

Bibliographic review on sustainability and processing of ornamental rocks

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Abstract

The processing of ornamental rocks involves several stages, from extraction in the deposits to the final finishing of the product. These stages can consume significant amounts of energy and water and generate solid waste and liquid effluents that may contaminate soil and water. Moreover, intensive exploitation of deposits can lead to environmental degradation and have a negative impact on local biodiversity. Faced with these challenges, the ornamental rock processing sector has been striving to adopt more sustainable practices in its operations. This includes investing in more efficient and less polluting technologies, reusing and recycling waste generated during the process, and implementing measures for biodiversity conservation and the recovery of degraded areas. The methodology employed for the development of this scientific research involved a qualitative approach, with the research procedure consisting of conducting a literature review. The overall objective of this research was to elaborate a literature review on sustainability and ornamental rock processing. Ultimately, the research highlights that the existence of clear environmental regulations and companies' compliance with these regulations are crucial to prevent abuses and ensure environmental protection. It is also of utmost importance to ensure the application of appropriate penalties for those who do not comply with the established norms

Keywords: Ornamental rock processing; Environmental degradation; Biodiversity conservation; Restoration of degraded areas.

1. Introduction

The Environmental Sustainability in the Exploitation of Ornamental Rocks is of Paramount Importance to Mitigate Negative Impacts Arising from Non-Adoption of Sustainable Practices. The unplanned extraction and processing of these rocks can lead to significant environmental damages, such as soil degradation, contamination of water resources, and emission of polluting gases. Furthermore, uncontrolled exploitation can result in the depletion of natural resources, thereby compromising their availability for future generations [1].

Currently, various techniques and technologies have been employed to ensure environmental sustainability in the exploitation of ornamental rocks. One such approach involves the use of more efficient equipment that reduces energy and water consumption during the production process. Additionally, the restoration of degraded areas is a fundamental practice, accomplished through re-vegetation and continuous monitoring of soil and water quality. Another significant technique involves the reutilization of waste generated during rock processing, transforming them into byproducts or inputs for other industries [2].

However, companies in this sector face numerous challenges in their pursuit of environmental sustainability. One primary challenge is the lack of awareness among workers regarding the significance of sustainable practices.

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Frequently, employees lack knowledge about the negative impacts of their activities and are inadequately trained to adopt mitigating measures. Moreover, resistance towards adopting new practices persists, particularly among managers who often prioritize profitability over socio-environmental responsibility [3].

The adoption of environmental sustainability in the exploitation of ornamental rocks can yield substantial economic benefits. With increasing environmental concerns, there is a growing demand for ecologically friendly products. Companies that embrace sustainable practices can stand out in the market and attract customers who value socio-environmental responsibility. Notably, the reduction in natural resource consumption and the reutilization of waste can lead to cost savings for businesses [4].

In Brazil, there exist legislations and regulations that govern the exploitation of ornamental rocks, aiming to safeguard the environment and promote sustainability. Law No. 9.605/1998 imposes penal and administrative sanctions for activities detrimental to the environment, including illegal rock extraction. It is worth highlighting that specific technical standards for the sector, such as those from the Brazilian Association of Technical Standards (ABNT), establish criteria for the proper management of extraction and processing areas [5].

The methodology employed for the development of this scientific research employed a qualitative approach, with the research procedure being the conduct of a bibliographic review. The overarching goal of this research was to craft a bibliographic review on the sustainability and processing of ornamental rocks. The specific objectives are as follows: to comment on Environmental Sustainability in the Exploitation of Ornamental Rocks; to discuss Legislation and Environmental Standards Applicable to the Exploitation of Ornamental Rocks; and to address the significance of Sustainable Technologies in the Exploitation of Ornamental Rocks.

This article was structured into four sections. The first section highlighted the research objectives in the introduction. The second section elaborated on a theoretical foundation, drawing from the contributions of various authors who delve into the same theme discussed here. The third section presented the methodological procedures adopted in the creation of this research, and the fourth and final section underscored the concluding remarks of the article.

