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Plan for closure and environmental recovery of the area degraded by limestone extraction in Caçapava do Sul/RS

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ABSTRACT

The activity of extracting ore for the production of consumer goods, whether for agriculture, civil construction or other areas, is seen by the majority of society as something that acts contrary to the environment, which will not bring benefits and from the moment that mining activity begins in certain places. The region will be abandoned at the end of the exploration. However, even before a mining process begins, preliminary studies are carried out, during the operation and after the closure of the enterprise at the site used for mineral extraction. These studies are essential objects for obtaining environmental licenses, project permits and other continuous studies so that the operation of an activity of such size continues to operate legally and according to the requirements of the competent bodies that, even after the closure of operations, need to be continued. Based on this, the work aims to prepare a plan for the recovery of the degraded area and the closure of the mine based on the extraction of limestone, whose activities have been suspended. The methodology applied to carry out the work was based on the collection of data from a project, mainly from field information, and then consultations were carried out with the literature and current legislation with the objective of applying steps so that the plan for closing and recovering the degraded area could be successful. The results demonstrated the path to be followed so that the type of mine closure that was classified as premature due to the suspension of activities from the realization of the economic unfeasibility and the quality content of the available ore can be carried out. In this way, the work demonstrates the importance of planning the closure of the mine and recovery of degraded areas given the number of people involved in the process, not only during the useful life of the mine, but in the future use of the region and the monitoring that will ensure the safety of the society that will stay there and, thus, ensure a successful procedure of environmental recovery.

Keywords: Area recovery, Closure plan, Environment, Environmental impacts, Environmental monitoring.

INTRODUCTION

Mining has emerged as an activity with potential for one of the areas that has developed the most in the country since the seventeenth century with the initial search for valuable metals such as gold, silver, and copper, as well as in the search for precious stones (diamonds and emeralds) (SOUSA, 2023).

The expansion of the field of research makes companies seek to expand their areas, based on the application of research programs, the main one being the drilling close to the units of operation (processing) or active mines that can become new reserves or new acquisitions of mining rights

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(RESENDE, 2009). Advances, however, have created an environmental liability over the years to the same extent that mining (underground or open-pit) has grown in territories with a focus on exploration (SILVA, 2023).

For this reason, mining is seen by part of the population as a negative factor environmentally, even though it is essential for the manufacture of everyday items, favorable prospects and economic indicators. But this is due to the lack of knowledge of society or confusion when compared to the predatory action caused by mining and restriction on the size of its impact on the environment (RESENDE, 2009).

In recent decades, the environmental appeal based on the records of abandonment of exploration areas with reserves that do not have economic viability, has brought to the fore discussions about the need for projects, whether they are in the implementation phase, under development or closure, that have a closure and recovery plan for areas degraded by the activity employed. (RAODEL, 2021).

Even temporary closures must be precautioned by companies, precisely because of the variation in downtime of the mine in question. This precaution is due to the environmental aspect of the site, which can lead to the maximization of environmental liabilities, such as the evolution of slope erosion processes, silting of water courses and an increase in areas contaminated by tailings (CAMELO, 2006).

According to Resende (2009), the absence of long-term safe planning and implementation of closure and recovery plans that comes from the companies, even during the useful life of the mines, in which the operation of extraction is a strong point, causes the insecurity of the population to be constant until the period of closure of activities.

The municipality of Caçapava do Sul has large companies that together are responsible for the extraction and processing of limestone, which supply approximately 85% of the dolomitic limestone produced in the State of Rio Grande do Sul for civil construction and agriculture purposes (FLORES, 2017). Due to this high demand, the extraction areas lack long-term planning aimed at the completion of the mining front after the phases of removal of the ore for industry (FLORES, 2017).

Thus, the work aims to carry out a mine closure plan and recovery of the area degraded by limestone extraction that had its activities recently suspended. The realization was based on the discussion regarding works that encompass the soil situation, plant species that are better adapted and native to the region, as well as methods that can be applied to the study site in order to plan the future use of the area according to the objective of those responsible for the project.

