WATER RESOURCE MANAGEMENT AND THE MINING INDUSTRY

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WATER RESOURCE MANAGEMENT AND THE MINING INDUSTRY

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WATER RESOURCE MANAGEMENT AND THE MINING INDUSTRY

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FOREWORD

The National Water Agency (ANA) is happy to introduce the new English edition of **Water Resources Management and the Mining Industry** publication in collaboration with the Brazilian Mining Association – IBRAM.

The demand for mineral commodities has been on the rise as a result of recovery signs by the European steel industry and booming emerging countries, particularly China. The investments mining companies in Brazil are expected to make by 2015 have once again broken a record – they come to as much as US$ 68.5 billion and trade in iron ore, for instance, is expected to double in 5 years to reach 787 million tons per year. According to IBRAM, all other mineral commodities are expected to follow suit, which should boost exports and revert into foreign capital for Brazil, providing considerable support to economic growth and development as a result of new jobs and new business across the entire supply chain.

The Government is continuously concerned with sustainability matters with regard to water use in the corporate sector and has engaged the industrial sector in the search for solutions designed to minimize the impacts from this use.

Hence, this publication is the culmination of joint efforts to enhance awareness of the significant interplay between the mining industry and surface and groundwater.

For the mining industry, this is an opportunity to display its desire to embrace social responsibility and commitment to sustainability.

This publication discusses the progress made in the mining industry towards implementing practices that minimize impacts on the water supply, and the high levels of water reuse in this industry attest to this.

Also, new technologies to treat effluents from mineral processing are gaining in popularity, and this provides for a massive reduction in pollution levels.

Conversely, ANA has been playing its regulatory role in the granting of rights to use water resources in accordance with Resolution CNRH No. 29, of December 11, 2002.

Finally, we would like to point out that ANA has been working towards regulating water use in the mining industry by setting conditions to ensure the water supply required by this industry in line with the specific mandates of environmental authorities and the National Mineral Production Department (DNPM).

Vicente Andreu Guillo
National Water Agency Chief Executive Officer

Photo: Olivier Boets

INTRODUCTION

Mine we shall, because minerals are essential to the quality of life desired by humanity and to our very survival, but we shall do it with constant attention to, and great care with, the environment.[1]

Ours is a mineral-oriented civilization, and Brazil is a mining country.

For the fulfillment of our needs, we must therefore have an adequate supply of mineral commodities, since they are essential to agribusiness, civil construction and the industrial sector, and the arts, i.e., all production chains and cultural manifestations of humanity. For example, airplanes, cars, computers, churches, sculptures, musical instruments, and many other items are nothing but processed minerals.

A major such essential mineral is water without a doubt, and there is broad consensus that the 21st century is the century of water, just like the 19th century was the century of coal and the 20th century was the century of oil.

"Water is needed in all aspects of life. The general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases," states Agenda 21.

It is precisely due to the fact that water is a vitally important mineral that the National Water Agency (ANA) and the Brazilian Mining Association (IBRAM) decided to offer this book to the Brazilian society.

So the two partners – ANA, an essential player for successful management and sustainable use of water resources, and IBRAM in its mission to contribute to an increasingly sustainable mining industry in Brazil – have joined forces to produce this book.

As stated by IBRAM in a previous publication,[2] "we believe that implementation of the National Water Resources System, as per Federal Law no. 9,433, of January 8, 1992, based on participation and decentralized management, is instrumental for society in its search for balance and harmony, progress and life, with justice and freedom; this System is an instrument for the development of a new ethic that is associated to the challenge of achieving balance."If this book, "Water Resources Management and the Mining Industry", can contribute towards Brazil improving the management of water resources in any way and making it sustainable, ANA and IBRAM will consider that is goals have been reached.

Ricardo Vescovi de Aragão
Chairman of the Board of Directors of the Brazilian Mining Association (IBRAM)

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[1] IBRAM. Mineração e Meio Ambiente (Mining and the Environment), 1992 (out of print).
[2] IBRAM. Modelo Nacional de Gestão de Recursos Hídricos: a posição do setor mineral na visão do IBRAM (National model for water resources management: the stance of the mineral sector from IBRAM's perspective), 2002 (out of print).

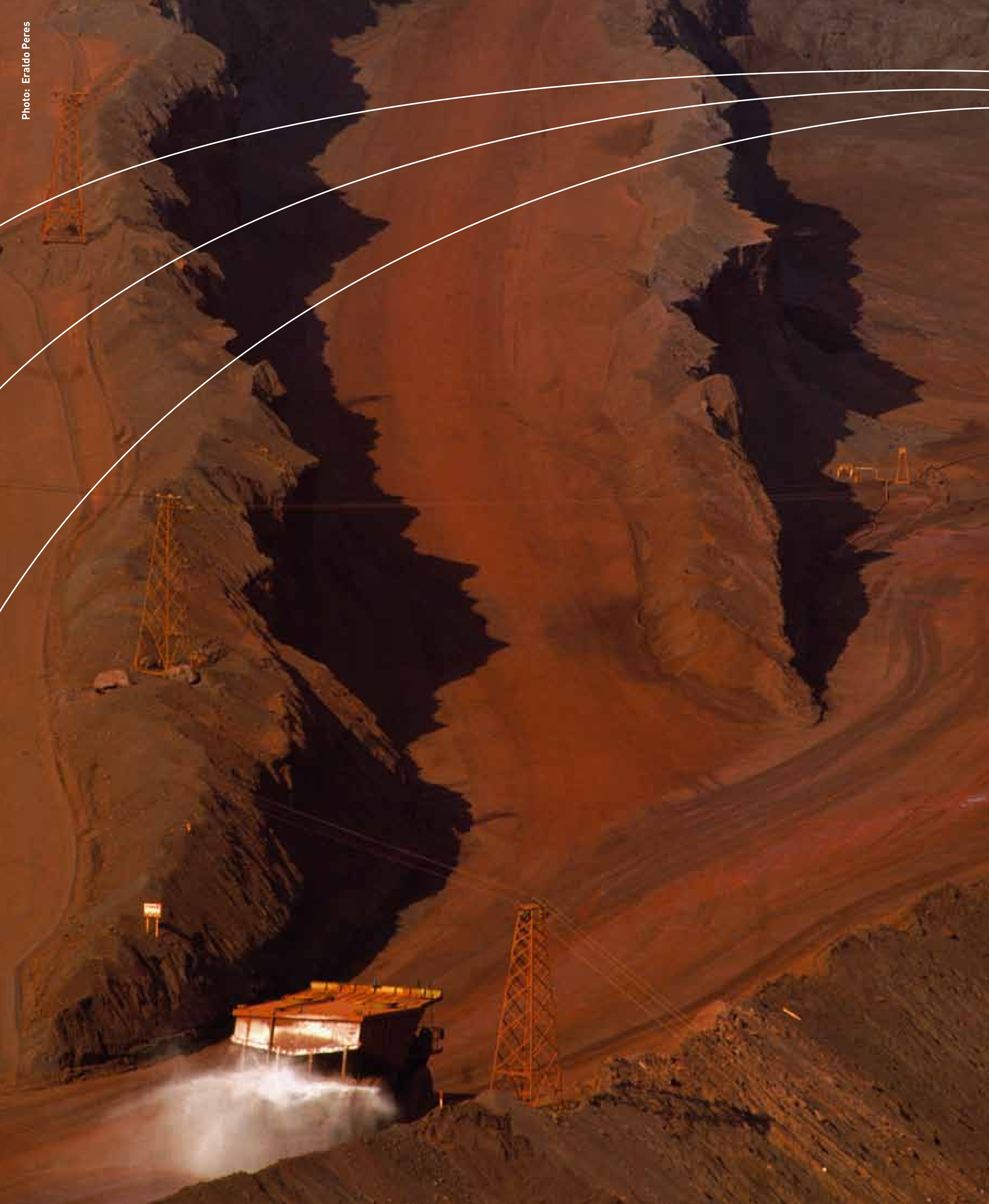

Photo: Eraldo Peres

CHAPTER 1

Photo: Olivier Boels

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1 INTRODUCTION

All mining practitioners are aware of water's dual nature: vital for many of the relevant processes and operations, but also a source of problems and major additional costs.

These problems often occur because mining takes place under the water table level, and superficial waters are also involved to a greater or lesser extent. A consequence is the need to drain water from mining sites, often times at significant flows resulting from the development of broad drainage cones that must be maintained throughout the mining operation; and sometimes at lower flows that greatly enhance stability conditions of the rock mass. This causes hydrological, environmental and economic effects that call for adequate management and administration of these waters.

This chapter provides an overview of the main problems derived from the mine-water relationship and also applicable technical solutions. Water contributions are also discussed, and the various anthropogenic and natural factors that could have an impact on these contributions either in terms of volume or flow rates for mining activities are considered, though no technical estimations are provided.

The view herein presented is that of Spain, a country that has been mining and managing water for 5 thousand years, and it also reflects the personal experience obtained over more than forty years working in nearly fifty countries in all five continents. Hence, all the cases herein described derive from first-hand knowledge.

2 WATER AND MINING

First of all, it should be emphasized that a successful mining operation depends largely on the adequate consideration of its interactions with water. Not taking this into account is suicidal.

Therefore, technical and economic feasibility of a mine is often times dependant on the adequate knowledge of the hydrological background where the mine is situated and the subsequent projection of water-mining interactions, which will be more efficient and cost-effective the earlier it is started.

[1] Scholar and professor emeritus at the Madrid Polytechnic University, President of FRASA Engenheiros Consultores. Awarded the Rey Jaime I prize for Environmental Protection.
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This is why conscious mining firms make plans from the exploration to the post closure stages to use adequate tools to address potential water-related issues by designing and implementing adequate preventative and corrective measures.

At any rate, one must not forget that the water-mining interaction is not limited to deposit exploration, but it also covers all ore milling processes, nor must we forget that one must take into account that once the mining operation has come to an end water-related impacts can linger for a long time.

Because of this, technologies are now available to avoid or mitigate the adverse water effect in very diversified situations according to the nature of the deposit and type of mine involved. The results are dependent on the appropriateness of its design.

To this end, one must be aware of the mining hydrogeological context, always bearing in mind that the activity must be dynamic, which requires updates and adjustments throughout the entire duration of the mining operation.

At this point, it should be pointed out that, once the mines are developed, in very diversified hydrogeological contexts , it is no easy task to realize and systematize water-mine relationships. To this end, the sole purpose of this chapter is to approach a summary of this interaction, with a focus on the most frequent issues. A comprehensive approach would make it necessary to write a monograph.

Unfortunately, we must realize that, even though these are not new challenges to mining practitioners, mining and consulting firms have not yet "sank in" the vast experience available as they have not put proper efforts into research and development, by assuming that the training and continuing education of its employees is a considerable investment and because its participation in meetings where technological innovations are introduced and discussed is not something usual. To this end, the best inputs are undoubtedly from the International Mine Water Association, which we founded in Granada (Spain) in 1978, whose activities are compiled at the conferences and annual symposia, as well as in numerous publications that are a must-use reference.

3 DRAINAGE WATER FROM MINES

Often times, a mine will provide much more water than ores. This is frequently the case of mines located under the piezometric level, and of unconfined or confined aquifers, out of which underground water must be pumped for as long as the mining operation is ongoing. By way of example, the open pit lignite mine in Belchatów (Poland) pumps 62,500 m3/h through dozens of tubular water wells situated in the surrounding area and inside the mine; this water only undergoes a decantation process in areas with a thick vegetation cover of phreatophytes in order to provide a clean effluent that is suitable for any use. Such a drainage system produces a broad cone of depression of the piezometric level.

In view of these problems, it is vital to implement more suitable actions to prevent waters (either superficial or underground water) to reaching the mine as much as possible by deviating the runoff, making use of geological barriers, preventing ceilings (upper layers) from cracking, conducting impermeabilization activities, sealing wells, etc.

If, despite all these efforts, drainage of the mine is necessary, the most suitable technology is the one called Preventive Advanced Drainage (DPA). In hydrodynamic terms, it is about creating a "sinking effect" in the hydrogeological environment where the underground water flows without reaching the pit. This is how quality water may be obtained, which is suitable for a number of applications and amenable to water resource management..

4 APPLICATION OF MINING METHODS

In principle, in order to use conventional methods to exploit any mineral deposits under the piezometric level, the pit must be drained and eventually flooded once the operation is finished. If an adequate drainage (and rehabilitation) system is implemented, this water may be a very valuable asset that can be used in a number of ways: normalization of the runoff, creation of ponds and water environments, industrial, farming or household supplies, tourist and entertainment applications, etc.

Once this assumption is accepted, one must first consider that mining methods are key for water discharges and water quantity and quality changes.

Conventional methods include open pit and underground mining in all possible variations; however, one must not forget other methods, such as dissolution and leaching (and bio-leaching), with all the associated hydrological conditions.

Open pit mining certainly allow not only for rain water and runoff to flow into the pit dug for the mining operation, but also affected underground waters. According to this method, when using the so-called transfer mining system, that is, filling sections that have already been exploited with materials from the mining fronts, such materials must be chemically inert in order to avoid leaching of these filling materials that would cause waters alterations.

As far as underground mining is concerned, excavation may interconnect aquifers, and abatements and subsidences may create connections to aquifers on its upper portion or allow superficial waters to flow in. Conversely, decompression of materials from the footwall could allow underlying waters at pressure level to flow in (just like in the case of the open pit mine).

For underground mining operations, filling procedures are also used to enhance excavation propping conditions and to reduce the surface covered by mine spoils. This filling is to be conducted with inert materials or under adequate conditions that will ensure its chemical stability or that aquifers will remain untouched.

When mining based on dissolution of soluble minerals (halite, potassium, borax, phosphates, thenardite, natron, etc.) is used, water in injected into the deposit (through adequate structures) and is later extracted, along with the dissolved salts. It is fundamental to ensure that both underground aquifers and superficial waters are not affected by the resulting salt waters or solutions. Under this method, and in the case of compact rocks, the rock is caused to fracture in order to make the deposit more permeable and establish a path of communication between the injection and production zones. In this case, the location, direction and extent of fractures must be calculated and considered, which are conditioned by geomechanical factors and by the anisotropy of geological formations in order to avoid leakages of these highly mineralized fluids, which could affect the quality of aquifers.

An additional problem with this mining method is the collapse of caves originating from dissolution, which could cause aquifers to communicate and go as far as the surface, as is the case of old halite (NaCl) mines in Polanco (Santander, Spain), or in Arheim (Netherlands). In this regard, one must consider that a significant portion of sodium chloride production involves in situ dissolution.

This mining system frequently requires removal of major amounts of salt water, which could be a source of water contamination. At the potassium mines in Cardona (Barcelona, Spain), we calculated the average chloride inputs to the hydrographic network at 68 t/day for runoff and 67 t/day for subsurface flows, which forced us to build a salt water pipe leading to the ocean and finally to a shift of the River Cardoner course through a tunnel as proposed.

Now, leaching-based mining is about using a solvent to dissolve minerals (acidulated water, for example). Metals that are suitable for use with this method include: copper, uranium, mercury, molybdenum, silver, gold, aluminum, and zinc. It should be pointed out that nowadays some leaching technique is employed at the majority of copper mines and in situ leaching is attracting increasing attention for a number of reasons, including economic and environmental reasons.

Leaching is also often used in uranium mining, especially if one is dealing with a poor mineral: it is frequently performed on mineral piles, which are sprinkled with an acid solution to attack sulfides and dissolve uranium (the pyrite contained in the rock is conducive to the development of acid waters that help the leaching process). The piles are laid on compact clay and/or a geomembrane after any terrain obstacles have been cleared, and the effluent is put into the lower section of a tank and is then transferred to the processing plant.

In these types of mining activities, i.e., based on leaching or dissolution, avoiding water leakages throughout the entire process is fundamental. To do so, it is vital to investigate the hydrological conditions of the entire area that could potentially be affected before starting the mining operation.

5 WATER FLOWS FROM MINES

5.1 GENERAL BEHAVIOR

Many mines require major drainages works, and the associated flow rates and volumes fundamentally depend on the characteristics of the aquifers affected (transmissivity, size of fractures, hydraulic charge, thickness of protective layers, etc.), inputs of superficial waters and sudden inrushes from rainfall.

Overall, the mines with significant water discharges are located in areas with the highest rainfall rates, as pointed out by Pei (1988) when he studied the inputs of water in 15,750 mineral deposits in China. In any case, the layman may be surprised at the amount of water drained from many mines. Hence, we could mention by way of example the Kursk iron ore in the former Soviet Union, covering 50,000 m3/h; the open pit lignite mine in Belchatów (Poland), covering 62,500 m3/h; or the flow rate of 226,800 m3/h for the group of coal deposits in the former Soviet Union (FERNÁNDEZ RUBIO, 1986b).

In some cases, these inputs force one to abort the operation either on a temporary or permanent basis. So, for example, excavation of well no. 2 in the Konkola mine (Zambia) was aborted after 1.4x106 m3 were pumped throughout seven months without a significant effect on the piezometric level. The mine itself had to be shut down for six years due to a sudden water burst that caused it to flood (STALKER, SCHIANNINI, 1978). We should keep in mind that this is considered by many to be the mine with the highest water discharge rate in the world – the pumping rate is above 15,500 m3/h (SWEENEY, 1988) –, with maximum monthly flows of 17,700 m3/h (MULENGA, 1991).

Another example is provided by the lignite mine in Neyveli (India), where 40 submersible pumps extract 9,600 m3/h to lower the pressure in the underlying aquifer up to 1.5 m under the mine level.

This means pumping 24 tons of water for every ton of coal extracted, and another 16 tons of infiltrated water could be added during the heavy rain season (BANERJEE, SHYLIENGER, 1978).

The ratio between infiltrated water flows and tonnage of coal/ore extracted in some mining areas around the world (see Figure 1) shows variations from 1:1 to over 100:1 (ARMSTRONG, 1988, in MULENGA, 1991).

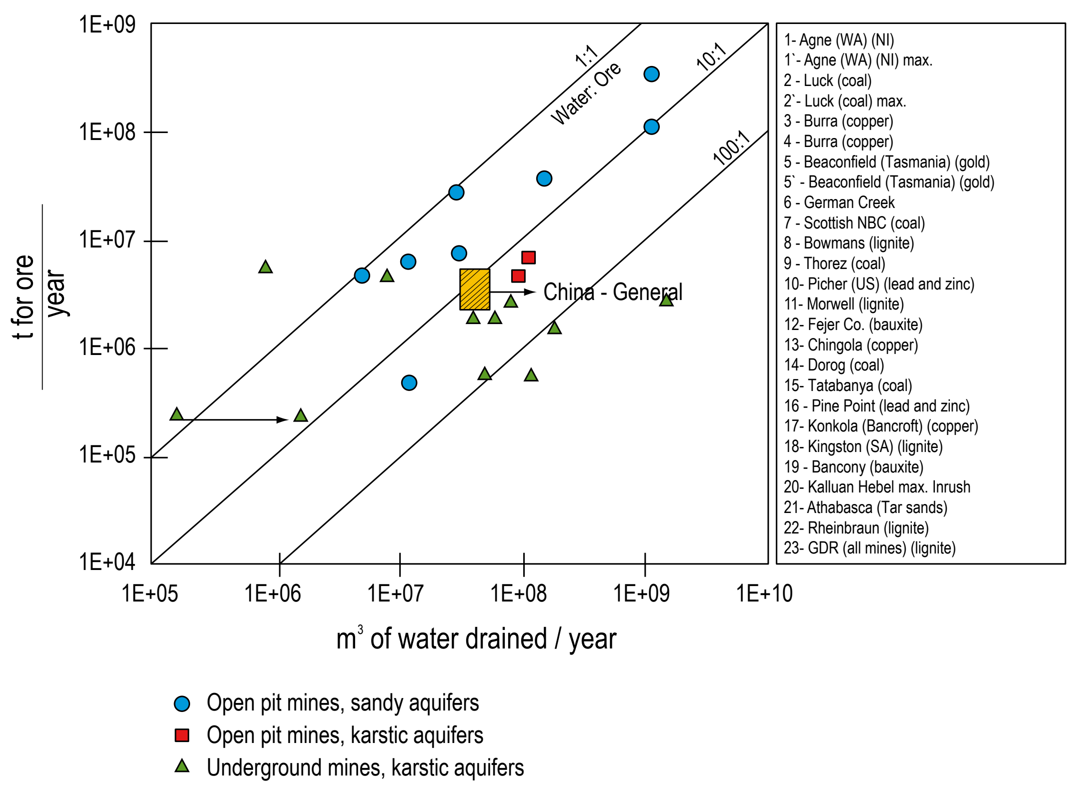

Figure 1. Ratio between mine drainage and the ore extracted in the main mining areas of the world (ARMSTRONG, 1988, in MULENGA, 1991)

For the coal mines in Spain, the average amount of 2.5 m3/t of washed coal is considered, and the range varies between 1.2 and 4 m3/t (FERNÁNDEZ ALLER, 1981). At the Mufulira copper mine, the ratio is 5 m3 of water per ton of ore extracted (Wightman,1978), while in Konkola (Zambia) the ratio has increased over time – from 30 to 90 m3 per ton (see Figure 2) (MULENGA, 1991).

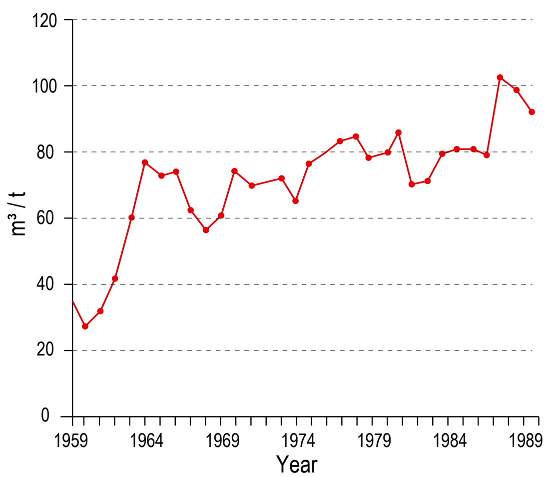

Figure 2. Ratio between volume of water pumped from the mine and tons of ore extracted from the Konkola mine (Zambia) (MULENGA, 1991)

In this sense, the energy costs per pumping are quite important. At the Pootkee mine, (Jharia Coalfield, India) out of the total power installed of 4,100 kW, 55% account for the pumping activities, with a specific consumption of 25 kWh/t of the coal extracted (BANERJEE; SHYLIENGER, 1978). At the Reocín mine (Cantabria), the drainage cost was estimated at one quarter of technical costs of mining (Trilla, et al., 1978, with NÁNDEZ RUBIO, 1980).

At the Nchanga open pit mine (Zambia), the underground pumping system's installed capacity is 7,200 m3/h (STALKER; at Fengfeng (China) approximately 7,200 m3/h of water are pumped (CHIH-KUEI; CHANG-LIN, 1978). At the Nchanga copper mine (Zambia), 41x106 m3 had to be pumped over the course of four years in order to lower the piezometric level, at an average rate of 30 m/year. By 1978, a total of 810,106 m3 had been extracted (STALKER; SCHIANNINI, 1978).

The Far West Rand gold mines (South Africa) have operations that go as many as 3 miles into the ground in a karstic environment, and the water volumes involved are extraordinary. Thus, when referring to the pumping activities from the Oberholzar Compartment, WOLMARANS and GUISE-BROWN (1978) are talking about 7,080 m3/hour.

At the coal mines in Northern China, a flow rate of 123,120 m3/h was reported in June 1984, at the Fanggezhuang mine in the Kailuan coal basin (Hebei province), with a production of 3 million tons as the result of the collapse of a cavity (see Figure 3) with 60 m in diameter and 313 m of height (BAIyING et al., 1988; PEI, 1988). Another catastrophic burst took place at the Jiangbei mine in August 1966 – it involved 90,000 m3/h (Pei, 1988; Zhongling, 1988). Both are considered to be the greatest water bursts in the global mining industry, but many other extraordinary bursts have occurred in China's mining industry.

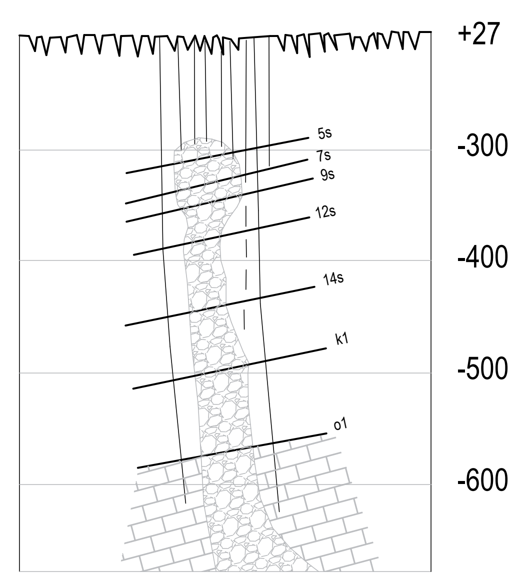

Figure 3. Cavity formed after a collapse at the Fanggezhuang mine (BAIYING, et al., 1988; PEI, 1988)

The lignite mine in Megalopolis (Peloponnese, Greece), in turn, is estimated to pump 13 m3/t of lignite during the first 11 years, and from then on 4 m3/t (SPILIOTIS, 1978). This deposit holds 500 million tons of lignite and it was estimated that 245x106m3 in water reserves would need to be pumped in order to reach the bottom of the mine (70m deep), and another 35x106m^3 would need to be pumped on a yearly basis.

All the data herein provided are a clear reflection of the high water volumes that often times must be drained during mining operations. Anyway, our experience shows that the most significant volumes are associated to karstic environments.

5.2 EVOLUTION OF WATER FLOWS ON THE GAUSSIAN CURVE

Many operations often involve major water bursts, with a robust increase in the flow at first, which then declines gradually until it stabilizes in relative terms. This is a typical behavior in heterogeneous hydrogeological environments, and it is normal when the water derives from:

- the interception of prominent channels in a heterogeneous environment;
- access to relatively confined, watertight compartments;
- collapsed ceilings that affect overlapping aquifers;
- footwall sub-pressures due to the pressure of confined aquifers whose waters burst through the protective layer; or
- sudden inrushes caused during heavy rain periods.

These are flows in the turbulent regime, which could drag major amounts of solid matter in suspension. If water bursts occur in mines developed without a protective layer, flows usually have slower increments than in mines with such a layer; conversely, the distribution of percentages of bursts for the various flows has the shape of a Gaussian curve, i.e., it is gentler when the layer is not available than when it is (SCHMIEDER, 1978a) (see Figure 4).

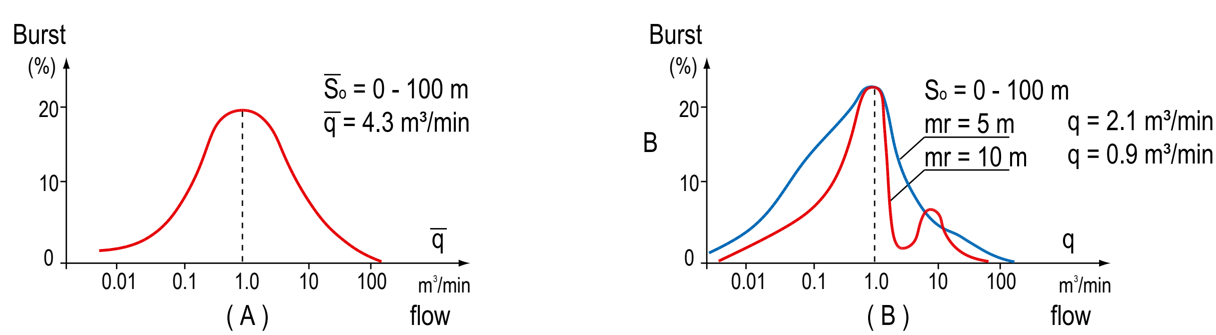

Figure 4. Frequency of the ratio between water bursts with no protective layer (A) and with a protective layer (B) (SCHMIEDER, 1978a)

A typical example is the gold mines in the Far West Rand (South Africa), which has a karstic dolomite aquifer that is 1,200m in thickness and whose underground stored water volume is estimated at 2,200x106 m3 (SCHWARTZ; MIDGLEY, 1975 in WOLMARANS; GUISE-BROWN, 1978). Interception of syenite dykes (about five to sixteen kilometers apart from each other) that isolate this aquifer has caused frequent water bursts with major maximum flows, such as the burst in Driefontein, 874m underground and at 4,500 m3/hour, in an area that had previously been designated as free from water in fissures since the reconnaissance drilling works had hardly indicated any water. Over 14,000 m3/h were pumped out of the Driefontein West & East mines, and drainage stabilized at 3,500 m3/h after seven years (see Figure 5). Up until 1976, a total of 1997x106 m3 had been pumped from four mines in the area, over the course of an average period of 25 years. Under these conditions, it is obvious that all attempts to drill mine wells were futile between 1898 and 1930, and this is when cementing was introduced, which made it possible to complete the first well in 1934 (wells have been drilled in over a dozen mines ever since) (WOLMARANS; GUISE-BROWN, 1978).

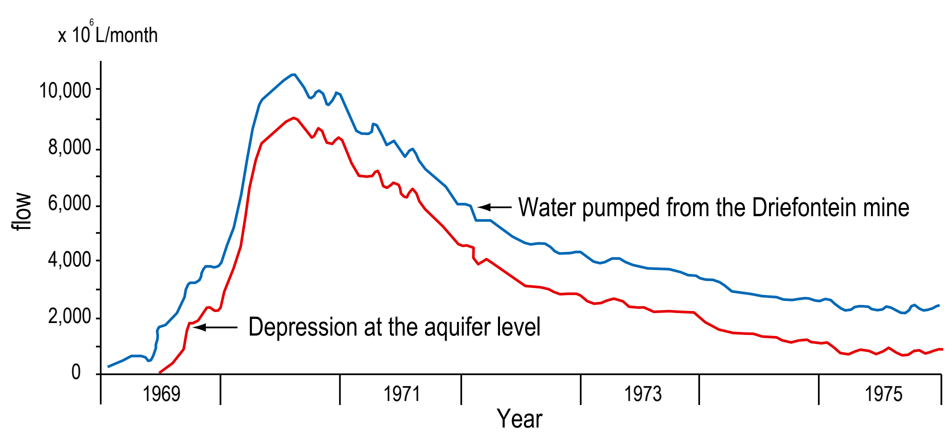

Figure 5. Pumped flows and depression obtained from the aquifer in the Driefontein West & East mines (WOLMARANS; GUISE-BROWN, 1978)

Another case in point is the deepest section of the Berga underground coal mine (Barcelona, Spain), where sub-pressure of the karstic aquifer was causing the underlying confined water to burst by causing the soil to fracture and raise in weakened and mined areas, with major flows that were hard to reduce. In this mine, other major sudden inrushes were associated to heavy rains and infiltration from the surface through underground mining fronts that had been abandoned.

A sudden water inflow immediately after blasting explosions occurred in two sections of the Juktan tunnel (Sweden). The initial flows were 648 and 306 m3/h, which soon stabilized at 126 m3/h in both cases (see Figure 6). Both bursts were associated to 20- and 35-meter long sections, with significant sub-vertical fracturing (CARLSSON; OLSSON, 1978).

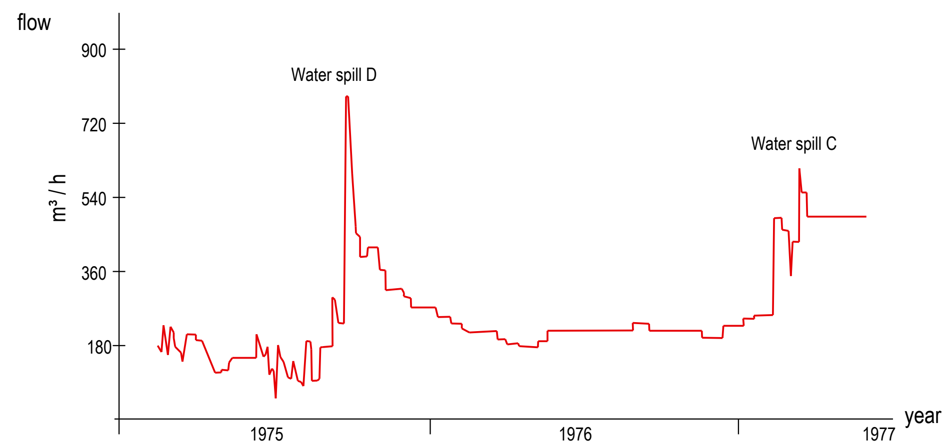

Figure 6. Water volumes during construction of the Jukta tunnel (Sweden) (CARLSSON; OLSON, 1978)

A similar example is provided by the La Oportuna mine (Andorra, Teruel), which involved underground coal mining. A number of bursts occurred as the result of ceiling collapses, and consequently intercommunication with the overlying multilayer detrital aquifer system also occurred. Drainage brought in sands and plastic clays, which eventually clogged the collapsed area until water flow levels returned to pre-burst levels.

Regarding coal mining in India, just like to other areas seasonally affected by heavy tropical rainfall, increases in the water flow in these climate periods. This is the case of heavy rainfall, where precipitations reach 800 mm in 24 hours to the north of Bihar (BANERJEE; SHYLIENGER, 1978) where during the 1975 major rainfalls, a large number of deep mines was flooded. At the Vazante mine (Minas Gerais, Brazil) it emerged that drainage hardly manages to bring down piezometric levels in particularly rainy years.

At the chromite mine in Domokos (Greece), water bursts of 500 m3/h were identified, with virtually immediate increases after the rain, so as to provide regular flows of 320 m3/h. The deposit is primarily located on peridotites, with sub-vertical fracturing that affects the surface, and through this such water inflows take place fundamentally along the high areas of the mine. For an annual pumping of 3.5x106 m3, 75% were pumped under less than 80 m in depth (MARINOS et al., 1978).

Extraordinary drainage pumping operations had to be performed due to very intense rains in 1973 at the Marquesado iron mine (Granada, Spain). A catastrophic rain event caused the dykes for the river waters to break, so water invaded the mining operation and flooded the bottom of the pit.

Also, in many underground mining operations involving collapse processes that cause subsidences over large surfaces, sudden water inflows take place during the rainy season, which is responsible for major peaks in the inflows that are pumped out. In these cases, the inflows could be the result of not only direct rainfall on collapse areas, but also on the drainage basin intercepted by them, and on the hydrographic network that runs over that surface. For example, this occurs at the Konkola mine, where subsidence affects Rivers Lubenguele and Kakosa (see Figure 7) (FRASA, 1993).

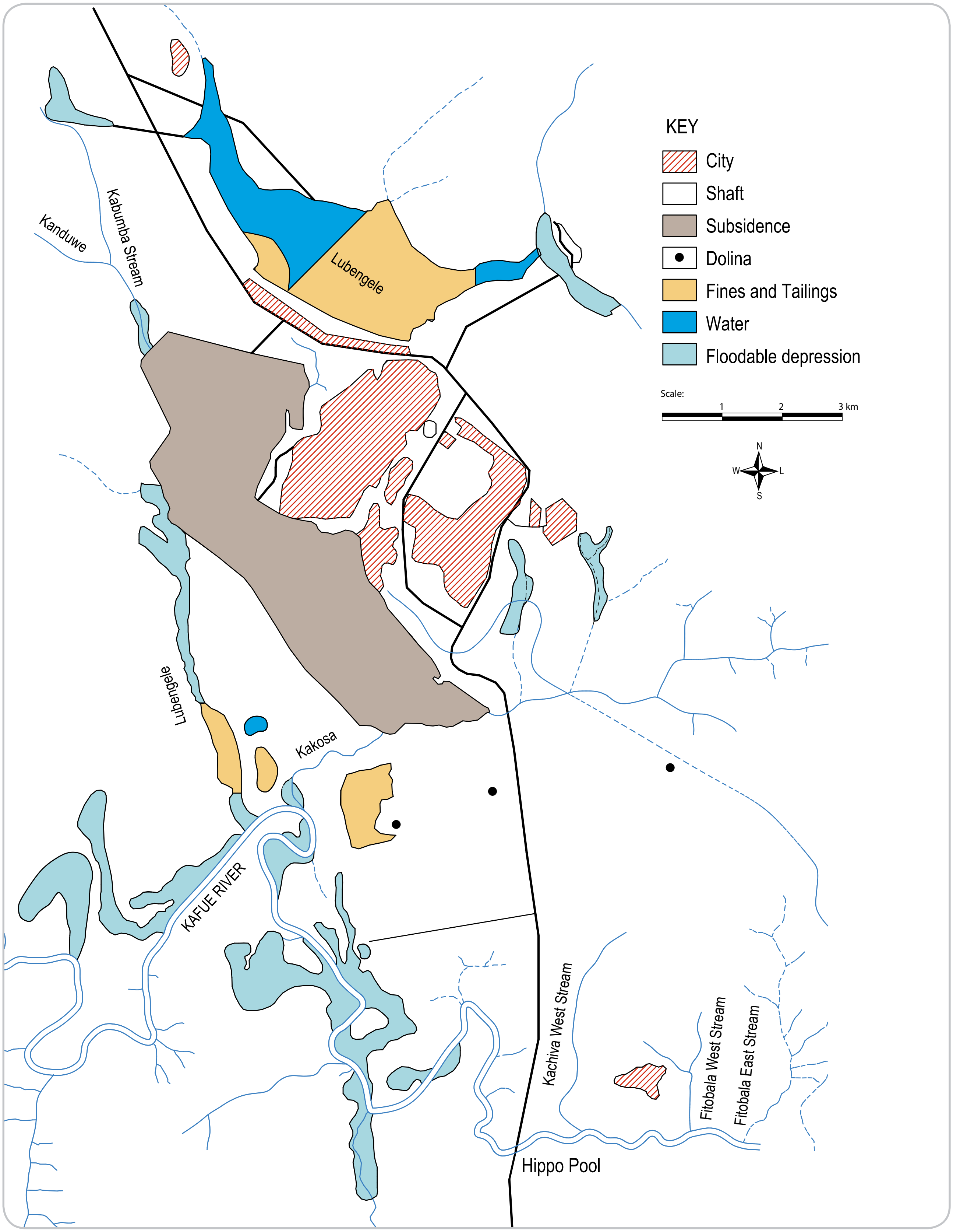

Figure 7. Interference from the subsidence area on the Lubenguele and Kakosa streams at the Konkola mine (FRASA, 1993)

Out of the 94 mining sites that were affected by collapses (especially in the south of China), Pei (1988) emphasizes the Enkou mine, with 6,100 collapses that affected buildings and agricultural fields and destroyed eight small dams. Where surface water inrushes were involved through these abatements, water inflows jumped from 1,300 m3/h to 4,250 m3/h. Special mention should also be made of the Siding lead and zinc mine, with over 6 thousand collapses. It was flooded during the rainy season of the summer of 1976; river waters came in through the cavities caused by the collapses and the Meintanba coal mine, which underwent two thousand collapses and over twenty intrusions of water and mud.

Also the result of the effect of subsidences are the flow variations reported in Pennsylvania mines, which bear a perfect relationship with river flow variations (see Figure 8) (GROWITZ, 1978). In this sense, mine drainage, and the corresponding drawdown of the piezometric level, could cause rivers to lose their flow when running across the drained area.

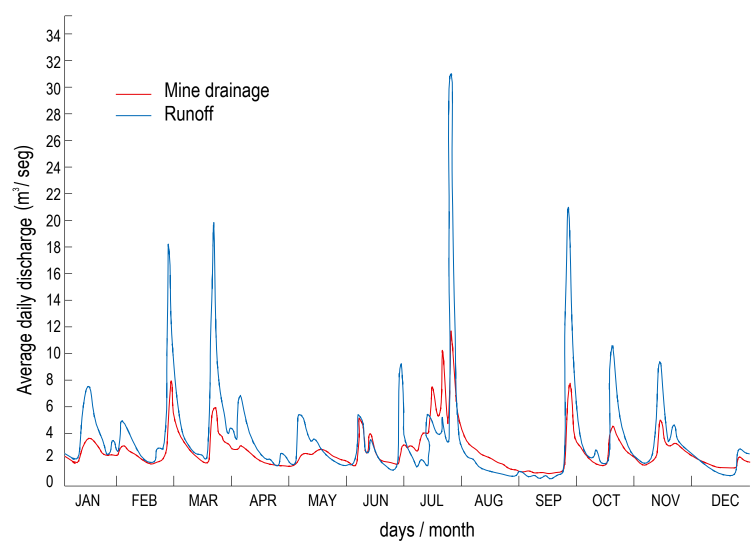

Figure 8. Hydrograms for mine drainage and flows for the year 1975 in Pennsylvania's coal mines (GROWITZ, 1978)

When these major temporary inflow increases take or could potentially take place, it is advisable to build underground repositories for inflow peak volumes to accumulate and regulate. Hence, at the Jharia coal fields (India), pumping variations between high and low periods go from 4 to 1. This can be shown by comparing monthly rainfall records and energy consumption figures (see Figures 9 and 10), with a difference of about a month between both peaks since the pumping operations were performed for a longer period of time because of the time required for the rain to percolate (BANERJEE; SHyLIENGER, 1978).

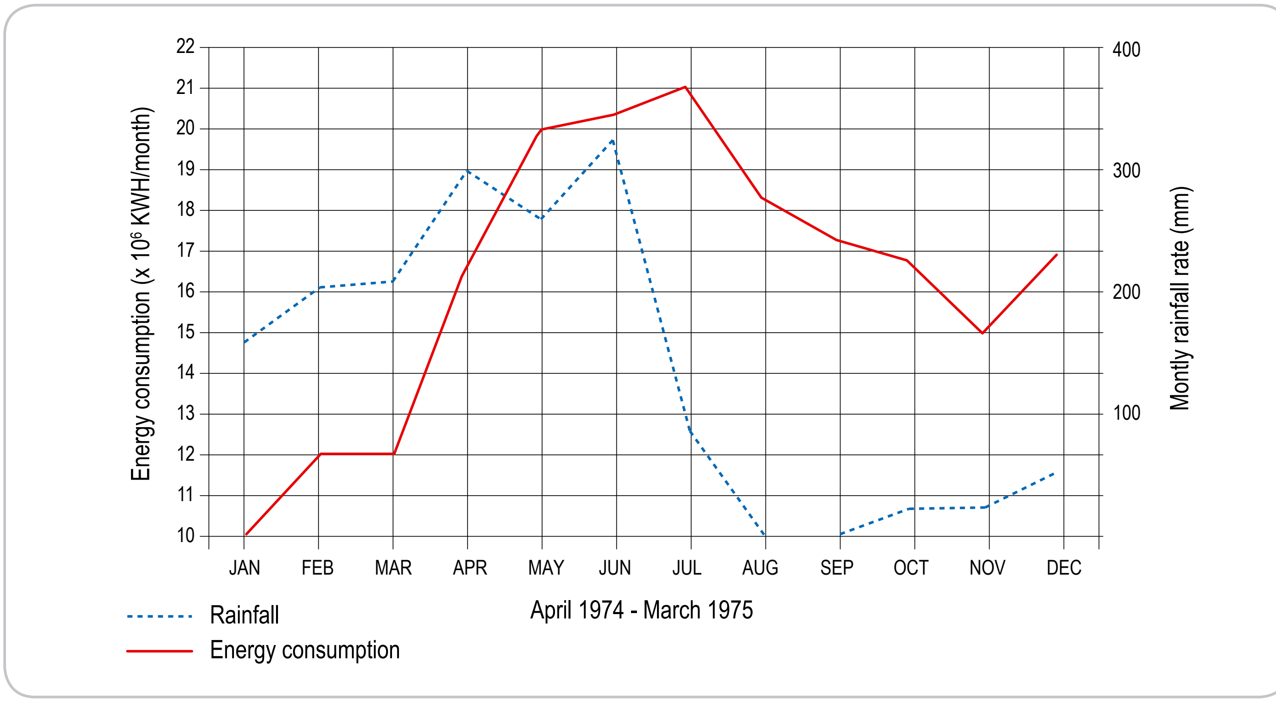

Figure 9. Monthly energy consumption and rain gauging. B. C. C. L. Jharia Coalfield, India (BANERJEE; SHYLIENGER, 1978)

Likewise, at the Reocín mine (Cantabria, Spain), the convenience of conducting pumping operations at night due to a reduced energy rate payment, justified managing part of the water with underground repositories to hold water during the day (FERNÁNDEZ RUBIO, 1980).

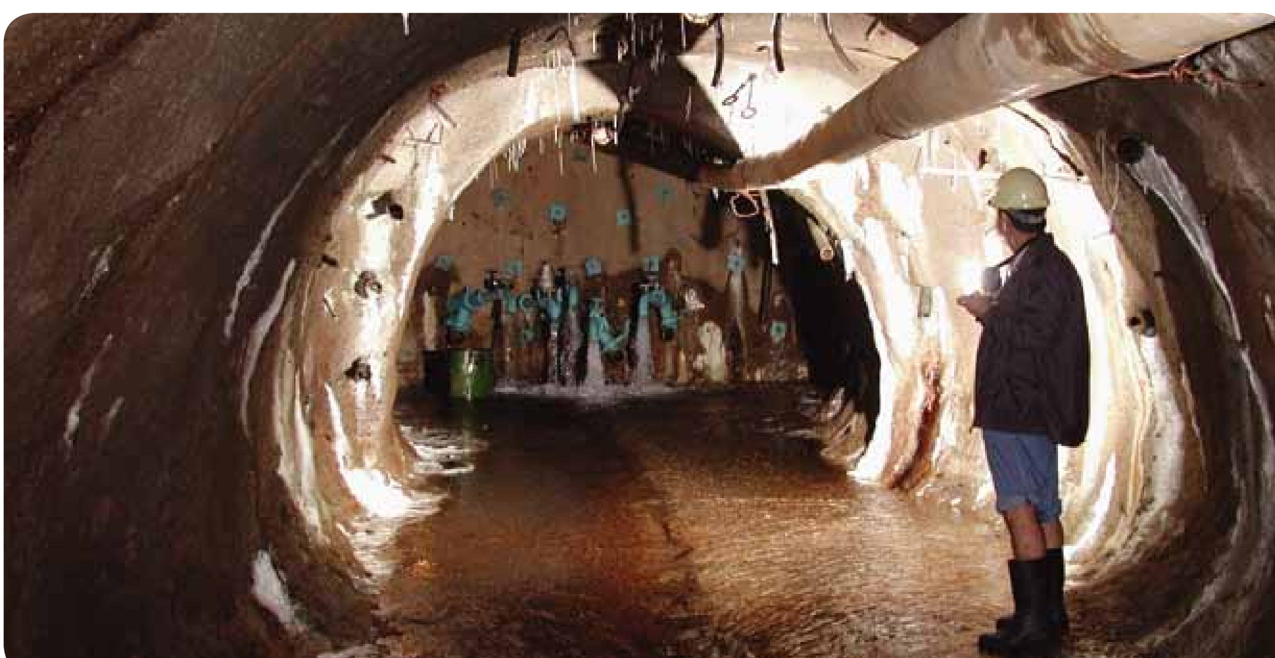

Photo 1. Feijão Stream, Minas Gerais, Brazil

Photo 2. Well – Checking System –Reinjection at an open pit copper mine (Seville, Spain)

5.3 EVOLUTION OF RISING FLOW RATE OVER TIME

The amount of water drained may increase gradually over time as a fundamental consequence of a deeper and larger mine (open-pit or underground excavation). This increment implies an enlarged drainage cone so as to allow for more runoff to come in and the recharge induced from other aquifers. This may be identical to the previous case under varying timeframes depending on whether the mining activities reduce or expand their scope on the surface.

A typical example of this behavior is provided by the Reocín underground mine (Cantabria, Spain), where the average annual flow increased by 126 m3/h over a number of years (see Figure 11). This water inflow is undoubtedly subject to variations that can be important to varying degrees due to rain events (infiltration through an advanced karstic system and old mining fronts), interception of drainage failures and regulation caused by water stored in the pit itself.

A different example is provided by the Nchanga copper mine, with a pumping volume of 870x106 m3 (1953- 1978), considering an average increment of only 25 m3/h, although a larger discharge was reported both at the horizontal and vertical level, which could be interpreted as a consequence of the potential peak flow in the hydrogeological system being reached. The drainage wells in this mine display sudden flow increments immediately after rains set in, which suggests that recharge via the surface is easy (STALKER; SCHIANNINI, 1978).

At the Mufulira copper mine (Zambia), records covering a twenty-year period show some increase with certain fluctuations in a range between 3,000 and 4,250 m3/h (see Figure 10) (WIGHTMAN, 1978).

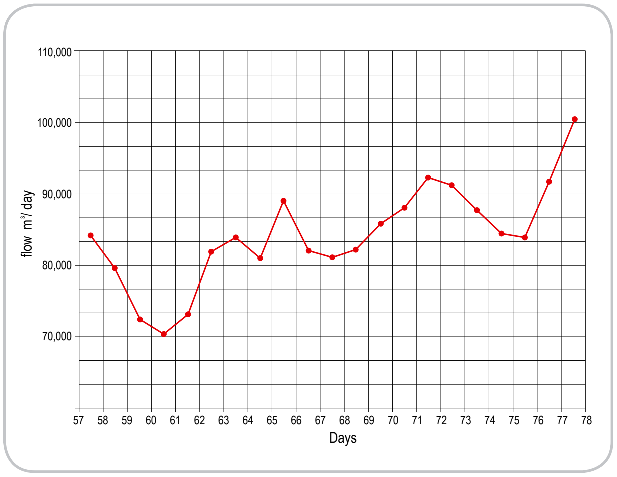

Figure 10. Average daily water pumping rate from the Mufulira mine, Zambia (WIGHTMAN, 1978)

At the Aliveri underground lignite mine (Greece), a sudden burst was caused in a crosscut of sublevel -38 m. The initial 120 m^3/h of water doubled in two hours and reached 900 m3/h two days later (see Figure 11). The gallery had to be shut down with a concrete dam, its walls received concrete injections downstream and then cement was injected through the dam's drainage pipes in order to insulate the water and resume mining works, which was the case 27 days later (MARINOS et al., 1978).

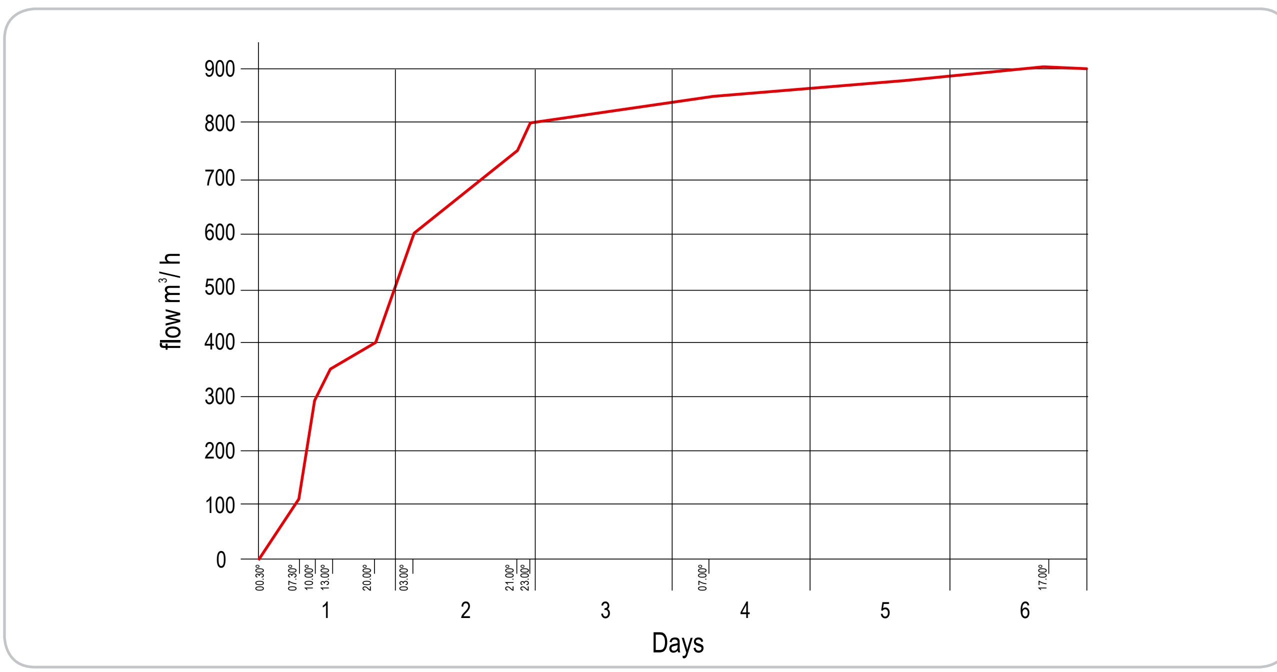

Figure 11. Development of a water burst at the Alivieri mine, Greece (MARINOS et al., 1978)

Increased pumping over time can also be implied by comparing the amounts of water drained from the group of coal mines in Pennsylvania, which jumped from 68,220 m3/h in 1941 to 93,960 m3/h in 1975 (GROWITZ, 1978). This could be interpreted as an effect of a larger surface being affected by the open pit mine. This increase in the water flows was coupled with an improvement in the quality of the water pumped out.

5.4 CONSTANT FLOW RATE

In many cases, mine drainage works have a flow rate that remains relatively constant over long periods of time. This can happen due to a number of circumstances:

- as a consequence of drainage regulation through holes (drains), with their corresponding shut-off valves, to adjust the flow to the pumping capacity installed;
- caused by the combination of the depletion of the reserve component of the aquifer that corresponds to the depth of drainage and the increase as a result of the area covered by the mine;
- as a result of the drainage in a multilayered aquifer system with dripping effects through intermediary aquitards; and
- as a result of decreased hydrogeological reserves offset by the increase in external water brought into the mining works.

In this sense, one should consider that the frequent decrease in permeability as the mining activity goes deeper into the ground has a clear impact on the reduction of water inflows. A textbook example is provided by Schmieder (1978a) for the variable permeability in a number of Hungarian mines in various hydrogeological environments (see Figure 12). For our part, we have observed the same behavior in mines that are developed in relatively homogeneous hydrogeological environments.

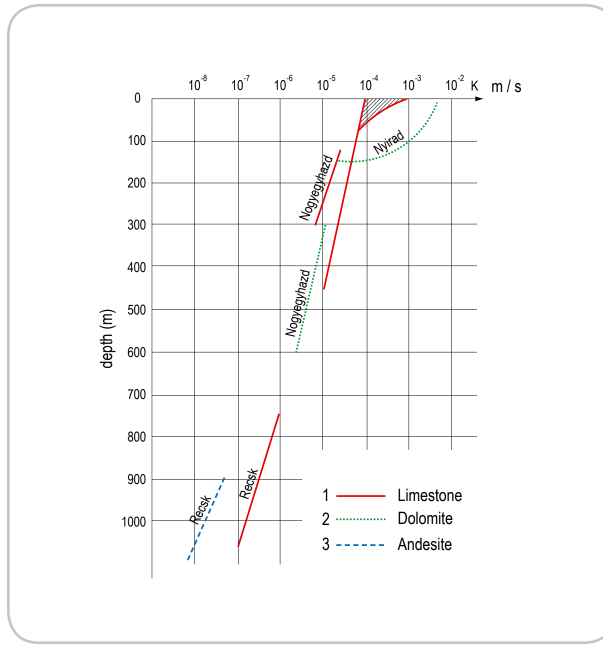

Figure 12. Filtration factor variation according to depth in karstic fractured rocks in Hungarian mines (Schmieder, 1978a)

Photo: R. F. Rubio

Photo 3. Drainage based on sub-horizontal surveys in a gallery front at the Konkola underground copper mine (Zambia), Konkola Copper Mine

Typical examples of this behavior may be related to the pumping works from the Konkola mine (Zambia), with a total pumping flow regulated by controlling the opening or closing of valves that are systematically installed in the underground drainage holes (controlled water) (Mulenga 1991).

Also, the Neves Corvo mine (Portugal) has an approximately constant evolution of inflows as the result of a balance between the reduced flow rate due to the drainage of stored reserves and the increase caused by continued deeper mining operations and side accesses to new areas (Fraser, 1987).

Photo: R. F. Rubio

Photo 4. water pumped from the Cottbus-Nord open pit lignite mine (Germany), Laubag

In the Marquesado iron mine (Granada, Spain), as a consequence of induced feeding from aquifers partially isolated by aquitards, semi-constant flows will occur since the pumping in vertical holes inside the cave reached a balance for each drainage depth (MEDINA SALCEDO et al, 1977).

5.5 EVOLUTION OF A DECREASING FLOW RATE OVER TIME

This behavior is normal when the drainage or the bust occurs in the following circumstances:

- drainage in a non permanent system, by pumping at a constant depression through vertical wells imposed by the depth of the pumps;
- Drainage where the whole catchment of water and the accumulated reserves with a gradual decrease in reserves and maintenance of water prevail at an early stage, and
- after a sudden burst of water in the mine, for whatever reason.

The first two cases could occur throughout the life of the mine or in a staged fashion, as new drainage levels develop periodically. This behavior was observed in the Castilla iron mine (Guadalajara, Spain), an open-pit mine drained through vertical holes located in its periphery and within it, whenever it was necessary to depress the water table level to lower the mining front to a new level (FERNÁNDEZ RUBIO, 1974).

Another case in point is that of the Marquesado open pit iron ore mine (Granada, Spain), where each time it was necessary to lower the dynamic level to deepen the pit, it was necessary to intensify the pumping works in order to extract the reserves accumulated between the stabilized cone and the cone required for the new mining level.

The evolution over time for the third type – sudden burst – corresponds to that for the depletion curves of water sources:

$$Q_t = Q_0 e^{-\alpha t} \qquad Q_t = Q_0(1 + \alpha t)^{-1}$$

where:

Q_t means the input during time t,
Q_0 is the initial input (time = 0), e
α is the depletion coefficient.

Total discharge (ΣQ) is given by the integration of Q_t for the duration of the water burst:

$$\Sigma Q = Q_0\, \alpha^{-1} \qquad Q = Q_0\, \alpha^{-1} \,\mathrm{Ln}(1 + \alpha t)$$

When Zhongling (1988) studied 74 water bursts and recorded maximum burst flows and initial hydraulic pressure, and he established the following relationship:

$$Q_{max} = \beta(H_t^{1/2} - H_i^{1/2})$$

where:

Q_{max} is the maximum burst flow (m^3/h),
β is the burst coefficient (approximately 3.600 m^3/h),
Ht is the total hydraulic pressure at the burst point (atmospheres), and
Hi is the initial hydraulic pressure (atmospheres).

This equation is similar to that of the hydraulic pipes. Hi varies with the type of mine, and Zhongling (1988) establishes three different categories of coal and iron mines in karstic environments in China:

Category A: Large karstic aquifers and sufficient recharge (abundant runoff). Well developed cavities, with open conduits and scarce filling. If the mine or tunnel is shallow (200-250 m under the piezometric level), Hi can be considered to be four atmospheres.

The equation to be applied is: $Q_{max} = 3.600\ (H_t^{1/2} - 2)$.

Category B: deep karstic aquifers that are underground, but widespread and powerful. Sandy filling in dissolution cavities and many of the connecting conduits completely open. If the mine is at 200-400 m under the piezometric level), H_i can be considered to be 7.5-8 atmospheres.

The equation to be applied is: $Q_{max} = 3.600\ (H_t^{1/2} - 2{,}75)$.

Categoria C: conditions are similar to those in Category B, but with a difference – in Category C, water either is transmitted through cracks or thin layers of limestone, or there are aquifuges between the mine and the aquifer. When the water flows through such obstacles, the hydraulic pressure undergoes heavy losses, and the values for Hi are between 12 and 13 atmospheres.

The equation to be applied is: $Q_{max} = 3.600\ (H_t^{1/2} - 3{,}5)$.

For these 74 well-documented bursts, Zhongling (1988) arrives at the representation for Figure 13.

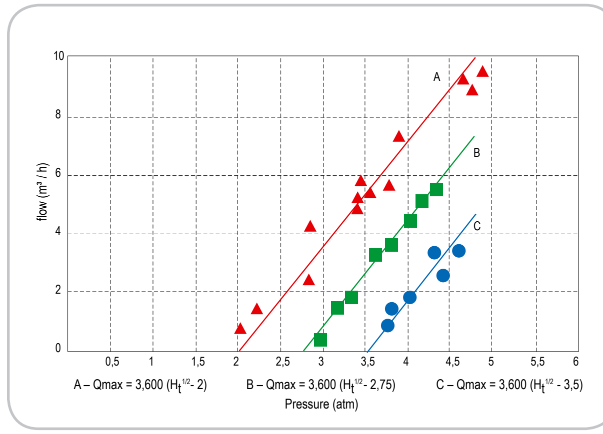

Figure 13. Sudden outbursts of water in coal and iron mines in karstic environments in China (ZHONGLING, 1988)

5.6 MIXED DEVELOPMENTS

In many cases, the evolution of the flow rate over time displays behaviors that are a combination of those discussed above.

Thus, the Morro da Usina mine in Vazante, Minas Gerais (Brazil) could be mentioned, where full-scale pumping tests were carried out by gradually increasing the drained flow until it reached the maximum level that could be pumped with the equipment available. In this case, the regulation was achieved by incorporating drainage holes that were controlled by valves (Fraser, 1991).

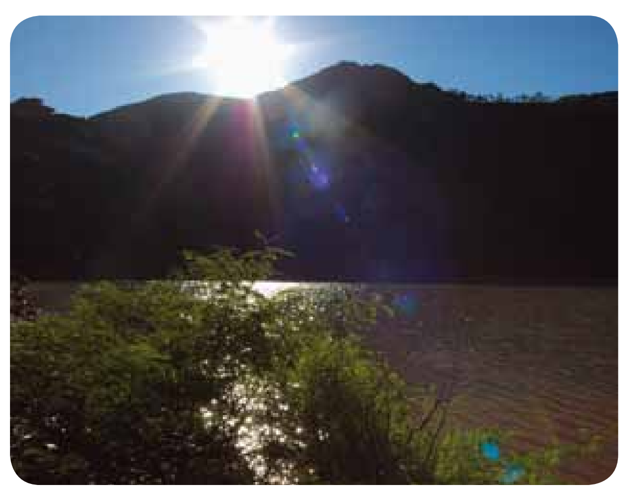

Photo: R. F. Rubio

Photo 5. Flood controlled after the Águas Claras iron mine was closed (Minas Gerais), by MBR-CAEMI

Photo: R. F. Rubio

Photo 6. Installation of drainage works at the Bajo de La Alumbrera mine (Catamarca, Argentina)

6 MINE WATERS: ENVIRONMENTAL ASSET

If appropriate technologies are used, mine waters can be a major asset that should be a part of water resource management.

In this regard, it should be noted that the aquifers in the mining environment are similar to those that often times provide water to meet urban, industrial, and farming requirements. When this happens, use of the Preventive Advanced Drainage (DPA) technique is required. In very simple terms, it consists of extracting water from the aquifer in areas from a distance of the mine so that these waters are not affected by the mining operations.

Under these conditions and in any deposits, including those that are potentially most contaminating – for example a bed of pyrite –, if water is obtained from a hole in the saturated zone that has not been explored, the quality of such water could allow it to be used in a number of situations.

Thus, two objectives are achieved – drawing down the piezometric level below the quotas of the mining front, and obtaining optimum water to meet the requirements of mining operations and water supplies of any kind.

When this DPA is applied properly, water is simply extracted from an aquifer that will not "see" our goal of draining the and, consequently, its quality is equivalent to the water that would be extracted from that underground aquifer.

The following are some examples of these actions.

6.1 REOCÍN ZINC MINE (CANTABRIA, SPAIN)

A particularly interesting case is that of the Reocín underground mine (Santander, Spain), which contains sulfide complexes. This is where the DPA was deployed, with an average quality-water flow of 1,200 L / s, which, in addition to meeting all mining requirements, was used to supply large industries with water and for the maintenance of an ecological flow of the rivers until the pumping operation was completed.

6.2 COAL/BAUXITE MINES IN THE VICINITY OF THE LAKE BALATÓN (HUNGARY)

For its spectacular nature, special mention should be made of the drainage of mines located north of Lake Balatón (Hungary), from which billions of cubic meters of water have been extracted through advanced drainage wells drilled on the surface and into the ground.

In these mines, together with the annual production of coal and bauxite, tons of trout are reared in the drainage water (we should not forget that the best water quality test are the trout themselves) as well as the millions of cubic meters of this water for the coverage of approximately half a million inhabitants.

Drainage is performed from a series of wells located in the vicinity of underground mines, from which water without any quality problems and no direct use is pumped to meet the requirements described above.

6.3 BETZE-POST GOLD MINE (CARLIN TREND, NEVADA, USA)

This important open pit mine, operated by Barrick, is an epithermal gold deposit located in Devonian metamorphosed carbonates and intrusive rocks that contain the gold. Their hydrogeological conditions are somewhat special due to the presence of a major aquifer with high temperature waters.

Drainage from the mine is carried out from wells, perimeter channels and inside the pit, pumping 3,670 liters per second. Special care is taken not to contaminate the water, so satisfactory quality is achieved.

About 5% of this water is meant for consumption at the mine, 10% is for irrigation of about 2,000 hectares (continually expanding surface) and 85% is re-injected in the same hydrogeological system, at a distance, through deep wells and recharge through surface dams.

The drainage water, due to its temperature above 60° C, is cooled to 32° C in an aeration system and a dam where the content of soluble CaCO3 coming from carbonate rocks is simultaneously reduced.

Due to the high temperature of the rock (57° C), an internal cooling system is required in the new nearby Meikle underground mine. In this case, the extracted water passes through cooling towers and is pumped to an air chiller to cool the mine.

6.4 CAPÃO XAVIER IRON MINE (MINAS GERAIS, BRAZIL)

This deposit contains 140 million tons of high-grade iron in exploitable reserves and is located in the so-called *Quadrilátero Ferrífero* (Iron Quadrangle), 15 km south of the city of Belo Horizonte, upstream from catchments for urban water supply and near a protected rainforest. All this led to the development of a very careful mine planning for the preservation of water and environmental resources in order to minimize the impact of the mine drainage and to achieve improvements in the aquifer's management conditions.

Achieving this was a very laborious process that involved gathering and studying all the meteorological, hydrological, geological and hydrogeological data, which allowed us to design the hydrological protection criteria through a preventive advanced drainage system (ten holes for drainage and tens of control piezometers), all subject to a thorough regulatory control and monitoring to match the mining operation with the water supply for the city.

The work focused on reconciling the drainage with maintaining the quality of water extracted to supply the city of Belo Horizonte, improving the conditions of supply security and optimizing water management, which is especially important in an area with very unstable rainfall rates that range from less than 500 mm and more than 2,800 mm / year, with the possibility of contributing with a lake environment for biodiversity in the region.

Thus, the entire mining activity was planned from its inception to provide, at the end of the mine's life, a quality water lake in the final pit (60 million cubic meters of capacity), which will have a positive impact on biodiversity in the area and will improve the landscape.

In this regard, detailed studies were conducted to prevent water eutrophication and salinity, in addition to the design of an environmental management system to ensure the proposed objectives were achieved and, most importantly, to ensure positive effects on water resources.

6.5 LAS CRUCES COPPER MINE (SEVILLE, SPAIN)

This deposit is located under a protected aquifer in the Iberian Pyrite Belt due to its use for water supply and irrigation, which is why the mining operation should not affect the quantity or the quality of this aquifer.

Therefore, as the open-pit mine required the aquifer to be drained throughout the excavated area, a system was designed to protect the aquifer through preventive advanced drainage, with holes outside and around the pit in order to intercept the groundwater, thereby preventing its contact with the oxidizing ore, in addition to a re-injection hole system located 2-3 km away from the pit. Thus, drainage and injection water (estimated at 200-250 L / s) will circulate in a closed and continuous circuit during the mining operation, all the extracted water being returned to the aquifer. Design of the device was based on mathematical models, and actual long-duration pumping-injection tests were performed.

For the water required by the mining project, once the main source of supply has been reduced to minimal amounts through recycling, it will be comprised of purified waste water from the city of Seville, which will be caught during the seven months of winter in order not to affect the flow of the River Guadalquivir during the drought season.

6.6 COTTBUS-NORTH AND JÄNSCHWALDE LIGNITE MINES (GERMANY)

These mines are located in the easternmost area of Germany, near Poland. These pits require removal of a cover of unconsolidated detrital and clay materials overlying layers of lignite in a significant sub-horizontal position which are extracted selectively.

The underground water is drained through deep perimeter holes, and once the surface water flowing into the pit undergoes a very effective clarification process, half of it is employed in steam production and cooling of thermal power, while the remaining half is released into the Rivers Spree and Schwarze Elster. The quality of that water is so good that it is used in fish farming operations and feeds lakes that are home to a large number of water birds (herons, gulls, swans, storks, etc.).

6.7 SIERRA MENERA IRON MINES (TERUEL AND GUADALAJARA, SPAIN)

A less impressive – but very educational – example is that of the Ojos Negros and Setiles iron mines (Teruel and Guadalajara, Spain), located along the border of the Atlantic and Mediterranean river basins and exploited intensively for decades. Iron mineralization in these mines is in contact with a confined karstic Silurian aquifer, comprised of limestone, dolomite and magnesite, which extends to both sides and along the dividing line.

When free of influences and considering the high karstic permeability, the water table in every mineral mass was confined by low-permeability cover and cave formations at a near horizontal level.

We proposed a preventive advanced drainage through inflow holes in both the periphery and in the banks of the pits, channeling all the pumped water through pipes until it was discharged in the river system at such a distance in order to ensure that it would not return to the mine. This water met all the requirements of the operation (mainly for watering the tracks and meeting the industrial demand), supplied the mining town of Ojos Negros and the city of Setiles, fed into a pond that was quite affected by the summer drought, was used in recreational activities, and covered the irrigation requirements of agricultural areas.

6.8 ALQUIFE IRON MINES (GRANADA, SPAIN)

Another case in point is the Alquife iron mines (Granada, Spain). The waters drained from them were used without any treatment until the end of the mining operation to meet irrigation requirements and to artificially recharge the drained aquifer remotely with a view to prevent irrigators from being affected.

7. WATER AND WASTE FROM MINING

Other hydrological problems in mining activities can derive from piles of ore and mine spoils, dams and settling of fines and tailings, as well as liquid waste from the mine or ore processing plants.

7.1 SOLID WASTE

Mining operations require the extraction of non-mineralized or low-grade sterile materials, generating tailings from its processing at quantities that are important to a greater or lesser degree. For example, in open pit iron mines, one often finds the sterile/ore ratio of 1 / 3 to 1 / 6 and, in the case of copper ores, minerals with yields of 0.5% are recovered, i.e. containing 99.5% of waste and tailings. These materials are accumulated in waste dumps and tailings dams or piles, and they can also be used as fillings for mining cavities.

If all of this solid waste and the piles of ore themselves are not inert, they will become potential sources of water contamination, and its effect may last for a long time following completion of the mining operation. In this case, it is important to reduce water inflow and infiltration as much as possible (from the rain or runoff). To do so, when the materials involved are reactive, they are appropriately placed on a continuous waterproof background, with a waterproof coverage (with surface drainage) and vegetable land for cultivation and restoration.

7.2 LIQUID EFFLUENTS

Many mining operations necessarily involve a change to the natural water system. For example, if the operation is extended under the water level of an unconfined aquifer or intercept a confined aquifer, the underground water should be removed for as long as the mining activity continues, which will act as a "sink" in the aquifer system thanks to the piezometric drawdown caused by the drainage. Therefore, in many mines, the amount of water extracted is much larger than the amount of surface runoff.

Depending on the lithological and mineralogical composition involved and the drainage method being used, these waters may be of excellent quality (especially if the so-called "preventive advanced drainage" technique is used) and discharged directly into the river system, or they may be used in irrigation and industrial applications. But when they have problems related to acidity, heavy metals, high salinity, etc. and the water falls short of minimum standards for release, it should be stored in evaporation dams or undergo appropriate treatment to achieve an acceptable quality for discharge.

The quantity – and especially the quality – of wastewater generated by mining operations influences ore processing, age of the equipment and sizing of the process.

8 QUALITY OF MINING EFFLUENTS

When the mining activity produces an effluent as the result of the drainage of groundwater or surface water inflows, one must ensure that its quality is acceptable. In this regard, there are many parameters to take into account, and some of them will be discussed here.

8.1 WATER TEMPERATURE

Temperature of the water being drained is the first parameter to be considered. Indeed, according to the geothermal gradient, the temperature in the underground – and therefore the temperature of the groundwater in contact with it – increases at a rate of 3° C per hundred meters, which means that, for standard depths in underground mining, which is several hundred meters and even thousands of meters, the temperature for the drainage water exceeds 30 or 40° C. In some cases, such as that of the Konkola mine in Chililabombwe (Zambia), the gradients are unusually low (only 0.1 ° C per 100 m) as the result of the large influx of surface water that cools the rock.

The warm waters before they are released into waterways require a thermal reduction, as is done at the Betz-Post mine (Utah, USA). In such cases, it is possible to recover heat through heat exchange devices.

8.2 SUSPENDED SOLIDS

Another frequent source of changes to water quality are suspended solids. In order to avoid this problem, flocculants are added and/or settling dams are used, which are often accompanied by biological filters, covering extensive wetlands.

At the mining water treatment stations (MWTS), physical and chemical processes are frequently used to facilitate flocculation and settlement of suspended solids, resulting in a final effluent that is in accordance with quality standards. This is the case of treating the mine drainage water from complex sulfides at Neves Corvo (Portugal), where the water circulates through a U-shaped dam, and it takes three days to decantate the solids and adjust its high pH by adding CO2. Also in the open pit lignite mines in Germany and Poland, treatment is vital to eliminate the large volume of suspended solids derived from the glacial source material covering the deposits of coal. Another relevant example of this treatment by settling is carried out at Morro da Usina mine in Vazante, Minas Gerais, Brazil.

Drainage and treatment systems should be designed to endure exceptional rainfall intensity. The selection of the payback period depends on the economic and environmental consequences, which could cause the drainage and/or treatment system to fail, compared with the cost of increasing storage capacity and/or treatment

8.3 ACID MINE DRAINAGE

The most serious problems facing the mining industry include drainage of acidic waters, which can have a significant impact on the quality of water. These acidic waters may be formed both within the mine pit and in waste and tailings settlement systems through oxidation of pyrite (FeS2) (and other minor sulfides), exposed to weather conditions as a result of mining activities.

In the case of sterile piles, acidic water begins to form in the most superficial zone, and because these piles are permeable, the water infiltrates, causes rocks and metals to leach and appears at the foot of the piles, seriously affecting the development of vegetation and, as a result, magnifies erosive processes.

Without going into details, which are discussed in the specific literature, it may be noted that four elements are essential determinants in the development of these waters:

- pyrite, which is ubiquitous in soils;
- oxygen, which is a substantial component in the pores and cavities of unsaturated soils;
- water, which can be found in the soil in the form of humidity or flows; and
- acidophilus bacteria (especially *Thiobacillus ferroxidans*).

This combination of factors appears in many mining environments, but especially in mines of coal and sulfide complexes, many of which having years of mining activities and visible environmental changes.

In the case of outcropping pyritic rocks, such as those in the Iberian Pyrite Belt in the southwest portion of the Iberian Peninsula, the aerobic oxidation process was already underway during the Pleistocene, with the formation of acid waters, leaching and transport of heavy metals through surface runoff. A consequence of this natural leaching process was precisely gold enrichment on the altered surface (gossan) of the mining site.

Acidic water attacks rocks and minerals in its surface and underground route, resulting in high concentrations of some ions to a greater or lesser degree according to the composition of the rock or mineral (copper, lead, zinc, nickel, silver, fluoride, uranium, antimony, mercury, chromium, selenium, cadmium, arsenic, aluminum, manganese, etc.).

When the acidic waters come in contact with carbonated materials, they are alkalinized, thus resulting in the precipitation of certain metal ions, except those that require much higher alkalinity levels to precipitate.

Both in quantitative and qualitative terms, acid mine drainage varies greatly from one mine to another, and shows fluctuations linked to the cycles of rain, with variations in the concentration of heavy metals, which tend to indicate:

- slow increase during the dry months;
- sudden increase after the early rains; and
- gradual reduction during the rainy season.

9 WATER QUALITY CONTROL

9.1 METHODS OF PREVENTION

When the quality of the water in the mine is affected, it should be treated effectively in order to minimize contaminating effects, but it is vital to avoid or reduce contamination in order to prevent this from happening. For this, one should consider that the contamination derived from mining activities is closely related to the methods of mining, the supply of water (either surface and underground water) and its processing.

Regarding the possible approaches, it should be pointed out that, in general, the operation is not restricted to a single procedure, but a combination of several procedures, and it is implemented according to a specific problem to be addressed, since its efficiency can be vary greatly from one case to another.

Whatever the case may be, it is very important to plan contamination prevention operations from the start of the mining activity, and continue without any interruptions until its completion.

With adequate planning, one can avoid or at least minimize contamination, and should this occur, one can apply a corrective treatment. As far as prevention is concerned, it should be noted that an important aspect to bear in mind is the greatest possible reduction of water inflows (either surface or groundwater water) in the mining area.

If the risk of acidic waters being present in pyritic environments exists, and considering that one cannot avoid the presence of pyrite, the following actions are relevant in principle:

- prevent water inflows through appropriate engineering or geological barriers;
- avoid the presence of oxygen by flooding the mine or submerging the pyrite tailings in water; and
- use effective bactericides to fight the presence of bacteria (although its time effect is currently limited).

If the input of water to the underground mine takes place through cracks or fractures that have been identified, it may be sufficient to channel the water flows that feed them, to use a low permeability cover, or even to use a waterproofing injection in these pathways. In the case of infiltration over a large surface area that is not specifically identified, it may be desirable (if possible) to divert the waters flowing to that area of infiltration. In the case of dumps for pyrite waste and tailings, an impermeable surface may be used (compacted clay or a geomembrane) to minimize water flowing into contaminating materials: this is a costly, but very effective technique, which is recommended for small scale dumps that produce toxic water and pose a serious problem at local level.

If atmospheric precipitations and the permeability of the rocks are high, one may want to remodel the slope surface and make it waterproof to allow drainage without any erosion. The water extracted should be removed from the place. To be successful, this technique must be informed by extremely detailed hydrogeological studies – if a single permeable route goes undetected, the diversion of surface water will fail.

Planned flooding of pyrite rocks is a very practical procedure to prevent acidic water from forming. It consists of flooding the mine (i.e., the abandoned mine) or the waste and tailings dump to prevent the sulfides from being in contact with oxygen, and this will cause oxidation of the pyrite to cease. However, while the flooding reduces oxidation of sulphides, in some cases there may be an increase in the contaminant load initially when pre-oxidized minerals are incorporated, or there may be an influx of water that has already been mineralized.

We have planned operations of this sort in Spain and Portugal, with funding from the European Union, including:

- tamponade and closure of mine drainage operations;
- perimeter channels around the mine and waste and tailings dumps to prevent water from flowing in;
- transfer of waste to mine pits; and
- sealing and impermeabilization of waste and tailings dumps.

In the case of open-pit mines, reactive materials can be sealed with compacted clay or phyllites and stabilized with a layer of non-acid producing tailings. In any case, this is not easy if the pit is exposed to weather conditions due to maintenance problems.

9.2 METHODS OF CORRECTION

In the presence of acidic water, as a consequence of an old mining activity for which environmental requirements were not considered, one must implement corrective measures.

