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Overview of mine closure in Minas Gerais, Brazil

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Resumo

Embora as regulamentações sobre fechamento de mina no Brasil sejam recentes muitas empresas de mineração têm buscado adotar as melhores práticas e estão enfrentando o desafio de fechar as minas da melhor maneira possível, em vez de simplesmente cumprir a legislação vigente ou abandonar o local da mina. O objetivo desse estudo é destacar as mudanças nos requisitos de fechamento de mina, bem como as melhores práticas de fechamento de minas no Estado. Para tal, o artigo sumariza o fechamento da mina de acordo com a legislação brasileira e a "Deliberação Normativa" COPAM Nº 127, que estabelece as diretrizes e procedimentos para avaliação do impacto ambiental na fase de fechamento de mina. Para exemplificar, esse artigo discute a legislação de fechamento de mina no Brasil e no Estado de Minas Gerais e apresenta alguns exemplos de programas de fechamento de mina no Estado. O artigo defende que, mesmo com alguma falta de leis e diretrizes abordando o fechamento da mina, a indústria da mineração brasileira, hoje, está na vanguarda das técnicas de minimização do impacto ambiental. Alguns estudos de caso em Minas Gerais, dois deles localizados no Quadrilátero Ferrífero, constituem excelente testemunho da experiência da indústria em processos de reabilitação ambiental.

Palavras-chave: Fechamento de mina, regulamentação, Brasil, Minas Gerais.

Abstract

Despite closure regulations being recent in Brazil, many mining companies are attempting to adopt best practice and are facing the challenge of closing their mines properly instead of simply complying with current legislation or abandoning the mine site. This paper summarizes mine closure according to both the Brazilian legislation and the "Deliberação Normativa" COPAM Nº 127, that establishes the directives and procedures for environmental assessment at the mine closure stage. Even with the lack of laws and regulations addressing mine closure, the Brazilian mining industry today is at the forefront of environmental impact minimisation techniques. Some case studies in Minas Gerais State, two of them located in the Iron Quadrangle, provide excellent evidence of the industry's rehabilitation expertise. This paper presents an overview of mine closure legislation in Brazil and in the State of Minas Gerais and gives some examples of mine closure programmes in effect. It is intended to highlight the changes on mine closure requirements as well as the best practices on mine closure in the State.

Keywords: *Mine closure regulatory system, Brazil, Minas Gerais.*

1. Introduction

The concepts and principles surrounding mine closure are rapidly evolving in terms of the supposed scope and responsibilities of the major groups involved. These groups include government, industry, impacted communities and other stakeholders such as, non-governmental organizations (NGOs), financial institutions and other components of civil society (Lima, 2005; Lima & Curi, 2002). Mine closure is a challenge for both industry and the regulatory system in many countries. This is certainly true in Brazil, where many long-operating mines are experiencing closure and regulatory agencies are preparing to impose new regulations.

Mines are closed for a variety of reasons. Naturally, when their reserves are exhausted. In many respects, this is the easiest scenario to manage. Among other causes, the principal is likely to be economic, specifically a steady decline in global commodity prices. In addition, geological, technical, regulatory and social or community pressure issues can cause mine closure (Laurence, 2006). Despite the reason of closure, a mining company must prepare and implement a closure plan that protects human health and safety; restores air, land, and water environments to the practicable extent including protection of fish and wildlife; reclaims the land to pre-mining uses where practicable; maximizes both local and territorial socio-economic benefits; and manages long-term environmental and engineering risks in a cost-effective manner.

This paper intends to present the recent regulations relating to mine closure, comment the lack and faults of these regulations in order to enforce compliance and, in addition, to assist mining companies in the development and implementation of a closure plan. To support the analysis of these regulations some case studies are presented as the state of art on mine closure in Minas Gerais, a state where mining reclamation practices have been reported by Toy & Griffith (2002). The cases are also expected to call attention to the need of timely planning for closure in order to avoid unexpected environmental liabilities and increased closure costs.

2. Methodology

The methodology followed to carry out this study encompasses a review and assessment of the regulatory system related with mine closure in Brazil and in the State of Minas Gerais, since this is the most important mining state in Brazil. Besides a review of the literature dealing with closure plans and rehabilitation of mines located in the State of Minas Gerais was carried out.

The State Environmental Agency (FEAM) and the National Mining Department (DNPM Portuguese acronym) were visited in order to collect information, data and to get access to three closure plans submitted by mining companies as well as data on mines closed or in process of closure.