OBJECTIVE

The present work has as its general objective the realization of the mine closure plan and forecast of the environmental recovery of an area degraded by limestone mining activity in the municipality of Caçapava do Sul/RS, as well as the following specific objectives:

- Case study for the realization of the mine closure plan;
- Establish the mine closure stages;
- Planning the recovery of the degraded area;

METHODOLOGY

The objective of this work was to carry out the plan for the closure and recovery of degraded areas of a limestone extraction mine in the municipality of Caçapava do Sul/RS that has been deactivated since 2014, in which the economic unfeasibility of the mine by the company that exploited it was attested.

The object of study is a deactivated limestone extraction area located in the municipality of Caçapava do Sul, in the state of Rio Grande do Sul, according to the coordinates of zone 22J, longitude 267,447.51 mE (east meters) and latitude 6,618,093.11 mS (south meters), both in UTM (Universal Transverse Mercator), as shown in FIGURES 1 and 2.

Figure 1 - Map of the mine's situation and location (DE FREITAS, 2014).

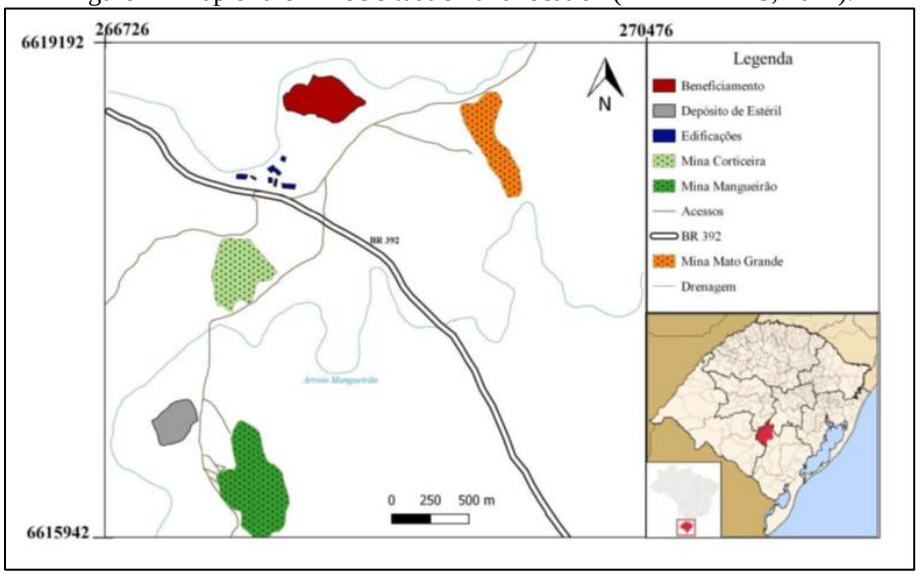


Figure 2 – Location map of the study area (Author, 2024).

The closure plan was carried out in the pit of a limestone extraction mine identified as illustrated in FIGURE 8, which had its activities paralyzed in 2014 (around 10 years) due to the economic unfeasibility for the continuation of the limestone extraction process for operational reasons (deepening of the mine, need to increase the suppression area, among other factors).

The mine is part of the closure plan prior to the exhaustion of the mine, since the continuity of exploration momentarily becomes economically unfeasible given the conditions of the area in which the mine is located, such as proximity to the municipal road and highway, an area that requires licensing with a more in-depth study, in addition to the content of the ore existing in the place.

For this, the model established by ANM resolution 68/2021 will be applied for an area of 0.7 hectares (ha) and the recovery calculation of this area will be carried out, establishing future use for the area.

As for the existing structures, a conceptual distinction of decommissioning of civil structures and physical and chemical stabilization of the structures that remained in place due to their proportion will be mentioned, in addition to rehabilitation actions of the area already executed, such as the inclusion of a recovery plan for areas degraded by mining activity.

