Alternatives for mitigation of acid mine drainage in a coal mine

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ABSTRACT. The impact of mining on the quality of surface and ground water is a hotly debated issue of great interest worldwide. The most significant among the several problems that can affect the quality of these waters is the generation of acid mine drainage (AMD). Unmanaged it can render the use of impacted waters totally unsuitable for recreational, agricultural or drinking purposes, and also seriously damage the ecosystems in the receiving environment. The Brazilian mining industry is striving to adopt sustainable environmental practices. As part of a contribution to these efforts CETEM and CAMEMET have put forward a joint project on mine rehabilitation. CRM, a coal mining company, is one of the partners actively involved in the Project through its Cunditoa coal mine located in southern Brazil. The initiative includes a systematic survey of existing local environmental data, supported by laboratory and fieldwork to identify and evaluate different sustainable rehabilitation technologies. The project began in January 1999 and will extend over a period of three years. This paper reports the Project's main achievements during its first year and describes the approach adopted by the partners - CETEM/CAMEMET/CRM - in dealing with acid mine drainage taken as one of the issues within an integrated mine rehabilitation concept.

1 INTRODUCTION

The growing importance of environmental issues has been a major source of environmental pressure on the mining industry worldwide. One can say that particularly in countries where this industry plays an important economic role, managers and researchers will certainly face increasing challenges in this new millennium to produce metals and mineral products according to the principles of sustainable development.

This is the case of Brazil where mineral production generates about US$ 7.5 billion. Taking into account the metallurgical and mineral transformation industry these figures reach US$ 53 billion which is equivalent to 7.6% of the Country's domestic gross product. These values can also be added on to others related to a number of services and small businesses levered by mining and metallurgical industries such as maintenance and equipment, spare parts, servicing, commerce and so on.

The great international significance of the Brazilian mining industry can also be measured by its capacity to attract foreign investments. Presently Brazil is ranked third in the world among the most attractive for investments in mining.

In Brazil, as in other countries the use of environmentally sustainable technologies has unfortunately not always been the practice of the whole mineral industry. On the contrary the public image of this industry has been associated with pollution of rivers, air and land as well as the depletion of non-renewable natural resources. As a consequence, it has been continuously subjected to environmental pressures.

The main sources of these pressures have been the improvement of the national regulation and enforcement system, the stakeholders interests and the increasing awareness of the society of the importance of environmental quality.

Within this complex scenario the Brazilian mineral industry has also to overcome the challenges of a global market where commodity prices are depressed and international non-tariff barriers based
on environmental issues can jeopardize its leading commercial position.

A possible response to these challenges is the adoption of sustainable mining practices in Brazil which, encompass, among other aspects, a comprehensive mine rehabilitation plan throughout the mining cycle and a technically sound decommissioning stage at the end of the mine life.

As part of their contribution to the efforts of the Brazilian mining industry as it strives to adopt and develop environmentally sustainable practices, CTEM and CANMET have put forward a joint project on mine rehabilitation.

The technology transfer elements of this initiative are partially sponsored by CIDA - Canadian International Development Agency. The overall initiative includes a systematic survey of local environmental data as well as laboratory and fieldwork to evaluate different rehabilitation technologies over a period of three years, beginning in January 1999.

The project has been carried out by building partnerships with various Brazilian mine operators who are willing to make their sites available for demonstration purposes. CTEM, a coal mining company, was one of the first partners actively involved in the project through its Candiota mine located in southern Brazil. The choice of Candiota as a partner was based on the fact that it is a major coal producer in Brazil and its management is strongly committed to the improvement of the company's environmental performance.

The paper reports the project's main achievements during its first year and describes how the partners - CTEM/CANMET/CRM - have been dealing with actual mine drainage taken as one of the issues within an integrated mine rehabilitation concept.

2. THE MINE SITE

2.1 Location

The Candiota Mine is operated by CRM, a state owned company and is located in the state of Rio Grande do Sul, in the most southern Brazilian state in a subtropical region close to the border with the Republic of Uruguay as shown in Figure 1.

The operation is headquartered in the village of Candiota which is about 2000 kilometers away from Brasilia and 410 kilometers from Porto Alegre, Rio Grande do-Sul's capital city. The local population is 12,000 people and the main economic activities in the region are coal mining, electricity generation due to the 400MW thermal power station that is fed by the mine, production of cattle breeding and rice cropping.

The local landscape is mainly dominated by small hills locally called 'coxilhas' which are usually not higher than 100 m and covered by pastures.

2.2 General climate data

Temperatures vary over a wide range in Candiota during the year. From its mild and rainy winter (-4°C in July) and hot summer (35°C in January). The average temperature is about 17°C though. Even in severe winters, snow is very rare and when temperatures drop below zero degrees Celsius, heavy frosts occur.

The cumulative annual rainfall is 1400 mm. The rains are more intense from July to October. The relative air humidity is slightly higher in winter (85%) than in summer (73%) and the region has about 2440 hours of sunny year.