We are not referring to recycling and reuse, which are recommended practices whenever possible (i.e., zero disposal), or the storage and controlled disposal when the stream flow has sufficient capacity for dilution. We are referring to active treatments with significant operating costs (use of chemicals, electrolysis, reverse osmosis etc.), or passive treatments that require low maintenance (tank storage and evaporation with aeration and oxygenation; aerobic or anaerobic lagooning; lenient treatments with little or no chemical additions).

9.3 ACTIVE TREATMENTS

Traditional chemical methods for acidic waters consist of its neutralization through chemical additives (usually lime), followed by mechanical aeration (addition of oxygen), clarifiers, and settling dams.

When water is alkalinized with a pH above 5 and up to 8.5-9, many dissolved metals hydrolyze and precipitate, while other heavy metals require a higher pH, which causes problems associated to effluent quality. If an unlimited supply of oxygen is available, the rate of oxidation usually increases as the pH goes up, which is why aeration must follow the neutralization process.

The precipitated solid is usually an amorphous mixture of oxides and hydroxides, and if lime has been added, it will also include plaster and part of the lime that failed to react. This sludge is pumped from the settling pond, and its volume should be reduced through a filter-press so that it can be deposited in suitable and safe facilities, or be partially recycled to the neutralization and aeration tank.

Some active treatments of a greater complexity are required for highly contaminated water, such as demineralization through reverse osmosis or ion exchange resins. In this sense, methods for the recovery and use of some metals that are dissolved when their content is high are becoming increasingly popular.

9.4 PASSIVE TREATMENTS

When effluent flows are not very significant, passive treatments are the best solution from the standpoint of cost-effectiveness. These are remedial measures, especially for acidic mine waters (but also for alkaline water), for which a great positive experience is available, though there are also failures from inadequate enforcement. These are basically limestone traps in anoxic environments, which are supplemented with anaerobic lagoons in all its variants.

In particular, special mention should be mode of the use of flooded areas, where biotopes of major importance to plant and animal life are developed, besides treatment of these waters.

These passive treatments are increasingly popular, and they can improve chemical parameters that have been causing problems for quite some time now. Even in places where other treatments have proved to be inadequate, we now have the possibility of bacteria-based sulphate reduction, which causes heavy metals to precipitate, thus forming actual mineral "deposits" in the bottom of these flooded areas.

The main factor in favor of the flooded areas approach is its low maintenance cost, associated to the fact that it continues naturally when an ideal environment for the development of sulfate reducing bacteria is established, which generate the alkalinity to increase the pH and to precipitate oxides and hydroxides in heavy metals.

The simplest passive treatment takes place in artificial anaerobic lagoons, but such treatment is only applicable to waters with a near neutral pH containing sufficient alkalinity to neutralize the acidity generated by hydrolysis and the precipitation of metals.

However, considering that the ponds by themselves do not add alkalinity and cannot be used to lower the manganese content, anoxic limestone drains (ALDs), alkalinity producing systems (APSs), and rocky filter beds are added to these anaerobic lagoons.

The thousands of facilities in operation are an indication of significant breakthroughs and flow treatments at an increasing rate. Often times, the constraint is due to a need for surface areas, since a long time for the water to circulate in the treatment system is required. Furthermore, it is necessary to study the kinetics of removal of contaminants in order to develop an appropriate design on a case-by-case basis. This means that there are no blanket models that are applicable to all circumstances, so this is a frequent source of failure of poorly designed facilities.

A flooded area or a conventional aerobic lagoon on clayey soil may be sufficient to treat neutral or alkaline waters with high iron contents, removing 10-20 g of iron per square meter per day. But these ponds are not relevant here as there are more effective ponds for treating acidic waters, considering that for the precipitation of iron as an hydroxide the pH decreases, which causes oxidation of dissolved iron to decrease.

The first improvement to neutralize acidity can be achieved by replacing the soil with a compost organic substrate and limestone. Alkalinity is produced both by sulfate-reducing bacteria and dissolution of limestone. Thus, acidity is neutralized in aerobic lagoons, where most of the water flows over the organic substrate, at rates ranging from 3.5 to 7 g of CaCO/m2 per day. One can get higher neutralizations by forcing the water to flow through this substrate, so that the action sulfate-reducing bacteria can have full effect.

A marked improvement can be detected when prior treatment with lime is performed, before the water flows into the pond. This is what one gets by using anoxic limestone drains (ALD). These are drains that are isolated from the atmosphere to prevent the ferric iron from oxidizing and precipitating, thus creating a film around the limestone that inhibits its alkalinizing effect. The same would happen with the precipitation of aluminum hydroxide.

The APSs are also very useful. These are drains that are isolated from the atmosphere, where the limestone is put under a bed of compost and under approximately a meter of water.

In any case, technological advances in this area are so important that its development should be followed on a daily basis by attending specialized conferences and referring to specialized publications, and the International Mine Water Association (IMWA) is playing an important role in this area.

The latest innovations are being used in areas flooded with free-floating macrophytes.

10 HYDROGEOLOGICAL MODELING

To plan and anticipate the issue of mine water in the intermediate and long term, it is necessary to perform very well documented studies that culminate in the modeling of the water flow and the flow of contaminants to predict their behavior over time. For this, one must always use a conceptual model that perfectly reflects all the circumstances, based on the identification of hydrogeological units, structures, boundary conditions, recharge/discharge mechanisms, etc. All of this refers not only to the active life of the mine, but also to the completion of mining activities.

An important aspect of modeling is the water balance to quantify the contribution of waters from various sources in the recharge and discharge in the mining environment. Recharges can derive from rainfall, surface water and groundwater flows. Discharges may include evaporation, flows to other aquifers, pumped water and surface flows.

Against this backdrop, any potential contaminant must be measured and characterized through a geochemical research program. The chemical processes that affect water quality are simulated by establishing physicochemical assumptions that make it possible to predict water quality over time. Considering that uncertainties relating to these processes are frequent, it is necessary to use probabilistic techniques to evaluate the range of uncertainty in predicting chemical quality.

Moreover, hydrogeological and hydrochemical models should be used to assess different scenarios for completion of a mining operation. Thus, for example, one can predict the evolution of the filling of the hydrogeological-mining system, the relationship between groundwater and surface water, the end quality of mine water, etc.

11 BASE HYDROLOGICAL STUDIES

A key aspect in the whole planning of water for a mining operation is the approach to be used from the earliest phase of the environmental research to learn about the previous conditions of the surrounding area that may be affected by the establishment of a mine, considering all aspects associated to surface water and groundwater (quality, quantity, water balance, relationships, etc.).

On this basis, one must address preventive and corrective actions, along with appropriate warning devices and control of all parameters that may be affected. Strict monitoring of this survey process is critical to avoid undesirable effects.

These studies make it possible to generate extensive databases and, most importantly, appropriate treatment packages with the support of geographic information systems to integrate cross-information flexibly and give them appropriate visual and graphic representations.

Treatment of the data should make it possible to:

- capture and import historical data from different sources;
- manage and organize data;
- validate data to ensure their consistency,
- export the information into data treatment programs;
- develop suitable drawings, diagrams and maps.

12 MINE WATER CONTROL

An approach to hydrological and mining issues must be accompanied by an ongoing monitoring program that makes it possible to trace, at any given time, the reactions of the system to the drainage of the mine. This control requires monitoring of a set of carefully selected water sources (springs, wells, boreholes, streams, etc.), not only in relation to the water table and outflow, but also to the quality of the water.

12.1 PIEZOMETRIC CONTROL

This space- and time-based control provides vital data. The piezometric map displays recharge areas, flow directions and areas of discharge, with the impact of mine drainage and natural recharges or recharges or induced by the mining operation. This information can be used to predict water inflow issues and also to anticipate issues regarding potential contamination.

12.2 WATER QUALITY CONTROL

In this respect, one must address the following:

- Control of potential sources of contamination and areas of solid and liquid discharges: tanks and piping systems for contaminant products should be systematically inspected given the possibility of leaks, and security systems should be put in place. Dump areas with suitable conditions should be chosen in order to avoid contamination problems, and periodic inspections should be performed.
- Sampling of water quality: these should include the boreholes or wells that have been built expressly for this purpose or those already existing. Water samples should be representative (pumping operations in the case of wells and boreholes, whose duration will depend on the local hydrogeology). Regular sampling and analysis campaigns should be run in water sources in order to detect changes in quality. Monitoring of the quality of streams will provide information on the flow of groundwater, and will be an indicator for the integrated quality of a certain number of springs.

Sampling points should be chosen according to hydrogeological criteria associated to the mine. An arbitrary distribution would involve excessive costs and would not cover the objectives. For this, geostatistics provides some badly needed help.

Regarding the frequency of sampling, it should be pointed out that, under natural conditions, the quality of groundwater in aquifers that are neither karstic or fissured changes slowly over time, which can respond to seasonal stationary cycles related to changes in recharge, piezometric levels and discharge. But man's action may involve more significant and rapid changes in groundwater quality.

Two common effects of contamination are: an increase in the amplitude of annual changes in the quality and progressive deterioration of this quality with regard to a period comprised of a number of years. Accordingly, the frequency for sampling of groundwater quality control depends on the sensitivity of the aquifer to natural and anthropogenic influences.

In the case of effluent discharges, which are subject to rapid changes in its composition, it may make sense to collect a daily or weekly sample. A biweekly or monthly sample may be enough to detect changes in the groundwater. In general, when one does not have adequate background information and seeks to establish periodic changes, the surveillance program should include at least two years of observations with such frequency, and from then on sampling can become less frequent – on a quarterly or semiannual basis –, for the long-term monitoring of changes in quality.

Control in nearby areas, downstream of a contaminated area, may require biweekly, monthly or bimonthly sampling. However, when a serious danger of contamination (e.g., toxic constituents) exists that might affect the urban water supply, the frequency of this control must be increased according to the severity of the situation.

Control of water quality should be focused on the analysis of specific contaminants, according to their dangerousness, persistence, concentration, ease of identification or other traits. In the case of mining activities, it is easy to anticipate which contaminants may exist and, therefore, will require control. These are not only inorganic since there may also be organic contaminants from products used in ore processing operations.

12.3 WATER BALANCE CONTROL

Control of the water balance in relation to quantity and quality is key to monitoring the effects of drainage and to predict the changes caused in the short, intermediate and long terms.

In the case of quality, it allows one to study and predict the effects of dilution, absorption/adsorption, retention, stratification, etc. of contaminants, as well as the associated risks.

These controls should refer not only to the context of mining in the narrow sense, but also to systems for the disposal of waste and tailings in evaporation ponds to predict whatever is associated to their effluents, as well as potential leaks.

12.4 POST-OPERATIONAL CONTROLS

Mining is virtually the only industrial activity that generates water, and it has another special characteristic that distinguishes it – the fact that, after completion of a mining operation, its influence on the aquatic environment may last for a long time until stability is restored, which may be different from the stability that existed previously. Therefore, one must think in further controls at a pace and locations that were justified by previous studies.

Such monitoring will enable periodic verification of forecasts and implementation, if necessary, of appropriate actions to solve problems that may occur, especially water quality issues.

13 FINAL REMARKS

Being vital for a number of mining processes and operations, water creates problems and generates significant additional costs as a result of both drainage requirements and interference in its quality, which is why it requires proper management.

In this sense, the success and viability of a mining operation depend to a large extent on the resolution of its interactions with water, which requires adequate knowledge of the hydrological environment in order to support hydrological and mining actions, and the sooner these start the more efficient and less costly they will be. These actions should cover the entire operation – from the exploration to the post-completion phase designing and implementing the most appropriate preventive and corrective measures.

The water-mining relationship must be considered in every possible aspect, not only in the stages of exploration, operation, completion, and post-completion, but also in the processing of the ore, without forgetting that the impacts on water resources may persist for a long time.

To face these challenges, very advanced technologies are currently available that make it possible to avoid or reduce the negative impact on water resources, proven by experience and conditioned by the nature of the deposit and the type of mine. To this end, one must have a sharp understanding of the mining hydrogeological context, always bearing in mind that the activity must be dynamic, which requires updates and adjustments throughout the entire duration of the mining operation.

In any case, since in countless mines much more water than ore is extracted, it is necessary to minimize access of waters (either surface or groundwater) to mining operations. If, however, drainage in the mining context is required, the most convenient technology is the Preventive Advanced Drainage, which yields quality water that can become a very useful asset to meet different demands and be integrated to the optimal management of water resources framework. This drainage allows for the lowering of water levels below the quotas of mining while allowing to obtain optimum water to meet the demand from mining operations and usage demands of any nature.

These drainages, flows and volumes essentially depend on the characteristics of the affected aquifers (transmissivity, dimensions of vectors, etc.), the inputs generated by surface waters and sudden inrushes from precipitations.

Other hydrological problems in the mining activity may be due not only to piles of ore and waste and tailings dumps, but also to liquid effluents from the mine or ore processing plant. When the mining operation produces an effluent as the result of the drainage of groundwater or surface water inflows, priority attention is required to ensure its quality is acceptable. Thus, one may want to control all parameter indicators.

To minimize the effects of pollutants, the most important thing is to avoid or reduce contamination since the beginning of the mining operation, continuing through to the post-completion stage. With adequate planning, contamination can be avoided or at least minimized, and should this occur, effective corrective treatments may be employed. Today, compared to conventional chemical treatments, especially for acidic waters, the best solution is provided by passive treatments (with thousands of facilities in operation), considering their cost-effectiveness and the relative simplicity of its maintenance, all of this being associated to the circumstances of its natural persistence. It is necessary to study, on a case-by-case basis, the kinetics of removal of contaminants in order to develop an appropriate design for passive treatment and to take into account the ongoing development of these technologies.

In the intermediate- and long-term planning, one must conduct very well documented hydrogeological and hydrochemical studies, which should be completed by modeling the flow of water and pollutants to predict their behavior in the short, intermediate and long terms. For this, one must always use a conceptual model that perfectly reflects all the circumstances, from pre-operation to post-completion. These hydrogeological and hydrochemical models should always be used to evaluate the different possible scenarios regarding quality, quantity, water balance, relations, etc.

Hence, one must address preventive and corrective actions, along with appropriate warning devices and control of all parameters that may be affected. An approach to hydrological and mining issues must be accompanied by an ongoing monitoring program that makes it possible to trace, at any given time, the reactions of the system under the influence of the drainage of the mine.

PARTICIPATORY AND DECENTRALIZED WATER RESOURCE MANAGEMENT AND THE MINING INDUSTRY: RISKS AND OPPORTUNITIES

CHAPTER 2

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1 INTRODUCTION

Ever since it emerged on Earth, humankind has been developing skills that set human beings apart from all other species because they enhance their knowledge of natural processes and allow them to master nature. Learning more about the materials and how to transform them, human beings gained the power to intervene in nature originally to cover their survival needs and, subsequently, their aspirations to build a complex social fabric and comprehensive comforts and benefits, though their understanding of the consequences of such interventions were minimal.

Symbolically, mining has come to mean to society the link between ancient men, who entirely depended on and were subject to natural processes, and modern men, with their desires and needs that could be met by managing nature. Through material production, the natural environment then starts to be transformed to provide products for human consumption.

Historically, mining has always been considered a strategic activity, since, for the reasons above, access to minerals would open the doors for their transformation into end products of interest to societies. As a result, the mining business has always aroused little interest in the knowledge of their processes since its benefits have always provided for the desired social welfare. More recently, when human beings begin to see themselves as part of a natural process with which they have a relationship of interdependence, the negative consequences of their interventions – the so-called environmental impacts – start to be detected, and their negative aspects are consistently emphasized. What are the reasons for this? Take the case of Brazil as an example.

The emergence of mining in Brazil was strongly tied to the strategic interests of the Portuguese Crown, which, in view of the need to finance itself, encouraged the development of groups of adventurers, who reached the most remote areas of the country through the so-called Entradas and Bandeiras (explorations and raids into the interior) thereby ensuring not only access to these goods, but the conquest of uncharted and wild territories and their subsequent colonization. For the leaders of these expeditions, the only thing that was opposed to their goals of wealth and domination was precisely the wild which, therefore, should be dominated and subdued.

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Ever since, a link between mining and environmental impact was established that often times goes beyond the actual damages and makes it difficult for modern society to identify environmental control processes that are currently employed by this industry. This bond is evident in research conducted by Consultancy Door to Door - Institute for Market and Opinion Research, hired by IBRAM and the Ministry of Mines and Energy's Department of Mines and Metallurgy. According to the survey, which included 2,455 face-to-face interviews in 24 cities in eight states in the five regions of Brazil from January 30 to February 8, 2002, the strongest association with the word 'mining' are mineral products, with a clear prevalence for gold and iron, followed by precious stones, energy products (oil and coal), and civil construction materials. Such products are associated to the foundations of a nascent society, with basic survival needs and the eternal dream of wealth that the image of the Eldorado has brought ever since the days of the Bandeirante explorers.

Therefore, when society started reacting to the growing impacts that progress brought about and the fact that it endangered the environment and its ability to provide support, the recall of the historical bond predefined a culprit: mining. And the transformations undergone by this industry have become invisible.

Nowadays, many minerals have lost their strategic nature, and have become mere commodities, leading to an increase in their supply in the international market and making competition fiercer. Competitiveness in global markets is also stimulated by rapid technological progress that strongly affects all segments of mineral production, in view of their nature, are technology-intensive. The growth in metals recycling, the reduction of the content of metallic materials in products, substitution between minerals for greater efficiency in production processes, the creation of new materials, the emergence of new technologies for environmental control, and the relentless quest for energy efficiency are some of the aspects of today's technological environment in the mineral economy. Hence, as a result of all this historical evolution, mining is a production industry with major contributions to make in the management of natural resources, especially the sensitive issue of water, which, in turn, has always been considered an inexhaustible natural resource as it is a renewable resource. The recent realization of the fallacy of this assertion starts to pose enormous challenges for its management to modern society.

Approaching the issue of water properly requires consideration of contemporary important changes in water management in Brazil. Such changes are due to many factors, including the following at the geo-economic level:

- accelerated urbanization process (over two generations, the urban population jumped from 20% to 80% as a share of the total population);
- increased per capita income;
- expansion of domestic consumption and exports of highly water-intensive products (fresh produce, pulp and paper, sugar and alcohol, mineral products, etc.);
- geographical spread of the demand and the impacts on soil and water as a result of the expansion of agribusiness – especially in the Cerrado region –, where over half of all grains and beef in Brazil are currently produced, in contrast with the weak production 25 years ago.

Such circumstances that generate environmental impacts and actual or potential conflicts over water use, coupled with international warnings (Rio-92 Conference, World Water Forum, World Bank reports, etc..), spurred a discussion, led by the government and involving broad participation of technical organizations and the National Congress seeking to establish the legal framework for the National Water Resource Policy and the National System for Water Resource Management. – SINGREH.

At political/institutional level, there was widespread belief that the State needed to be reformed, with an emphasis on a reduced role of the State as a producer/investor (privatization program) and an enhanced role for the State as a regulator. Of course that domestic circumstances (financial inability to investment) and external circumstances (pressure from globalization and liberalization) were prominent.

2 DECENTRALIZED AND PARTICIPATORY WATER MANAGEMENT

In this context, the Lei das Águas (Water Act) (Law 9.433 of January 8, 1997) was enacted, which is quite different in form from the majority of Brazilian laws. It focuses more on negotiations than on enforcement. Its main contribution is to establish the concept of water as a finite good with economic value, in contrast to the widespread perception of water as an infinite bounty of nature. In doing so, it seeks to establish instruments for its effective management. It is more geared towards formulation and negotiation instruments, including instruments to prevent problems, than command and control instruments that are traditional in the sense of the State being a centralist entity.

Obviously the law does not change the tradition of centralization (even under Brazil's circumstances) of a constitutional, democratic and republican regime, but it provides for mechanisms for the participation of water users and members from segments of the society, such as in river basin committees, in which the government does not have the support of the majority for decisions. This is a breakthrough in the management of a public good, which effectively indicates the possibility of shared management and generation of an embryo for a desired process of social control.

One should note that, in general terms, the attribute of a public good has never been properly understood by society and even by public officials, and there is even some confusion between public and government accountability. This occurs perhaps because of Brazil's fragile democratic experience, where the State has prevailed over the individual. Some people expect or seek a solution via the government to solve community problems whose shared solution would be more effective and lasting.

In other words, due to the nature of some issues, assigning this responsibility solely to the government is unsuitable, costly and inept. The environment provides some typical cases, in which diffuse obligations and rights are present. An example is the case of urban sanitation, where the relevant service will never be fully effective without changes to the behavior of the population. Another example would be soil and water conservation, where the actions of the various economic stakeholders (farmers, miners, industries, mining companies, sanitation companies, power generation companies, etc.), social stakeholders (misuse of water by the population, with excessive and unnecessary consumption) or public officials (mostly local officials) always prevail, for good or for ill, over the formal mechanisms of supervision and control of the State apparatus.

Accordingly, it is worth noting that the Water Act has brought about a modern, innovative approach by assigning the river basin committees a position as central entities in the water management process. Therefore, they are the top authorities in their respective arenas regarding issues related to the management of water resources. The Water Resource Councils – both at state and national levels – are State bodies in charge of setting the policy at a macro level for the management of water resources, and they are also appellate bodies to which unresolved disputes at the committee level are escalated. They are supported by their executive branches, represented by the National Water Agency (ANA) at the federal level and by the various state organizations that are responsible for implementing the Water Resource Management System in their states. These, in turn, are government bodies since their managers are appointed by the incumbent administration and they are not collegiate entities with participation from other segments of the society. Unfortunately, the perception of that reality is still limited, and it should situation should change in order not to thwart the ample room for improvement of water resource management in Brazil, with focus on Law Nº. 9,433, of 1997.

The management of water resources must be perceived as a phenomenon that is much more of a social than of a technical nature. The previously mentioned inability of successive governments to provide address social problems effectively places a great responsibility on the collegiate bodies, such as the committees, since effective breakthroughs will be achieved through concerted action by the various segments of society, and these breakthroughs will materialize through negotiations that lead to a social consensus. Ultimately, this should represent the aspirations of society for its own sustainable development, with water as one of its main vehicles.

It is therefore crucial to understand that the National Water Resource Management System does not establish internal hierarchies. In conceptual terms, the decisions made by a committee relating to a federally controlled river do not take precedence over those made by a committee relating to one of its tributaries that is under state jurisdiction. It is imperative that these entities act in a concerted fashion to seek common solutions. These conditions reinforce the need for reflection and action in order to strengthen society's participation in the water management effort. It must be acknowledged that the representation of society in the committees and councils via technical entities and NGOs is not sufficient to ensure effective participation of communities in the management of water resources, as would be desirable. This is explained by the fact that, in comparative terms, such entities do not have the same degree of representativeness and knowledge of the diffuse interests involved as the members of user groups in relation to their objective interests. For these reasons, it is necessary to appreciate, respect and encourage the participation of individuals and communities.

The traditional knowledge held by local social groups cannot clash with scientific and technological knowledge, otherwise prominence of the latter may eclipse the former and, as a result, traditional knowledge would be lost and it would not be possible to reconcile it with knowledge of a more technical nature, which in turn would lead to repudiation of the search for solutions and to an endless conflict. It is therefore crucial to find ways to democratize scientific and technical knowledge, establishing synergies with traditional knowledge, and this is one of the natural missions of the committees.

The "spirit of the law" refers, directly or indirectly, in many ways and opportunities, to the indispensability of the inclusion of communities and their members in the water management process. Below are some quotes from the legal text:

Fundamentals

Article 1 - The national policy on water resources is based on the following grounds:

I - Water is a public good;

[...]

VI - Water management always provides for multiple uses, and must rely on the participation of the Public Authorities, users and communities.

Article 3 – The following are general guidelines for the implementation of the national policy on water resources:

[...]

II – Tailoring of water resource management to the physical, biotic, demographic, economic, social, and cultural aspects of the various hydrographic regions in the Country.

[...]

Without going into further detail at this time, it is important, however, to stress that water has characteristics that are strongly differentiated from other public goods, such as for example:

- Multiple uses and roles – these range from input to production to that condition where it represents the central element in spiritualistic rituals or religious creeds, such as in baptism and in purification baths.
- Mobility – it is especially interesting to consider how rapidly and constantly water changes geographical position and physical state throughout its natural cycle. It could be said that water is an inherently migrant entity.

This whole process, which is much more far-reaching and complex than the process that is technically and scientifically dubbed as hydrodynamics, requires a constant and deliberate effort to include individuals in the water management effort. A good approach on the subject can be found in the book Gente Cuidando das Águas (People Caring for Water) (FILHO ROMANO, 2002), in which the authors discuss the topic in depth and yet pragmatically.

Both philosophy and practicality can be considered to be found in the assertion that water, considered in its most subtle level, will never be part of the formal water resources agenda (i.e., legal and institutional agenda), where actual interests prevail, especially those related to economic use. As a counterpoint to the management of water resources, caring for water is a lighter, more human agenda. This requires brotherhood to be practiced in lieu of technical and formal negotiation. This is an approach that catches people's imagination from the perspective of well-being and contributing to improve the world. The purpose of the book People Caring for Water is, therefore, to motivate, to engage people's emotions and energies to care for the water in addition to the action and performance of the legal and institutional framework for the management of water resources.

Considering the power of real-time communication and democratization of information, one must pay special attention to formal decision-making rituals. After all, the so-called "powers that be" have proved difficult to keep track of the changes advocated by society or pursued by it in practice. As far as management of water resources goes, a parallel with democracy can be drawn. This is formally representative and intends to be participatory, but Utopia is direct democracy.

Understanding and practicing complementariness dissolve tensions and promote effective interaction in pursuit of a shared goal: increasing the supply of water, both qualitatively and quantitatively. It also means a path to practicing and expanding the express concept of the law, thus showing the need for implementation of attributes such as integration, decentralization, community participation, democratization, and shared water resource management.

All of this represents a reflection, in the law, of nature's requirements for the management process, and shapes the demand for an ongoing social mobilization effort, which would have its own agenda supported by the transcendence of water for life and for social welfare.

Social mobilization, as proposed, would signal the key points to guide the agenda of agencies and entities that have been established for the management of water resources, as well as governments and users. All this is geared towards harmonization and development of interests and objectives, which would bring about social control over the decisions aimed at solutions to the serious problem of water availability.

3 MINING AND WATER RESOURCE MANAGEMENT

The mining activity is often perceived as a business that gives rise to various conflicts. It could be said, for example, that the benefits generated by the mining business are perceived to disappear once mines are exhausted, while many negative impacts generated in the environment remain.

The mining industry is probably among the main users of water in Brazil, which involves some major peculiarities. It covers from complex ventures with major impacts – but at the same time with modern and efficient environmental controls on such impacts, including mitigation and compensation measures – to small potters, miners and sand or gravel extractors that have no planning or environmental control, often times operating with the indulgence of the local community. There are also projects with some degree of primary processing (concentration, separation or washing of ore) or a construction application for the handling of tailings (dams, etc.). Not so unusual are projects that require dewatering, which inevitably interferes with the stability of naturally established processes, which could cause environmental impacts on its surroundings as the result of a lower water table.

This is not the occasion to discuss technological shortcomings. The knowledge is available, which means that solutions exist to reduce or offset water-related environmental losses. As it turns out, many projects still have no control or rely on poor environmental control. Three aspects should be considered to gain insight into the issue:

- the need for mineral extraction to meet society's increasing demands;
- the environmental impacts that are inherent to mining activities;
- the proven effectiveness of environmental control processes.

With regard to the second and third aspects above, it is worth mentioning data from a study on the causes of erosion conducted in 2000 in the Alto Rio das Velhas region.

Box 1. Summary findings on the causes of erosion in a mining site at the upper São Francisco River

Types of land use and occupation	Occupied area (ha)	Generation of sediments		
		Rates (t/ha/year)	Total (t/year)	%
Urban	2,400	170	~ 410,000	20,0
Mining exploration without a control system	900	700	~ 630,000	31,5
Mining exploration with a control system	3,600	25	90% retained in treatment dams 10% non retained ~ 10,000	0,5
Grazing	57,000	15	~950,000	48,0
Other uses	6,300			
Grand total released			**2,000,000**	**100,0**

Source: Golder Associates – 2001/ANA/GEF/PNUMA/OEA

The study reveals the impact of the mining business without a control system, the high urban erosion rate (both infrequent, despite their large scale) and the oft-overlooked, but no less relevant, widespread erosion caused by farming activities.

Being an area of concentration and intense urban and mining activity, it is striking that the erosion caused by grazing and other rural uses accounts for 48% of the total. And, as shown in the study, when performed under environmental control, the mining business produces 25 t/ha/year, which is a share that is about 100 times smaller than the share of grazing. As it turns out, control in concentrated processes (i.e., mining) is much more feasible than in diffuse processes in rural areas, where physical, economic and cultural considerations prevail. This study also shows the influence of roads as the cause of erosion in mining projects. It should be noted that an assessment of the perception of the local society revealed that there was no mention of rural activities as a source of environmental problems. As for urban erosion, it is inexplicable that it continues sharply to account for 20% of the total area covered by the study (ROMANO, 2004).

It would not make sense to argue that the environmental losses caused by mining operations are isolated and that, therefore, its impact is more restricted than damages of a different nature. It is appropriate to recognize that the measurement of environmental losses cannot be restricted to physical or economic parameters; it must take into account that they generate psychological impacts since they capture people's imagination due to the change to nature and the landscape itself. In layman's parlance, for example, the most common term to refer to the environmental impact caused by surface mining is "destruction." And, in fact, this is what happens when an open pit mine involving a quarry is exploited. A hill is removed or transformed. No matter how local and isolated the effect may seem, it is visually shocking, even if the project is conducted according to the most efficient environmental control system available. A reaction of this sort occurs in relation to the destruction caused by uncontrolled mining works and even manual activities that cause silting to streams, wipes out springs and leaves visible trails of holes, often times as a permanent source of erosion.

By way a comparison, people do not react the same way in relation to the diffuse effects of economic or even social activities, either due to ignorance or lack of a psychological impact resulting from physical loss, that is, mainly by a sense of conformity generated by the enjoyment of progress. This is remarkable in the process of rapid and uncontrolled urbanization that took place in Brazil, and especially so in large cities, where social predicaments are confused with environmental plights. Typical cases include landfills serving as a source of livelihood for people.

Similarly, aren't people disturbed by air pollution as much as by the quarry described above, or a tree being felled (sometimes undergoing a senescence process) on television? What about the visual pollution that was once an attractive migration factor romantically represented by the "city lights"?

And what happens in rural areas where, for lack of knowledge and for economic reasons, soil degradation and, consequently, water degradation lingers on? In the beginning, trees were being felled to give way to grazing and cropping lands, particularly coffee crops. And how does one produce coffee (which was the foundation for industrialization in the Country) or milk without wiping out forests? This was the "way forward" that was accepted and supported by the government and society, thus making for a dangerous dichotomy that deifies agriculture as supplier of food (therefore with lenient acceptance of the associated impacts) while demonizing mining as a supplier of raw materials for the manufacturing industry. The underlying unconscious thought is that the removal of mining would do away with its impacts, without realizing, however, the consequences for the quality of life for current and future generations.

Thus, economic and political cycles run across history with enormous social, environmental and human sacrifices, and shape new concepts in the life and culture of peoples along the way. For example, in colonial times, the notion that nature was aggressive to humans – and not the other way round, as held nowadays – established with a strong rational appeal that for the sake of progress everything was possible. That was extreme anthropocentrism. As a backlash to environmental degradation processes in the mid-twentieth century, preservationist movements with strong emotional appeal come about as champions of biocentrism. The role of these movements was mainly to draw attention to the need to move to a mediation process to build sustainable development, which should respond to and meet social, economic and environmental demands.

In the coming years, the mining industry will continue to be urged to improve its environmental and social performance. The public is increasingly sensitive to environmental impacts in general and on water resources in particular, caused by practices that are inconsistent with environmental conservation and quality of life. It will continue to demand a more significant social return from a business whose concept of sustainability cannot be found within itself since it deals with non-renewable natural resources, but will be increasingly found in the way it creates wealth and shapes values for societies within its reach.

Nowadays there is a widespread perception by businesses that environmental and social adaptation in the mining industry is a key factor for its sustainability so that, from a modern and contemporary perspective, the mining sector must incorporate environmental protection by using methods and processes that are conducive to a professional standard that is consistent with the principles of sustainable development. Therefore, one must select those methodologies for planning and control that ensure the implementation of the best technical and economic alternatives and comply with the applicable regulatory framework. The mining plan, the environmental impact assessment, the environmental management system, and the mine closure plan emerge as indispensable tools for the exploitation of mineral resources in a compromise between economic and social benefits resulting from its use, and for the preservation of quality in natural systems on which current and future generations depend.

The moment is ripe for the mineral sector and other water-consuming industries that have specific knowledge on their activities, a good sense of corporate organization and good relationships with technical organizations (universities, research centers, etc.) to either initiate or step up efforts to develop sustainability benchmarks. These will provide guidance for discussions with government officials and organizations devoted to environmental advocacy (environmental movements) with a view to overcoming the false dilemma of development versus preservation. It is true – and it is important to point out – that there is room for sheer and simple preservation, a priority being the definition of special areas in which necessary measures must be implemented. Examples among many include:

- areas of unique scenic beauty;
- areas with a wealth of biodiversity and concentration of springs;
- special areas for aquifer recharge.

Even if protected, these sites still are subject to economic uses (i.e., recreation) or scientific uses (i.e., research).

And what about areas where resources are extracted, as is the case of mining? It should be emphasized that the accumulated knowledge, either technologically or at the planning level – including social and cultural aspects –, facilitates the development of parameters of sustainability mentioned above. Hence, this is not a purely technical task, though studies and actions on issues of this sort are prevalent. Nor is it about expanding traditional mitigation measures (at economic, social and environmental level).

This is put forward through a construction process in a win-win game where suspicion, opposition, feelings of loss or the indifference expressed by communities effectively interested or somehow involved simply disappear.

The insufficiency or poor efficacy of public hearings is implied, as are the conventional EIS/EIR required by law. For the sake of reflection and evaluation, what is being proposed here is an ongoing social mobilization effort as prevention to the reaction of people in relation to the unknown or generic perception of degradation they have when mining comes to mind. This effort is supposed to complement the formulation and in-depth discussion at the technical and institutional levels (water management bodies and government agencies). There must be an initiative to generate or encourage interest in the relevant themes and adjust the language and agenda for discussion so that it is representative of the issues of interest for the community and that they are within its ability to grasp.

It is in this environment that the basin committees become notoriously important for the mining industry. Because its peculiarities as an industry include the so-called "rigid location", the mining business cannot choose where its operation will be established. This in itself will be predefined by the location of the mine itself. Hence, what emerges in the vast majority of cases is mining's pioneering characteristic, through its actual potential to take quality of life conditions to far-off areas that would otherwise be unthinkable. But while this is true, the mining business also causes environmental impacts where these would not otherwise happen, at least in that way. It is also worth mentioning that the improvements undertaken by the mining business during its operation can be reversed if the mineral resources are exhausted, and the social segment that had previously benefitted from this may become subject to major social problems since the better conditions from the advent of mining at their location may cease to exist as soon as the exploitation becomes economically unviable.

Bringing technology to the mining activity with modern techniques of environmental management and control, the mining industry meets basic conditions to engage in the dialogue development process among various social groups involved in a debate where water is a major reference.

Note that one of the tasks of river basin committees is "to promote the discussion of issues related to water resources and coordinate the roles of the entities involved." It is perfectly understandable that, whether or not a committee has been set up, the mining sector, for their bodies, will take the initiative for such a promotion within and outside the committee. Two important meanings should be highlighted in this formulation: (i) from the political viewpoint, it means that the mining sector, as a water-consuming segment, would be taking a proactive and leadership stance, rather than a reactive or defensive one, which is quite common among all water users, (ii) from the social point of view, the industry would recognize and exercise the noblest, most complex, most difficult, and most effective characteristics for water management programs, which is sharing, decentralization and effective participation of individuals and communities. Special mention should be made of the relevance of this stance, primarily towards the mining business, which deals simultaneously with two public goods: the ore itself and the water. In this context, the issue of risk could be mentioned, including political risk, and the initiative previously proposed. Just to inform discussion and provide an opportunity for a productive internal discussion, conservatives typically do not assume risks, and the certainty of their future is, at best, survival, and never sustainable growth.

A significant portion of the mining companies in Brazil have demonstrated an innovative and bold profile, be it by taking market risks and risks associated to the development and use of new technologies, be it by standing out due to the establishment of new management strategies and new standards for logistics. For all these reasons, this is also the right time for its industry leadership in this new water management process in Brazil whose legal guidelines, concepts and foundations are considered to be advanced, but whose implementation lacks practice that is faithful to the law that incorporates the society's participation.

The Water Act includes the following in its general guidelines for action:

[...] integration of water resource management and environmental management; joint planning of water resources with user segments and regional, state and national planning; joint management of water resources and land use; integration of river basin management with the management of estuarine systems and coastal areas.

The legislation stresses the importance of integration between environmental, cultural, economic, and social elements for planning and management purposes. For effective implementation of these guidelines, it is essential to build a good relationship and involvement with the community. In fact, the basin committees are mechanisms that generate social capital. As such, they have the tangible possibilities of bringing up a whole range of issues that need to be addressed and adequately dealt with when one thinks about sustainable development, which is ultimately the desire of the whole organized society.

Thus, the mineral sector, like other segments of society, has the opportunity to operationalize a modern management approach, with representation at the river basin committees as water users and in discussions related to water resource management. For the large mining corporations in Brazil, the allocation of staff time and a team for external representations that discuss and improves water management, adopting the aforementioned proactive and open stance, in appreciation of the community's values and stimulating increasing participation by other sectors.

4 SOCIAL RESPONSIBILITY IN THE MINING INDUSTRY

The theme of social responsibility recently came to the foreground, be it by structural changes in the very structure of the Brazilian State, be it by changing perceptions of society, and especially leaderships in the production sector regarding the profound changes underway in Brazil and worldwide.

The bureaucratic, centralized and paternalistic State that has prevailed over the public is still part of Brazilian culture. However, the increasingly evident failure of the State to fulfill its constitutional responsibilities towards its citizens began to draw attention in terms of what companies could do to help in the process. At first, well-organized companies became aware of this issue due to the potential risk that the growing social predicaments represented for their competitiveness. Being an "island of excellence" amidst a "sea of poverty" and its terrible consequences was definitely something that would undermine the competitiveness of businesses in the intermediate and long term, both due to the growing shortage of skilled labor to work with increasingly sophisticated and necessary technologies and due to the mounting social tension created by the "social potential" gap between the universe of a company and the community that surrounds it. In a world where the relationship between competitiveness and technological innovation capability has become crucial to corporate survival both from the engineering and the managerial perspectives, companies began working toward narrowing this gap. This is the genesis of the so-called Corporate Social Responsibility. This move was perceived by social agents who called for solutions. The circumstances of the recent processes in the Country, mainly reflected in the known political liberalization and economic globalization, revealed unacceptable levels of poverty and income disparity, and mainstreamed the theme of social responsibility in Brazil.

The social and environmental practices in the production sector, which go beyond their legal obligations, now play a fundamental role by filling gaps creatively and innovatively in addition to legal requirements.

Hence, a number of examples come to show that corporate social participation is called for. From the viewpoint of the industry, mining became particularly prominent due to its peculiarities that were discussed earlier. In particular, because it is established in areas that are remote and deprived of the presence of the State, the mining business often encounters gargantuan social gaps. The typical industrial activity is heavily concentrating, for it seeks to settle in locations that bring together various industries and have the opportunity to be guided by the areas where the State structure allows for enhanced development, thus providing better access to skilled labor and advanced infrastructure. In the case of the mining industry, which has to go where the ore is, it is the other way around.

As a result, this sector has emerged as a natural cradle for the development of a bolder concept of social responsibility. Because of its extractive nature, however, which mistakenly comes across as a low-tech business, and also due to its colonial roots, the mining business attracts enterprises with glaring technological differences in terms of the management of its impacts. Unfortunately, society has not been able to distinguish between those practices and places them all under one umbrella called "mining", which brings together modern, high-tech practices and primitive, highly degrading practices. This paradox is currently the biggest challenge facing the industry, as well as an excellent opportunity to show its importance to modern society.

This is how a number of examples of pioneering mining activity in the practice of social responsibility can be presented. For example, this industry established the practice of developing a Social Balance Sheet, seeking to make available to the public activities that so far had been restricted to the corporate business. By exposing itself, the mining industry faced harsh criticism, but which allowed it to embrace new practices. Because it normally comes across poor infrastructure during the deployment phase, the mining business has to invest in schools, hospitals, roads, and other social facilities. Social programs related to education and healthcare are frequent, usually through partnerships with local and state governments. Archaeological and historical sites that had been in an outright state of abandonment are now being rehabilitated or surveyed for subsequent study.

Among all the practices that the mining industry has been developing, one deserves special notice in view of the importance that it has been gaining in this context. These are discussion groups – the Advisory Committees – which firms have been creating on their own initiative, which relies on the participation of members of the civil society and public sector, whose aim has been to establish a joint discussion to decide where social investments sponsored by companies should go. This practice reflects an innovative approach where a company is no longer the only one to determine the investments it intends to make and starts sharing the decision with stakeholders and creates the healthy habit of having the community discuss its own problems.

It is based on these roots that government and society have been improving environmental regulatory frameworks, and some of these are quite questionable since they attempt to incorporate into the legislation voluntary initiatives that should remain as such, for example environmental compensation, in addition to constraints of patents (comprising aspects of a social nature), among other mechanisms. This is a complex issue, and it has been looked at from different perspectives. Apart academic or methodological concerns, however, it should be clear that it encompasses important aspects of a social nature, in addition to managerial and technical aspects.

In tandem with the social component, the development of rapport between the State and society should be considered. Moreover, the evolving understanding that representatives of the production sector have of their current role as citizens and entrepreneurs brings about new behaviors in the relationship between the social and market components, between the human and production components, thus pointing to the restoration of fundamental values in an optimistic view. Some of these are part of the concept (and current practice) of social welfare for its intangible nature. This transformation is related to the exhaustion of a vicious, predatory and evil cycle where disrespect of citizenship and the right to a healthy environment prevailed. It is important to note that mere compliance with laws or philanthropy are far from covering the concept that is meant to be one of social responsibility. Accordingly, the practice of social responsibility where managers or groups of people (when it is not only about institutional responsibility) can thrive as the generators of cultural change involves essential values that must prevail. Thus, a virtuous circle of fraternity, peace and solidarity cultures is born.

For this process to be sustained, one must avoid the pitfall of immediacy and easy campaigns, where often times the capacity of mobilization of guiding bodies prevails over the depth of the proposal. It is essential, therefore, that strong conscience, conviction and tenacity are well established elements so as not to thwart the long-range results.

The weaknesses and even failure of traditional political or programmatic mechanisms by the State apparatus and diminished credibility of the State as a manager stress the importance of the leading role played by the production sector and community representatives in the transformation of social reality.

The ethical aspect proves to be important because in broad terms the whole approach to social responsibility affects people's lives, whether they are treated as customers, opinion makers, etc. In other words, leadership and proactive attitudes influence the general public.

Where does the mining industry and participatory management of water resources fit in this exercise of corporate social responsibility?

Initially, it is necessary to recognize that this process is not innovative in terms of the concepts of the legislation on water resources. Rather, it reinforces them and qualifies them. Therefore, the mining sector should welcome the proposed social responsibility as an opportunity to take a leading role to guide the processes that are directly or indirectly related to the management of water resources, but which always mediately or immediately affect the quality and quantity of water available, thus affecting quality of life.

The opportunities created by Law No. 9,433 of 1997 – the Water Act – are enormous for the mining industry to be able to spur its learning process over the past few decades. By setting up collegiate bodies – the river basin committees –, by developing management tools that enable the achievement of goals and by establishing concepts in which negotiation and social compromise prevail, SINGREH uniquely creates all opportunities to develop social capital, backed by open and participatory debate, which makes it possible to build a new model of society toward inclusion and sustainable development. And the reason why this is a unique approach is associated to the fact that the model has the issue of water as the basis for discussion, which is essential when discussing any sustainable development model.

In view of the experience it has obtained in negotiation processes with social actors, and also because it uses public natural resources as raw materials, the mining business could make a significant contribution to bring about such a pact. The initiatives by a number of mining companies towards encouraging and participating in the various forums on the development of this system reflect a desire to participate and contribute to its success in a substantive manner. The mining industry will certainly be a part of the solution in this case, and will put aside the perception by society that is has to be a part of the problem.

Probably a transition effort should be made for the establishment of approaches in which transparency is the driving force of mining businesses in their relationship with the community. Transparency is an important factor for building respect and credibility and to generate sustainable and harmonious relations with society, which should be the aspiration of the production sector as a whole. The professional standard in a competitive firm can also be used as a source of good information and communication in order to generate a fruitful cooperative relationship with the community.

5 FINAL REMARKS

The discussion on the decentralized and participatory management of water resources and the mining industry is extremely timely and relevant, as it is for all segments of water users.

The opportunity appears to be even strategic as the guidelines in the new policy on water resources have been positively evaluated, but its effective implementation is still incipient. However, governments, users and members of the society have sought to develop and advance their particular agendas, which should converge into a common agenda that that is based on and pursues sustainable development and collective well-being.

Water being an important component for environmental management, it follows that it is used as a practical benchmark of the quality of its management process, as well as of the impacts of anthropogenic activities. And this is how, though in empirical terms, individuals and society see what happens around them by simply observing the availability and quality of water in their surroundings and the likely causes of its alteration.

The water resource management system has plenty of room for groups of users in a collegiate management approach. This, in turn, guides its decisions through a process of continuous negotiation in which the majority or consensus is built through the influence of arguments and commitment to far-reaching causes, but also as the result of situational injunctions.

It is vital that companies in the mining sector commit to monitoring (at the least), or conduct processes in their interaction with society in light of major developments where technology and social rapport are essential elements for building a cooperative and harmonious relationship between the these businesses and society. To this end, it is necessary to interact with the community through mobilization processes where transparency of information and definition of common goals are challenging and rewarding for people.

The following quotation is explained by the complementarity between the use of instruments for managing water in search of its rational use and people's devotion, engaged in their own way to improve the availability and quality of water: "Rationality organizes and emotion mobilizes."

Finally, out of this small collection of assessments as a proposal for debate, the opportunity stands out for the mining industry to lead processes where the goals of genuine social welfare and citizenship-based water management come together as one. The mining sector has strategic knowledge for proper management of this paramount natural good – water. Past mistakes, heated discussions and the strong demands made by the various social actors have certainly taught the mining industry impressive lessons. It must be understood that society does not accept that this knowledge is used only as part of business activity. Much more than that, the underlying message is that knowledge must be shared in a transparent manner and in accessible language, making it part of the common good. Certainly, when mining firms have a better understanding of this, many demands made today, which are often absurd and meaningless for the sake of sheer and simple environmental control, will turn into dialogue and negotiation, because society needs to know how to address the terrible problem of shortage of water resources needed for welfare and development, and perhaps will begin to perceive the mining industry as a source of safe and reliable information. But this will only happen if the mining industry perceives itself as a major actor in this process as well and if it is willing to do its share. And it seems that the optimal forum for this are the river basin committees.

This can be considered to be a sense of social responsibility, but it will also certainly be a way to build a new win-win culture in the relationship of the mining sector with the society.

Photo 7. 2nd Water Forum for the Development of Minas Gerais

WATER MANAGEMENT TOOLS AND THEIR IMPLEMENTATION IN THE MINING INDUSTRY: BRAZIL'S EXPERIENCE

CHAPTER 3


Photo by: Eraldo Peres

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1 INTRODUCTION

Law Nº 9,433 of January 8, 1997, which establishes the National Water Resources Policy (PNRH), defines six instruments for water management: the Water Resources Plan; the classification of bodies of water; the grant of right to use; charging for use; the Information System on Water Resources; and compensation for municipalities. As Article 24 of Section V of this law (compensation to municipalities) was vetoed, only the first five instruments mentioned above will be discussed. In fact, these are the main instruments of a decentralized and participatory management policy whose peculiarities for their individual implementations according to the unique features of the mining sector shall be highlighted.

2 BASIC CONCEPTS

The 1988 Constitution provides that water is a public good, and no such thing as private waters exist, and dominion (administrative and managerial responsibility) is concurrently with the individual States and with the Central Government. In other words, the Central Government controls "lakes, rivers and any water streams within its dominion, or which cover more than one state, serve as borders with other countries, or extend to or from a foreign territory, as well as bank lands and river beaches; the States control "surface water or groundwater, flowing, springing or still waters, except, in this case, pursuant to the relevant law, those arising from works by the Central Government."

Art. 21, Section XIX of the Constitution also gives the Central Government the power to "establish a national system for water management and to define criteria for granting rights to its use." Thus, the Central Government issued Law No. 9,433, of 1997, which established the National Water Resources Policy and created the National Water Resources Management System (SINGREH).

Hence, according to Werneck (2003), "the powers granted to the Central Government stems, in particular, from an irrevocable fact, i.e., the hydrological cycle, which requires waters, albeit in different domains, to be managed together".

WERNECK proceeds: "in line with the guideline adopted worldwide, Law 9,433, of 1997, elected watersheds as management units, whose basic concept

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is that of a land area for the drainage of a watercourse or lake, where the following exist together: a) multiple, often conflicting uses, b) water bodies in different dominions (Central Government and States - Art. 20, Section III, and Art. 26, Section I, of the Brazilian Constitution), and c) that are located in territories of different states, municipalities, the Central Government, and sometimes even other countries. All these characteristics of water resources require a management at national level, which must be integrated because federal rivers flow into state rivers, and vice-versa. Isolated, autonomous management of this life-supporting good by the individual States would be completely ineffective. For this reason, the Constitution delegated the Central Government the power to establish a national water management system; a system that is unique and integrated, mainly because of the seamlessness of the hydrological cycle".

In 1992, in Dublin, the first international meeting was held to discuss, at global level, a growing concern regarding the world's supplies of potable water and their distribution to humanity. As general principles for the management of water resources, the conference in Dublin established an integrating approach, involving society and protection of natural ecosystems, the need for social participation, and recognition of water as an asset with economic value. Based on these assumptions, Art. 1, Section VI of Law No. 9,433, of 1997, establishes as one of the foundations of PNRH that "water resources management must be decentralized and involve public authorities, users and communities."

Thus, the SINGREH, which is in charge of coordinating integrated water management (Art. 32, Section I, of Law No. 9,433, of 1997), brings together organizations representing all federal entities, water users and representatives of the civil society and communities. The water resources councils and river basin committees, which are collegiate bodies up to which are the most relevant decisions, are comprised of the public authorities, representatives of users (including the mining sector) and NGOs and civil organizations working with water resources (see Art. 34 and 39 of Law No. 9,433, of 1997).

Again, quoting Werneck, "although the Constitution has assigned to the Central Government exclusive authority to legislate on waters (Art. 24, Section IV), there is full consensus in the law that the States have the power to legislate on water management in their dominions, provided that the rules of concurrent jurisdiction are respected. This is so because the States have bodies of water under their dominion and because they have concurrent jurisdiction to legislate on environmental protection, pollution control and liability for environmental damages (Art. 24, Sections VI and VIII).

Also according to Werneck, "noteworthy is the fact that the principle of user participation in public administration has now attained constitutional status through Amendment 19/98 (Art. 37, Paragraph 3), as another manifestation of participatory democracy reflected in the Brazilian Constitution."

In this context, once again quoting Werneck, "it is up to the Central Government to establish general standards, and it is up to States to supplement or complement the Central Government's general rules to meet their specific requirements as described under Art. 24 of the Constitution." Thus, the public officials of the States and the Federal District are the ones responsible for implementing management tools for the waters in their respective dominions as defined in the Constitution. Public officials in the Central Government, in turn, are responsible for the deployment of management tools for federal waters. All, however, must follow the general rules specified under the National Policy.

The mining business has specific characteristics in relation to water use that stand out from other exploitation and processing activities and, therefore, deserve an analysis of these instruments that takes into consideration its peculiarities. The purpose of this analysis is to support the entities responsible for the implementation of these instruments, given the call to participation by Law No. 9,433, of 1997, thus contributing responsibly to the best development of regulations on the implementation of these instruments as regards the mining industry.

Three characteristics of the mining business stand out and imperatively need to be considered when deploying all the management tools under Law No. 9,433. These are: a) both mineral resources and water are public goods that belong to the Central Government, and their exploration and exploitation are governed by specific legislation, b) the prospecting and mining of mineral resources are authorized or granted in the best national interest, considering the public good c) mining is a locationally constrained business.

Moreover, it is worth underscoring that modern life, with all its technological achievements, from a prosaic tooth treatment to the great achievements in space, simply would not exist if the mining business did not exist. Thus, mining is and will remain a strategic business for any organized society, and water is naturally associated to mining and mineral processing activities. Therefore, as an inherently critical matter of survival for the mining business today, it relies on a rational mineral production, with absolute control of environmental safeguards associated with the use of advanced technologies and the relentless pursuit – with investment in new research – for an increasing rational use of mineral resources, including recycling of products and, in particular, the rational and optimal utilization of water resources, which is also a primary input for this business.

3 WATER RESOURCES PLAN

The Water Resources Plan is the strategic planning mechanism for watersheds and serves the Dublin recommendation, which establishes that

> "Water Resources Management is an integrated planning process that takes into account both the needs of long-term and short-term, incorporating environmental, economic and social considerations within a principle of sustainability. Management must also cover the needs of all users as well as the imperatives of prevention and mitigation of disasters related to water, and it is ultimately an integral part of the development planning process."

This instrument has implications on three levels. The Water Resources Plan at the national level, the Plan at the state and local level, or at the river basin level. Thus, considering the inherent need of integration between these levels, the key in implementing the Plans is the involvement of civil society as a whole, and of major users of water resources, particularly in the drafting process.

In fact, the National Water Resources Policy as expressed by Law 9,433 sets out clearly that the management model recommended is not governed by command or control. In other words, the emphasis on the implementation of PNRH is not only on results: water supplies with sufficient quantity and quality for everyone, but especially for the consolidation of SINGREH indelibly requires the establishment of an institutional organization that integrates and articulates decentralized units. Thus, improving water in both qualitative and quantitative terms in the intermediate- and short-term is a goal to be pursued under the Water Resources Policy, but not the only result. If it were, it would not be necessary that, out of the six established instruments, including the Plan, only one (grant) was actually command and control. It would be sufficient to establish the granting and monitoring instruments for water management. However, one should keep in mind that even surveillance is mentioned as an instrument, and all others, except collection, which is an economic instrument, are in fact planning tools, thus with an ex-ante emphasis. In this sense, it is a consensus that one cannot establish a Plan for achieving a single outcome or to obtain immediate results that are easily measurable.

Therefore, the Water Resources Plan should, above all, become the enabling instrument for this new concept of public policy management and administration established by Law No. 9433 and embodied by the development of SINGREH. In other words, this instrument will foster the implementation of a new administrative model in which management objectives are not expressed solely by technical standards or rules of conduct, but reflect the outcome of negotiations between multiple actors. Thus, the Plan should point the way for greater acceptance of the decisions contained in it, ensuring greater ease of implementation, with achievement of effective integration of various public policies – especially local policies – with the policy for water resources management of a given river basin, State of even the Central Government.

When preparing the Water Resources Plan for a river basin, a State or the Central Government, one should be careful not to be overly impressed at a beautiful piece of water engineering, whose outcome is restricted to the definition of benchmark flows for granted use for the various sub-basins or for the management of demands. One should also be cautionary so that the action strategy does not become nothing more than an efficient monitoring of this order. In this sense, it should be pointed out that Law no. 9433, "by entrusting river basin committee with its design"[4], in fact meant "more weight to political choices," rather than technical choices. And seeking "conditions for greater participation of the actors in the water management community by enabling, even during the drafting of the document, conduction of negotiations on the various demands, which gives greater legitimacy to the process." In addition, considering that the Water Resources Plan, in accordance with Law no. 9,433, in principle, as "the expression of political will" of the participants, should include mechanisms that make this instrument a "development contract for water affairs agreed between the various actors." According to the terms of reference for the State Water Resources Plan for the State of Minas Gerais (Coelho, et al, 2000), the Plan "must require stricter compliance with concepts relating to the requirements for the sustainability of its interventions, and also to application of the principle of subsidiarity, whenever issues regarding the allocation of work between the National Plan for States, River Basin and river tributaries of the main course are concerned."

Also in accordance with the terms of reference for the State Water Resources Plan for the State of Minas Gerais, "interaction with the plans mentioned above shall be effected by means of dialogue with the river basin committees, which are decision-making

[4] The quoted texts are by Antônio Eduardo Leão Lanna, Jaildo Santos Pereira and Gilles Hubert – Os Novos Instrumentos de Planejamento do Sistema Francês de Gestão de Recursos Hídricos: I Apresentação e Análise; II Reflexões e Propostas para o Brasil (New planning instruments in the French Water Resources Management System: I Introduction and Analysis; II Ideas and Proposals for Brazil).

bodies that lay down one of the fundamental premises of the planning process and decentralized management of water resources." Thus, success of the Water Resources Plan is expected as a result of the commitment undertaken during its development between the parties directly or indirectly involved in its implementation.

The preparation process for a Water Resources Plan can be divided into three main parts: a) a diagnosis for the reconnaissance of environmental conditions, water potential of the basin with application of water resource assessment models and historical and natural socioeconomic penchants b) the establishment of water resources management models, and c) the actual master plan, which consists of establishing goals and strategies for harnessing water resources for sustainable development of the basin, driven by the results of the diagnosis.

In the definition of goals and strategies lies establishment of the development model suited to potential water resources in the basin, and it has critical influence on the implementation of all other management tools.

Indeed, water quality goals will feed into the watercourses classification process, the priorities for use in obtaining a grant and, finally, investment plans that will serve as an input for the calculation of water use charge amounts, which also include studies on the economic status of the user community for the river basin, among other parameters.

Law no. 9,433 provides that it is up to the committees, with the support of agencies, to review and approve their Plans, and it is also up to these committees to ensure implementation of the actions described in the Plan; it is the duty of the State Water Resources Councils to approve State Plans; and it is up to the National Council to approve the National Plan.

As mentioned earlier, one of the characteristics of the mining business that must be emphasized for implementation of this instrument is that mining has geographical constraints. When building alternative scenarios for the Plan, one does not have the leeway to opt for locating the mining operation further downstream or further upstream, nor can one choose among tributaries in a river basin. The mining business will always settle where the mineral resources are. Thus, the definition of quantitative and qualitative water-related goals and strategies for a development model suitable to the potential water resources of a river basin where mining is the main social and economic activity should consider the need for a balance between the main activity and the ability to support the basin.

For the purposes of establishing the Plan, one must consider, therefore, that the various types of interference in water bodies, whether these are surface or underground waters, depending on the inherent particularities of the mining process, should be well known and therefore addressed in the Water Resources Plan according to their actual size.

4 A CLASSIFICATION OF WATER BODIES

CONAMA Resolution No 20, of June 18, 1986, was revised and revoked by CONAMA Resolution 357, of March 17, 2005, which provides for the classification of water bodies and environmental guidelines for its regulatory framework, and it establishes conditions and standards for effluent discharges, among other provisions. Pursuant to art. 3, freshwater, brackish and saline waters in the national territory are classified according to the quality required for their main uses under 13 classes of quality. Law 9,433 provides that the classification of bodies of water into classes according to prevailing water uses is an instrument of the National Water Resources Policy and therefore of the management of these resources with a view to ensuring water quality that is consistent with its most demanding uses and to cutting costs to counter water pollution through ongoing preventive actions.

According to CONAMA Resolution No. 357, 2005, fresh waters are classified as follows:

I – Special class – water for:

- human consumption (disinfected water);
- the preservation of the natural balance of aquatic communities; and,
- the conservation of aquatic environments in fully protected areas.

I – Class 1 – water for:

- human consumption, after simplified treatment;
- the protection of aquatic communities;
- primary contact recreation, such as swimming, water skiing and diving, pursuant to CONAMA Resolution 274/00;
- irrigation of vegetables that are consumed raw and fruits that develop in connection to the soil and are eaten raw without the removal of their skin;
- natural and/or intensive rearing (aquaculture) of species for human consumption.

III – Class 2 – water for:

- human consumption, after conventional treatment;
- the protection of aquatic communities;
- primary contact recreation, such as swimming, water skiing and diving, pursuant to CONAMA Resolution 274/00;
- irrigation of vegetables and fruit trees and irrigation of parks, gardens, sports and entertainment fields with which the public might have direct contact;
- aquaculture and fishing; and
- watering livestock.

IV – Class 3 – water for:

- human consumption, after conventional or advanced treatment;
- irrigation of tree, grain and fodder crops;
- recreational fishing; and
- secondary contact recreation.

V – Class 4 – water for:

- navigation;
- landscaping harmony.

This resolution shows that the classification depends on the intended use for water. This very classification for freshwater is provided for brackish and saline waters. For each class has limits and/or minimum quality requirements based on physical and chemical parameters of water, which are also included in the regulation. For more noble uses, the required parameters for best water quality are more strict.

Resolution No. 12 of the National Water Resources Council, of July 19, 2000, provides for the classification system, defining it as "the establishment of the quality level (class) to be achieved and/or maintained at a given segment of the water body over time." In addition to being a tool for the management of water resources, the classification of bodies of water is also very important as a planning tool for the management of water resources. In short, it reflects the desired body of water, the body of water that is possible and the body of water that is sought. Therefore, it is in fact a goal of water quality to be achieved, and its implementation involves investments in the river basin, such as installation of machinery and equipment for the desired improvement in the quality of liquid and gaseous effluents and for the improvement of the waterway being used. Thus, the classification system is closely related to the Water Resources Plan, which also sets targets for sustainable development, considering the support capacity of the watershed.

Indeed, the implementation of the classification system is based on the body of water currently available (i.e., diagnosis) and aims at the body of water of tomorrow. This tomorrow may involve various horizons (one, two, three, ten years), with various scenarios, according to river basin's water, environmental, and socioeconomic support capacity. In other words: the classification system covers a plan of goals or policies for the sustainable use of water resources.

The way it is put forward in the legislation, the classification system provides for the management of water resources through an evaluation and design of land use (cities and states). In this sense, it is, by definition, an instrument for the reconciliation of environmental management with water resources management.

The classification process – or the determination of the desired, possible and sought body of water – is only possible when premises of participation, integration, and coordination are employed, which are fundamentals of the National Water Resources Policy.

Again, an interrelation between management tools exists. Indeed, the investment required to achieve the targets set for the classification system is one of the elements to calculate the amounts to be adopted in the basin to charge for water use. This involves the need for the watershed community, through their representatives, to work actively in the classification process, and this should seek ways of engaging people at all stages of implementation.

According to Law 9,433, Resolution No. 12, of 2000, the CNRH stipulates that water agencies are in charge, within their jurisdictions, of proposing a classification system to the river basin committees, so that within the participatory process for its implementation the community is informed about the consequences of the agreed system, including the restriction on certain uses in certain stretches of water courses. In other words, in river basins that are suitable for mining activities, prior knowledge of the impact of such activity on water quality is required before deciding on the classification of a particular water course, given the mining business' inherent immobility. We should also bear in mind the size – even if estimated – of the investment required to achieve the desired classification system since this cost, as mentioned earlier, should involve the calculation of charges for use.

5 GRANT OF RIGHT OF USE

The purpose of the granting of rights of use for water resources in accordance with Law No 9,433 is "to ensure the quantitative and qualitative control of water use and the effective exercise of rights of access to water." It is important to stress that this legal instrument establishes that the grant is an act by the competent public authority, and it does not involve partial sell-off of water, but a mere right of use. This Law also emphasizes that the grant may be partially or totally suspended under special circumstances.

In simple terms, the grant is an accounting procedure of water resources in a watershed that aims at meeting the goals of the National Water Resources Policy as follows: i) ensuring the necessary water availability to current and future generations, under quality standards that are appropriate to their uses; ii) the rational and integrated management of water resources, including waterways, with a view to sustainable development, and iii) the prevention of and protection against critical hydrological events occurring naturally or resulting from misuse of natural resources. Thus, in the case of the catchment of surface water, when performing the act of granting, a balance is performed between the amount of water at one point of a given body of water (which is its water potential) that can be measured in units of flow or volume and the demands already authorized upstream and downstream in the inflow spots of this body of water, also considering a remaining or residual flow which is also called minimum instream flow. The result of this accounting process is compared to the request for water volume/flow use contained in the grant application. Hence, the grant is a response to the issue of water availability in the basin considering the objectives of PNRH for authorizing or not the use requested. It is a management tool that helps establish parameters for a planned and rational use of water, taking into account seasonal variations, specific times of abundance or scarcity, and to resolve use conflicts.

Based on these concepts, procedures for the granting of the catchment of surface water have now been well established, which leads to the need for further studies and improvements on the procedures for the granting of specific uses of water resources, with an emphasis on the exploitation of groundwater in the case of mining.

Like the other tools mentioned earlier, this requires effective participation of community of users of the basin, primarily to set priorities of use for the grant to be confirmed. Although the granting is exclusively up to the entity managing the water resources owned by the States or Central Government (under the dominion approach) from the legal viewpoint, the grant should be given in accordance with the use priorities defined in the basin plans, which are approved by the relevant committees. It should be pointed out that the legal provision establishes that the committees have the power to approve the plans for the basins, among other powers. The minimum content in the basin plans includes the prioritization of water uses in their respective basins. As the grant ensures use in a specific time, the community must also play a role in encouraging legalization of all uses through this act as the only way of ensuring the flow required for the operation of the projects in the river basin.

The grant is therefore an instrument of control that helps evaluate the actual status of the watershed in terms of its water potential. By registering granted uses, it is possible to know the capacity of the river basin to support the desired development. Thus, this is a basic instrument in developing the Water Resources Plan since it supports the proposals for a classification system, and it is the basis for the discussion on the terms on which water use will be charged.

For the mining industry, some considerations for the deployment of this instrument shall be presented here. First, establishment of the Information System on Water Resources is considered to be a key requirement for implementation of the granting scheme. There can be no seriousness in supplying an increasingly precious resource such water without an updated and consistent information base that contains data on water potential and users, thereby validating water availability in the basin. The lack of adequate foundation work for a grant to be given can amount to the crime of authorizing investment for projects located in a watercourse that cannot support them. In addition, a refused grant may mean denying the region where the relevant watercourse is located potential social and economic improvements from the project.

Another important aspect is that there is a vast field of research for groundwater management – with which the mining sector is more closely related. Many management tools are not self-applicable to such waters, among them the grant scheme. Thus, a partnership between the granting agent and the mining sectors is suggested so that a number of the technical deficiencies for proper management of groundwater can be overcome.

Accordingly, it should be pointed out that this is an area where the mining industry has a major contribution to make, because knowledge of groundwater is normally a requirement for the mining activity, either as an input in the production process or the need to perform drainage of the mine to ensure continued operations. It is currently well known that major mining companies are likely to be the holders of the very best knowledge in the country on core hydrogeology, the correlation between surface water and groundwater and also the impacts of local and regional mining projects on the regional water balance. Special mention in this regard should be made of the central region of Minas Gerais – a major iron mining site –, which today is one of the most well-known sites in the country in terms of water supplies, thanks to the geological and hydrogeological surveys conducted by industry.

Likewise, there is still a vast field of research and studies to validate the grant for the release of effluents for which discussion and development the mining sector can contribute. For example, the tailings dams are multiple systems for waste disposal, water catchment and recycling (reuse), as well as effluent treatment systems.

Another highlight is the operation of underground reservoirs. A commonplace fact in countries with a more significant tradition and expertise in the area of hydrogeology, unlike Brazil, is that the criteria for this procedure are yet to be established in the existing granting models. Also in this front, the mining industry may participate in a pioneering fashion in determining the criteria for regulation.

Finally, it should also be emphasized that the mining activity has a peculiar water balance that must be taken into account throughout the granting process. For example, when groundwater is collected for the purpose of depletion or lowering of water levels in many ventures, this prime drinking water is made available for water bodies that supply communities, but, alternatively, this is stored in an appropriate and economically viable manner for future strategic use. Moreover, the wide variety of uses and catchments for the same enterprise nearly always means that the water will be reused.

Thus, for granting processes, use of water resources related to mining developments should be submitted to and reviewed by the granting entity as a single process, which should include and consider for its review and approval a plan for utilization of collected waters, the water balance (both surface water and groundwater) in the affected area, also considering, according to the hydrogeological and hydrological characteristics of the area under consideration and the mining operation, the possibility of increased water availability in the basin. Throughout the mining process, mainly for depletion or lowering of water levels, the plan for collected water use becomes an essential tool in the granting process for the mining activity and should include scenarios for future uses considering the mining operations over time.

Along these lines Resolution No 29 was passed on December 11, 2002 under the CNRH. This resolution provides for the granting of use rights for waters for the mining business. In this Resolution, special mention should be made of the water use plan, which is defined as:

> A document which, according to the purpose and size of the mining venture involved, describes the structures for water catchment and effluent discharge with their respective catchment or dilution volumes; uses and management of the water produced during the operation; the operation's water balance; changes in water supplies generated by mining operation in the watershed; the plans for quantitative and qualitative monitoring of the water; actions for the mitigation and offsetting of potential hydrological impacts and characteristics of systems lowering water level, if any (Art.1, Section XIV).

Art. 2 of Resolution No 29, of 2002, provides the following: "The uses of water resources related to mining operations and subject to the granting scheme are:

I. derivation or catchment of surface water or extraction of groundwater for end-user consumption or as an input to the production process;

II. discharge of effluents into water bodies;

III. other uses and interferences, such as;
- catchment of groundwater with a view to lowering water levels;
- diversion, correction and channeling of streams needed for mining exploration activities;
- damming for the settling and contention of fines in water bodies;
- damming for the normalization of the water level or flow;
- systems for the disposal of spoils and waste;
- exploitation of minerals in water bodies, and
- catchment of water and discharge of effluents associated to the transportation of mining products.

Special mention should also be made of paragraph 1 of Article 4, which states the following: "The grant shall be issued by the proper granting authority upon a single administrative act, where appropriate, for the project as a whole, based on the Water Use Plan."

Many of the uses of water resources discussed earlier, especially those relating to Section III of Resolution No 29 of the CNRH, deal with the peculiarities of the mining sector. Accordingly, the dialogue between the mining industry and the granting authorities is essential to harmonize procedures and criteria for applications and their review.

Along these lines, the National Water Resources Council approved the resolution for implementation of the Water Use Plan for the mining sector. This resolution established general guidelines for a term of reference for the preparation of this Plan, which, as reported previously, should be the master document for the review of applications for grants for mining projects.

6 CHARGING FOR WATER USE

Since the Stockholm Conference in Dublin in 1992, water has been assigned an economic value. Water being considered a natural element that is fragile and increasingly rare, the economic valuation was the path suggested by major leaders and scholars from around the world to reverse a picture of extreme poverty and shortages for millions of people. According to UN data, one third of the population in developing countries has no access to drinking water, and over the next twenty years, 2.8 billion people could be living in areas affected by chronic droughts.

Following the Dublin assumptions, as the National Water Resources Policy was enacted in Brazil through Law 9,433, an economic mechanism for the management of water resources was established: charging for water use. Since then there has been much discussion on the subject, and some segments of society are unreasonably terrified at this discussion because water is deemed to be a commodity – it is called "blue gold" of the 21st century.

As mentioned above, charging for water use is, in fact, a managerial mechanism. According to the Brazilian legislation, it has two basic objectives: stimulating its rational use and investing in the watershed generating the funds to improve the quality and quantity of its waters. In other words, the expected result from implementation of charges is that the whole society will use more carefully – avoiding wastage and the release of untreated sewage – a good that now has an economic value attached to it. With less wastage, less pollution and more investment in its maintenance, there will be water for everyone, forever.

Charging for water use as a managerial mechanism has nothing to do with fees, tariffs or taxes. Nor is it a penalty, much less a license to pollute. The purpose of a charging system is to regular use, shape habits and rectify degradations. Hence, this emerged as a tool to help comply with the constitutional principles of human dignity, reflected in ensuring access to water for all, and transactions involving funds from the fees charged for water use are not typical transactions of a financial system, but a system of social development and promotion.

Two elements of the Brazilian legal system are essential for permanently steering clear of considering the charging for water use as a tool that could lead to the development of a water market or transform it into a commodity. First, according to our Constitution, and as noted earlier, water is a public good. As such, its use must be authorized by the State through a granting system. In other words, any direct use of a water body – whether surface or underground water – except for negligible uses, shall be duly authorized by the competent public authority. Secondly, according to Law 9,433, of 1997, charging for water use is a determination of the respective river basin committees, which are decision-making bodies made up of various representatives in the surrounding area of a basin to establish a local policy of use, control and protection of its waters. In other words: amounts, charging criteria and application are determined by all segments of the society that are directly concerned, which are represented in these committees. Thus, charging for water use, rather than a management mechanism, is a gesture of environmental responsibility.

One can conclude, then, that a charging system can only be implemented based on the will and action of the user community. The normative text is explicit in this matter by assigning the committees the power to "establish mechanisms for charging for water use and suggest the amounts to be charged." The jurisdiction of committees to manage these mechanisms is without doubt the greatest challenge that the National Water Resources Policy brought about to civil society, and the mining sector has an important role to play in the development of this through its active and responsible participation in pursuing the sustainable management of water resources.

Indeed, once a charging system for water use in the basin of Paraíba do Sul River was implemented, as determined by the Committee for the Integration of the Paraíba do Sul Basin (CEIVAP), it was immediately clear that having a systematic procedure for the use of proceeds from fees charged for water use that were in line with the national financial system was a paramount challenge. This system is very complex and involves very conservative operational principles, which hinders the effectiveness of a river basin or water agency, a private organization selected by the relevant committee to administer the proceeds from the user fees, and act as the manager and allocator of the proceeds in the relevant river basin.

Along these lines, the Brazilian Mining Association (IBRAM) and other segments of users co-sponsored two workshops on this topic, with the support of public institutions belonging to the National Water Resources Management System, and following an initiative by the National Water Resources Council's Technical Collection Chamber (CTCOB / CNRH), in which IBRAM has effective participation. Based on these workshops and in conjunction with a number of other initiatives by the CTCOB, which resulted in very objective submissions by CNRH, the Executive Branch submitted a provisional measure to regulate the procedures for a charging system, which culminated with Law No 10,881, of June 9, 2004.

This law provides for the management contracts between the National Water Agency and entities that take on water agency duties regarding the management of water resources belonging to the Central Government and other matters. It is a major step forward for the implementation of a charging system across the national territory, as it facilitates and regulates the transfer of public funds to a private entity for it to make use of the money as determined by the relevant river basin committee. The coming into force of this law reinforces the assumption that the proposition and implementation of a river basin (or water) agency model that can effectively act as an agent for the investment and allocation of the proceeds from fees in a river basin are prerequisites for a charging system to be put in place.

The amount to be charged for water use should be scaled according to programs and projects to be developed in the river basin, which are directly associated to users' ability to pay the statutory fee, thus reflecting an optimized equation for water management in a basin, which results in achievable goals over a given period of time. All of this makes up the respective Water Resources Plans (Articles 21 and 22 of Law No 9433, of 1997). Thus, the charging system materializes as a management tool, rather than a collection tool, since the general rule for the amounts to be charged for water use must be defined according to the relevant water resources plans of a basin and approved by the corresponding committees.

For the mining sector, this is the right strategy because the fee will be associated with a chart of specific targets that are agreed on for the basin, i.e., the motivation for the charging system is explicit and will most likely be accepted by all users. Another important aspect that is highlighted by the mining sector is that, as a management tool, the charging system should cover all users (except for those who make negligible uses of water), taking into account their ability to pay and considering the exact intervention in the parameters of quality, quantity and water regime of the water body based on status preceding the intervention. In other words: users pay a fee that is commensurate with their actual uses and interventions. Compensatory mechanisms when a user makes interventions that result in improved parameters should also be considered. In fact, it is essential that these references consolidate mechanisms that encourage positive inputs.

Finally, it should be emphasized, quoting Professor Aldo Rebouças, that:

> The act of granting and charging for the right to use water, far from being a mere bureaucratic function of self-assertion, creates a definition of responsibility. In other words, the grantor, or the entity stipulating the charge, takes over the responsibility for ensuring the quality and quantity of water that has been granted and charged for. This means that this entity should have in-depth knowledge of the good being granted/charged for – surface and groundwater regimes, their supplies available and quality characteristics – both within the relevant watershed and over time.
>
> International experiences, argues Professor Rebouças, demonstrate that the granting process and charge for the use of water – whether surface or underground water – means radically changing the institutional and business autocratic culture. In other words, the entity responsible for granting and charging is not an entity that merely approves or rejects applications and charges for water use, but it should be prepared to take responsibility for its actions.
>
> The teacher concludes that, in view of these features, the grant and charge for the right to use water should inevitably be considered as a whole in terms of a global reality.

7 INFORMATION SYSTEM ON WATER RESOURCES

As mentioned earlier, the Information System on Water Resources is a fundamental management tool for the correct application of all other instruments. This system includes the collection, treatment, storage and recovery of all water resource-related information and factors for their sound management. This system should also include studies, analyses and prognostic assessments aimed at supporting actions for planning and prevention of conflicts of uses and minimize negative social and economic effects arising from adverse water events. Also, this system should be designed so that it can accommodate in an integrated and convergent manner all information generated by the members of SINGREH, so design of the Information System involves compliance with the two basic principles of water resources management contained in Law No. 9,433: decentralization and participation. Thus, for its proper operation decentralized approaches for obtaining and generating information and easy methods of access to the entire community in a watershed should be designed, taking into consideration a plural society comprised of both complete laymen and several resources water practitioners.

In fact, true social participation in water management is only possible through information – and therefore knowledge. Thus, to ensure effective social participation, all stakeholders must have equal opportunities to put forward and reject justifications, and all justifications must be submitted to free review by everyone, and none of the stakeholders should suffer any coercion. In other words, information must be the foundation for the establishment of equal opportunities and an indispensable tool so that there is no coercion of those who "know" over those who "do not know". Thus, the Information System on Water Resources emerges as a tool that is capable of providing all communities in a river basin with the knowledge necessary for their effective participation, and it is a mechanism for the integration and sustainability of decentralized management.

Hence, it is important to develop a National Integrated Water Resources Information System which, in a coordinated and concerted fashion with all the actors of SINGREH, is capable of standardizing incoming and outgoing data, database and relational system architectures, and especially to establish mechanisms for ongoing maintenance and updating. The National Integrated Water Resources Information System should therefore have a computerized structure that is capable of handling information to be shared with all entities that comprise the SINGREH, thus allowing easy and transparent access to all users and communities involved in water resources management. The availability of this computerized system is a key aspect for the decentralized entities of SINGREH, which take up responsibility for water management in accordance with Law No. 9,433. It should be noted that the development of an information system such as the one described above and its implementation require training activities and capacity building of the technical staff of the entities under SINGREH and also of the users of the system. It also calls for an assessment of the existing information systems, identification and search for solutions and development of an adequate technical architecture that includes the specification and the definition of high-speed networks, search tool software programs and servers for various services. With these definitions, this system can be implemented using metadata as a means of integrating information systems, can be delivered via the Intranet and Internet, thus fulfilling its mission of a fundamental tool for the implementation of all other management tools, can be an instrument for effective social participation in the management of water resources and can be a mechanism for integration of decentralized management.

With regard to mining activities, it is worth emphasizing, once again, the lack of locational alternatives. This makes it even more important to implement an Information System as the one discussed above in order to make available all the planned water resources interventions for mining activities and their relationships in the same area with other sectors of water users, especially those prioritized by the legislation: human supply and watering of livestock.

