Social impact assessment in the mining sector: review and comparison of indicators frameworks. Forthcoming 1–14. doi:10.1016/j.resourpol.2018.02.002
Meira, R.M.S.A., Peixoto, A.L., Coelho, M.A.N., Ponzo, A.P.L., Esteves, V.G.L., Silva, M.C., Câmara, P.E.A.S., Meira-Neto, J.A.A., 2016. Brazil's mining code under attack: giant mining companies impose unprecedented risk to biodiversity. Biodivers. Conserv. 25, 407–409. doi:10.1007/s10531-016-1050-9
Milanez, B., Puppim de Oliveira, J.A., 2013. Innovation for sustainable development in artisanal mining: Advances in a cluster of opal mining in Brazil. Resour. Policy 38, 427–434. doi:10.1016/j.resourpol.2013.07.003
Moran, C.J., Lodhia, S., Kunz, N.C., Huisingh, D., 2014. Sustainability in mining , minerals and energy : new processes , pathways and human interactions for a cautiously optimistic future. J. Clean. Prod. 1–15. doi:10.1016/j.jclepro.2014.09.016
Munhoz, L., 2019. The Brazilian Brumadinho Mining Disaster: Environmental Regulation on Debate. Nat. Resour. Environ. 34, 37–41.
Neves, A.C. de O., Nunes, F.P., de Carvalho, F.A., Fernandes, G.W., 2016. Neglect of ecosystems services by mining, and the worst environmental disaster in Brazil. Nat. Conserv. 4–7. doi:10.1016/j.ncon.2016.03.002
Oosterhuis, F., 2009. VAT reduction for environmentally friendly products and services [WWW Document]. URL http://www.ivm.vu.nl/en/projects/Archive/VAT-reduction-for-environmentally-friendly-products-and-services/index.asp (accessed 4.27.15).
Owen, J.R., Kemp, D., Lèbre, Svobodova, K., Pérez Murillo, G., 2020. Catastrophic tailings dam failures and disaster risk disclosure. Int. J. Disaster Risk Reduct. 42. doi:10.1016/j.ijdrr.2019.101361
Peterson St-Laurent, G., Billon, P. Le, 2015. Staking claims and shaking hands: Impact and benefit agreements as a technology of government in the mining sector. Extr. Ind. Soc. 2, 590–602. doi:10.1016/j.exis.2015.06.001
Pimentel, B.S., Gonzalez, E.S., Barbosa, G.N.O., 2015. Decision-support models for sustainable mining networks: Fundamentals and challenges. J. Clean. Prod. 112. doi:10.1016/j.jclepro.2015.09.023
Rametsteiner, E; Berg, S; Laurijssen, J., 2008. EFORWOOD Project Deliverable 1.1.6: Revised FWC - Sustainability Indicator Set Document. BOKU, Vienna.
Richards, L., 1999. Data Alive! The Thinking Behind NVivo. Qual. Health Res. 9, 412–428. doi:10.1177/104973239900900310
Roca, L.C., Searcy, C., 2012. An analysis of indicators disclosed in corporate sustainability reports. J. Clean. Prod. 20, 103–118. doi:10.1016/j.jclepro.2011.08.002
Sivakumar, R., Kannan, D., Murugesan, P., 2015. Green vendor evaluation and selection using AHP and Taguchi loss functions in production outsourcing in mining industry. Resour. Policy 46, 64–75. doi:10.1016/j.resourpol.2014.03.008
Suopajärvi, L., Poelzer, G.A., Ejdemo, T., Klyuchnikova, E., Korchak, E., Nygaard, V., 2016. Social sustainability in northern mining communities: A study of the European North and Northwest Russia. Resour. Policy 47, 61–68. doi:10.1016/j.resourpol.2015.11.004
Werhahn-mees, W., Palosuo, T., Garcia-Gonzalo, J., Röser, D., Lindner, M., 2011. Sustainability impact assessment of increasing resource use intensity in forest bioenergy production chains. GCB Bioenergy 3, 91–106. doi:10.1111/j.1757-1707.2010.01068.x
World Commission on Environment and Development. WCED, 1987. Our Common Future.
World Bank-International Finance Corporation (2016). Commodities prices. World Bank Group Mining. Available at: http://www.worldbank.org/en/research/commodity-markets (accessed 27.03.16.)
Yilmaz, O., Anctil, A., Karanfil, T., 2015. LCA as a decision support tool for evaluation of best available techniques (BATs) for cleaner production of iron casting. J. Clean. Prod. 105, 337–347. doi:10.1016/j.jclepro.2014.02.022