A questionnaire was prepared in order to collect information on the field. Its purpose was to guide the interviewers in finding out the existence or not of a closure plan and its scope, the status of the mine closure planning, the main rehabilitation activities being carried out, the main problems faced, the measures adopted, the closure cost estimation procedure and the closure team involved. There was not a prescriptive interview procedure to be followed during the mine site visit.

An analysis of all sorts of technical documents including PRADs, mine closure plans, consultancy and internal reports was planned to build the basis for this research. However, it was not possible to have access to all of them. The reasons include the absence of some (e.g. closure plans), restrict access, concern for confidential information, poor control of files on the part of government agencies that raised difficulties for us to access such documents.

3. A review of regulations dealing with mine closure

From 1989 through 2001, the basic obligation imposed on the mining concession holder, related to mine closure, was to rehabilitate the mined area according to the Plan for Rehabilitation of Degraded Areas (PRAD, Portuguese acronym) approved by the environmental agency. The rehabilitation requirement for PRAD uses the basic worldwide concept that the site must be left in a state suitable for, or appropriate to, the established or agreed upon final land-use.

In 2001, the National Department of Mineral Production (DNPM), enacted the Mining Regulation Norm (NRM 20), that deals with mining suspension and closure. According to NRM 20, new mining projects should add a closure into the plan of economic exploitation (PAE, Portuguese acronym) to obtain the mining rights. For operating mines, the company should communicate the Ministry of Mines and Energy when a mine is about to enter the closure process, justifying the closure and presenting a closure plan. NRM 20 also establishes for mines not having a closure plan enclosed in their mining plan, that the submission of one should be requested at the discretion of DNPM's Director. However, NRM 20 is vague and indifferent about the point in time required for both mining company to submit the plan and DNPM to assess, report and manifest about the plan (Flôres & Lima, 2007).

In the State of Minas Gerais the Environmental Agency (FEAM) enacted "Deliberação Normativa" Copam Nº 127/2008, establishing the guidelines and procedures for environmental assessment of the mine closure process. According to Copam DN 127, from the 1st of July 2009, a mine in process of revalidating its operational license must include the plans for mine site rehabilitation in the Environmental Performance Assessment Report (RADA). Every mine, at least two years before closure, must submit the Environmental Plan for Mine Closure (Pafem, Portuguese acronym) to the Environmental Agency. Copam DN 127 also requires a Pafem from mines whose rights are suspended, expired or declared null by DNPM, as well as, from mines with abandoned status.

Now, another actor to be considered in mine closure legislation is the State Attorney Office. An agreement signed on September 2009 by the State Attorney and a mining company, for reopening Várzea do Lopes Mine requires, for the first time in Minas Gerais, a mining company to post a financial

guarantee for mine site rehabilitation. Therefore, although Copam DN 127 and NRM 20 do not require financial guarantee for mine closure, there is a clear tendency to demand it in the mine closure license process.

4. Case studies

This research faced some problems to review mine closure plans. Although the plans should be available for consultation at the environmental agency the researchers had difficulties to have access to them. The reasons include the absence of the plan (Osamu Utsumi Mine); difficulties to find the plan at the environmental agency (in the last three years FEAM moved three times), e.g. Mina Velha and Riacho dos Machados Mine and in the case of Germano Mine, Samarco has a general closure plan for its operations but no information exists that this plan has been submitted to the environmental agency. The only closure plan available and consulted was that of the Aguas Claras Mine. A closure plan for Osamu Utsumi Mine is being prepared and INB provided all sorts of documents related to mine closure to the researchers. This study did not consider some PRADs. Although PRAD must be part of a closure plan, many of them were submitted to the environmental agency in 1989 which was enough to comply with the law. These PRADs were not assessed since their importance for mine closure was minimal according to Lima et al. (2006) and Flôres and Lima (2007). Table 1 summarizes some information gathered from the mines studied.

Mine	Company	Town	Ore	Year of closure	Reason of closure
Águas Claras	Vale	Nova Lima	Iron ore	2001	Reserve exhausted
Riacho dos Machados	Vale	Riacho dos Machados	Gold	1997	Oxide ore exhausted
Osamu Utsumi	INB	Caldas	Uranium	1995	Reserve exhausted
Velha	Anglo Gold Ashanti	Nova Lima	Gold	2003	Not specified
Germano	Samarco Mineração S/A	Mariana	Iron ore	1992	Reserve exhausted

Table 1
Mines Closed or in process of closure in the State of Minas Gerais.