8 FINAL REMARKS

The integrated analysis of all management tools leads to the conclusion that the National Water Resources Policy is essentially grounded on planning actions. In other words, instead of regulation and control actions – i.e., command and control actions – the management of water resources, as envisaged in Law No. 9,433, is founded on principles of coordination, negotiation, relentless pursuit of consensus towards the achievement of a social agreement among all public and private, social and economic actors in a watershed, and this social agreement is embodied in the Water Resources Plan, which concretely translates dreams into consolidated pacts. Based on the classification of bodies of water – where a definition is provided of a river that belongs to a society, the river that this very society can have in a given period of time until it achieves the desired river –, the Plan outlines goals and policies with direct implications in the application of grants and charging for the use of water resources.

According to IBRAM's publication Modelo Nacional de Gestão de Recursos Hídricos – A Posição do Setor Mineral (National Model for Water Resources Management – The Stance of the Mining Sector) and according to technical and legal concepts and interpretations of instruments for water resources management presented here, the following points are to be stressed. The granting instrument is a response to the issue of water availability in the basin, under analysis, for authorization or refusal of the requested use at a given location of a particular body of water belonging to it. It is a management tool that seeks to establish parameters for planned and rational use of water, considering its seasonal variation, specific times of abundance or scarcity, and for the solution of conflicts of use. The grant is therefore the primary tool to evaluate the actual status of the watershed in terms of its water potential. By registering granted uses, it is possible to know the capacity of the river basin to support the desired development.

Experience in the application of this instrument, especially when related to mining, shows that there is a vast field of research for groundwater management – with which the mining sector is more closely related.

It should also be pointed out that granting the right to use water for the mining industry should be considered within a global context, taking into account regional water balances, both at present and in the future, so that in the granting process the uses of water resources related to mining projects are referred to a granting agent and reviewed by it as a single process.

With regard to charging for water use, this is a management tool whose financial resources are an economic support that is essential to maintenance of the National Water Resources Management System, established by Law No. 9,433, which is based on the principles of decentralized and participatory management. Hence, as a management tool, charging for water use is complex to enforce, and it should not in any way look like an additional tax or fee, i.e., a collection model. Water use fees should not be a punishment mechanism, and they should be agreed on with users as a condominium system for which charging stems from a social agreement.

Upon implementation of the management tools in river basins where mining is an existing or potential business, especially for the preparation of the river basin plan and implementation of the classification system, the emphasis is on the mining sector's locational constraint.

The Information System on Water Resources supports the entire National Water Resources Management System and the management tools mentioned above.

Indeed, information not only is essential for the correct application of the granting scheme, definition of the classification system, preparation of the Plan, and the fair implementation of water use charges, it is the communicative solution for conflicts, and thus the only possible source for the development of solidarity, the basis for the National Water Resources Policy and backed by the principle of participation.

Photo: Olivier Boels

THE MINING SECTOR AND WATER USE IN MINING AND ORE PROCESSING OPERATIONS

CHAPTER 4

Photo: Ecotrópica

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1 INTRODUCTION

The mining industry stands out from all other water-using sectors for its significant interaction with surface and underground water resources. This interaction requires careful attention, considering the intrinsic characteristics of the mining business, such as locational constraint and yet irreplaceable character of most of the minerals for the maintenance of quality of life, considering that water is indispensable to life. Thus, its use in mining operations should be based on the principles of efficient administration, in compliance with the tenets of multiple and sustainable use expressed in Law No. 9,433, of January 8, 1997. In this context, increasingly demanding legislation on water use and effluent control bring about the need for more research and development for new mining technologies and new design techniques for ore processing facilities.

Most minerals used by society have a low added value, so the use of technology and control of the cost of inputs become key requirements to ensure economic viability of mining operations. From this perspective, water as a major input in the mining sector stands out for its relative availability and its unique chemical and physical properties. Hence, although the mining sector is not as water-intensive as other industries such as agriculture, water availability is a basic requirement for mineral processing, and it is a key factor for the location of an ore processing plant. Therefore, reliable and adequate supply of water, as well as its storage and transportation, are critical for mineral processing. Though seemingly elementary, this is an issue that cannot be overlooked by mining practitioners.

Depending on the specifics of each stage of mineral production, uses of, or interferences with, water prove to be diverse and require methods and technologies that are sometimes complex. It is in the pursuit

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of improving mining techniques and manufacturing steps that lies the potential for optimizing use and minimizing interferences with water resources by the various mining projects. In this context, for example, reuse, recycling and water recirculation are being increasingly considered for the sake of sustainability since water scarcity at local or regional level, the need to abide by legal requirements for water management and the cost of paying for water use will have a direct impact on the mining production.

As a result, from the second half of the 1970s on, when discussions on environmental issues became widespread, the mining industry has sought to boost studies related to environmental management, with a focus on water resources. It should be pointed out, however, that there are few technical records that could serve as inputs for a broader assessment on water management promoted by the industry.

This chapter provides considerations about the use of, and interference with, water at different stages of mining operations, from inception to closure.

2 SOURCES OF WATER USED IN MINING OPERATIONS

Knowledge on the source of water has become increasingly important, in particular the nature of the sources that supply water to mining operations, primarily groundwater and surface water sources, and the so-called waters for reuse.

Additionally, water from tailings ponds, spacers, filtering operations, etc. is recycled in concentration plants and contributes to reduce consumption in this process.

The sources of water for use in mining projects are studied in order to investigate ways of lowering costs. Nowadays there have been more and more cases where treatments are required prior to the use of water in the concentration process. When this occurs, there can be many causes:

- the locally sourced water is hard, and the concentration of ions derived from the dissociation of minerals can have a negative impact on the process;
- the seawater supplied to a plant generally lacks treatment;
- fresh water contains significant portions of suspended matter, especially clayey material.

2.1 SURFACE WATER SOURCES

These cover water from dams or large reservoirs, water courses, lakes, etc. These are the most appropriate waters for processing in general due to its accessibility and because they are free from significant contamination that affects the performance of processes, notably the flotation process. However, the possible need for pretreatment, its scarcity, the production cost, and environmental constraints limit its use, thus encouraging the search for alternatives, particularly recycled water.

2.2 UNDERGROUND WATER SOURCES

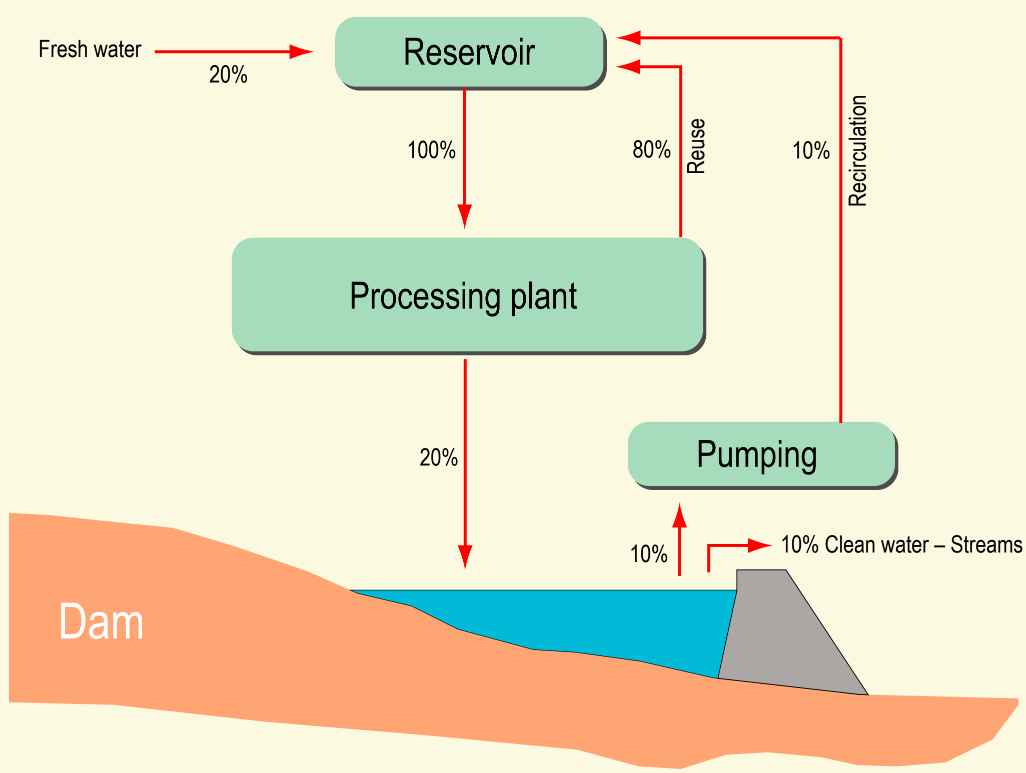
Underground waters are used most often where its supply is relatively abundant and surface water is scarce or there are environmental restrictions on the use of surface water. The various forms of provision (network of wells, galleries, canals, drains, sumps) can make their production cost higher compared to surface water. However, when aquifers need to be drained for mining operations to be performed (lowering of the groundwater), its use is almost always more advantageous. Depending on the nature of the aquifer, there are cases where hard water affects the performance of the process, particularly the flotation process. In such cases, treatments prior to its use in the processing of ores are required.

2.3 RECYCLED AND RECIRCULATED WATER

The most common sources are the reservoirs of tailings dams or those resulting from the process of dewatering by filtration, screening, and thickening (see Figure 14). The correlation between the amount of fresh water and reused/recycled/recirculated water varies from case to case. The ideal situation is the so-called zero discharge, i.e., optimization of the recycling process makes it possible to reuse all of the water already used. In the case of iron ore, for example, the volume of reused water comes to as much as 80%. The use of such water is on the rise for a number of reasons, including the following:

- The cost of obtaining fresh water in view of water supplies in the process.
- The nature of the process, which makes it easier to reuse this water.
- Environmental control, which regulates the quality of effluents being released.

3 WATER USE BY



Source: MBR

Figure 14. Water recirculation system for iron mining operations

THE MINING INDUSTRY

Considering that the mining business has unique uses and consumption of water that can lead to changes in the quantity and quality of existing of water bodies, the National Water Resources Council adopted Resolution No 29, of December 11, 2002. Article 2 of this resolution lists uses and interferences in water resources by the mining sector which are subject to the granting process as previously mentioned and discussed in Chapter 3:

I. derivation or catchment of surface water or extraction of groundwater for end-user consumption or as an input to the production process;
II. discharge of effluents into water bodies.
III. other uses and interferences, such as:
   - catchment of groundwater with a view to lowering water levels;
   - diversion, correction and channeling of streams needed for mining research activities;
   - damming for the settling and contention of fines in water bodies;
   - damming for the normalization of the water level or flow;
   - systems for the disposal of spoils and waste;
   - exploitation of minerals in water bodies, and
   - catchment of water and discharge of effluents associated to the transportation of mining products.

These uses and interferences listed in CNRH Resolution No. 29, of 2002 will be discussed below for the mining and mineral processing stages.

4 WATER USE IN MINING OPERATIONS

The interference of mining operations with water resources starts once the project begins, when surface drainage can be modified due to morphological changes occurring on the ground. As mining activities are performed, water to be used arises from the catchment of surface watercourses, reservoirs of dams or groundwater catchment. At this stage, water blasting procedures can be used to spray lanes and squares to control dust emission (see Photo 8 – a and b), washing of equipment (see Photo 9 – a and b), and the transportation of materials. In most cases, water requirements at this stage are much smaller than requirements for ore

Photo 8 (a and b). Water used to control dust emission.
Source: MBR

Photo 9 (a and b). Water used to wash equipment
Source: MBR

processing.

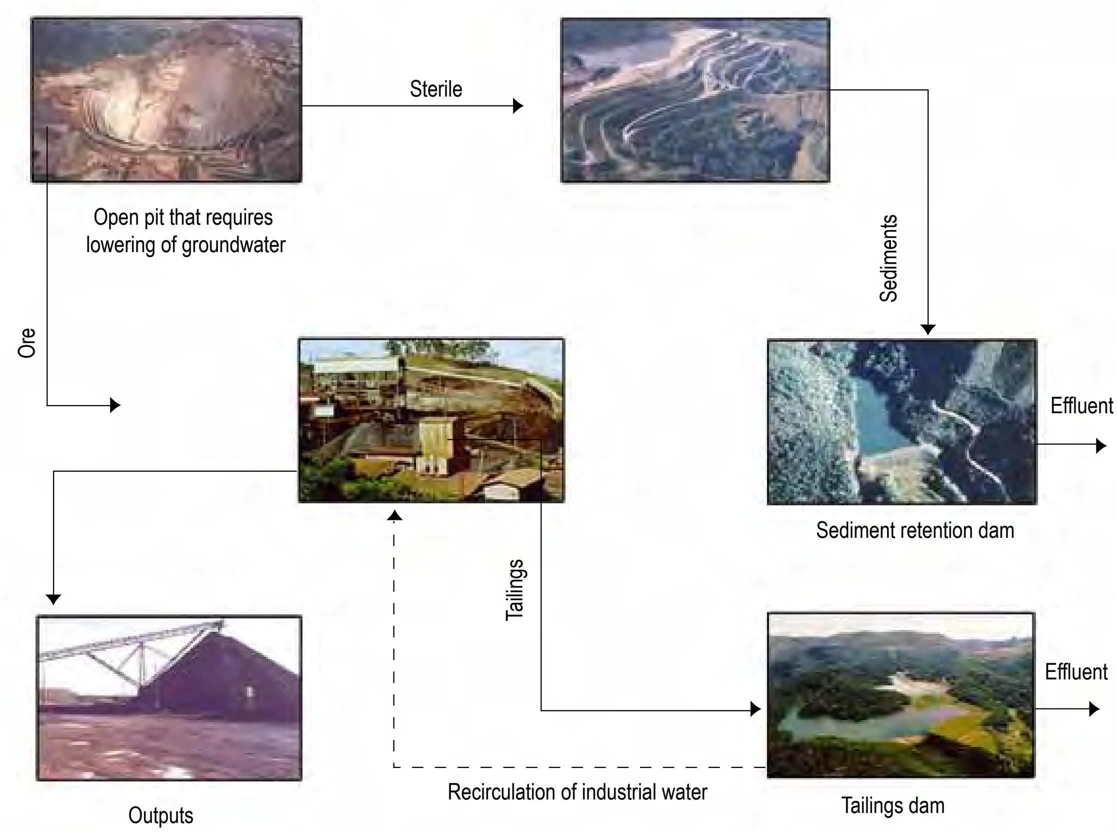
When water blasting is employed, water pressure is used to break down the ore and convey it to the processing site.

According to Luz (1998), kaolin mines in Devon and Cornwall, England, use the water-blasting open pit mining approach, during which a pre-concentration procedure is conducted to minimize excessive handling of sterile materials. The resulting kaolin in the form of pulp is collected through a gravitational process in a pit and pumped to the processing plant.

In Brazil, Mineração Hori, in the municipality of Mogi Guaçu, Sao Paulo, also uses the water blasting method to extract kaolin. The blasting of alluvial gold and cassiterite ore in the Amazon is an example of this mining method in practice.

There are cases where water is used only as a means of transport, i.e., it conveys the ore to the processing plant. This water use is common during the stage of mineral processing to move semi-finished or finished products between various processing plants and shipping sites.

The most significant water-related interferences that occur during performance of mining activities include construction of dams and dumps for the disposal of sterile materials and the lowering of groundwater levels.



Source: MBR

Figure 15. Shows the flowchart for the main stages of a mining operation and their influence on water resources in iron ore mines

Photo 10 (a, b, c). Dams in mining sites (Source: MBR).

4.1 DAMS

Dams (Photo 10 – a, b, c) are an important structure in a mining venture and are usually built for operation during all phases of mining and mineral processing.

Sediment retention dams are built to contain sediments carried during the rainy season with a view to ensuring the quality of final effluents. In general, these dams are located downstream of operational areas and tailings dumps, and they have been recently called "green dams" due to their primary function.

Tailings dams are intended to form the accumulation basis for the waste generated at ore processing plants and the accumulation of water to be reused in the industrial process. These dams are built in valleys downstream of mining operations and are usually supposed to retain sediments (fines).

Dams are usually built with homogeneous earth that is temporarily taken from areas within or adjacent to the future reservoir. These are residual soils that are duly prepared (compacted, moisture-corrected, etc.) to ensure safety and effectiveness of the project.

Methods of water outputting (effluents) from the reservoir of the dam include drainage through weirs and, in cases of massive percolations through the bulk of the dam or its foundation, via drains, consisting of stones-to-hand enveloped in granular materials suitable for ensuring water drainage.

As an additional safety measure to ensure that the downstream slope remains water-free and to avoid internal erosion, vertical drains are usually built (draining walls) to intersect the line of infiltration, conveying it to the mat drainage and the standing drain (see Photo 11).

The reservoir (lake) is built according to the requirements associated to accumulation of tailings and/or sediments for a certain period of time.

As this period is about to end, the accumulation capacity must be increased through dam elevations.

Photo 11. Water drainage through an internal drain in the bulk of the dam.
Source: MBR

The efficiency of dams as systems capable of ensuring maintenance and preservation of the quality of downstream water bodies, which are fed by their effluents can be measured for example by the quality of the water that runs through its weirs (Photo 12).

Photo 12. Disposal of dam effluents through a weir.
Source: MBR

4.2 WASTE DUMPS

Waste dumps are set up near the mining pit and they are used for the disposal of sterile matter, i.e., non-ore materials, which must be removed to allow for ore extraction.

According to engineering parameters, waste dumps can be set up in any type of relief, and the main interference in relation to water resources is associated to alterations of the runoff, which might generate minor water deviations depending on size and shape (see Photo 13).

When the dump is built in valleys or depressions, it is essential to identify all water springs that will be buried. From an environmental standpoint, the springs should be preserved, and in terms of the dump's safety, catchment and conveyance of water should be effective and efficient.

Photo 13. Waste dump under construction downstream from the mine pit. Source: MBR

Figure 16 shows the construction of an internal drain for a dump to capture a water spring, and Photo 14 shows the outflow of an internal drainage in a completed dump.

4.3 LOWERING OF

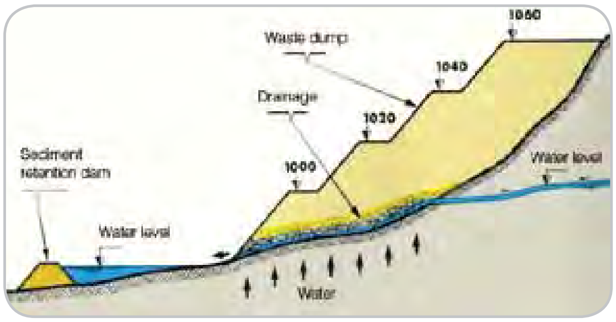


Figure 16. Internal drainage of a water dump (MBR)

Photo 14. Water outflow through internal drainage of a dump. Source: MBR

UNDERGROUND WATER

Groundwater exploitation for open-pit or underground mining can involve high and even prohibitive costs for ore extraction, especially when a water pumping and distribution system involving high-scale drainage operations is required. Issues[7] in mining operations involving water either in open-pit or underground mining include:

- jammed excavation and transportation equipment;
- increased transportation costs due to wet soils;
- increased blasting costs as a result of special explosives;
- increased costs associated to road and excavation site maintenance;
- shorter truck tire life off the road;
- delayed production;
- accident hazard from energized cables;
- unhealthy working environment as the result of high humidity levels;
- unstable slopes, reliefs and galleries cause injury and property damage risks;
- potential floods that could shut down entrances;
- increased costs of investment in special equipment.

In view of all this, a drawdown of groundwater

[7] Since ancient times, man has encountered groundwater in mines, and history shows that this was one of the main difficulties in the performance of mining operations. A typical example of this is known in the so-called Quadrilátero Ferrífero (Iron Quadrangle), when the Englishmen abandoned the underground mines of gold associated with iron formation because they were unable to work under the water level (e.g.: Maquiné Mine).

is often performed in mining operations. This drawdown is performed both in open-pit and underground mines by exploiting water from an aquifer in excess of its recharge capacity (removal of water from natural aquifers), which causes this level to lower.

There are different ways of draining this water, for example by pumping through deep tubular wells (see Photo 15), pumping water collected in sumps, galleries, sub-horizontal drains, trenches (see Photo 16), and even a combination of these various methods.

As the lowering of groundwater levels interferes directly with the hydrogeological properties of an aquifer being drained, it must be extremely effective in order to allow for continued mining activities, and it must be extremely well scaled so that its impact is minimized while preserving the ecological conditions that are dependent on this system.

Photo 15. Underground water pumping through a deep tubular well.
Source: MBR

Photo 16. Trench digging for drainage and water conveyance to mine sumps.
Source: MBR

> According to A. C.
> Bertachini, some mines come to pumping huge amounts of groundwater – around billions (109) of cubic meters per year. Considering a demand of 300 liters per capita daily, a billion cubic meters per year corresponds to the consumption of a city of 9 million inhabitants, which is far beyond the water consumed by the mining industry itself. In the mining context, this surplus is used in various ways – public supply, irrigation, industrial applications, etc. Whenever this is the case, the impacts on water resources generated from mining projects are minimized. In certain situations, the hydrological impacts are positive and the mine's drainage system becomes a tool for integrated water resources management.

As an additional warning with regard to the need to use adequate techniques for the water lowering process, it is noteworthy that, due to the large amount of water generated by this process, it is necessary to distribute it through several drainage procedures or water mains, or even the construction of dams to regulate flows in order to avoid an excessive intake of water which drainage could cause significant erosion.

Regarding the quality of water generated in the lowering process (e.g. in the case of saline, brackish or acidic water), it is necessary to treat this water in reservoirs of dams so that it can be released in rivers. When high quality water is drained, surface waters are cleansed, and it may be used to supplement the supply of urban areas.

When groundwater levels are depleted, water flows in springs associated to the aquifer may be reduced and, as a result, drainage flows may go down, which could be mitigated by using the water withdrawn through the lowering process.

Another potential problem may occur, particularly in karstic areas or sedimentary sand deposits: ground subsidence and craters could form due to the sapping of underground caves.

> According to Bertachini,
> the right tool to scale the impacts on groundwater resources is the numerical modeling for underground water flows in aquifers. Once this model has been duly calibrated, in addition to planning the lowering process, one can predict impacts on springs, wells and other groundwater catchment areas. In regions covered with groundwater aquifers, the modeling also makes it possible to predict the area in which the lowering is likely to have an impact on phreatophyte species that depend on groundwater.
>
> According to Sobreiro (2002), studies on the lowering process have evolved and, in conjunction with the experience gained over the last two decades, they serve as inputs for an array of papers and activities, both to fulfill the needs of mining operations and to meet the requirements of environmental and water agencies.

In general, according to the author, the procedures employed in iron mining projects to lower water levels can be summarized as follows:

Lowering Project

- Establishment of a geological model.
- Hydrography and inventory of springs.
- Development and implementation of a monitoring network.
- Water monitoring program and operation.
- Establishment of a conceptual hydrogeological model.
- Development and implementation of a lowering system.
- Modeling: analytical methods and numerical models.
- Water resources management plan and definition of mitigation measures.

Water Lowering System Operation (Extraction phase)

- Groundwater Lowering System Operation.
- Systematic Monitoring for re-evaluations of the methodology and recalibrations of the hydrogeological model.

Decommissioning of the Water Lowering System

- Deactivation of the water lowering system.
- Monitoring of the recovery of groundwater levels.
- Formation of lakes in the depleted pits.

Upon discontinuation of the mining operation, once the life of the mine comes to an end, accumulation of water inside the depleted pits could cause large lakes to form, and these will most often become major sources of aquifer recharge. If well managed, these lakes could become reservoirs of water for multiple uses.

An example of the transformation of a mining pit in a water reservoir as the aquifer is recharged is the Águas Claras Mine, by MBR (included in a case study discussed in Chapter 5 of this book), located in Nova Lima, Minas Gerais. Its pit will allow for the accumulation of about 60 million cubic meters of water for various uses, especially human supply in the metropolitan region of Belo Horizonte. In this case, the groundwater level was lowered by about 275 meters, and once the pumping was discontinued, in 2000, it has recovered by approximately 100 meters, which is an indication that it is possible to revert the lowering process. (Photos 17, 18 and 19).

Finally, in underground mining deactivation of the drainage system (drainage) for groundwater allows for the flooding of galleries and entry points to the mine. The flooded galleries Passagem de Mariana's gold mine were converted into diving sites.

Photo 17. Águas Claras Mine pit in 2000.
Source: MBR

Photo 18. Águas Claras Mine pit in 2003.
Source: MBR

Photo 19. Águas Claras Mine pit in 2005.
Source: MBR

Thus, the lowering of water levels should be perceived as an intrinsic procedure to the mineral extraction process, thus requiring studies and accurate techniques for its performance. It should be conducted in such a manner to comply with principles of water resources management; it poses additional difficulties to the mining business, and thus may result in an extraordinary event – increased availability of a prime product, i.e., excellent quality water. If managed properly, underground water for lowering of the water in the pits can both be used as an input during the mining and processing stages as it can be released into downstream drainages. In both cases, an increase in water supply to the mining project environment occurs.

Photo 20. Passagem de Mariana Gold Mine, Minas Gerais

5 WATER USE FOR MINERAL PROCESSING

As mentioned earlier, water is essential for most mineral processing operations. It is used across the board in mineral processing plants that employ wet separation processes (gravitational, magnetic, flotation, flocculation, spherical agglomeration, leaching, and so forth). Moreover, modern processing plants increasingly require high quality water and water/ore ratios ranging from 0.4 to 20 m^3/t.

Its availability is a basic requirement in mineral processing, and it is a critical factor for the decision on where to set up the processing plant. Reliable and adequate supply of water, as well as its storage and transportation, are critical for mineral processing.

Another relevant factor in setting up an ore processing plant is related to the basin for the disposal of tailings. The legislation on water use and effluent control is increasingly demanding, and they significantly foster a new concept for mining ventures.

In most mineral processing plants, water is recovered in filters, thickeners or tailings ponds and reused to minimize operating costs, reduce the amount of effluents released into the environment and, in some cases, recover reagents. Reusing water significantly reduces the need for fresh water in the plant, and it minimizes catchment costs.

Water usage in mining operations involves significant figures. As far as flotation is concerned, one should bear in mind that the total water used comes to 85% of the amount of ore pulp/water ratio (LeVay, 2001). In the flotation of iron ore at Samarco, for example, about 3.80 m3 of water per ton of ore are used, and 6.0 m3 of water per ton of ore produced; only 6% is fresh water, the remainder being recirculated water.

In special cases of fresh water scarcity, highly saline water and even seawater is used. An example would be the copper mine in Batu Hijau, Indonesia.

The special interest in water quality control in the processing of ore – especially in flotation, control and treatment of aqueous effluents released into the environment – has prompted the development of methods for monitoring parameters such as suspended solids, Eh and pH variations, reaction and dissolution of minerals, residual reactants and their interactions with ore constituents.

The requirements for water quality parameters are related to the physical and chemical characteristics that are consistent with the desired use. Therefore, just like the water supplied to households is different from the water used in industrial environments, agriculture, etc., the same holds true for the mining sector. In this industry, water is used as a medium in which concentration procedures occur, and its quality can have a significant impact on the efficiency of processes. In this respect, the water used in flotation differs from the water used in gravitational separation, in dense media, washing and settling processes, leaching, and so on.

Water quality parameters for use in mineral processing applications are based on the results of laboratory and pilot research. Such studies provide water quality parameters as well as parameters for the water to be released into the environment, which must comply with the environmental regulations in force. Often times, tolerable or beneficial water quality parameters are yet little known in the industrial operation of a plant because it is difficult to be replicated in a laboratory and/pilot plant. In these cases, only after the industrial plant has been in operation for about a year or more can one learn about the interactions between different types of ores, as well as the effect of their compositions or blends in the plant feeding process. Meanwhile, the water available to the operation goes through known seasonal cycles, and it takes time for it to reach the necessary balance conditions.

5.1 WATER FOR THE FLOTATION PROCESS

Flotation is a superficial physicochemical process to separate minerals, which causes an aggregate to form – mineral particles and air bubbles – which floats in the form of foam in an aqueous medium. The affinity of the mineral particles with air bubbles is usually induced by chemical reagents called "collectors". Also important in this process are reagents of other types, such as foams, depressants, activators, and pH modifiers. All of these reagents are soluble in water at varying levels. The solids and flotation reagents both have an impact on and are impacted by water quality. Thus, the chemical composition of water is a parameter for flotation control. Water, for example, may have high ion concentration because of partial or total dissolution of the minerals that make up the pulp. Basic examples include carbonate minerals, phosphates, sulphides and chlorides, among others, which cause significant changes in the ionic concentration of water as a result of their dissolution. This holds true both for fresh water and for recycled water, the latter coming from thickeners and tailings disposal ponds, where it is stored for long periods. Additionally, water recirculation with flotation reagents causes these reagents to accumulate, which has an impact on the response of the ore to this concentration process. Other impacts may be caused by organic and inorganic compounds (especially Ca2 + and Mg2 + ions, expressed as hardness), as well as suspended solids. The causes are:

- formation of complexes between metals and ions of collectors, both dissolved in the aqueous medium, which reduces or eliminates the collecting effect of these ions;
- presence of certain cations in the aqueous medium, which can result in the activation of gangue minerals, making them floatable;
- control of the dissolution rate for several collectors, thus inhibiting their adsorption capacity on the surfaces of minerals.

The difference in the response of certain minerals to flotation can be significant – particularly through the cleaning stages – when one compares the results of tests using pure water against the water found on the project's current or future (if this is a new project) site, recycled water, contaminated water or water containing suspended solids. It is important that a prior evaluation of process performance is carried out by means of specific tests with water from the site where it will be caught, with a simulation of the recirculation and other potential impacts. In some cases, it is possible to mitigate the detrimental effect of water recirculation; this will be addressed later. There are also indications that the use of recirculated water can bring benefits such as reduction of flotation reactives, especially foams. Photo 21 shows the mechanical and column flotation cells, with the tailings dam in the background, and with foams in the flotation column on the left.

Photo 21. Mechanical and column flotation cells on the right, with the tailings dam in the background, and with foams in the flotation column on the left, Sossego copper plant/mine, CVRD.

5.2 WATER FOR CLEANING PROCESSES

The cleaning processes consist of ore processing steps that require large amounts of water. Most often, the water does not require a strict quality control procedure, depending on the final product to be obtained. In the case of some industrial minerals, however, parameters involving whiteness are prevalent as a control requirement, and make the monitoring of washing water quality more critical. In such cases, this is performed not only with clean or clear water, but also with a chemical composition that is suitable for the process. The chemical constituents contained in water can react with the surface of minerals in the suspended mineral/water blend, thus changing their physical and chemical properties on the surface and may compromise their industrial application, such as the whiteness and brightness of kaolin.

5.3 WATER FOR GRAVITY CONCENTRATION PROCESSES

Designing a gravity concentration circuit requires a detailed analysis of the water balance, and of the optimum pulp density for the individual operations. Therefore, to ensure the operation is successful, water balance parameters should be studied in detail in the pilot plant, where the solid/water ratio should be known for each step in the circuit. One should bear in mind that the percentage of solids in the Reichert cones is 55% -60%, 20% -25% on vibrating tables, and 7% -10% in the Bartles-Mozley separators. These devices are very sensitive to variations in quantity and, to a lesser extent, in water quality.

Unless the plant has a large supply of fresh water without any environmental restrictions, a significant amount of water will be required for recycling. For gravity concentration, just like for washing, it is easier to recycle the water because of low requirements regarding its quality since chemical constraints are tolerable. This is a remarkable opportunity to use the zero water discharge approach. In most cases, the clear water containing few suspended solids meets the requirements of the process, except where parameters like whiteness of the final products are required. This is very common in the processing of industrial minerals.

5.4 WATER IN HYDROMETALLURGICAL PROCESSES

Typical hydrometallurgical processes involve dissolution reactions of the relevant metal in an acid medium, where copper and nickel are produced through dissolution with a sulphuric acid solution or dissolution in an alkaline medium, such as production of alumina from digestion of a concentrated solution of caustic soda. These operations can be performed under normal pressure and temperature or in autoclaves, under high temperatures and pressures. In general, this step is followed by solid-liquid separation operations, which are designed to separate the aqueous phase containing the dissolved metal (liquor) from the solid waste. At this stage, thickeners are used (often in several counter-current steps) and filters. The solids are disposed of, for example, in tailings ponds, and every care must be taken to mitigate the potential environmental impacts. The liquor obtained, which contains the relevant element or elements, goes on to the steps of obtaining the metal. The purpose of the solvent-based extraction, which is commonplace in copper, uranium and nickel plants, is to remove other metals that were dissolved in leaching and which would affect subsequent stages.

In general, the final metal is obtained by means of electrowinning or precipitation in the form of an oxide, hydroxide, sulphide or salt. The water used in the processes above is largely recycled in order to reduce consumption of fresh water and reagents. In case of disposal, pretreatment is often required since metal ions or non neutral pH is frequently the case. In cases of acid effluents containing metallic ions, lime or limestone is commonly added in order to achieve pH values where the metals are precipitated as a hydroxide or oxide. Effluent disposal must comply with legal discharge standards.

5.5 WATER IN PYROMETALLURGICAL PROCESSES

According to Ciminelli et al (2005), pyrometallurgical processes use water indirectly for cooling equipment, such as in blast furnaces, the towers for gas washing, etc., or directly during the steps of steel rolling and drawing, or during the pickling step. In the latter, the water is used in an acidic solution for surface cleaning, and is contaminated with heavy metal ions and iron. Water consumption figures range from 100 to 200 m3/t in steel production. Approximately 3-5% of the total amount consumed must be replenished with fresh water, the remainder being recycled. Considering that Brazil produces 30 million tons of crude steel per year (www.ibs.org.br, 2005), significant amounts of water are consumed in this activity. These authors argue, however, that the main source of chemical contamination in steelmaking processes is the carbochemical sector. In this domain, emissions containing ammonia, cyanides and phenols must undergo biological and chemical treatments prior to disposal.

5.6 WATER AS A MEANS OF TRANSPORT

Water is the primary means of transport in mineral processing. Thus, water is used intensively as a means of transport in various operations, such as water blasting in mining operations, ore washing and wet concentration processes. In this particular case, in addition to a means of transport, water plays a direct role in the separation and/or concentration of minerals. There are cases, however, where water is used only as a means of transport, such as ore pipelines. In this case, viscosity, the percentage of solids and other rheological characteristics of the pulp are among the many factors that influence the transport of ore.

This type of transport has been used in Brazilian mining since the 1970s with the ore pipeline of SAMARCO (this case study discussed in Chapter 5). The pipeline is 396 kilometer long, and it connects the mine in Mariana, Minas Gerais, to the plant in Ponta de Ubu, near the city of Guarapari, on the coast of Espírito Santo (www.samarco.com.br, 2005). In 2004, some 15 million tons of pulp containing 70% solids were transported, which accounts for 6 million m3/year of water. There are other pipelines in the phosphate mines in Minas Gerais and in the kaolin mines in Pará.

CVRD is now building the first pipeline in the world for the transportation of bauxite ore, which will be 244 kilometer long. The start-up is planned for 2007. The pipeline will connect the bauxite mine in the town of Paragominas to Barcarena, which are both in the state of Pará. SAMARCO is also planning for duplication of the pipeline between Mariana, Minas Gerais, and Guarapari, Espírito Santo. As a result, Brazil's ore pipelines will come to 1,600 kilometers in total.

6 MINING EFFLUENTS

Effluents from mining operations and ore processing units cannot be released into rivers or lakes. Effluents are cloudy in appearance, and most of them contain small, dispersed particles with little capacity to sedimentation; their cloudy nature is one of the greatest challenges for their treatment (FENG, 2004). Furthermore, such effluents can contain salts and synthetic organic compounds, usually flotation reagents that can potentially harm the flora and fauna. For this reason, these flows are treated before disposal in order to achieve the quality required by the environmental legislation.

As far as effluents from mining projects are concerned, acid drainage is one of the most harmful for the environment. Acid mine drainage (AMD) occurs when large quantities of tailings and/or sterile sulphides are exposed to weather at the surface, thus producing sulphuric acid, which in turn solubilizes some minerals. AMD cases are of particular concern when minerals containing heavy metals like lead, zinc, copper, arsenic, selenium, mercury, and cadmium, which are highly toxic elements in general. These ions do not generally interact with the biological cycle of living beings; they are stored and, consequently, their concentration is enhanced in the living tissues that make up the food chain of the ecosystem. Naturally occurring bacteria found in minerals can act as catalysts by accelerating the development of acids, and this process is amplified in hot and humid climates. The generation of acids can last for decades, centuries or longer. There have been reports of old mines that continue to generate acids even 2000 years after the discontinuation of their operations (GLOBBO E PEREIRA, 2004). If the resulting effluents reach water courses, they may have an negative impact on areas that are hundreds of miles away from the mining site. Besides the negative impact on the food chain and human beings, heavy metals reduce the self-purifying capacity of the water because of the toxic effect they have on microorganisms, which are responsible for recovery of the water by decomposing organic compounds from effluents (AGUIAR, 2002).

The minerals that pose the highest risk of generating acid drainage are those that contain high amounts of pyrite or pyrrhotite and small amounts of neutralizing minerals such as limestone, dolomite and some silicates. This is common for gold, silver, copper, zinc, lead, uranium, and coal ores, and it is virtually impossible to be reversed with the existing technologies. An example of this in Brazil is the coal mines in Santa Catarina and the uranium mines in Poços de Caldas, Minas Gerais.

According to Pereira and Globbo (2004), management of acid mine drainage can be conducted in two ways: a corrective action according to the control, collection and treatment of the acidic effluents generated once they occur, or a preventative treatment through detailed studies of the potential occurrence of this event during the project's development stage. Before exposure of rocks to the weather, the corrective method is practically the only solution. Once the process starts, lime or carbonates are added, which leads to precipitation of heavy metals at high pH. Its cost is usually very high. A successful preventive method depends on the ability to predict the formation, extent and impact of this phenomenon before mining operations and the process start. This knowledge allows for pre-planning of tailings disposal procedures and, even with AMD, it makes it possible to determine the best way of retaining and treating the resulting effluents. Several methods have been studied for predicting AMD. These methods fall into two categories: static and kinetic. Pereira and Globbo (2004) describe the various methods available. The static tests are typically conducted at bench-scale and their primary purpose is to examine the balance between acid-generating components (e.g., pyrite) and acid-consuming components (carbonates, silicates) from representative samples of all rock types in the deposit. These tests are so named because they do not take into account the relationship between production rates and consumption of acid, and their main objective is to provide a preliminary notion of the potential generation of acid from the material under study. Among the several existing methods, special mention should be made of the ABA standard (Standard Acid Base Accounting Procedure for Neutralization Potential), the modified ABA, the NAG test (Net Acid Generation), and the Sobek Neutralization Potential Method.

Although there are several methods, the static tests follow the same principle – determining the acid/base balance. The ability of a sample to consume acid is called neutralization potential or NP, and the potential to generate acid is called acid potential or AP. These two quantities should be expressed in comparable and consistent units. The difference between the neutralization potential and the acid potential is called net neutralization potential or NNP (NNP = NP – AP). If the NNP is positive, it means that the sample has the potential to consume acid.

For some researchers, however, a mere comparison is not enough. According to Ferguson and Roberts (2004), quoted by Pereira and Globbo (2004), only when NP/AP is greater than 2 can it be said that acid is not generated. Other researchers argue for an NP/AP that is greater than 3.

Kinetic tests are necessary when static tests indicate that there is a potential for generating acid drainage or when the tests are not conclusive. These tests simulate the actual conditions of effluent formation, which, on a larger scale, require more time than the static tests. Over a period of a few months, environmental conditions to which the material is subjected during years of exposure are emulated in order to simulate the passing of days and nights and the various seasons. In general, they make it possible to confirm the potential for acid mine drainage, to assess the oxidation rates of sulphur and the ability to neutralize the effect of bacteria and, ultimately, control planning and strategies and management of tailings disposal.

Among the main methods for predicting acid drainage, the most common are humidity cells and lysimeters. Photo 22 illustrates the acid mine drainage study laboratory in Rio Paracatu Mineração.

Another major environmental impact of mining effluents are cyanide ions used in the leaching

Photo 22. AMD laboratory with lysimeters in Rio Paracatu Mineração

of gold and silver ores. These ions are harmful to the fauna because they bind strongly to metal ions in living matter, e.g., the iron in haemoglobins, preventing it from transporting oxygen to the cells of organisms during the cellular respiration process. Several cases of fish mortality have been reported at concentrations above 0.1 ppm (RUBIO and TESSELE, 2004). Another contaminant that is often found in gold- and silver-mining effluents are arsenic ions, a consequence of dissolution of minerals such as arsenopyrite which usually contained in these minerals. Arsenic and arsenic compounds are known to be toxic and carcinogenic to all living beings, especially to trivalent species. The lethal dose for humans is considered to be around 0.6 mg/kg per day. However, continued exposure to trace amounts of this element can cause irreversible damage, such as skin diseases, vascular diseases, neurological disorders, and cancer. Ciminelli et al (2005) report studies on gold-mining effluents in Minas Gerais, an activity that resulted in high levels of arsenic, especially in areas near the towns of Santa Barbara, Barão de Cocais and Nova Lima. In some collection sites in these regions, concentrations of 1,000 mg/kg of soil and up to 547 mg/kg of sediments have been found. These high content levels occur because of geological anomalies involving arsenopyrite, which are aggravated by the large amount of waste from those mines. It has been found, however, that the concentration of arsenic in drainage from tailings dumps is much higher than that in neighboring groundwater. This natural purification process is accounted for by the adsorption capacity of clay minerals and iron oxides, which are abundant in the Iron Quadrangle region, or even by the reaction of As3 + ions with ferrous ions and arsenites as the solution moves to more oxidizing environments. These natural phenomena are also used in the remediation process.

Another example of an environmental impact of mining effluents is the reaction of calcium and magnesium ions, which are sometimes found in high concentrations in uranium mines. They cause this element to dissociate and, consequently, the effluents' toxicity increases. The flotation reagents may be considered as agents that have an impact on the environment, for example reagents resulting from:

- reverse flotation of iron ore, where amines and fatty acids are used;
- flotation of phosphates or xanthates and foams in the case of copper mineral flotation

Rubio and Tessele (2004) list the main reagents used in mineral processing plants that may be contaminants in aqueous effluents. The toxicity of these reagents varies, ranging from very toxic, such as thiol collectors (e.g., xanthates), sulphonates and amines; moderate, such as most foams; and non-toxic, such as starch. Another example of mining-generated pollutant emissions into the water are suspended solids, which sometimes are colloidal solids. In the case of coal, liquid effluents generated are known as black water, and it contains oils and various ions, in addition to fines and ultrafines.

Most mining effluents are disposed of in tailings ponds. In general, there is a significant loss of deposited water, either by the effect of evaporation, especially in the semi-arid region, or by losses from infiltration into the soil, which is the single major factor for environmental contamination. The water evaporation rate in these tailings ponds is used as a factor for calculating the water balance in concentration plants. The weather conditions in the individual regions are taken as the basis for this index.

During sedimentation procedures, when reagents are used for coagulation or flocculation, recycled water or discharge flows may contain trace amounts of reagents for copper, zinc, and cyanide ions, in most cases as complex, soluble salts of fatty acids (in the case of alkaline waters) or soluble amine salts, among others.

If this water is recycled in the flotation process, studies at laboratory and/or pilot scale are needed to determine the effects of water on the performance of the process. If kaolin is involved, one must check whether there is an impact on its whiteness. However, the quality of effluents released into the environment is even more important. Existing treatment processes are diverse and have varied efficiency. The scientific and technological development in this front presents a challenging picture, making it necessary for various research institutions to collaborate, better training of human resources to be delivered, existing processes to be optimized, and new technologies to be sought (RUBIO and TESSELE, 2004). The mining industry must seek to follow the strictest quality standards in order to preserve human health and the habitat in which we live.

7 WATER REUSE BY THE MINING INDUSTRY

7.1 RECYCLED WATER

In general, the return of raw materials to the production cycle is called recycling, although this term is commonly used to denote the set of associated operations. In most cases, the recycled output is completely different from the original inputs. The term was coined in the 1970s, when environmental concerns began to be treated more rigorously, especially after the oil crisis, when recycling became strategically important.

Brazil recycles large quantities of waste, but wastes significant amounts of recoverable raw materials, especially water, which is usually disposed of as an environmental liability, particularly in rivers and springs.

In the mining industry, recycled water is the water either returned to production after treatment or not and whose physical and chemical properties are suitable for the process. In operating plants that employ modern workflows, the recycling step includes water from thickeners, recovery systems, tailings ponds, among others. Some mines, in addition to having adequate tailings ponds, are located close to the concentration plant, thus making the recycling process easier after proper settling.

In thickening operations, it is necessary to use coagulants and flocculants to increase the rate of sedimentation of solids, promote the clarification of water and reduce the size of thickeners. Thus, the physical and chemical properties of the water from the thickeners should be fit for use in the process. The pH and Eh values for the water are the simplest and most basic control parameters, yet this is not the only check.

Recycled water with chemical and physical properties consistent with the process is commonly obtained in modern plants in order to ensure control of the operation. Indeed, water recycling procedures vary widely depending on the type of ore involved. However, the following factors are generally taken into account:

- limited availability of fresh water because of the location of the plant or due to environmental constraints;
- high water treatment costs to return it to the environment;
- reduced operating costs from the recovery of residual reagents;
- potential cost reduction for the pumping of fresh water from long distances;
- removal of residual solids from the water, which is the most frequently used process in Brazil;
- compliance with legal requirements for the environment.

7.2 RECYCLED WATER QUALITY

Water recycling in mineral processing does not differ from water recycling in other applications, considering the characteristics of individual applications. Therefore, the results of previous studies in laboratory and pilot units determine water standards at the plant. Once the additional studies at industrial scale are completed, then the process optimization step is finished during the early years of operation. Recycled water in an industrial plant has significant differences from the recycled water in the pilot plant. Reasons for this include the following:

- in commercial unit applications, it remains for a longer period in the thickeners than in studies at a pilot scale;
- the recycled water in industrial plants often comes from a tailings dam, whose environmental and chemical conditions have not been studied at a pilot scale;
- the fresh water used in the pilot plant is different from the one in the industrial plant, and therefore the recycled water has physical and chemical properties that are equally distinct.

As a result, unexpected events occur in industrial operations, which require appropriate knowledge on the mineralogical constituents dissolved in water and how they interfere with the process. Therefore, monitoring of the recycled water and also the fresh water is recommended.

Fresh or recycled water quality is defined according to operational requirements, the reagent system, and the definition of quality depends on the individual applications. The relevant water quality parameters are those that have a beneficial or harmful effect on the operation. This is why understanding these parameters is paramount, i.e., such parameters should be defined in detail.

Sound knowledge of water chemistry and the elements contained in it is indispensable for treatment procedures of both the fresh and recycled water. Standardized analytical procedures are available for the determination of chemical parameters; however, these methods are continually tailored to specific situations and/or plant conditions. The chemical composition of water varies continuously throughout the duration of the operation, and requires an ongoing chemical analysis system to better monitor these variations. A database on the chemical composition of water should be put together during the pilot-scale studies, as well as at the beginning of the industrial operation. This procedure is valuable for adjusting and controlling the water supply system in every concentration plant while maintaining the operational stability of the process.

8 EFFLUENT TREATMENT PROCESSES

Selection of an effluent treatment system generated by any human activity, including mining, depends on the following:

- the characteristics of the effluent, the predominant form of the pollutant, its biodegradability, presence of toxic organic and inorganic compounds;
- the required effluent quality after treatment (in accordance with the legislation in force);
- operating cost of the process for the compliance with legal requirements.

Generally, each effluent treatment plant follows three steps, with different methods to define the overall process. The steps are: primary, secondary and tertiary (see Figure 17). Some authors add two more steps – a preliminary treatment before the primary step, for removal of constituents that interfere with the subsequent steps, and a step for treating the resulting solid residue, which is called sludge.

The primary treatment is used in most effluent treatment plants to remove dispersed solids, oils and fats. The separation of solids occurs in grids and through various processes such as disintegration, equalization, flocculation, sedimentation, and flotation.

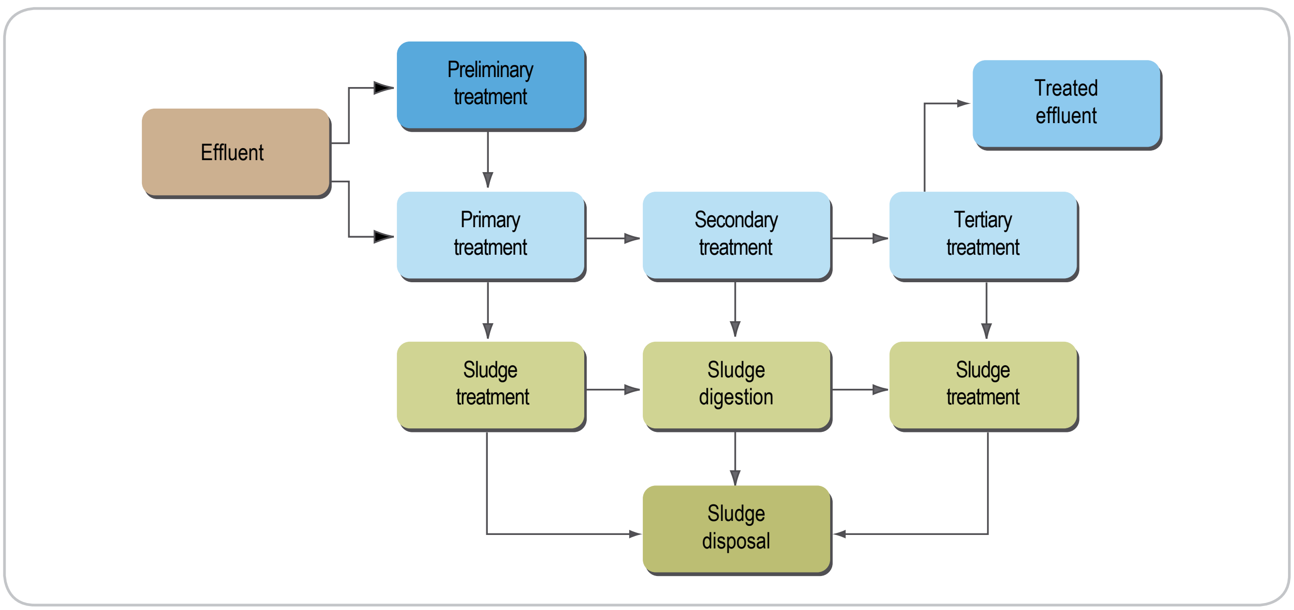


Figure 17. Flowchart for a traditional effluent treatment system

During the secondary or biological treatment step, metabolism of microorganisms is used to transform contaminants of effluents into harmless substances. In traditional effluent treatment plants, biological processes used to be restricted to the degradation of dissolved organic and colloidal compounds; oxidation of nitrogen from ammonia in nitrites and nitrates; conversion of nitrates into gaseous nitrogen; removal of phosphorus compounds; and stabilization of organic sludge. With biotechnological advancements, however, biological treatments are also applied to insoluble organic compounds and compounds that are harder to degrade, inorganic constituents and metallic ions (AKCIL, 2003).

Tertiary treatments involve physical and chemical operations for removing specific types of pollutants, including microfiltration operations, adsorption (mostly with granular activated carbon), reverse osmosis, ion flotation, advanced oxidation, electrowinning, etc.

8.1 PRIMARY TREATMENT

The primary treatment or clarification is probably the oldest water purification process. It is generally based on a solid-liquid separation step to reduce the cloudiness of the effluents. Suspended solids in effluents are removed through plain sedimentation, coagulation sedimentation, flotation, and dehydration. The plain sedimentation process is used to remove from water coarse gravel, fine gravel, coarse sand, medium sand, fine sand, extra fine sand and silt, depending on the duration of sedimentation. However, the clay requires coagulant or flocculating agents, since the formation of colloids (<2.0 μm), i.e., small particles dispersed in water, make sedimentation difficult and make the effluent cloudy.

Flocculation is the step where small and colloidal particles are aggregated, which is of great importance to increase the efficiency of the solid-liquid separation process, involving sedimentation, dissolved air flotation, and filtration processes. In the mining sector, the most commonly used flocculants are polymers, which cause fine particles to aggregate in the form of flakes. Flocculants are natural, modified or synthetic, have low or high molecular weight, and are neutral, anionic or cationic. The efficiency of flocculation depends on the choice of flocculant, the application method, the chemical environment, the hydrodynamic system, and the size of the particles. Coagulation requires addition of chemicals and controlled agitation (up to a critical value in order not to break the flakes) to neutralize the colloidal charges and form and the flakes for easy removal.

The most widely used flocculants in the mining business are polyacrylamides, poly(oxide)ethylene, polyacrylic and its salts (mainly polyacrylamides) and polyethyleneimine (BALTAR, 2004).

Clarification of the liquid medium can be obtained through sedimentation or dissolved air flotation. As far as sedimentation is concerned, because of gravity, the suspended particles have a downward movement in the liquid medium of lower density, while flotation involves rising suspended particles and adherence of microbubbles of air, giving them lower density than the environment where they are (BERNARDO, 2003). Air bubbles are generated by a sudden reduction of pressure in the saturated liquid stream of air from a saturator (see Photo 23), where a compressor feeds air into a

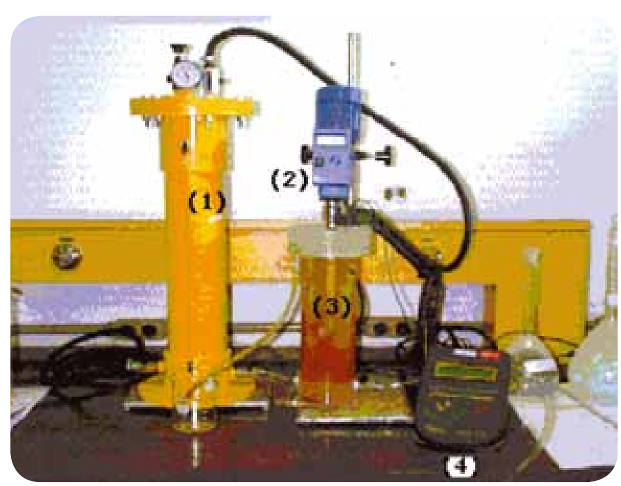


Photo 23. Bench-based dissolved air flotation unit. (1) Saturator, (2) mechanical stirrer, (3) flotation cell, V = 2, 0 L, (4) pH meter

tank at 4 to 5.5 atm, and a sharp decrease in pressure generates microbubbles of air, after they stick to the flakes, which rise and accumulate on the surface of the effluent. This is shown in the bench experiment illustrated in Photo 24. According to Costanzi (2002), who carried out experiments to compare flotation-based sedimentation with a view to reducing cloudiness of effluents in a paper mill, the dissolved air flotation is more efficient than using operating plants covering smaller areas.

Photo 24. (a) Start of dissolved air flotation, with the addition of saturated water at the base of the tank, (b) End of flotation and discontinuation of saturated water feed, and (c) treated water at the completion of the experiment

In sedimentation processes, removal of solid particles contained in the effluents is prompted by the gravitational field, which makes the process inexpensive and operationally simple. Generally, the sediments are classified in thickeners, with high solid content (the relevant output is the solid matter) and clarifiers (the relevant output is the liquid), with low solid content (FRANÇA, 2004). In ore processing plants, thickeners are traditionally used for water recovery (industrial recycling) and thickening of tailings with high concentrations of solids in order to make transport and disposal more effective (see Photo 25).

Photo 25. Thickening of flotation tailings in an ore processing plant

Dehydration is the final process to obtain sludge with the lowest humidity content possible for the disposal of solid waste at appropriate locations in effluent treatment plants. The various dehydration devices include: Drainage presses, centrifuges, filter presses, and rotary vacuum filters. The filter press was the first equipment used to dehydrate sludge from coagulated effluents. The chamber filter press (see Photo 26) was the first system to produce the pie residues with high solid content of solid and suitable for direct disposal in industrial landfills

Photo 26. Filter press to produce pie residues with high solid content

8.2 SECONDARY TREATMENT

The main types of processes used in conventional treatment plants are suspended-growth aerobic systems (activated sludge, aerated lagoons); aerobic fixed-film systems (biological filters and biodisk); combined systems (biological filter and activated sludge or activated sludge and biological filter); suspended-growth anaerobic systems (anaerobic digestion, anaerobic lagoons and suspended denitrification); anaerobic fixed-film systems (anaerobic filter and fixed-film denitrification); and the systems that associate aerobic metabolisms with anaerobic metabolisms (facultative lagoons). Although the individual systems use specific microorganisms for each type of contaminant, the most commonly used one is activated sludge (its treatment steps are illustrated in Figure 18), which consists of the production of an activated mass of microorganisms, some of which is recirculated to the aeration tank and mixed with the effluent in order to stabilize the organic matter in the tank. Because they are denser than water, microorganism cells are separated from the liquid in the settling tank and some of it is recirculated and mixed with the effluent at the entrance of the aeration tank.

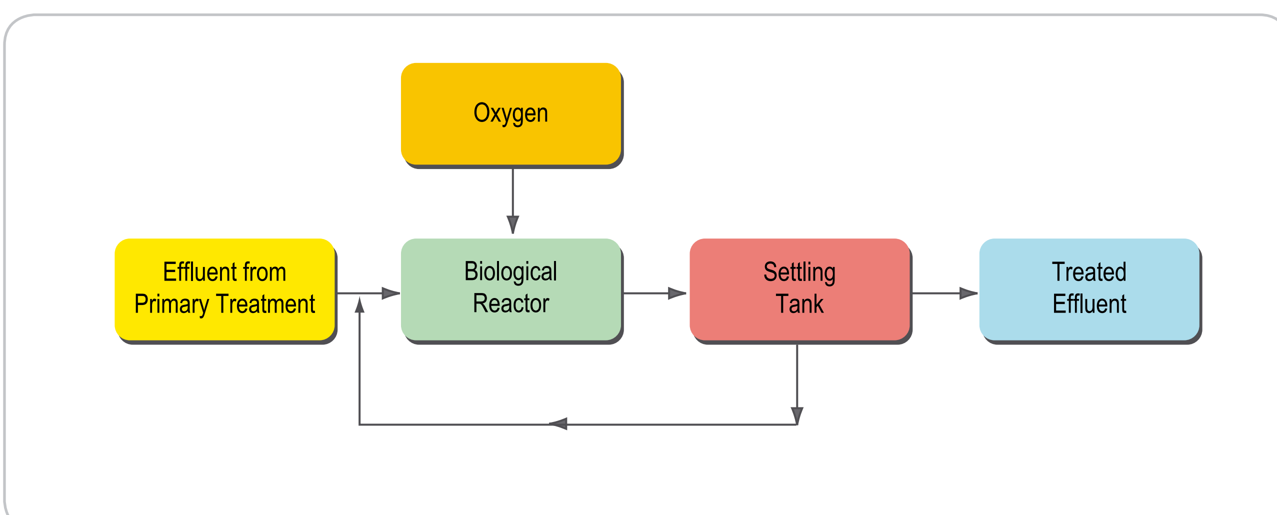


Figure 18. Workflow for the conventional activated sludge process

Generally, under the aerated system the organic matter associated with oxygen becomes carbon dioxide and water; the ammonia in the effluents turns into nitrites and nitrates, and under anaerobic conditions the organic matter is converted into methane and carbon dioxide. In this context, a sequence of anaerobic and aerobic reactors with activated sludge is often used to remove a combination of compounds from the effluent, such as nitrogen, phosphorus and degradable organic matter, and the use of combined reactors is also expanded for removing some specific constituents such as cyanide ion, derived from the leaching of gold and silver ore.

As cyanides and thiocyanates are destroyed by microorganisms, bacteria convert these ions into carbonates, ammonia and sulphate (in the case of thiocyanate only), and the free metal is adsorbed within the biofilm. The ammonium ion produced in the degradation of cyanide can also be treated by Nitrosomonas bacteria and by nitrobacteria, and it is converted into nitrite and nitrate. Employing the Pseudomonas sp bacteria in mining effluents has proved to be efficient for the degradation of cyanide ions, competing with other chemical treatments (AKCIL, 2003).

Similarly to biological sand filters, the vertical flow mud filters containing different macrophytes are effective for treating domestic effluents and some industrial effluents. Use of these filters has been expanding with aerobic and anaerobic areas for the treatment of mine drainage effluents with low levels of copper and lead (diffuse pollution) and containing a variety of bacteria, fungi, algae, and protozoa (SCHOLZ, 2002 and 2003). In this context, use of bioremediation has been on the rise with activated sludge in low pH effluents since the traditional neutralization method can become very costly, and it can produce sludge that requires proper drying and disposal (BURGESS, 2002), but also biosorption processes for the recovery of effluents with concentrations above the acceptable standards of ions Cd2 +, Co^{2+}, Cr^{3+}, Cu^{2+}, Hg^{2+}, Ni^{2+}, Pb^{2+}; AsO_2^-; CrO_4^{2-}, MoO_4^{2-}, WO_4^{2-} (XIE, 1996).

8.3 TERTIARY TREATMENT

Tertiary treatment is sometimes applied to effluents containing specific constituents, toxic substances and recalcitrant substances, or if quality is not satisfactory after primary and/or secondary treatments are used. The various metal ions and synthetic organic compounds are removed from the effluents under chemical and physical methods or by combining these with biological methods.

The metal ions from effluents are usually recovered by precipitation, or just neutralization, especially when arising from an acid drainage. In some cases, however, it is necessary to remove complexing agents such as cyanides and ammonia, which can hinder full recovery of copper ions. It is sometimes essential that oxidation takes place prior to precipitation, such as in the case of transforming arsenite into arsenate for the recovery of arsenic. Another item to be considered is the difference between ions in solubility products, which prevents full recovery in a single pH value (FENG, 2004). This process may become unaffordable for low concentrations due to the large amount of reagents required to achieve the necessary concentration for precipitation.

In such cases, other processes are used, such as filtration through activated carbon or adsorption and ion exchange processes (usually with resins). The softening process, for example, is the traditional water treatment method for the partial or total removal of hardness, and it causes fouling in industrial equipment and/or interferes with the dissolution of ions (content of calcium and magnesium ions, almost always in the form of bicarbonate, sulphates and chlorides), uses precipitation for the recovery of calcium and magnesium ions in effluents with higher concentrations; resin-based ion exchange is used for effluents with lower concentrations.

Certain materials have sorption capacity when in contact with solutions, such as activated carbon, which is widely used for the adsorption of organic compounds, thus reducing the odor of effluents. The resin-based ion exchange process is the most commonly used when total removal of ions in water is necessary (deionization or demineralization) to make it deionized. In this process, water goes through cation resin columns (cation resins should always be first because they act as a filter and protection for anion resins) and anion resin columns separately. Alternatively, it can go through a single column that contains these two types of resins, which is called a mixed bed. Regeneration of the materials in the adsorbent columns is a key issue when the adsorbent material is expensive or when the regeneration liquids contain high levels of toxic ions, such as radioactive ions, thus requiring post-treatment for storage or disposal. In such cases, it is important to utilize the electrolytic deionization process, where the columns are continuously regenerated by an electric current that crosses the solution flow and results in less waste (FLECK, 1960).

The attraction between the surface and the adsorbed species is probably due to interactions such as hydrogen bonding, coordination reactions, covalent bonding and ionic exchange reactions, which are defined as sorption processes for the recovery of ions in effluents. It should be emphasized that the use of ion exchange resins makes the process much more costly, and this justifies sorption studies on various lower-cost materials.

Precipitation of chromium hydroxide, for example, replaces adsorption processes by allowing the removal of hexavalent chromium ions in a single step since it needs to be reduced to chromium III during precipitation. Low-cost adsorbent materials are widely studied for effluent treatment in place of activated carbon, with special mention to co-products, agricultural and industrial waste, such as natural materials, especially zeolites (MATIS, 2004; PAIVA, 2004).

The research conducted by Erdem and his associates was innovative, and they used thermally activated bauxite for adsorption of chromium ions VI for reuse in the production of alumina (Erdem, 2004). Several peatlands are also compared to inorganic materials for adsorption efficiency. The blast furnace slag has proved to have good adsorption capacity after neutralization. The adsorption processes have been associated with dissolved air flotation processes for the removal of the adsorbent material (FENG, 2004; RINGQVIST, 2002).

To retrieve a metal ion, the low-concentration co-precipitation process can also be used. Iron salts or aluminum, or calcium or lanthanum is added to the effluents with arsenic and the hydroxides are precipitated. These generate effluents at levels lower than 0.005 mg/L by dragging arsenic into the solid phase.

The copper ions are traditionally removed from the effluents by precipitation at high pH levels with sodium hydroxide. Because of the costs and time involved and the need to remove complexing agents, however, precipitation methods have been replaced by other methods, such as sorption by activated carbon and/or electrodialysis. Solvent extraction processes used for obtaining ions at high concentrations (above 2 g/L Cu) are not viable for effluent treatment, because once they become dilute solutions they require treatment to comply with environmental standards of 0.5 mg/L of copper.

Obtainment of effluents from mines and mineral processing plants can be studied by looking at dissolved air flotation, ion flotation using xanthates, flotation of copper hydroxide precipitates, and flotation of zeolite adsorbing particles (LAZARIDIS, 2004; MATIS, 2004). Induced air flotation is also used to remove fine particles, but with more compact system than dissolved air flotation, whose terminal velocity is lower and therefore requires large equipment (JAMESON, 1999). Obtainment of chromite fines was performed by means of column flotation with several collectors (FENG, 2004). Electroflotation can be applied to effluents, where electroflotation and electroflocculation take place in the cell. This is mainly used for oil and grease (CRESPILHO, 2004).

The treatments most often used for tertiary effluents containing cyanide ions are based on the oxidation of cyanide ions into cyanate. Electrochemical oxidation allows for the recovery of metals complexed by cyanide without the need to add chemical reagents, which is eventually consistent with environmental requirements (SOBRAL, 2002). Other options include molecular oxygen dissolved in high temperatures or air at high pressures, stronger oxidants such as Cl2 or ClO-, oxygen peroxide, oxygen with a copper salt catalyst, which is an electrochemical process for high concentrations, following oxidation with ClO for the residual solution (BAIRD, 2002).

Conventional effluent treatment methods are often ineffective for synthetic organic compounds, which are dissolved and at low concentration, such as trichloroethene (TCE) and tetrachloroethylene (PCE), which are both widely used industrial solvents and the most common groundwater pollutants. In this context, in order to purify effluents with extra-stable organic compounds, the so-called advanced oxidation processes (AOP) are also used. These processes are based on the generation of a hydroxyl radical (OH-) with high oxidizing potential, which can cause various polluting compounds to degrade in a short period of time. The purpose of the advanced oxidation processes is to mineralize pollutants, i.e., convert them into CO2, H2O and mineral acids, such as hydrochloric acid. Among the various processes to obtain these free radicals, use of ozone, hydrogen peroxide stands out, as well as their mixing and combination with other elements (e.g., a mixture of hydrogen peroxide and ferrous salts) (DANIEL, 2001 and BAIRD, 2002).

Generating hydroxyl free radicals in a solution is a costly process, so it is important to conduct pretreatment of effluents by removing most of organic and inorganic compounds through simpler and less costly processes so that only the most stable compounds are obtained and treated with the hydroxyl radicals. In this sense, thanks to the efficiency of POA, the number of studies aiming to develop alternative techniques to obtain these radicals at lower costs and shorter timeframes has increased. A very interesting example is provided by ceramic transducers, which generate waves in the reaction medium and accelerate the emergence of hydroxyl free radicals. These ceramics are made from piezoelectric materials (INCE, 2001).

In the tertiary treatment step, specific compounds that were not evaluated in previous steps (primary and secondary) are usually removed, such as desalination, which can be accomplished in following ways: reverse osmosis, ultrafiltration, electrodialysis, and electroplating.

The processes that use membranes, such as reverse osmosis (including reverse osmosis at very low pressure) and nanofiltration, have wide application in treatments for reuse of effluents as it enables the removal of various types of constituents, such as dissolved solids, organic carbon, inorganic ions and toxic organic compounds in trace amounts (BELLONA, 2004; INTO, 2004). Guo et al associated flocculation and adsorption processes to maintain the critical flow (GUO, 2004).

In reverse osmosis – or hyperfiltration – two solutions with different concentrations separated by porous membranes are used; pressure is exerted on the area of high concentration, directing water to the diluted solution, which increases the concentration of brine. The process is highly sensitive, involves low energy cost and is independent from the salt content in the effluent; however, the membrane should be even and allow high-speed filtration. The most widely used membrane is cellulose acetate, which is primarily treated with magnesium perchlorate, which enhances permeability. A reverse osmosis facility contains little equipment, but pre-treatment of effluents is necessary so that the solid waste involved will not damage or obstruct the membranes (BERTRÁN, 1988).

In Tutuka, South Africa, an industrial plant based on the reverse osmosis process was established for total reuse and no disposal of water from the coal mine and the cooling tower. The plant had a pre-treatment step using sand filtration to reduce organic contaminants (BUHRMANN, 1999).

Ultrafiltrations using membranes have been applied for the removal and recovery of copper, lead, iron, and manganese ions with the addition of polymeric binder (carboxymethyl cellulose) to be retained in the membrane (PETROV, 2004). Alumina ceramic membranes modified with silica (pore size equal to 100 nm) and alpha alumina (pore size equal to 10 nm) were used by Laitinen et al (2002) for removing very fine solids in suspensions of effluents from open pit mines to reduce cloudiness.

Electrodialysis also employs membranes, and it is used to decrease salinity and to prevent corrosion of equipment in mineral processing units in the case of water reuse. This process is based on the effect generated by applying a continuous electrical current throughout the effluent and an array of alternate cation and anion exchange membranes, thus causing a decrease in concentration in a given compartment and an increase in the adjacent compartment, and so on throughout the entire equipment. Electrochemistry can also be used for the recovery of metal ions in effluents since it makes electroplating in cathodes possible.

For mining effluents, sometimes disinfection may be necessary, especially in recirculation, as some microorganisms can cause corrosion of equipment in processing plants or interference with processes such as flotation. This step may use the chlorination process, which is the most frequently used and least costly. Alternatively, other disinfectant agents may be used if chlorination interferes with processing.

In summary, effluents from mines or ore processing plants may utilize treatments using only the primary and tertiary steps, i.e., the so-called physical and chemical treatments; or biological treatments only, or a combination of the physical, chemical and biological treatments.

9 MONITORING

To optimize and facilitate the monitoring of effluents, it is critical to analyze the entire process in order to determine what the potential contaminants are and then choose analysis techniques. One should bear in mind that chemical analyses of effluents involve high costs because they use instrumentation resources. Classical methods are rarely used due to their detection limitations, since the values of toxic organic and inorganic compounds are in the order of ppm or ppb.

The classical physico-chemical analyses to ascertain cloudiness or dissolved oxygen concentration, for example, need to be performed while the constituents of individual mining sites and/or processing unit may require development of specific analysis techniques to their monitoring, as well as custom methods for effluent treatment.

The water monitoring during the mining stage seeks answers about effects that can be caused by water drainage, and it is usually conducted by means of piezometers[8] or water level indicators (WLI) as follows:

- the mine pit area, the lowering of water level is checked for assessing the performance of the network of tubular wells;
- slopes in the mine, the efficiency of depressurization stimulated by horizontal or tilted drains is checked;
- in the bulks of dams and sterile dumps, the efficiency of the drains is checked.

It is important to emphasize the need for water monitoring, not only simultaneously with the mining operations, but also, in many cases, prior to this stage. According to MDGEO,

> the timing of the mining activity and the nature of the desired drainage are the factors that determine the drawdown to be held. In medium and large mines, the pre-lowering principle should always be followed, i.e., when a new bank or gallery is dug in depth, the bulk must be properly drained. If the decrease in humidn to be held. In medium and large mines, the pre-lowering principle should always be followed, i.e., when a new bank or gallery is dug in depth, the bulk must be properly drained. If the decrease in humidity is a critical factor, the drainage system requires greater anticipation because the reduction in humidity, where possible, is slower.

Both in open-pit mines and underground mines the lowering of water levels should be set depending on the progress of the mine, trying to keep a certain distance between the elevation of water level and the mine. Ideally, all changes should be made before the next rainy season starts because this is when recharge is processed and the pace of lowering decreases.

For environmental control in the mining site regarding reduction of the flow of water courses whose sources are associated with lithologies affected by pumping from wells, monitoring is accomplished both by piezometers and weirs[9] installed in waterways located in the vicinity of the mining project. In all types of monitoring associated to water inputs, either for the measurement of flows or for water levels, one should associate such values to rainfall series, whose data are obtained by reading the rain gauges located in the mining site[10] on a daily basis. Also according MDGEO Hydrogeology Services, compilation of meteorological data – mainly rainfall levels –, evaporation and air temperature, as well as regional streamflow data, are vital for defining the preliminary hydrogeologi-

[8] Piezometer - Observation well in which the water table level or piezometric height is measured (DNAEE, 1976).
[9] Weir - A device used to control and measure small flows of liquids in open channels (Batalha, 1987).
[10] Rain Gauge - An instrument with a graduated device, where the accumulation of rainwater allows one to record rainfall levels continuously for a period (modified from DNAEE, 1976).
[11] O modelo hidrogeológico deverá fornecer as condições de contorno para o modelamento numérico do aqüífero, fundamental à elaboração do projeto de rebaixamento e à previsão dos possíveis impactos sobre as águas. Todas as descargas de água subterrânea devem ser explicadas pelo modelo hidrogeológico e, caso necessário, o monitoramento das drenagens deve ser readequado para expressar as descargas das unidades hidrogeológicas presentes.

cal model[11], and it should be pointed out that to define the hydrogeological model for the mine local rainfall and hydrology data must be available. In areas where rain gauges are not available, these should be installed locally.

The hydrological data on the microbasins located in the area surrounding the mine are obtained through weirs, which will also provide insight primarily into basic flow rates, among other data.

The inventory of water points is undoubtedly the most important activity to be performed in a hydrogeological study focusing on the lowering of water levels. This is a laborious task, which consists of a systematic inventory of all water points located within the area surrounding the mining project.

The whole area should be covered and a survey of the following should be conducted: springs, sinks, natural ponds, dams, tubular wells, dug wells, monitoring wells, piezometers, drains, etc.

When surveying the water points the following should be taken into consideration:

- llocation in the field based on aerial photography or ortophotomapping;
- topography- or GPS-based location;
- name of the landowner;
- local name of the point of water;
- existing catchments, water use;
- location and access sketches;
- reference to the basin/sub-basin;
- geological scheme of springs;
- the following should be surveyed specifically for wells and piezometers: lithological and constructive profiles, drilling company, materials used, data on static and dynamic levels, flows, equipment etc;
- topography- or altimeter-based (barometric) leveling of outcropping of the water level of springs, or the benchmark for measurements of water levels in wells and piezometers;
- express checks of flows in springs and drains;
- measurements of the water level in piezometers and dug wells, with express infiltration tests;
- measurements of flows, static and dynamic levels in tubular wells in operation, with express pumping tests;
- on-site determination of air and water temperature, pH, Eh and electrical conductivity;
- compilation of data on measurements of flow, levels, physical-chemical analyses, etc.;
- photos of water points.

All drainages surrounding the relevant area should be covered, including those that have dried out.

Demarcation of the area to be inventoried should be based primarily on technical aspects such as the extent of the aquifers that could potentially be affected by a drawdown of water levels. Once the inventory is complete, tubular wells and piezometers should be selected to perform pumping and infiltration tests.

Once the inventory of water points has is complete, the next step is the development, implementation and operation of a monitoring network, which should contain the following instruments:

- piezometers and water level indicators;
- weirs for measuring the basic flow in springs and drainage network in the surrounding area;
- construction and operation of tubular wells or other drainage structure to perform the long term pumping test as needed;
- determining points and parameters for hydrochemical monitoring and water quality;
- rain gauge or weather station, as needed.

Besides the instruments to be installed in the mining site and its surrounding area, other instruments can be monitored, such as:

- stability drains for slopes in their flows;
- bottom drainage of sterile dumps;
- catchments of groundwater and surface water;
- discharges and levels of dams and natural ponds.

Deployment of the monitoring network must precede as much as possible the water level lowering operation and gathering as much data as possible prior to the drainage operation. In new mining ventures, monitoring begins even before the mine is opened.

10 FINAL REMARKS

The discussion on the use of water, its distribution, consumption, quality and preservation, etc., is not a specific aspect of the mining sector. This is a global issue that runs across the society. The wrongheaded notion that water is a renewable and abundant mineral has now been dispelled, and the word "shortage" has been in the everyday life for its users for a while now. By 2025, only 25% of humanity will have water for their basic needs. This warning by the UN shows that water resources are one of its priority concerns. In view of this, there is vivid awareness in the mining industry of the need to use this mineral in a rational manner, in perfect balance with the environment and economic development; now this awareness needs to be shared by everyone.

With regard to mining in Brazil, the practice of water treatment is limited only to the primary treatment stage for solid-liquid separation, i.e., removal of solid waste from effluents; this is comparable to the widespread use of thickeners and tailings dams as a more usual treatment step with a view to primarily increasing water recirculation. Lack of data on consumption, the source and quality of the water used in mining projects hinders a correct approach to the issue, making it necessary and urgent to conduct an accurate survey of this data by companies and public organization in the mining sector for planning, environmental control and water management in mining ventures.

The process engineers and/or researchers and specialists must have in-depth knowledge of the impacts of water and its constituents in the processes for which they are responsible. This will make it possible to establish wisely the parameters for quality control of the water to be used in mining activities, as well as that intended for disposal.

In the case of effluents from acid mine drainage, treatment promotes neutralization of acidity and precipitation as a consequence, then immobilizing the species dissolved in the sludge. Alternatively, passive treatment systems can be used since they require little or no maintenance. These systems involve a large number of natural physical, chemical and biological processes resulting from interaction between water, soil, plants, microorganisms, and atmospheres to treat effluents from acid drainage, and a bioremediation occurs.

In the mineral processing front, there are significant breakthroughs in terms of research in the fields of surface chemistry, optimization of grinding processes, concentration, etc. However, the influence of water in ore processing has received little attention from researchers, experts, managers, and entrepreneurs in the mineral sector. Existing efforts focus on the control of water quality – particularly in water reuse – simply because of the deficiency in fresh water supplies or environmental requirements. There is still a long way to go for the rational and environmentally-aware use of this mineral asset by the various mining segments.

Yet, there have been cases of operations with zero water discharge, i.e., optimization of recycling systems (LeVay, 2001).

For full recovery and reuse of water resources, developing efficient treatment systems is paramount. Fine particles and residual reagents are basic contaminants contained in effluents from the processing of various ores in Brazil. Hence, the need for processes that speed up degradation of the reactants and reduce the solids content in effluents becomes evident. Once this is achieved, it will be possible not only to reduce tailings dams in number and size, but also to improve the economic use of ore fines, thus contributing to sustainable development.

The mining sector should make an effort to tap into the technological breakthroughs over the past few years in the area of water treatment in order to become more efficient in terms of water use. It is suggested that the degradation of certain synthetic organic compounds derived from flotation units be accelerated by the advanced oxidation process, thus decreasing the time it remains in tailings ponds, and consequently the size of these.

On the uses of and interference with water resources, with regard to mining and subject to a granting scheme, as detailed in CNRH Resolution No. 29, of December 11, 2002, the following conclusion is stated in a text published by IBRAM:

> Water use in mining operations has specific features that must be understood at a global level, and when considering the water balance in the mining industry, the small amount of appropriate water resources (consumptive use) in each river basin becomes apparent.