![Location of Candiota Mine (Mina Candiota)](image-url)

2.3 The coal

Coal reserves represent a significant fraction of the non-renewable energy resources in Brazil. The largest deposits are located in the southern state of...
3. THE PROJECT APPROACH

3.1 General Considerations

A balanced site rehabilitation plan requires an appreciation of the global aspects of a site. It starts with an inventory of the various site components, selecting the areas of concern, and only then focusing on the more troublesome issues. This approach is cost-effective because it avoids the trap of collecting more data than is appropriate for remediating a site (Outlawstreet, 1997).

One can say that mine rehabilitation operations on strip mined areas generally involve recontouring, reseeding, and replanting soil on the mined area and revegetating it. A site rehabilitation approach, which focuses exclusively on these tasks, though, will almost certainly fail, as a multidisciplinary approach is definitely necessary.

All potential impacts of a mine operation on the various environmental components must be taken carefully into consideration, and the most cost-effective options to mitigate these impacts should be implemented for a successful rehabilitation project. Some of these impacts are summarised as in Table 1.

Table 1 - The Impact of Mining & Processing on the Various Environmental Components (Van Huygenste, 1996)

<table>
<thead>
<tr>
<th>Environmental Component</th>
<th>Impact</th>
<th>Manifestation</th>
</tr>
</thead>
<tbody>
<tr>
<td>AIR</td>
<td>Gas and particulate transfer</td>
<td>• Particulate deposition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in air composition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Noise</td>
</tr>
<tr>
<td>TERRESTRIAL ENVIRONMENT</td>
<td>Solids transportation and moving</td>
<td>• Point sources of contamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Waste piles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in vegetation cover</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ground instability</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in surface morphology</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Underground cavities</td>
</tr>
<tr>
<td>SURFACE ENVIRONMENT</td>
<td>Soluble element transfer and suspended solid load change</td>
<td>• Chemical contamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in suspended load</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Disturbance of banks</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Diversion of water courses</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Creation of new water bodies</td>
</tr>
<tr>
<td>GROUND ENVIRONMENT</td>
<td>Soluble element transfer</td>
<td>• Chemical contamination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in water table level</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Change in aquifer properties</td>
</tr>
</tbody>
</table>
The work started by implementing a systematic, stepwise approach, according to the following topics:

- Conducting a preliminary survey on the mining and waste management practices on site.
- Assessing the existing data and reports on the environmental impacts of the operation.
- Conducting on-site training of the mine's technical staff.
- Recommending and executing a complimentary diagnostic laboratory test work program.
- Recommending further investigative fieldwork.

These topics were broken down into activities and relevant information was systematically collected. The progress of the work is summarised as follows:

3.2 Mining and waste management practices on site

The ore in Candiqua is extracted by strip mining using a 38-cubic-yard walking dragline. The waste to ore ratio is 1.6 m3/t and the "run of mine" extracted coal seams are jaw-crushed and conveyed to the thermal power station four kilometers away from the mine site. No further beneficiation facilities are available on site.

A large amount of waste (overburden, sandstone, and a non-economic intermediate coal waste) is produced in the process.

Mined areas are usually re-contoured to a shape as close as possible to the "local oxidation" and subsequently covered with top soil (about 0.2m thick). This soil comes from adjacent, more recently mined areas. Various types of grasses and in some cases trees, such as acacias or eucalyptus are presently being used for re-vegetation.

In the adherent areas no topsoil was kept for re-establishing the mined areas. Re-vegetation was done using different understory, straight (cut) - dump waste without a soil cover. Consequently, different degrees of success were achieved.

A small portion of the ash produced in the thermal power station is sold to local cement factories. Most of it goes back to the mine and fills some of the empty spaces created in mined areas. These ash deposits correspond to about 15% of the mine site area. A schematic view of the process is shown in Figure 2.

Acid generation from the coal waste is significant despite the fact that the sulphur content of the waste material can be as low as 1%. This is because the volume of the waste is significant and the waste is widely spread all over the site in a manner which promotes weathering and AMD generation.

5.3 Previous data about the operation

Many Brazilian researchers have studied the environmental impacts of the Candiqua Mine and the adjacent thermal power station.

Zucchini (1982), Zanella (1987) and Zanella (1988) characterized the environmental impacts associated with the coal combustion and the ashes generated in the thermal power station. The authors mention problems associated with heavy metals in gaseous emissions and discuss the practice of disposing ashes in the mine and dust generation.

![Figure 2: Back-filling procedure with ashes as practiced at Candiqua](image-url)
Sources (1995, 1998) studied the metal mobility and kinetics of pyrite oxidation in Candiotas. Schultze (1999) assessed some alternatives for mine rehabilitation focusing on slope stability and re-seeding issues. In addition to these reports, the recent Environmental Impact Assessment (EEA) for mine reclamation by the company also included a comprehensive collection of information on the operation and its impact on the surrounding environment.