Águas Claras Mine

The Águas Claras Mine operated from 1973 through 2002, (Figure 1). The first large mine in Brazil being closed, its closure is probably a remarkable point in the Brazilian mining industry, under the sustainable development point of view. The location and physiography of the area favour an anthropogenic post mining use, a village, surrounded by the preserved Jambreiro Forest and the lake being created in the depleted pit. The closure plan establishes the creation of an urban centre in an area of 194 ha that represents 9% of the total area. This urban centre will encompass a museum and cultural space a park for fairs, an open mall, commerce and services, teaching and research, hotel and residential buildings, as well as the administrative centre of Vale. This infrastructure is expected to generate 20,000 new jobs over the next 20 years.

Figure 1
Aerial view, from 1998, of the Águas Claras Mine from the top of Curral Mountain. Source: MBR courtesy.

The Águas Claras mine closure plan is divided into 4 major items:

1. Environmental assessment:

• Physical aspects: climate, water quality, geology, geomorphology, hydrogeology, and geotechnics.

• Biotic aspects: fauna and flora.

• Anthropogenic aspects: economics, legislation, land use.

2. Definition of the future scenario

3. Assessment of environmental impacts upon decommissioning and risk analysis.

4. Elaboration of closure and post-closure programmes and procedures.

Among these items, the creation of the in-pit lake is by far the most interesting one. Several studies have been carried out (or are under way) to address this issue including: slope stability upon filling; impact on groundwater and determination of the required time for filling; expected lake water quality and verification of lake induced seismology (Franca, 2001).

Mina Velha and Mine Facilities

The town of Nova Lima, in the State of Minas Gerais, home of the old Morro Velho operations (now Anglo Gold Ashanti) has been a gold mining centre since 1830, when large-scale mining first began. The underground gold mine "Mina Velha" was commissioned in 1830 and closed in 2003. Until its closure Mina Velha was the oldest gold mine in operation in the world. In 2004, the Federal Mining Department (DNPM), following a technical visit, issued a partial closure certificate for surface infrastructure and the mining operation at Mina Velha, and final decommissioning is underway. The State Environmental Agency (FEAM) is still evaluating the closure from an environmental perspective (Lima, 2005).

Besides Mina Velha decommissioning programme, Anglo Gold Ashanti is conducting rehabilitation activities of old tailings deposit in Nova Lima (Figure 2). To address the potential hazard associated with the historic tailings disposal practices, a rehabilitation project was initiated in 1995 covering the old tailings dumps and the arsenic recovery plant site. This included a massive revegetation programme at a cost of US$500.000,00. Studies and consultancy findings from 2002 indicated that tailings encapsulation would be required to avoid future risk of human exposure.

A rehabilitation programme, started in 2004, focused on the complete removal of topsoil and tailings from the Morro do Galo old arsenic trioxide recovery plant. The Morro do Galo hillside has now been completely rehabilitated and the Galo tailings deposit is in its final stage of recovery (Figure 3). In 2005, the programme included the old tailings deposits at Resende, Matadouro and Fabrica de Balas being concluded in 2006. An extensive communications programme has been undertaken with the local residents (some 40 families - approximately 160 people - surrounding the Morro do Galo and Galo tailings deposits). The cost of about U$4 million was estimated for this rehabilitation programme (Anglo Gold Ashanti, 2004; Alves, et al. 2008).

Figure 2
Galo tailings
deposit before rehabilitation (left)
and after rehabilitation (right).
Source: Anglo Gold Ashanti courtesy.

Figure 3
Morro do Galo hillside before
rehabilitation (left) and after
rehabilitation (right).
Source: A picture from Milton Nascimento
Record called Sentinela, 1980 (left)
and AngloGold Ashanti courtesy (right).

Germano Mine

The iron ore open pit of Germano Mine, from SAMARCO, supplied itabirite to Germano Concentrator Plant from 1976 through 1991. After Germano pit lifetime end, many landslides occurred in the pit caused by slope instability impacting the conveyor belts production system passing through the bottom of the pit, haul road obstructions and other equipment security problems. According to Samarco, Germano's pit closure focuses on slope stability and environmental rehabilitation. Due to the poor geotechnical quality of the pit walls the option found was to fill it with coarse sand tailing from Germano Plant. This option also proved reasonable since it could increase the lifetime of the tailings reservoir. Geotechnical studies defined the final angle of the sand filling to 18° and a maximum safe height of 150 m. The pit-filling programme was divided into two phases. Phase 1 filling from the bottom of pit (elevation 945 m to 970 m) and Phase 2 from elevation 945 to 1,100 m (Figure 4, left). Burle Marx, the world-renowned Brazilian landscape architect, developed a conceptual landscape project as part of the rehabilitation programme (Figure 4, right).