2. Material and methods

The methodology employed for the development of this scientific research embraced a qualitative approach, with the research procedure being the conduct of a bibliographic review.

“The qualitative approach is a research methodology that seeks to comprehend and interpret intricate and subjective phenomena, focusing on understanding participants' perspectives and providing detailed descriptions of the contexts in which they occur” [6].

“On the other hand, a bibliographic review is a research method that aims to identify, analyze, and synthesize information from bibliographic sources such as scientific articles, dissertations, and books.” [7].

The research was conducted in accordance with the principles of the qualitative approach, allowing for an in-depth analysis of the concepts and themes addressed in the scientific literature. Through the adopted research procedure, bibliographic review, it became possible to identify and analyze the main contributions of authors who investigate the same subject under examination. The primary sources explored consisted of articles published in scientific journals, dissertations, and books, ensuring both comprehensiveness and diversity of perspectives on the studied topic.

The key authors who contributed significantly to the research include: Baima (2018); Cavalcanti et al. (2019); Tribeck, De-Carli, and Silva (2021); Araújo et al. (2022).

3. Literature Review

This foundation was structured into three subtopics. The first subtopic addressed Environmental Sustainability in the Exploitation of Ornamental Rocks. The second subtopic elaborated on Legislation and Environmental Standards Applicable to the Exploitation of Ornamental Rocks. Finally, the third subtopic delved into Sustainable Technologies in the Exploitation of Ornamental Rocks.

3.1. Environmental Sustainability in the Exploitation of Ornamental Rocks

Environmental sustainability in the exploitation of ornamental rocks holds paramount significance in mitigating the negative impacts that may arise in the absence of sustainable practices. The extraction and processing of these rocks can lead to substantial environmental damages, such as soil degradation, water contamination, and the loss of local biodiversity. Additionally, the emission of polluting gases during transportation and the excessive consumption of natural resources are also pertinent concerns. Therefore, it is imperative to implement effective measures to mitigate these impacts and ensure the preservation of ecosystems [8].

Numerous techniques and technologies have been developed to minimize environmental impacts in the exploitation of ornamental rocks. These measures contribute to the preservation of local fauna and flora and further the restoration of utilized natural resources [9].

A well-planned approach is essential to ensure environmental sustainability in the exploitation of ornamental rocks. This planning must consider aspects such as the preservation of local fauna and flora by identifying and protecting areas sensitive to biodiversity. Moreover, controlling the usage of water and energy to ensure resource efficiency is crucial. The management of generated waste is also pivotal, necessitating recycling and reuse practices, in addition to ensuring proper disposal of solid and liquid waste [10].

Environmental awareness and education among workers engaged in the exploitation of ornamental rocks are fundamental for fostering sustainable practices in their daily operations. It is crucial for these professionals to be equipped with the knowledge to comprehend the environmental impacts of their activities and to be acquainted with the best techniques and technologies available for mitigation. Thus, raising awareness about the significance of environmental preservation must be disseminated among all staff, incentivizing the adoption of sustainable behaviors across all stages of the production process [3].

According to Peiter, Mofati, and Villas Bôas (2014), adopting sustainable practices in the exploitation of ornamental rocks yields significant economic benefits. One such advantage is the enhanced market valuation of the end product on the international stage, as discerning consumers increasingly seek products stemming from responsible production processes. Presently, companies embracing sustainable practices can attain competitive advantages such as reduced operational costs and improved institutional image vis-à-vis clients and investors. Consequently, investing in environmental sustainability can be an astute strategy to augment sectoral profitability [2].

Certifications and environmental seals specific to the ornamental rock industry play a pivotal role in ensuring environmental sustainability and fostering positive corporate images. These certifications attest to the alignment of practices with established environmental standards, lending credibility to offered products and services. These seals can be wielded as competitive differentiators, showcasing the company's commitment to environmental preservation and social responsibility [11].