Actions aimed at monitoring and maintaining the areas after the full recovery of the site will be presented. A plan for the physical and chemical stabilization of the remaining structures will be presented, once a schedule has been established that will integrate the pre-closing, closing and post-closing period, in a way that respects the adequacy of the area for the future use of the site.

Along with the monitoring data, the assessment of the risks arising from the closure and ways of mitigating any damages resulting from the activity will be presented, which will be applied and monitored over the years so that there are no future problems when the area is used.

The steps of the Closure Plan are arranged as follows:

- Classification of mine closure according to ANM classification;
- Establishment of future use of the extraction area;
- Measures that will be taken upon deactivation;
- Risk analysis;
- Establishment of the follow-up and post-closure monitoring plan;
- Establishment of schedules for the mine closure plan;

DEVELOPMENT

IDENTIFICATION OF THE ENTERPRISE

The project, according to FEPAM license, promotes the activity of Limestone Mining, Industrial Clay (Kaolin) – Open Pit and with Recovery of Degraded Area, and is located at the ANM polygonal number 811.030/1970 according to the geographic coordinates below and research demonstration on the ANM (National Mining Agency) website:

- Latitude: -30,54761200;
- Longitude: -53,42197100.

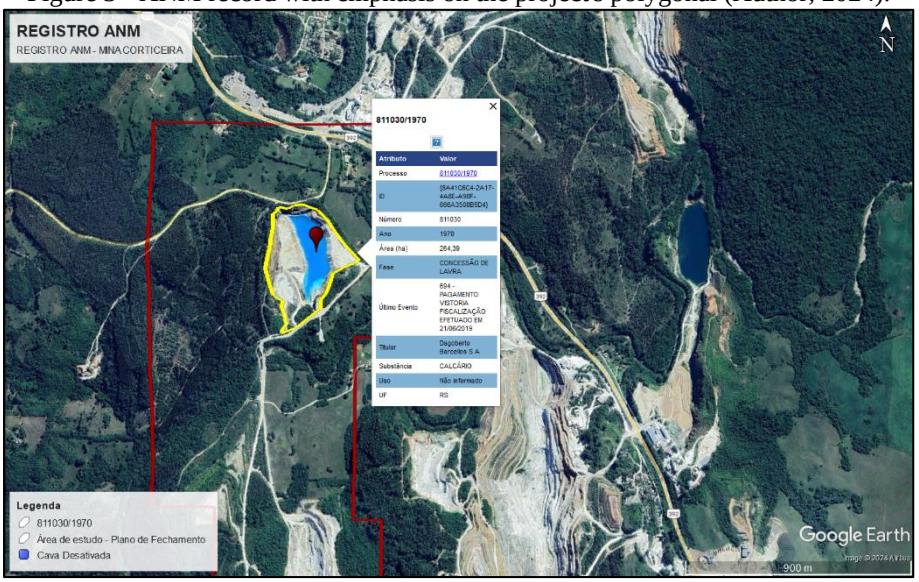
The area of the polygon is about 264.39 ha, but as informed in the LO (Operating License), the useful area of the enterprise is around 52.70 ha and finally, the study area for the present work is approximately 11 ha, as highlighted in FIGURE 3.

The mine shown in Figure 3 began its activities with the National Mining Agency in 1970 with mining being carried out in the open pit (BRASIL, 2024).

With the passing of the years of extraction and the quality content of the ore (neutralizing power of the limestone) extracted showing a significant drop, the continuity of the extraction became economically unfeasible for the enterprise.

Thus, it was necessary to deepen the pit and this would require the enlargement of the area around it, which made the process even more complicated, given the proximity of the site to municipal access roads, causing the mine to suspend its operations in 2014 and the company opted to focus on other fronts of operation of the enterprise.