Phase 1 sandy tailing pile begun in 2001, with foundation excavation and building of a drainage blanket (internal drainage system) and a start-up dike. A pumping system was used to build the sandy pile raised by upstream method. Stability management during construction included the installation of piezometers and inclinometers plus periodical safety inspections. The sandy tailing storage volume loaded at Phase 1 was 5 x 106 m³. Phase 2 includes building of start-up dike and drainage blanket (internal drainage) and drainage gallery, pumping system to dispose the sandy tailing in the 2nd phase pile, installing of piezometers/ inclinometers and safety inspections. Sandy tailing storage capacity will reach 48 million m³. 16 years are estimated for sand tailing disposal in the pit at a cost of US$2 M (Phase 1), US$8M (Phase 2) and US$ 2M for vegetation (Lima et al., 2007).

Figure 4
Germano pit Phase 1 construction (left) and final pit illustration after Phase 2 revegetation (right). Photo Samarco courtesy.

Osamu Utsumi Mine

The Osamu Utsumi mine from Industrias Nucleares do Brasil (INB) is located in the town of Caldas, in Southern Minas Gerais. The so-called Caldas Unit produced uranium concentrate from the onset of its activities in 1982, that basically supplied the demands of Angra 1 reactor reloads and technical developments programme. Besides its importance as an ore deposit, it was in Caldas that the fuel cycle technology development and the uranium concentrate (yellowcake) production as ammonium diuranate (ADU) began. The Osamu Utsumi open pit mine was exploited down a depth of 120m (Figure 5 on left). About $47x10^6 m^3$ of overburden material, ore and waste rock were taken out of the pit. The mining activities from 1977 through1996 generated $45x10^6 m^3$ of waste rock. The waste rock is characterized by the presence of low-grade uranium below 200 ppm of U_3O_8. Out of the five waste rock piles, two of them, named "waste dump 4 and waste dump 8" have produced large amounts of acid drainage (Figure 5 on right). The plant running at full was able to process 2,500 ton of ore/day and produce 400 ton/year of concentrate. Solid and liquid wastes were sent to a tailings dam. Since the beginning of operation, control actions were taken to minimize environmental impact, such as (Cunha et al., 2006):

- Acidic water treatment.
- Lining sterile heaps surface and waste rock piles with 30cm layer of compacted clay in order to avoid percolation of rain water through the piles.
- Alternatives of vegetation aiming at stabilization of the deposits against erosion due to wind, water and humidity penetration into the waste rock piles.

Some rehabilitation and stabilization of the pollution potential of these areas were performed by the development o an Environmental Control Programme However, since the shutdown of opera tions a closure plan for the complete uni has not been prepared or submitted to the environmental agency. A previous assess ment from SRK consultancy reports an estimate of 10 to 15 years to carry out a closure programme for the site at a cos of US$30M (INB, 2006).

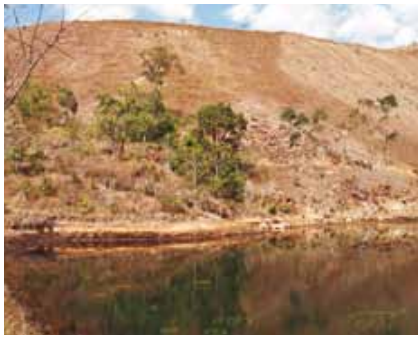

Figure 5
Osamu Utsumi pit partially filled with water, pH=3,5 on the left and "waste dump" 4 on the right. The lake in bottom of the "waste dump" 4 is formed by water drained from it, pH = 2,5. The water from the "waste dump" is pumped to the pit and then to an active water treatment system.

Riacho dos Machados

Riacho dos Machados was an open-pit oxide heap-leach gold mine where Vale ran operation from 1989 through 1997 (Figure 6, right). The mine was located in the small town that gave the name to the mine, 150 km North of Montes Claros, North of Minas Gerais. Its main economic activity before and after the mining operation is fruit and cotton growing and cattle breeding. The region is semi-arid with savannah vegetation. There are only two watercourses and one dam, which are essential to these economic activities. 250 direct jobs plus 750 indirect ones were created by the mine resulting in a highly positive impact over the local community - 8,000 inhabitants, half of then living in town. Impacts on the infrastructure included urban development - supermarkets, bakeries and bars; a doctor's and a dentist's office and a small hospital provided by the mining company, as well as a secondary school and rebuilding of rural schools. Socio-economic consequences included increase in the population income and real estate speculation - the cost of a piece of land increased from US$120.00 ha to US$1,500.00/ha.