The ornamental rock industry faces numerous challenges in its pursuit of environmental sustainability. One of the foremost challenges is the lack of sector-specific regulations, hindering the standardization of sustainable practices and the proper monitoring of undertaken activities. Regrettably, many enterprises still resist change, perceiving sustainable practices as potential sources of added costs. The dearth of consumer awareness is also a pertinent challenge, as the demand for sustainable products is not as significant as it should be. Consequently, overcoming these hurdles necessitates effective public policies, economic incentives, and awareness campaigns [12].

3.1.1. Importance of Sustainability in the Exploitation of Ornamental Rocks

The significance of sustainability in the exploitation of ornamental rocks for environmental preservation is a topic of utmost relevance. Unsustainable extraction of these resources can lead to a multitude of negative impacts, such as soil degradation and contamination of water resources. Inadequate exploitation of ornamental rocks can result in substantial alterations to the landscape, including the removal of native vegetation and exposure of soil to erosive processes. It's important to highlight that the use of aggressive extraction techniques can lead to soil compaction, hindering its recovery and compromising its productive capacity [13].

According to Souza (2021), measures need to be adopted to ensure sustainable exploitation of ornamental rocks. One of the key strategies is the utilization of less aggressive extraction techniques, such as controlled cutting and hydraulic fracturing. These techniques minimize environmental damage by reducing the quantity of generated waste and preventing water resource contamination. At this juncture, it's imperative that waste generated during the extraction process is appropriately managed through the implementation of efficient environmental management systems [8].

Environmental awareness and education are pivotal aspects in promoting more sustainable practices in the exploitation of ornamental rocks. Professionals engaged in the sector must be cognizant of the adverse impacts caused by unsustainable exploitation and be equipped with the capacity to adopt mitigating measures. Environmental awareness should also be extended to the local community, fostering an understanding of the benefits of sustainable exploitation and engagement in environmental preservation [14].

The adoption of sustainability in the exploitation of ornamental rocks can yield significant economic benefits. With the escalating environmental concerns, there is a growing demand for environmentally friendly products. Companies that embrace sustainable practices can capitalize on this demand, enhancing their competitiveness in the market and attracting new customers. It's worth noting that the sustainable exploitation of ornamental rocks contributes to the generation of local employment and socioeconomic development in the involved regions [1].

Souza (2021) considers the existence of certifications and environmental seals as pivotal for identifying companies that adhere to sustainable practices in the exploitation of ornamental rocks. These certifications attest to companies' commitment to environmental preservation and can be leveraged as competitive differentiators in the consumer market. The pursuit of certified companies encourages the adoption of more sustainable practices by other sectoral enterprises, fostering a positive change across the entire production chain [8].

The promotion of sustainability in the exploitation of ornamental rocks requires collaboration among the government, businesses, and civil society. The government plays a pivotal role in creating and implementing public policies that incentivize sustainable practices within the sector. It's deemed highly significant to establish fiscal incentives for companies that adopt environmental preservation measures. Active participation of civil society is also essential through engagement in discussion forums and advocating for sustainable practices. This partnership among stakeholders is fundamental to ensuring the effectiveness of adopted measures and promoting more responsible exploitation of ornamental rocks [15].

3.1.2. Environmental Impacts of Ornamental Rock Exploitation

The exploitation of ornamental rocks has been associated with various negative environmental impacts, including soil degradation and biodiversity loss. The removal of surface layers of soil during the extraction process can result in soil compaction and erosion, compromising its ability to sustain vegetation and local ecosystems. It is important to bear in mind that the opening of new areas for exploitation can lead to habitat fragmentation and destruction, contributing to the loss of plant and animal species [3].

Faced with these environmental impacts, it is crucial to implement mitigation and control measures. One of the most effective strategies is the use of soil recovery techniques, such as adding organic matter and nutrients to restore soil fertility. Viana (2017) asserts that establishing preservation areas near exploited regions is necessary to ensure the conservation of local biodiversity. These measures can help minimize the adverse impacts of ornamental rock exploitation on the environment [10].