Figure 3 - ANM record with emphasis on the project's polygonal (Author, 2024).



ENVIRONMENTAL IMPACTS OF THE PROJECT

As it is a project that has direct interference in a certain location, the impacts caused lead to significant changes in the mine's operating environment, which makes it necessary to adopt measures to control and mitigate the effects of the work carried out on the site to be scored in the general impacts caused by the mining activity.

The occurrences of environmental impacts and the need to carry out such studies are due to the consequences of mine closure occurring in a varied way, especially when in areas that are more environmentally fragile, changes make the impacts more pronounced (PINTO, 2017).

The first impact was the instability of the mine's slopes, which due to the proximity of the municipal traffic route, an area of vegetation in which the extraction polygonal has the authorization and the inclination of the benches, can lead to the erosion process and jeopardize the safety of the site for future use. If it was necessary to reconfigure the slopes by expanding the area of the embankment, this expansion brings an improvement in stability, helping mainly to prevent soil erosion through the passage of water conducted through ditches to sedimentation basins.

The impact caused by the movement of the equipment due to the disposal of the waste material and soil for the recovery of the area and the transit of the equipment (trucks and bulldozer) on the access roads was contained by the use of a water truck on the driest days so that the dust could be reduced.

The possible contamination of nearby water resources occurred from the exposure of the soil and the dragging of the chemical composition of the rock from the actions of time. For this, the lake formed from rainwater in the area of the pit that was suspended, serves as a sedimentation basin not allowing possible contaminants to go to nearby water resources.

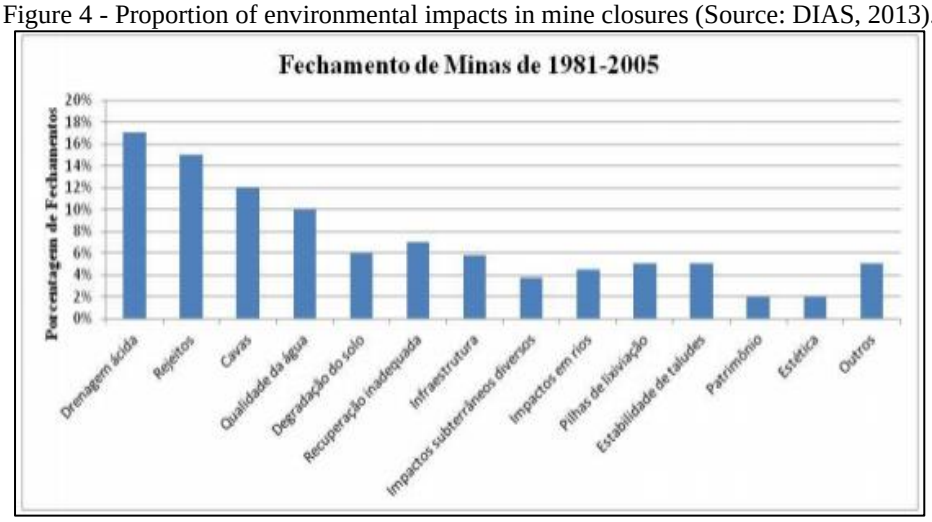
As for the impacts caused by deforestation and the suppression of the vegetation that existed in the pit area, its recovery will take place through the expansion of the landfill area, disposal of natural soil from other areas of advancement of the enterprise, or better known as sterile because it is not used as a product.

The socio-environmental impacts that may influence the region's economy will be mitigated even with the deactivation of the cork mine, due to the fact that the project has two more mining areas in operation next to the ore processing.

Thus, according to Pinto (2017), the extension of ore exploration contributes to more accentuated occurrences, especially in activities that have a longer exploration life - which spend centuries of operation, with the potential for greater impacts on small ones at the time of closure of activities.