References that the impact of the mining on the quality of surface waters of the region and AMD generation date back to 1988 (Fiedler & Solari, 1997). These authors analyzed samples taken from Arroio Poças and its tributary Arroio Carvoeiro. These creeks collect mine site effluents although the quality of Arroio Pocas can be considered as a baseline point for comparison. As mining has not yet begun, results to be shown in Table 2 revealed AMD generation. Recent data collected at the same points contain previous evidence as also shown in Table 2. As described, results do not follow CONAMA Standards.

5.4 Technical training and recommended complementary work on AMD.

To address the generation of AMD, the Project team began firstly by organizing training sessions at the mine site aimed at giving Candiotas's technical staff a comprehensive overview of all elements involved in developing an integrated rehabilitation plan, focusing particularly on AMD prediction, prevention and mitigation.

Secondly, since AMD generation and water availability on site are closely related, climate and topographical data have been systematically compiled and analyzed to enable a site-water balance to be calculated and examined in conjunction with the water drainage patterns of the mine property.

The use of dry covers to mitigate AMD has been considered, as water resources in the region are apparently heavily sourced (evaporation > precipitation for many months).

Simultaneously, a series of supporting laboratory tests have been recommended and are being performed at CETEM. Generated data will be used to support the choice of the best rehabilitation plan and particularly the most adequate AMD management option for the mine property.

Tests of materials available at the mine site include grain size analysis, moisture retention curves, chemical and mineralogical characterization. Laboratory scale AMD simulation tests are being performed to give the Project team an insight on various chemical processes involved during the weathering of the coal waste and the rate of oxidation rate of sulphide minerals present in Candiotas wastes.

Table 2 Water samples from Candiotas (apud Fiedler & Solari, 1998)

<table>
<thead>
<tr>
<th>Parameter (mg/l)</th>
<th>Mine drainage</th>
<th>Carvoeiro Creek</th>
<th>Poças Creek</th>
<th>Standard Values CONAMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ca</td>
<td>55.9&lt;sup&gt;*&lt;/sup&gt;</td>
<td>6.9</td>
<td>1.9</td>
<td>1.8</td>
</tr>
<tr>
<td>Sr</td>
<td>1.4</td>
<td>0.64</td>
<td>0.3</td>
<td>0.5</td>
</tr>
<tr>
<td>Mg</td>
<td>20.3</td>
<td>13.4</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Zn</td>
<td>0.07</td>
<td>0.2</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Cd</td>
<td>0.006</td>
<td>0.002</td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>Cr</td>
<td>0.06</td>
<td>0.01</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Cu</td>
<td>0.05</td>
<td>0.009</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>Ni</td>
<td>0.02</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Mn</td>
<td>0.008</td>
<td>0.002</td>
<td>0.002</td>
<td>0.002</td>
</tr>
<tr>
<td>Fe</td>
<td>0.003</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Co</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
<td>0.004</td>
</tr>
<tr>
<td>K</td>
<td>8.1</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>Na</td>
<td>12.3</td>
<td>3.6</td>
<td>3.6</td>
<td>3.6</td>
</tr>
<tr>
<td>Si</td>
<td>54.1</td>
<td>16.8</td>
<td>16.8</td>
<td>16.8</td>
</tr>
</tbody>
</table>

* Samples taken in 1999.
Complimentary laboratory tests have also been performed to evaluate the possibility of using power station ash as neutralising agent for AMD. Lysimeters have been assembled in the laboratory with wastes from Candiotã, to simulate and study the possible use of geochemical barriers in situ as a means to stop acid generation.

On-site fieldwork has been also recommended to assess and position the local water table. A preliminary drilling campaign involving solids sampling and piezometers installation has been indicated to examine how the local water table depth varies according to rainy or dry seasons as this can be crucial to understand how AMD generation varies in the property throughout the year. During this campaign, water and solid samples will also be collected which will contribute to evaluate the stage of the AMD process in the field. Ground water quality, and the direction and rate of its movement, in the waste will be determined.

4 CONCLUSIONS

Generally speaking, any mine rehabilitation plan is heavily site specific. In other words it is not possible to design a rehabilitation plan which would universally fit all mine sites regardless of their characteristics. Each property has different location, geology and surrounding area. This determines different geographical (weather, topography, rivers, vegetation, etc), socio-political (local policy, neighbour communities, borders, etc), geological and economic constraints which will demand different rehab solutions.

On the other hand, an AMD management and control plan can only be successful if it is design as one of the elements of a more comprehensive mine site rehabilitation Project. This Project should be a multidisciplinary exercise encompassing various different issues as location of the mine property, local climate and hydrology, engineering materials available on site, local vegetation, slope stability, erosion, and so on.

The joint Project carried out by CETEM, CANMET and CRM has been addressing AMD in Candiotã within this perspective.

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REFERENCES