In this context, the Water Use Plan, which was established through Resolution No. CNRH 29, of 2002, includes water balance in the affected area in its quantitative and qualitative aspects, as well as its variations over time and increased water supplies generated by the mining operation in the river basin or basins, if applicable. It should be pointed out that the drafting of this resolution was an initiative by the mining sector, thus clearly reflecting in the legal text – organization of mechanisms and proposed standardization – the intention of the sector to contribute, both in theory and in practice, for the implementation of integrated, shared and participatory management, as recommended by the existing modern set of laws in the area of water resources management.

WATER RESOURCE-MINING MANAGEMENT INTEGRATION: CASE STUDIES

CHAPTER 5

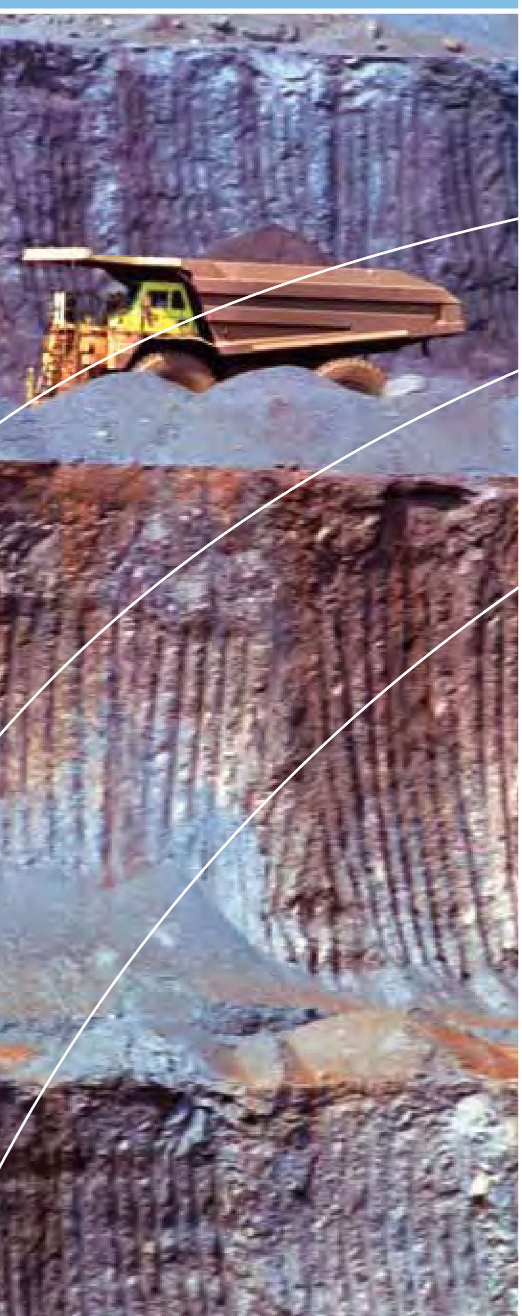


Photo: Vale do Rio Doce

FOREWORD

A popular saying goes that "theory into practice is something different." However, the nine case studies presented here not only confirm the theory of water resources management in the practice of mining, but also the possibility for this theory to be developed and improved. Nine experiences of mining entrepreneurs show that mining can be reconciled with environmental balance, especially with regard to controlling the use of and conserving water resources.

Driven by legislation, and by environmental awareness, growing ever more demanding and having as allies the development of management mechanisms and criteria and new process technologies, the mining of sand, gold, iron, marble and granite, quartzite, and nickel provide the solutions adopted in their production units that aim at addressing one of the paradoxes of modern life: reconciling development and conservation. Obviously, none of the solution discussed here fully and definitively accounts for the relationship between the two paradoxical points, because much is yet to be developed, investigated and learned for the improvement of this relationship. But the solutions undoubtedly point to development possibilities based on the mining activity with minimal environmental impacts, with emphasis on water management.

The first experience is that of the Vale do Rio Doce (CVRD), which in February 2002 implemented the corporate Water Resources Policy, establishing the CVRD Water Resources Management System (SGRH), across the entire Company. This is followed by the experience of Minerações Brasileiras Reunidas (MBR). MBR has been operating for over forty years in the headwaters of the Velhas river, Minas Gerais, and it demonstrates with facts and data that a harmonious coexistence between mining and conservation of water sources is possible to supply the metropolitan area of Belo Horizonte.

Then a description of Samarco Mineração's operations is provided. Samarco was a pioneer in the management of water resources as it established the first pipeline in Brazil for transporting iron ore slurry back in 1977. Coal mining in the state of Santa Catarina, presented by the National Mining Department (DNPM), emphasizes water management operations to minimize significant environmental liabilities and control of future interferences, with emphasis on effective community participation.

The management of water resources in the ornamental rock industry in the state of Espírito Santo focuses on delivery of solutions designed to minimize and address its main interferences with water bodies, especially regarding the generation of waste (abrasive sludge) during the cutting of marble and granite blocks. The fruitful partnership between universities and the entrepreneur community is noteworthy.

Gold mining is featured by the Rio Paracatu Mineração S/A (RPM). Company's technicians provide a brief description of the operation and the strategy for water resources management, with an emphasis on past and present corporate actions as part of its sustainable development project, for which one of the objectives is rational use of water resources.

Votorantim Metais presents the Water Management Plan for the mining of nickel sulphide, where the actions to control acid drainage are discussed. The case study on sand mining in the Paraíba do Sul river basin describes the implementation of a water use charging system within the Committee for the Integration of the Paraiba do Sul River Basin (Ceivap) with the participation of representatives from this mining segment.

Finally, a discussion is provided of the experience with environmental management and water resources of a company with operations in a small quartzite mine in the Serra do Curral area, which has been listed by the Municipality of Belo Horizonte.

It is believed that the nine case studies discussed here help achieve the ultimate goal of this book: informing and instigating research in the fields of hydrology, hydrogeology and mining, and also clarifying some issues related to mining and water resources management, with a discussion of not only the risks but the chances of a successful coexistence between the mining industry and water supplies based on the development and implementation of best management

José Roberto Centeno Cordeiro[1]

and process techniques.

MANAGEMENT OF WATER RESOURCES IN VALE DO RIO DOCE'S MINING OPERATIONS

1 INTRODUCTION

Vale was established on 1st June, 1942 to explore iron ore in Minas Gerais. Privatized on 7th May, 1997, Vale is now the transoceanic worldwide market leader in iron ore mining, the largest diversified mining company in the Americas and the largest provider of logistics services in Brazil.

Throughout its history, Vale has expanded its operations from the Brazilian Southeast to all regions in the country. The company has a broad portfolio of mineral products and has established itself as a major player in the logistics sector. Vale operates an extensive network of railways, ports, and terminals, and runs coastal shipping operations, offering a comprehensive intermodal service in the Brazilian market. It runs operations in 13 Brazilian states: Minas Gerais, Espírito Santo, Pará, Maranhão, Tocantins, Sergipe, Bahia, Rio de Janeiro, São Paulo, Goiás, Mato Grosso do Sul, Rio Grande do Sul, and Santa Catarina.

It is the second largest global producer of manganese and ferroalloys, and it also produces bauxite, potassium, kaolin, aluminum, and alumina. It owns shares in three hydroelectric plants in operation and six other plants under construction, in addition to holding interests in four steel producers.

The company has offices and operational units in the following countries around the world: United States, Belgium, Japan, Mongolia, China, France, Norway, Argentina, Peru, Chile, Venezuela, Bahrain, Gabon, Angola, South Africa, and Mozambique.

In all its ventures, Vale stands out for its commitment to technological innovation, the environment and social responsibility.

The trends in Europe prompted a discussion in Brazil on the drafting of specific legislation aimed at a better use of water resources. As a legal framework, Law No. 9,433, of January 8, 1997, was passed in the National Congress, which established the National Policy and created the National Water Resources Management System.

As one of the instruments of the Policy, the granting of rights of use of water resources was established, and "use" was defined as any interference to change the regime, quantity or quality of the water in a body of water.

Implementation of the Policy and the National Water Resources System has been accelerated in

[1] Environmental Licencing and Technical Support Manager with CVRD.

recent years because of the water deficit in 2001 in Brazil. In several regions, the water shortage for urban and rural supply has been encouraging efforts towards the creation of river basin committees.

Vale's consistent and systematic performance with regard to water use in its operating units avoids different positions in relation to the type of water use and its indispensable grant.

> The granting of water use rights is based on water availability in a specific body of water. Therefore, according to this approach, ensuring the granting of right of use means obtaining a guarantee that the water amounts required by production operations will be available.

Vale uses water in all its operations. For example, Table 1 illustrates this use, and it should be pointed out that the figures may vary according to the type of processing system and the content of natural ore concentration.

Table 1. Water consumption per ton produced

Amount of water consumption per ton produced	
Steel	250.000 L
Aluminum	1.500.000 L
Copper processing	330.000 L

The highest consumption figures refer to plants, where water is used for ore processing, cooling, spraying yards of raw materials and products, accesses, and trails, and it is also used as an input in the production process as it is added to end products. In these plants, the rate of water recycling and reuse is greater than 90%, yet the absolute figures for fresh water are significant.

Water is used for human consumption, ore transportation and washing equipment and parts; a total of 137 million m3/year are consumed in 17 operating units, which is equivalent to the average annual consumption of a city with 1.5 million inhabitants.

CVRD makes interventions in water resources that do not involve consumption in the following activities:

- lowering of water levels in mining operations, which is a necessary procedure for the extraction of ore located in saturated areas;
- dams for settling and retaining fines and tailings, which are engineering structures constructed in order to retain solids from erosion and carriage from stripped mining areas or waste dumps;
- dams for retaining tailings, which are structures in the Ore Processing System; and
- settling of waste dumps, which requires drainage of its base.

2 VALE'S WATER RESOURCE MANAGEMENT POLICY

Considering that the mining business has a significant interaction with surface and underground water resources, and the scope of CVRD's operations in Brazil (see Figure 19), the company has strengthened its commitment to environmental quality in all its operations – industrial processes and services, in particular; management of water resources according to the principles and tenets of Law No.

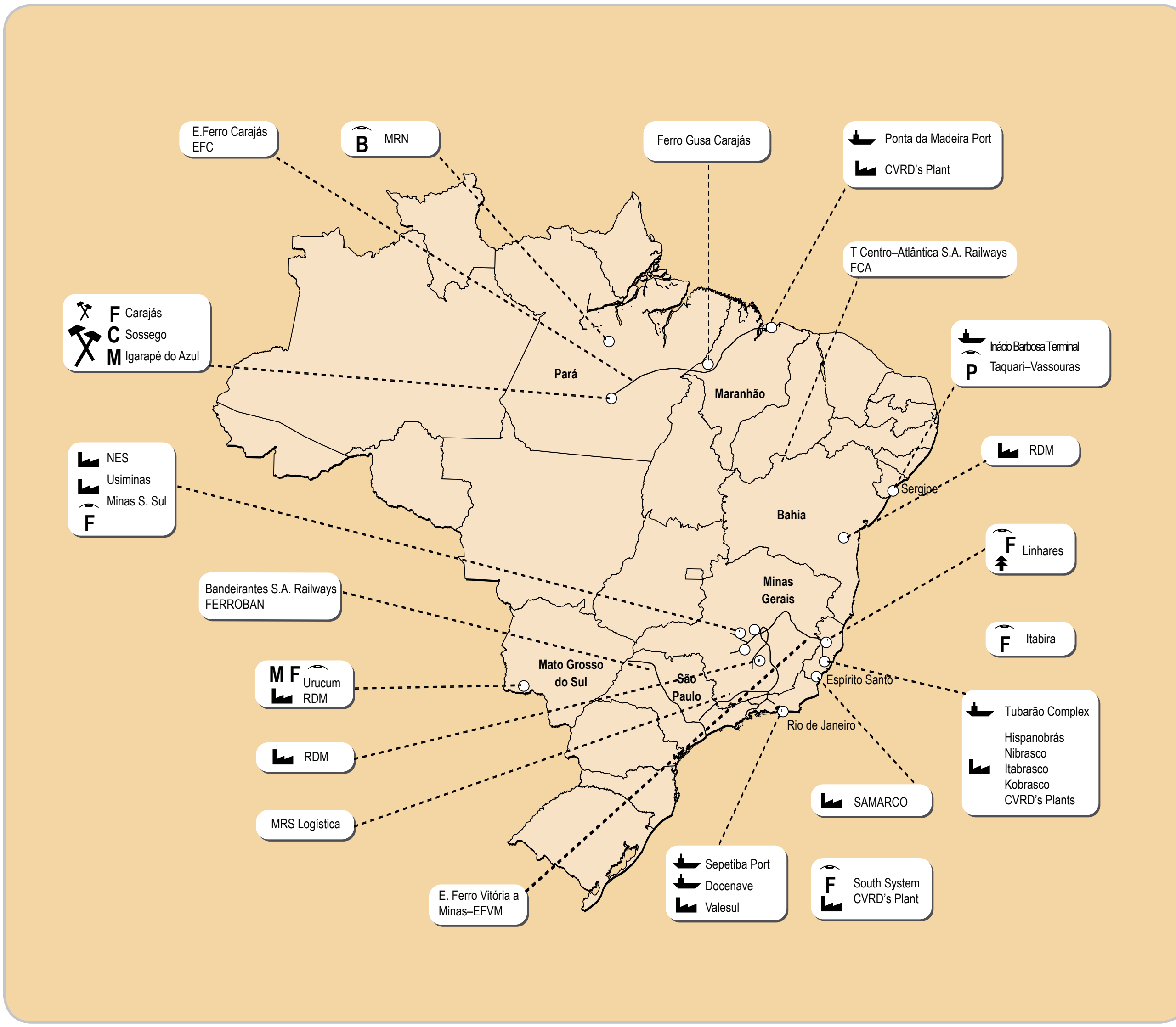


Figure 19. Chart of CVRD's operations

9,433, of 1997.

Thus, Water Resources Management (WRM) is one of the core concerns of the company. This focus is based on a unique feature of its activities – locational constraint of mining and port operations. This feature drives the need to ensure on-site water quantity and quality requirements for the individual processes in relation to ensuring multiple uses and maintaining the quantity and quality for priority uses, if any: public supply and watering of livestock. Indeed, considering that most industrial activities in CVRD require interventions in surface and ground water resources, and that in a large number of them the water serves as a vital input to the processes involved, only an effective water resource management approach may establish a sustainable use, with the assurance of multiple uses of water within Vale's operations.

In response to these considerations, the domestic environmental responsibility and legal requirements, CVRD's National Water Resources Policy (PNRH/CVRD) and implementation of CVRD's

Water Resources Management System (SGRH) were approved on February 4, 2002. The PNRH/CVRD as well as the SGRH were formally implemented in the company through a Decision of the Executive Board (DDE 0044/02).

The PNRH/CVRD and the SGRH were developed by the technical staff of the Department for Environmental and Territorial Management (DIAT), with support from specialists from the various operational units of the company.

2.1 PRINCIPLES

The PNRH/CVRD is based on the following three basic principles:

- maintaining a Water Resources Management System to ensure that its activities are carried out in compliance with the legislation; ensuring the right to use water as per the quality and quantity needed for its processes; and minimizing the impacts of charging for water use in the cost of its products and services;
- developing research and incorporating economically and technically viable technologies that allow for rationalization of water use and minimization of interferences with water resources due to operational processes;
- participating directly or through representative bodies in the various forums on the management of water resources at national, regional and local levels.

2.2 INSTRUMENTS

For the implementation of its Water Resources Management Policy, CVRD developed and consolidated management instruments with a view to facilitating consistent implementation of PNRH/CVRD throughout the national territory where Vale operates. These instruments are described below:

- CVRD Water Management Manual – this describes the requirements and establishes general and specific procedures, and it also harmonizes and contains the specific procedures for Vale's various processes, establishing the framework for implementation of SGRH in its several levels;
- CVRD Water Resources Management Plan – this harmonizes and consolidates the Water Resources Programs for the operating units and their budget proposals for its implementation and maintenance; and
- CVRD Water Resources Programs – these set the objectives, goals, deadlines, responsibilities, and proposals for the resources needed to implement actions arising from SGRH within operational units. This system is coordinated by the Department for Environmental and Territorial Management (DIAT) at corporate level.

2.3 DUTIES AND RESPONSIBILITIES

For the implementation and monitoring of PNRH/CVR, CVRD has also established a flowchart of responsibilities for its management units, thereby formalizing its commitment to implementation in all SGRH units.

a) As the corporate coordinator, it is up to the Department for Environmental and Territorial Management to:
    - establish the guidelines, general criteria and normative instructions concerning the management of water resources at CVRD;
    - implement and maintain the CVRD Water Management Manual by establishing, together with operating units, the general, particu-

lar and specific requirements and procedures;

- conduct the Preliminary Water Resources Diagnosis;
- represent CVRD with the federal agencies that make up the National Waters Resources Management System, notably the Ministry of Environment's Secretariat for Water Resources (SRH) and the National Water Agency (ANA);
- participate, either directly or through corporate entities, in the National Water Resources Council (CNRH) and its Technical Chambers;
- assist the operational units in the handling of matters in their respective state agencies when it comes to matters of a strategic nature;
- provide advice to the operational units in the respective River Basin Committee from its inception to resolution of strategic issues of the Committee, such as approval of its By-laws and the definition of specific charging criteria for the river basin;
- implement and maintain the water resources module in the CVRD Environmental Information System in order to manage relevant information;
- provide advice to operating units on the implementation and maintenance of their Water Resources Programs and keep CVRD's management and technical team informed about the management of water resources, promoting the necessary training actions;
- systematically and periodically check compliance of CVRD's water resources management with the Policy's principles and the requirements and procedures established in the manual;
- promote and coordinate, together with representatives – water managers – from each operational units in the CVRD System, actions that provide: (a) dissemination and standardization of technical information relevant for the management of water resources at CVRD; (b) interaction and integration of particular and specific procedures; (c) discussion and exchange of experiences and information to harmonize the actions related to SGRH at CVRD; and (d) identification of alternatives to maximize the opportunities for improvement and cost minimization involved.

b) It is up to operational units to:

- appoint one or more Water Representatives/Managers (GHs) and establish which of them will act as facilitators for the implementation and maintenance of CVRD's Water Resources Management System within its business unit;
- implement and maintain its Water Resources Program;
- identify, implement and sustain actions that allow for the rational use of water and the ensuing minimization of the impact of charging on the operational cost of their products and services, where economically and technically feasible;
- implement and/or maintain the Water Resources Monitoring Plan in its respective unit in order to provide inputs to water use management in their processes;
- feed and keep the Environmental Information System's water resources module up-to-date;
- represent CVRD with state and local agencies responsible for water management according to procedures established by SGRH/CVRD;
- make arrangements to obtain the relevant

preventive grants and water use rights grants, as may be necessary;

- participate and coordinate CVRD's participation in CVRD's River Basin Committee(s), under the advice of DIAT, from the inception stage;
- provide training to its employees and contractors to enable them to act in accordance with the CVRD Water Resources Policy and its instruments.

2.4 THE PNRH/CVRD IN PRACTICE

With a view to implementing the improvement actions identified by the Water Resources Diagnosis (one of the steps in the Policy) water resources commissions were created for each unit. These commissions are comprised of representatives from segments in the fields of environment, production, maintenance, services, utilities, engineering, and legal for each operating unit. All members attend a water resources training program provided by DIAT's corporate group. The purpose of a water resources training is to standardize basic concepts necessary for management, and the program includes concepts related to hydrology, hydrogeology, water use, recycling and reuse, effluent treatment, and Brazil's federal and state Water Resources Policies.

As part of CVRD's Water Resources Management Policy, internal meetings with all managers in different units of CVRD have been held three times a year since 2003. In these meetings, technical seminars are organized with in-house professionals or external experts, where the relevant issues for the management of water resources are addressed with a view to improving the training of managers. Subjects that have been covered include water resources monitoring, reuse, policy-making, and legislation.

Photo 27. A training session

3 PRELIMINARY RESULTS OF THE PNRH/CVRD

As a result of implementation of the PNRH/CVRD, CVRD carried out a Water Resources Diagnosis. The purpose of this diagnosis was to obtain the current water use scenario; profile improvement opportunities; identify the need for the preparation of studies; inform granting processes and identify interferences in the quantity, quality and regime of water bodies and check the consistency of measurements and monitoring actions. A step in the diagnosis included a survey of data concerning use of water resources was conducted, including a description of the water workflow: collection, conveyance, distribution, reservation, consumption, recycling, reuse, treatment, and release in all its operating units from August 2002 to March 2004. Figure 20 shows water use in each of CVRD's operating units as the result for the diagnosis.

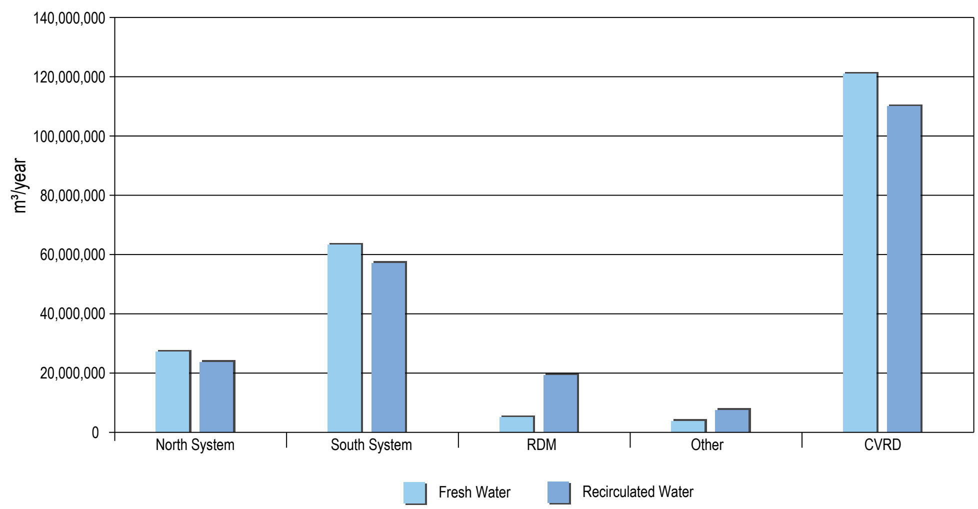


Figure 20. Diagnosis of water use in each of CVRD's operating units

These data show that CVRD recycle 80% of the total water consumed in its operating units.

For the development of the diagnosis, two specialist firms were hired. The purpose of the consultancy services was to profile the use of water resources by all CVRD units scattered across the different regions of Brazil as shown in Figure 20.

With a view to systematizing the task, DIAT's technical team developed standardized forms. These forms were paramount for the systematization of information, as well as for comparison and consolidation of data at the units.

To profile the use of water resources, the following were identified: catchment of surface and groundwater; water supply systems for human consumption; sewage treatment systems; oily effluent treatment systems; and industrial effluent treatment systems. For each of these systems, their characteristics were identified as shown below.

Catchment of surface and groundwater

- type of catchment;
- location of catchment;
- equipment used;
- quality of water caught;
- operating conditions of the catchment system (facilities, operating procedures);
- actions for the compliance of the systems with technical standards and the legislation in force;
- monitoring plans.

Water supply systems for human consumption

- location;
- quality of water caught;
- type of treatment;
- operating conditions of the treatment system (facilities, operating procedures);
- quality of water supply;

- supply systems (conveyance, reservoirs, cleaning procedures);
- Verification by proper laboratories based on water analysis (identification, accreditation, testing procedures)

Sewerage systems

- location of system;
- identification of type of system in place;
- operating conditions of station (capacity, status, proper identification, operating procedures, cleaning and maintenance schedules);
- survey of relevant documentation (projects, operating manual);
- quality of effluent;
- receiving water body (classification);
- Verification by proper laboratories based on water analysis (identification, accreditation, testing procedures).

Oily effluent treatment systems

- influent and effluent flows;
- contributing areas and activities;
- conditions of treatment system (capacity, status, operating and maintenance procedures);
- survey of relevant documentation (projects, operating manual);
- quality of effluent;
- receiving water body;
- Verification by proper laboratories based on effluent analysis (identification, accreditation, testing procedures).

The data collected helped clarify several questions regarding the use of water resources by CVRD, such as the various water catchments for its processes; the water demand by the individual operating units and activities; the amount of recycled and reused water in each operating unit; the treatment of water for human supply; and the different types of effluents and their treatments. Based on these results, it was possible to outline a program for improved management of water resources for the individual operating units.

The information obtained through the survey and that reflect the use of water by CVRD and the high circulation rate mentioned earlier include:

- 218 underground catchments and 59 surface water catchments;
- 53 water treatment plants (WTP);
- 11 sewage treatment plants (STP) and 518 septic tanks;
- 126 water and oil separators (WOS), 3 oily effluent treatment plants (OETP) and 61 industrial effluent treatment plants (IETP).

4 SUPPLEMENTARY ACTIVITIES TO STRENGTHEN PNRH/CVRD

Alongside the implementation of PNRH/CVRD and with a view to engaging their employees to the issue of water resources management, Vale chose this topic as a parameter for evaluating environmental performance indicators, with direct results of the performance of its management and technical team.

An Environmental Performance Indicator, as defined in ISO 14,031 Standard, is a specific term that provides information on the environmental performance of a company. Thus, the Environmental Performance Indicator should be related to significant environmental aspects associated with the activities, products and services provided by the company, and it should consider the views of stakeholders while serving as the basis for planning and effective funds provisioning aiming at continuous improvement of the company's Environmental Performance.

In 2004, CVRD added an indicator for Water Resources Management to the performance indicators of its managerial and technical team. For the evaluation of this indicator, five levels of priority actions by the company were established, according to improvement processes identified through the Water Resources Diagnosis aimed at the rational use of water resources and at minimizing the impacts caused by the typical interventions in the production process.

Also, CVRD has developed environmental education programs to protect the waters in the communities living in the vicinity of its operations, focusing on water as a topic for environmental education in 2004 and 2005.

The environmental education programs were developed for family members of employees and for students, with the participation of municipalities, mainly in the state of Minas Gerais, and also the cities of Vitória, São Luís dos Carajás and Canaã; 100,000 people benefited from the programs. In Canaã dos Carajás, 3,000 children and adolescents, 80 school teachers and 6,000 parents participated in the development of models and the map of the city's waterways, the purpose of which was to help these children to understand the importance of water and the water supply and sewerage system that the city is receiving this year.

Vale committed to follow up on the environmental education programs for another three years with the community, municipality and all local development agents.

Photo 28. Brasil das Águas Project. www.brasildasaguas.com.br (Margi Moss).

Finally, also as an activity in support of strengthening the PNRH/CVRD, Vale co-sponsored the Brasil das Águas Project. Designed by Gérard Moss, this project included a survey of the status the main rivers and river basins in Brazil, with emphasis on water streams located in areas of influence of the company's operations. An amphibious aircraft turned into a laboratory was used in order to collect water samples during sweeping flights. The sample collection on board of the aircraft took 14 months and covered 120,000 km, which is equivalent to more than two turns around the Earth in all river basins that supply the country.

5 IMPLEMENTATION OF WATER RESOURCES MANAGEMENT IN CARAJÁS IRON MINES

The Carajás Iron Ore Project (see Figure 21) is an integrated mine-rail-port system by CVRD. It covers the development of open-pit mines and a complex for industrial processing, both located in the Carajás National Forest, in municipality of Parauapebas, which lies 550 km southwest of Belém, Pará. This system includes the Carajás railroad (892 km long), linking the mine to the sea terminal of Ponta da Madeira, 9 km southwest of São Luís, Maranhão.

Figure 21. Carajás Iron Ore Project

Ore beneficiation at the Carajás plant basically consists of crushing, grading, draining, milling, and filtering operations. Currently, there approximately 70 million tones of processed iron ore are produced per year, and about 12 million tons of waste are released at the Igarapé Gelado Dam. The resulting products are transported via the Carajás railroad to the Ponta da Madeira ferry terminal.

The water used in processing operations and supply for human consumption in the Carajás iron mines derives from surface and groundwater sources.

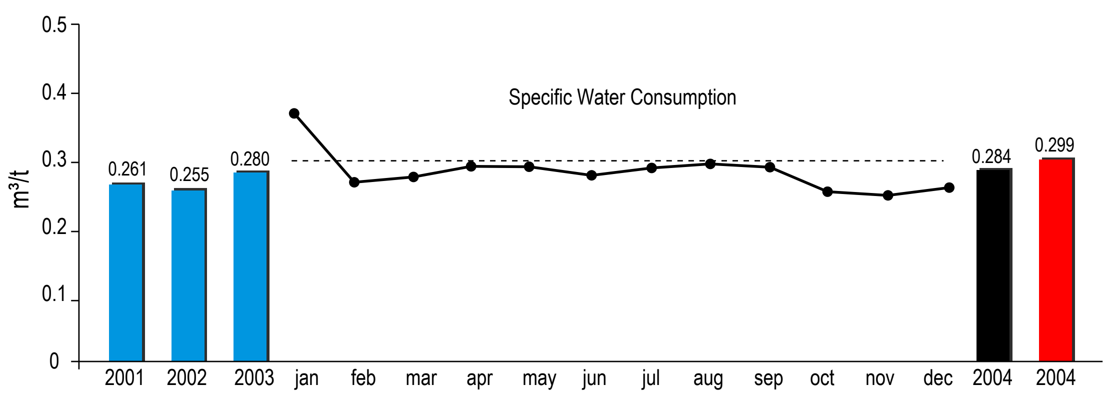
The main source of surface water comes from the Igarapé Gelado basin and is extracted from the Igarapé Gelado dam. This is a tailings dam – the Igarapé Gelado tailings dam –, which has a flooded area covering 460 hectares and three arms that are used for the sedimentation of tailings. The dam is located in the headwaters of Igarapé Gelado, a tributary of the Parauapebas river and a part of the Araguaia-Tocantins river system. A total of 2,390 m3/h is currently pumped. Superficial raw waters from the Carajás iron mines are extracted from this dam, which receives water from surface draining derived from the water level lowering system in the Carajás mines, waste dumps and tailings from the plant.

The main source of underground water is an aquifer made up of the iron formation. This water is caught by means of deep tubular wells set up in the mines, which are intended to lower water levels in these mines to enable iron ore mining.

In 2002, following a Preliminary Water Resources Diagnosis in the Carajás mines that identified that the unit used approximately 29 million cubic meters of water per year, an action plan was drawn up for water use management in the unit, which addressed all the recommendations outlined in the Diagnosis, especially the following:

- pumping of all water produced by the wells from the mine to the plant, thus optimizing the drainage gallery's pumping system;
- monitoring the amount of water used in the mine's automatic sprinklers;
- inventory of all water points in the vicinity of the mining operation;
- development and operation of a monitoring network of surface and groundwater, with emphasis on water quality, hydrochemistry, control of flows, and water levels;
- improved use of equipment by changing operating procedures;
- development and implementation of actions to inform and train the team with a view to reducing wastage and water consumption at the plant;
- pig piping cleaners to reduce the roughness generated by mineral waste that get trapped in the walls.

Following implementation of the Water Resources Policy and as a result of the commitment of the management team, the Carajás ore processing plant is now showing improved control of water consumption specifically in ore processing as shown in Figure 22 below.



2003	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Actual	0.368	0.269	0.275	0.292	0.291	0.279	0.289	0.295	0.291	0.253	0.248	0.259
Target	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299	0.299

Figure 22. Specific Water Consumption – Carajás Iron Ore Project

The graph in Figure 22 shows water consumption in cubic meters per ton of iron produced. Please note that the PNRH/CVDR was implemented in 2003, therefore the data for 2001 and 2002 are somewhat inaccurate. The red bar represents the target set based on the diagnosis for the consumption of water in the Carajás Iron Ore Project. The black bar is the result achieved with the implementation of actions identified. The graph shows the reduction in water use was even higher than the desired target. The information bar underneath the graph shows monthly use figures achieved and the target monthly figures for the year 2004. These figures reflect the progress of actions towards achieving PNRH/CVRD's goal of reducing water consumption in iron production progressively.

6 FINAL REMARKS

Due to the significant consumption, CVRD could be considered a major user of water in river basins where its units are located. In this sense, the importance of implementing the PNRH/CVRD becomes apparent. The Water Resources Diagnosis provided not only insight into the actual mining-water use relationship in the company's units, but also helped identify priority actions to rationalize water use.

The most relevant actions identified include recirculation of water through the retention basins; separation of networks for collecting sewage and industrial effluents and rainwater to improve efficiency of treatment systems; monitoring the quality and quantity of water supplies; training of professionals and dissemination of knowledge on new technologies or processes that reduce water consumption in operating units. As part of the Policy, these actions have been implemented in all CVRD's operating units and discussed by water managers at semiannual meetings.

In all CVRD's units, the water resources commissions have been working in the search for solutions. The purpose of the technical work for changing and adjusting processes, in conjunction with the awareness and training work involving all employees of Vale, is to generate buy-in for the need to promote proper use of water resources in all corporate units, including administrative and social management units. This task has guided the actions of the entire management team and, most importantly, it has strengthened the work of more than three hundred members of water resources committees.

Leandro Quadros Amorim, M.Sc.[1]

MBR'S OPERATIONS AND THE VELHAS RIVER BASIN: RECONCILING WATER AND MINING

1 INTRODUCTION

Minerações Brasileiras Reunidas S/A (MBR) is the second largest producer and exporter of iron ore in Brazil and the fifth in the world, and it focuses on the extraction, processing, transportation and marketing of iron ore. The company currently has five active mines, which are all located in Minas Gerais, south of the metropolitan area of Belo Horizonte (RMBH), in the municipalities of Nova Lima, Itabirito and Brumadinho. MBR also owns a port at the Guaiba Island, in the municipality of Mangaratiba, Rio de Janeiro.

The majority of mines is located upstream of the Velhas river, the main source of water for RMBH. Against this backdrop, MBR is faced with the challenge of reconciling mining in world class iron ore deposits with the rational utilization of water resources by making use of appropriate planning and advanced environmental control techniques.

The Velhas river starts near the city of Ouro Preto and runs its course towards north-northwest for about 800 km to its mouth on the right bank of the San Francisco river, near the city of Pirapora, both in the state of Minas Gerais (see Figure 23).

Along the initial 80 km of its course – which stretches from the source to its intersection with Serra do Curral – the Velhas river runs through the mining district of the Iron Quadrangle. Immediately north of the Serra do Curral and on the left bank of the Velhas river lies the city of Belo Horizonte, with about three million inhabitants.

Until mid-twentieth century, the water supply for Belo Horizonte came from small catchments located north of the Serra do Curral. Iron ore mining was still in its infancy, and the land south of the Serra do Curral in the valley of the Velhas river were scarcely populated.

Foto: Arquivo Manoelzão

Photo 29. Velhas river

[1] Geologist and Environmental Manager with MBR.

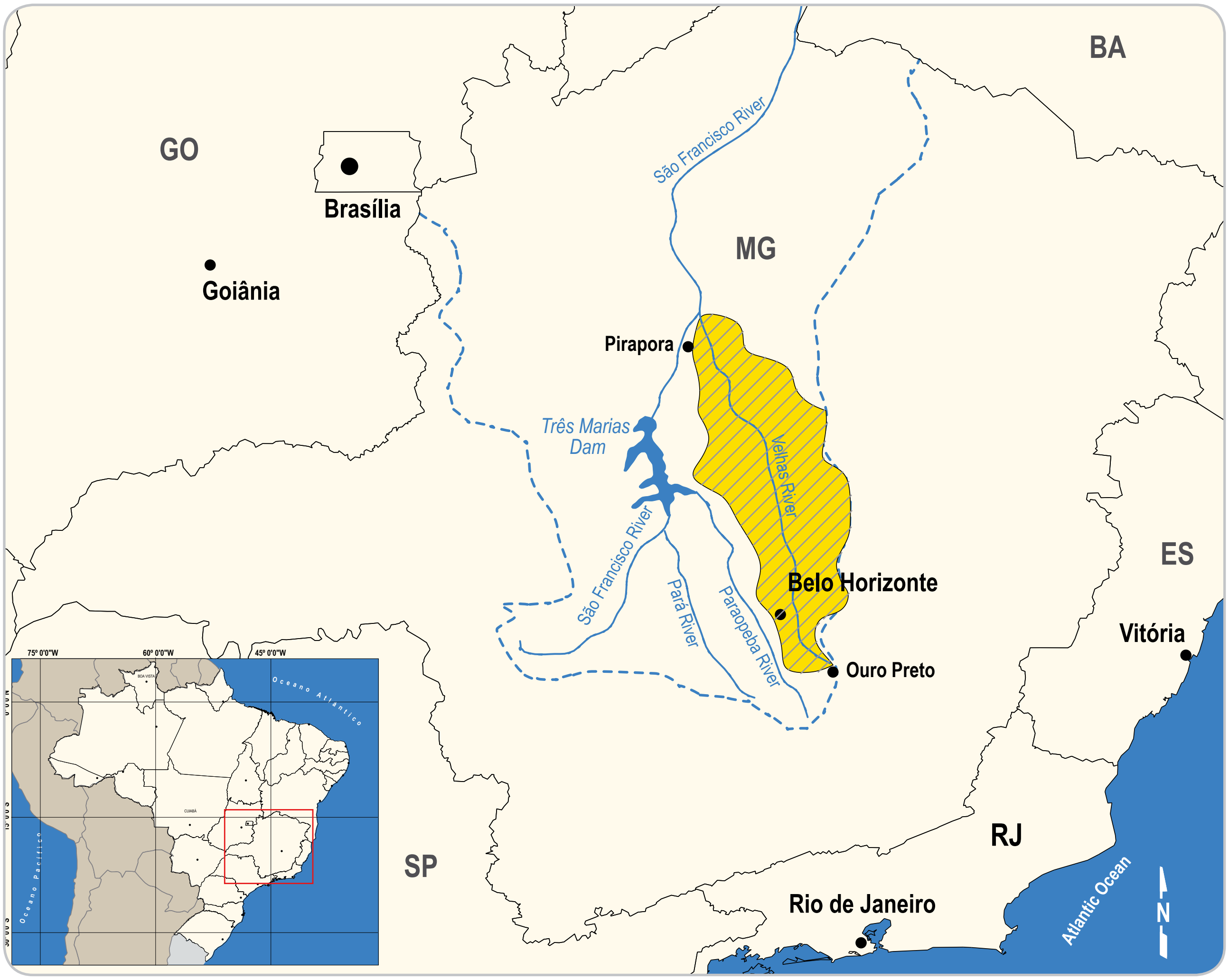


Figure 23. Location of the Velhas river basin

From the second half of the twentieth century, iron ore mining has experienced significant growth with the implementation of large-scale mining projects to serve the steel complex that had just been established in Brazil, and also the transoceanic iron ore market that emerged during the postwar period. Thus the industrialization process began, with a focus on the steel industry and later on the automobile industry (both industries being backed by the iron ore supply chain), and the pace of growth of RMBH intensified. Another hallmark at the time was the construction of roads, which made the area south of the Serra do Curral easily accessible to the population.

Population growth caused the demand for water to surge. It was not until the 1970s that this demand was satisfied, when a large water collection and treatment system for the Velhas river was put in place south of the Serra do Curral, right in the heart of the Iron Quadrangle. Ease of access intensified the urban growth process growth in this area, and the upper Velhas river became the stage of three major activities: iron ore mining, water collection and urban occupation.

Society in general has the perception that such activities are mutually exclusive and that mining is perceived as the biggest "threat" to water resources. MBR's approach shows, however, that, contrary to popular belief, the extraction of iron ore and water collection are not only compatible but also complementary as they make it possible to use mineral and water resources simultaneously, with mutual benefits – so the two activities can perfectly coexist peacefully.

The purpose of this section is to illustrate this compatibility; it discusses a case study on MBR's operations for the past forty years in the upper Velhas river.

2 BRAZIL'S IRON ORE INDUSTRY: HISTORICAL BACKGROUND

In the third quarter of the twentieth century, after the Second World War, the world's steel production experienced spectacular growth, jumping from 200 million tons in 1950 to 700 million tons in 1974 (see Figure 24). This growth was due to the demand arising from the global industrialization process, reflected in increased use of automobiles, appliances, machinery and equipment, metal structures and weapons – a characteristic of the postwar era.

Iron ore is the main raw material for steel production, which requires about 1.5 ton of ore for every ton of steel. Thus, this demand increased substantially the transoceanic market for iron ore, which was once incipient, enabling the emergence of Brazil and Australia as major exporters of this ore, each accounting for about a third of world exports. The remaining third is accounted for by all other exporting countries. Around this time Brazil developed a competitive steel production complex.

Over the following three decades – from the early 1970s to the late 1990s –, the global steel production reported a more modest growth than that in the postwar era. It rose from 700 million tons in 1974 to 800 million tons in 1999, thereby consolidating a market structure. In the late 1990s, a new

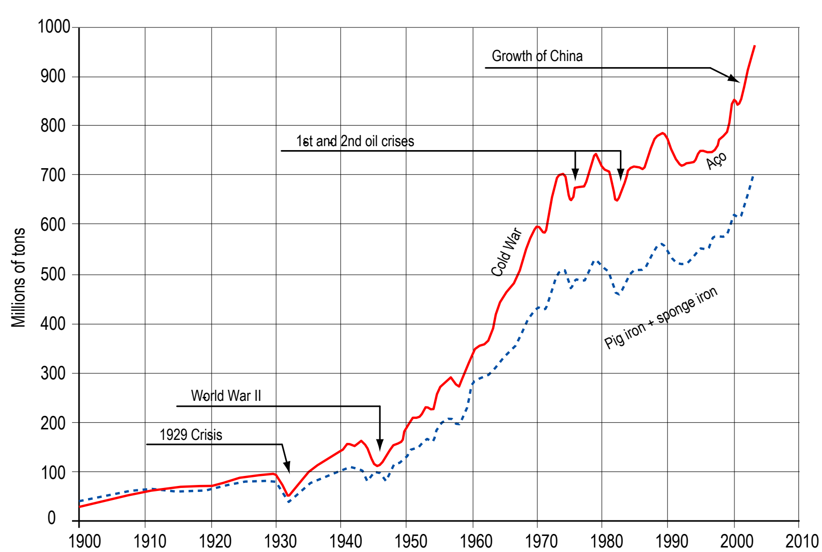


Figure 24. Variation of the world's steel production

cycle of intense growth sparked by China's industrial development began. For 2005, the global steel output is estimated to come to around 1 billion tons. Again, the growth in steel production boosted the demand for iron ore in the transoceanic market.

As shown in Figure 25, the iron ore industry in Brazil experienced remarkable growth from the second half of the 1960s, becoming the basis for a huge supply chain from the extraction and transportation of ore, the steel industry, construction, to the manufacturing of household appliances, automobiles, machinery, engines, equipment and aircraft.

Brazil's iron ore production is a key industry, and it can more than meet the demand of the Country's steel industry – the surplus is exported. In 2004, the income from such exports was 4.8 billion dollars, accounting for 5% of Brazil's trade balance. As this goes to press, all indicators suggest that iron ore will be the top product in Brazil's export mix in 2005.

Until 1986, when iron ore extraction was established in the Serra dos Carajás, in Pará State, Brazil's total production came from the Iron Quadrangle in Minas Gerais. The Iron Quadrangle currently accounts for about 74% of the Country's production; Carajás accounts for 25%, and the deposits of Urucum, in Mato Grosso do Sul, for approximately 1%.

3 THE VELHAS RIVER BASIN: LAND USE

For planning purposes, the basin is subdivided into upper, middle and lower Velhas river, with the first sub-basin covering approximately 10% of the total area, and the remaining two covering about 45% each.

The upper Velhas river covers the stretch between the towns of Ouro Preto and Belo Horizonte, and its substrate is the Iron Quadrangle, where iron ore mining is quite intense.

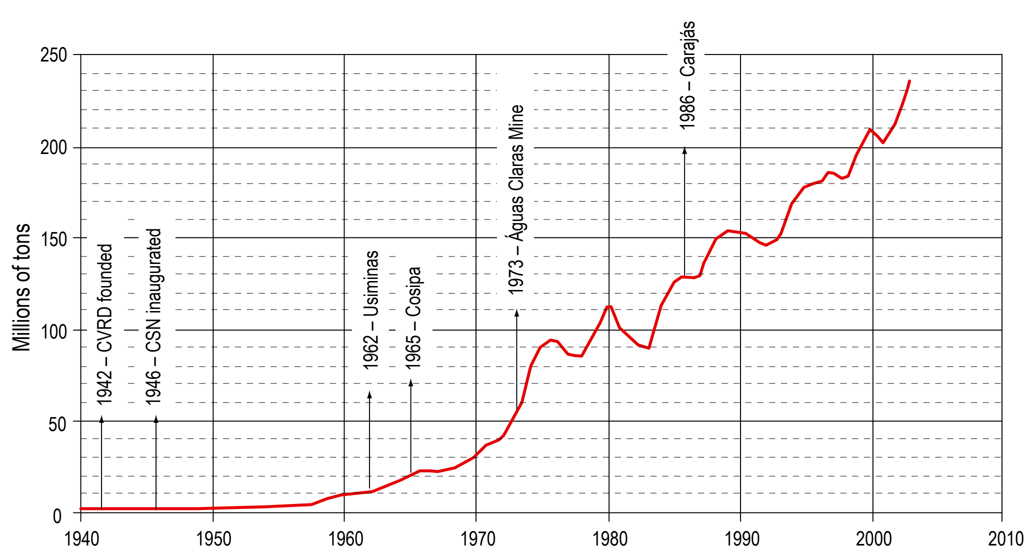
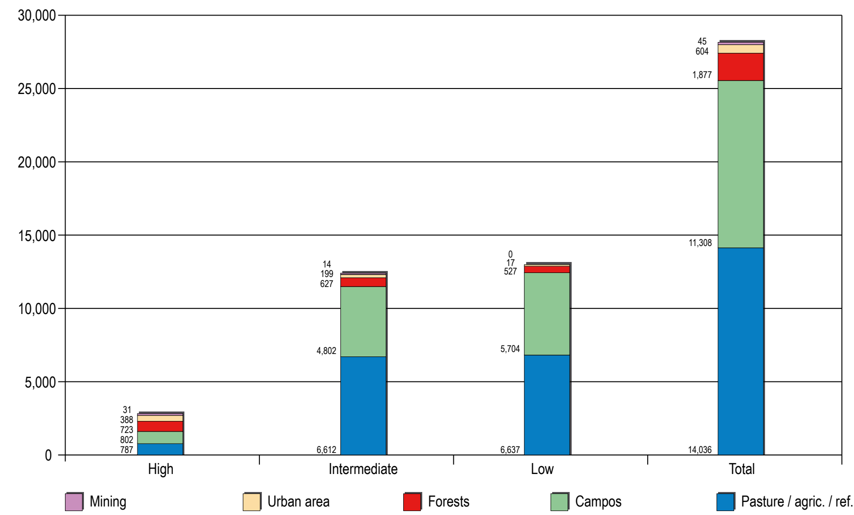


Figure 25. Variation of Brazil's steel production

The survey conducted for the Master Plan for Water Resources Management in the Velhas River Basin in 2004 describes the various types of land use in the basin (see Figure 26).



Source: Master Plan for Water Resources Management in the Velhas River Basin (2004)

Figure 26. Distribution of land use in the Velhas river basin (km^2)

Agriculture and cattle ranching – especially cattle ranching – are widely prevalent in the basin. With only 31 km^2, the mining areas of the Upper Velhas river are primarily covered by iron ore mining, and the mining in the Middle Velhas river (covering the 14 km2) focuses on the extraction of limestone.

Figure 26 shows that for every square meter of mining in the basin there are approximately 13 m2 of urban areas, 42 m2 of native forests, 251 m2 of fields, and 312 m2 of pasture. This means that for every square meter of mining in the basin another 325 m2 are occupied by all other human (urban and rural) activities, and 293 m^2 are covered by native vegetation (forests and fields).

In absolute terms, the urban, forest and mining areas have a similar profile, i.e., they are larger at the top and decrease toward the lower Velhas river. The distribution of land use in the middle and lower Velhas river is similar. There is, however, a particularity regarding the upper Velhas river. This particularity becomes more evident by looking at the data in Figure 27 in proportional terms, as represented in Figure 28.

Photo: Manoelzão archive

Photo 30. Velhas river

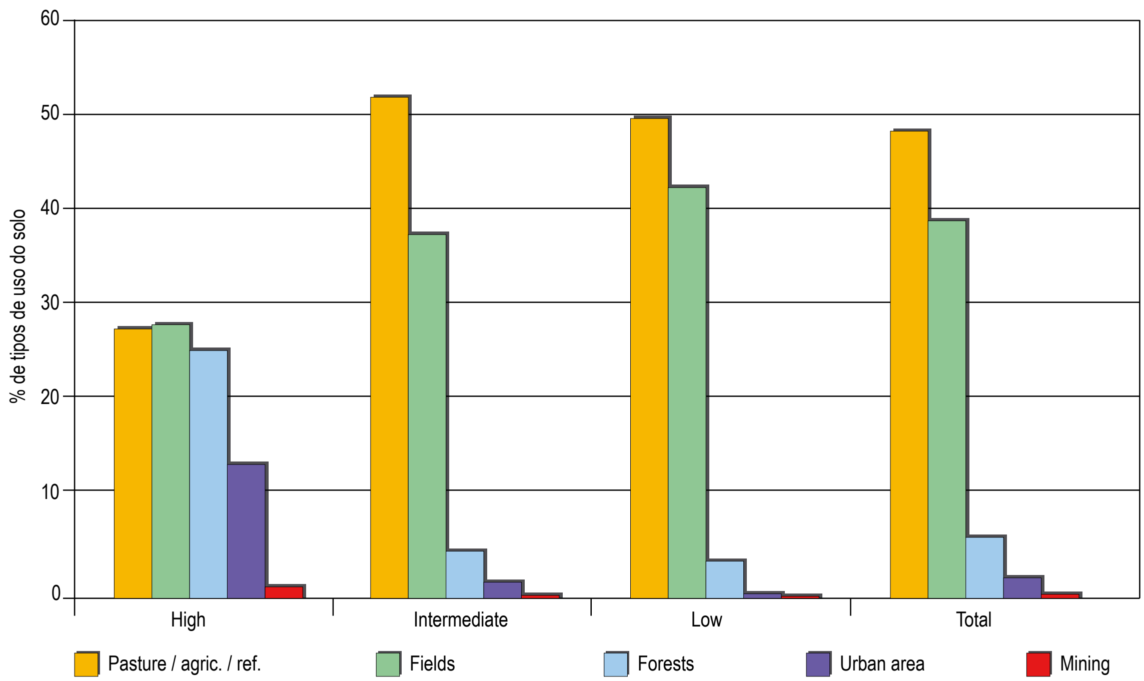


Figure 27. Distribution of land use in the Velhas river basin (%)

The Upper Velhas river is different from the other sub-basins in the sense that it has significant forest and urban areas. As for the local iron ore industry, occupying about 1% of the sub-basin – less than 0.2% of the entire basin –, MBR alone produced 15% of Brazil's iron ore output in 2003, according to the DNPM (SUMÁRIO MINERAL 2004).

Thus, it is clear that the extraction of iron ore covers a minute portion of the territory, and is located in a region with significant forest cover. This leads to the following question: Is there any relationship between the iron ore deposits and this significant forest cover? The answer is yes.

The stretch between Belo Horizonte and Ouro Preto of the upper Velhas river has the Iron Quadrangle as its geologic substrate, which does not provide lands that are suitable for farming or cattle ranching, except for its central portion, the so-called Complexo do Bação (see Figure 28). Therefore, the Iron Quadrangle (except for the Complexo do Bação) was spared the massive deforestation process for cattle ranching purposes, which occurred in the rest of the basin.

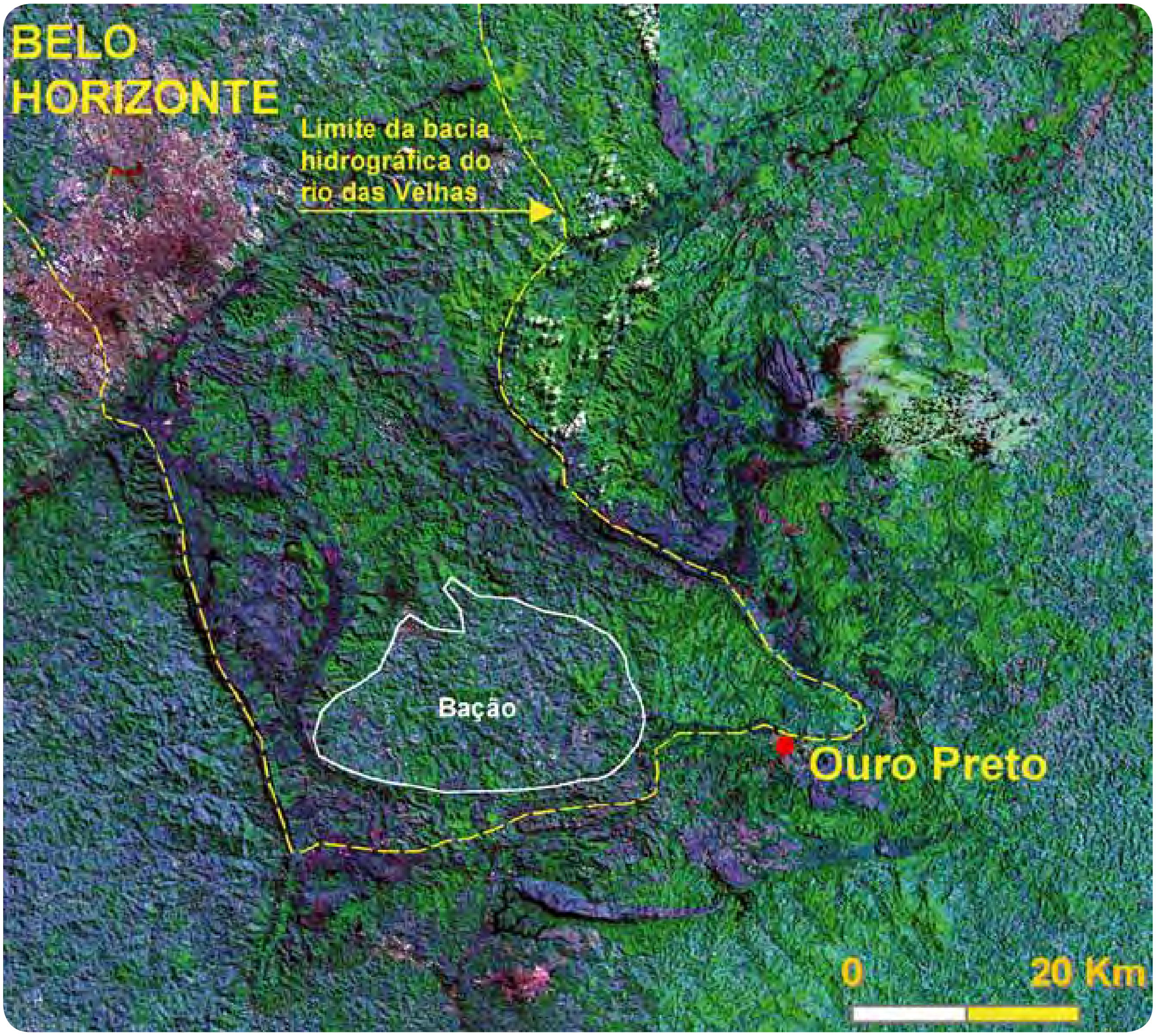


Figure 28. Landsat image for the area south of Belo Horizonte

Another significant factor is that the existence of gold and iron ore deposits south of Belo Horizonte prompted English mining company St. John D'el Rey Minning Co. to acquire large tracts of land in this region even before the city was established. In the mid 1950s, this company branched into two companies: MBR was born out of one of them, with a focus on iron ore, and the other company was Anglogold, with a focus on gold.

The fact that large tracts of land belonged to only two mining companies prevented the areas from being involved in the urban sprawl process, as was the case in the north.

Additionally, the implementation of MBR's iron ore mining operations culminated in the creation of large tracts of land used for environmental conservation. MBR's areas for environmental conservation currently cover 31 km^2, which coincidentally is equivalent to all mining areas in the upper Velhas river.

Thus, land use in the upper Velhas river differs from the use in all other areas of the basin as it is more significantly covered by forests and towns, in addition to bringing together all iron ore mining activities in the basin. The forest areas correspond to both those that were spared from deforestation for agricultural purposes because they were unsuitable for farming and those which were protected from real-estate speculation by mining companies.

4 WATER QUALITY AND LAND USE: A CLOSE RELATIONSHIP

This section looks at the relationship between the distribution of land use and the quality of water bodies in the Velhas river basin. This requires looking at the official data on water quality in the Velhas river.

The description of the quality of surface waters in the Velhas river was based on data collected between 1997 and 2003 in the various sampling stations being monitored, through the Mining Water Project,[2] and the National Environmental Program II - PNMAII[3], in order to develop the master plan for water resources management in the Velhas river basin.

A key indicator of water quality is known as the Water Quality Index (WQI), developed by the National Sanitation Foundation, from the United States. A set of nine parameters that were considered to be most relevant for the identification of water quality were developed: dissolved oxygen, fecal coliforms, pH, biochemical oxygen demand, nitrate, total phosphate, water temperature, cloudiness, and total solids. Each parameter was assigned a weight according to its relative importance in calculating the WQI, and water quality average variation curves were plotted as a function of its concentration. The values for the index range from 0 to 100; water with a WQI under 25 is classified as very poor; between 25 and 50 as poor; between 50 and 70, as average; between 70 and 90 as good; and greater than 90 as excellent.

The graph contained in the master plan (see Figure 29) shows the WQI along the Velhas river and some of its tributaries. To facilitate interpretation and discussion of these results, a line has been drawn to connect the points of the Velhas river and set it apart from its tributaries, whose names have been inserted for clarity.

Water quality in the Velhas river clearly declines once it joins the Arrudas and Jaguar rivers, into which the sewage of RMBH are released. Before reaching a final conclusion, however, it is worth looking at the data more closely.

First, one should consider that the sample is not evenly plotted along the basin. The stretch of the upper Velhas river, which covers about 10% of the basin from the source to the confluence with the Onça river (point 154 BV) contains 20 samples; the section corresponding to the middle Velhas river, covering about 45% of the basin and located between the confluences with the Onça and Paraúna rivers (point 143 BV), has only 13 samples; finally, the lower Velhas river, also covering approximately 45% of the basin, has the remaining 5 samples.

[2] This is a program for the monitoring of water quality implemented by the Minas Gerais Secretariat for the Environment and Sustainable Development.
[3] This is a national-level program to strengthen the National Environment System, implemented by the Ministry of the Environment.

For the upper Velhas river, by comparing the WQI for the tributaries to those for the Velhas river, the most polluting tributaries are the rivers Maracujá, Itabirito, Água Suja, Arruda, and Onça (see Figure 29).

Besides, the Fazenda Velha, Peixe and Macacos rivers are the tributaries that provide water with a higher quality than the Velhas river, thus helping dilute impurities. Hence, this avoids a more significant drop in the water quality of the Velhas river, despite the low water quality in Itabirito and Água Suja rivers, which receive the sewage from the towns of Itabirito and Nova Lima, respectively. However, this dilution becomes insufficient after confluence with the Arrudas and Onça rivers, which receive the sewage of the metropolitan area of Belo Horizonte, lowering the WQI for the Velhas river to poor.

Once its quality is affected by the effluents from Belo Horizonte, the Velhas river receives inputs from its tributaries Taquaraçu, Jequitibá, Santo Antônio and Paraúna (the latter has the Cipó river and a tributary), which helps gradually improve the quality of the Velhas river water through dilution and, 300 km away from the RMBH, the water quality of the Velhas river is restored and can be compared to that upstream from the town of Nova Lima. The negative impact from the release of urban and industrial sewage in the water quality of the Velhas river is therefore evident.

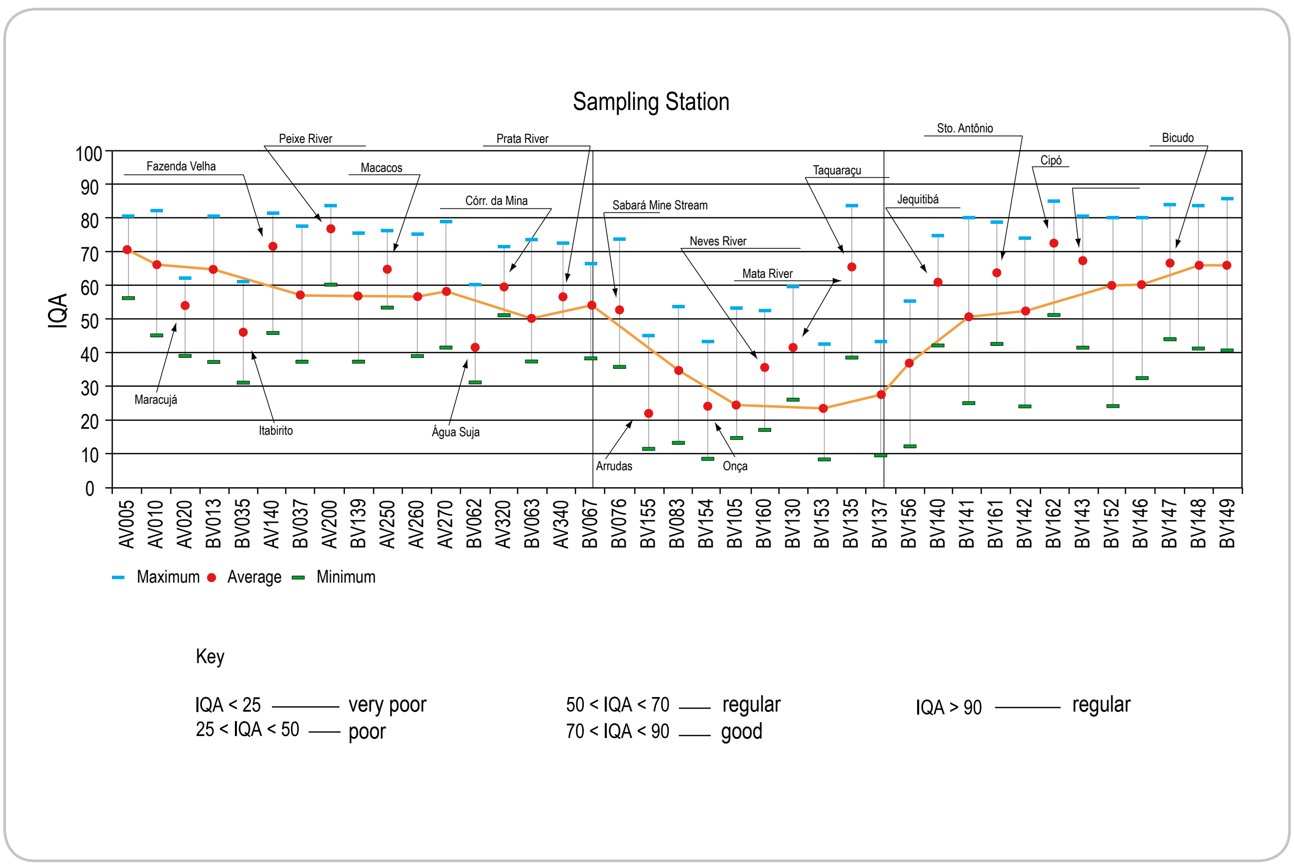


Figure 29. Variation of WQI along the Velhas river (1997-2003)

In view of this, the following question is asked: What is the actual relationship between the iron ore mining sector and RMBH's water collection systems regarding a threat to water availability, whether in qualitative or quantitative terms?

To answer this questions, a comparison is drawn between the main uses of water at the upper Velhas river, i.e., public water supply and sewerage and MBR's mining operations, based on monitoring (as mentioned earlier) and systematic studies on water resources in the basin. The purpose of this comparison is to dispel widespread concerns about the negative aspect of the mining-water resources relationship.

4.1 PUBLIC WATER SUPPLY

The Velhas River Collection System for the Supply of RMBH is located at the upper Velhas river, in the municipality of Bela Fama. This system processes about 6,000 L/s, thus accounting for 44% of total consumption in the region. The inputs from Cercadinho, Mutuca and Fechos feed the so-called Morro Redondo System, which processes about 700 L/s, i.e., 5% of total consumption. These inputs, in addition to that from Barreiro, are all located in the Velhas river basin, and account for about 50% of the total supply in the metropolitan region. The Rio Manso, Serra Azul, Vargem das Flores and Ibirité systems, located in the Paraopeba river basin, make up the remaining inputs that complement the supply for RMBH, and they account for the remaining 50% (see Figure 30).

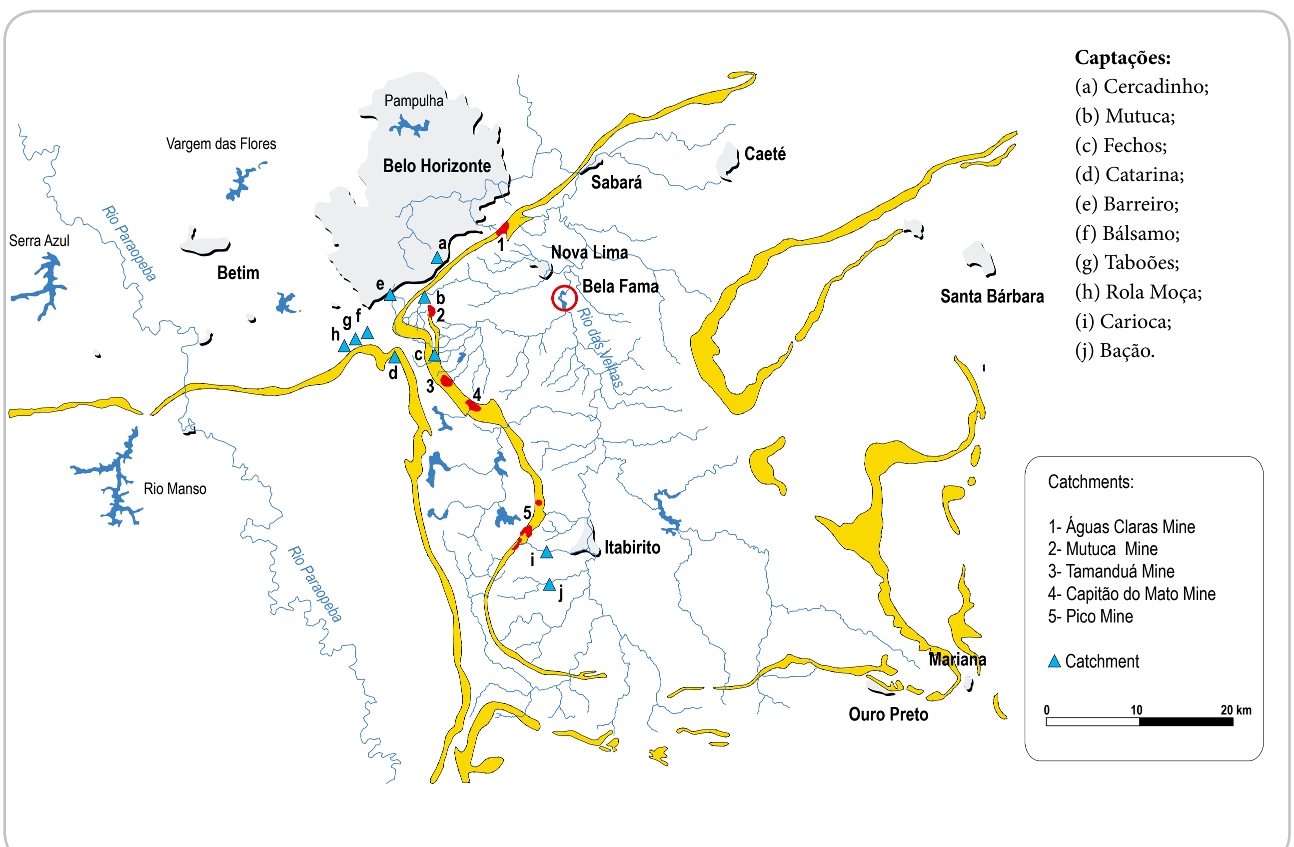


Figure 30. MBR's mines and water catchment facilities for RMBH

From the standpoint of water quality going through the basin, it is considered that the use of water for public supply from the upper Velhas river results in a twofold worsening of the WQI around the RMBH. Firstly, because high-quality water is collected from streams upstream of Belo Horizonte and are then "returned" downstream in the form of sewage; secondly, because when clean waters are removed from the streams they weaken the Velhas river's dilution capacity in the river section downstream of Nova Lima.

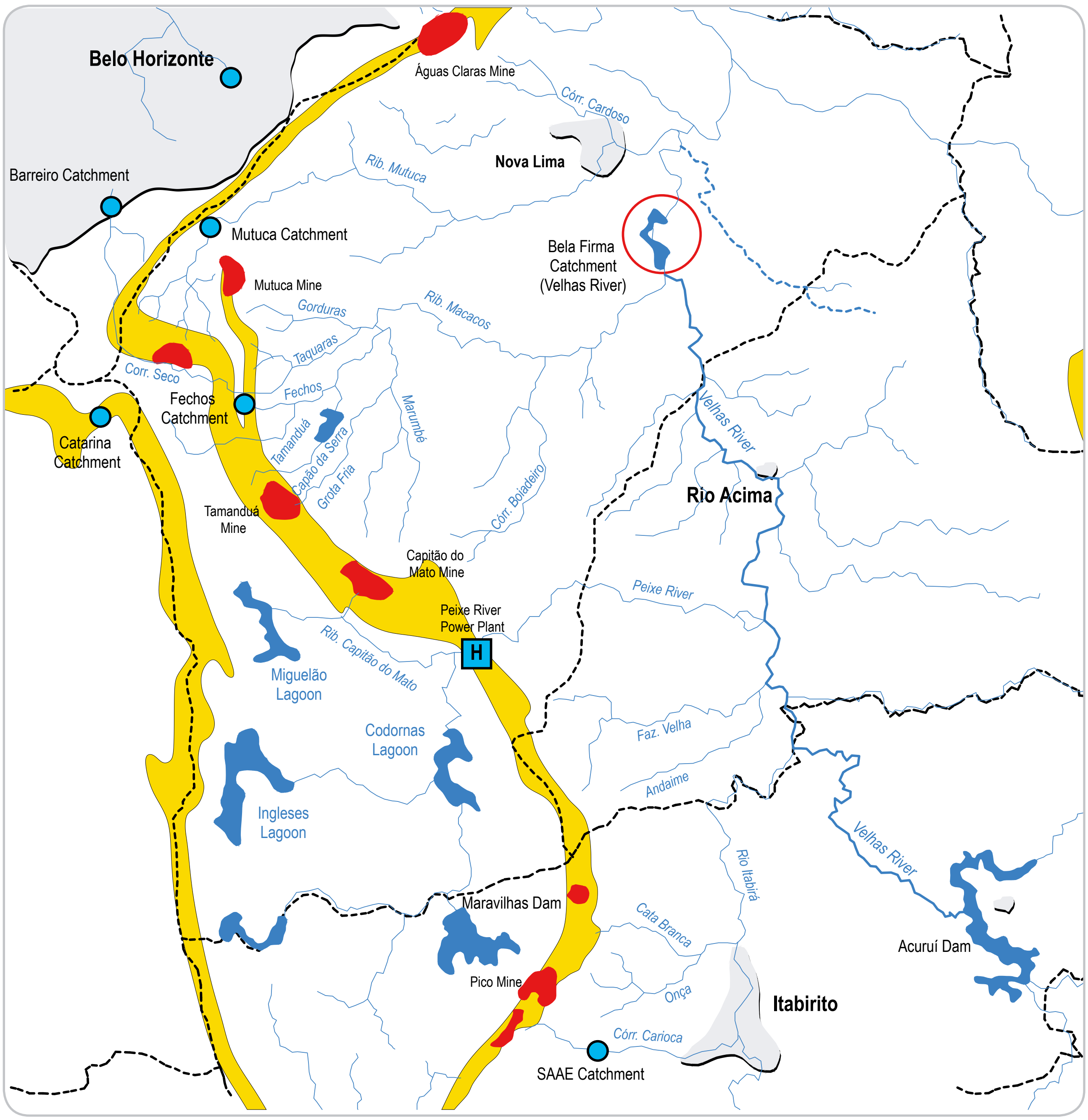


Figure 31. MBR's mines and water catchment facilities for RMBH along the upper Velhas river

4.2 IRON ORE EXTRACTION

MBR's use of water resources for iron ore mining in the upper Velhas river takes place in four active mines – Capão Xavier, Tamanduá, Capitão do Mato, and Pico –, in addition to two exhausted mines – Águas Claras and Mutuca (see Figures 30 and 31).

Except for the Águas Claras mine, all other mines lie upstream of the Bela Fama catchment system, and the Mutuca, Capão Xavier and Tamanduá are located near the water catchment points of Mutuca and Fechos.

Thus, MBR's iron ore operations launch their effluents into the Macacos and Peixe river basins, which are both tributaries of the Velhas river, which have high WQI rates, as shown in Figure 29.

The table below shows that these are high-quality waters, which, therefore, partially offsets the clean water deficit caused by the Mutuca and Fechos catchments, and thus contribute positively and directly to the public water supply for RMBH.

Table 2. Average quality of effluent water from MBR's mines in the Velhas river basin (2001-2005)

MINE	Águas Claras	Mutuca	Capão Xavier	Tamanduá	Capitão do Mato	Pico
Receiving basin	Água Suja river	Macacos river	Macacos river	Macacos river	Peixe river	Peixe river
pH	7,06	7,59	6,82	7,26	5,49	7,63
Cloudiness (NTU)	4,47	9,03	7,94	14,83	0,84	17,72
Suspended solids (mg/L)	2,79	4,63	3,35	10,09	0,73	11,15
Dissolved solids (mg/L)	50,01	89,86	28,33	46,19	9,02	120,43
Electrical conductivity (μS/cm)	42,50	94,77	23,55	34,00	6,60	128,74
Dissolved oxygen (mg/L)	7,44	7,05	7,28	7,33	7,43	7,40
BOD (mg/L)	0,38	1,05	0,14	0,37	0,32	0,74
Soluble iron (mg/L)	0,11	0,07	0,18	0,07	0,06	0,05
Soluble manganese (mg/L)	0,23	0,07	0,05	0,22	0,05	0,06

The good quality of effluents derived from MBR's operations is attested by the fact that the iron ore is fundamentally extracted from an open-pit mine, and the final dimensions are defined by the size and geometry of the ore bodies. Basically, two types of materials are extracted from this mine: the ore, which is taken to a processing plant; and steriles, which are made up of all non-ore rocks and are disposed of in a controlled manner in appropriate, predefined locations.

High-grade iron ore is processed by sorting the raw ore from the mine into different size classes. In addition, for low-grade ores, those minerals that are not usable by the steel industry must be removed from the ore. A portion of the raw ore is processed into different products for commercial purposes. The remaining, useless portion are the tailings.

These tailings are placed in dedicated tailings dams (see Photo 31). The dimensions (useful accumulation volume) for these dams are defined by the total ore volume to be mined and the type of processing used, which makes it possible to estimate in advance the total amount of tailings that a particular mine will generate throughout its life.

Photo 31. MBR's tailings dam

In order to prevent downstream stream from being silted with materials from the mine or sterile dumps, which would be washed away by rain water that seeps into the ground, it is often necessary to build dams or dikes to retain sediments in these watercourses.

As in most industrial processes, a liquid effluent is generated and released into a watercourse. Thus, effluent control is a key element of the mining process so that it does not pollute the receiving watercourse.

In this regard, the control required is a simple settling process since good effluent quality lies in the fact that this mining process does not affect water quality, and this is so because the minerals that make up the local rocks are chemically inert – These include iron oxides and hydroxides, carbonates and silicates without salts or sulphides that could alter water quality when mixing with it. Additionally, chemicals are not used for ore processing, so there are no natural or artificial contaminants.

Hence, by means of an environmentally responsible mineral extraction approach that generates high-quality effluents, MBR may help increase water supplies, which in turn enhances the dilution capacity of water bodies and can occasionally improve the waters in the upper Velhas river basin qualitatively.

It should be pointed out that the Peixe river, which receives effluents from two mines operated by MBR, has the best average WQI rate in the entire Velhas river basin; it is even higher than that for the Cipó river, which is famous for the quality of its waters, originating in the Serra do Cipó, a fully area protected, and flowing into the Paraúna river, a tributary of the Velhas river.

Thus, the location for the iron ore industry in the upper Velhas river is precisely the place where the waters have the best quality as a result of the quality of effluents and the high standards of environmental conservation. In compliance with the environmental legislation, which requires that mining operations establish and maintain protected areas, as well as its territorial management, MBR has protected their areas against predatory and uncontrolled urban growth. This is reflected in the vicinity of nearly the entire area owned and managed by MBR, which is an area of environmental excellence, with noticeably positive results not only for the Velhas river basin, but for the entire RMBH.

5 IRON ORE EXTRACTION AND WATER RESOURCES: QUANTITATIVE ASPECTS

5.1 INTERFACE WITH GROUNDWATER

The large iron ore mining projects in Brazil (Iron Quadrangle) began almost simultaneously between the mid-1960s and the mid-1970s. At the time, the fact that the Cauê iron mine is also an aquifer was unknown (or overlooked). As pits were dug deeper, many mines reached the water level. At first, in the early 1980s, when hydrogeological studies were launched for the solution of what was then a problem for mining, the drainage of mines found water in mining fronts by means of gravity and channels. From the mid-1980s, the process of lowering water levels in mines by means of deep tubular wells began (BERTACHINI, 1994).

The "discovery" that the iron ore formed an aquifer triggered a process of growing perception that was the focus of the 1990s – the suspicion that iron mining would be threatening water resources. As a result, hydrogeological studies, which had been previously restricted to mines, were extended to the surrounding areas in order to check for possible environmental impacts.

Meanwhile, with the development of environmental legislation, previous hydrogeological studies encompassing the entire area covered by mining projects began to be required and monitored by environmental agencies in the licensing process for new mining ventures. These studies have been developed over the past 15 years, and they are the primary source of information and data for the scientific investigation of the hydrogeological system in the Iron Quadrangle.

Currently, the iron ore industry is entering a new era, which overlaps with the start of the exhaustion of the early mines dug in the 1970s. This will cause some of the pits to be flooded, thus resulting in deep lakes. Detailed studies were developed in order to make a future use of these lakes that is environmentally sound, helping to maintain the high quality of their waters. These studies suggest leisure and public water supply as potential uses for these lakes.

5.2 WATER LEVEL LOWERING

The orebody is also an aquifer (a rock that can store and transmit water). Thus, as pits are dug deeper and the ground water level is often reached, it must be lowered so that the mining operations can continue. This lowering is achieved by extracting water from the aquifer through drainage wells or galleries in such an amount that is greater than the natural recharge caused by rainwater flowing into the soil. Disposal of this water during operation and recovery of the aquifer once the mine is depleted is an important aspect of the interface between water and mining, and therefore must be considered in mining projects.

This lowering of the water level can occasionally interfere with the natural flow of some springs located around the mine, so this is another major aspect to be taken into account in mining projects.