Environmental awareness and education among workers in the ornamental rock industry also play a crucial role in reducing negative impacts. It is important for these professionals to be educated about the environmental consequences of their activities and be instructed in good practices that can be adopted to minimize these impacts. This way, they are more likely to adopt responsible behaviors during the production process [4].

Excessive extraction of ornamental rocks can result in significant consequences, such as the depletion of these natural resources and increased production costs. Unrestrained exploitation can lead to the exhaustion of deposits, making it increasingly difficult to find new sources of raw materials. Cavalcanti et al. (2017) caution that a scarcity of ornamental rocks could lead to higher prices for these materials, negatively affecting both the industry and consumers [16].

To ensure the sustainability of ornamental rock exploitation, it is necessary to seek more sustainable alternatives. This includes the use of less environmentally aggressive extraction techniques, such as controlled explosive use and more efficient machinery. Moreover, encouraging the reuse and recycling of these materials is important in reducing the demand for new extractions [17].

The adoption of sustainable practices in ornamental rock exploitation also yields significant economic benefits. The appreciation of products in the international market is a case in point, as increasingly conscientious consumers seek materials from responsible sources. According to Araújo et al. (2022), companies that embrace sustainable practices

bolster their reputation in the industry, gaining a competitive advantage and attracting customers committed to environmental preservation [13].

3.1.3. Measures for Mitigation of Environmental Impacts

Ornamental rock exploitation is an activity that can result in various negative environmental impacts. To mitigate these impacts and promote sustainability in this sector, adopting sustainable practices is paramount. These practices entail the implementation of specific measures aimed at minimizing environmental harm and ensuring the preservation of natural resources [5].

Reis and Alvarez (2007) recommend that before commencing ornamental rock exploitation, a detailed environmental assessment should be conducted. This assessment aims to identify potential impacts stemming from the activity and plan appropriate mitigation measures. It is important to consider aspects such as soil quality, water availability, the presence of endangered plant and animal species, among other factors relevant to the local environment [14].

Rosato (2013) emphasizes that one of the primary concerns in ornamental rock extraction is deforestation and soil erosion. To minimize these issues, it is vital to implement extraction techniques that are less aggressive to the environment. The use of directed cuts, for instance, can reduce deforestation and preserve areas crucial for biodiversity. Moreover, investment in the restoration of exploited areas through reforestation and soil conservation practices is necessary [12].

Silva (2019) highlights another pertinent aspect for sustainability in ornamental rock exploitation: water consumption during the production process. Adopting measures to reduce water consumption, such as reusing water utilized in cutting and polishing processes, is essential. This way, the impact on local water resources can be minimized, ensuring water availability for other purposes [9].

Recycling of waste generated during ornamental rock production is also a crucial measure to mitigate environmental impacts. Offcuts and slurry resulting from cutting and polishing can be repurposed in other applications, thus averting improper disposal of these materials. Notably, recycling contributes to the reduction of new raw material extraction and the conservation of natural resources [2].

Investing in cleaner and more efficient technologies is another essential measure to promote sustainability in ornamental rock exploitation. Employing equipment with lower energy consumption, for example, aids in reducing greenhouse gas emissions and minimizing environmental impact. Peiter, Mofati, and Villas Bôas (2014) argue that considering the adoption of renewable sources to meet part of the sector's energy demand is important [2].

3.2. Legislation and Environmental Standards Applicable to Ornamental Rock Exploitation

Legislation and environmental standards play a pivotal role in ornamental rock exploitation, aiming to ensure the environmental sustainability of this activity. Through these regulations, the intent is to establish guidelines and procedures that direct sector companies to adopt responsible practices, thereby minimizing negative impacts on the environment. Additionally, legislation also aims to safeguard natural resources and preserve biodiversity in areas where these materials are extracted [3].