3,220,000 ton of gold ore were extracted: 6,878,739 ton of waste rock to produce 4.8 ton of gold. In 1997, the op eration was shut down. The environmenta rehabilitation activities took place in 200 and according to Vale's environmenta management system the monitoring and maintenance programme was planned to last 5 years. The pit was filled with wate becoming a lake (Figure 6 right). The waste rock piles and tailings beach were covered

and vegetated. As a closure agreement the town received a sewage collection system and most of the streets and the main access road to the town were paved. However, unemployment has been massive. The health system has been dismantled and the economic activity has been emptied. The most impressive consequence has been the reduction of the number of urban inhabitants upon their return to the rural area. All this happened because the company's staff was much more concerned with the environment recovery than with the community (Chaves, 2000). By now the Toronto-based explorer, Carpathian Gold Inc. is finishing a feasibility study and released an updated resource estimate on the Riacho dos Machados deposit.

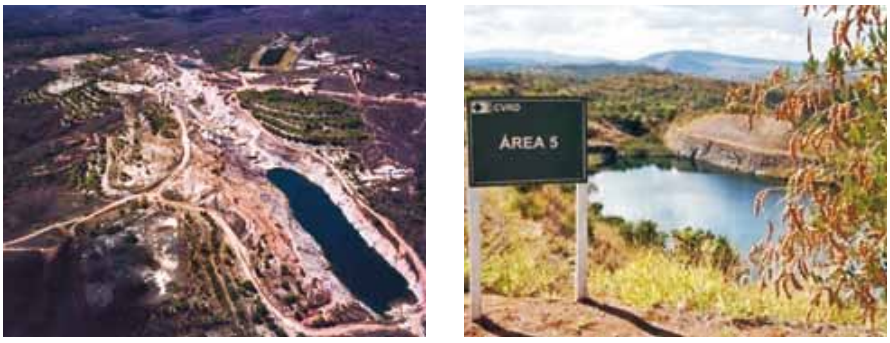

Figure 6
A view of Riacho dos Machados Mine immediately after closure in 1988 (left) and North Pit rehabilitate by Vale. Vale courtesy.

5. Conclusions

The regulation on mine closure in Brazil is still far from completion. To date, the inclusion of a closure plan into the PAE and the submission of one is enough to obtain the license for a new mine and to justify the continuity of one operation, respectively. In addition, as showed by Resende et al. (2010), the 30 PAEs studied, all of them prepared after the enactment of NRM-20 did not include any closure plan, although Law requires it. This allows us to infer a lack of guidelines from DNPM related to enforcement and assessment of the presented mine closure plan.

Until the enactment of the DN COPAM Nº 127, in Minas Gerais, a closure plan was submitted just to comply with the requirement of the State Environmental Agency (FEAM). And, mining companies did not receive any notice about their submitted plans. The lack of criteria for mine closure plan evaluation is the main and trained staff is cause. On the other hand, DN 127 was prepared by a workgroup including academics, mining companies' managers, NGO's members, DNPM staff and lead by FEAM's staff.

As a consequence of the new mine closure regulatory system, mining companies are now required to better integrate economic, environmental and social considerations into mine closure planning to justify the continuity of a mine operation. Therefore, it is expected that this new system be readily accessible by mining companies, be non-prescriptive by the environmental agency, reaches the agreed objectives, and have the force of the law.

The closure processes of the large mines dealt with in this paper show the adoption of the best practices on environmental rehabilitation as the examples of Águas Claras and Mina Velha mine closure programmes, which include a self-sustainable future use for the mine site and the remediation of potential hazard associated with the historic tailings disposal practices, respectively.

The example of Osamu Utsumi mine calls the attention to the importance of early closure planning and implementation. Although INB is carrying out an effective monitoring and maintenance programmes, mainly for acid mine drainage control, at a cost of about US$ 7M/year, this is too high an amount to be expended for a long time after mine closure.

Social and economic impacts from mine closure processes in many mine towns, such as Riacho dos Machados, must be better considered by both mining companies and the governmental agencies in order to avoid social and economic disruptions to local communities.

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