Mitigation measures for impacted sources consist of water replenishment by using the water from the lowering wells. At the end of a mine's life,[5] as the pumping operation is discontinued, a lake is formed in the pit, causing the water to return to its original level, restoring the original underground water flows and putting an end to hydrological impacts that are therefore reversible. All of these actions are integrated and are included in the hydrologic management plans

[4] The Águas Claras mine's life was thirty years. The water level lowering process took place for 19 years, until the mine was eventually shut down.

that are thoroughly and carefully put together by the mining companies. These plans are then submitted to environmental and water resources authorities, and by River Basin Committees (if any) for approval. According to these studies, most mining projects are conducted without any reduction in the water available in the area covered by the project, whether during the operation, decommissioning or post-decommissioning of the mine, when the water balance in the whole process is reviewed.

From the standpoint of water conservation, the mining process will have reduced its potential impact on the environment at the possibility of researching and evaluating environmental aspects related to it and the feasibility of mitigating the damages caused by mining.

6 MBR AND MULTIPLE WATER USES IN THE VELHAS RIVER BASIN

The Águas Claras mine became operational in 1973; it was MBR's main mine, and the company had also been exploring the Mutuca mine since 1961, and the Pico mine, which had been in operation at a small scale since the 1940s. This is how MBR has become the second largest iron ore exporter in Brazil and the fifth in the world.

In the early 1980s, as pits were dug deeper for the extraction of iron ore, the Águas Claras and Mutuca mines reached the ground water level. The company immediately focused on hydrogeological studies to find the solution for what was then a problem for mining – water in mining fronts. From the mid-1980s, the process of lowering water levels in mines by means of deep tubular wells began, and this solution was adopted by the mining industry worldwide.

Thus, by pumping average flows of 73 L/s in the Águas Claras mine and 30 L/s in the Mutuca mine over about 15 years, the water level in these mines was artificially lowered by 300 and 250 meters, respectively, allowing the pits to be dug deeper under safe operational conditions.

In the late 1980s, when procedures to lower water levels in the Águas Claras mine were put in place, it was believed that such activity would be interfering with the flow of the headwaters of the Mangabeiras Park, a former iron ore mine owned by the City of Belo Horizonte, located on the northern slope of the Serra do Curral, which was converted into a park in 1982 after its exhaustion. Studies were conducted based on a rigorous monitoring system operated for over ten years proved that there was no interference by mining activities in the headwaters of the park.

In the Mutuca mine, lowering of water levels was also performed without any interference of flows of its watershed next to the mine: The Mutuca watershed was built in the 1950s to supply water to the City of Belo Horizonte.

In the early 1990s, MBR conducted an expansion program at the Pico mine in the town of Itabirito to complement the dwindling production of other mines, thus preparing their replacement once they were fully exhausted. Procedures to lower the water levels in this mine were implemented in 1994 and expanded from 1999, and pumped flows are currently about 400 L/s.

In 1999, concerns were raised that this would be affecting the headwaters of the Carioca stream, where catchment facilities for municipal waters are in place. Similarly to what happened in the late 1980s in the Águas Claras mine, studies once again showed no interference with the water for public supply.

The waters pumped into the Pico mine are released into the tailings dam, from where they flow to the Codornas pond, which is actually a dam that belongs to a hydroelectric plant located on the Peixe river. Built over one hundred years ago by the mining company St. John D'el Rey Mining Co., this small hydroelectric plant is still in operation. The water flows through the plant, then the Peixe river, and reach the Velhas river.

This provides a remarkable example of multiple use of the water from the mine: industrial use (ore processing); landscaping (in the pond); generation of electricity (from the plant); and finally public supply, because the Peixe river is one of the main tributaries of the Velhas river, which is upstream of the existing water catchment. Therefore, these waters are ultimately meant to supply the RMBH.

In the mid-1990s, in order to follow up on its mine expansion and replacement program, MBR began operations in the so-called Tamanduá Complex, which comprised the Tamanduá and Capitão do Mato mines, both located near the Morro do Chapéu residential condo.

With a pumped flow rate of about 350 L/s, water levels in these mines started being lowered in 2005. According to an agreement between the company and the condominium, however, MBR started drilling and operation of the first well for water lowering earlier in order to supply water to the condo and to replace the existing small wells, which failed to meet the demand satisfactorily. So the condo has been served by MBR for eight years now.

Like in the Pico mine, the waters from the water-level drawdown in these two mines are used to supply the RMBH since they are released into streams that flow into the Velhas river.

The hydrogeological studies in the Capão Xavier mine started in 1993. After a long, multi-step environmental licensing process, this mine became operational in June 2004, and it is also located near the Mutuca watershed. Because of their proximity to this and other watersheds that serve the metropolitan area of Belo Horizonte (RMBH), and based on the experience with the Águas Claras mine, which has resulted in an accumulation of knowledge specifically related to mining and water supplies, even more advanced protection and environmental control steps were taken.

7 NEW USES FOR FORMER MINING AREAS

The Mutuca mine became exhausted in 2001, and this was the case for the Águas Claras mine in 2003, after forty and thirty years of nonstop operations, respectively. Thus, MBR embarked on a new phase in its history as it discontinued operations in its early mines.

The depleted pit in the Águas Claras mine, which is part of an environmental rehabilitation process that began decades ago, is now being transformed into a deep lake. Because of the high quality of the water in this reservoir, the area formerly used for mining is appropriate for new uses, and it is integrated to surrounding areas that are protected by the company, thus making up an impressive area of high environmental quality.

The depleted pit in the Mutuca mine will be used differently. It will be used for disposal of both steriles (matter extracted from the mine that has no commercial value) and tailings (the thinnest portion of ores that is typically retained in dams) from the Capão Xavier mine in the future. Therefore, mining projects in Capão Xavier will help rebuild topography of the depleted pit in the Mutuca mine. Once it has been rebuilt, the former mining area will be fit for new uses.

The Capão Xavier mine will be instrumental in tapping into the local hydro potential. Eleven years ago, when hydrogeological studies were first conducted to assess the impact of mining in the surrounding springs (Mutuca, Fechos, Catarina, and Barreiro), it was assumed that the proximity between the mine and the springs would be a problem. However, these studies proved otherwise. This mine will help increase water availability in the public water supply network.

Studies show that lowering water levels in the mine could cause water flows in the Fechos watershed to gradually diminish. It is known, however, that the impact will be reversible, i.e., filling of the lake that will form in the Capão Xavier mine pit once it has been exhausted, similarly to what happens today in the Águas Claras mine, will help restore the regular flows in these springs.

An important aspect is that the water pumped out of the mine to lower water levels will be noticeably higher than the reduction of water flows from the springs, which will provide a water surplus that will be made available to the public supply network.

As a result, the water pumped from the mine will be used directly for the supply of the Jardim Canada neighborhood and for the Retiro das Pedras and Jardim Monte Verde condos, which are located near the mine.

In addition to helping rehabilitate the regular flow of springs that may be affected, the lake that will form in the pit following exhaustion of the mine will be a large water reservoir, with a capacity for 57 million cubic meters. This reservoir will be integrated into the water supply network, thus helping regulate flow rates by accumulating water during the rainy season – when there is plenty of water – and using it during the dry season – when there is a water deficit.

8 FINAL REMARKS

In view of the various aspects discussed in this chapter, it is our conclusion that MBR's operations, which have been ongoing for over forty years along the upper Velhas river, show that the assumption that iron ore mining and water use cannot coexist in the upper Velhas river does not reflect the reality.

The high quality environment found in that section of the basin is due to the existence of iron ore deposits, since the soil in the Iron Quadrangle, for its very ferruginous nature, is not suitable for farming or cattle ranching, and therefore was spared the heavy deforestation process that took place in the rest of the basin.

Additionally, large tracts of land south of Belo Horizonte have been purchased by mining companies, so these tracts were not affected by the uncontrolled urban growth process that occurred in all other peripheral areas of the city.

The location where the Velhas river has the best water quality is precisely where MBR operates, and this is so because their effluent are of good quality and the area is located upstream of the major polluting source in the basin: residential and industrial sewage discharges in RMBH. Nevertheless, there are other major sources of pollution to be considered, including the sewage from the towns of Itabirito e Nova Lima.

Compared with the areas used by other human activities, the area used for mining is proportionally very small. Besides, MBR is directly responsible for establishing and maintaining important environmental conservation areas south of Belo Horizonte, which helps maintain water quality.

MBR's mining processes are in line with the best environmental practices with a view to complying with control and mitigation measures so as to avoid adversely affecting water resources both in qualitative or quantitative terms so that the relationship between mining and these water-related aspects – which are supposed to be a problem – actually proves to be beneficial for society to rationally use "mining water", provided that mining companies have adequate procedures for environmental and water resource management in place.

Photo 32. Águas Claras iron mine pit in Serra do Curral, Belo Horizonte, in 2005

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Ana Cristina Calil R. Bragança[3]
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Edmar Fantini[9]
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WATER FOR ORE TRANSPORTATION AND PROCESSING – CASE STUDY FOR MINING OPERATIONS IN MARIANA – SAMARCO MINERAÇÃO S/A

1 INTRODUCTION

Samarco Mineração's business includes iron ore mining, processing, transportation, and pelletizing. It is the second largest exporter of pellets across the Atlantic for use in blast-furnace and direct-reduction steelmaking processes.

Its iron ore extraction and processing activities are carried out in the Germano unit, where the Alegria mines are located, with deposits estimated at four billion tones. This unit is located in the towns of Mariana and Ouro Preto, Minas Gerais. Through a pipeline that is 396 kilometers long, the ore produced at the Germano unit is channeled to the Ubu unit in Anchieta, Espírito Santo. This unit houses the pellet plant and the port.

Samarco was a pioneer in the management of water resources, and it was the first Brazilian company in the mining industry to obtain a license to use them. Samarco was also an industry pioneer with regard to the implementation of liquid effluent treatment, and it make sure it uses water responsibly in all of its operations. To this end, actions designed to reduce water consumption and monitor the physicochemical and biological properties of effluents and the ponds and rivers into which they are released are planned and implemented on an ongoing basis.

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[3] Chemical Engineer, UFMG; Processes Engineer
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[7] Mining Engineer, UFOP; Processes Engineer
[8] Metallurgy Engineer, UFOP; Overall Pelletizing Manager
[9] Mechanical engineer, PUC/MG; Ore Pipeline Construction Coordinator
[10] Geologist, USP; Chief Manager for Sustainable Development
[11] Electrical engineer, PUC/MG; Head of the Ore Pipeline Operation Department

By obtaining the ISO 14001 certification in 1998, Samarco became the first mining company in the world to receive this certification for all stages of its production process. Since then, objectives and goals relating to corporate commitments and actions to be implemented with a view to continually improving its process are set from time to time. Whenever these objectives and goals are reviewed, the management of water resources are addressed in order to reduce consumption or improve the quality of effluents.

At internal level and in the communities where it operates, Samarco promotes awareness campaigns and rational water use. In Minas Gerais, the company monitors the performance of three River Basin Committees – Doce river, Piracicaba river and Piranga river. In Espírito Santo, Samarco participated in the establishment of the Benevente River Basin Committee.

Water is a key input in Samarco's production process, and it is caught for use at the Germano unit from two sources: the Piracicaba river (fresh water), which is a tributary of the Doce river, and the Santarém dam, which is 11 km from the processing plant. This is a retention dam on the Santarem stream, one of the watercourses on the Piranga river basin. An additional catchment takes place on the Matipó river, also located on the Piranga river basin, for use at the Bombas II Station, which lies 154 kilometers away from the pipeline.

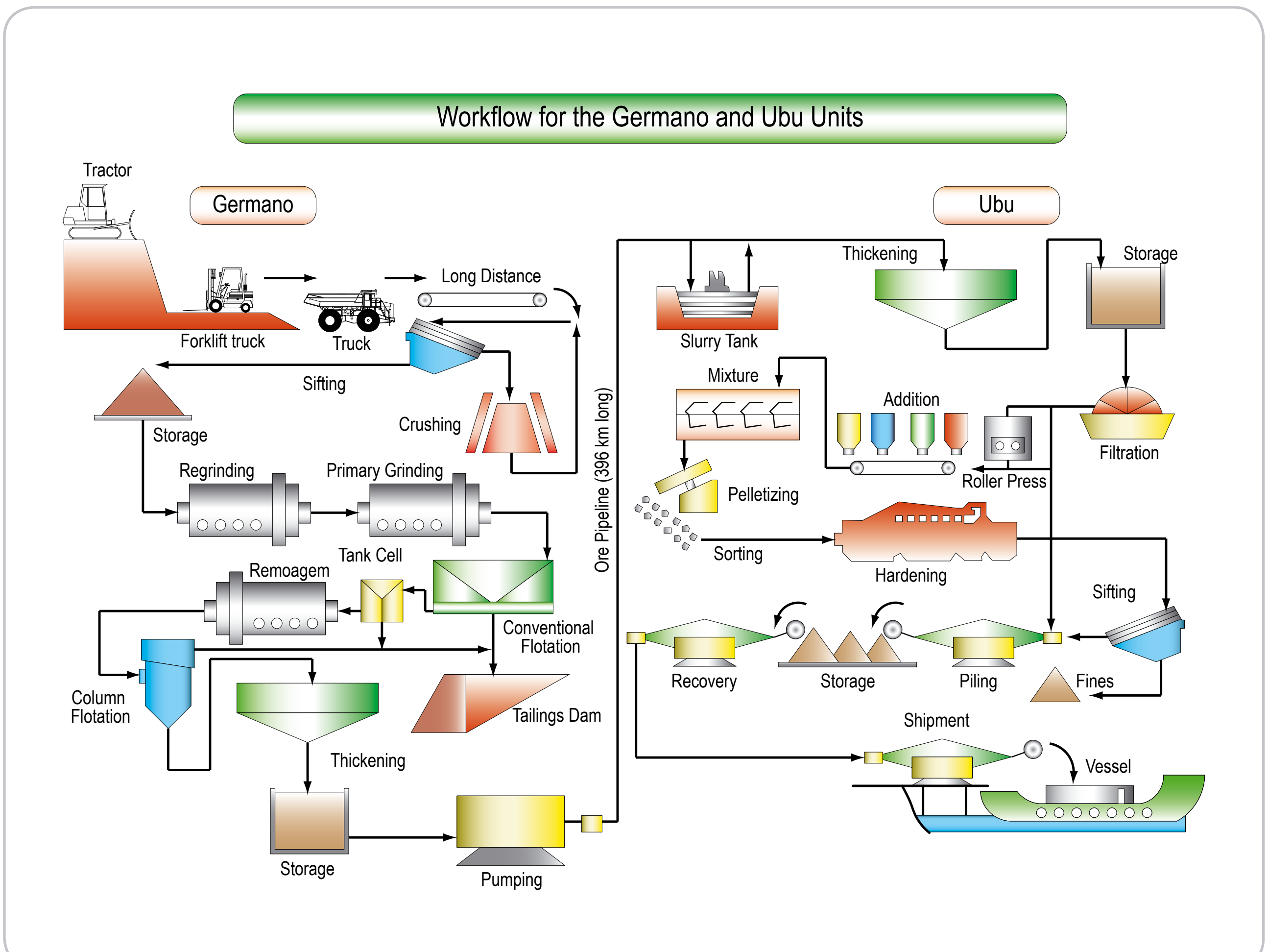

Figure 32a. Samarco's production workflow at the Germano and Ubu Units

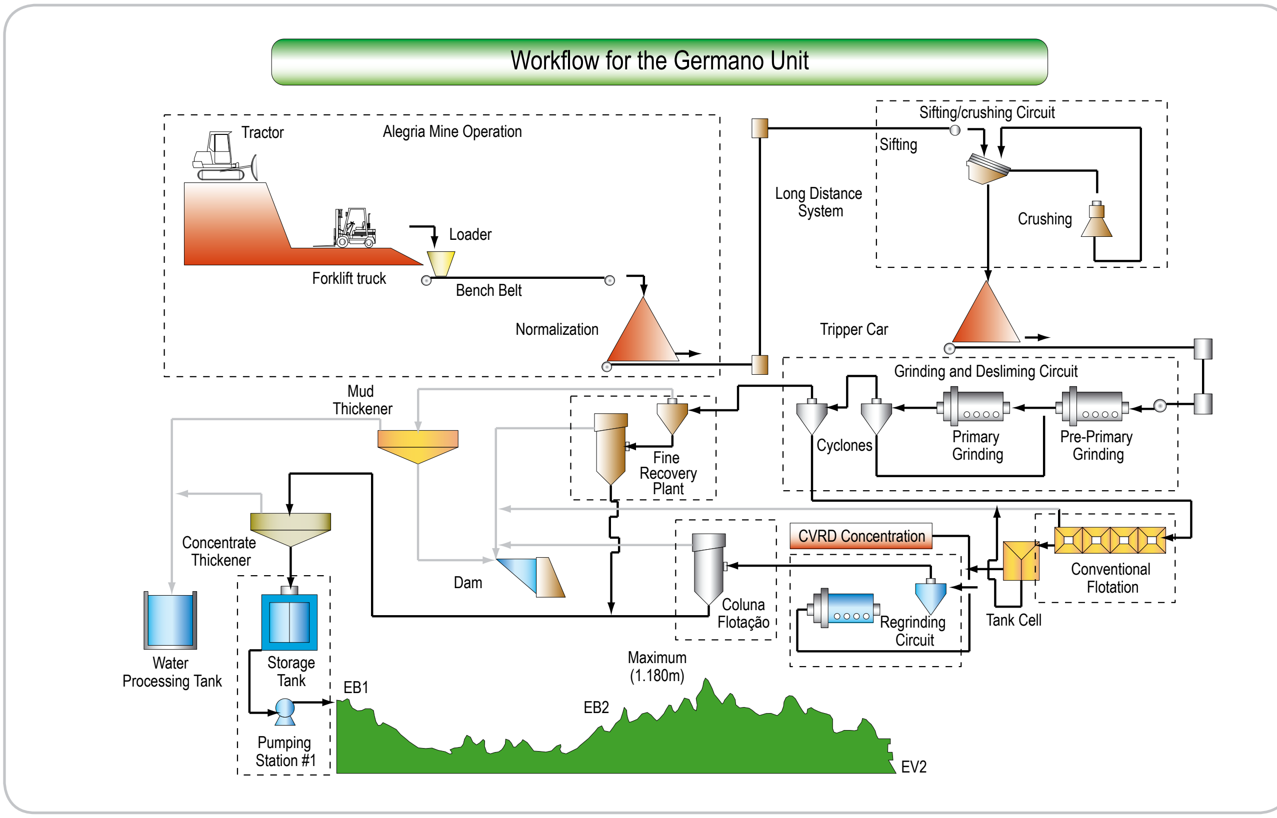

Figure 32b. Workflow for the Germano Unit

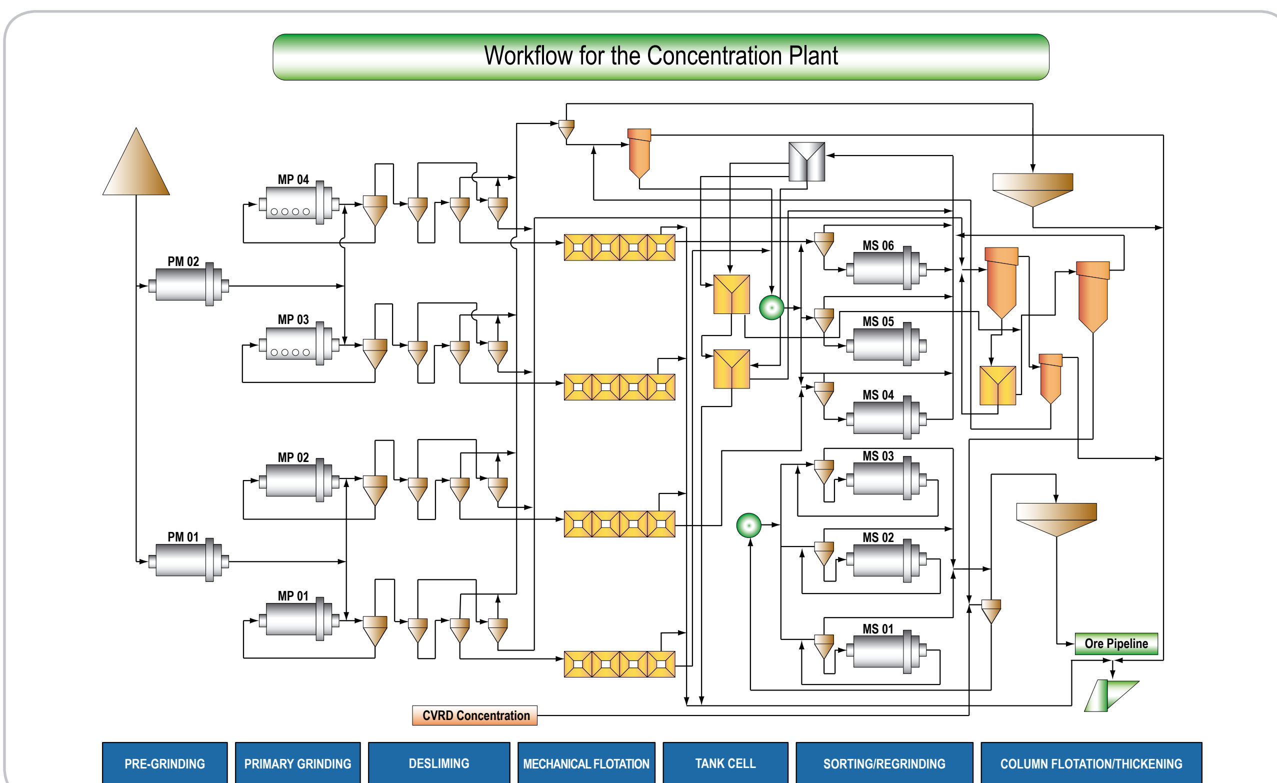

Figure 32c. Workflow for the concentration plant

Photo: SAMARCO's archive

Photo 33. Germano Industrial Unit

2 SLURRY PRODUCTION

The ore from Samarco's mines is primarily comprised of quartz and hematite particles. The quartz particles are useless in the subsequent steelmaking processes, so the ore must be processed for this material to be removed. This takes place in the processing plant, where ore particles are broken into smaller particles and quartz is separated. This process generates two products: a concentrate product, which is transported along the ore pipeline to the Ponta Ubu unit, and the waste, which is released into the Germano dam.

3 THE SAMARCO ORE PIPELINE

Ore pipelines have been used for a long time to transport solid particles, but its use is particularly attractive when the distances are long and ore processing is done in a wet environment.

The Samarco ore pipeline was the first pipeline in Brazil to carry iron ore slurry; it became operational in May 1977 as it carried concentrate produced at the Germano mine processing plant to the Ponta Ubu pellet plant in Espírito Santo. It is 396 kilometers long and consists of two pumping stations, two valve stations, a nozzle station, and a terminal station. Because it is a duct, there are no environmental impacts resulting from loss of materials associated to its transportation routine. The use of electricity for the operation of pumps reduces the costs and impacts associated with the use of fossil fuels.

Photo 34. Ore pipeline, km 0

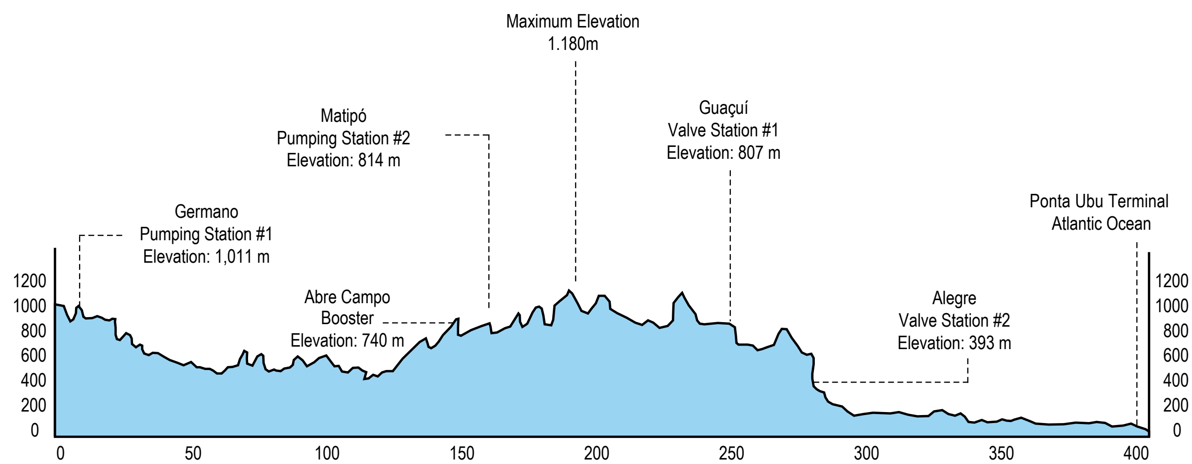

Figure 33. Ore pipeline profile

The pipeline lies along a right-of-way that is 35 meters wide and covers 24 municipalities in Minas Gerais and Espírito Santo. Of its total length, over 99% of its structure is buried.

Studies and actions implemented to optimize its operation make it possible to transport slurry containing 70.38% of solids (2004 data), while its initial specification provided for operating conditions where the percentage of slurry solids would be between 60% and 70%.

In addition to those in the stations, the pipeline has eight pressure monitoring points along its length. All points provide information for operational control and also for the leak detection system, which is a system for satellite-based data transmission that makes it possible for all stations to be managed from a centralized location. This, together with the data presented on-line, allows a high level of security and reduced levels of impact caused by any leaks, since the pumping can be interrupted immediately, and leaks can be detected with a high degree of accuracy.

Leaks are prevented by protecting the walls of the pipeline against the corrosion caused by its interaction with the ground – the pipe is coated with a PVC tape and cathodic protection, which prevents corrosion associated with the soil's pH levels. The correct functioning of the protections is monitored by periodically checking the thickness of the pipe's walls.

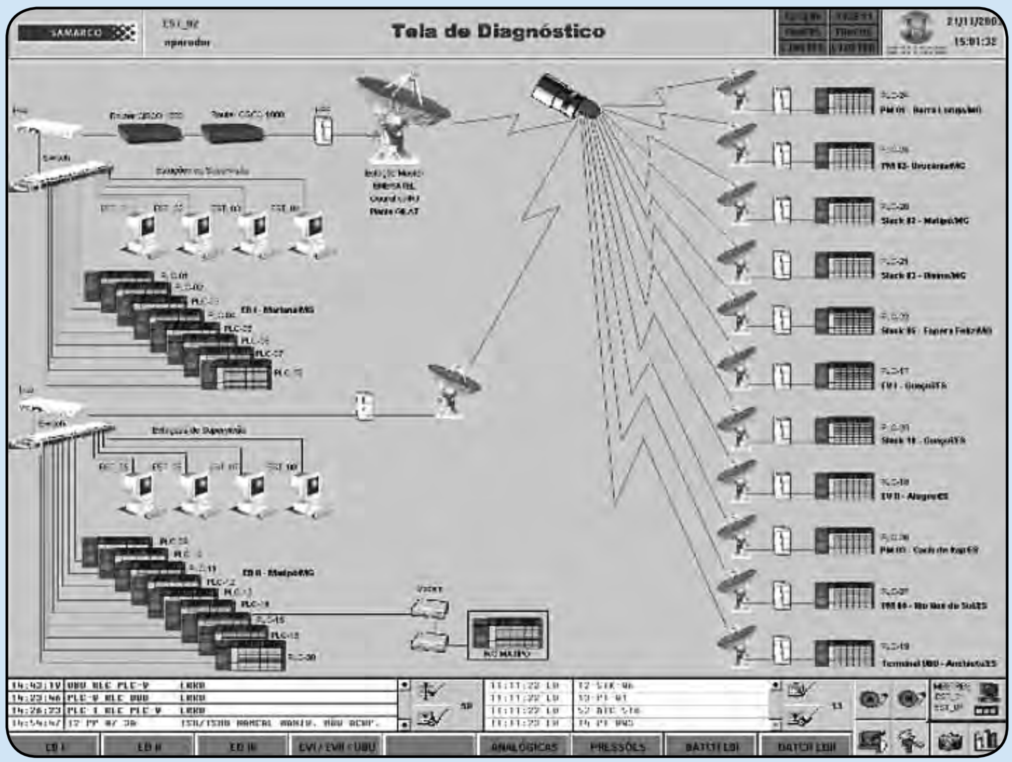

Figure 34. Satellite-based monitoring system

The pipeline currently operates satisfactorily, at a level that is better than expected for projects, as a result of the implementation of plans for preventive and predictive maintenance of improvements in operational control, reduced corrosion rates, and systematic control of the pipe thickness. Achievements include:

- increased life: according to the initial forecast, the pipeline would last for 20 years, and its expected lifetime is now 42 years;
- pumping capacity: the expected capacity was 12 million tons of slurry per year, but the pipeline is currently operating at a pumping capacity of 15.5 million tons.
- availability: this can be defined as the time during which the equipment can be operated. Initially designed to be available for 93% of the time, the pipeline is currently operating at 99% on average.

To mitigate environmental impacts from operation of the pipeline, the following measures have been taken:

- periodical environmental inspections that are based on checklists that cover the most important topics, such as waste generation and collection control and removal of water leakage spots.

- wide dissemination of a Pipeline Safety Manual, which includes actions to be taken in case of operational emergencies. This manual provides responses for leaks, clogs and third-party actions, among other issues.
- implementation of a maintenance program for the right-of-way whose purpose is to maintain integrity of the pipeline while seeking to minimize environmental impacts on the right-of-way.
- implementation of a Leak Detection System (LDS) whose primary purpose is to minimize environmental impacts that may result from leaks.

Among the management actions related to consumption of water resources implemented at the Germano unit, the increase in the percentage of slurry solids pumped through the pipeline is directly associated to reduced catchment from the Piracicaba river. This is so because in comparison with process-related losses and consumptive uses of water by the company, the transportation of the concentrate accounts for the largest share of water outflows from the unit. The decrease in the percentage of water in the slurry means a smaller water output from the processing stage and, as a result, a decreased need for fresh water inputs.

This chapter discusses the actions that allowed the operations in the Germano unit to achieve results that account for the ongoing improvement of water use levels, including operation of the pipeline.

4 SAMARCO'S WATER RESOURCES MANAGEMENT

4.1 METHODOLOGY

Water use improvement is based on data that demonstrate the interaction between water and the production process. A balance sheet showing the inputs (catchments) and outputs (effluents and spillways of dams) of water in the unit shows the potential for increasing water recirculation in Germano's internal areas, which prevents it from being released and subsequently being repumped from the Santarém reservoir. In spite of also storing drainage water, this reservoir receives water primarily from the Germano dam, which is used to retain the tailings generated by the production process. As a result, greater use of the water stored in the Santarém reservoir – most of which derives from the effluents in the Germano unit – entails a reduced need to catch water from the Piracicaba river, which is considered to be fresh water for this process.

Below are the actions related to the target established in 2001 to reduce specific consumption of the water caught from the Piracicaba river and the Santarém dam by 35% based on the amount of water caught in 1999. This target dates back to 2000, and it was a revision of a proposal made the previous year for a twenty-five-percent reduction. Based on the checking, analysis and process adjustment work in the area, an even more challenging target was put forward and approved.

4.2 IMPROVEMENT ACTIONS

The actions toward achievement of the target were initially based on a diagnostic survey carried out in 1999. The resulting report contained 31 items for improvement, including an item that was considered a priority: water recirculation during the process.

4.2.1 WATER RECIRCULATION SYSTEM

Considered to be a key factor for the achievement of significant results, many of the actions for the improvement of Samarco's water system focused on the processing stage.

Concentration of iron ore is a wet process where water is used during the steps of ore grinding, removal of sandy tailings (flotation), classification of the particles in the material being processed (cycloning), and preparation of the slurry concentrate on thickeners.

Water reuse in these processes has a major impact on reduction of the water catchment at the source.

The water recirculation system had been deployed previously, and it received investments to increase its efficiency. Actions implemented include installation of the third pipe in the system (investments worth US$350,000) and two additional pumps for recirculation (investments worth US$60,000). As a result, water recirculation increased by 11.8% when comparing 1999 with 2004.

In order to make information more readily available and more reliable, flow meters were installed at catchment, recirculation and consumption points, which made it possible to generate data online. Investments during this phase totaled US$80,000.

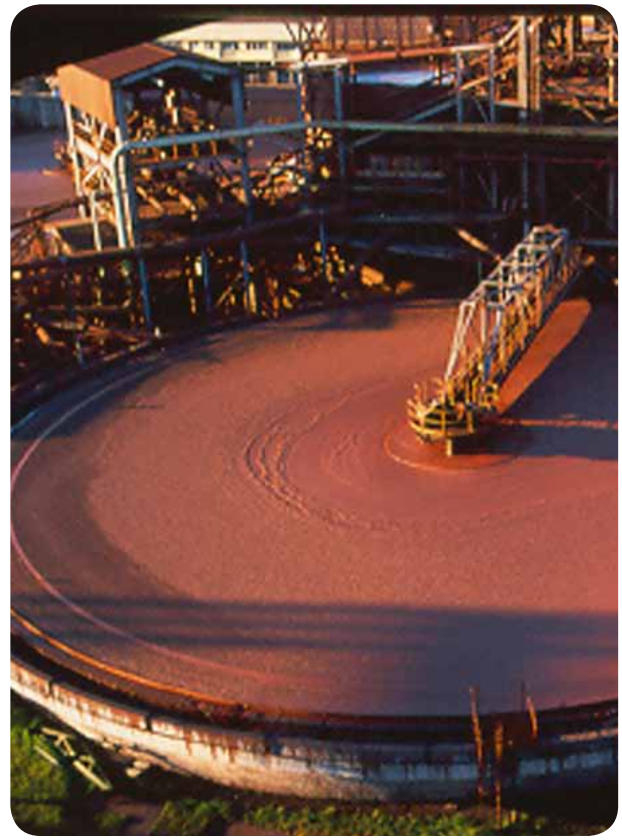

Photo 35. Thickeners

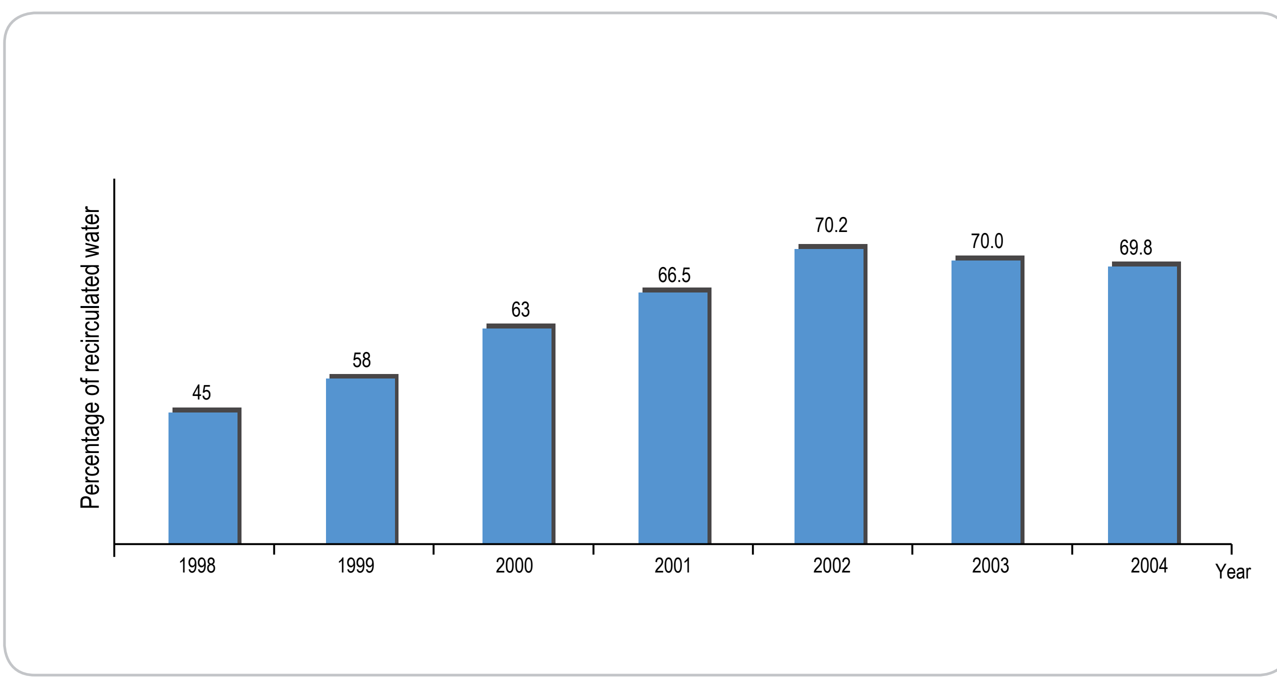

Figure 35. Water recirculation percentage evolution during the process

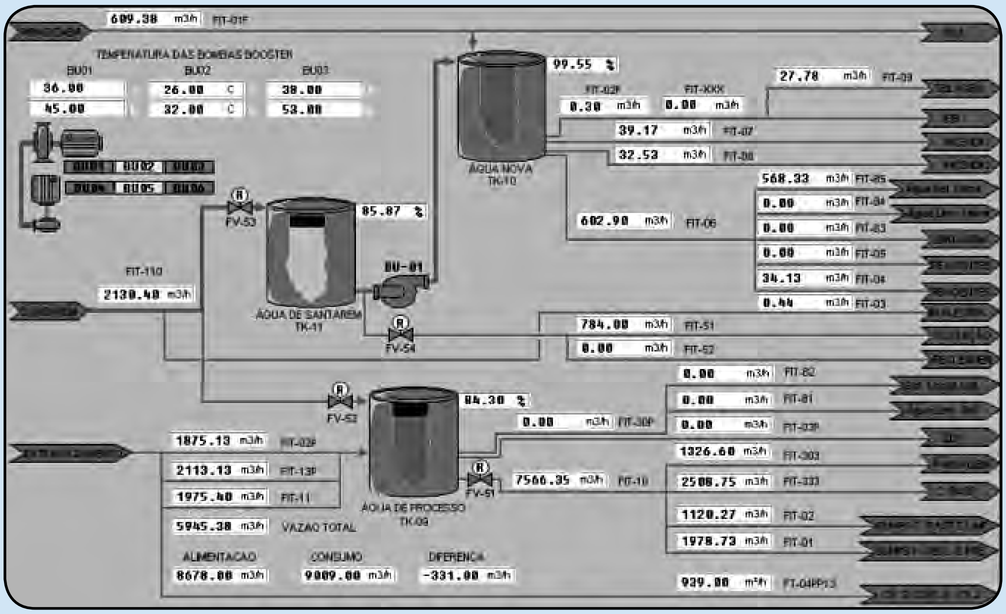

Figure 36. Summary of the Germano water system

To ensure that improvements are implemented to the water recirculation system, several actions aimed at reducing specific water consumption at the Germano unit were conducted between 2001 and 2004.

- Increased availability of recirculated water

To obtain water to increase reuse in the process, the amount of water in the concentrate slurry was reduced, which is carried through the pipeline, and also the tailings from ore fines that are released into the retention dam (Germano dam). As a result of a decreased amount of water that is derived from the process through the effluent from the plant and the concentrate slurry, a greater amount of water is available for recirculation. Enhanced pumping capacity made it possible to increase this amount.

Density of the ore concentrate slurry increased by 2.36% since 1999, reflecting a reduction in the amount of water flowing through the pipeline by 0.0431 m3/t of concentrate produced.

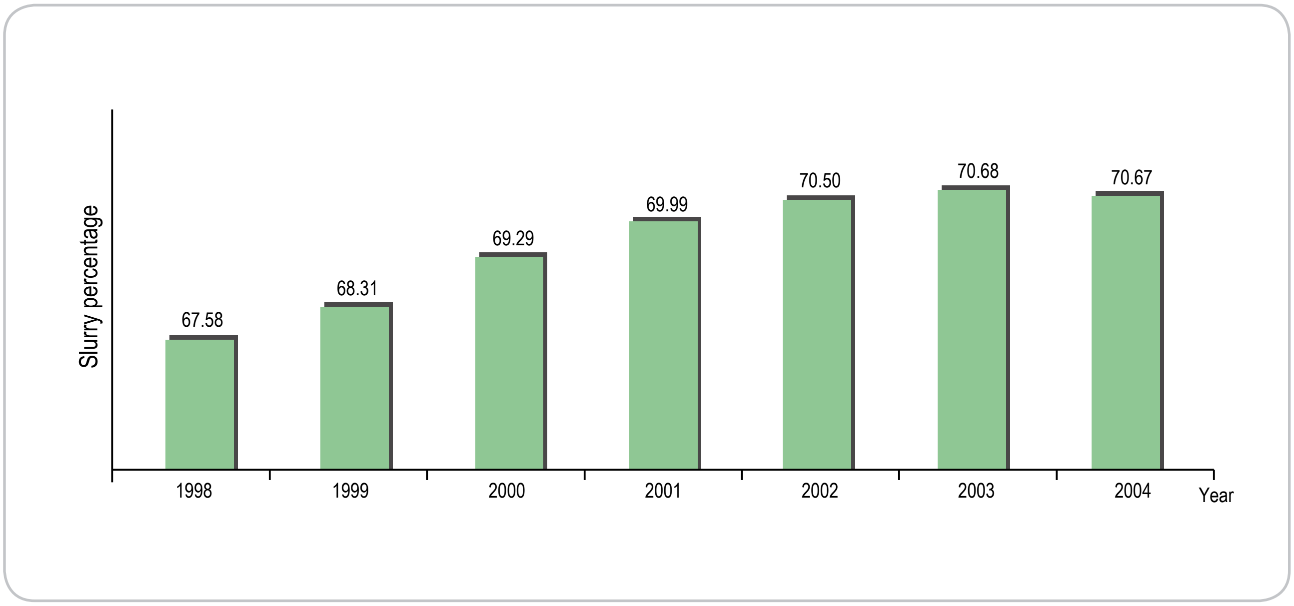

Figure 37. Percentage of slurry solids flowing through the pipeline

- Implementation of a daily water balance

  The daily balance quantifies all water inflows, recirculations and outflows at the Germano unit. This balance also helps monitor specific consumption of water in the process on a daily basis.

Photo 36. Santarém dam

Photo 37. Germano dam

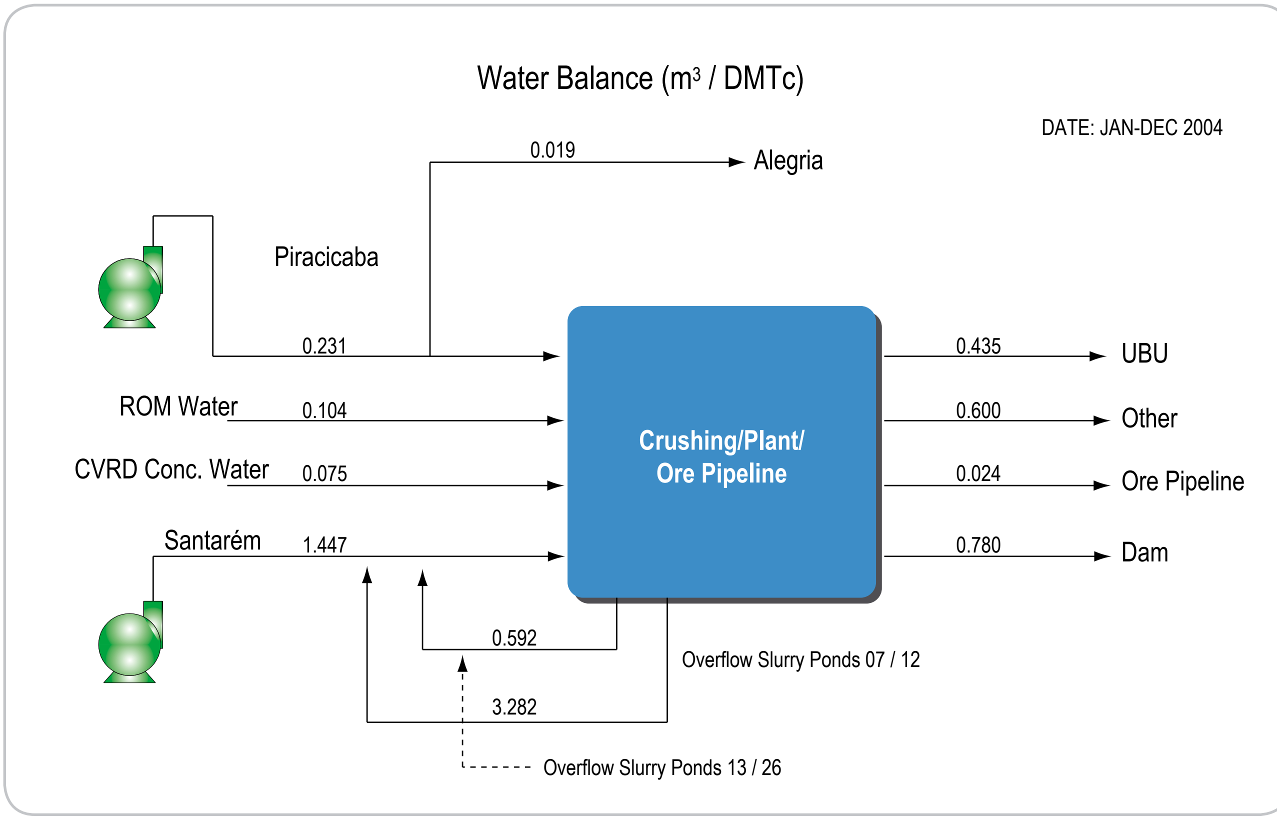

Figure 38. Water balance at the Germano unit

- The water collected from the Piracicaba river accounts for approximately 4% of water inputs; in addition to being used during the processing stage, a part of it is diverted for purification and use by the staff of the Germano unit.
- The moisture content in the mined ore (ROM) is put down to the water balance. Other water inflows from sources other than Samarco's catchment that are associated to products are also accounted for. These correspond to about 2.2% of the water entering the process.
- The dams have the function of retaining the tailings from the process and storing the water from the effluents and its drainage area. The effluents released into the Germano dam are treated (i.e., retention of solids and clarification) and move on to the Santarém dam.
- The water stored in Santarém corresponds to approximately 24% of the water entering the process, and it is pumped for reuse. The water poured through the dam feeds into the Santarém stream. A bypass in the dike ensures minimum flows for the stream during the drought season.
- The concentrate slurry, i.e., the final product from the ore processing stage, is channeled to tanks and pumped to the Ubu unit. The pipeline carries about 7.6% of the water fed into the processing activity.

4.2.2 INTRODUCTION OF SPECIFIC WATER CONSUMPTION IN THE PROCESS AS AN ITEM FOR ROUTINE CONTROL

Specific water consumption in the process refers to the sum of the amount of water caught in the Santarém dam, the water abstracted from the Piracicaba river and the water recirculated internally divided by the iron-ore concentrate output – the final product from the Germano unit. Once the control for this parameter was integrated into the unit's routine and specific goals were set as a result, reporting and implementation of corrective actions, the specific consumption of water in the process was reduced by 13.7%.

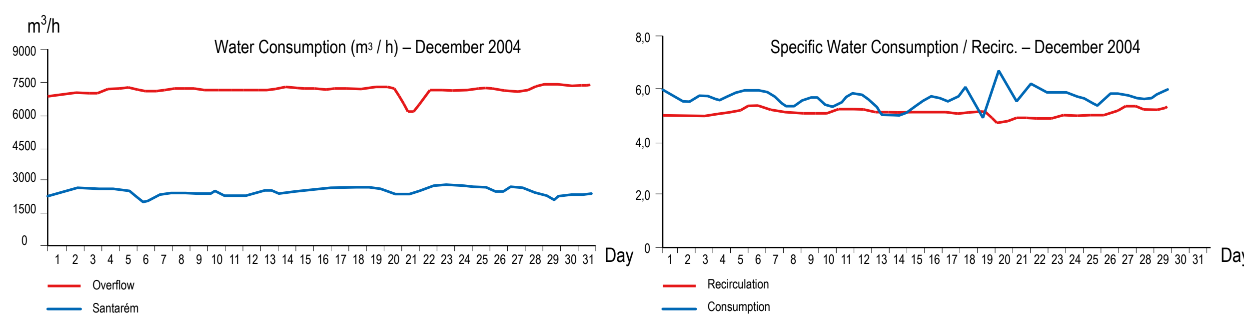

Figure 39. Ore processing parameters that are monitored on a daily basis

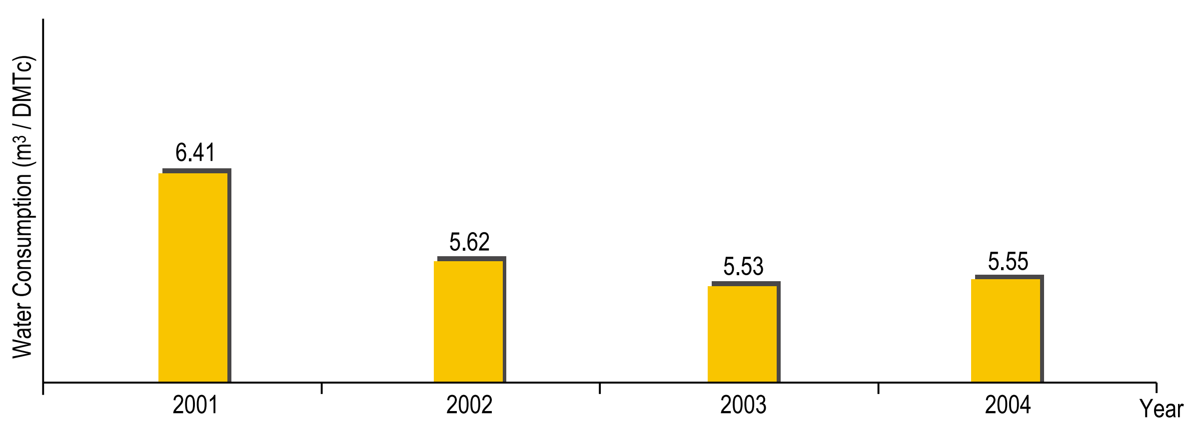

Figure 40. Specific water consumption in the process

In addition to specific water consumption in the process, other parameters are monitored to ensure that the generated data can support decision makers in the search for improved systems. When considered together, these parameters make up themes, which in turn make up a controlled environment indicator and are submitted to all divisions of the company on a monthly basis.

The theme of water resources is comprised of six elements, and three of these are related to water consumption in Samarco's production process. Each element, in turn, breaks down into parameters whose characteristics are consistent with the theme.

The individual parameters are given a score according to the measured result for the period. The total score for each element relative to the maximum possible score defines the result of the month for the theme. The minimum percentage for each theme is 80%.

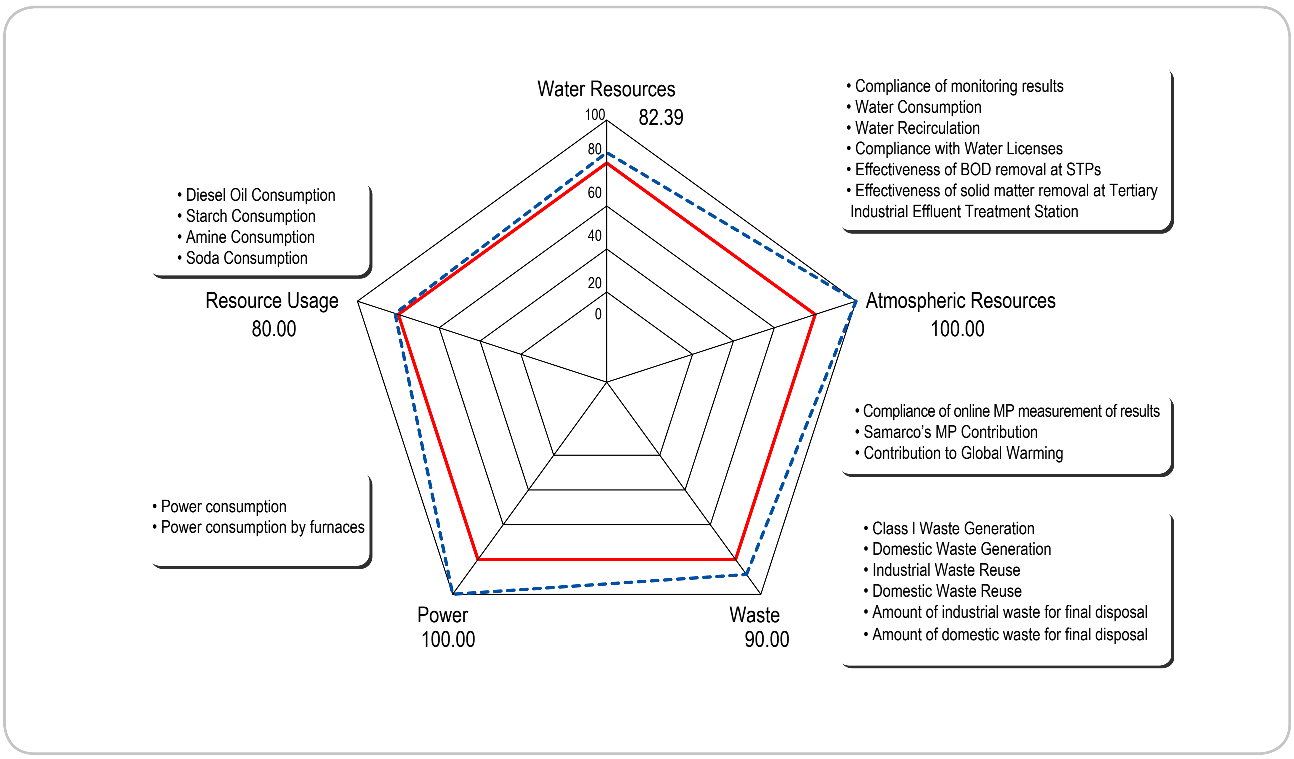

Figure 41. Environmental indicators monitored on a monthly basis

4.2.3 INTERNAL CAMPAIGNS ON RATIONAL WATER USE

For positive results to be consistently achieved, the participants in the process must be aware of the importance of new practices and the benefits derived from the results.

Environmental education campaigns focusing on the responsible use of water resources have been prepared and presented to Samarco's employees and contractors.

In conjunction with the campaigns, another important tool was a program called Campo de Ideias (Field of Ideas), in which those employees whose ideas come to be implemented receive cash prizes.

The ideas must lead to gains in at least one of the following domains: quality, service, cost, occupational safety, organizational climate, and the environment. Among the actions implemented with an environmental focus, the water theme was included in both the issue of correction of small leaks and changes to the production process (this case study for instance).

Foto: Arquivo SAMARCO

Photo 38. Ubu Port (Espírito Santo)

Figure 42. A brochure and poster used in internal campaigns

4.3 IMPLEMENTATION OF A WATER AND ENERGY USE PROGRAM

Samarco developed a program for the rational and efficient use of water and energy in the Water/Waste System at the Germano Unit. This program is still underway, and its purpose is to implement improvements in order to increase the rate of rational use of water and energy. It includes four stages:

- profiling of energy consumption in entry and exit points of the water tank;
- an analysis of the repowering of electric pumping equipment for the overflow;
- an analysis of hydraulic loss reduction in the system;
- an assessment of the potential energy savings by using variable speed pumping.

5 FINAL REMARKS

The actions implemented in the company's production process show a decrease in specific the consumption of water caught from the Piracicaba river and the Santarém dam, rationalized use that comes to 31.4% of the total water consumed in 1999, when the reduction target for specific consumption of water was set by the company. As a result, in 2004 catchment of about 12,000,000 cubic meters of water was no longer required, considering the production for the period. This production shows that in 2004 approximately 3,000,000 cubic meters of water from the Piracicaba river were not caught (baseline: catchment figures, 1999).

As the density of the slurry pumped through the pipeline jumped from 68.31% to 70.38%, in 2004, the annual water pumping requirement to Ponta Ubu fell by approximately 320,000 cubic meters in comparison with figures for 1999.

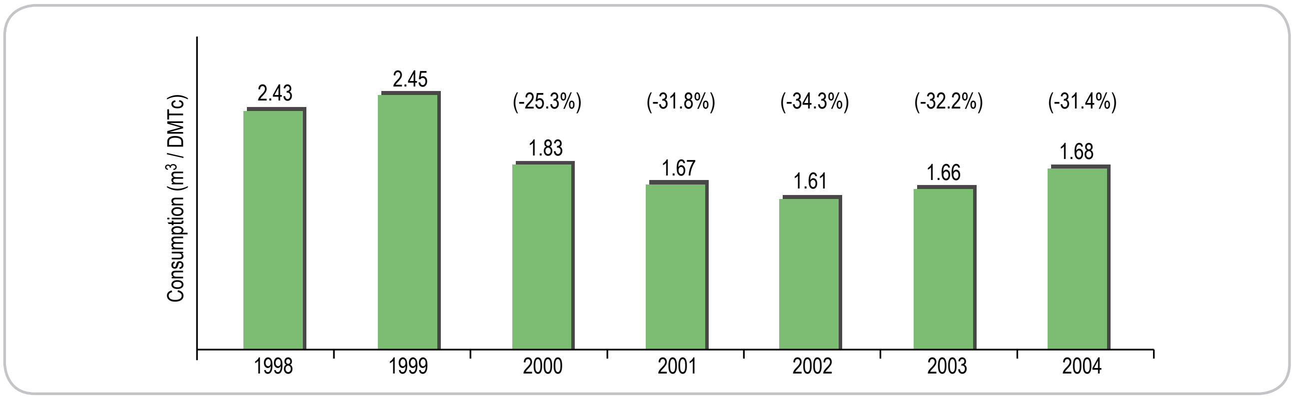

Figure 43. Variation of specific water consumption at the Santarém Dam and Piracicaba River

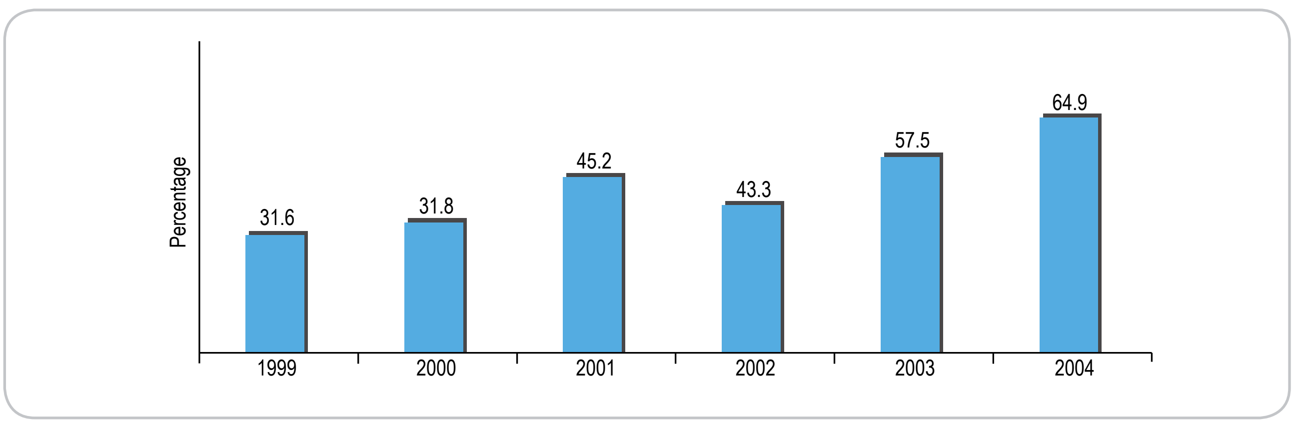

Figure 44. Percentage variation in rationalization of water catchment from the Piracicaba river

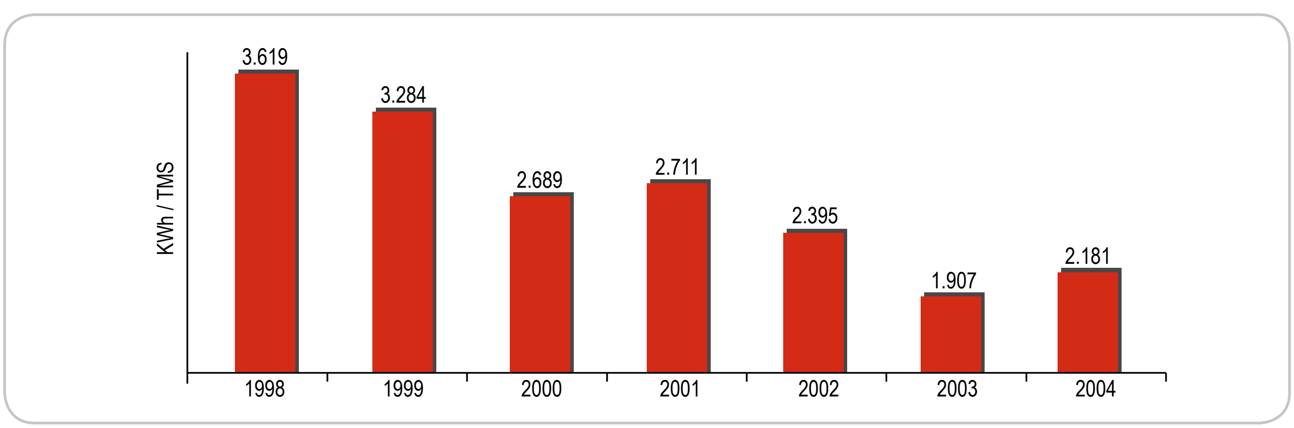

Figure 45. Variation in specific power consumption in the water system

Photo: Ecotrópica

Dario Valiati[1]
Dário Moraes de Almeida[2]

MANAGEMENT OF WATER RESOURCES IN COAL MINING – TREVO MINE CASE STUDY, SIDERÓPOLIS, SANTA CATARINA

1 INTRODUCTION

The Santa Catarina coal basin is located in the southern side of the state (see Figure 46), with a direct impact on three watersheds, namely the Araranguá, Urussanga and Tubarão river basins (see Figure 47).

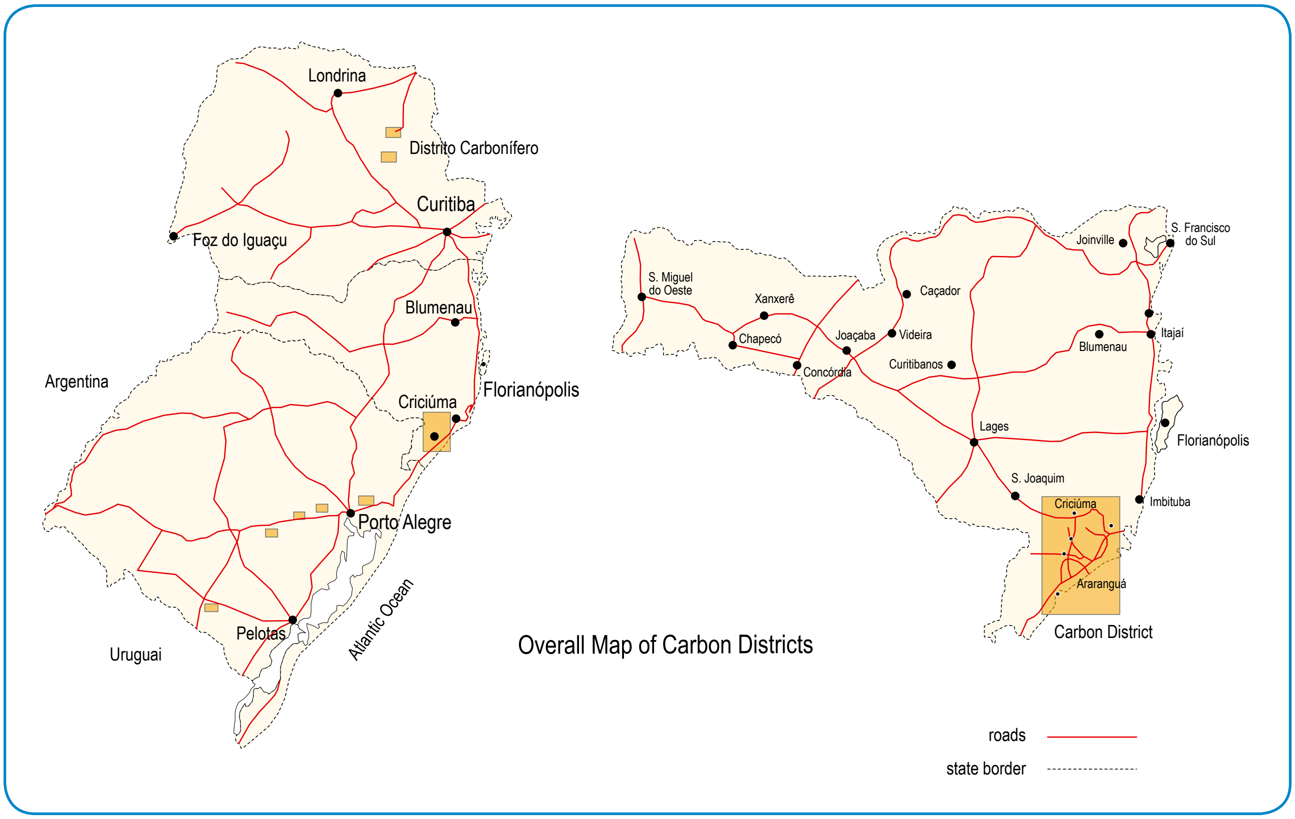

Figure 46. Location of Santa Catarina's Carbon District

[1] Geologist, advisor with DNPM/11º DS, Criciúma, Santa Catarina.
[2] Mining Engineer with DNPM/11º DS, Florianópolis, Santa Catarina.

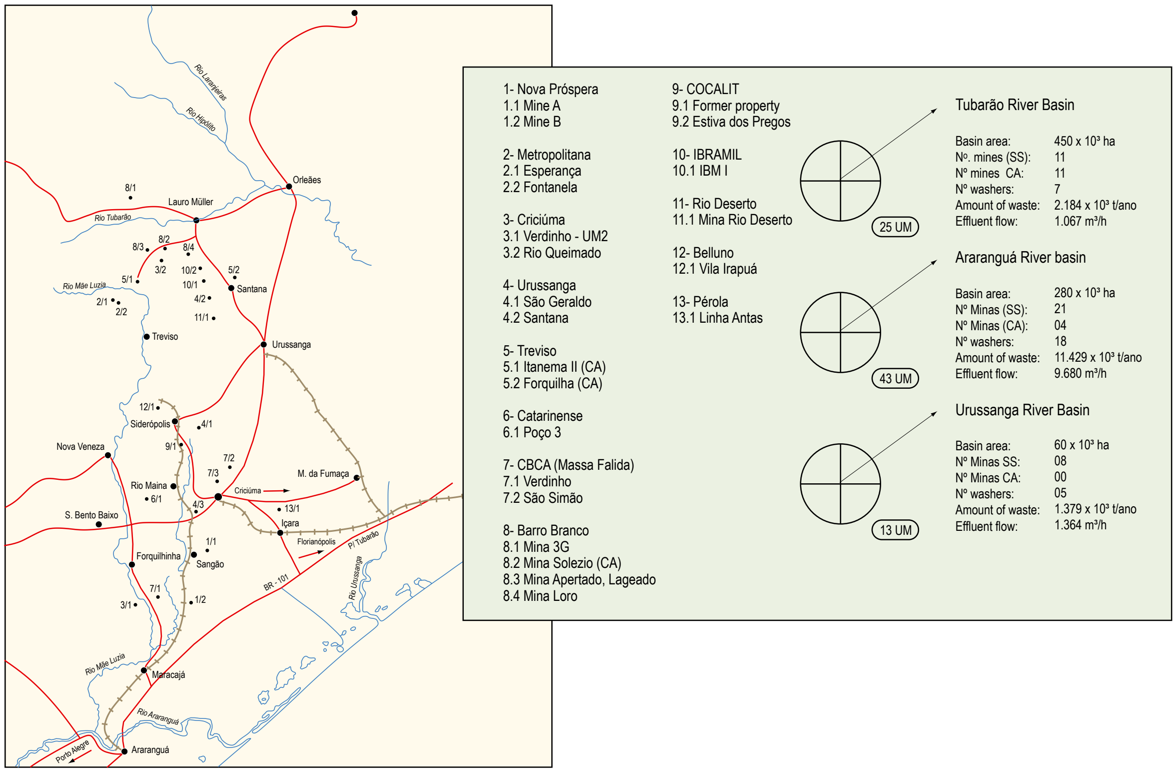

Figure 47. Location of mines and watersheds across the coal extraction areas

The commercial coal seams can be found at the top of the Rio Bonito formation and are called, from top to bottom, Barro Branco, Irapuá and Rio Bonito. The Barro Branco seam reaches the entire coal basin and has been mined for over a century. It lies 10-20 m below the interface between the Rio Bonito and Palermo formations, followed by the Irapuá and Bonito seams with a smaller area – 15 and 50 m below, respectively (see Figure 48).

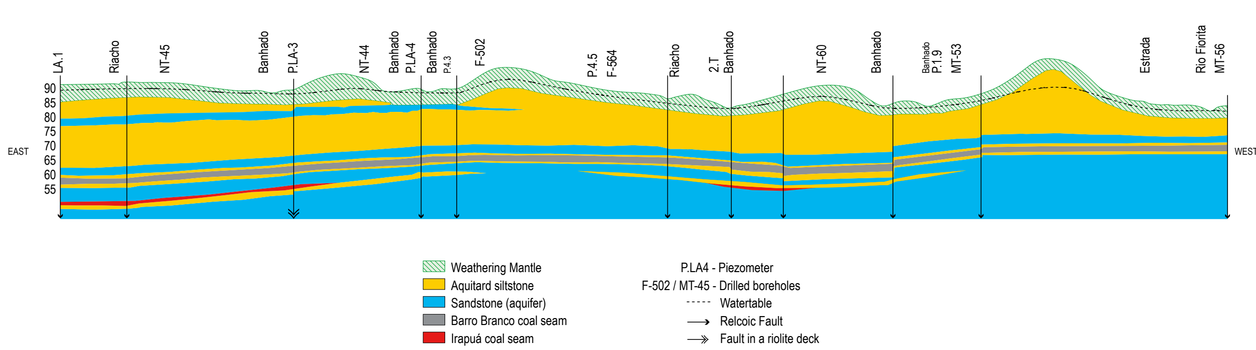

Figure 48. Stratigraphic profile of the Trevo mine (ICDR, 2001)

Coal mining currently takes place in 14 mines, eight of which are underground and six are open pit mines.

When coal mining activities started in the region, the open pit mining operations were conducted with large equipment where the maximum depth of the coal seam was 25 meters, without rehabilitation of the mined area. Upon completion of the mining operation, large flooded pits formed as the result of the upwelling of groundwater. The room-and-pillar method was used in the underground mines, with the blasting of pillars, so the pillars formed after the opening of parallel and perpendicular galleries were also mined, thus making the rock mass unstable. The blasting of pillars caused subsidence and fracturing of cover rocks and, as a result, groundwater would flow into the mines.

Both the underground and open pit mining methods generated acidic effluents as water came in contact with the sulphides contained in the underground coal seam or with carbonaceous tailings deposited in the pits. The water carried from underground to the surface turned into acidic effluent and was released into the receiving drainage system without any treatment, and this was also the case with the acidic effluents from the open pit mines.

In the 1970s, the Brazilian Federal Government implemented the Energy Mobilization Plan (PME), which aimed to significantly increase coal extraction with a view to tackling the crisis caused by the sharp rise in oil prices in the international market.

Approximately twenty million U.S. dollars were spent by the federal government in research programs that blocked areas where large mines were mechanized. Establishment of these mines was also funded by the government and it increased the extraction of run-of-mine (ROM) (crude ore), which jumped from 3,506,314 tons in l970 to 19,781,089 tons in 1985.

At the time, there was no proper concern with the fact that increased coal extraction and processing brought about a sharp rise in the amount of effluent acids from the process. As a result, on September 25th, 1980, through Decree No. 85206, the coal region was designated the 14th National Critical Area for Pollution Control and Environmental Quality. By that time, all watersheds in the coal extraction area had been affected.

On July 6th, 1982, Interministerial Directive 917/MME-Minter-MIC established that the companies involved in coal mining and processing should submit executive projects for the construction of controlled waste disposal sites and the operation of closed-circuit processing plants and subsequent treatment of resulting effluents. However, the technical procedures described in the projects were not fully implemented by the mining companies, so the quality of drainage failed to improve substantially. Even today this continues to cause problems to the region, especially for public water supplies.

In view of this, the National Mineral Production Department (DNPM) set out to implement new coal mining procedures, with the primary purpose of preserving groundwater and surface water resources, as well as reducing the amount of acidic effluents from the mining activities.

Thus, in the early 1990s mining companies were required to change their mining methods – a ban was put on pillar blasting methods, thus avoiding subsidence and fractured rock covers (see Figure 49).

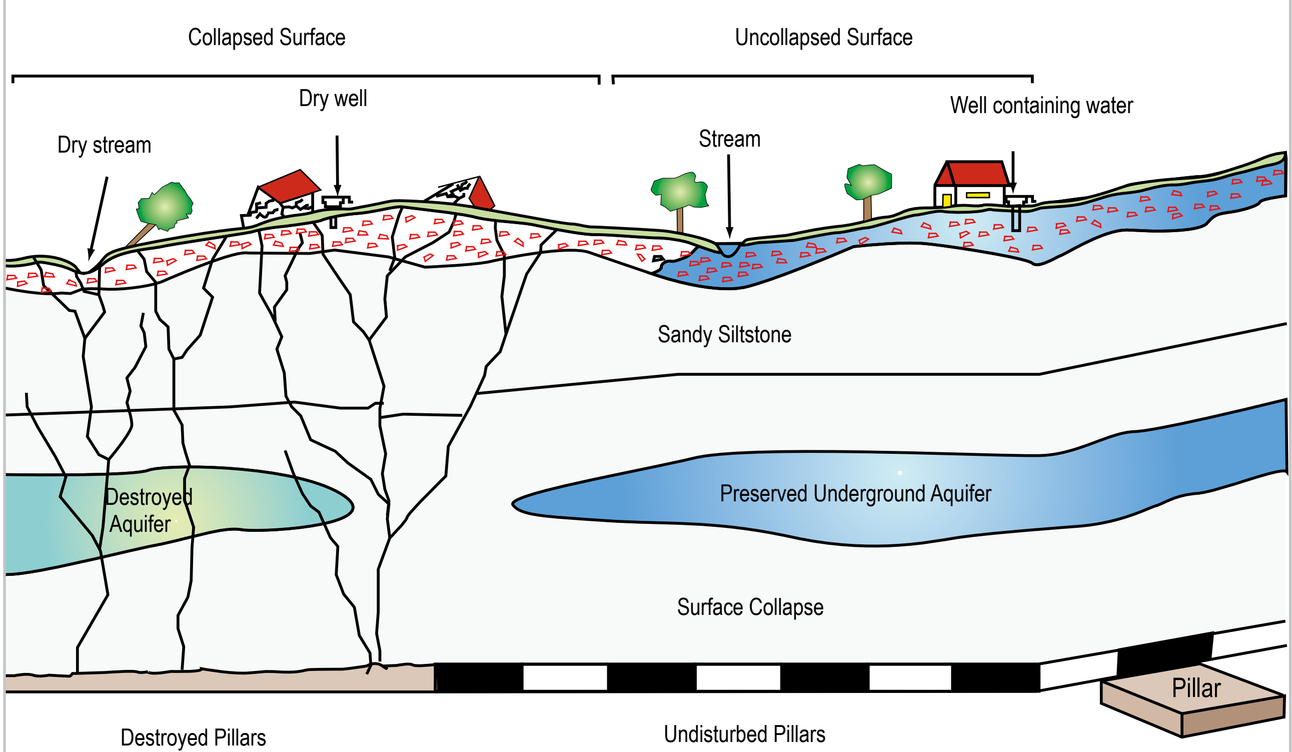

Figure 49. Underground mine profile with and without the restoration of pillars

This measure also proved efficient in reducing the amount of acidic effluents that resulted from the mining operations. This was not enough, however, to bring about a substantial improvement in water quality standards as measured in the water receiving the effluents. It follows from this that the mines should be systematically monitored in order to enable preventive actions for the preservation of the water bodies in the vicinity of the mining activities.

Also in the 1990s, in relation to open pit mining, DNPM put a ban on lithological inversion for the removal of the coal seam. This requirement was intended to prevent the burial of clay and organic soil and, consequently, exposure of sulphide-rich rocks to air oxidation, causing the water and soil to be polluted.

Another measure taken was related to decommissioning of operations. Thus, it was required that upon completion of coal mining operations the rock cover were placed back in their position in the reverse order of extraction for topographic reconstruction purposes. A subsequent requirement was to make the cover with the clay and organic soil previously stored and replant the area for its protection against erosion and its reintroduction into the landscape.

The Trevo mine discussed in this case study is operated by Indústria Carbonífera Rio Deserto Ltda (ICRDL) and is located in the municipality of Siderópolis, near the Mãe Luzia river, a major drainage system in Araranguá river basin. For its implementation back in 1998, new requirements were made for approval of the mining technical project, thus putting in place in the region a new system for the management of groundwater and surface water at coal mining operations.

2 MINING ACTIVITIES IN THE TREVO MINE (SS)

2.1 GEOLOGICAL PROFILE

The relevant coal seam is called Barro Branco and its cover within the mine's area ranges from 20 to 180 meters. The seam inclination is 1 degree towards the southwest, and this can be steeper locally. The variation in the thickness of the cover reflects the presence of a topographic high where the rock formations Palermo (siltstones) and Irati (shales) crop up from bottom to top, the latter having diabase on its top. This geological formation houses water in three different situations:

- At higher levels, such as low-permeability springs interfacing the Irati formation overlapped with the diabase. The water is stored in fractures of the dia-

The National Mineral Production Department (DNPM)

The National Mineral Production Department (DNPM) was established on March 8th, 1934 through Decree 23979, under the Ministry of Agriculture. In 1960, when the Ministry of Mines and Energy (MME) was created, the DNPM became subordinated to this Ministry.

The DNPM is currently a federal self-governing parastatal agency, established by Law No. 8876 of May 2nd, 1994, under the Ministry of Mines and Energy, with economic, administrative and financial independence. It is based in Brasilia, in the Federal District, and its jurisdiction covers the entire national territory.

The objective of the DNPM is to foster planning and promotion of mineral extraction and mineral resource processing, and to supervise geological, mineral and mineral technology research, as well as to ensure, monitor and oversee mining activities throughout the national territory in accordance with the Mining Code, the Code of Mineral Waters, the relevant regulations and their supporting legislation.

The mission of the DNPM is to manage Brazil's mineral wealth in a socially, environmentally and economically sustainable manner by using regulatory tools for the benefit of society.

base, and through the springs it perpetuates the surface drains that flow to topographically lower levels.

- Free groundwater, fed by rainfall water and surface drainage when it is stored in the soil and in altered Palermo formation siltstones. This water forms a reservoir with unchanged, low-permeability siltstones underneath it and, in conjunction with springs and reservoirs, supports the activities conducted by the dwellers of the mining area.
- a confined aquifer, stored in the sandstones of the Bonito river between the top of the Barro Branco seam being mined and the interface between this formation and the Palermo formation. The behavior of this aquifer changes during the coal mining activities, when the sandstones are exposed in the ceiling of the galleries in the form of intense dripping, without affecting the surface waters and the groundwater.

Structures such as diabase fractures, faults and dikes that cut the sequence of sedimentary rocks sub-vertically may, depending on their characteristics, hydraulically connect the surface water and groundwater with galleries in the underground, causing them to lower or disappear.