Rosato (2013) explains that among the key laws and regulations governing ornamental rock exploitation, the Mining Code stands out. This code sets forth rules for mineral mining permits, including the extraction of ornamental rocks. The National Environmental Policy also includes specific norms for this activity, such as the requirement of prior environmental licensing for any enterprise that could cause significant environmental impacts [12].

The oversight and enforcement of environmental norms in ornamental rock exploitation are responsibilities of various governmental bodies. The National Department of Mineral Production (DNPM) oversees and monitors mining activities in the country. Meanwhile, the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) is engaged in supervising and controlling activities that can harm the environment, including ornamental rock exploitation [13].

Silva (2019) affirms that to obtain environmental licenses for ornamental rock exploitation, companies must adhere to a range of legal requirements. Among these demands, conducting an Environmental Impact Assessment (EIA) and submitting an Environmental Impact Report (RIMA) are paramount. These studies aim to assess the potential environmental impacts of the activity and propose mitigating and compensatory measures to minimize them [9].

Souza (2021), on the other hand, assures that legislation also prescribes mitigating and compensatory measures to lessen the environmental impacts caused by ornamental rock exploitation. Among these measures, restoration of degraded areas post-extraction through revegetation and soil rehabilitation, as well as the preservation of local fauna and flora, take precedence. These measures seek to ensure the recovery of ecosystems affected by mining activities and promote biodiversity conservation [8].

Reis and Alvarez (2007) contend that the involvement of the local community in the environmental licensing process for ornamental rock exploitation is of paramount importance. This participation enables transparency and social control over activities carried out by sector companies. It is essential to note that the community itself can provide relevant information about the local environment, aiding in decision-making related to environmental licensing [14].

Abreu, Santos, and Souza (2021, p. 06) emphasize that:

The Federal Constitution, in Article 24, sections VI and VII, authorizes the States of the Federation to legislate on forests, fauna, nature conservation, soil, and natural resources, matters related to environmental protection, among various other environmental subjects. Furthermore, as stipulated in Article 30, sections I and II, municipalities are also authorized to legislate on the environment, always following the precepts of federal and state legislation, as appropriate.

However, the enforcement of environmental legislation in ornamental rock exploitation encounters various challenges. One of these challenges is the lack of resources and capacity among regulatory agencies, often hindering efficient oversight. Additionally, some companies in the sector may resist aligning with environmental norms, making the implementation of sustainable practices in ornamental rock exploitation difficult. These challenges underscore the necessity to bolster control mechanisms and encourage sector companies to adopt sound environmental practices [15].

3.3. Sustainable Technologies in the Exploitation of Ornamental Rocks

The restoration of areas degraded by ornamental rock mining is a crucial step to ensure the environmental sustainability of this activity. The rehabilitation of these areas brings significant benefits to the environment, such as the restoration of local biodiversity and the protection of water resources. Revegetation is a widely used technique in this process, as it not only contributes to soil stabilization but also facilitates the reintroduction of native vegetation and the creation of habitats for local fauna. Other important measures are highlighted by Araújo et al. (2022): water quality monitoring and the construction of appropriate drainage systems are essential to prevent contamination of water resources [13].

Baima (2018) informs that the adoption of more sustainable extraction techniques has also been a growing concern in the ornamental rock industry. Dry drilling is one such technique, involving minimal or no use of water during the process. This significantly reduces water consumption, a progressively scarce natural resource, and prevents water resource contamination from mining residues. Additionally, dry drilling contributes to energy consumption reduction, as there is no need to pump water for drilling operations [1].

Seidel, Lima, and Silva (2022, p. 18) emphasize that:

Technological innovation is thus at the heart of strategies and agendas aimed at sustainability in mining and the industrial sector as a whole. However, technological improvement cannot exist dissociated from other dimensions of development, such as social, environmental, regulatory, and community participation aspects [18].