Figure 4 shows a graph based on a study that is related to the main environmental impacts from the closure of mines in Australia between 1981 and 2005, since it demonstrates the importance of attention to the post-closure period of mining companies around the world, and in Brazil, more in-depth studies are still needed because there are many projects still in operation or without the closure of the right way. (DIAS, 2013).

Figure 4 - Proportion of environmental impacts in mine closures (Source: DIAS, 2013).



TYPE OF MINE CLOSURE

The mine closure plan has become an essential tool for the continuity of mining activities and before they start, considering that every mine will have its end and from this topic it has become a concern (PINTO, 2017).

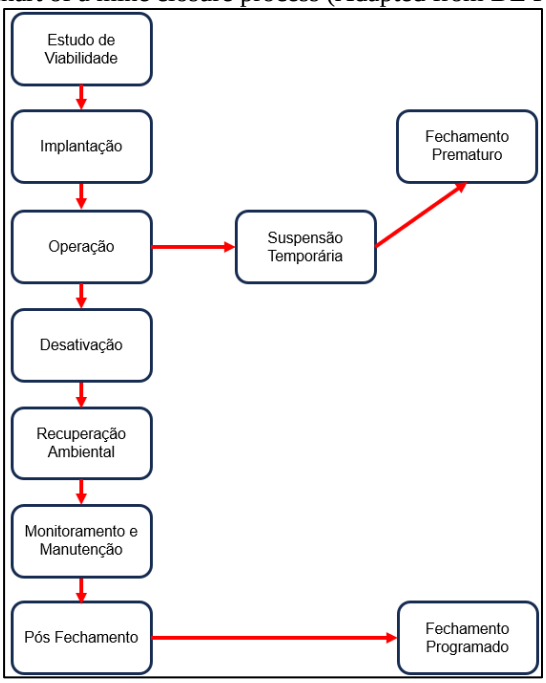
De Freitas (2014) presents a flowchart in FIGURE 5, which refers to the two main types of mine closure according to the ANM, which separates into two main types, the premature type, which is the

study of the present work, and the scheduled closure, which refers to the plan presented at the beginning of the project, that is, in the implementation phases.

The type of PFM that fits into the mine, which is the object of study of the work, is that of premature closure, since it was not planned by the technical team of the enterprise through the company's closure plan. This is due to the temporary suspension of activities with the economic unfeasibility of the pit extraction process and the cost that is involved in the process of drying the water and advancing the mining.

Temporary suspension after a certain period of time leads to the definitive closure of the mine and falls under premature closure because it is earlier than foreseen in the initial plan.

Figure 5 - Flowchart of a mine closure process (Adapted from DE FREITAS, 2014).



DEACTIVATION PROCESS

The stage that involves the deactivation of an enterprise of the size of the mining activity can be defined as one of the parts of the process of closure of extraction activities, whether due to exhaustion of the mineral reserve, economic unfeasibility of the continuity of extraction (DOS REIS & BARRETO, 2001).

Sanchez (2013) mentions that deactivation can also be defined as the period that begins before the closure, time before the confirmation of the closure of mining activities and has as its conclusion, the removal of all facilities that are considered unnecessary and allows the recovery process of the area.

The current case of the company used as the basis of the study, for the case of the equipment, mine structures (works, offices, storage of supplies) that will be deactivated, went through a process of relocation to other areas in activity of the enterprise.