Technical profile – Trevo mine (SS)

- Setup date: 21 January 1998
- Production start date: June 1998
- Barro Branco coal seam
- Mining area: 3,789,390 square meters
- On-site reserve: 14,005,000 t
- Mining method: blast-free rooms and pillars
- Estimated annual production: 912,000 tons of ROM
- Mine life: eight years
- Access to the underground: two inclined planes (galleries) and one vertical well (ventilation and emergency exit)

2.2 THE MINING PROCESS

The mining of coal in the Trevo mine (SS), which now relies on a new system for the management of groundwater and surface water for coal mining (see description in the next section) is performed by building a shaft that is comprised of ten parallel galleries and is strategically positioned in relation to the mining area. Panels, i.e., quarries, are developed from the shaft and perpendicularly to it, with twenty galleries.

Photo 39. Trevo Mine

Each panel has a belt that carries the mining output to the shaft. Once on the shaft, a higher-capacity belt receives the ore from all panels and carries it to the surface, where it is processed (see Photo 39). The panels are physically separated, each with a pump that transfers the effluents from the extraction process to the main dam of the mine and then to the surface.

As shown in the description in the next section, the procedures to control and mitigate impacts on water resources, the effluents pumped from the individual panels to the drainage station and then to the surface are monitored on a daily basis. The numbers are recorded in a dedicated book. A hydrometer is used daily to keep track of the unpolluted water caught on the surface and used underground in operations such as drilling of the coal-bed (mine detonation) and rocks on the immediate roof layer of the galleries (anchoring), as well as wetting of the ore in order to avoid dust from building.

3 MANAGEMENT OF GROUNDWATER AND SURFACE WATER

Since this is a farming and diversified cattle ranching area that depends essentially on water, the local community come together to requested support from the DNPM and the Santa Catarina State Foundation for the Environment (FATMA) to promote a broad discussion that would ensure that mining operations would take place without prejudice to the surface water and groundwater, thus guaranteeing their sustainable development.

After careful review of the Mining Technical Project, which already included extraction procedures and techniques with a strong emphasis on the preservation of water resources, several changes were required and enforced until the project could be approved with minimal risk to water resources.

Fatma, the environmental agency in charge of issuing a license to the venture, and the DNPM collaborated to develop requirements for mine development, processing, inspection, and monitoring in conjunction with environmental control actions and compensatory actions to be fulfilled by the company for the benefit of the local community. All requirements were contained in the Environmental Impact Assessment and Environmental Impact Report (EIA EIR) and prompted extensive discussions prior to final approval of the licenses necessary for the mine to be setup.

Special mention should be made of the main procedures required to issue environmental licenses and for approval of the Technical Mining Plan in the mineral extraction process.

3.1 MINE

- Mining method: blast-free rooms and pillars, thus avoiding subsidence and fracturing of the rocks coverage.
- Pillar building with a minimum safety factor of 1.8 according to the South African method, or 1.35 under Dimenpil, depending on which method provides the larger dimensions. These methods make it possible to calculate the capacity of the pillars to support loads, and they take into account their shape and size, and the width and height of the galleries, as well as thickness of cover rocks.
- Geophysical survey to determine the spatial position of structures such as diabase fractures, faults and dikes that may serve as a conduit for surface and groundwater when crossed by galleries.
- Horizontal underground drilling when the mining front is 50 meters away from the structures detected by geophysical methods with a view to

checking if surface and groundwater percolate to the underground.

- Packing of all boreholes drilled during exploration and development of the mine, thus preventing water from flowing into the underground through them.
- Waterproofing of the structures found in the development of the mine (fractures, faults and dikes) that went undetected by geophysical methods and that cause groundwater or water reservoir levels to lower due to percolation or decrease the surface drainage flow rate.
- Monitoring of seismographic detonations carried out underground at coverages that are lower than 30 meters, in compliance with the thresholds established by the Brazilian Technical Standards Association (ABNT), preserving the civil buildings located within the mining area.
- Computation of flows and installation of a clock in the pumps located in the various underground levels, with the resulting data used in the mine's water balance.
- Installation of hydrometer in the pipe that carries water to the underground, with the data being used to determine the mine's water balance.
- Installation of rain gauge to record rainfall levels in a strategic location within the mining area, with the data being used to determine the mine's water balance.
- Installation of a level ruler in all reservoirs in order to establish a correlation between the water level in the reservoirs and the flows of effluents pumped from underground and rainfall data.
- Installation of a network of piezometers for monitoring groundwater level in order to establish a correlation between its level and the flows of effluents pumped from underground and rainfall data.
- Installation of gutters in all surface drainages for measuring flows in order to establish a correlation between them and the flows of effluents pumped from underground and rainfall data.

3.2 PROCESSING

- Operation of the plant with an effluent closed circuit and reuse of liquid effluents in the processing stage.
- Catchment of the worst water quality among the available sources, originating from underground effluents or local drainage, for use in the processing plant.
- Controlled disposal of the waste from the processing activities.

These measures makes it possible to capture any significant changes in the mine's water balance and the data in the displays in real time, allowing for immediate intervention in the cause of the problem and making the rocky mass coverage stable while avoiding environmental damage.

As compensatory measures for the opening of the mine, a Statement of Commitment involving Indústria Carbonífera Rio Deserto Ltda (ICRDL), government agencies and residents was signed, including participation of the environmental religious group associated to the Archdiocese of Tubarão. According to this statement, the ICRDL undertook to implement the actions and procedures described below.

- A choice of the University of Southernmost Santa Catarina (UNESC) and the Santa Catarina State Agricultural Research Agency (EPAGRI) to provide the monitoring and tracking services related to water, the underground, surface, waste dump, the air, vegetation and agriculture in general. Legal provision: Article 8, CONAMA Resolution No. 001, of January 23rd, 1986; Article 2, VII, Law No. 6938 of August 31st, 1981.
- Assessment of the properties by a surveyor engineer and three real-estate agencies chosen by the farmers and the mining company specializing in area surveys and computation of the worth of the affected properties, as well as the

payment of expenses needed for the registration of these properties in a notary office and all costs associated to this item. Insurance for registered properties. Legal provision: Federal Constitution, Article 225, paragraph 1, item III; Resolution 1/96, Article 6, item I, and Article 8.

- Environmental protection areas versus mining area: immediate demarcation of the surface line between the environmental protection area and the mining area, with a compensation paid to dwellers in the area that is commensurate with the damage caused in the land-demarcation process. Legal provision: Law No. 6938, of 1981, Article 2, item V; Mining Code, Article 47, item VIII, Directive No 148/80, item I (H, I).
- Monitoring expenses: payment of all expenses of community members involved in the monitoring process (monthly inspections) of the Trevo Mine, as well as the per diems for each of the members in the monitoring commission. Legal provision: Article 8 of CONAMA Resolution No. 001, 1986.
- Construction of reservoirs and filters: construction of at least ten water reservoirs in locations to be established according to technical projects developed by Unesc and Epagri, pursuant to technical standards such as filtering and other recommended treatments. Improvement of existing reservoirs located in the communities involved. Legal provision: Mining Code, Article 47, sections X and XI.
- Medical assistance: through the execution of agreements with professional and specialist clinics.
- Education: provision of all school supplies for children of the farmers within the mining areas in high school and 70% of the supplies for those enrolled in vocational courses.
- Santa Ana Church: comprehensive reform of the Santa Ana Church, according to a technical project prepared by an entity chosen by mutual agreement between the mining company and the farmers (see Photo 40).

Photo 40. Santa Ana Church after a company-sponsored refurbishment

- Machinery: Donation of a brand new Valmet 78 tractor, with at least the following tools: two-disk plow; twenty-four-disk grid; planting/fertilizing equipment with three rows for corn and five rows for beans, for conventional and no-tillage plating; mowing equipment; agricultural cart: capacity for five tons; a five-leg-subsoiler; a mixer with a deck and bagger; a boom sprayer: capacity for six hundred liters; spraying nozzle for banana plantations; limestone and dry manure dispenser with a conveyor belt: capacity for five tons.
- Telephone: installation of a phone line for community use.
- Monitoring: access by all members in the Monitoring Committee for the Trevo Mine to data related to monitoring, mining processes and facilities in the Trevo mine, with technical monitoring and without notice. Legal provision: CONAMA Resolution No. 001, 1986.
- Forest garden: agreement with the municipal government of Siderópolis to restructure the garden and freely supply ornamental plant

seedlings, commercial trees (pine, eucalyptus, palm, among others) for reforestation purposes, and fruit-bearing plants to the residents of communities affected directly or indirectly by the mining process.

- Rehabilitation of one hundred hectares of degraded areas by old non rehabilitated coal open-pit mines located in the area around the community.
- Construction of a sports pitch

So far, all items related to compensatory measures have been delivered by the company, except for property insurance. The works related to sports pitch construction and rehabilitation of an area covering one hundred hectares are in progress.

The procedures described below were also required as control and legalization measures.

3.3 INSPECTIONS

- Regular inspections conducted by the DNPM (two to three times a year), to verify compliance with the Annual Mining Plan (PLA), which designs actions for the prevention of percolation of surface water and groundwater into the mine's underground, among other procedures (see Photo 41).

Photo 41. An inspection conducted by a technical team from DNPM

- Monthly inspections by the Trevo Mine Monitoring Commission, which is comprised of community members and is supported by technicians from DNPM and FATMA in order to gather information on the mine's status regarding water resource conservation and properties and share it dwellers of the mining area (see Photos 42 and 43).

Photo 42. A meeting prior to an inspection to the mine by the community

Photo 43. A mine inspection by community members

- A monthly meeting involving the commission and the company, with technical support provided by DNPM and FATMA in order to discuss problems identified by the inspection and propose actions to be implemented by the company (see Photo 44).

Photo 44: Meeting between the community and the company's technical team and public officials following an inspection

- Information exchange with a community representative hired by the company, who has his own office at the mine site's office and follows all mining and monitoring work on a daily basis.
- Seismographic measurements of detonations with a view to preserving civil surface works carried out by the DNPM (see Photos 45 and 46).
- Measurement of dust level in the underground by the DNPM in order to maintain quality and healthiness levels in the workplace.
- Measurement of dust level in the mine's yard by the DNPM in order to maintain air quality levels at the community and in the workplace (see Photo 47).
- Measurements of noise in the underground and on the surface by the DNPM to minimize disturbances at the workplace and in the area around the mine.
- Measurement of wind direction and speed by the DNPM.
- Measurement of physical properties for underground and plant-generated effluents by the DNPM to enhance management of water resources.

Photo 45. Seismographic measurement of detonations, with monitoring by experts from the Federal University of Rio Grande do Sul

Photo 46: Seismographic measurement of detonations in a training organized by the DNPM

Photo 47. Air quality monitoring

3.4 MONITORING

Monitoring began concurrently with mining operations, and the number of data display devices was gradually increased as the mining area expanded. Thus, the mining water resources monitoring network consists of 2 rain gauges, 179 piezometers, 39 flow measurement gutters, 9 underground water pumps, 18 reservoir rulers, 13 water sampling points for analysis, and 5 soil sampling points for analysis. A more detailed description is provided below.

Rainfall data are measured by two rain gauges installed at strategic locations within the mining area, and are checked on a daily basis (see Photo 48 and Table 3).

Photo 48: Collection of rainfall data

Piezometers for groundwater monitoring are built on a regular grid, with its lower level reaching unaltered, low-permeability siltstone in the Palermo Formation. The groundwater level in wells, which are located up to 150 meters away from the mining front, is checked on a daily basis, and the frequency is reduced as distance increases (see Photos 49 and 50).

Photo 49: Piezometers

Photo 50: Piezometers in detail

Table 3. Underground water level measurements

Indústria Carbonífera Rio Deserto LTDA - Zone: Trevo Mine												
Water table Level											Weather Conditions	Rainfall (mm) Time: 7 p.m.
Points												
Surface level		98,579	96,012	94,568	93,322	91,079	89,425	93,682	86,956	86,001		
Base level		93,969	92,582	90,938	90,252	86,269	85,635	87,652	84,316	83,401		
		E2	2	2,1	2,2	2,3	2,4	2,5	2,6	2,7		
Month	Days	MEASUREMENTS (meters)										
MARCH 2001	1			92,768	92,212						Good	0,00
	2			92,708	92,152						Good	0,00
	3	Saturday									Good	0,00
	4	Sunday									Good	0,00
	5			92,558	92,042						Good	0,00
	6			92,478	91,992						Cloudy	1,80
	7			92,438	91,972						Good	0,00
	8	97,039	94,872	92,408	91,912	88,739	88,395	89,792			Rainy	11,80
	9			92,388	91,862						Rainy	7,50
	10	Saturday									Good	0,00
	11	Sunday									Cloudy	1,20
	12			92,328	91,722						Rainy	6,80
	13			92,318	91,682						Good	0,00
	14	96,519	94,682	92,308	91,622	88,609	88,225	89,552	85,071		Cloudy	3,20
	15			92,308	91,622						Rainy	33,60
	16			92,328	91,742						Good	0,00
	17	Saturday									Rainy	2,00
	18	Sunday									Cloudy	1,40
	19			92,298	91,722						Cloudy	0,70
	20			92,288	91,642						Rainy	3,40
	21			92,278	91,612						Good	0,00
	22			92,238	91,562						Good	0,00
	23	96,319	94,572	92,208	91,532	88,589	88,135	89,512			Good	0,00
	24	Saturday									Rainy	7,00
	25	Sunday									Good	0,00
	26			92,188	91,472			89,412			Rainy	5,10
	27			92,168	91,462			89,402			Cloudy	2,60
	28			92,198	91,462			89,402			Cloudy	0,50
	29	96,059	94,362	92,138	91,402	88,499	88,125	89,362	85,726	84,971	Good	0,00
	30			92,098	91,382	88,499		89,332			Good	0,00
	31											12,00

(Source: ICRD, 2001)

Flow gutters for monitoring surface water are arranged in all drains in the area covered by the mine, and they are monitored on a daily basis. The number of gutters is directly proportional to the number of drains, and for a particular drain it depends on its length.

Table 4. Gutter flow measurements

Indústria carbonífera Rio Deserto Ltda Zone: Trevo Mine													
Computation of Flows/period: March 2001													Weather Conditions
Day	Points												
	C1			C2			C3			C4			
	Time	Measure (mm)	Flow (m^3/h)	Time	Measure (mm)	Flow (m^3/h)	Time	Measure (mm)	Flow (m^3/h)	Time	Measure (mm)	Flow (m^3/h)	
1	8:05	39	48,24	8:55	113	255,60	10:30	300	1.177,20	10:05	122	288,00	Good
2	8:00	31	33,84	8:50	94	191,52	10:25	272	1.008,72	10:05	100	212,40	Good
3	Saturday			Saturday			Saturday			Saturday			Good
4	Sunday			Sunday			Sunday			Sunday			Good
5	8:00	28	29,52	8:55	68	116,64	10:30	195	601,20	10:05	69	119,52	Good
6	9:20	25	25,20	9:10	61	96,48	11:00	152	408,24	10:45	55	82,80	Cloudy
7	9:40	23	22,32	9:20	58	89,28	11:55	142	365,04	11:20	55	82,80	Good
8	8:10	21	19,44	9:15	57	87,12	11:50	134	334,80	11:30	54	80,64	Rainy
9	8:05	21	19,44	8:55	54	80,64	10:30	124	295,20	10:05	50	72,00	Rainy
10	Saturday			Saturday			Saturday			Saturday			Good
11	Sunday			Sunday			Sunday			Sunday			Cloudy
12	8:35	21	19,44	9:25	50	72,00	10:35	109	241,20	10:20	48	67,68	Rainy
13	8:00	19	16,56	8:50	46	63,36	10:40	106	230,40	10:25	43	56,88	Good
14	8:25	18	15,12	9:10	42	54,72	10:30	99	208,80	10:15	40	50,40	Cloudy
15	8:10	17	13,68	9:00	40	50,40	10:30	96	198,00	10:05	39	48,24	Rainy
16	8:10	20	18,00	8:20	54	80,64	11:30	149	395,28	11:10	49	69,84	Good
17	Saturday			Saturday			Saturday			Saturday			Rainy
18	Sunday			Sunday			Sunday			Sunday			Cloudy
19	8:05	14	10,08	8:15	42	54,72	11:10	96	198,00	10:50	40	50,40	Cloudy
20	8:10	18	15,12	8:20	46	63,36	11:10	92	185,76	10:50	43	56,88	Rainy
21	8:15	18	15,12	8:25	40	50,40	11:30	89	177,12	11:20	39	48,24	Good
22	8:20	17	13,68	8:10	37	43,92	11:35	82	156,96	11:20	36	41,76	Good
23	10:00	14	10,08	8:20	36	41,76	11:20	78	145,44	11:10	33	36,72	Good
24	Saturday			Saturday			Saturday			Saturday			Rainy
25	Sunday			Sunday			Sunday			Sunday			Good
26	8:00	14	10,08	7:50	36	41,76	10:30	74	133,92	10:20	31	33,84	Rainy
27	8:15	24	23,76	8:05	43	56,88	10:30	74	133,92	10:20	31	33,84	Cloudy
28	14:10	10	7,20	13:10	32	35,28	8:30	70	122,40	15:30	26	26,64	Cloudy
29	8:35	10	7,20	9:25	31	33,84	11:00	62	99,36	10:40	26	26,64	Good
30	8:10	10	7,20	9:10	29	30,96	10:30	60	93,60	10:10	25	25,20	Good
31	Saturday			Saturday			Saturday			Saturday			Rainy

(Source: ICRD, 2001)

Rulers are installed in all reservoirs and make it possible to record water levels on a daily or weekly basis, depending on its distance from the mining front (see Photo 51 and Table 4).

Regarding the monitoring of water quality parameters, DNPM performs measurements at the mine, plant and drainages, especially pH, conductivity, temperature, dissolved oxygen, and cloudiness.

Photo 51: Level measurement rulers

Table 5. Reservoir level measurements

Indústria carbonífera Rio Deserto Ltda Zone: Trevo Mine								
Reservoirs Height of rulers (cm) Period: March 2001								
Day	Ruler 1	Ruler 2	Ruler 3	Ruler 4	Ruler 5	Ruler 6	Ruler 7	Ruler 8
	Close to Point 1.1	Close to Point 2.4	Close to Point E3	Close to Point 7.3	Close to Point 4.4	Close to Point 4.6	Last open pit mine cut	Last open pit mine cut
1								
2								
3	Saturday							
4	Sunday							
5								
6								
7	77,0	87,0	81,0	83,0	75,0	44,0	110,0	120,0
8								
9								
10	Saturday							
11	Sunday							
12								
13	70,5	85,0	81,0	82,0	74,5	37,5	98,5	170,0
14					74,0			
15					74,0			
16					76,0			
17	Saturday							
18	Sunday							
19					75,0			
20					74,5			
21					74,0			
22	64,0	84,5	81,0	79,0	73,5	35,0	110,0	140,0
23					73,0			
24	Saturday							
25	Sunday							
26					72,0			
27					72,0			
28	62,0	84,0	81,5	81,0	72,0	35,0	108,5	140,0
29					72,0			
30					71,5			
31	Saturday							

(Source: ICRD, 2001)

3.5 WATER BALANCE

The monitoring data (rainfall, groundwater and reservoir levels, drainage flows, amount of effluents pumped from underground, and amount of unpolluted water drained into the mine) provide real-time information on the underground of the mine in order to record the amount of percolated water, existence of old, unpacked boreholes and structures such as diabase fractures, faults or dykes, which are structures that reach the surface and are locations where water percolates.

If it is proved that the sudden change in the data in the display was caused by expansion of the mining activity, the site can be confined through concrete dams, or waterproofing of the structure responsible for the percolation of water, thus modifying the mining plan at local level.

It should be pointed out that this situation was faced in the development of Panel 1 for the Trevo mine, where there was a sharp drawdown in a piezometer level, and after the site was confined the groundwater was restored to its original level.

Also, in order to strengthen control and management actions, another procedure available is to perform a horizontal bore underground from the quarries, with preliminary confirmation of groundwater and surface water in response to the expansion of coal mining underground.

Any sudden change in any of the displays is subject to immediate analysis, where data on rainfall, the mining front where the display is located, a record of the water pumped from the panel in the mine and, if necessary, an inspection to identify structures such as diabase fractures, faults and dikes, which had been identified by a geophysical survey conducted previously.

These structures are sites where water percolates, and establishment of its spatial position makes it possible to change mining front expansion patterns so as to allow the mine to be crossed in advance by a single gallery. In this gallery, the structure is studied in detail by measuring water flows percolating into the underground through it. The data obtained will indicate the number of galleries that can be traced by means of the structure, without significant damage to surface water and groundwater. If the water flowing into the galleries displays physical and chemical properties that allow its use in underground operations, an equal amount of water, with the same purpose, ceases to be carried from the surface to the underground (see Figure 50 and Table 5).

When significant flows occur in these structures, they are waterproofed with special resins.

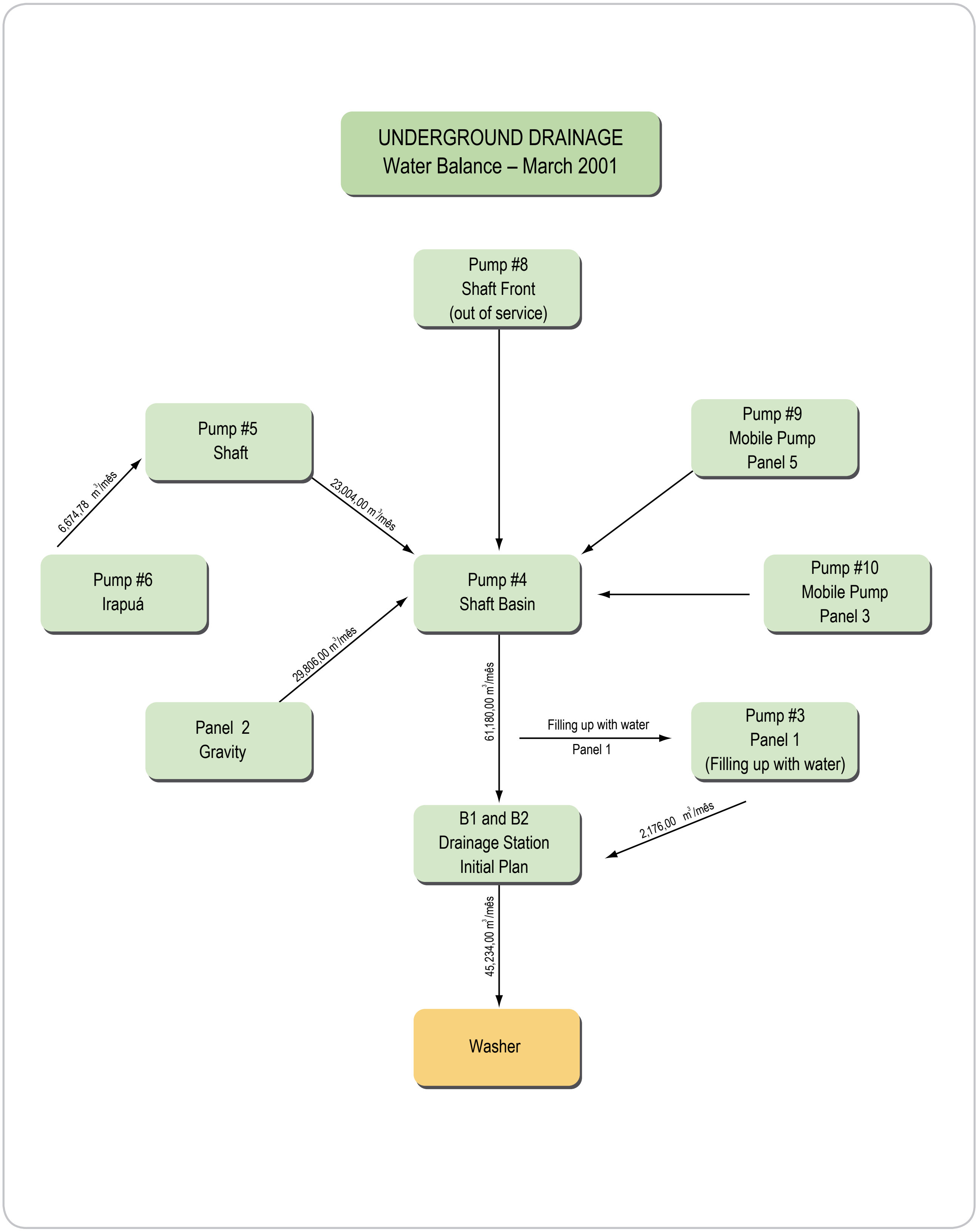

Figure 50. Underground drainage (ICRD, 2001)

Table 6. Mine water outflow measurements

Indústria carbonífera rio deserto LTDA zone: trevo mine						
Water outflow from the mine (daily basis) Month: march year: 2001						
Day	Water outflow hour meter					
	Pump #1 60 CV / 103 m³/h	Pump #2 60 CV / 120 m³/h	Pump #3 – P.01 60 CV / 64 m³/h	Pump #4 –B.EIXO 20 CV / 95 m³/h	Pump #5 - Eixo 10 CV / 36 m³/h	Pump #6 - Irapuã 8 CV / 24,01 m³/h
	Flow (m³/dia)	Flow (m³/dia)	Flow (m³/dia)	Flow (m³/dia)	Flow (m³/dia)	Flow (m³/dia)
1	618,00	720,00	0,00	3135,00	1044,00	144,06
2	721,00	720,00	0,00	1805,00	900,00	192,08
3	618,00	840,00	0,00	1805,00	828,00	216,09
4	824,00	720,00	0,00	1710,00	828,00	240,10
5	721,00	840,00	0,00	1710,00	828,00	216,09
6	618,00	720,00	0,00	1805,00	864,00	192,08
7	721,00	960,00	0,00	1805,00	792,00	192,08
8	618,00	840,00	640,00	1900,00	720,00	168,07
9	721,00	720,00	640,00	1900,00	756,00	216,09
10	515,00	840,00	896,00	1900,00	756,00	240,10
11	618,00	840,00	0,00	1900,00	720,00	216,09
12	618,00	720,00	0,00	1805,00	756,00	168,07
13	721,00	840,00	0,00	1900,00	720,00	216,09
14	618,00	720,00	0,00	1900,00	684,00	168,07
15	721,00	840,00	0,00	1995,00	756,00	192,08
16	618,00	840,00	0,00	1995,00	720,00	192,08
17	721,00	720,00	0,00	1995,00	648,00	168,07
18	618,00	840,00	0,00	1900,00	756,00	192,08
19	721,00	840,00	0,00	1900,00	756,00	168,07
20	618,00	960,00	0,00	1995,00	684,00	144,06
21	618,00	720,00	0,00	1995,00	684,00	120,05
22	721,00	720,00	0,00	2090,00	792,00	144,06
23	618,00	840,00	0,00	1995,00	792,00	240,10
24	618,00	720,00	0,00	1995,00	828,00	288,12
25	515,00	840,00	0,00	2090,00	828,00	264,11
26	618,00	960,00	0,00	1995,00	864,00	240,10
27	618,00	840,00	0,00	1995,00	828,00	288,12
28	721,00	840,00	0,00	2090,00	468,00	336,14
29	618,00	720,00	0,00	2185,00	432,00	336,14
30	721,00	720,00	0,00	2090,00	468,00	336,14
31	721,00	840,00	0,00	1900,00	504,00	240,10
T	**20.394,00**	**24.840,00**	**2.176,00**	**61.180,00**	**23.004,00**	**6.674,78**

(Source: ICRD, 2001)

3.6 COMMUNITY INVOLVEMENT

Every month, the company runs a report that contains all data collected from the data display devices during the period, and an assessment of water balance is conducted in response to expansion of the mining operation. These reports are submitted to the DNPM and FATMA for review.

As a result of the water resources management process, it was established that on the last Wednesday of every month a committee representing the community, along with technicians from DNPM, FATMA and the company would perform an inspection of the underground mine in order to verify compliance with the Annual Mining Plan (PLA) that had been previously reviewed and approved, and check for any abnormal water flows. It was decided that in the evening of that day the group who took part in the inspection would hold a meeting to discuss the issues identified, with a formal, signed record in the meeting proceedings. This procedure found support from the community, so much so that the mayor of Siderópolis established a Commission for the Monitoring of the Trevo Mine (CAMT) through Decree No. 1982 of August 20th, 1998. The Commission is comprised of six people from the community, including the president and secretary (who hold elected offices); two representatives from Indústria Carbonífera Rio Deserto Ltda., the concessionaire; and representatives from the DNPM; the Environmental Foundation; Southern Regional Coordinator (FATMA/CERSU); the Mineworkers Union of Siderópolis; the City of Siderópolis; the City Council; the Rural Union; and EPAGRI.

CAMT's mission is to conduct monitoring to ensure full compliance with the Annual Mining Plan (PLA). This plan is periodically officially submitted by the coal mining companies until December 1st of every year. Once it has been approved, any changes to the PLA can only be implemented after review and approval by the DNPM.

It is also reviewed by the company's technical representative, among other people. If any issues are identified that require corrective action, this is noted in the proceeds and submitted to the company according to DNPM's standard format.

As part of the management process, the monthly reports are made available to Federal University of Rio Grande do Sul's Hydraulic Research Institute (IPH) on a bi-yearly basis, which interprets the monitoring data in order to record the behavior of surface and groundwater vis-a-vis the development of underground coal mining. Once analysis of the reports is complete, technical experts from the Institute deliver talks to the commission comprised of representatives from the community, where they present maps and data on the behavior of the water resources in the mining area (see Figure 51).

One representative of the community with CAMT, who is hired by the company, has his own office within the mine site office, and on a daily basis s/he checks the mining, processing, monitoring and operation of deposits of tailings and the settling system, immediately reporting any issues to the DNPM.

Systematic monitoring is conducted by community members, who are hired by the company, thus avoiding problems associated to reliability of the data obtained from the readings of the data display devices.

4 FINAL REMARKS

Establishment and development of the Trevo mine (SS) from June 1998 was only possible thanks to the company complying with all the requirements made by the DNPM and FATMA. These requirements placed emphasis on quarry planning, which should include a monitoring plan that would guarantee preservation of surface and groundwater during and after the performance of mining works.

Community involvement has been paramount, and they managed to set up a commission to monitor mining activities and engage society; they entered the Attorney General's Office in the process, thereby contributing to full compliance with the mining and environmental legislation. Considering the slow expansion of the mining fronts and the monthly inspections involving the community, and also considering the daily presence of a representative from the Monitoring Committee at the mining site office, any problems occurring in the mining operations that could result in alterations of the groundwater and surface water resources or cause subsidence and related issues are identified in real time, and the company is required to take immediate action.

Since the start of mining activities, harmonious coexistence exists between the company, which manages to conduct its mining activities smoothly, and the community, which has suffered no adverse impacts and sees the environment preserved.

DNPM along with FATMA, requires that the Mining Technical Project (PTM) take into consideration preservation of water resources and include a monitoring plan that should guide all mining activities. within the analysis of PTM, the community within the planned mining area becomes aware of the mining venture through a public presentation of the EIS/EIR and meetings organized by technical staff from the DNPM, where the community is briefed on the duties and obligations of the mining company, and receives guidance in order to participate in the monitoring of the approved mining projects.

It is recommended that any exploration or mining activities that could cause changes to the behavior of surface and groundwater and the rock mass covering the ore, or where they fit – especially near urban areas – be monitored as a requirement. This procedure has proved efficient in the coal region of Santa Catarina, and it is a critical factor for the viability of new mining ventures with preservation of the various activities taking place on the surface, both in urban and rural areas, but especially in the latter.

João Luiz Calmon[1]
Sergio Augusto C. da Silva[2]

MARBLE AND GRANITE MINING IN THE STATE OF ESPÍRITO SANTO: ENVIRONMENTAL PROBLEMS AND SOLUTIONS

1 INTRODUCTION

This purpose of this case study is to discuss, albeit in a non-exhaustive manner, environmental problems in the ornamental rock sector in the State of Espírito Santo and what has been done to minimize and solve these problems. Special emphasis is given to the generation of waste (abrasive sludge) during the cutting of granite and marble blocks.

2 BRIEF COMMENTS ON THE IMPORTANCE OF THIS INDUSTRY IN THE STATE

The marble and granite industry is one of the most important economic sectors in Espírito Santo. The state is home to all production activities in the sector, and the majority of supporting activities, such as manufacturing and distribution of machinery, equipment and other industrial inputs, in addition to associated services.

According to a publication by Sindirochas (2004, a), the ornamental rock sector in Espírito Santo led the Brazilian exports of marble and granite from January to July 2004. Out of the historical record of US$ 234.5 million in Brazilian exports in 2004, the Espírito Santo industry accounted for 65% of total sales of blocks and slabs.

According to Villaschi Filho and Sabadini (2000) the vast majority of companies in Espírito Santo – almost 91% of them – are located in southern and northern areas of the state. Rock mining currently takes place in two distinct mining hubs in the state. The oldest of these is in the municipality of Cachoeiro do Itapemirim, which contains many marble mines and most of the industrial processing facilities. The northern town of Nova Venécia stands out for the production of granite in various shades (ADERES, 2003).

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[3] For more detailed data on the marble and granite industry in Espírito Santo, see Villaschi Filho and Sabadini, 2000.

In order to provide a profile of the Espírito Santo marble and granite industry in relation to Brazil, Table 7 shows different indicators for a comparison between Brazil and Espírito Santo.

Table 7. Statistics on exports of ornamental rocks: a comparison between Brazil and Espírito Santo (2000)

COMPARISON BASIS	UNIT	Brazil	Espírito Santo	ES/BR (%)
Production	1.000.000 t	5,2 (4,0)	2,4	46 (60)
Quarries (mines)	units	1.163	400	34,4
Bandsaws	units	1.574	900	57,2
Sawing capacity	1.000.000 m^2	40,6	25,0	62,5
Companies	units	10.000	1.200	12,0
Jobs	units	105.720	20.000	18,9
Exports (monetary amount)	US$ 1.000.000	271,54	116,05	42,7
Exports (weight)	tons	1.101.737	487.701	44,2
Exporting companies	units	508	154	30,3
Port shipments (rocks)	1.000.000 t	1,10	0,67	60,8
Port shipments (total exports)	1.000.000 t	230	96	42
Port arrivals (total imports)	1.000.000 t	92	11	12
Territorial area	Km^2	8.500.000	46.184	0,54
Population	1.000.000 hab.	180	3	1,66

Source: Sindirochas (2004,b)

Noteworthy is the large extraction volume (about 800,000 m3 per year) and the number of bandsaws in operation (some nine hundred), accounting for approximately 57% of all equipment in Brazil. Espírito Santo also relies on logistical infrastructure in the port of Vitória, which has been increasingly participating in Brazil's exports of ornamental rocks.

The state is home to something between 750 and 1,200 companies in the industry generating around 20,000 jobs, and this accounts for about half of the domestic production of ornamental rock slabs. This is a key sector in the economy of Espírito Santo, highly reputed at international level, especially in Italy, its main importer. The United States of America are now becoming a major importer.

Figure 51 shows a sketch of the location of marble and granite deposits in Espírito Santo and their commercial names, by municipality.

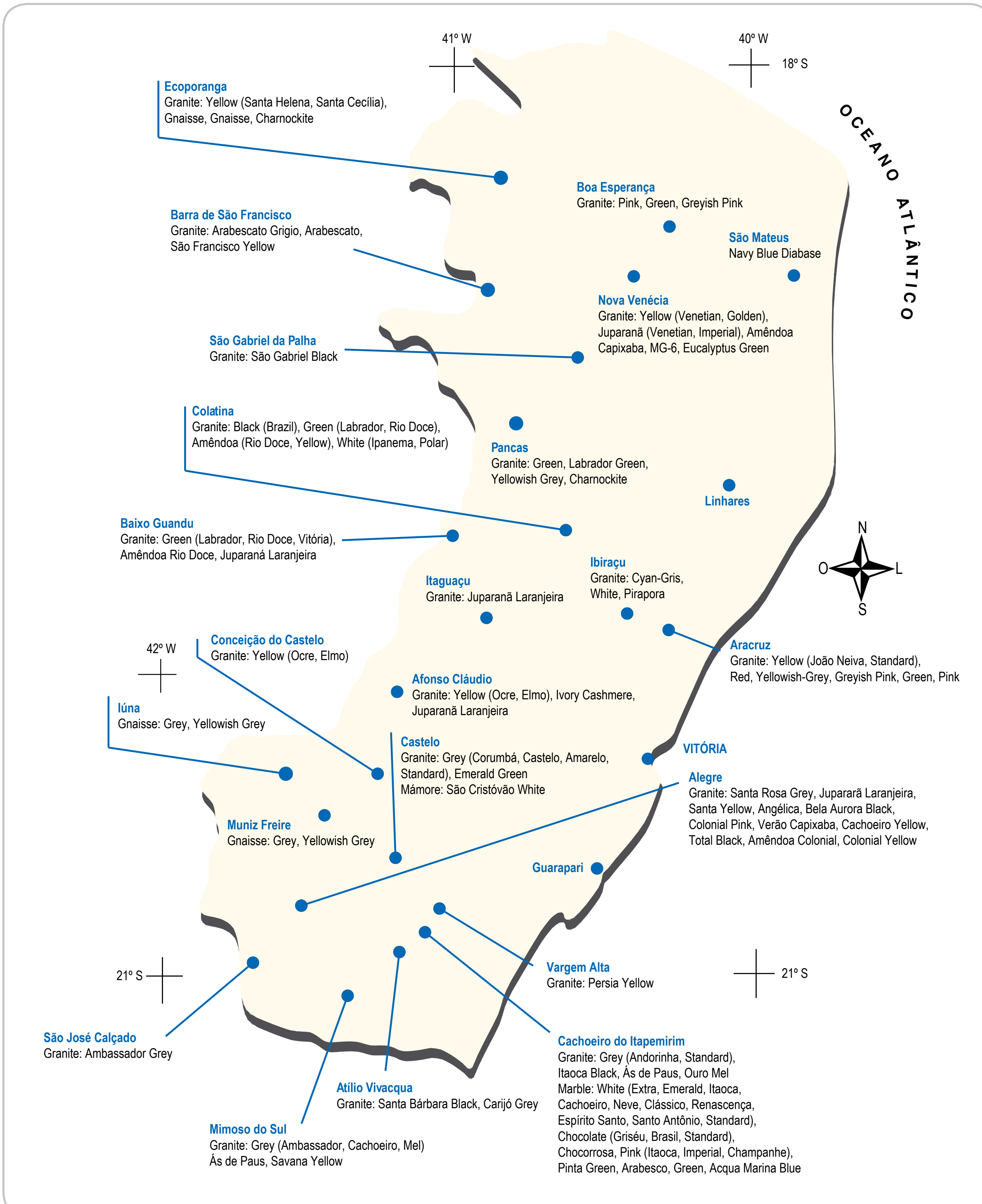

Figure 51. Rough location of marble and granite deposits by municipality in Espírito Santo and their trade names (IPT, 1993; apud SILVA, 1998)

The industry has been making a significant effort to make headway in the economic, social, technical and scientific, and environmental fronts. A significant number of bottlenecks are yet to be eliminated. Representatives from the Local Production Arrangement (APL) for ornamental rocks in Cachoeiro do Itapemirim have recently discussed the systemic factors that should be addressed to develop the ornamental rock sector as a whole. It is worth mentioning, among others, factors related to logistics and transportation; the production process (extraction, processing and polishing); environmental impacts; new technologies; systems for water rehabilitation in the production process; the disposal and recycling of abrasive sludge; energy and infrastructure (Sindirochas, 2004a).

3 AN OVERVIEW OF THE TYPICAL PRODUCTION PROCESS FOR ORNAMENTAL ROCK CUTTING IN THE SAWMILLS IN THE STATE OF ESPÍRITO SANTO

3.1 TYPICAL PRODUCTION PROCESS IN ESPÍRITO SANTO PLANTS

During mineral exploration, the production process basically involves extraction from deposits, processing (sawing and polishing) and supporting activities. All subsystems involve causes and impacts on the environment (water, air and land), and this holds true for the extraction and processing of ornamental rocks in Espírito Santo.

Figure 52 shows some operations in the manufacturing of ornamental rock blocks.

LOCAL PRODUCTION ARRANGEMENTS

Fernanda Delorence
Project Advisor with Cetemag

Production Arrangements are clusters of businesses located in a given area that have specialized production and have internal coordination, interaction, cooperation and learning relationships and with other local stakeholders, such as the government, business associations, and credit, education and research institutions.

A Local Production Arrangement brings together a significant number of companies focused on a core business. For this, one must consider the dynamics of the area in which these companies operate, taking into account the number of jobs, revenues, growth potential, diversification, among other aspects.

A Production Arrangement for Ornamental Rocks (i.e., marble and granite) in Espírito Santo is comprised of two central clusters that house most companies devoted to marble and granite extracting and processing. The first cluster is located around Cachoeiro do Itapemirim, and the second cluster in around Nova Venécia.

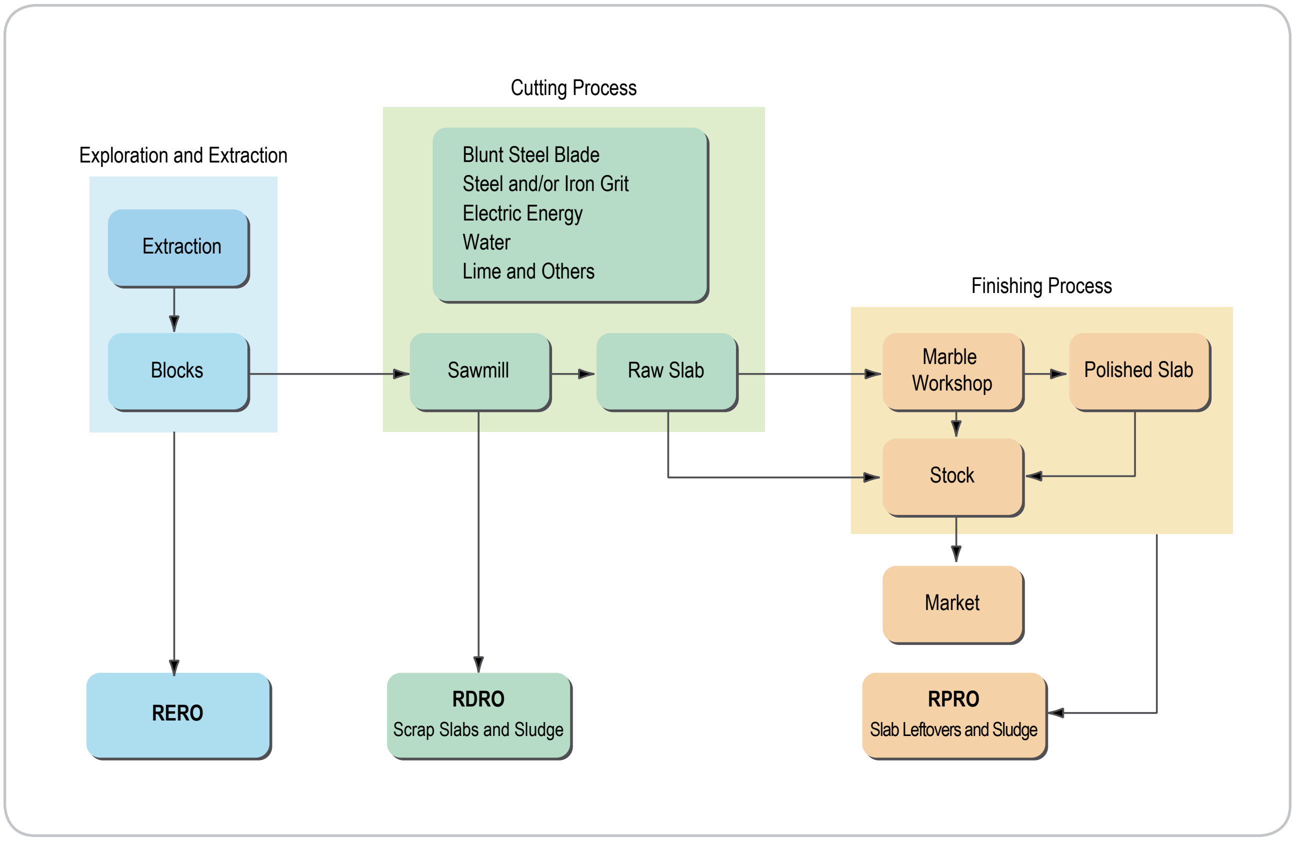

Figure 52. Ornamental rock production workflow (adapted from SILVA, 1998; PREZOTTI, 2005)

Where RERO stands for waste from ornamental rock extraction; RDRO stands for waste from ornamental rock cutting; RSRO refers to abrasive sludge only here; and RPRO stands for waste from ornamental rock polishing.

The production process is complex through the entire chain – extraction, processing (cutting and polishing), storage, and transportation. Therefore, considering the scope and complexity of the matter, not all stages of production and associated environmental impacts will be covered here. Emphasis will be placed on the cutting and polishing steps, which generate large amounts of waste that require proper handling to avoid compromising the local area's environment.

Once rock blocks have been extracted, they are taken to sawmills for cutting and sawing.

Machines called bandsaws are used for cutting and processing of blocks into slabs or semi-finished slabs, with thickness ranging from 1 to 3 centimeters. Approximately nine hundred bandsaws (57.2% of the total in Brazil) can be found in several businesses that are usually located in the state's production areas.

Bandsaws are rugged hardware consisting of four columns, which prop up a frame that performs a swinging movement. This frame holds longitudinal steel blades that are parallel to each other. The blades are made from high-hardness carbon steel with significant mechanical strength in order to better resist movement and abrasion (SENAI, 1992).

Photo 52 shows a typical bandsaw with an abrasive mixture for splitting blocks of ornamental rocks. The outputs here are semi-finished slabs. The main

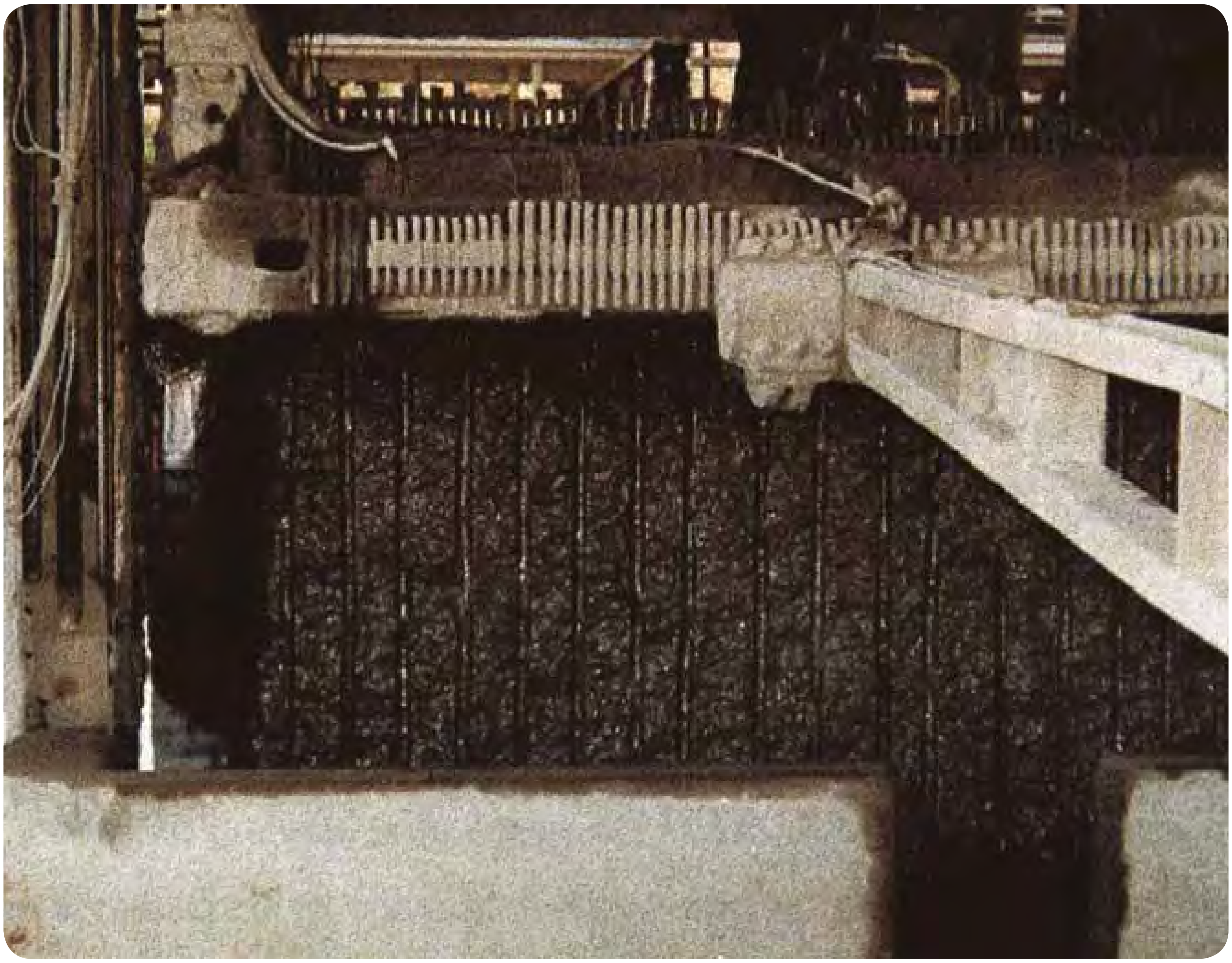

Photo 52. Bandsaw for cutting ornamental rocks with an abrasive mixture

inputs in this stage are: abrasive component (steel or cast iron grit for the sawing of the blocks), water, lime (limestone, calcium carbide or a similar substance), and electricity.

Use of multiblade bandsaws (one hundred or more blades per bandsaw) with an abrasive mixture is now widespread across ornamental rock sawing plants.

Whether low-tech methods for abrasive mixture control (which requires experience and common sense by the operator) or new technologies are also used depends on the investments made by the various companies in this sector.

The slurry or abrasive mixture is sprinkled over the block through a pumping shower. After infiltrating the fractures opened by the blades on the block, the slurry is returned to the pumping tank and is then pumped again, in a closed loop operation (Freire and Motta, 1995).

As part of the mixture control process, the thinner portion of the sludge is removed. During this rock processing stage, waste is generated from the sawing of granite blocks. Photo 53 shows a pumping tank beneath the bandsaw. The finer particles of the abrasive sludge is removed, and the remaining sludge goes for recirculation.

Photo 53. Abrasive sludge pumping tank

There are also diamond-blade bandsaws and diamond-disk bandsaws (diamond block saws). Use of diamond bandsaws is not yet very widespread in Brazil, while this is used across the entire industry in the developed world.

Diamond-blade bandsaws use a water shower for cleaning, lubrication and cooling of their blades, which are different from the high-hardness carbon steel blades in that they have industrial diamonds in their bottom. This process is costly because of the blade replacement and maintenance required, and also the high cost for the acquisition of a bandsaw. The waste generated by this bandsaw can be considered to be one with the least impact on the environment since it does not use an abrasive mixture, which makes one think that the amount of waste generated can be considerably less.

The facilities of industrial plants for the transformation of blocks into semi-finished flat slabs include: shed for the machinery (bandsaws); a block storage yard and slab storage yard (both finished and raw slabs); a yard for processing raw slabs; a yard for loading and unloading vehicles; maintenance shops; a warehouse; offices etc.

In general, the primary equipment used are: mechanical bandsaws (with use of an abrasive mixture) or diamond-block saw for block cutting; block carts; block carriers.

The sawing process begins when a rock block is placed under the equipment's frame, and it is constantly bathed with the abrasive fluid. The swinging motion of the frame cause the blades and the abrasive mixture to perform a cutting action by friction and impact against the block.

This movement is driven by an electric motor through a connecting rod-crank system, with the aid of an inertial wheel. The abrasive mixture is fed by a pump-driven hydraulic circuit (ROCHAS DE QUALIDADE, 1989).

The slabs obtained after the sawing stage go to marble plants for initial polishing. At this stage, the surface of raw slabs is trimmed to give them the look and shape required for final polishing.

These finishing operations are carried out with applications of polishing gear that use successively finer abrasives, and the surfaces of the slabs are trimmed until the final polish (trimming and polishing).

Once the slab is flat and smooth, the buffing stage takes place, which will give the piece the appearance required for final use. Obtaining the necessary polish requires specific treatments, regardless of the type of rock being processed.

Once the slabs have their final appearance, it is time to give them the desired shape and size. At this stage, rotary saws with diamond blades are normally used. The finished product can then be used in civil construction applications (CARUSO, 1985).

For these stages, water should be used in large quantities, not only to cool abrasive substances, but also for the removal of the waste generated in the process.

3.2 THE WASTE FROM GRANITE BLOCK CUTTING

Block-cutting operations are typically based on a certain amount of mixture from the previously sawn blocks. When this is not possible, the following composition is used for a new mixture: 50-100 kg of lime or 30-50 kg of calcium carbide (CaC2) sludge, with grit being added continuously in small quantities by hand or by an automated device (SENAI, 1995).

The abrasive mixture is pumped over the block or blocks thoroughly and continuously in all blades (bandsaws currently have about 100 blades). In general, these systems consist of multiarm dispensers, each with nozzles for spraying the abrasive fluid (ROCHAS DE QUALIDADE, 1989).

As the granite blocks are sawn, the composition of the abrasive sludge in the bandsaws undergoes significant variations in a short period of time. This is due to an increase in rock fragments (dust), metal waste from the grit and the interaction of the blades with the abrasive mixture. As the original composition for this mixture changes, it gradually loses its effectiveness (ROCHA DE QUALIDADE, 1993).

If such fragments were not removed from time to time, the mixture would gather more and more solid particles, which would substantially increase its viscosity, thereby reducing its cutting power to the point that much of the energy between the blade and rock would be wasted in grinding fragments of rocks that had already been cut, and would magnify the mechanical wear-and-tear of the blades and bandsaw, which could lead to defects in the sawn slabs (SENAI, 1993).

Therefore, it is necessary to control viscosity of the abrasive mixture by periodically adding water and removing the finer particles in the mixture, which have physical properties that could adversely affect the development of the abrasion required in the block-cutting process. The discarded waste also contains metal fragments from the wear-and-tear process affecting the blades and grit, in addition to the lime or alternate substance (limestone or blast-furnace slag).

Photo 54 shows an abrasive sludge pumping tank processing the disposal of the finer particles in the sludge.

Photo 54. An abrasive sludge pumping tank; the disposal of a portion of the abrasive sludge along a collection gutter

The tank in the picture above shows a specific case where the finer particles to be discarded are sorted. This is performed by the hydrocyclone shown in the picture.

In the most customary cases, the tank is filled up to its top level, which allows for the disposal of the finer particles. Since these particles have a lower density, they will remain on the surface, from where they will be removed as a result of the overflow.

After this removal, the sludge is channeled (see Photo 55) to a pit and then pumped into the tanks for final disposal.

Photo 55. Channel for the conveyance of the waste sludge from a bandsaw

The previous picture is an illustration of this process in a particular company. However, most companies set up a direct connection between the waste sludge distribution channel and the sludge recirculation tank beneath the bandsaw.

The waste slurry is diverted along these channels and then is released into a pit that is used to pump the waste to the settling tank. Photo 56 shows this waste pumping pit.

From this pit, the waste from the sawing of ornamental rock blocks is pumped to the final disposal tank, which can have many different shapes and sizes. Photo 57 was taken exactly at the moment when waste is released into a final disposal tank.

Photo 56. Waste pumping pit for final disposal

Photo 57. A typical tank for final disposal of the waste from the sawing of ornamental rock blocks (disposal)

Most of these tanks are built improperly, and they absorb all waste from the cutting of the rocks until they reach their capacity. Once they are full, the waste is removed from the tank so that it is ready to receive more waste.

> According to Prezotti (2005, p. 22), in virtually all cases, block cutting companies release their waste in a semi-solid state (as fluid sludge) into accumulation tanks that lie directly in touch with the ground, without any proper sealing. The fluid is not recirculated in any way. Part of the water in the waste is eliminated by evaporation and seepage into the soil, and the rest of the water remains as waste moisture in the open (see Photo 57).

It should be pointed out that the issue of water infiltration and its movement on the soil is still an unknown matter in the case of abrasive sludge effluents from the finish/polishing stage.

3.3 WASTE PRODUCED FROM GRANITE SLAB POLISHING AND FINISH

The waste in this processing step is comprised of semi-solid residues in the form of fluid sludge containing fine particles of rock that are hard to settle and solid waste comprised specifically of abrasive remains that can contain diamond-like, resin or magnesite substances, plastic materials from packaging (plastics, cardboard, etc.).

Virtually all companies that perform cutting and polishing operations have some form of recirculation of the settled water. In general, reinforced concrete tanks equipped with baffles are used. They are built underground and their size does not follow any specific technical criteria for this type of waste (fluid sludge from polishing), as shown in Photo 58. The sedimented matter is moved by means of hydraulic pumps to dumps that are also in touch with the ground.

Photo 58. Effluent treatment system for waste from polishing processes. Source: Prezotti (2005)

3.4 ASSESSMENT OF WATER USE ACCORDING TO PREZOTTI

Generally, water is obtained from a water table, possibly through pumping from rivers, when the mining company is located near water bodies. Water is supplied by Cesan (the water utility) to some companies located in the Greater Vitória area and other locations. No reliable survey of water catchment for the industrial sector is available.

It should be pointed out that engineer and researcher Julio César Simões Prezotti (PREZOTTI, 2003, 2005) studies and monitors the liquid effluent treatment stations from marble and granite processing plants in Espírito Santo.

It is also worth mentioning that the information provided is completely new and much more is yet to be done and researched in order to have an accurate and thorough understanding of the water cycle involved in the process. A census of users that covers all ornamental rock processing and polishing companies in the state is required.

However, studies and information provided by Mr. Prezotti made it possible to put together an estimation of the use of water in marble and granite cutting and finishing activities in the state.

According to the researcher, the basis for the calculation of water consumption in the processing of ornamental rocks in Espírito Santo are as follows:

BANDSAWS

Table 8. Bandsaws in Espírito Santo (ES)

REGION OF ESPÍRITO SANTO	Bandsaws – Estimated number (b)
Northern ES (a)	120
Greater Vitória	100
Southern ES	580
Total	800

Key: (a) Bandsaws in northern ES: Nova Venécia = 55; Barra de São Francisco = 50; Ecoporanga = 4; other in the North = 11; (b) Estimated required water flows = 3.0-6.0 m3/day per bandsaw

The bandsaws listed in Table 8 have about 70-75 cutting blades. Larger bandsaws, with about 200 blades, are included in the listing through equivalency measurements.

POLISHING HEADS

Table 9. Polishing heads in ES

REGION OF ESPÍRITO SANTO	Polishing heads – Estimated number (b)
Northern ES (a)	250
Greater Vitória	250
Southern ES	1500
Total	2000

Key: Northern ES: (a) Nova Venécia = 90; Barra de São Francisco = 90; Ecoporanga = 20; other in the North = 50; (b) Estimated required water flows = 15.0-25.0 liters/minute per head.

CUTTING DISKS

Table 10. Cutting disks in ES

REGION OF ESPÍRITO SANTO	Cutting disks – Estimated number (b)
Northern ES (a)	80
Greater Vitória	Information not available
Southern ES	Information not available
Total	1,000 (c)

Key: Northern ES: (a) Nova Venécia = 30; Barra de São Francisco = 35; Ecoporanga = 5; other in the North = 10; (b) Estimated required water flows = 20.0-25.0 liters/minute per disk. (c) actual figure is unknown

BLOCK AND FLOOR TILE CLEANING

Estimated between 2.0 and 3.0 m^3 per block sawn.

Even if a more thorough inventory is required, these data help calculate the consumption of water in cutting and finishing processes:

Bandsaws in Espírito Santo: (operational) = 800 x 4.5 x m3/day per bandsaw* = 3,600.00 m3/day
(*) Denotes an average of the figures gathered by the author.

Polishing heads in ES: (operational) =
2,000 x 20.0 liters/minute per head* = 28,800.00 m3/day.
(*) For 12 hours of operation per day.

Cutting disks in ES: 1,000 units* x 22.5 liters/minute per head** = 16,200.0 m3/day. (*) 1,000 is an assumed amount.
(**) For 12 hours of operation per day.

Block and floor tile cleaning: 6,400 sawn blocks/month x 2.5 m3/block sawn* = 16,000 m3/month = 534 m3/day.
(*) 800 bandsaws performing an average of 8 sawing operations per month per bandsaw = 6,400 sawing operations per month = 6,400 blocks sawn per month.

In total, the estimated water consumption required for rock processing and finishing in Espírito Santo is 49,134 m^3 per day.

This amount does not include the water recirculated in the system. If the system for liquid effluent treatment in the flowchart displayed in Figure X (for convenience, this will be presented under section 6) is used, one can estimate recirculation above 60% of the total water needed. Few companies have a liquid effluent treatment system in place. As a result, nowadays about 90% of the water is included in the sludge from the cutting and finish processes; it is placed in disposal tanks of which a significant portion evaporates. It should also be noted that the majority of tanks is not adequate, and, moreover, little is known about the flow of fluids in the subsurface (i.e., porous media) with potential contamination to streams and rivers and the very subsurface soil.

Converting the necessary amount of water without recirculation in terms of population equivalency gives (assuming an average per capita consumption for Espírito Santo of about 180 liters per inhabitant equivalent x days): Amount for an equivalent population = (49,134 m3 per day) / (0.18 m3 per inhab. x days) = 273,000 inhabitants per day. It would be possible to supply approximately 273,000 inhabitants per day = 8.8% of the population in Espírito Santo per day with the water that is consumed in the production process of the ornamental stone industry. It should also be considered that this figure is very close to the demand of the capital of Espírito Santo, Vitória (292,304 inhabitants in 2000.)

It should be noted that the calculations provided should not be taken at face value and are intended to show a certain order of magnitude. More accurate calculations would depend on a census of the entire industry in the state of Espírito Santo, and this is one of the important goals to be achieved.

As far as granite and marble mining is concerned, no in-situ data are available, and the flow rates required for the cutting equipment are not very meaningful in relation to other steps in the process.

4 ENVIRONMENTAL IMPACTS

4.1 CUTTING AND POLISHING ORNAMENTAL ROCKS

various impacts are caused by the ornamental stone industry from its mineral exploration to the cutting of rocks and polishing of slabs. The impacts are also classed as to the type of impact – social, economic, civic or labor-related impacts, or whether they cause direct damage to human health or indirect damage through environmental contamination.

This section is not intended to provide such a comprehensive and systemic coverage. However, before describing the impacts caused by the sawmills, it is important to show the impacts on water and soil quality during mineral exploration, extraction, processing and in the supporting areas in the ornamental rock production process (see Table 11).

With the regard to marble and granite cutting, the pollution flow is basically shown in Figure 53.

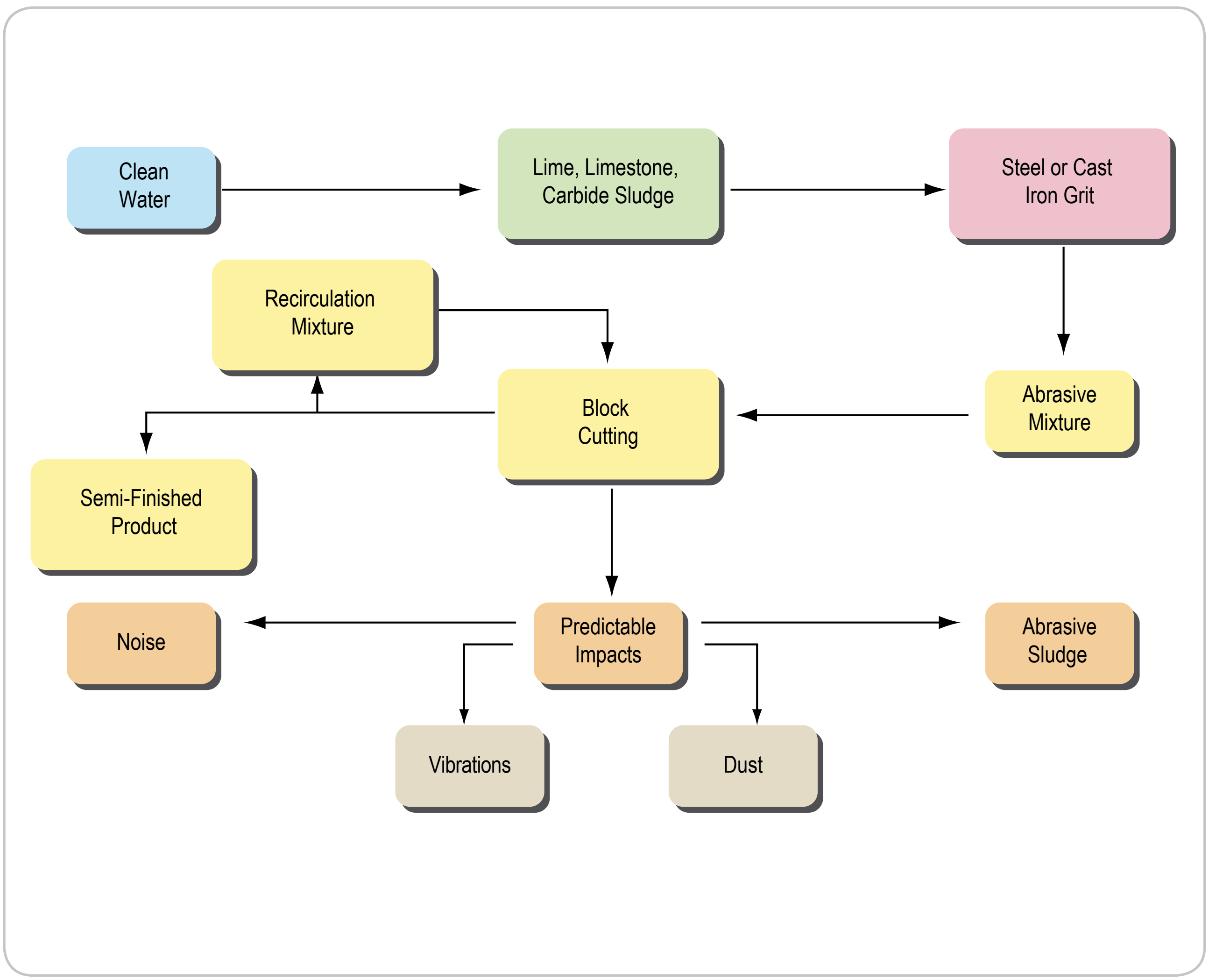

Figure 53. Flowchart for the pollution generated from ornamental rock block sawing (SILVA, 1998)

Table 11. Impacts generated during mineral exploration and all other stages of ornamental rock production

Mineral exploration		
Type	**Cause of impact**	**Cause parameter**
Rotary or percussion drilling	Particles dragged by rainwater	Increased cloudiness and suspended solids
Large-scale drilling and sampling	Stirring and turbulence of wetlands and beds of watercourses	Increased cloudiness and suspended solids
Mining (extraction)		
Tipo	**Causa do impacto**	**Parâmetro gerador**
Open-pit bench mining	Fine particles from open-pit areas dragged by rainwater	Increased cloudiness and suspended solids
Water blasting	Inflow of particles dragged by rainwater and release of slurry waste	Increased cloudiness, suspended solids, pH, and other compounds
Processing		
Type	**Cause of impact**	**Cause parameter**
Block sawing	Slurry waste released into disposal tanks or watercourses	Increased cloudiness and suspended solids, with potential metal solubilization due to the duration of exposure to water
Polishing and cutting	Slurry waste released into disposal tanks or watercourses potentially containing thick chemicals	Increased cloudiness and suspended solids, potentially with organic substances
Support areas		
Type	**Cause of impact**	**Cause parameter**
Garages	Use of fuel oils and lubricants	Increased concentration of oils and greases
Households, kitchens, toilets, etc.	Release of organic wastewater	Increased coliforms. Decreased amount of dissolved oxygen

Source: Ibram (1992), pages 23-24

The abrasive sludge is usually dumped in large final disposal tanks found in most of the sawmills in the state of Espírito Santo. It is estimated that the amount of this waste generated every month in the state of Espírito Santo is around 60,000 tones (wet weight), or 49,000 tones (dry weight), considering only 60% of the sawing capacity.[4] The findings of research conducted by Prezotti (2003) show figures around 1,500 m^3/day or 3,000 tons/day, which means 90,000 tones (wet weight) of liquid effluents released by the industry per month. In the case of abrasive sludge, about 500 kg of steel grit per sawing are used (a set of blades performs about two sawings operations). It can be estimated that, together with the effluents, about 186,000 kg of ferrous waste are discarded on a daily basis without any proper controls to minimize environmental impacts (PREZOTTI, 2003).

[4] The amount of waste, abrasive sludge and regular sludge from polishing require more accurate calculations, though the figures provided here provide a good basis for the present time.

It important mentioning that during the sawing process 25-30% of the block turns into powder (minimizing this loss depends heavily on improving the cutting technology). This material generated by the sawing operation – usually involving conventional bandsaws – contains steel grit, water, limestone, and other substances. Thus, treatment of this waste should be assigned high priority by the industry, noting that their final disposal in industrial landfills causes large deserts to form and therefore is not the best solution to the problem.

Hence, as a matter of urgency, the production process must be improved and technologies must be developed to reduce waste and for its recycling, which will add value to the final product and allow its application in other industrial sectors. Industrial landfills should always be the last alternative under an environment-friendly policy.

Photo 59 shows the surface dimensions that a final disposal tank can have for the waste from the sawing of ornamental rock blocks.

Photo 59. A tank for final disposal of the waste from the sawing of ornamental rock blocks

Photo 60 shows the depth and dimensions that a final disposal tank can have, while (Photo 61) displays a saturated final disposal site. Under such conditions, the excessive amount of waste will be removed and dumped elsewhere.

Photo 60. Depth of the tank containing solidified abrasive sludge

Photo 61. An end-of-life tank

Photo 62 shows the environmental contrast in ornamental rock producing areas. Despite the efforts and concern of the sectors involved and the individual companies, the waste and tailings are often released directly into the natural environment without undergoing any treatment process to eliminate or reduce the harmful components in the materials being dumped.

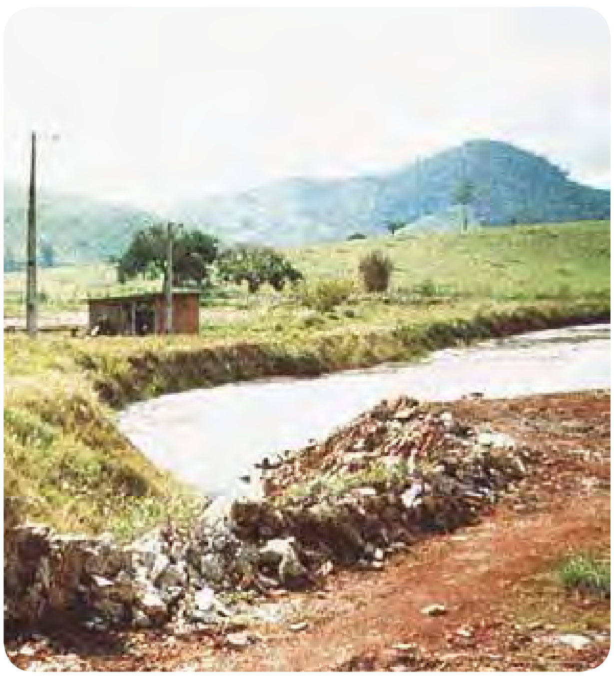

Photo 62. Environmental contrast in ornamental rock producing areas

As it turns out, waste may be released directly into water bodies. When they are released onto the soil, they may be being dumped in inappropriate places without proper protection and waterproofing. In addition to contaminating the soil itself, this could alter the characteristics of the subsoil and water table. Photo 63 captures a situation where the waste is released directly into a watercourse, and the change in water color and pH is visible, which cause damages to the local fauna and flora).

Photo 63. Release of ornamental rock sawing waste into a watercourse

Photo 64 illustrates the accumulation of waste generated in a rock sawmill.

Foto 64. Acúmulo de resíduos gerados

In summary, the data provided by Prezotti (2003) show that, in virtually all cases, block cutting companies release the wastewater generated by their bandsaws into accumulation tanks that lie directly in touch with the ground, without any proper sealing. There is no fluid recirculation whatsoever;

some of the water will either evaporate or seep into the soil, while some of the water will remains as moisture in the waste.

About 2% of the 1,200 companies in this industry in Espírito Santo do have effluent separation procedures of the effluents generated, and they have treatment systems in place that include a mere physical-chemical treatment consisting of a coagulant dosage, primary sedimentation, and a filter-press for dewatering the sediments.

4.2 IMPACTS OF ORNAMENTAL ROCK EXTRACTION ACTIVITIES ON THE QUALITY OF WATER

Although there is great need for studies and research work on the damage to water bodies and groundwater, some findings by different researchers are available.

• Assessment of changes in water quality – Caiado and Mendonça (1995) reported the results of studies for the assessment of changes in water quality in the basins of the Castelo and Fruteiras river, and the final third of the Itapemirim river, located near the town of Cachoeiro do Itapemirim, south of Espírito Santo.

The results were compared with those for the Norte Braço Direito river basin, which serves pasture and farming areas and has outcrops of gneisses, which have not yet prompted major investments for prospecting and is therefore taken as an example.

Research has shown that the marble and granite mining and processing activities cause significant changes to the quality of water resources in the region, increasing concentrations in all parameters considered, except for the concentrations of magnesium and iron, which showed no changes that could be described as the result of impacts from these activities.

The changes in water quality observed by the researchers indicate the need for greater control of mining companies, which have caused damage to the use of water resources and harmful changes to the aquatic fauna and flora.

• Análise de solubilização e lixiviação dos resíduos gerados na fase de desdobramento de rochas ornamentais (in natura e incorporados em produtos)

In his Master dissertation, Silva (1998) discussed at length the features of the ornamental rock production industry as an attempt to bring to light the generation and final disposal of the waste from the sawing of granite blocks. A chemical, morphological/structural, physical and environmental profile was developed, and the potential use of this waste for the production of building elements was assessed.

The experiments discussed in this dissertation show that, although the waste is described as Class II, unprocessed – non inert, due to aluminum concentrations above the maximum limits set by standard NBR 10004/87 –, when it is added to a product such as bricks and mortar it poses no environmental risks. This finding is the result of analyses of solubilization (NBR 10006/87) and leaching (NBR 10005/87). In other words, addition of solid waste to typical construction, ceramics and other products either mitigates or eliminates the environmental impact caused by the unprocessed waste.

• An analysis of solubilization and leaching of waste generated during the cutting of ornamental rocks (unprocessed waste)

In studies conducted by Gonçalves (2000) and quoted by Prezotti (2005), for the use of waste from the cutting of granite in concrete, the environmental risk of this material was assessed through leaching tests (NBR 10005/87) and solubilization tests (NBR 10006/87). The RBRO[4] were classified as Class II – non inert, because they had fluoride concentrations above the maximum limits established under NBR 10004/87.According to Prezotti (2005), considering the partial results from the sampling and profiling of semi-solid dried waste (dried fluid sludge) conducted according to standard NBR 10004/04, laboratory tests indicate the classification of waste as Class II A – non inert, because they had cadmium concentrations (leaching tests from one of the companies considered) and iron (solubilization tests from one of the companies considered) and fluoride (solubilization tests from one of the companies considered) above the caps stipulated by NBR 10004/87. These results corroborate the information in the relevant literature.

It should be pointed out, however, that it is not possible to establish the classification of this type of waste conclusively since the RBRO profiling studies published in Brazil are few in number, and the methodology used does not bear statistical significance, especially with regard to the sampling runs and environmental profiling parameters studied.

The results from laboratory tests performed to date indicate the classification of semi-solid dried waste (dried fluid sludge) as Class II A.

According to the author, the idea is to increase the number of samples, analyzing the waste in a semi-solid state and separating them by stage of processing – sawing and polishing. The objective here is to obtain specific knowledge by type of waste for differentiated treatment and for greater efficiency in the mitigation of the potential impacts associated with this process.

[5] Waste from Ornamental Rock Processing.

5 PAST AND CURRENT RESEARCH PROJECTS BY THE ACADEMIC AND SCIENTIFIC COMMUNITIES ON THE DEVELOPMENT OF SOLUTIONS FOR THE USE OF ABRASIVE SLUDGE FROM THE CUTTING OF MARBLE AND GRANITE BLOCKS IN THE STATE OF ESPÍRITO SANTO

Significant work and efforts have been ongoing at both regional and national level in order to find applications for abrasive sludge; these are generally associated to research focused on its potential use in the civil construction industry as construction items and materials, in road development, the ceramics industry and so on.

In Espírito Santo in particular, the authors of this section have been developing research at the Center for Civil Construction Development (NDCC) and the Federal University of Espírito Santo's Technological Center since 1995. The research focuses on the use of abrasive sludge as mortar for masonry laying and soil-cement bricks (research project sponsored by SEBRAE-ES). These research projects have culminated in a Master dissertation on environmental engineering by Silva (1998) and two papers published in domestic conferences: Calmon et al. (1997a); Calmon et al. (1997b); and Calmon et al. (1998). The research project and the dissertation itself were fairly broad, and they included a profile of abrasive sludge in chemical, morphological, microstructural and environmental terms, in addition to the applications considered. From an environmental standpoint, the sludge was analyzed both in unprocessed form and with new materials (mortar and soil-cement bricks).

5.1 PAST RESEARCH PROJECTS

It is not our intention to cover this topic fully here, but to be as accurate as possible. Table 12 contains the research projects and/or published papers, mostly at national level, on potential applications for this sort of waste. Great prospects for use primarily in

Table 12. Published papers relating to the applicability of abrasive sludge

Author (year)	Title
Freire e Motta (1995)	Potential for commercial use of sawing granite waste
Calmon et al. (1997a)	Recycling the waste from granite cutting for the production of mortar
Calmon et al. (1997b)	Using the waste from granite cutting for the production of mortar for masonry laying
Calmon et al. (1998)	Using the waste from granite cutting for the production of soil-cement bricks
Silva (1998)	Profiling of the waste from granite blocks sawing. A study on its potential use in the production of mortar for masonry laying and soil-cement bricks
Gonçalves (2000)	Using the waste from granite cutting as an additive for the production of concrete
Lima et al. (2000)	Study on the technical feasibility of replacing conventional ceramic powders with granite powder in low-pressure injection of ceramic pieces
Hernández-Crespo and Rincón (2001)(1)	New porcelainized stoneware materials obtained by recycling of MSW incinerator fly ashes and granite sawing residues
Falcão Pontes and Stellin Júnior (2001)	Using tailings from sawmills in Espírito Santo in the civil construction industry
Rodrigues (2001)	Using waste from the sawing of granite rocks as filler in hot-laid asphalt concrete
Gonçalves et al. (2002)	Assessing the impact of using the waste from granite cutting as an additive for the mechanical properties of concrete
Alvarenga (2002)	Housing made from light steel structures and recycled components – A conceptual essay
Moura et al. (2002)	Using the waste from marble and granite cutting in mortar coating and manufacturing of floor tiles
Menezes et al. (2002)	The state of the art on the use of waste as alternative ceramic raw materials
Moreira et al. (2003)	Using granite sawing waste from the state of Espírito Santo in red ceramics
Miranda et al. (2003)	Using kaolin and granite waste in the development of plastic masses in the making of sandstone ceramics. Proceedings....UFPB, 2003
Ferreira et al. (2003)	Using industrial waste from the sawing of granite for use in the development of masses for the making of ceramic coatings
Silva et al. (2003)	Recycling granite waste for use in the development of plastic masses for the making of rough ceramic tiles
Souto et al. (2003)	Using granite sawing waste in the development of white ceramics. Proceedings... UFPB, 2003
Prezotti (2003)	Findings from the monitoring of liquid effluent treatment plants from marble and granite processing industries based in the town of Cachoeiro do Itapemirim
Menezes et al. (2004)	Use of granite sawing wastes in the production of ceramic bricks and tiles
Souza et al. (2004)	Using waste from the sawing of granite rocks as filler in hot-laid asphalt concrete

Continued...