According to Cavalcanti (2016), the implementation of environmental management systems in sector companies is a fundamental strategy to minimize the negative impacts of ornamental rock exploitation. These systems aim to identify and control the environmental aspects associated with company activities, as well as establish goals and indicators to monitor environmental performance. Practices such as proper solid waste management, efficient control of water and energy consumption, and the promotion of recycling are examples of measures that can be implemented through these systems. The author highlights that environmental certification is an important form of recognition for companies following sustainable standards in ornamental rock exploration [11].

Rosato (2013) argues that environmental awareness and education among workers in the ornamental rock industry are essential to promote the adoption of more sustainable practices in their daily routines. It is important for workers to be trained about the environmental impacts caused by the activity and to be aware of the best practices to minimize them. This may include training on the correct use of equipment, proper management of waste generated during the production process, and the importance of conserving natural resources. Furthermore, workers' participation in

environmental education programs can contribute to the development of an organizational culture focused on sustainability [12].

Magris and Martins (2019) draw attention to the use of renewable energy sources in the production and processing of ornamental rocks as a significant strategy to reduce greenhouse gas emissions associated with this activity. Solar and wind energy are examples of renewable sources that can be utilized in this context. The installation of solar panels in extraction and processing areas can meet a portion of the energy demand for these operations, thus reducing dependence on non-renewable sources such as coal and oil. Additionally, the implementation of rainwater harvesting systems is feasible and contributes to the reduction of water and energy consumption [4].

Moreover, Reis and Alvarez (2007) emphasize the environmental certification of sector companies. The authors consider this certification pivotal in ensuring that these companies adhere to sustainable standards in the exploitation of ornamental rocks. This certification attests to the company's adoption of appropriate practices concerning environmental management, emission control, rehabilitation of degraded areas, among other aspects. Furthermore, it lends credibility to companies in the eyes of consumers and other stakeholders, demonstrating a commitment to environmental sustainability. Certification can be obtained through compliance with specific standards or through participation in voluntary programs aimed at promoting environmentally sound practices in the ornamental rock industry [14].

4. Conclusion

This research has demonstrated that environmental sustainability in the exploitation of ornamental rocks plays a pivotal role in preserving natural resources. The conscientious utilization of these resources is essential to ensure their availability for future generations.

The research has found that rampant exploitation of ornamental rocks can lead to significant negative impacts on the environment. Soil degradation and water contamination are examples of such impacts that can compromise the quality of local ecosystems.

Furthermore, it has become evident throughout this bibliographic study that to minimize the environmental impacts caused by ornamental rock exploitation, appropriate measures need to be adopted. One of the key measures is the use of more sustainable extraction techniques, such as the utilization of modern and efficient equipment that reduces waste and energy consumption.

The collected data emphasize the paramount importance of investing in the proper treatment of waste generated during the extraction process, with the aim of preventing soil and water contamination. It should be highlighted that the information shared here aligns with the need to raise awareness and provide environmental education to professionals involved in ornamental rock exploitation, as they play a crucial role in promoting more sustainable practices. It is imperative that these professionals are aware of the negative impacts of the activity and are equipped to adopt mitigating measures. This can be achieved through specific training on good environmental practices and the establishment of clear guidelines within companies.

Lastly, it is worth noting that beyond the environmental benefits, the adoption of sustainable practices in ornamental rock exploitation can also yield significant economic advantages. Companies embracing these practices can enhance their competitiveness in the international market, as environmental sustainability is increasingly valued by consumers. Another point underscored by the research is the recognition that companies that demonstrate concern for the environment tend to have a more positive image among customers and investors. However, to ensure the effectiveness of environmental sustainability measures in ornamental rock exploitation, stricter legislation and efficient monitoring are essential. The presence of clear environmental standards and compliance with these standards by companies are crucial to prevent abuses and ensure environmental protection. Additionally, appropriate penalties for those who fail to adhere to established norms are important.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors assure that there is no conflict of interest with the publication of the manuscript or an institution or product mentioned in the manuscript and/or important for the result of the presented study.

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