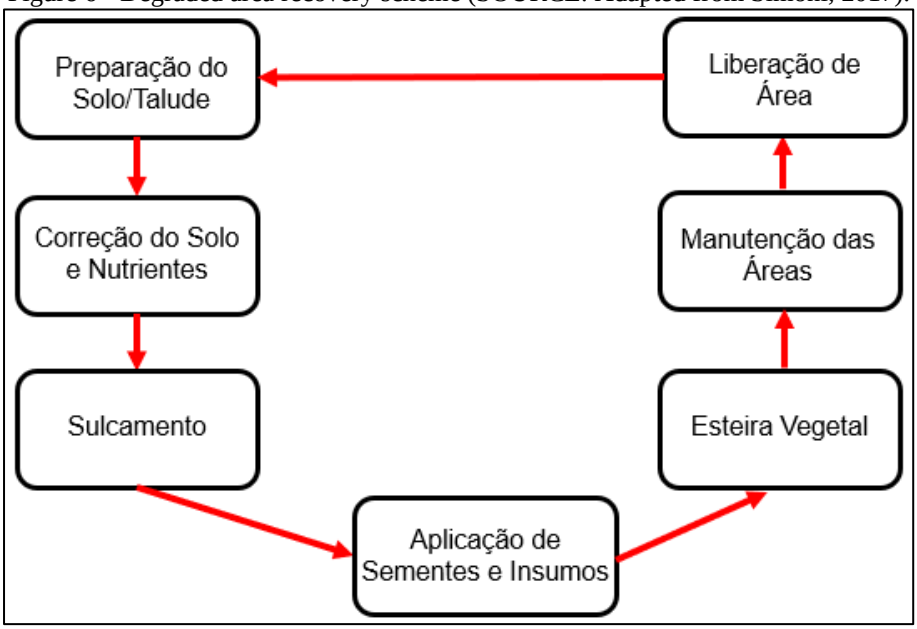
For mobile equipment (excavators, wheel loaders and trucks), there may also be a fleet sizing, so that there may be a process of selling them to other companies, giving them a destination.

ENVIRONMENTAL RECOVERY PROCESS

The recovery of degraded areas is related to earth movements, changes in topography and revegetation in all mine structures (pits, dams and waste piles) so that recovery is guaranteed not only at the end of operations, but also during production processes (FLÔRES, 2006). The need for recovery is based on projects that are adequate and coherent with the characteristics of the environment in which the project is inserted.

Thus, for each degraded surface, there must be a project, even if it is not possible for the area to return to similar vegetation formation prior to the beginning of the activities. Figure 6 elaborates a general scheme of the stages of environmental recovery so that the necessary conditions for the planting and growth of healthy vegetation can be guaranteed (SIMONI, 2017).

Figure 6 - Degraded area recovery scheme (SOURCE: Adapted from Simoni, 2017).



The environmental recovery process in the case study referring to degraded areas will take place from the filling of the pit with sterile or rocky material, soon after a drainage system will be laid out in order not to overload the surface water runoff and finally organic soil (vegetation cover) will be placed, as shown in Figure 7.

Figure 7 - Model of an area with environmental recovery (Author, 2024).

The application technique is based on the release of grass seeds in proportions of 10 kg/ha. This type of sowing can help in the stability of the slope, stability and reforestation of the site, with development linked to the climate and adaptation to the planting site.

Reforestation, on the other hand, will take place from the planting of native trees and eucalyptus trees in the areas surrounding the cork mine, cases of waste piles and banks of the mangueirão and salso streams, as compensatory measures and after well-stabilized slopes and with the grasses in an advanced stage of sowing.

As part of the process of maintaining the planting of native seedlings, measures will be taken regarding their cultural treatments, aiming at the success of the planting and recovery of the areas, from the completion of the steps mentioned below:

- Staking with structure to guide the development of the seedling (FIGURE 16);
- Crowning;
- Fighting pests (ants);
- Replanting, if necessary;
- Irrigation in prolonged periods of drought.

The seedlings need a minimum height of 1.0 meters of aerial part with admission of loss of 10% of the amount in which the planting was carried out.

Table 1 shows the schedule used by the enterprise for the planting and reforestation process for environmental recovery of the company's landfill areas.

Table 1 - Planting schedule followed by the company for the year 2021.