Table 12. Published papers relating to the applicability of abrasive sludge (continued)

Author (year)	Title
Calmon (2005)	The current state of research on waste from ornamental rock processing. Emphasis on its potential use
Prezotti (2005a)	Proposal for the management of waste generated in ornamental rock processing
Costa (2005)	Using waste from marble quarries as secondary materials for the construction industry
Mothé Filho (2005a)	A study of liquid effluents in the marble and granite industry
Correa (2005)	Using waste from ornamental rock sawmills in the making of asphalt
de Mello (2005)	An evaluation of the use of sludge from marble and granite finishings as raw material in red ceramics
Mello (2005)	Potential use of fine waste from the sawing of marble and granite blocks in the cement industry
Mothé Filho (2005,b)	Recycling: the case of solid waste from ornamental rocks

Note: (1) The authors are from the Instituto de Ciencias de la Construcción Eduardo Torroja, Madrid, Spain.

the civil construction and ceramics industries have been identified.

In the case of waste from ornamental rocks in the research projects provided in Table 12, in most studies the waste was used as is, i.e., including the grit. Some studies addressed the issue of magnetic separation of the grit, testing different magnetic separation methods in order to select the most effective one.[6]

It should also be pointed out that even when the magnetic separation method was used, not all grit could be removed, because approximately 60% of the particles are magnetically susceptible at room temperature (see Mössbauer spectroscopy in Silva, 1998). It is our judgment that using this waste in the ceramics industry requires more caution; however, it is indeed feasible, and a number of success stories are available. Although many papers have been written, some findings by researchers Falcão Pontes and Stellin Júnior (2001) are used here:

- Purifying the waste through high-intensity magnetic separation is technically feasible. This process was able to remove up to 75% of the iron, i.e., reducing its contents from 3.2% to 0.7%, thus enabling prime uses.
- Cyclone-based purification studies require further development, because in spite of their results (removal of 30% of the iron) being worse than those for the magnetic separation studies, these results can be improved. Furthermore, this approach involves low operating investment costs.
- The results for use of the waste in red ceramics and civil construction were considered to be promising.
- The processed waste may be used in up to 30% of mass composition for red ceramics.
- In view of its size, the processed waste may be a good replacement for coarse clay that potters often mix with their finer clay to decrease plasticity.

[6] See, for instance, Falcão Pontes and Stellin Júnior (2001).

- Unprocessed waste fails to provide the minimum mechanical strength at 900 °C at proportions of 20% and 30%.
- Although the unprocessed waste does meet the requirements at 1,100 °C, it has surface and internal defects such as a black core that make its use in formulations for red ceramic pieces unfeasible.
- Unprocessed waste fails to provide the minimum mechanical strength at 900 °C at proportions of 20% and 30%.

A research project that deserves special mention was conducted by Alvarenga (2002) under the guidance of Professor J. L. Calmon, one of the authors of this case study. The culmination of this research project was a dissertation called "Housing made from light steel structures and recycled components – A conceptual essay. The project brought together the concepts of sustainability with the use of steel structures and various components recycled as architectural elements. One of the components was the sealing walls for the building, made from granite scrap slabs from the ornamental rock industry.

The idea is to use the scraps, which is an abundant waste, as an alternative for the sealing of buildings. It is low cost, tough and durable, and it can be obtained through existing, affordable technologies.

When a granite block is sawn to produce slabs, the "slices" from both ends go to waste, and these are what we call "scrap slabs", which can be seen in Photo 65. The block has a major characteristic for its intended use: one smooth, sawn side; and one rough, uneven side. As the structural light steel frame system makes use of sandwich-like sealings, i.e., the panels or slabs are fitted on both sides of the structure, thus concealing it, so the smooth side can be visible and the rough side faces the other way. This was the origin of this alternative exterior sealing for buildings.

Another important project that has been conducted is the Atecel® (Luiz Ernesto de Oliveira Junior Technical and Scientific Association), under an agreement with the Federal University of Paraíba (UFPB). An important line of research is developed in the domain of waste reuse, which has been called "Esse lixo é um luxo", which can be freely translated as "Wonder Waste". A project that stands out is "Tirando leite de pedras" ("Milking stones").

Photo 65. First and last "slice" from the sawing of blocks on a bandsaw

The project's overall objective is to promote a culture of recycling stone materials and mineral waste in general in Paraíba. The specific objectives are: a) production of bricks and building blocks based on composite solid waste; b) production of ornamental stones and handicrafts, also based on composite waste, c) manufacture of tools for homes and offices consisting of cheap green composites d) production of inputs for civil construction from construction leftovers and demolition debris; e) reduction in the amount of waste to be managed by the government, f) lowering of civil construction costs and other costs.

It is worth mentioning also the teamwork conducted at UFPB on the use of waste from the ornamental rock industry in the ceramics industry, and the work currently being done at the State University of Feira de Santana (UEFS), in Bahia, regarding use of abrasive sludge as a building material.

5.2 RESEARCH AND DEVELOPMENT PROJECTS

A joint research program is currently being conducted by a partnership that includes the State University of Feira de Santana (UEFS), the Federal University of Espírito Santo (UFES) and the Technological Center for Marble and Granite (Cetemag), sponsored by Finep/MCT. It is called RSROHIS – Project for the Utilization of Waste from Ornamental Rocks in the Production of Ready-Made Parts for Social Housing. The project's coordinators are Professor Washington Moura, PhD (UEFS) and Professor Joao Luiz Calmon, PhD Engineer (UFES).

The project has a two-fold rationale. First, the environmental issue associated to the waste generated from the cutting of granite both in the state of Espírito Santo, one of the largest producers of granite in the country, and the state of Bahia. Secondly, the issue of housing demand at national level, where such waste could be used in the making of various architectural elements for the civil construction industry.

This project is a good indicator and example of integrated research among universities, creating networks of researchers with a view to solving an issue that is both a regional and a national problem.

This project will include a feasibility study on the use of waste from the sawing of ornamental rocks (marbles and granites) to produce ready-made parts (sealing blocks and precast floors) for Social Housing (HIS), which will contribute to innovative product development technologies while adding value to the waste used as an alternative product aimed at building homes for low income families will be created.

As far as self-compacting concrete is concerned, research studies are ongoing within the Graduate Civil Engineering Program at UFES under the guidance of Prof. Joao Luiz Calmon. As the self-compacting concrete requires a considerable amount of filler, marble and granite wastes are being studied for use in large quantities. No conclusive results are available as of yet.

Figure 54 provides a graph showing the potential uses of abrasive sludge in industrial sectors.

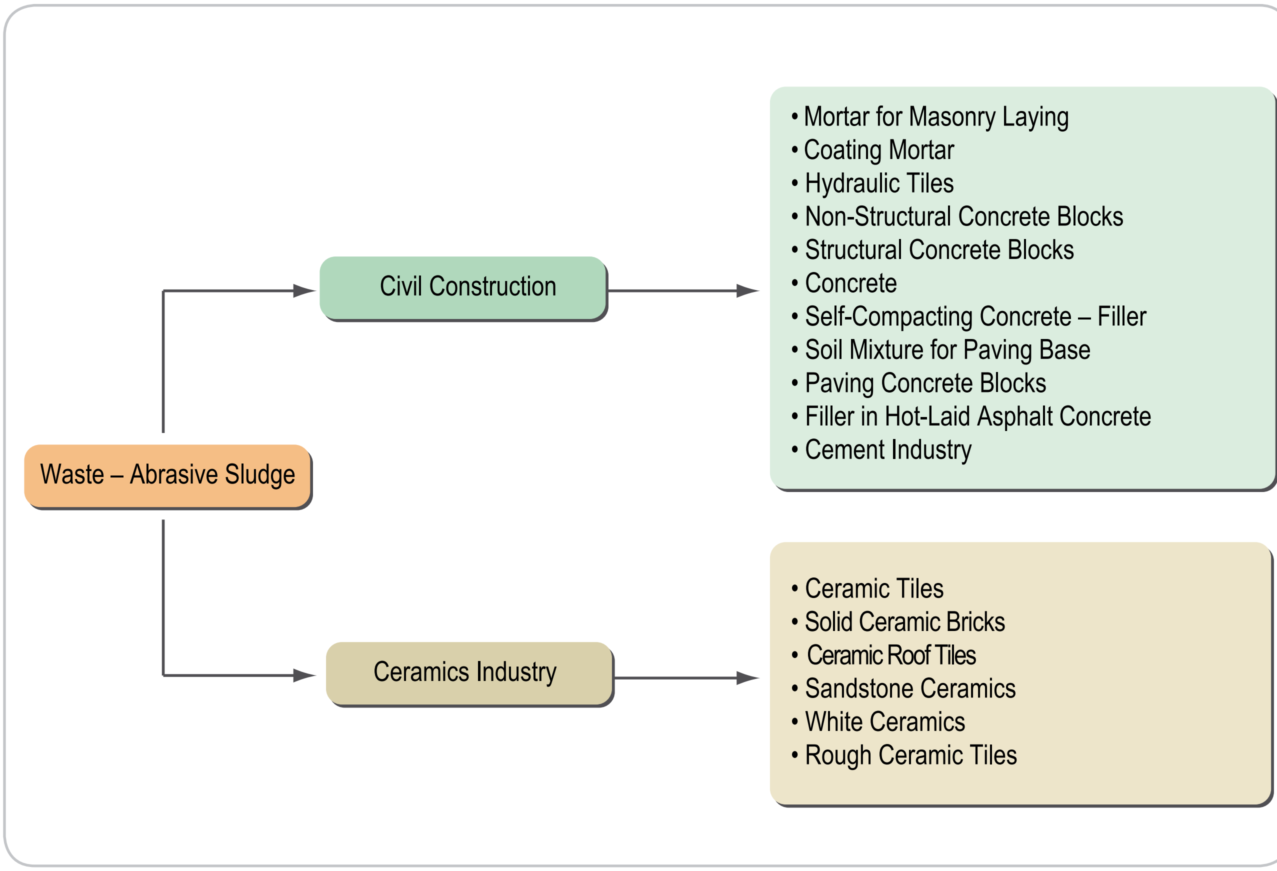

Figure 54. Uses for abrasive sludge in the civil construction and ceramics industries

5.3 RESEARCH PROJECTS IN THE PIPELINE

- Integration of the research studies on abrasive sludge – Rochab[7].

The integrated research mentioned earlier was proposed by Calmon (2004) in a draft research project submitted to the Technological Center for Marble and Granite (Cetemag) (Cachoeiro do Itapemirim, Espírito Santo, Brazil) with a view to obtaining funding for the project.

The overall goal of the project is to bring together the knowledge generated from research studies conducted so far. Also, the idea is to optimize the investments that have been made in R&D by different funding stakeholders so far. To this end, the experimental development and product and process engineering phase is launched, the next step being a critical transfer of technology, especially for micro and small businesses (mostly "homegrown" businesses) manufacturing various products or buildings materials.

For this, a housing prototype called Rochab is built with materials or products that include waste from ornamental rock sawing (RSRO) in their composition. These materials are: concrete with additions for different housing elements (Econcreto),

[7] Civil Construction Development Center (NDCC) and the Federal University of Espírito Santo (UFES).

concrete blocks structural masonry laying (Ecobloco), coating and laying mortar (Ecomassa), concrete roof tiles (Ecotelha), blocks for interlocking pavements (Ecopav), and hydraulic floor tiles (Ecopiso). The housing units to be built will raise the profile of the social, economic and environmental viability of using the various products mentioned above. The prototype could include about five or six tons of RSRO for the same type of waste per housing unit covering a built area of 42,00 square meters.

It should be underscored that the solution to make this type of waste economically viable is not necessarily associated to residential construction, but the whole of small manufacturers of construction items and materials. These manufacturers will sell such products with waste added to them in accordance with the specifications required by the Brazilian Association for Technical Standards (ABNT).

For environmental sustainability, there should ideally be the option of generating as little waste as possible, even early in the design phase of the manufacturing process. When this is no longer possible then recycling the waste generated is the next step. Finally, one should opt for landfills and the waste deposits for the different classes.

No doubt, however, that the civil construction market is an excellent alternative for this large volume of waste that is generated and discarded during the manufacturing process.

Once the housing unit has been built (Rochab), it will become a token of the various possible products that use RSRO, and this will help integrate and build on the research studies carried out so far at national level.

The primary focus of the project is improving technologies that are developed during the research work and are applied to different products in conjunction with process and product engineering. The prototype will reflect the ability to add about five or six tons of RSRO to different components in a single social housing unit. It is estimated that a small residential complex with two hundred homes would consume about 1,100 tons of waste, not including street paving, whose RSRO consumption would be approximately 150 tons per kilometer for interlocking paving blocks with 6 centimeters in thickness. In terms of the housing units, the estimated consumption for a group of 12 blocks containing 16 housing units each is more than three hundred tons of RSRO for the structural masonry blocks alone.

• Social and Environmental Project – Cetemag

The overall objective of the social and environmental project is to outline the first steps in an umbrella project of integrated actions that will contribute to the development and deployment of new technologies aimed at addressing the socio-environmental problems that currently hamper the activities conducted by the APL in Cachoeiro do Itapemirim, Espírito Santo.

The project has the following specific objectives: a) creating, in a syndicated manner, geographically dispersed stations for storage, treatment and reuse of waste generated by the sector, in accordance to the requirements of environmental agencies; b) attracting business that use these wastes as raw materials in their production processes; c) establishing technology partnerships that expand the range of commercial use for waste; d) reusing the waste generated in production processes, e) creating jobs for the communities in each station by establishing new ventures; f) conserving the environment where the APL is based; g) establishing the image of an industry that is committed to environmental and social integrity in their local region; h) providing training and recreation areas for the community in each station; i) rehabilitating degraded areas; j) setting up environmental hubs that will include marble and granite businesses; k) issuing a Socio-Environmental Certification for the companies participating in the stations.

The ideas and goals outlined in the project are vitally important to make sure that the scientific research conducted so far can be implemented since it relies on waste storage logistics and the informed cooperation of micro entrepreneurs, who could produce items for the civil construction and ceramics industries, among others

6 EQUIPMENT AND NEW TECHNOLOGIES INCORPORATED INTO THE PRODUCTION PROCESS

6.1 THE ECOTEAR ("GREEN BANDSAW") (SINDIROCHAS, 2004A)

Entrepreneur Aristides Fraga Filho has been working on a device to cut rock blocks without using water for nine years now. The equipment is called Ecotear ("Green Bandsaw") and reconciles environmental conservation and production savings. It could revolutionize the entire ornamental rock production industry.

The Green Bandsaw is nine meters long and four meters wide, and it weighs about 45 tons. It is smaller than a conventional bandsaw, and it is used to cut blocks into slabs. The novelty is that it uses no water in the cutting process, which minimizes the environmental impact of the industrial processing of ornamental rocks.

In addition to operating without water, the Green Bandsaw cuts blocks vertically, allowing the grit to be directly inserted into the cutting slot by means of a dosage and distribution system that feeds each channel individually.

The Green Bandsaw generates waste in powder form, which sets it further apart from the conventional bandsaw, whose waste is abrasive sludge. The equipment will be insulated to prevent suspended particles from being dragged, enable the collection of waste and also avoid excessive noise, thus complying with the applicable legislation.

According to the entrepreneur who developed the equipment, as the waste is generated it goes through a magnetic separation process to sort the metal from the mineral elements. According to plan, the mineral waste can be packaged and sold for the production of mortar and other items. The metal waste, in turn, can be used for steel production.

Funding from the Ministry of Science and Technology (MCT) is expected for tests to start.

6.2 THE FILTER-PRESS

A filter-press is an essential device in the marble and granite production industry. It performs a pressing process that removes excess water from abrasive sludge and returns this water for reuse in cooling while blocks are cut on the bandsaws. This reduction in the moisture level in the pressing process makes the waste more suitable for use in the manufacturing of construction materials and products in the ceramics industry.

A major solution would be to put filter-presses in the waste stations or plants in industrial facilities for reuse of the water contained in the abrasive sludge and processing of the waste for storage and subsequent use. This idea is reflected in Cetemag's Social and Environmental Project, which has set out to create, in a syndicated manner, waste stations or units spread geographically within the APL. These plants will be for storage, treatment and reuse of the waste generated by the sector, and will comply with the requirements of environmental agencies. At the same time, the idea is to encourage use of the waste in the companies concerned

6.3 USE OF RAINWATER IN INDUSTRIAL PROCESSES

In order to boost the economy, rational use of natural resources and education of entrepreneurs about the importance of water reuse, consultant Marlon Antonio Machado (an engineer hired by Sindirochas) has been disseminating the practice of rainwater harvesting for use in industrial processes among the business community in the industry (Sindirochas, 2004c).

According to Mr. Machado, southern Espírito Santo currently has about 1,500 companies in the ornamental rock industry. Considering that industrial plants have at least eight hundred square meters in covered area, this would total 1,200 square kilometers of covered area available for rainwater harvesting. Some companies are already doing this via a cistern.

Under the licensing obtained by company Bruno Zanetti, researcher Julio Prezotti estimated the possibility of harvesting about 960 cubic meters per month, with a covered area of about 10,000 square meters and average monthly rainfall of 120 mm/month. In this case, a cistern was built with capacity for about 450 cubic meters of rainwater.

Considering rainwater harvesting for use in rock processing, and taking an average of 1,000 square meters of covered area per company and a total of about eight hundred large companies (excluding small companies), it would be possible to collect about 2,560 cubic meters per day, which is equivalent to 5.2% of the total needed for the industry in Espírito Santo (49,134 cubic meters per day). Assuming that 75% of the water would be recirculated through an effluent treatment system and a filter-press (water consumption would be reduced by about 36,851 cubic meters per day), and considering the feasibility of harvesting rainwater (2,560 cubic meters per day), the system would need to capture around 9,724 cubic meters of water per day from other sources.

Therefore, if harvested, the flow of rainwater would be: Q = c. I. A, where c denotes the runoff coefficient (assumed to be 0.8 for a reinforced concrete roof cover), I is the monthly rainfall, or 0.12 meters per month; and A denotes the harvest area, which in this case is 10,000 square meters. The flow rate would be Q = 0.8 x 0.12 x 10,000 = 960 cubic meters/month. It's quite a lot of water that can be used. In the case under consideration, a cistern was built with capacity for about 450 cubic meters of rainwater.

The same reasoning can be used for the entire covered area in this industrial sector. Considering an average of 1,000 square meters of covered area per company and a total of about eight hundred large companies (excluding small companies), each company could collect about 96 cubic meters per day, i.e., 76,800 cubic meters per month, or 2,560 cubic meters per day, which is equivalent to 5.2% of the total required by the industry in Espírito Santo (49,134 cubic meters per day). Assuming that 75% of the water would be recirculated through an effluent treatment system and a filter-press, and considering rainwater harvesting (2,560 cubic meters per day), the system would need to capture around 9,724 cubic meters of water per day from water tables, rivers or from utility Cesan. This simulation should obviously not be taken at face value in light of the probabilistic nature of rainfall, since rainfall varies according to region in the state of Espírito Santo. So, considering the rainfall profile of the various regions of the state, rainwater harvesting could reach 189,360 cubic meters per month, or 6,312 cubic meters per day. Thus, the system would need to catch 5,971 cubic meters per day from water tables and/or other sources.

It is worth noting that the figures above are estimates and are a mere indication of the magnitude that can be achieved by using rainwater in rock processing systems. Accurate calculations would depend on a comprehensive register across the industry in the state of Espírito Santo.

6.4 EMPRESA POLITA – A NEW BANDSAW (SINDIROCHAS, 2004D)

The implementation of a bandsaw imported from Italy that has a diamond instead of a blade for sawing blocks is a differential for Polita, a company based in Cachoeiro do Itapemirim, Espírito Santo. The bandsaw provides advantages such as increased production, decreased cutting time and environmental improvements since grit is not used.

6.5 EQUIPMENT PRODUCED BY BERMONTEC E AÇORES METALURGIA – CACHOEIRO DO ITAPEMIRIM, ES

• Grit recovery system

This equipment allows one to recover 100% of active grit by eliminating the waste (sawdust and fine grit), and it automatically monitors the level of the pit of the bandsaw and the viscosity of the sludge in order to add mixture (water plus lime). Using grit in the sawing process has a direct impact on costs, and when the abrasive sludge is eliminated, it helps enhance the consistency of waste particles for later use.

• Water settling and purification system developed by Açores Metalurgia (Cachoeiro do Itapemirim), with automation powered by BERMONTEC

In order to recover and preserve water resources, the company has been developing and manufacturing high performance equipment for the recovery of water used in the marble and granite processing industry in Cachoeiro do Itapemirim.

6.6 MARCEL – MÁRMORE COMÉRCIO E EXPORTAÇÃO LTDA

• Successful experiences (based on information provided by the company)

A Marcel, há 19 anos em Cachoeiro de Itapemirim-ES, atua no segmento de beneficiamento de rochas ornamentais em todas as suas ramificações. Sempre teve como um de seus objetivos o melhor aproveitamento possível dos recursos naturais utilizados em seus processos produtivos bem como uma grande preocupação com o destino final dos rejeitos dos processos industriais.

Marcel was established in Cachoeiro do Itapemirim 19 years ago, and it works in all segments of ornamental rock processing. One of its objectives from inception has been to maximize the best use of natural resources in their production processes, and the final disposal of the waste from their industrial processes has always been a major concern.

According to Mr. Rodrigo Guilherme, a company representative, some processes have been revised, and equipment to recycle more than 6 million liters of water per month have been put in place. This is equivalent to the consumption of three hundred (300) households (three or four people each), thereby providing significant savings of the water resources available.

In addition, Marcel has equipment for the recovery of the steel grit used in granite sawmills, and this grit is once again reclaimed as part of the sawing process, thus avoiding contamination of the environment.

Under a partnership with Cerâmica Cimaco Ltda, several tests confirmed the effectiveness of abrasive sludge from Marcel's processes in the mass used in the making of ceramic products as a replacement of one of the clays required for optimal burning.

The company's representative points out that among all types of sludge tested the only type that was approved were those that had gone through a pressing process through a filter-press, which removes excess water from the sludge, the water being available for reuse.

It was also observed that using abrasive sludge in the making of ceramics led to decreased shrinkage in the burning of a more uniform and standardized finished product, and free of the cracks usually found in tiles, bricks, etc.

As a result of the partnership and integration between Marcel and Cimaco, six hundred tons of abrasive sludge are currently recycled every month, which prevents it from being inappropriately disposed of and the associated damages to the environment, in addition to adding value to the waste and significantly reducing the impact on the environment.

Marcel also has a water treatment plant in operation whose physical structure was imported from Italy, which is considered to be a benchmark for ornamental rock mining and processing technology. Such stations are widespread in Italy for the treatment of such water waters (PREZOTTI, 2003), as can be seen in Figure 55 in this case study.

The effluents treated at Marcel are completely recirculated in the manufacturing process, and the solid waste is used in the making of red ceramics.

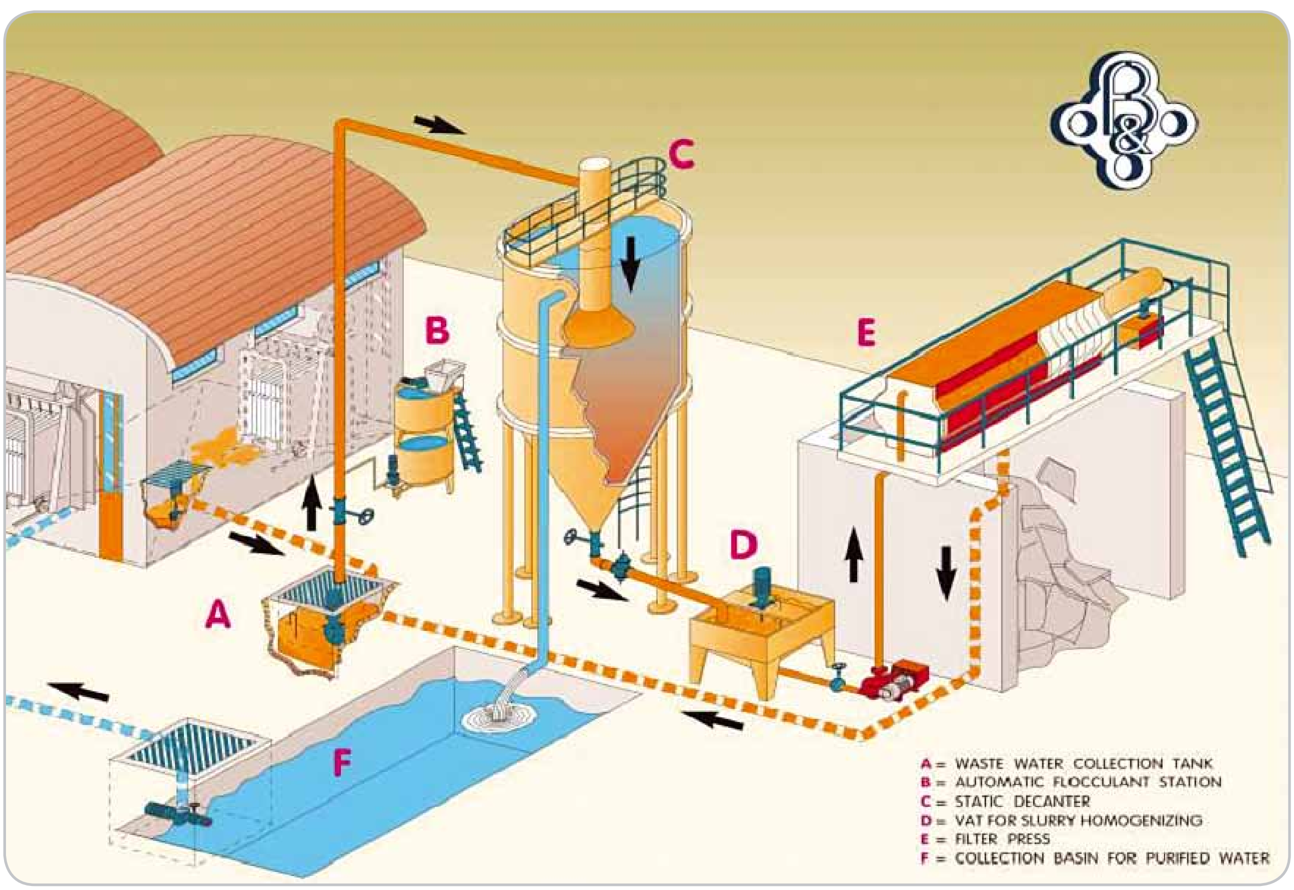

Figure 55. Project design for a treatment plant at Marcel (PREZOTTI, 2003). Courtesy of: Fracarolli and Balsan (Italy)

6.7 PROJECT DESIGN FOR WASTE DEWATERING PROPOSED BY PREZOTTI

Prezotti (2005) proposes a dewatering system comprised of a series of units where a physico-chemical process is performed by means of coagulation/flocculation, primary sedimentation and dewatering of sediments in a filter press. Figure 56 shows a flowchart detailing the treatment throughout various stages in the industrial process (washing of blocks and floors, splitting of blocks, polishing of split slabs, and cutting of polished slabs as seen in Figure 52). The system's physical structure is similar to those in Italy, such as those Marcel has in place.

Prezotti (2005) also proposes a properly designed landfill in accordance with the technical and environmental requirements established by Brazilian Standards ABNT: NBR 13896 (1997) and ABNT: NBR 11174 (1990). After dewatering, the waste is transported to the properly designed landfill.

Photo 66. Cutting and polishing of marbles and granites

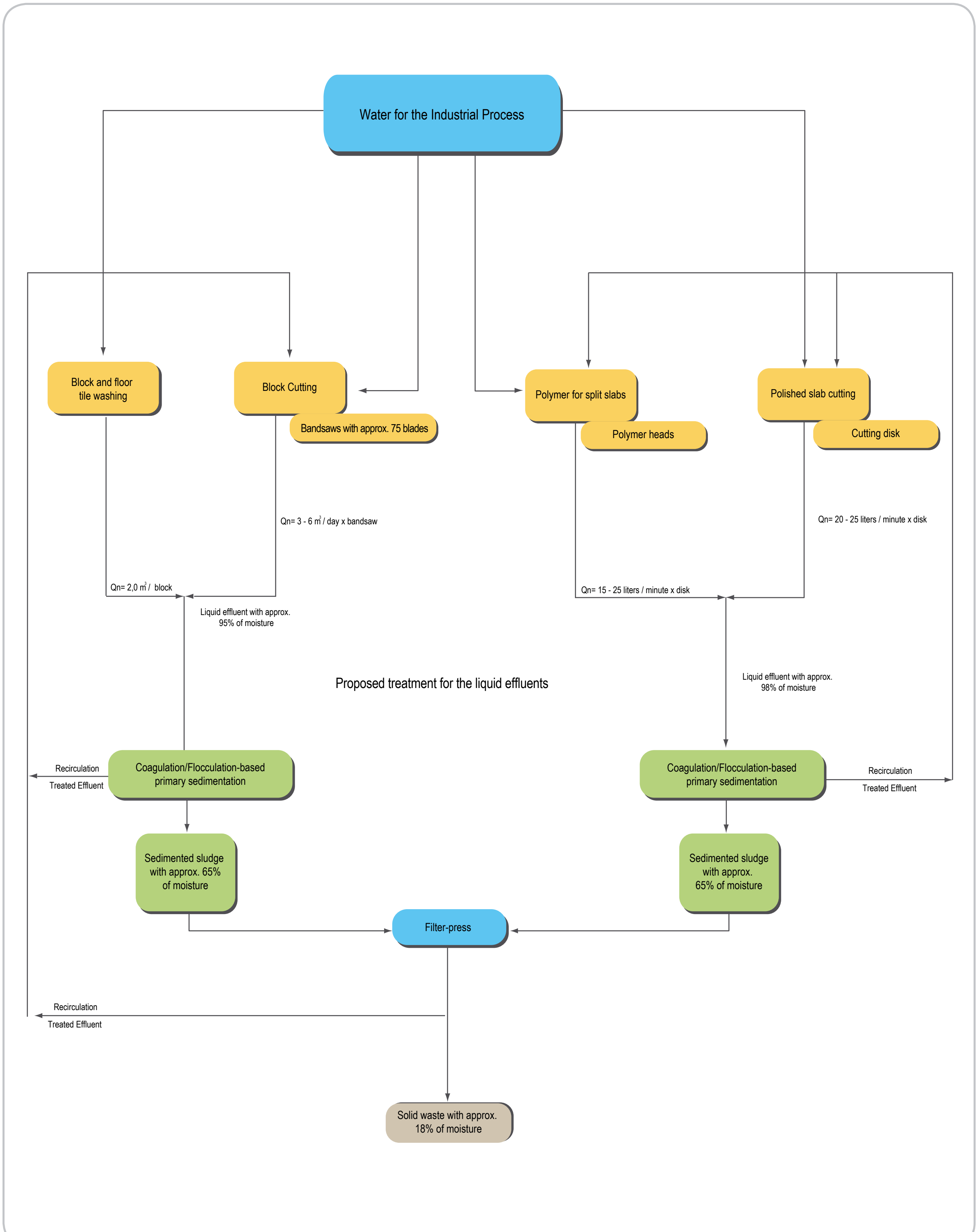

Figure 56. Proposed treatment for the liquid effluents from the industrial process

It is noteworthy that after treatment and dewatering, a policy for the recycling and reuse of solid waste as a raw material for the construction, ceramics and cement industry could prompt replacement of disposal of waste in specific landfills and ensure its transformation into an industrial byproduct.

6.8 THE CASE OF MARMOCIL LTDA

Marmocil Ltd. is based in Cariacica, ES, and occupies a total area of 61,600 square meters. The company belongs to the Granasa Group and its core business is coating stone processing and marketing.

Some corporate initiatives to minimize environmental impact during the production process were submitted by Engineer Sirley Olivieira, from the Group's Department for the Environment.

Ever since the establishment of its processing plant, Marmocil has been making efforts to reduce the waste from slab cutting and polishing, and, therefore, invested in modern equipment that is capable of generating waste that is as clean as possible.

A modern fifteen-blade bandsaw by Wires Engineering, Model Falcon 615, is used for the cutting operations. During the cutting process, water is used for cooling the blades. This water, along with the stone-powder from the cutting process is channeled to a slop tank before it is taken to the filter-press and storage facilities.

The filter-press shown in Photo 67 performs the separation of water from the solid matter. The water is returned to the blade cooling system in the bandsaw, and the waste is stored in a bucket before it is taken to an industrial landfill.

The return on the investment in the diamond blade-based bandsaw and the filter-press is significant from an environmental standpoint, since it allows the water for cooling to be reused and the waste's moisture level is more suitable for use in new materials.

Photo 67. The filter-press

In the wake of its modernization, Marmocil developed studies that demonstrate how technically feasible it is to use waste in the manufacturing of mortar; the waste from both the bandsaw (i.e., stone powder) and the polishing device (i.e., abrasive sludge) are suitable for use. The waste acts as a substitute for a clay mineral used as feedstock for a line of products manufactured by Lorenge. The research results have not yet been fed into the production process.

The use of waste in the cement industry is currently under review by a specialized firm in order to identify the potential use of the waste from the bandsaw (stone powder) in the making of cement. Analyses have proved that the waste can be incorporated into the clinker after undergoing processing and blending that produces optimal mixing and size so that it can be added to the product.

The waste associated to rock flakes from the splitting of rocks and the trimming of blocks have also been covered. For the development of this waste, a Mosaic School is also being established in Cariacica, ES, and it will be managed by the Waldomiro Robson Social and Environmental Institute.

The school will offer professional training programs and its purpose is to train manpower to work with waste from the industry, which should foster social development in the region of Cariacica as jobs and income will be generated.

This project is being conducted under a partnership with the Instituto Internazionale del Marmo (IS.I.M.), Italy, which is involved in all phases – from planning and scaling of machines to training of manpower. All machines were imported from Italy, and operations are scheduled to start in the second half of 2005.

7 FINAL REMARKS

In view of the above, the question becomes why do people continue to dump abrasive sludge at landfills – most of which are totally unsuitable and provide no impermeabilization – considering that there are so many research projects – applied, experimental development and prototyping and other complementary projects, whose results, if implemented, can add value to the waste itself, foster regional development and reduce significantly the environmental impact from the activity.

What these authors can say and argue is that the research conducted and prototypes provide security from the scientific and technical viewpoint, and there is a major range of practical applications. One can argue, without risking exhausting what has been accomplished so far, that significant basic and applied research has been conducted on the use of abrasive sludge (RSRO) aiming at the development of different components and/or cement-based construction materials for buildings and the ceramics industry. Obviously, there must be progress in basic research on the use of fillers – granite cutting waste in the manufacture of sandstone ceramics in the ceramics industry, oil industry (in the area well digging, a topic that has been raise, but is still nascent) in the cement industry and in terms of the use of such waste as a filler in high-performance self-compacting concrete, which is currently being studied under the Civil Engineering Graduate Program at the Federal University of Espírito Santo.

It seems that moving from prototyping to implementation and technological innovation depends on other factors, such as the following: strong political will; more effective environmental law enforcement; concerted action among agents and actors in the process, which involves the ornamental rock industry and their representatives; in addition to other sectors, such as civil construction and ceramics, municipal and state governments, and universities and research and development (R&D) centers.

The state of knowledge, or state-of-the-art on the subject makes it possible to argue for a major integration of the research projects conducted so far at the regional and national levels, as proposed by the Rochab Project, which as of yet has no funding and is complemented by the Cetemag Social and Environmental Project.

In summary, it can be said that the marble and granite production industry should make investments to upgrade their systems and seek partners such as universities, government institutions, professional trade organizations and development agencies working on research and technological innovation in order to mitigate the environmental impact arising from this activity in those cases where their processes are not properly controlled.

Such investments should be concentrated in the areas of solid waste recycling from processing and finishing operations; making bandsaws and polishing systems more efficient; design and deployment of systems for the treatment of liquid effluents (sludge), which allow the water to recirculate across the production system and the waste to be dewatered at filter-presses for later use in recycling processes in the construction, ceramics, and cement industries, in addition to other applications; use of rainwater to supply the processing and finishing system; and establishment of landfills in accordance with the Brazilian legislation; logistic assessment involving the establishment of solid waste plants that would absorb the waste from sawmills to feed the production of building materials; development of a survey of the industrial sector in terms of existing equipment, water consumption, and recirculation, water harvesting systems, among others; studies and research projects in the areas of transport and contamination of soils, streams and rivers; and impact studies on river basins.

It is time to apply the knowledge gained to date by research centers and implement developments from a socio-economic-environmental perspective, which means pursuing sustainable development.

8 ACKNOWLEDGEMENTS

The authors would sincerely like to thank the Technological Center for Marble and Granite (Cetemag) for their major collaboration and, in particular, Marmocil Ltda. and Marcel Mármore Comércio e Exportação Ltda. The authors would also like to thank Engineer Julio Prezotti Simões, M.Sc., for his important inputs on water use in the industry, and Professor Jair Casagrande, from the Environmental Engineering Department of UFES's Technological Center for their guidance on rainwater harvesting.

Photo: Ecotrópica

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WATER RESOURCES MANAGEMENT AT THE MORRO DO OURO MINE

1 INTRODUCTION

Rio Paracatu Mineração S/A (RPM), a Kinross Group Company, extracts gold ore from the Morro do Ouro mine, gold ore being a phyllite rock that can be either oxidized or sulphide. The Environmental Management System (EMS) is a component of RPM's Integrated Management System (IMS), and it has extensive experience in the management of acid drainage and water resources. This section provides a brief description of the operations and the strategy for water resources management, with an emphasis on past and present corporate actions as part of its sustainable development project, for which one of the objectives is rational use of water resources.

2 BASIC INFORMATION

2.1 TAILINGS DAM

RPM is based in Paracatu, a town that lies 230 kilometers from Brasilia. The operation consists of an open-pit mine, a processing and hydrometallurgy plant, a tailings dam, a sulphide waste disposal tank and infrastructure facilities. The operation currently processes about 18 million tons per year and produces six tons of gold. Kinross is the only shareholder of RPM, and the gold mine operated by the Company has lowest content of gold in the world (0.42 g/t). Economic feasibility of this low-content ore has been ensured by specific conditions of operation, such as the absence of capping, softness of the ore, frequent optimizations, and increased production scale.

Photo 68 shows a satellite image with an aerial view of the industrial area of RPM, including the mine and rainwater drainage tanks and dedicated tanks, the tailings dam, the industrial plant, and the administrative areas. The bottom of the image provides a partial view of the town of Paracatu.

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2.2 GOLD GEOLOGY AND MINERALIZATION

The stratigraphic column in the Morro do Ouro (see Figure 57), consists basically of phyllite, and horizons C, coverage T, transition and B1, and oxidized ore, which make up the oxidized portion of the mineralized body, in addition to unit B2 for primary sulphide ore, which has higher hardness.

Groundwater systems are recharged during the rainy season causing groundwater levels to rise. This recharge is relatively small because of the low permeability of the phyllite bedrock. The water flows primarily through fractures and faults, i.e., zones of increased permeability in the rock mass.

Photo 68: Satellite image of an aerial view of RPM in 2003

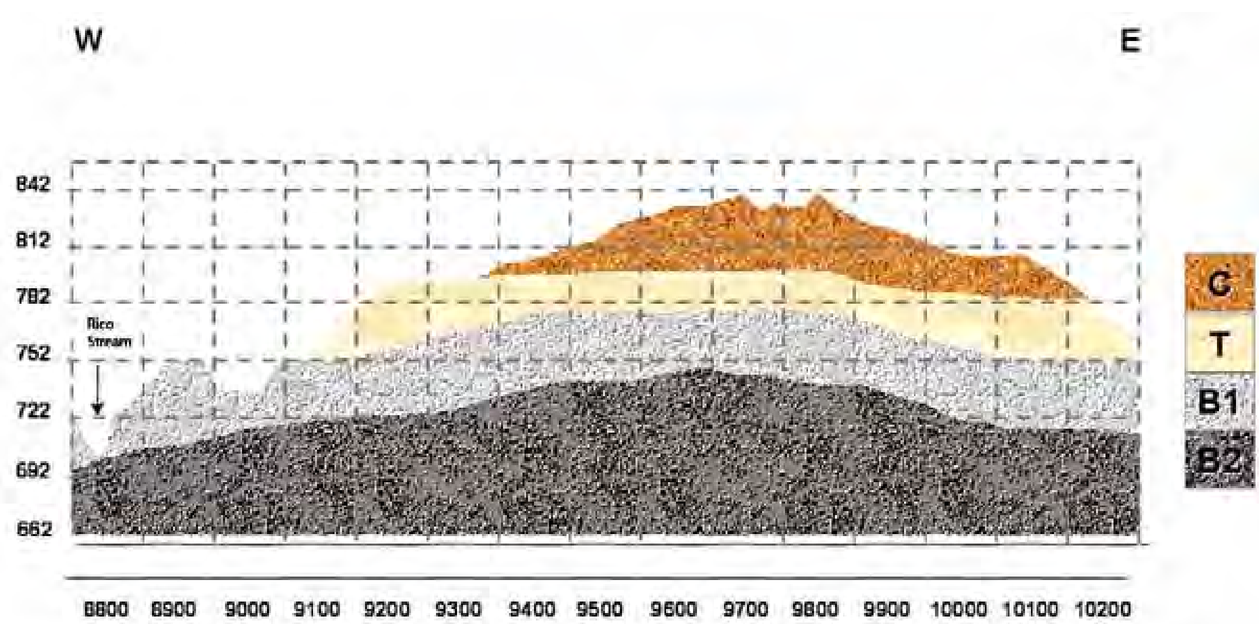


Figure 57. Schematic geological profile of mineralization in the Morro do Ouro Mine

2.3 THE MINE AND MINING OPERATIONS

This is an open-pit mine and there are no prominent slopes around it. Rainwater drainage from the mine is stored in sumps placed at the lower elevations of the mine, in southern and southwestern portions. There is no significant capping, splitting is performed by mechanical means and digging is performed directly by D10N crawler tractors with tillers, and explosives are only used for loosening rocks with a work index (WI) greater than 9. Normally, two sides are operated in the mine – an oxidized and a sulphide side – in order to blend the contents and hardness of different types of ore. Each mining front uses two bulldozers, one loader and four or five 85-100 ton, off-road trucks. The loaded trucks take the ore directly to crushing or stockpiling. Photo 69 provides an aerial view of the mine, showing sumps for rainwater collection. The large extent of the mine and the closely Paracatu can also be seenw.

Photo 69. Aerial view of the Morro do Ouro mine

2.4 ORE PROCESSING AND HYDROMETALLURGY

In general, historical average performance of the gold recovery plant is about 77%. Figure 58 displays a simplified flowchart of the estimated gold and silver production process for 2005.

The ROM ore is crushed in four crushing lines (one in which remains in standby mode) that individually produce about 850 tons per hour. The grinding circuit consists of four primary mills (15" x 19") and a secondary mill with a larger diameter (16.5" x 25") to regrind a portion of the load in the primary circuit. The mills have a closed circuit and hydrocyclones. The current load goes through four jigging lines for gravity-based gold recovery. Flotation is performed in three stages – flash (unit cell), scavenger and cleaner – for the recovery of sulphide minerals and, as a result, the gold and silver that might be associated with these.

The concentrate produced at the plant – around 45 t/h (i.e., 1.5% of ROM) with an average content of 20-30 g/t of gold – moves on to hydrometallurgy, and half of the tailings from flotation are thickened before being released into the tailings dam.

Once in the hydrometallurgy plant, they undergo a regrinding and gravity-based separation process in a Knelson centrifugal concentrator. The reground concentrate (90% < 325 #) is thickened and moves on to the leaching (CIL circuit), elution (where the gold is removed from the coal) and electroplating steps. The final output from these steps is calcined and melted by induction. The bullion (gold bar) produced in this process is comprised of 70-75% of gold and 25-30% of silver, with minor copper and iron impurities. The gold refining process is performed externally.

The following is the simplified flowchart for RPM (see Figure 58) and for the processing and hydrometallurgy plant.

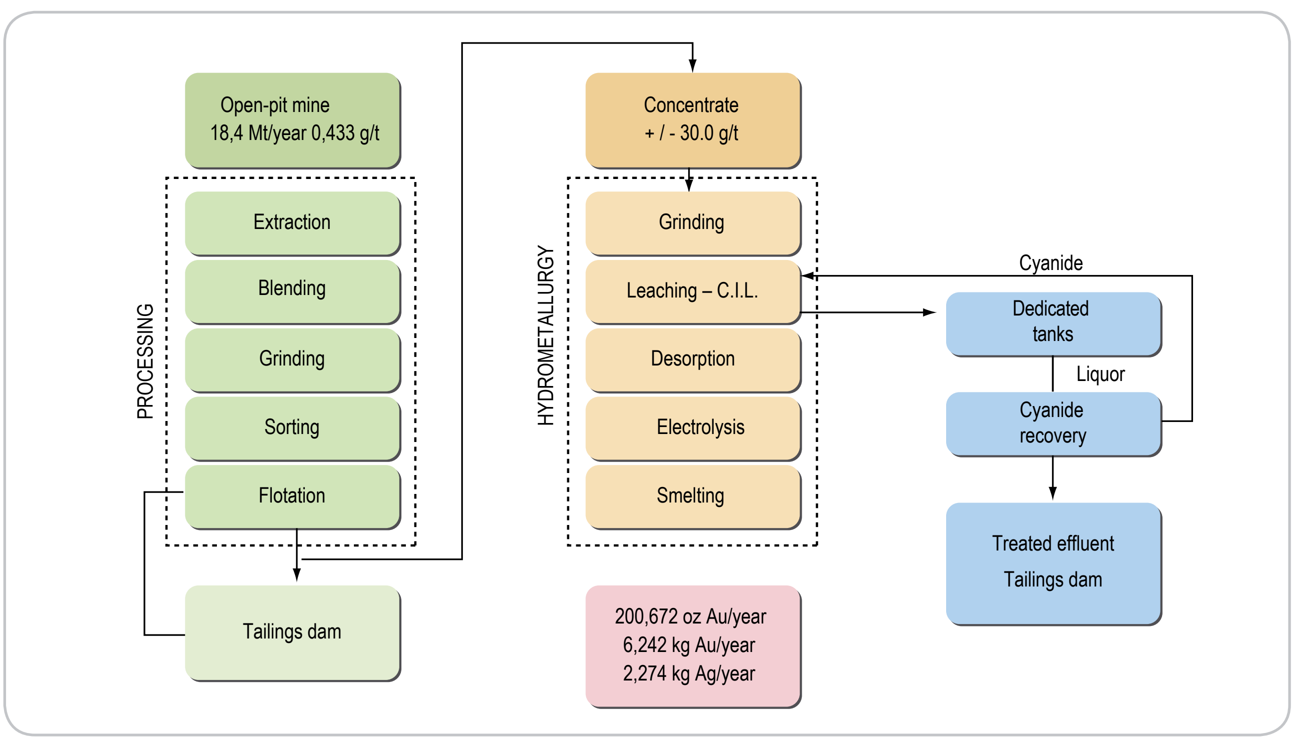


Figure 58. Simplified production workflow (2004)

Photo 70 provides a view of RPM's industrial plant area. From top to bottom one can see operations involving trucks, crushing, the processing and hydrometallurgy plant, as well as two thickeners and two equalization tanks that supply water to the plant.

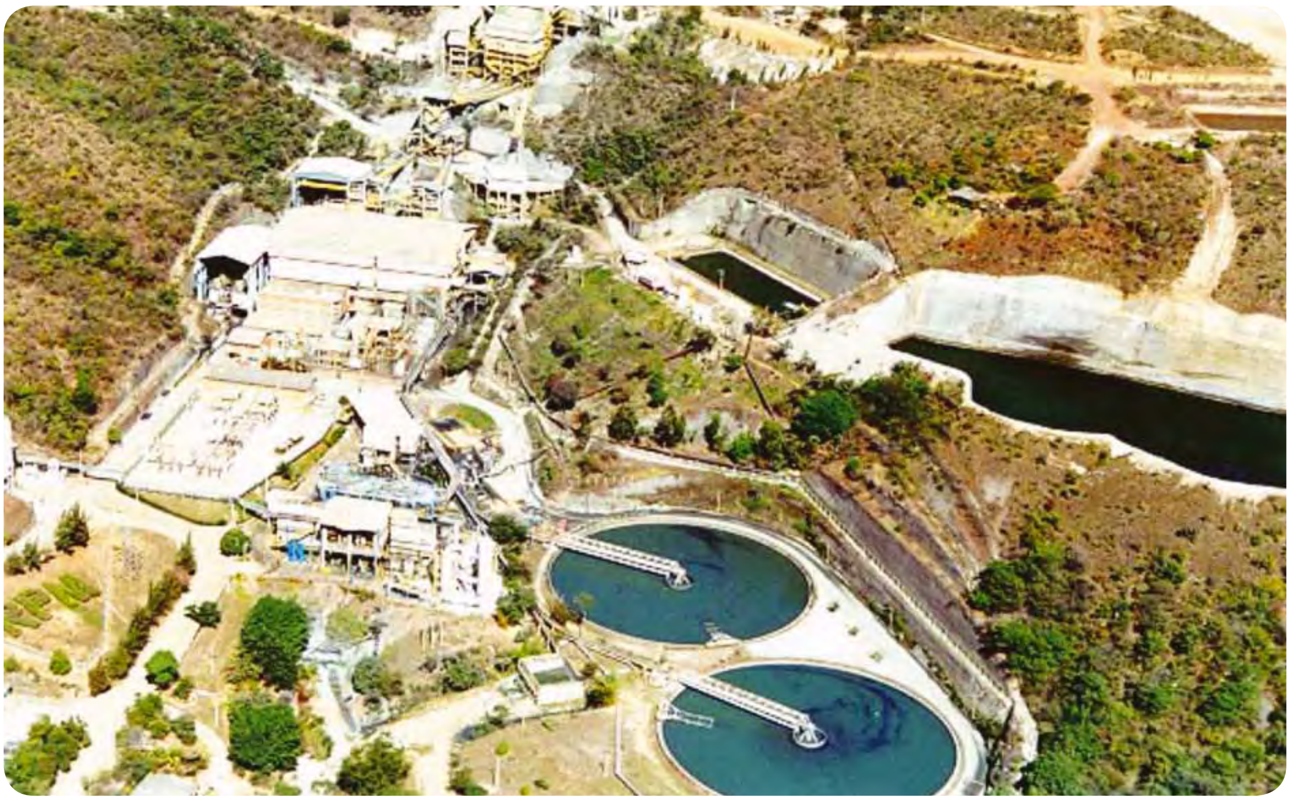


Photo 70. Aerial view of the RPM's processing and hydrometallurgy plant

3 EQUIPMENT, PROJECTS AND CONTROL PLANS FOR THE ENVIRONMENTAL MANAGEMENT SYSTEM - EMS

Since 2000, RPM has an EMS in place that is certified by the ISO 14001 standard, which regulates all activities for the prevention of pollution and promotion of RPM's ongoing improvement of environmental performance. According to the EMS developed by RPM, all facilities at the Morro do Ouro mine undergo internal and external audits.

The following is a summary of the key points of environmental management by RPM and the environmental challenges they are faced with

3.1 WATER MANAGEMENT AT THE MINING AREA

The open-pit mine covers a large area of surface-exposed sulphide minerals, resulting in acid drainage. The rainwater drainage that falls on the mining area is routed to six sumps located at the lower levels of the mine. This makes it impossible for the acidic water being poured into streams around the mine.

The sumps use gravity to feed a concentrator tank equipped with a pumping station. The idea is to keep the tank empty, sending water for reuse at the plant or to supply water trucks. The very low permeability of phyllite (10-6 cm/s), the water pumping operation and the high evaporation rate all provide low percolation rates, which are further attenuated by the carbonate matter contained in the phyllite. The concentrator tank holds the largest amount of water and for longer, and its bottom is sealed with a layer of limestone.

3.2 TAILINGS DAM

RPM has a large tailings dam that holds all the waste from flotation, which accounts for about 98% of what is fed into it. The bulk of the dam is about 3.8 kilometers long, 80 meters high and covers a total area of approximately 800 hectares, which includes the clay and silt extraction areas for construction of the bulk. The dam contains only the sulphide waste, which is not recovered by the processing plant. To prevent acid drainage from taking place at the dam, limestone is added in stoichiometric amounts in relation to the concentration of sulfur in the tailings from the flotation. The dam also receives the final waste from the AVR plant – which treats cyanide waste – so as to avoid detection of high concentrations of total cyanide in the water in the lake resulting from the dam. There is no water overflow, and the only effluent from the dam is the water from the drains at a flow rate of approximately 120 cubic meters per hour. The quality of this water is consistent with the standard for Class II waters under the Law of the State of Minas Gerais. The pH is kept neutral (between pH 7 and pH 8). Currently, about 84% of all water in the process is recirculated in the dam.

3.3 DISPOSAL OF SULPHIDE WASTE

A small fraction of the plant feed is recovered as sulphide concentrate. The waste is permanently placed in the so-called dedicated tanks, which are dug in the mining area and sealed to prevent groundwater contamination. The potential risks posed by these wastes are related to high concentrations of cyanide and arsenic sulphide minerals in water. The total cyanide and arsenic concentration is up to 100 ppm.

The water settled in the tank is pumped back to a special circuit for recovery of cyanide and arsenic precipitation, known as AVR plant – acidification, volatilization and recovery –, which recovers about 60% of the total cyanide contained in the clarified water from the dedicated tank. The levels of solution-based arsenic contained in the effluent of the AVR plant are subsequently treated through a chemical precipitation as ferric or ferrous sulphate is added. The treated water is released into the tailings dam.

Once a dedicated tank is filled, the solid waste in it is consolidated over time, and the excess water is pumped into the AVR plant. The groundwater in the area under the potential influence of these tanks is monitored.

The first three dedicated tanks have been closed and tests are being developed especially for them for the assessment of the performance of the current coverage and establishment of a final coverage project. The tests are basically geotechnical and geochemical evaluations of various samples collected from waste and materials that can possibly be used in multilayer coverage, in addition to the installation of a full weather station with humidity sensors and thermal sensors for soil conductivity. In 2006, an initial modeling of coverages will have the prediction of behavior and their long-term risks as the main output. From these results, changes to the closure strategy will be defined as necessary, including multilayer coverages to prevent acid drainage and leaching of metals from occurring in the long term.

The only tank currently in operation is dedicated tank V. This tank has a system of sealant layers, including a layer of Pead geomembrane that is 1.5 mm long, 0.3 m of a compacted clay layer, a layer of sand and a central drain collection above the sealant system. Photo 71 shows dedicated tank IV, which includes a Pead geomembrane used in his jacket.

Photo 71. Overview of the dedicated tank IV

3.4 DUST AND GREENHOUSE GAS EMISSIONS GENERATED

Because the mine is near the town of Paracatu, dust control is particularly important for RPM. Background dust levels in Paracatu were established before RPM's operations started. Ongoing monitoring has shown a reduction in dust levels in Paracatu, and most of this reduction is due to improved quality of the town's streets and roads that have been paved and asphalted. The start of RPM's operations did not affect the reported emission levels (see Figure 59). This shows the evolutionary history of air quality monitoring conducted by RPM through HI-VOL devices installed in the area surrounding the mine and in Paracatu.

RPM monitors and sets targets for greenhouse gas emissions, which, in the case of RPM's operations, are those generated mainly from diesel consumption by the equipment at the mine and the dam, gasoline consumption, use of lime for neutralization of tailings in the dam and the deficit in the balance between cleared and rehabilitated areas.

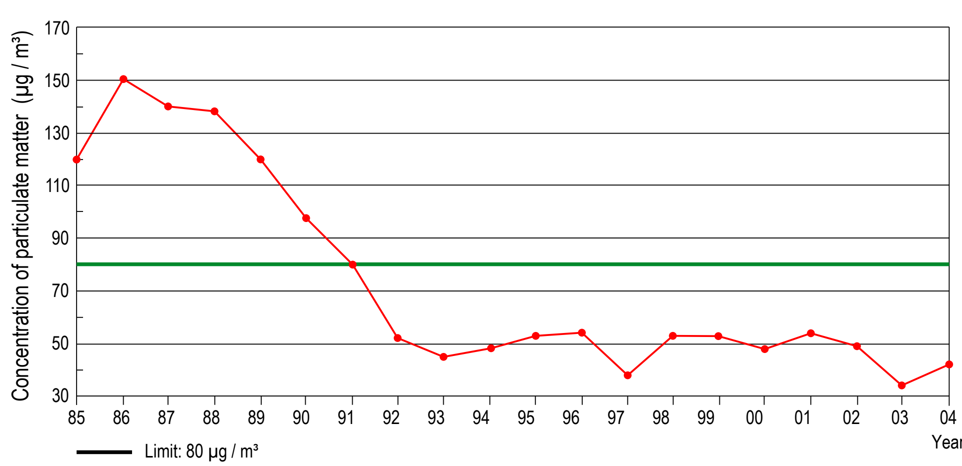


Figure 59. Air quality monitoring conducted by RPM at Paracatu, from 1985 to August 2004

3.5 CLOSURE PLAN

RPM covers a total area of approximately 3,000 hectares. This includes the mine, the tailings dam, dedicated tanks, industrial plant, infrastructure, and other areas, such as environmental reserves. RPM carries out studies to determine the best strategy for closing all areas managed by RPM. RPM updates its closure plan whenever it is appropriate. This document is prepared in accordance with the Kinross Group's guidelines.

Most of the research on the closing is focused on prevention of acid drainage. The most relevant studies underway are the field tests conducted by RPM under a partnership with the Federal University of Viçosa (coverage and rehabilitation tests), kinetic tests (lysimeters) performed in a laboratory at RPM, and a development program, which includes biodiversity studies and mathematical modeling for coverages based on the results of past and current tests.

3.6 INTEGRATED MANAGEMENT SYSTEM - IMS

RPM has integrated all health, safety and environment systems, like the National Occupational Safety Association (Nosa) program, RPM's Health, Safety and Environmental standards and the EMS. RPM supports re-certification and maintenance of the EMS by using the structure of the IMS, which is available from the corporate intranet to all employees and contractors who are authorized to access the network.

4 WATER RESOURCES MANAGEMENT

A simplified water balance for RPM's operation, which is updated annually, is described below and shown in Figure 60.

- Average water inflow: 4,348 m3/h.
- The rate of evaporation at the dam is 881 m3/h (24 hours per day), while the infiltration rate is 100 m3/h (Promon, 1988).
- Water recycled from the dam: 3,386 m3/h (78% of RPM's total consumption).
- Water recirculated from the thickeners: 201 m3/h (4% of RPM's total consumption).
- Water recycled from the mine's tanks: 425 m3/h (10% of RPM's total consumption).
- Freshwater pumped from streams downstream of the tailings dam: 340 m3/h (8% of RPM's total consumption).
- Disposal of tailings: 0.52 tons of water per ton of dumped solids, which is equivalent to 66% of solids in final tailings (Promon 1988).
- The minimum annual rainfall for Paracatu is 852 mm/year. The annual average for the past forty-two years is 1,379 mm.
- Potential Evapotranspiration for Paracatu (Penman's Method): 1,734.4 mm (2004).
- Potential Evapotranspiration (Thornthwaite's Method): 1,112.4 mm (2004).

RPM's present installed capacity for pumping is greater than the amount of water that has been pumped to the plant. The installed capacity can be used for the processing of up to 30 million tons per year, but nowadays under 20 million tons per year are mined. The following is a workflow showing the current capacity of RPM's industrial water supply system.

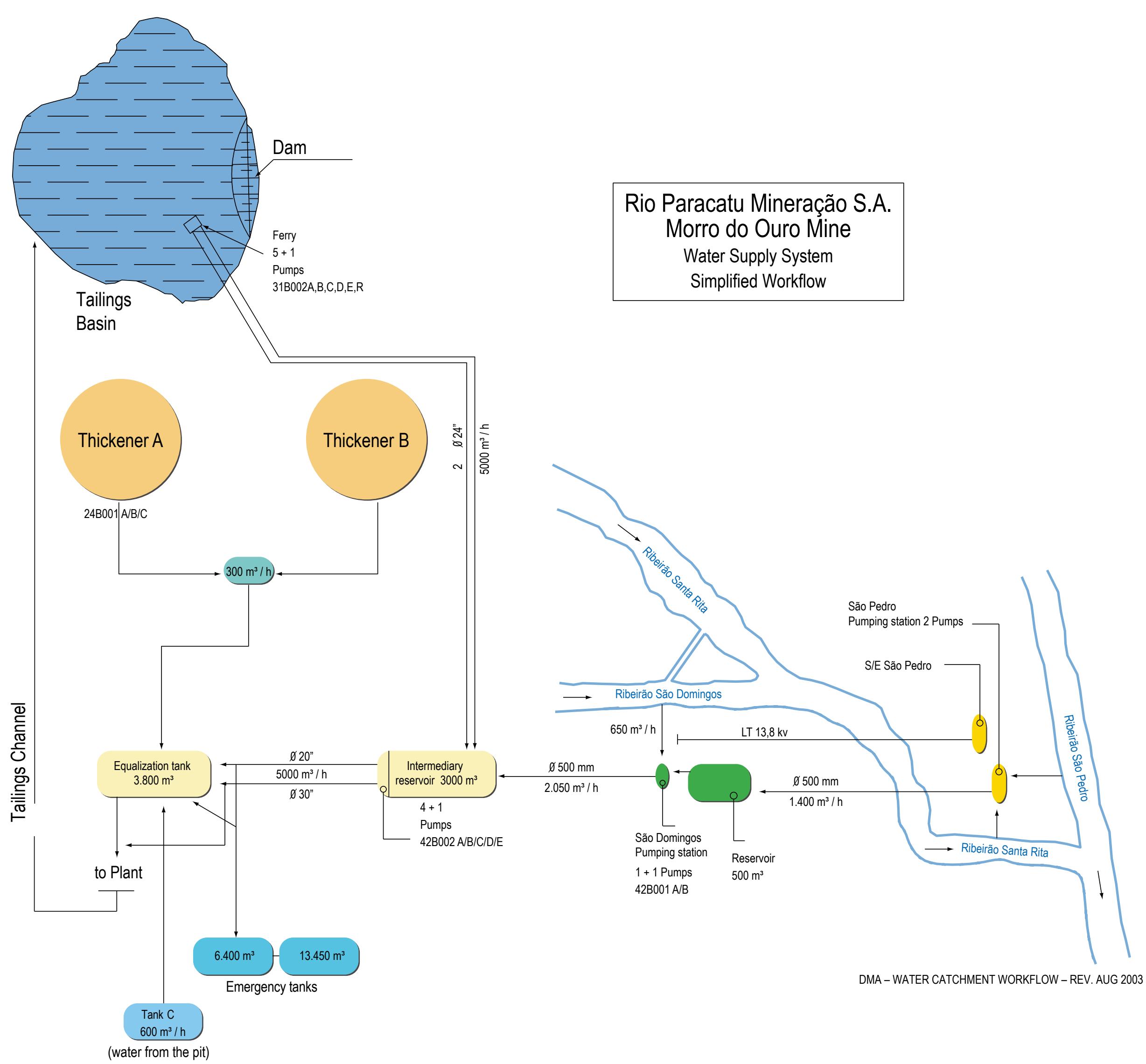


Figure 60. Simplified workflow for the industrial water balance supply system for RPM's operation (August 2003)

According to typical operating standards for RPM, the company has routinely taken a series of measures aimed at reducing specific consumption of fresh water and control of their emissions (effluent) into the environment. These measures include:

- Raising of the tailings dam one step above the normal requirement for the construction project so as to prevent overflows, in such a way that enhances rainwater harvesting at the tailings dam's micro basin, thereby allowing for reuse of up to about 84% of all industrial water used by RPM.
- The rainwater drainage system for the mine, which directs rainwater into a series of tanks (sumps) allows recycling about 1,000 m3/h of water during a part of the year (for as long as there is water in the tanks). Recently, a new station was set up in another section of the mine (northeastern extension), with capacity for 300 m3/h, which will allow for better use of water at the mine, which will be pumped in larger quantities and more quickly, thus minimizing losses, mainly by evaporation.
- RPM thickens 50% of the waste generated before its released into the tailings dam, thus enabling reuse of that water directly into the plant, without higher pumping costs and minimizing evaporation losses;
- Performance of educational campaigns and establishment of plans for the ongoing improvement of water management.
- Daily monitoring of water pumped from several sources, which are: tailings dam, mine, thickeners, and catchment of fresh wate.

Monitoring of daily rainfall rates at the rain gauge station located at RPM's Geology building. Maintenance of a meteorological station with a daily data collection system using a datalogger:

- Since 1997, when RPM started mining sulphide ores, the company has not shed water from the tailings dam into natural water stream; effluents from the dam are those from the dam's bottom drain. This effluent is comparable to Class II waters (DN Copam 010/1986);
- RPM performs periodical biological monitoring of lake water and tailings dam's drain, and at a section located downstream of the dam, at the stream into which its effluents are released;
- The lake for the tailings dam is home to a great wealth of biodiversity, including several species of fish and bird that inhabit the surrounding areas.
- Water from the mine's tanks, which are exposed to acid drainage rainwater, is not released into natural drainages;
- Finally, it performs a continuous, dynamic control and monitoring of groundwater under the influence of RPM's various operations.

Management of all actions that had been taken by RPM in order to improve their management of water resources was assigned to the committee responsible for implementation of the Project for Sustainable Development, as will be described below, so that such actions are framed within a broader and more structured concept.

5 THE SUSTAINABLE DEVELOPMENT PROJECT

In 2003, the Rio Tinto Group, through Rio Tinto Brazil, used the RPM as a case study for implementation of the Sustainable Development policy: "To ensure that businesses, operations and products under the Rio Tinto Group provide a positive contribution to the global transition towards sustainable development".

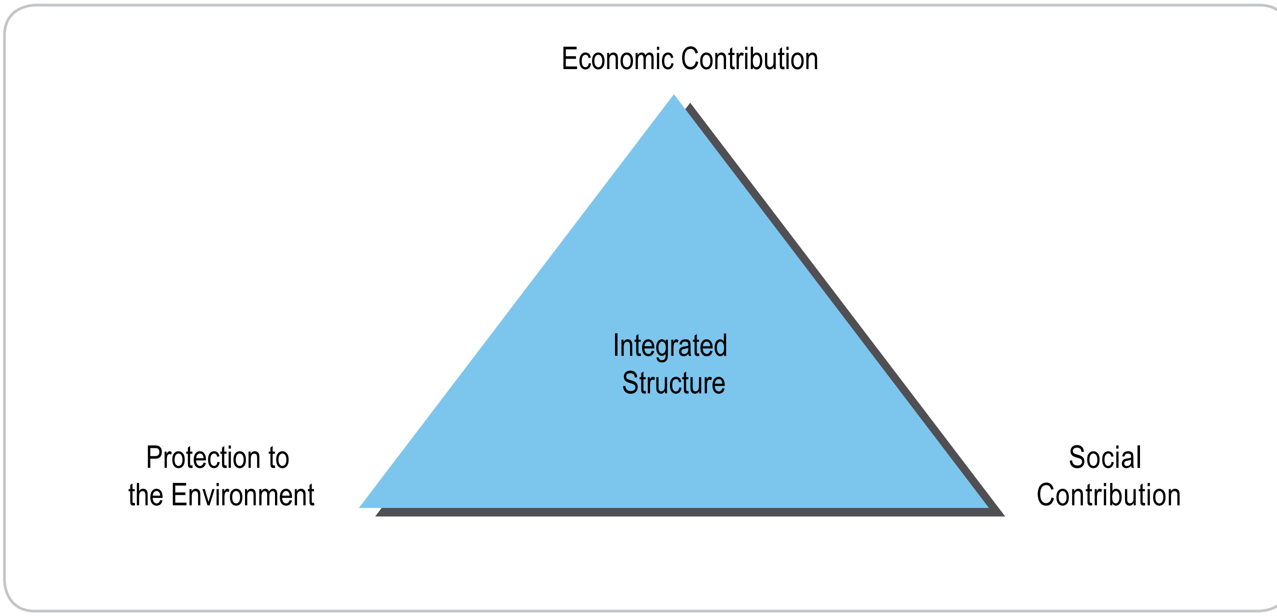


Figure 61. Simplified workflow for the industrial water balance supply system for RPM's operation

This was when a Sustainable Development Committee was set up with a view to steering all the actions that had already been taken with respect to matters of Health, Safety, Environment and Community in an integrated way with economic and sustainability issues associated to RPM's venture.

The Sustainable Development Project that has been conducted at RPM contains an over-arching objective concerning Rational Use of Water at RPM. This goal was divided into two sub-goals, one of which placing more emphasis on internal actions to be implemented at RPM and the other sub-goal with an emphasis on actions focused on the river basin and other users of the region in which RPM is based:

Objective 1. External environment – "Ensuring the future availability of water for RPM". The following goals were set:

1a. Acting effectively with the Paracatu River Basin Committee from the 2004 mandate.
The Paracatu River Basin Committee is now in its third mandate. RPM has intensified its participation, and has acted as vice-chair of the Executive Secretariat for the 2004-2006 mandate.

1b. Supporting the review and update of the Master Plan for Water Resources Management in the Paracatu River Basin in 2005.
As a member of the River Basin Committee's executive board, RPM supported a review of the Master Plan for Water Resources Management

in the Paracatu River Basin, which is due to be completed in April 2006.

1c. Setting up and operating control stations to measure water inflows into the rivers São Pedro, between Ribeiros and Santa Rita, as of 2004.
Timing water discharges of the main streams, which are used for water catchment in the region, allows for enhanced management of water use and forecasting the risks of water shortages during drought periods.

Photo 72. Water level rulers – Entre-Ribeiros stream

Photo 73. Data Collection from the Automated Station – Ribeirão São Pedro

Objective 2. "Reducing RPM's Specific Consumption of Water". The following actions/goals were established:

2a. Establishment of the Water and Power Management Committee – GGAE in 2004-2005.
The main actions by the GGAE are the establishment of best strategies related to optimization and reduction of the specific consumption of water and energy. Below are some actions already implemented that produced actual gains in terms of reducing the specific consumption of water:

• Installation of five magnetic flow meters at the main water catchment and pumping points
This measure enabled a more consistent balance of the flows pumped at the various springs. Meters have been installed at the freshwater catchment station; at the station where an intersection between the freshwater and recycled water from the tailings dam takes place; and at the entrance of the Plant.

Photos 74 and 75 show two flow meters installed in freshwater and recirculated water catchment pipelines at the tailings dam.

Photo 74. Flow Meter – Thirty-feet pipe

Photo 75. Flow Meter – Twenty-feet pipe

• Validation of water- and energy-related notions in RPM's Ongoing Improvement Program:

1. PIG passage along the pipelines;
   Removal of organic matter and encrustations on the pipelines to improve pumping performance and, as a result, save energy.
2. Optimization of the processing circuit: As the percentage of solids in the plant increased from 31% to 34.5%, a reduction in specific water consumption from 2.20 m3/t to 2.00 m3/t was achieved. The main actions were: decommissioning of the unit flotation circuit and reprocessing of the secondary classification overflow.

2b. Establishment of goals for reducing consumption of fresh water – "Reducing the catchment of fresh water per ton of output by 10% in the period 2004-2008 (taking 2003 as the base-year)".

Now that performance targets and indicators have been set, RPM is now better tracking monthly progress and projections in the long term.

2c. Establishment of a goal linked to RPM's employee profit sharing (PS). By way of example, below are the targets for 2005 and 2006, respectively: "Water consumption under or equal to 2.08 and 2.03 m3/t of processed ore".

Thus, RPM's corporate goals branched into individual targets involving all employees. The idea is to have increasing feedback-based participation and more strict operating performance.

• Completing the hydrogeological and hydrogeochemical studies for the Morro do Ouro mine and the surrounding areas. Deadline: June 2005.

A hydrogeological and hydrochemical study is underway to update and complement the existing information. This work started in 2002 and is comprised of three phases, all of which have been completed. The overall objective of the study was to determine the hydrogeological and hydrogeochemical conditions at RPM (mine, dedicated tanks and tailings dam) in order to assess whether current and future mining operations will have any impacts on groundwater and surface water, making it also possible to assess the environmental impacts of the Mine Expansion Project. The information available have allowed for enhanced water management by RPM. As the final phase was completed, RPM was able to fine-tune its water and mass balance, also to follow up on operational enhancement actions in terms of water resources management.

In view of the great importance of this matter, below is a summary of the objectives and main actions for developing this study.

The specific objectives that were met during the study included:

- determining whether the existing hydrogeochemical and hydrogeological information would be sufficient to develop conceptual models for groundwater and hydrochemical conditions;

- reviewing the groundwater and surface water quality sampling programs and determining whether the data collected are consistent with appropriate quality control standards (QA/QC) so that they can be used for detailed analysis and interpretations;
- developing a preliminary conceptual hydrogeological and hydrochemical model based on the existing data and experience gained in other mines;
- based on the preliminary conceptual models, estimating the potential impacts of current and future operations on the local and regional water resources;
- identifying the need for additional data collection to enable the interpretation of the conceptual models;
- evaluating new data for review and refinement of the conceptual hydrogeological and hydrogeochemical models; and
- developing mathematical hydrogeological and hydrochemical models to determine the impacts on local and regional water resources, particularly with regard to:
  - nature and extent of impacts on surface and ground water in the mining area;
  - nature and extent of impacts on surface and ground water located near the tailings dam;
  - nature and extent of impacts on surface and ground water located near the dedicated tanks;
  - Development of a prototype for the lake to be formed in the pit once the Mine Expansion Project is implemented (is is now undergoing the licensing process). The goal is to predict potential impacts on the levels and quality of groundwater and surface water.
- provide recommendations for hydrogeological and hydrochemical monitoring that is already underway at RPM.

In order to accomplish the objectives described above, the following activities were developed in Phase I of the work program:

- compilation and evaluation of the data already available at RPM, including: regional and local geology, hydrology, hydrogeology and hydrogeochemistry;
- evaluation of available data on the quality of surface water and groundwater;
- conducting field inspections to support an initial approach to the conceptual hydrogeological model and to review the previously defined scope;
- development of a complementary program for monitoring surface water and groundwater;
- developing a preliminary conceptual model that integrates the hydrogeological, geochemical and hydrochemical levels.

The activities in Phase II included:

- development of an inventory of springs and water surges for a hydrologic profile in area surrounding the mine;
- measurement of spring flows and underground water levels and determination of practical water quality parameters; and
- implementation of a comprehensive water quality sampling program.

Besides these activities, as the work progressed the need for the following additional services was identified:

- geophysical survey of the area where the dedicated tanks are located;
- water balance for the tanks in the mine;
- drilling and installation of groundwater monitoring wells;
- permeability tests (also called slug tests) in the monitoring wells; and
- geochemical profiling of samples of rocks and tailings.

In Phase III, computational hydrogeological and hydrogeochemical models were developed for the mine in its current and future status (final pit for the Mine Expansion Project), for the tailings dam and for the dedicated tanks already installed. These models will serve as a tool for detailing the surface and groundwater management program during the consolidation of the Environmental Control Plan for the venture.

• implement and update RPM's Water and Masses Balance, using specialized software for the development of dynamic modeling and probabilistic simulations: March 2005.
Complete. The Goldsin software was used to fine-tune RPM's water balance and mass, which provided a systemic overview of water resource management, future projections and ongoing improvements.

• implementation of Rio Tinto Environmental Standards – establishing the main actions and responsibilities related to water quality use and control: December 2004.
The following have been implemented and incorporated into the RPM's IMS: Environmental Management System; Acid Drainage Forecast and Control; Air Quality Control; Emission of Greenhouse Gases; Hazardous Materials Control and Contamination; Responsible Land Use Management; Mineral Waste Management; Non-mineral Waste Management; Noise and Vibration Control; Water Quality Use and Control. As far as the main topic of this section is concerned, the standard for Water Quality Control of Use deserves special mention since it made it possible to systematize water management actions and responsibilities at RPM.
• establishment of a weather station in the Morro do Ouro mine area for continuous data collection: October 2004.

RPM put in place a comprehensive meteorological station for continuous data monitoring based on a specialized data collection software program (i.e., a data logger). The data provided by this station will serve as more accurate inputs to the water balance. This balance also uses other historical data collected from RPM and Paracatu.

5.1 PERFORMANCE INDICATORS

Figures 62 and 63 show the trend for decreasing consumption of water and fresh water. This achievement is largely thanks to the various actions described here, as part of the Project for Sustainable Development.

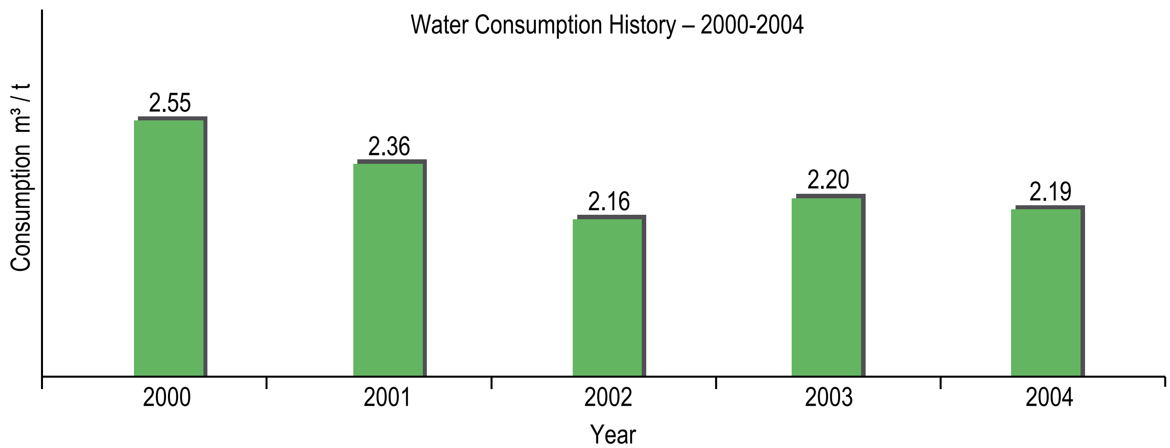


Figure 62. Specific Water Consumption History from 2000 to Oct. 2004

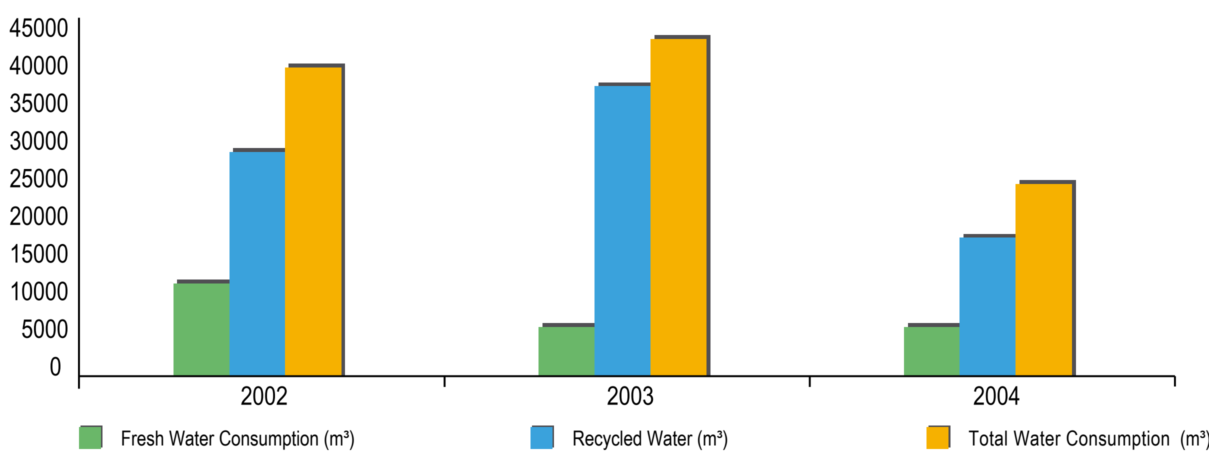


Figure 63. Comparative water consumption, by source of supply, at the Morro do Ouro Mine, from 2002 to Aug. 2004

Photo 76. Aerial view of the Morro do Ouro mine – Paracatu, MG

6 FINAL REMARKS

The main challenges faced by RPM are acid drainage prevention and control, and water and soil management. By means of an extensive program designed to promote continual improvement of its EMS as discussed here, all of which focused on risk reduction and pollution prevention, especially the control and protection of water resources, RPM is part of a league of companies where corporate environmental and social responsibility runs through all of its decision-making levels.