Operations / Month	J	F	M	The	M	J	J	A	S	Or	N	D
Hollowing					X	X	X					
Planting					X	X	X					
Installation of tutors					X	X	X					
Replanting								X	X			
Fighting the ant					X	X	X	X	X	X	X	X
Cultural Treatments					X	X	X		X		X	
Monitoring			X			X			X			X

RISK ANALYSIS

During the closure phase, the possible risks that the project may cause or suffer to the environment and the surroundings of the ore extraction pit area are surveyed while the closure occurs and after the period. Risks can encompass physical, chemical and biological agents and within each group there are risks that can occur with a certain frequency while others have a remote possibility of happening when in large quantities.

Among these environmental risks, the instability of slopes that can form erosion and landslides, leakage of oils and grease from the movement of machinery, contamination of water resources and silting of the ditches of rainwater drainage systems can be mentioned.

FUTURE USE OF THE RECLAIMED AREA

Bitar (1997) states that there are two types of situations that can influence the future use of areas degraded by mining activity, being them in a disorderly way characterized by the abandonment of the area and areas with post-closure project implementation being divided into 24% for the first case and 76% for planned closures.

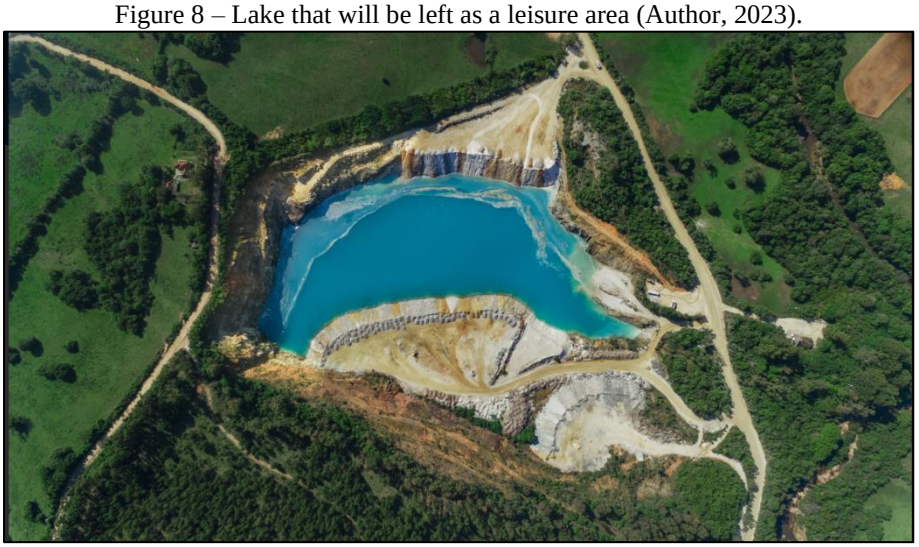
The types of disorderly use are housing or irregular waste disposal that generate risks for the general population and the environment, given the instability of the site. There are risks of erosion and landslides that are aggravated by the instability of the rock block, in addition to soil and water contamination not only of the site, but of nearby areas (BITAR, 1997).

On the other hand, according to a study of PRADs carried out by Bittar (1997), many of them are aimed at environmental preservation and conservation with a focus on pastures, agricultural activities, commercial reforestation, water and sewage treatment areas and waste disposal. However, uses such as leisure, recreation, road system and areas aimed at education are also included.

The area in question will not undergo decommissioning because it is a site owned by the project and there is no provision for the use of the area for economic purposes in terms of planting or land use, with the first objective being recovery to maintain the sustainability and environmental quality of the site.

The objective of future use of the project is the use of the site as a leisure area from the exploration of the tourist potential of the region and the lake formed from rainwater and runoff from the surroundings that causes the formation of a lake shown in Figure 8.

Figure 8 – Lake that will be left as a leisure area (Author, 2023).



Thus, from the moment that the object of study has as its main characteristic of being an area of private property and relevant distance from the population of the municipality, the future use will be the creation of a leisure area focused on the tourist context in which the region has from the maintenance of the lake in the center of the area in which the extraction of the ore was carried out. fitting into the planned future use, even if it is a premature termination.

ENVIRONMENTAL MONITORING

Environmental monitoring is the organization and follow-up of recommended measures to prevent and mitigate the impacts of the operation of the project during and after the closure of the mine and deactivation.

Monitoring must rely on coordinated actions, which follow the applicable legislation and continuously evaluate environmental quality, environmental monitoring that develops efficient mechanisms for minimizing or eliminating the sources of impact found during the process and become a mechanism that adds knowledge about the factors related to the reestablishment of fauna and flora (SIMONI, 2017).

Monitoring is carried out by the technician responsible for the recovery project based on the monitoring of the performance of the vegetative elements, biodiversity of the species, comparison of different space times, soil issues and evaluation of the continuity or change of the type of intervention (RODEL, 2021).

The environmental monitoring that will be carried out is based on the parameters of greatest influence on the population and can directly and indirectly impact the neighboring communities near the project, so it is necessary to carry out the monitoring mentioned below:

a. Topography / Slope stability;
b. Water resources;
c. Soils;
d. Atmospheric Emissions;
e. Vegetation;
f. Return of the Fauna;
g. Environmental Conservation and Preservation.

According to Rodel (2021), the monitoring stage of the recovery process of degraded areas is one of the most important because it is a process that involves diagnosis, decision-making, and intervention based on the analysis of the results presented after its conclusion.

PHYSICAL TIMELINE OF THE MINE CLOSURE PLAN

The physical schedule presented in Table 2 represents the planning of what will be carried out in the extraction pit during the closure and environmental recovery of the area.

Table 2 - Physical schedule for PFM from the year 2021 (Author, 2024).

Operations	Period from 2021 Month											
	J	F	M	A	M	J	J	A	S	O	N	D
Loading & Shipping												
Disposal of sterile												
Configuration of waste pile slopes												
Revegetation with grasses and trees												
Maintenance of the implanted vegetation												
Maintenance of pile drainage systems												
Maintenance on roads and accesses												
Control of erosive processes in the pile												
Sterile pile monitoring program												
Surface Water and Effluent Monitoring Program												
Monitoring of the measures implemented												

FINAL THOUGHTS

Mining activities are often considered harmful in the way in which the process of deactivation of enterprises and their structures occurs, in which it is left with a character and visual aspect of abandonment in the region where the extraction of a certain mineral asset occurred, which often makes the

insertion of new mining companies in the municipalities complex and was in a way a common characteristic of old mining in the region. Country.

From this point on, the mine closure plan became a vital process for the establishment of an enterprise in several regions of Brazil, as it involves the entire community and a long-term planning that does not only discuss the useful life of the mine or the enterprise on the site (as in the case of the company that was the object of study of this work that has more than one extraction area), but also the post-extraction period.

The elaboration of the mine closure plan and the consequent recovery of areas degraded by mining activity has become a complex and essential task to serve as a way to guarantee the sustainability of the region, which will suffer the various impacts of a project of the size of a mining company, without the exclusion of any mineral asset.

The plan highlights the need to contemplate the ecological recovery of the areas, but mainly the socioeconomic impacts on the communities that will be benefiting from the generation of jobs and development of the region at the time of operation. For this, it is necessary to have the engagement of all parties involved in the process and, above all, to demonstrate the relevance they have and the role of each one so that the process can evolve, with public consultations, frequent meetings, needs of all parties and transparency of the processes.

The need to promote the economic sustainability of local communities after the closure of the mine becomes essential due to the possibility of creating training and qualification programs, which allows workers to relocate to other areas of work, in addition to encouraging local entrepreneurship.

Thus, for the mine closure and recovery plan for degraded areas to be carried out, there is a need for a complete and integrated approach so that the main aspects of the region in which a project is installed are integrated, being environmental, social and economic. From the moment these pillars of sustainability and transparency with all those involved in a project can guarantee success effectively and with benefits for all and in the useful life, aiming at the medium and long term.

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