Under RPM's Sustainable Development Project, as shown here, several actions have been implemented for continuous improvement of water management, and a significant reduction in specific water and fresh water consumption can be clearly observed in RPM's processing plant. These actions are key to ensure sustainability of the Morro do Ouro Project, ensuring its operation in harmony with environmental and social issues in the local area.

Ana Lúcia Taveira[1]
Luiz Lourenço Fregadolli[2]

WATER MANAGEMENT PLAN: A PREPARATION AND IMPLEMENTATION METHOD FOR THE MINING INDUSTRY. CASE STUDY FOR VOTORANTIM METAIS'S FORTALEZA DE MINAS UNIT

1 INTRODUCTION

Issues related to water use have successfully made it to the agenda of government agencies, businesses and the society in recent years. Indiscriminate use of this resource has generated unheard-of levels of pollution and shortages. Environmental experts predict that, if this situation is not resolved, by 2010 the world will be faced with serious water supply problems that will impair its development. In some regions of the world, water has become a matter of dispute among different peoples, where the right of ownership over rivers, lakes, dams, and other water sources is being claimed. This is all because water is life; It is the essence of survival.

In the search for alternative solutions to change this negative scenario, society has been making efforts to establish sustainable uses for water resources. Governments have put together water management policies ranging from the establishment of stricter laws for water usage to sanitation projects and pay-per-consumption schemes, sewage discharge and changes to water body regimes, quantity and quality. The community has been engaging in campaigns to decrease water consumption and control the pollution affecting water. Companies have increasingly invested in programs and projects on water use rationalization, establishing water management plans that seek to optimize and set sustainable guidelines for the river basins under their influence.

From this perspective of sustainable use of water resources, Votorantim Metais's Fortaleza de Minas Unit (MSF) established its Water Management Plan, which is discussed below.

2 BASIC INFORMATION

Water is one of the various natural resources with the most diversified, legitimate and current uses. Nowadays, in view of humankind's social and industrial progress, the following multiple uses for water can be listed:

[1] Environmental Coordinator for Votorantim Metais's Fortaleza de Minas Unit.
[2] HR, Organizational and Environmental Manager for Votorantim Metais's Fortaleza de Minas Unit.

- public supply;
- industrial consumption;
- industrial raw material;
- irrigation;
- watering livestock;
- recreation and leisure;
- power generation;
- transport;
- dilution of effluents;
- flora and fauna conservation.

The first five uses in this list involve collecting water from a spring. But for all other uses this is not necessary. The use of water for the dilution of industrial and domestic effluents has been decreasing due to environmental laws, which have gained momentum in the early 1990s, especially with medium and large firms.

With the rapid growth of population and industrial and technological development – primarily after World War II –, the sources of water available are becoming more and more compromised or risk outright depletion, especially in large urban and industrial areas. Pollution of water sources, deforestation, silting of rivers, its inappropriate use for irrigation, soil sealing, among many other human actions are responsible for the degradation of water resources now taking place in various parts of the world. This is further compounded when water availability is considered: 97.5% of the world's water is salt water, 2.493% is contained in glaciers or underground areas that are difficult to reach, and only 0.007% account to freshwater available for human use, with a large portion of this involving pollution levels that make it unfit for consumption. Another worrying factor is the waste caused by indiscriminate water use, for cultural reasons in most cases.

Water pollution is the result of the existing or added matter or energy with an intensity, quantity, concentration or characteristics that are inconsistent with the environmental quality standards established by law, which therefore causes a harmful interference with the main uses of water (CONAMA Resolution No. 357, March 17, 2005; ABNT, 1987). In the specific case of the mining industry, water pollution is associated to the carriage of particles from outdoor areas[3] by rainwater; direct release of steriles[4] into water courses; disposal of tailings; disposal of non inert solid waste; pumping of water containing solid matter from ground water drawdown operations in mine pits; disposal of sewage and oily effluents from workshops. This situation becomes even worse due to the features of the soil in the mine, such as sulphide mines, where drainage is acidic. Furthermore, the incorrect catchment of water as well as the lowering of water tables that interferes with replenishment areas can have an adverse impact on water availability.

As a consequence of this misuse of water resources, eighty countries are already facing serious problems due to lack or scarcity of water, including Saudi Arabia, Israel, Egypt, Ethiopia, Haiti, Iran, Libya, Morocco, Syria, and South Africa. To make matters even worse, the population is growing faster in areas where water is scarce (MEDEIROS-LEÃO, 2001). In Brazil, this situation is no different. Besides the uneven distribution of water (68% of this resource is in the North region, which is home to

[3] Extracted from the soil's superficial layer.
[4] Materials extracted during the mining process, but with no mineral or commercial value.

only 7% of the population, and 6% of all water is in the Southeast region, which is home to 43% of the population), waste and pollution caused by lack of effluent treatment further aggravate this problem in Brazil. Between 40% and 60% of treated and supplied water is wasted as a result of misuse and poor conditions of the distribution network in Brazil (FERREIRA, 2001).

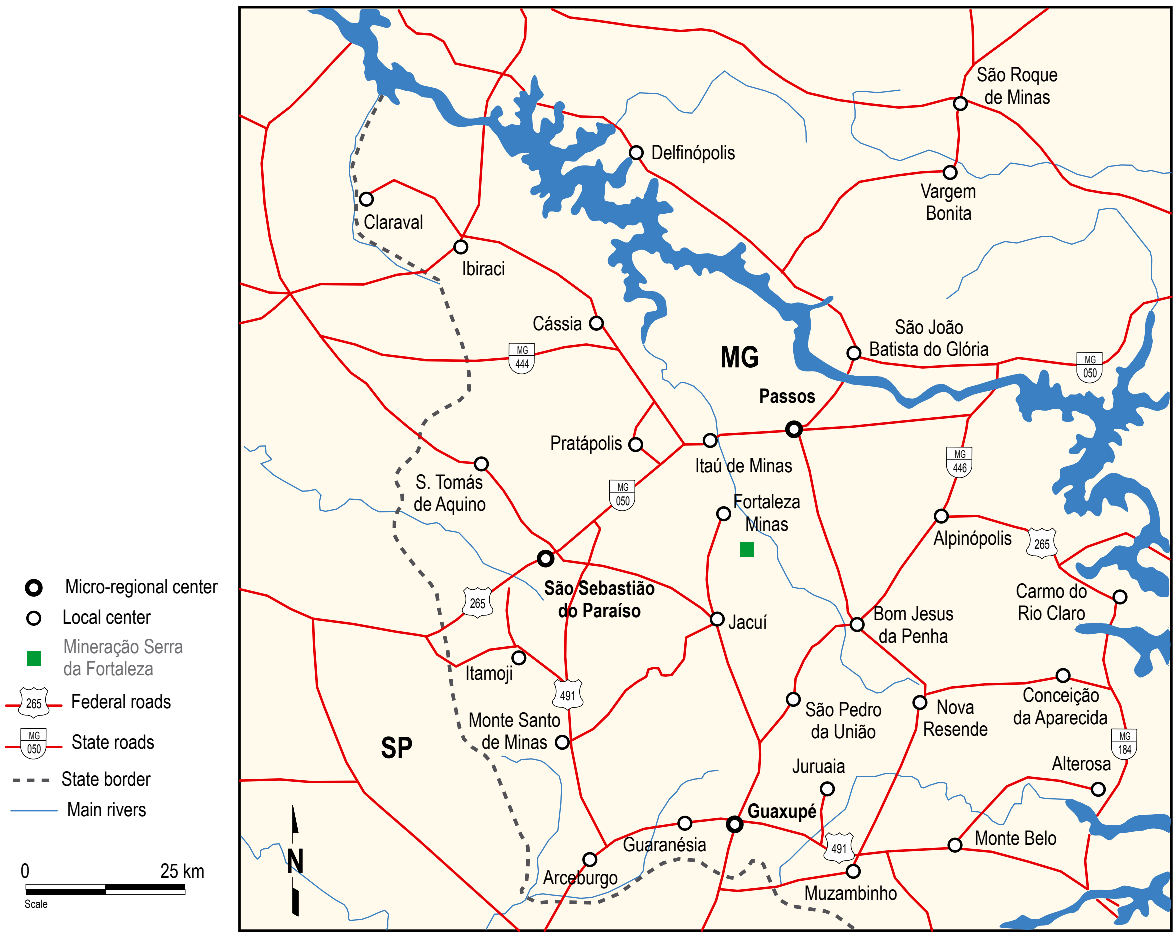
To manage these problems, a water resource management system is urgently needed. The system establishes water quality standards and criteria for its use for sustainable use purposes based on present and future scenarios. This has been the model adopted by several countries, with an institutional structure that reflects their individual social, political and geographical conditions, with a view to establishing guidelines for the sustainable use of water by the various segments of society.

In this case study – Fortaleza de Minas Unit (owned by Votorantim Metais), located in the town of Fortaleza de Minas, Minas Gerais –, the sustainable water management principle applies to minimization and control of qualitative and quantitative interferences arising from the company's operations in the watershed under its influence. This work has made it possible to learn about their interferences, to establish the best way to act proactively and the commitment from all internal users towards the conservation and rational use of water.

3 THE FORTALEZA DE MINAS UNIT

The Fortaleza de Minas Unit (MSF) is located in Fortaleza de Minas, in southwestern Minas Gerais. It lies about 370 kilometers from Belo Horizonte, and its main access is the MG-050 road to the junction to Fortaleza de Minas, and then a twenty-three kilometer route along a secondary road. The location of the unit is provided in Figure 64. Their activities began in 1998 with the extraction of nickel sulphide ore. Until 2000, open-pit mining was carried out, and from then on underground mining operations started. Steriles are placed on a pile that covers a thirty-five hectare area.

Photo 77. View from the belvedere – Fortaleza de Minas



Source: Road Map for the State of Minas Gerais (DER/IGA/SECTIMA-1988)

Figure 64. Location of MSF

MSF's production process covers concentration, smelting, and acid plant operations. The concentration process includes all steps necessary to obtain a sulphide concentrate of nickel, copper and cobalt from the ore extracted from the underground mine. The concentration steps include comminution (crushing and grinding) of the ore, flotation, [5] thickening, and filtration of the resulting concentrate. The resulting waste is placed on the waste deposit, which has an hexagonal shape.

The waste is placed on the deposited up to them brim according to a certain inclination level so that the liquid portion of the slurry quickly separates from the solid matter and is channeled through a duct in the central part of the deposit to the recirculated water container, thus closing the water circuit and providing full water reuse at the processing plant. Therefore, this disposal method is conducive of stability conditions for this deposit since what comes into contact with the slope are the larger solid particles.

[5] Raising of suspended matter to the liquid surface in the form of foam, through aeration, gas insufflation, use of chemicals and subsequent removal of the foam.

The concentrate is moves on to the smelter for production of nickel matte,[6] which is MSF's end product. The first step in the smelting process is drying the concentrate. It then goes to the flash furnace, where matte and slag are produced. The slag is fed into the electric furnace, which gives the final slag to be dumped and another portion of matte, which is added to that produced in the flash furnace. Therefore, the matte and slag undergo a granulation process by adding water. To obtain chilled water, a cooling tower is used; to obtain steam, an oil-fired boiler is used. The gases obtained from the flash furnace move on to the acid plant for the recovery of sulphur and production of sulphuric acid, which is also a product by MSF.

Figure 65 provides an overview of the production process.

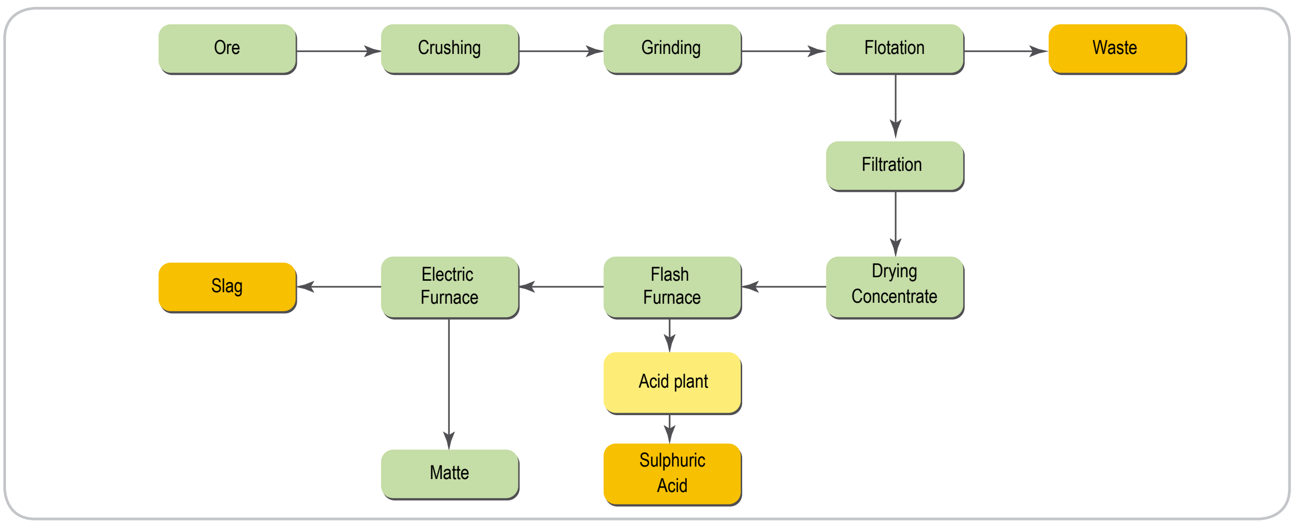


Figure 65. Simplified workflow for MSF's production process

Approximately 50% of the water make up (fresh water) for consumption by the production process comes from the raw water dam, and this is because of losses from evaporation. The other 50% are from recirculated water. All effluents generated in the industrial area of the MSF, as well as rainwater drainage from sulphide ore yards, are taken to the recirculated water container, thus closing the water circuit and preventing the acidic water from being released into the raw water dam. All of MSF's non-contaminated rainwater are channeled to the raw water dam, which is located downstream of the entire project area, including the effluents for the sterile deposit.

The waste water from the raw water dam (50 m3/h) and excess rainwater that overflows over the side channel, a spillway (reaching up to 200 m3/h), feed the Muniz stream, whose water is available to the community. Therefore, the water in this dam must be of adequate quality. To this end, it is necessary that all control actions regarding water quality at MSF, including the recirculation process, are carried out in the industrial and sterile storage areas since any sort of treatment, even for polishing purposes, is impossible in a body of water the size of the raw water dam, which covers an area of 15 hectares.

Figure 66 provides a clear view of MSF's water balance.

[6] Granular aggregate comprised of several metals, particularly nickel, cobalt and copper.

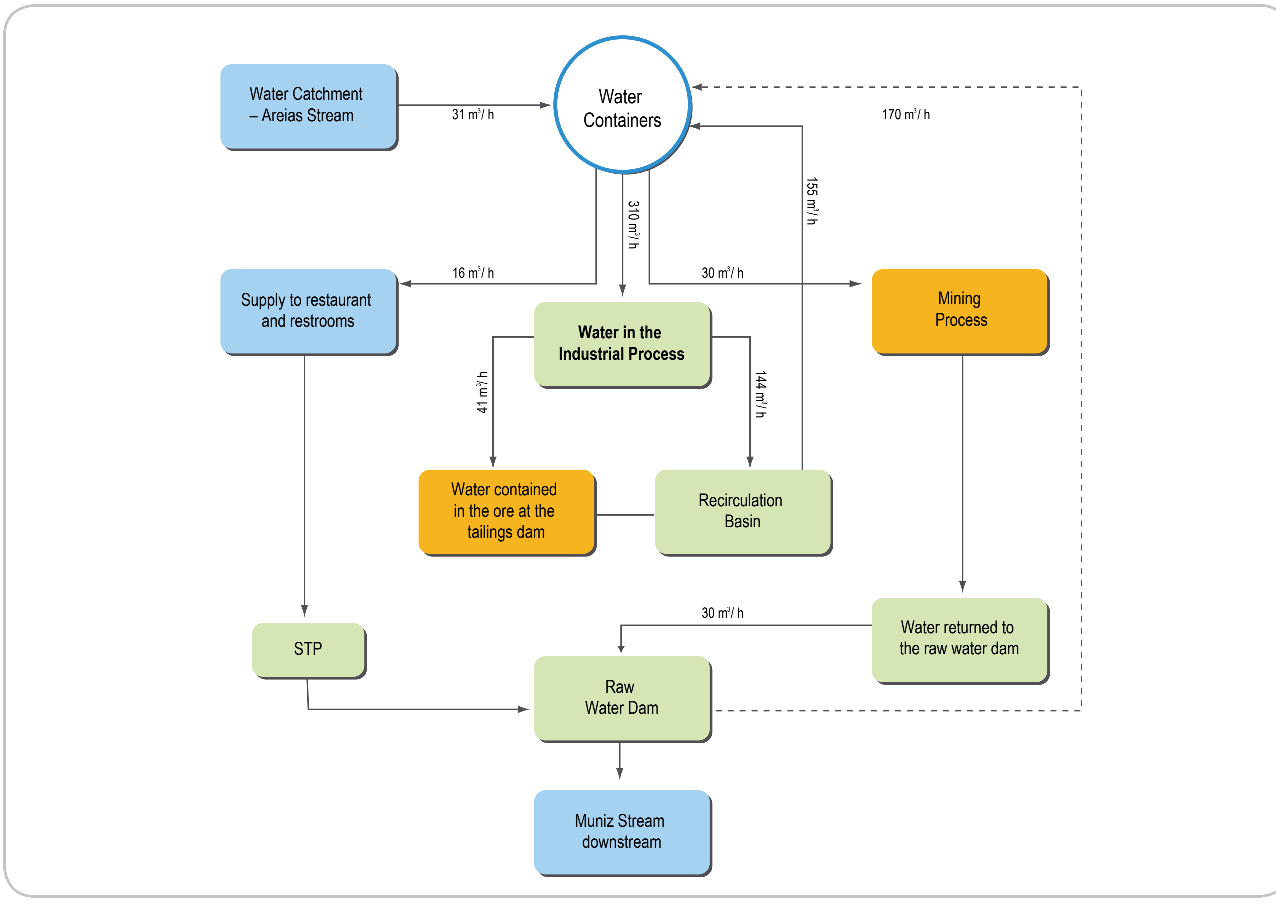


Figure 66. MSF's simplified water balance (Make-up not included)

Two events triggered nickel contamination processes at MSF's raw water dam – the first occurred in 1998 (first year of operation), when the water drained from the sulphide ore yard was channeled to this dam in error. Once the problem was detected by sampling the water from the dam, the drainage was immediately reformulated and directed to the production process through the flotation tailings tank, where pH is offset for the precipitation of metals in the waste deposit. The other event occurred in 2001, when acid drainage was detected in the effluent contained in the sterile tank, caused by dilution between ore and steriles, the contaminated effluent being released into the raw water dam. This still occurs, but some measures have now been taken. The chemical and passive treatment (using the so-called Zero Valent Iron – ZVI process) was put in place for this effluent, coverage was enhanced and a drainage system was established to prevent water infiltration, which is channeled to production. The problem was minimized as the result of these measures; however, hydrogeological, hydrochemical, evaluation and bioleaching studies are being conducted, as well as an assessment of "ideal" coverage that prevents rainwater infiltration, with a view to identifying problems and establishing future actions for full control of the acid drainage process.

Thus, it is clear that acid drainage is the top priority in terms of control required at MSF. Generation processes are inevitable, but they are manageable in the short term by using water sensibly and controlling its sources of contamination.. To this end, MSF has developed its Water Management Plan. With a wider horizon for completion, detailed studies of acid drainage areas are underway so that this event can be minimized and controlled. These studies focus on the treatment at source in order to either eliminate it or control it if it has occurred.

4 BOUNDARY CONDITIONS FOR THE WATER MANAGEMENT PLAN

In 2002, the MSF implemented its Water Management Plan with the primary objective of initiating the decontamination process of the raw water dam, and it was only fed with the treated effluent from the sterile deposit and uncontaminated rainwater, which falls on the industrial area. It is important to mention that the dam was scaled considering the hydrological studies in the region and the safety of operations. The effluents from the acid drainage were once released into this dam, and they are now returned to the plant, thus closing the water circuit. However, if they need to be disposed of, they will be treated in advance in order to ensure water quality at the raw water dam.

4.1 PROFILE OF THE WATERSHED UNDER THE INFLUENCE OF MSF

MSF is located in the Rio Grande basin, which is a sub-basin of the São João river, with the Muniz stream as its tributary on the left bank in the town of Fortaleza de Minas, MG. The Muniz steam cuts through farms before flowing into the São João river.

The Areias stream has catchment of fresh water as an influence from MSF through the pumping station installed on the banks of this stream, with no effluents whatsoever being released.

The Muniz stream starts within the industrial area of the company and branches into two. The left branch receives flows from the production area (foundry, concentration and maintenance). The right branch receives feeds from the sterile tank. These two branches flow into the raw water dam and the resulting effluents are released into the Muniz stream, which subsequently flows out of the company. It's approximately three kilometers for the Muniz stream to flow into the São João river, which is the main water body. Along these three kilometers, the stream runs through several farms.

The Fortaleza river and José Mendes stream do not receive any flows from MSF, although they run along areas adjacent to the firm. However, they are influenced by farms located along its banks.

Photo 78 shows the river basin in MSF's surrounding areas. It is noteworthy that the Areias and Fortaleza streams do not show in this photo.

Photo 78. River basin in MSF's surrounding areas

The surface watershed community considers that the information on the impact of MSF in the drainage area is divided into:

a) direct impact, i.e., bodies of water receiving MSF's effluents or suffering any other kind of mining-related impact. In this category are the Muniz stream (discharge of waste flows, overflow of the raw water dam and water make up for the process from the raw water dam) and Areias stream (water catchment for human consumption and utilities);
b) indirect impact, i.e., they are under the influence of MSF, but do not suffer any sort impact from the company. In this category are the Fortaleza and José Mendes stream.

The groundwater is influenced by the industrial area as a whole due to the disposal of steriles; the underground mine; tankage areas/basins and concentration and smelting storage areas; the system of dams, the landfill and effluent treatment systems.

Several documents have discussed the good performance of the watershed in MSF over the years. The region's background is covered in the EIA/EIR prepared by MSF for its Preliminary License, and it has been used in several subsequent studies with a view to evaluating and strengthening the company's actual impact on the region.

4.2 RELEVANT ENVIRONMENTAL LEGISLATION

According to Federal Law 9605, of February 12, 1998, the following actions, amongst others, are classified as environmental crimes:

Cause the death of aquatic species by releasing effluents or dragging particles; cause pollution of any sort at such levels that results or potentially result in damages to human health or damages that cause the death of animals or significant destruction of the flora.

Therefore, uncontrolled release of effluents; negative change of the quality of surface water or groundwater; and catchment without proper authorization (eligibility and licensing) can be classified as environmental crimes if they cause adverse effects on the environment. Therefore there is an array of specific laws that provide for qualitative and quantitative water control, as discussed below.

4.2.1 FEDERAL LEVEL

DFrom the standpoint of water pollution control, the Brazilian legislation is based on two criteria: the water quality of the receiving water body which makes it possible to frame it in a particular class of main uses; and the act of using water resources involving changes to their quality – among others – as might occur through the release of liquid or gaseous waste because of their physical-chemical and biological properties, and toxicity. With respect to the recipient water body, the classification is based on the quality required for their main uses; it covers freshwater, saline and brackish water, and includes 13 classes of quality. The limits and conditions relating to water bodies are listed in CONAMA Resolution No. 357 (2005), which updated and superseded CONAMA Resolution No. 20, of June 18, 1986. As for the effluents from any polluting source, these can only be released – whether directly or indirectly – into water bodies after appropriate treatment and provided that they satisfy the conditions, standards and requirements set forth in the resolution above and other relevant standards.

Law No. 9433, of January 8, 1997, established the National Water Resources Policy and created the National Water Resources Management System and makes other provisions. It establishes the need for granting the right to water use for the derivation or catchment of portions of water contained in a body of water or for the extraction of water from an underground aquifer for consumption purposes, including public supply or as input for production processes; for the discharge of sewage and other liquid or gaseous waste into a body of water, whether or not treated, for dilution, transport or final disposal purposes of the amount withdrawn and other uses that alter the system, the quantity or quality of the water in a body of water.

4.2.2 STATE LEVEL

MSF is subject to the Environmental Legislation of the State of Minas Gerais regarding water quality, i.e., DN Copam No. 10/86, since this standard is more restrictive than CONAMA Resolution No. 357, of March 17, 2005. In accordance with that resolution, the standards to be met by MSF and specified in its Environmental Management System (EMS) are those under Class II, as stipulated under item C of Article 11 of this resolution.

Due to the lack of specific legislation on groundwater, the water quality standards for monitoring groundwater at MSF are consistent with DN Copam No. 10/86 for Class II, as adopted for surface water. This requirement is set forth in MSF's Environmental Impact Assessment/Environmental Impact Report (EIA/EIR).

As far as effluents are concerned, MSF also follows the DN Copam No. 10/86.

Law No 13,199, of January 29, 1999, establishes the National Water Resources Policy and makes other provisions. Article 18 defines uses for which rights are granted by the Government, whether users are in the public or private sector.

Law 13,771, of December 11, 2000, provides for the administration, protection and conservation of groundwater under the jurisdiction of a State and makes other provisions.

Administrative Ordinance Igam No. 010, 1998, amends the wording of Ordinance No. 030, of June 7, 1993. This Ordinance establishes requirements for grants and sets the mode of use or works that are subject to the grant.

4.2.3 MUNICIPAL LEVEL

No specific legislation is available.

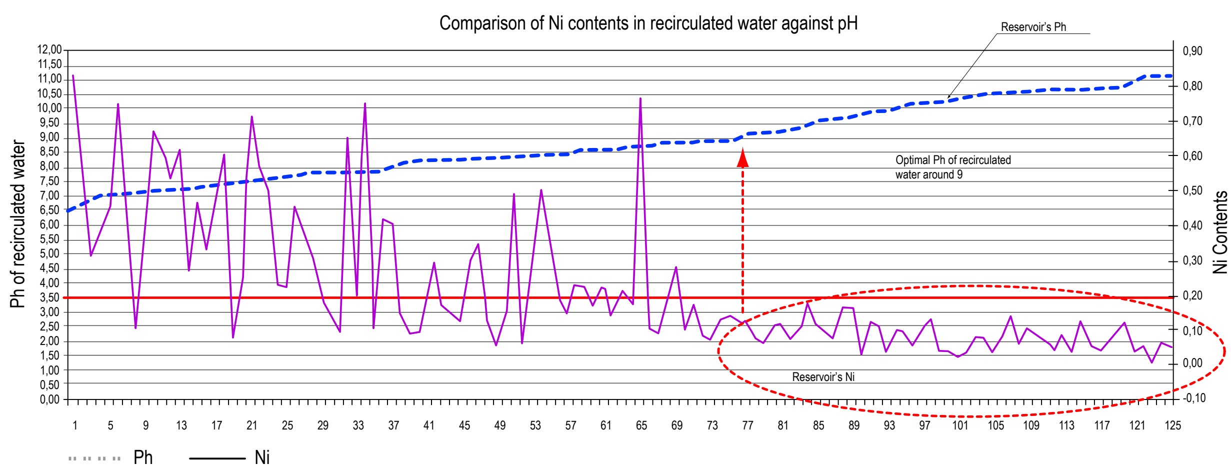
4.2.4 MSF'S INTERNAL STANDARDS

MSF's internal standards are those established in its Water Management Plan for attaining the levels established in the internal goals of the company (which make up the Plan) with a view to continuously improving the system or, at a minimum, complying with the environmental legislation in force, both in qualitative and quantitative terms. These levels are based on the analysis of MSF's historical data and bibliographical references, and they are processed and reviewed periodically by the corporate Department for the Environment.

For any effluent from the industrial area (in general, foundry and concentration) to be released into the raw water dam, the pH level must be 9. This value was established in order to precipitate Ni (main heavy metal that contaminates MSF's effluents), which occurs at pH 8.5, also considering a safety margin, due to reading errors that can occur in pH meters (i.e., equipment that reads pH levels) as well as in MSF's historical data.

Figure 67 displays the behavior of Ni as a function of pH, where the ideal range is above 9. The figures refer to recirculated water, which was a major internal effluents for MSF during the rainy season before the Water Management Plan was implemented. It reflects the share of the waste from concentration, water from the mine, slag granulation from smelting, and floor washing in the industrial area.

Nowadays, all of the recirculated water returns to the production process. This was possible after the corporate water balance was established in order to optimize water recirculation. The changes were all focused on the replacement of raw water (caught from the raw water dam) with recirculated water and on managing all sources of water i.e., ensuring adequate water quality so that in case of an overflow (which is an unusual situation), the raw water dam would not be contaminated. Until then, the recirculated water container would flow into the raw water dam, thus contributing to its contamination since the control of all their feed supplies had failures in their operational management. Furthermore, consumption of raw water, i.e., the Muniz stream dam, was high.



N.B. The analyses were conducted at the MSF laboratory

Figure 67. Comparison of nickel contents in recirculated water against pH

4.3 A IMPLEMENTATION OF MSF'S WATER MANAGEMENT PLAN

Once contamination of the raw water dam was detected due to the 1998 and 2001 events, MSF made investments in a series of corrective projects for the prevention of this and other similar events. However, the firm had yet to identify why the decontamination process did not occur effectively. After a risk assessment for the entire water system using the "look and impact" approach, it was established that the problem was mainly related to failures in the operation of treatment systems in place. Thus, the Water Management Plan focused primarily on the management and raising staff awareness of this issue.

MSF's Water Management Plan is a document that brings together and consolidates all information regarding the use of water (both surface and underground water) under the influence of the company, both for their own consumption (either human and industrial consumption) and for those whose water may suffer interferences in terms of quantity or quality as a result of industrial activities.

Thus, the wealth of information used by MSF's Department for the Environment for water control is gathered, evaluated and made available. Production divisions participate actively in this Plan for the implementation of established guidelines and continuous improvement of their processes. Hence, using it in practice depends on all employees.

This document provides information on the following major topics: controls implemented by MSF to evaluate the consumption and quality of the water disposed of by the company; the impacts on the watershed under the influence of MSF, the risk analysis of interferences (routine and emergency) caused by MSF in the watershed; the processing and reporting system for data, targets, indicators, responsibilities, etc.

The purpose of bringing all this information together is to make the company's entire water management system available in a single document, making this information easily accessible to those who need it. Also, through periodic scheduled reviews, this is the time to review comprehensively the interference and control implemented by MSF, assessing the need for implementation or change in a particular control.

Therefore, the Water Management Plan consists of the following topics, following the principles under the ISO 14001 standard:

- introduction and objective;
- legislation and internal standards;
- local rainfall system;
- profile of the watershed under the influence of MSF;
- profile of the MSF's production process – water balance;
- profile of the effluent from the raw water dam;
- treatment systems (description, effectiveness and improvements);
- quantitative water control;
- qualitative water control;
- risk assessment for current situations, new projects or changes;
- analysis of environmental accident risks that affect water quality and control measures implemented;
- goals and objectives – improving the system;
- responsibilities;
- reporting;
- education and awareness;
- audits;
- review control.

Thus, the Water Management Plan is based on the PDCA cycle and ongoing improvement, as the diagram below shows:

RIt is noteworthy that one of the most focused

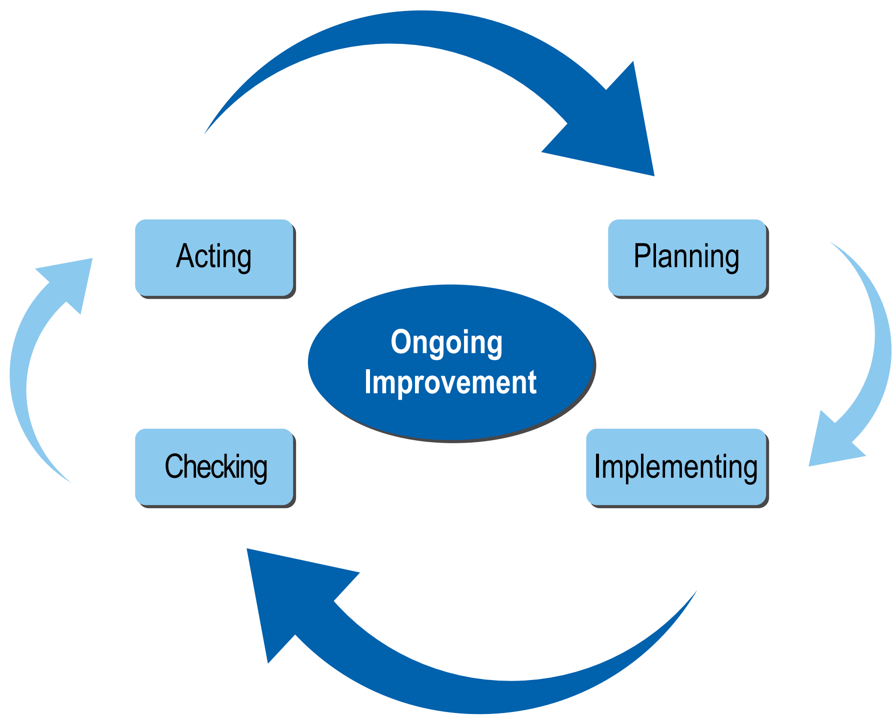


Figure 68. Cycle of actions for ongoing improvement

topics in the Water Management Plan was the awareness of MSF's employees and contractors. This is because the deviations that occurred under water management were much more related to operational performance than to lack of a proper treatment system, which did exist, but was often poorly operated. Evidence of this were the constant deviations detected in the water effluent from slag granulation, the water pumped from the mine, the effluent from the waste and sterile deposit, and the constant overflow of the recirculated water of inadequate quality.

The only structural flaw detected once the Water Management Plan was implemented was the need to establish a treatment plant for the effluents in the sterile deposit and for the water in the mine. Even the employees themselves, as they got involved with implementation of the Plan, they identified new uses for the recirculated water, which helped increase its consumption and has been preventing overflows from occurring. In addition, their responsibility regarding the quality control of effluents was defined.

For this "cultural change" to catch, employees and contractors in the Metallurgy Division (staff working at the concentration, foundry and acid plant) were the initial target audience, since most of the effluents were generated in these areas. The remaining effluents generated by other areas are controlled by the Department for the Environment. A decision was made to provide a mandatory training and that it would be part of the Profit Sharing Program (PSP) for all employees.

An internal monitoring network was set up, with a weekly analysis and interpretation of data. The weekly evaluation conducted by the unit's coordinator of the environment was shared with area managers, coordinators and supervisors in order to establish their involvement and inform them of achievements and future actions. Moreover, environmental performance indicators related to water management were created, which began to be disseminated throughout the company and discussed at a critical analysis meeting (established under ISO 14001).

Another management tool established inspections of the area, which were carried out by operational areas in tandem with the Department for the Environment. These include raising awareness of employees and contractors at the workplace, checking the effluent control spreadsheets and if they were considering the risks associated to the Preliminary Risk Analyses (PRAs), which are mandatory risk assessments for each worker performing a task. It is checked periodically by the immediate supervisor).

Finally, the results and contributions by each area for the achievement of these results became public in talks given by the coordinator for the environment. Thus, each employee started learning about their share of responsibility in their results, their area and the company. This method of awareness has been used since 2002.

4.4 RESULTS ACHIEVED

Two years into MSF's Water Management Plan implementation, the following results can be highlighted:

- 100% of employees (the target-audience) trained in the Water Management Plan;
- no deviation in the quality of the effluent from the granulation of slag;
- no deviation in the quality of the effluents in the sterile deposits;
- no deviation in the quality of the effluents in the waste deposits;
- no deviation in the quality of the effluents pumped out of the underground mine;
- 1 year and 6 months without any overflows from the recirculated water dam, with all water returning to the entire production process;
- gradual process of improving the raw water from MSF, as Figure 69 shows. By looking at the Muniz stream, since January 2004 it can be considered that nickel and manganese have been controlled so as to comply with legal requirements.

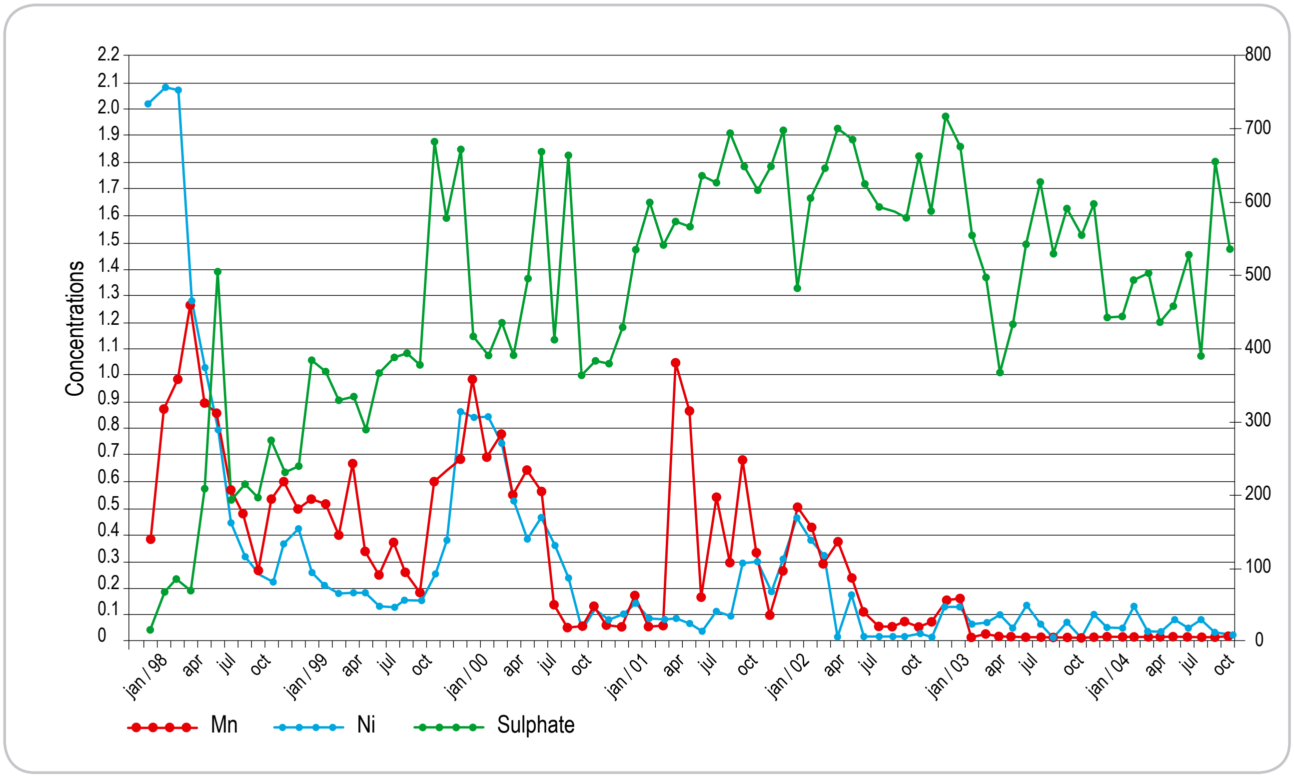


Figure 69. Qualitative data for MSF's raw water dam

5 FINAL REMARKS

Acid drainage generation involves controlling a number of variables and results in a complex process. In the case of MSF, managing this process in the short term became a priority for the company. The base was a review of implemented projects; their adjustment to new risks identified; setting clear performance guidelines for all staff; and awareness raising. As a result, the company has been managing to achieve all of their short-term goals relating to water quality, with satisfactory performance. In the long run, the process is dealt with more broadly, including several studies.

After two years of work on the Water Management Plan, the conclusion is that participation of the operational area, along with the management of an enterprise, is the basis for all success. It is still early to assert that MSF is a case of environmental awareness leading to cultural change, because demands are still made and small deviations are reported since this is a new process. However, one thing is certain: the company is on the right track.

Luís Antonio Torres da Silva[1]
Patrick Thadeu Thomas[2]
Pedro Carlos Pocciotti[3]

WATER USE IN SAND MINING OPERATIONS ON THE PARAÍBA DO SUL RIVER BASIN

1 INTRODUCTION

Sand extraction for civil construction, which is a major economic activity in support of urban life, as our civilization knows and appreciates, causes environmental impacts associated with the exercise of this activity, whose mitigation is possible and should be pursued with the same efforts as the attempt to improve extractive processes. Thus, it is important to note that mining is a temporary activity, which allows one to establish a program for future use of the area where it is installed that will comprise and meet the future needs of communities in this region. It is therefore in this context that both the implementation of necessary control measures that are established and monitored by environmental agencies and the management of water resources, which is adopted by entrepreneurs, who are aware of their obligations to care for the environment according to sustainable development principles.

Against this backdrop is the operation of the sand mining companies in the Paraíba do Sul river basin, in the implementation of the collection management tool for water use. Established under Law 9,433 (1997), this instrument is a management mechanism whose objective is recognition of water as an economic good, and gives users an indication of its real value, while encouraging adoption of procedures to lower consumption, aiming at the rationalization of water use. It should be emphasized here that, as regards the proper charging for water use, this is fixed in terms of relative figures for derivations, catchments and extractions of water, i.e., the amount removed and the variation system, the release of sewage and other gas and liquid waste, the released portion and its variation system and the physico-chemical, biological and toxicity properties of the effluent. Thus, fair values are to be assigned by reducing the supply of water derived from the

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mining project, and the relative compensations to permanent loss of the global supply of water in the water body (future unavailability for other uses) with regard to the importance and economic capacity for the user sector.

2 BASIC INFORMATION

2.1 SAND EXTRACTION PROCESSES AND WATER RESOURCES USE

Virtually all natural sand extracted for civil construction purposes includes water in its processes, which falls in one of the following three major groups:

a) sand ports;
b) alluvial pits;
c) water blasting of soil waste.

2.1.1 SAND PORTS

Sand ports are those cases in which the extraction of sand is made directly from the river beds through floating dredges. The extracted material is stored along the banks of rivers. So a cleared area (i.e., a deforested area) along the margin is necessary, otherwise a barge can be used for direct river transport to other locations.

From the standpoint of the environment, the impacts are associated with the need for deforestation along the river banks and in water bodies, the stirring of particles at river bottoms, with potential damages to the river's biota, in addition to changes in the dynamics of sedimentation, with movement and disposal of fines elsewhere. Losses in the process are restricted to the water incorporated into the product.

Deepening of river troughs may occur for brief periods. Over time, however, new replacements of materials will occur in extraction sites, since the source of these sediments remains.

2.1.2 ALLUVIAL PITS

In alluvial pits one finds those cases in which sand extraction takes place in a closed loop and progressively deeper, using groundwater as a vehicle for this process. The process is based on mechanical means until the water table is reached, and then it becomes controlled by the groundwater.

2.1.3 WATER BLASTING OF SOIL WASTE

The water blasting procedure, also known as 'areia de barranco' in Portuguese (sandbank sand) is simply the pressure washing of fines (clay and silt) located in stockpiles of waste soils to separating them from the sand. Waste soils usually derive from the weathering of granite, gneiss, quartzite and schist rocks.

As a result of the fines separation process, these are carried together with the blasting water – usually to sedimentation basins. If this does not occur, these fines are carried along with the water possibly to a water body. The extraction of sand through the water blasting approach in waste soils can cause environmental damages that could easily be controlled and mitigated.

2.2 THE NATIONAL WATER RESOURCES POLICY

The National Water Resources Policy (PNRH) and the National Water Resources Management System (SINGREH) were established by means of Federal Law No. 9,433, of January 8, 1997. The rationale for this law is that water is defined as a public good; a limited natural resource with economic value. Hence, the granting of rights to use water resources and charging for the use of these resources, among others, were established as mechanisms of the National Water Resources Policy. The design and implementation of those mechanisms, and all other assumptions of the PNRH can be found in Chapter 3.

Ceivap – Committee for the Integration of the Paraiba do Sul River Basin

Ceivap is based in Resende, RJ, and was established through Federal Decree 1842, of March 22, 1996. It is a democratic and participatory forum for decentralized discussions and decisions on issues relating to the use of waters from the Paraíba do Sul river basin.

The Committee brings together representatives from the government (35%), user community (40%), and civil society organizations (25%) with an important role for the conservation, preservation and restoration of water quality in the basin. Ceivap currently has 60 members, including three members from the Federal Government and 19 from each state that is covered by the basin (RJ, SP, MG).

Ceivap's main duties include: approving the Water Resources Plan for the Basin and monitoring its implementation; establishing the mechanisms for charging for water use and suggesting the amounts to be charged; arbitrating as an initial administrative level on conflicts related to water resources and define quality standards (framework) for the waters in the basin.

On November 4, 2002, in the town of Resende, RJ, the Committee

On November 4, 2002, in the town of Resende, RJ, the Committee for the Integration of Paraiba do Sul River Basin (Ceivap) decided as a plenary session, based on current legislation, on the implementation of a charge for the use of water resources by the following sectors: sanitation, industry, agriculture, aquaculture and electric power generation from small hydroelectric plants.

Because of the particularities regarding impacts and uses of water resources by the sand mining industry, Ceivap established on that occasion that effective implementation of the charging scheme would take place within one year from that date, and the criteria for water use charges for that sector would be defined within that timeframe.

In the second half of 2003, two studies to support the criteria for charging for water use by the mining sector were launched: one of these would be developed by the staff of Coppe/UFRJ's Hydrology Laboratory, under the coordination of civil engineer Paulo Marcelo Lambert Gomes; and the second study would be prepared by the National Water Agency team, under the coordination of Patrick Thadeu Thomas, building on contributions previously made by Pedro Carlos Pocciotti, especially in cases of charges related to alluvial open-pits. These studies were completed and presented at the meeting of Ceivap's Technical Chamber on March 2, 2004.

Considering the studies presented and the concerns raised, another meeting was held on March 23, 2004, in the city of Taubaté, SP, to allow for the experts in the industry and other stakeholders to provide feedback on the studies. By the end of the meeting, consensus was reached on proposed charging criteria.

The discussions culminated in the presentation of such proposed criteria for charging for water use in the segment of sand-bed river mining in the Paraiba do Sul river basin to a plenary session of Ceivap at the meeting held on March 31, 2004 in Juiz de Fora, MG. The proposed criteria were approved by the plenary session and resulted in Ceivap Resolution No. 24, of March 31, 2004.

In a pioneering initiative in the country, the National Association of Construction Aggregate Producers (Anepac) followed and participated actively in discussions at the Ceivap's Technical Chamber with technical support from members of the São Paulo Sand Industry Union (Sindareia, SP).

Building consensus on the criteria for charging for water use by the segment of sand mining from the river bed in the Paraiba do Sul river basin can be considered as an example of decentralized decisions with a coordination involving users, the civil society and government, which are the mainstays of the National Water Resources Policy.

Photo 79. Paraíba do Sul river

Charging Formula

Formula established by Ceivap Resolution No. 8, of December 6, 2001, and Resolution No. 15, of November 4, 2002, for charging for the use of water resources in the Paraíba do Sul river by users in the sanitation, industrial, agriculture and aquaculture sectors:

Total Charge =

Catchment charge

$$C_{CAP} = Q_{CAP} \times K0 \times PPU \quad +$$

Consumption charge

$$C_{CON} = Q_{CAP} \times K1 \times PPU \quad +$$

Discharge charge

$$C_{LANÇ} = Q_{CAP} \times (1 - K1) \times [(1 - K2\,K3)] \times PPU$$

K0 – Multiplier coefficient for the catchment price per unit = 0.4

PPU – Public Price per Unit (R$/m3) = 0.02 (sanitation and industry), 0.0005 (agriculture/livestock), and 0.0004 (aquaculture).

Q_{CAP} – Water catchment flow (m^3/year)..

K1 – Consumption coefficient (share of caught water that will not return to the water body).

K2 – Percentage of treated effluent flows in relation to the total flow of effluents or coverage rate for effluent treatment.

K3 – Efficiency Level of Biochemical Oxygen Demand (BOD) Reduction..

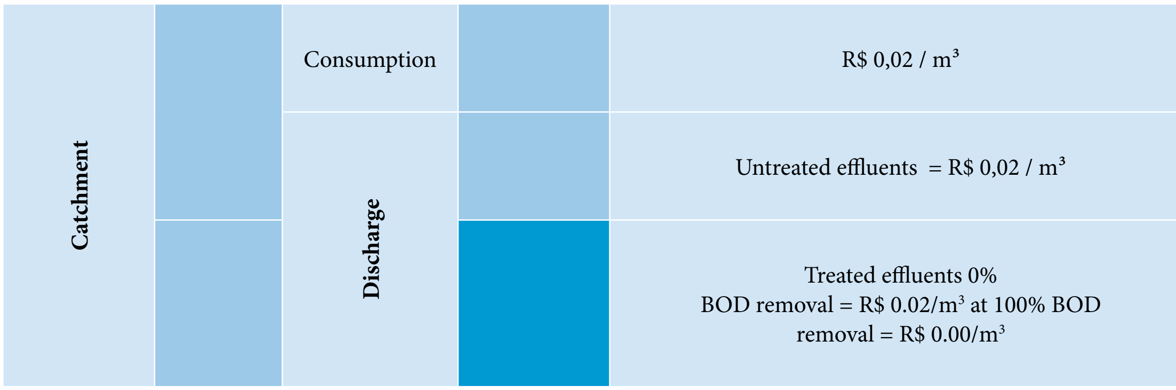

Figure 70. Charge for use of water resources in the Paraíba do Sul river

3 CHARGING FRO WATER USE IN SAND EXTRACTION OPERATIONS IN RIVER BEDS IN THE PARAÍBA RIVER VALLEY

The charge for water use in the mining sector covers all those who use water in the extraction of sand from the bed of federal rivers in the Paraiba do Sul river basin. The charging formula involves three installments:

- charging for the amount of water collected from the spring: in the case of bed mining, this amount is represented by the water that makes up the dredged slurry along with the sediments. For this calculation, the miner must provide the average monthly sand production and the average water/sediment ratio obtained from the dredged slurry;
- charging for water consumption (proportion of the amount of water collected that will not return to the river bed): this consumption is represented by the moisture content in the sand; for calculation purposes, a miner must provide, in addition to the information mentioned above, the average content humidity of the sand that is sold;
- charging for the disposal of effluents in the receiving body: in the case of sand mining, this is zero, since, at this moment, since the only parameter to assess the quality of the effluent returned is the Biochemical Oxygen Demand (BOD), which relates to the organic load discharged, mining, for not interfering in the level of BOD, so a payment exemption for this third installment applies.

Thus, the calculation for the charge is based on the information provided by the miner when they registered with the public agency responsible for granting and charging. This information may change as significant modifications occur in the parameters reported. Those who use less water considering their proportion of dredged slurry and sell drier sand will pay less. This is one of the objectives: those who use water more sensibly pay less.

It was also stipulated that in no event the amount paid for water use may exceed 0.5% of the cost of producing the mineral.

3.1 CHARGING FOR WATER IN SUBMERGED PITS

The extraction of sand for the civil construction industry in the Paraíba Valley, especially in the São Paulo portion of the Valley, currently takes place exclusively through the submerged pit system and is carried out in disturbed floodplains of the Paraíba do Sul river, which currently covers about 2,000 hectares of water surface generated by the activity, thus representing 99.6% of sand production in this portion of the state of São Paulo.

For now, this type of mining is not covered by the charging system established under Ceivap because, since greater coordination with state governments is necessary for its implementation, considering agreements already disclosed by the state government of Sao Paulo that the water in pits should be considered groundwater, and, according to the Federal Constitution, this is the state's domain. Considering the ongoing negotiation and partnership strengthening process, especially among the national and state agencies in charge of enforcing the water resources policies in the Paraíba do Sul river basin – the foundation of the success of Ceivap's initiatives –, it is believed that soon the procedures for implementing the charging scheme will also be standardized for this sort of use and interference within the river basin.

Even without being subject to the charging scheme, this issue was raised and shed some light on the discussions that will follow.

Regarding the charge for water catchment, according to an initial hypothesis it would be calculated the same way as for the extraction of sand in river

Criteria for Charging for Water in the Extraction of Sand from River Beds

The formula for charging for water from sand mining in riverbeds established by Ceivap Resolution No. 24, of March 31, 2004, is similar to the formula applicable to other sectors. The difference lies in how catchment and consumption flows are calculated. There is no discharge since the extraction of sand from river beds does not involve any organic matter being released into the river.

Charge Total R$ 64,95/mês

- **Catchment flow** → **Catchment flow** $Q_{CAP} = Q_{AREIA} \times R$
- **Consumption charge** → **Consumed amount** $Q_{CAP} \times K_1 = Q_{AREIA} \times R$
- **Discharge charge – not applicable**

K0 – Multiplier coefficient for the unit catchment price = 0.4

PPU – Public Price per Unit (R$/m3) = 0.02 (sanitation and industry), 0.0005 (agriculture/livestock), and 0.0004 (aquaculture).

Q_{CAP} – Water catchment flow (m^3/year).

Q_{AREIA} – Average sand amount production (m^3/year).

R – Dredged slurry water/sand mixture ratio. For example, for water at 60% and sand at 40%, R = 1.5.

U – Moisture content for the sand produced. For example, for moisture at 10%, U = 0.1.

beds. As for the charging for water consumption, it is suggested, in principle, that a charge could exist, in addition to that related to the moisture content of the sand in the case of a river bed, to the evaporation of water in the lagoons that are formed as a result of the opening of pits, as well as the "perpetual evaporation" generated in these lagoons once the exploration period is ended.

The charge for evaporated water is based, among other things, on the possibility that, although the evaporated water returns in the form of rain to complete its cycle, one cannot guarantee that it will fall on the same river basin or even upstream of the site where it was caught. Furthermore, it should be noted that water management revolves around the concept of availability or security of access for multiple uses.

It should be emphasized, however, that discussions have only started, but some difficulties in understanding are clear, including: charging from all users who generate "surface evaporation"; the impact of the opening of these pits on the water balance; impossibility of knowing where the evaporated water will "rain" and which amount will fall on the actual basin or on neighboring basins, either upstream or downstream from the catchment.

3.2 FINAL CHARGING AMOUNT IN RIVER BEDS AND ITS DEPENDENCE ON THE SAND-WATER MIXTURE FACTOR

The abacus below shows roughly the order of magnitude for the annual charge for operations related to sand mining in river beds of federal rivers in the Paraiba do Sul basin, taking into account the amount of sand produced in terms of m3/month and the water-sand mixture ratio. The difference in the final charge is shown, noting, for example, an output of 60,000 m3/month with water at 60% in the mixture compared with the same output of 60,000 m3/month with water in the mixture at 90%. In the first case, the annual charge will be around R$ 10,000, and in the second case, albeit with the same output, would be about R$ 52,000, hence 5.2 times higher, for a mere change of water percentage in the mixture from 60% to 90%. The same reasoning can be viewed on the vertical lines of the abacus, where for the same annual charge amount increasing amounts of sand can be extracted simply by using lower amounts for the water-sand mixture. Nothing new in this concept – the more water is involved, the greater the charge. It is a matter of progressiveness. In practice, very low mixture ratios, i.e., little water and too much sand, are harmful to the equipment because of excessive wear. In addition, excess water will entail higher charges.

The implementation of a charge system for water use in the segment of sand extraction has covered only nine users in the Paraíba do Sul river basin so far. This small number reflects the fact that the process was implemented only to users of federal rivers, and today the strength of sand extraction in the basin is actually associated to open-pit mining operations, and not river bed extraction.

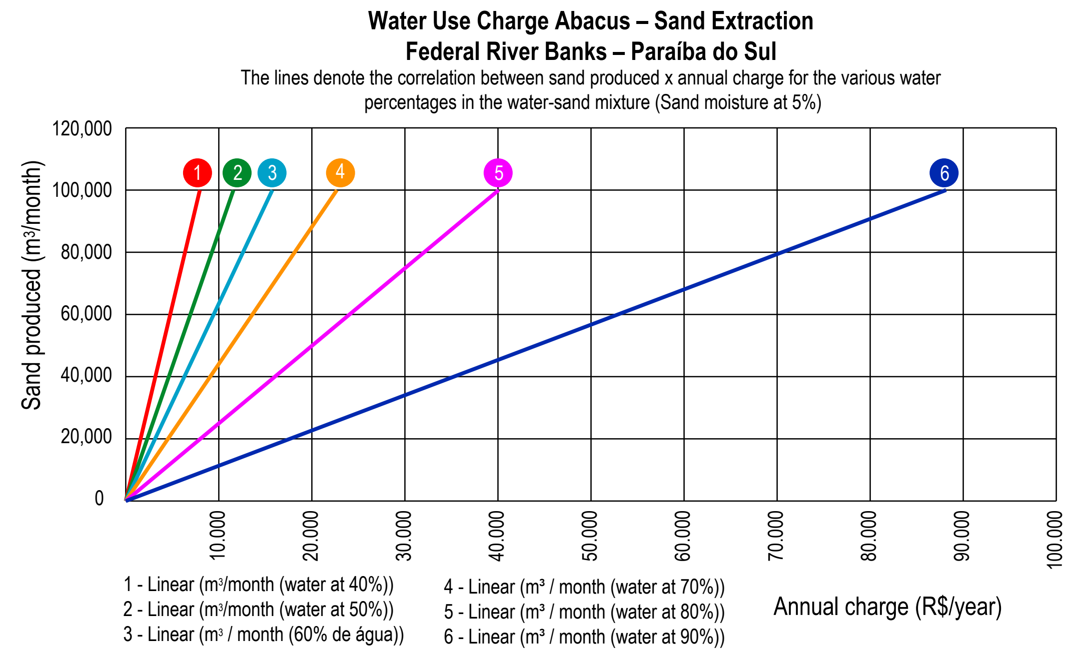

Figure 71. Abacus for the charge for use of water resources from sand extraction on the Paraíba do Sul river

4 FINAL REMARKS

Two aspects stand out in the entire process of implementing a charging system in the Committee of the Paraiba do Sul River Basin, especially the establishment of criteria for charging for the use of water resources for sand mining on riverbeds.

The first aspect is to which extent the social segment represented by users in the mining industry in the basin is prepared for incorporating actions to conserve and protect the environment, especially water resources, in their activities and processes. The participation and contribution of ANEPAC and experts from SINDIAREIA – SP in the formulation of criteria for charging for the use of water resources, which never stood as an obstacle, reflects this. This is the advancement of a new paradigm enforced for modern management of any company wishing to survive in today's globalized market, namely corporate social and environmental responsibility.

In this context, it should also be noted that the partnership approach adopted by the National Water Agency, which never assumed the position of a public officer's in command and control, making themselves available, with all its technical and managerial attributes, to reconcile preservation of economic activity and preservation of water resources. Indeed, these breakthroughs need to be recognized and mainstreamed by other agents and other environmental management actions.

Second, the certainty that in a scenario, such as that advocated in SINGREH, the management actions in favor of environmental and water resources preservation resulting from a social agreement translated by Ceivap's deliberations, is the way to build the true meaning of the Sustainability-Development duality.

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ENVIRONMENTAL RECOVERY AND REVERSAL OF IMPACTS ON WATER RESOURCES AT A SMALL MINING COMPANY: CASE STUDY ON SICAL INDUSTRIAL'S QUARTZITE MINE

1 INTRODUCTION

The management of water resources in the mining industry is a justifiably controversial topic among the layman and the expert alike who have an interest in environmental issues. Therefore, those practitioners more closed involved with the environment, especially technical consultants, are often faced with the need to clarify certain commonplace statements that, however well intentioned, seem to be partially entangled in misunderstandings.

One of these assumptions has to do with the notion that the mining business is incompatible with the conservation of water resources and... period. Another assumption, less extreme, but also imbued with a restrictive attitude to mining companies, argues that only large companies have the capabilities to rehabilitate degraded areas since this requires massive financial resources.

This section discusses an experience that took place between 1994 and 2002 during the development and implementation of an Environmental Control Plan by a company with a small mining operation – Sical Industrial – based in Belo Horizonte, Minas Gerais, and operating from Serra do Curral, which is an area listed by the municipal government.

The actions in this Plan were so successful that Public Prosecution Service and the Belo Horizonte Council for Artistic, Cultural and Natural Heritage, which administers the listed heritage, after having investigated the area covered the company – which had already been prosecuted for noncompliance with its environmental license by the Municipal Secretariat for the Environment – concluded that "the company, after a certain time, undertook a significant improvement in environmental terms, and it now can be

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considered to be fully compliant with its obligations associated with the environmental license."

The case presented here shows that, in response to legal requirements, mining companies have imposed an obligation on themselves to implement measures to mitigate the obvious impacts of their activities. In pursuit of the same goal, experts, researchers and technicians have sought to develop studies and practices meant to find the most appropriate solutions to each actual challenge being faced – including as regards the economic feasibility of implementing the proposals vis-à-vis the venture's investment – so as to reconcile the environmental conservation requirement and the commercial interests of small and medium mining companies. As they often believe that they lack the financial resources to address environmental liabilities incurred or inherited by them – some of which having been incurred prior to the applicable law –, they postpone the recommended actions for proper environmental rehabilitation. As a result, the existing problems facing mining projects are further compounded and the associated financial costs increase.

To provide a better understanding of this account, this section is divided into various subsection, each covering roughly each phase of the work undertaken at Sical Industrial's quartzite mine.

In this sense, the subsection following this introduction describes the project and also shows how its location in an area of fundamental importance for the conservation of water resources – in addition to being listed by the Municipal Heritage Authority – has made the legal requirements and restrictions on its operation stricter.

In response to legal requirements, the company was forced to prepare environmental studies – Plan for the Rehabilitation of Degraded Areas (Prade) and the Environmental Control Plan (PCA), which required a thorough knowledge of the project.[3] This will be discussed under Project Description and Applicable Legislation.

When Prade and the PCA were prepared, several environmental problems were caused by Sical's mining and industrial operations and the need to run several procedures to rehabilitate lands and address the impacts on local water resources became apparent. This issue will be described under "Integrated Planning and Mitigating Actions".

Finally, the closing remarks on the work will be provided under Conclusion, which will also highlight the lessons that this experience can offer to anyone dealing with mining and environmental management issues.

2 PROJECT DESCRIPTION AND APPLICABLE LEGISLATION

Sical Industrial is a mining/industrial complex consisting of a quartzite mine, a factory of autoclaved cellular concrete blocks and a storage yard for their production. The company established itself in the southern side of Belo Horizonte after having purchased a mine from former Companhia de Mineração de Minas Gerais (Comig), now Companhia de Desenvolvimento de Minas Gerais (Codemig).

[3] Sical was implemented prior to CONAMA Resolution No. 001/86, which requires potentially polluting projects to undergo Environmental Impact Assessments (EIA). Thus, their licensing required corrective measures that did not involve the preparation of this kind of study.

[4] Autoclaved cellular concrete is a light product, developed from a reaction of lime, cement, sand, and aluminium powder that, after steam drying at high pressures and temperatures, provides calcium silicate, which is a stable chemical compound gives the products that are based on it – i.e., blocks and panels – an excellent performance in civil construction.

Its industrial design, which is based on a Swedish technology, focuses on the production of blocks and modular pieces obtained through a chemical and physical process that uses sand from quartzite, aluminum, lime, and cement formations which, mixed together, make up an expanding mass. Once dry, this mass is cut into predetermined sizes that undergo an autoclaving process for the production of blocks and panels for the civil construction industry.

The operations are located on the north side of the Serra do Curral, a landmark and symbol of Belo Horizonte that lies on the northern edge of the so-called Quadrilátero Ferrífero (Iron Quadrangle). Bordering the entire south and southeast sides of the city, this rocky shield is one of the few areas in the region to preserve the natural environment seamlessly. This becomes even more evident by virtue of a feature of Minas Gerais's capital: Belo Horizonte was built at the foot of the Serra do Curral on a depressed area. Thus, from virtually anywhere in city one can have a broad view of its higher side. Thus, the corporate premises face the city and can be sighted from the urban area (Photo 80), which exposes the company's operations to Belo Horizonte's residents and visitors.

Photo 80. A picture of the city of Belo Horizonte from its northern border, at the "Belo Horizonte Depression", seen in the foreground. The Serra do Curral, a symbol for Belo Horizonte's residents, is sighted at the background, forming a southeast-southwest lining that makes up the northern edge of the Iron Quadrangle. Sical is located on the mountain, on the right side of the photo.

As already stated, Sical's operations consist of three units: the mine, block factory and storage yard for industrial products. The mine covers two quarries, both facing the city. Front 2 – designated here as F2 – on a steep slope, is located on the left bank of an arm of the Jatobá stream, which is main local drainage. Front 1 – called F1 here – lies sideways to F2, but on a lower topographic position. In the intermediate area between these two fronts, upstream of F1, is the factory – with its administrative support

[5] SICAL's premises ushers the entire city and surrounding areas, which will be discussed in detail later when environmental education programs for company employees and students and teachers from schools in the outskirts of the factory are discussed.

facilities comprised of the reception, offices, scales, restaurants, and the parking lot – and the big yard for the storage of blocks.

It is important to point out here that the Sical's mine is located on lithological formations that occupy a narrow strip between the quartzite rocks in this geomorphological mass and also in the Serra do Curral. The environmental importance of these rocks and their structure is evident when one realizes that they are an area for local aquifer recharge, where, therefore, the springs that feed the water catchment bodies for the Minas Gerais Sanitation Company (COPASA) can be found, which serve a significant portion of the population of Belo Horizonte.[6]

One can well understand why this company's location – in a vital area for the conservation of water resources in the region and with a major landscaping and cultural relevance – puts Sical Industrial's project under serious legal restrictions, as Photo 81 shows.

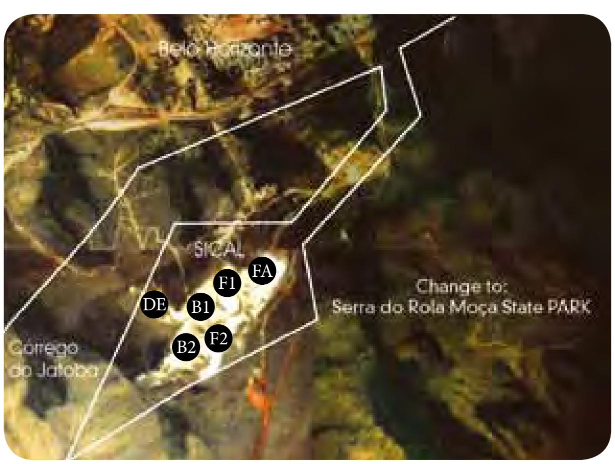

Photo 81. Mosaic of aerial photos of Sical and borders with the Serra do Rola Moça State Park – PESRM.

The requirements in environmental laws include those promulgated by the National Environment Council (Conama) and backed by the Brazilian Constitution – especially the constitutional requirement under article 225 of Chapter 6 – requiring that mining companies submit Plans for the Rehabilitation of Degraded Areas (Prade). In this very sense are the requirements stipulated by the State of Minas Gerais, that by introducing its Environmental Policy-Making Board (Copam) provides several regulations for mining activities to ensure environmental balance in the state of Minas Gerais.

In the case of Belo Horizonte, in addition to the measures enacted by the Municipal Council for the Environment (Comam) in March 1990, the Municipal Organic Law listed the entire mountain ridge of the Serra do Curral, which is the site of the mining project discussed here.

In 1991, the listed area was reviewed and expanded to the current 40 square kilometers, which account for 10% of the total area of the municipality.

[6] The areas adjacent to Sical are under legal protection since they are sources of water catchment. In 1998, the Serra do Rola Moça State Park (PESRM) was established in the area, administered by the Government of Minas Gerais's State Forestry Institute (IEF). Sical helped establish this protected area by providing materials for the construction of its headquarters in the district in which the company is located (Barreiro) and donating equipment for its operation, such as guard booths and gates.

All of these regulations were introduced after the mining operations started, and they impose severe restrictions and obligations on them that even result in constraints to the mine's output capacity.

In view of the legal requirements listed above, the company saw itself compelled to conduct studies to assess the environmental situation of its project with a view to applying for an environmental license. Then the Plan for the Rehabilitation of Degraded Areas (Prade), the Environmental Control Report (RCA) and the Environmental Control Plan (PCA) are prepared, which are studies and documents that support the environmental licensing application.

It is worth mentioning that SICAL, upon receiving their Operating License, is required to comply with the various conditions, environmental impact control and mitigation measures from their business, among which is the maintenance of the original characteristics of the listed property, including its landscaping heritage and the physical and biological integrity of the lands whose shape must not be changed.

3 STATUS OF THE PROJECT

To enable the preparation of the studies mentioned above and the development of actions relating to rehabilitation, mitigation and control of environmental impacts required by the licensing process, it was first necessary to conduct a detailed survey of the environmental status of the project. For the implementation of this procedure, it was observed that the landscape was affected by the exposed areas of the mine, with no vegetation. [7] Located on a steep terrain, the quartzite mine was open before it was purchased by Sical and it had undergone deforestation and removal of the topsoil in a large area that was conducive of erosion – upper and middle slopes and top of a massif with a declivity value above 500 and approximately 100 meters at F2 and 35 meters in F1. The erosion in the two pits was evident, and through them the ore was carried to the rainwater drains, thus silting up the Jatobá stream, the main local drainage.

The rain runoff above the infiltration was causing deep grooves to form across the terrain.[8] As a result, the benches in the mine had been destroyed and much ore was being carried away, i.e., the raw material used in the industrial process was also being lost. There was no planned rainwater drainage nor a system for the collection of rainwater. Moreover, the volume of the material being carried had caused a port of sand to form that was operated in an environmentally incorrect and illegal manner. The damage was both financial and environmental, caused mainly by siltation of the Jatobá stream. The project also had no tailings deposit, which is a vital resource for any mining venture for the proper disposal of the earth matter removed with the ore.

In another front of the mine's massif, the area of the Serra do Rola Moça State Park – a listed property indirectly protected against interventions – was undergoing degradation of its landscape, which was caused

[7] All the problems arising from this had been caused by the method for opening the mine. As a one-off procedure, it was not consistent with the best engineering standards, according to which a mine should be opened gradually while the areas being used should be rehabilitated. In this regard, another mistake was working on the mine from its base.

[8] This was the most serious problem in terms of water resources.

by uncontrolled mining activities, mainly by erosion generated by rainwater carrying solid material to the streams that cut through this area (see Photo 82).

Photo 82. Serra do Rola Moça State Park as seen from Sical

It is apparent that there had been negative interventions with local water resources, both with regard to those intended to public supply and those that are important to preserving the environment because they form drainage basins with natural vegetation areas that are a wildlife sanctuary. Also, due to the exposure of the subsoil and the sharp steepness of the slopes, it was clear that it was difficult for rainwater to seep in, which affected the potential for aquifer recharge.

All this calls for emergency procedures to restore the degraded terrains and address the impacts on local water resources, which are of unquestionable importance to the region. Photo 83 shows the mine's location.

Photo 83. Overall appearance of the mine as of commissioning of an Environmental Control Plan (1994). F1 in the foreground; a partial view of the large deposit of industrial shards in the center, on the left; F2 in the center; one of the headwaters of the Jatobá stream on the right.

4 INTEGRATED PLANNING AND MITIGATING ACTIONS

The implementation of mitigating, control and rehabilitation actions for the area to be discussed here – defined as required actions in the licensing process and will be presented here – were only possible thanks to the integrated management adopted throughout the implementation of the proposed Control Plan, which relied on all divisions of the company: management, operational management, specialized technical consultancy, and staff designated to be part of the implementing team, who were trained and briefed on every action to be implemented. During the training efforts, special attention was given to the transfer of information on the reasons for and importance of environmental control interventions regarding the proper construction procedure for the individual actions. Without such an interest to participate, it would certainly have been impossible to rise to the challenge of solving the problems in the project.[9] Due to the low budget[10] available for the works to address environmental liabilities, alternative, low-cost solutions had to be pursued. This was achieved through practical training of personnel, use of available resources in the project and reconciliation of production and environmental control activities. This helped dilute environmental rehabilitation costs into production costs, which made it financially feasible to cover all environmental requirements. To ensure maximum understanding of the guidelines provided by the technical consultants hired during the talks delivered to company employees at the beginning of each working week, a notebook was in place. The detailed actions to be implemented were recorded in this notebook, including illustrations with drawings, together with all explanations necessary for the task, such as measurements, types of materials and procedures to be used. Thus, the performance of employees was boosted, which was essential to ensure success of the proposed environmental rehabilitation.

The actual environmental rehabilitation works started in 1997, and basic lines of action were planned and agreed on for addressing the serious environmental problems inside the mining area and outside it, which were the result of the associated impacts in the latter case.

Because the project was located between the city of Belo Horizonte and the area of catchment springs initially called for the rehabilitation of degraded areas. To this end, it was necessary to make adjustments to the mining plan so that the zone facing the area covered by the springs and the top of the massif (F2) ceased to be explored. Thus, the mountain ridge would be preserved. This procedure required that the life of the mine be reduced – from 72 to 41.25 years – and determined that the mining works would only take place at the area facing the city, which required special care to avoid landscape degradation, which could be seen from the whole urban area.

The issue of landscape-related impacts had been much emphasized in the license granted by the city government, requiring it to be immediately addressed. It should be noted that “landscape-related impacts” means “sight of the exposed substrate”. This fact is important, but it is much less severe than what this exposure means to the quality of water resources, which suffer the effects of the huge carrying of solids caused by rainwater flows that take place due to a lack of vegetation cover to protect the surface.

When it is available, the vegetation conceals the subsoil and allows water to seep in, which thus feed the underground water reserve instead of flowing away. In addition, this vegetal cover helps slow

[9] We would like to mention the names of some people who participated more closely in the effort to restore Sical’s area: Flaviano, in charge of field operations, dubbed as “the efficient Baianinho”; Mr. João, the truck driver; Serginho, in charge of operating the plant; José Antônio, from the projects division; Rogério Matos, industrial manager; Ênio Freitas, managing director; and Maurício Dias, the entrepreneur.

[10] It is worth mentioning that, because of this level of corporate financial investment in the works for environmental rehabilitation, these interventions lasted longer than would be expected in similar cases, when the interventions are completed in less than a year.

down rainwater at the ground level, once again facilitating their infiltration and preventing the development of erosion processes. Stems, leaves and roots act as the access points of this water to the underground and prevent subsurface water from evaporating. In addition to all these functions, the presence of vegetation also minimizes impacts on the landscape.

It cannot be emphasized enough, however, that, to restore vegetation in a degraded area it is critical to start by solving those problems related to rainwater (rainwater drainage). This requires that they are properly caught, channeled and disposed of, which reinforces the notion that leaving them where they fall is still the best solution.

With regard to this issue in Sical, the problem was the existence of two large degraded areas on the mining sites, and another area consisting of a large waterproof yard – the three of them lying on the top of the massifs (see Figure 72). This generated a huge flow of rainwater, which, in turn, caused deep erosion.

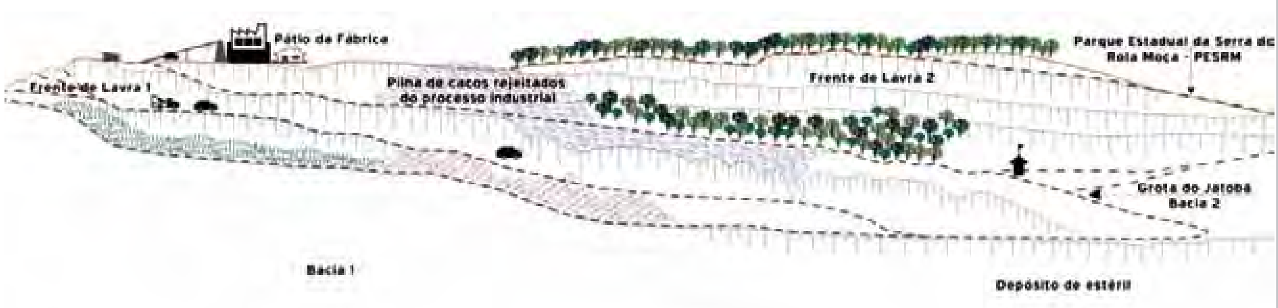

Figure 72. Front diagram showing the distribution of Sical's mining-industrial units

The water that fell on top of the mountain ridge ran down steep places without a suitable location for its final disposal due to the topography of the terrain. This situation forced the search for a balance between the mining operations in one of the pits (F1) and the opening of a sump that could hold those waters and prevent them from being released directly onto the slopes in the outskirts of the industrial zone. To this end, the approach to ore extraction had to be modified. That decision was helped by the local stationary climate, which allowed for mining and storage operations to be conducted during the dry season and for the pit (then down) to be used as a sump in summer, during which time rainfall levels in Belo Horizonte exceed 1,200 mm.

Yet, the Jatobá stream remained unprotected, as the other mining front (F2) had all of the rainwater drainage naturally directed to it. It was therefore necessary to create a sump that controlled rainwater flow speed and removal of sediments in this front, at least during the topographic reconstruction works that would be conducted on the whole contribution area over the next ten years.

This control was achieved once an entry point into the inner gorge of Jatobá was established, which would also serve as a dyke, which was planned[11] to withstand the water volumes from rainfall on that area. To build this entry point and dyke, shards of waste blocks from the industrial process were used, which formed a big pile of inert waste hindering mining works at F1. Due to its filtering capacity, this material allowed sediment-free water to go through, which accumulated in the sump, leaving the Jatobá stream free from matter generated by erosion. It should be pointed out that, for the development of these works for environmental rehabilitation, it was first necessary to prepare a new topographic survey of the area. Based on it, both the works required by the new mining plan and the work of cubing the reserves of quartzite, the sterile/ore ratio and the controlled sterile disposal project.[12]

Under this project, storage of the sterile in the deposit followed ABNT's standards, which recommends that the layers that are 20 cm thick are compressed, and wetting during the dry period. The drainage system was built as the deposit grew, by topographical conformation. Thus, the inclination of the banks – along, 1.5%; across, 4% – would favor routing drainage along channels set up at the feet of slopes, while final disposal of the waters would take it outside the body of the massif, to an appropriate location in natural terrain.

Basic structuring of the deposit took place from minor removals of vegetation,[13] cleaning the area, and building a dam and start draining the mattress.[14] The vegetation removed and the cleaning material were stored sideways. The startup dyke was built with blocks and boulders obtained at the company. The draining mat was deployed with the same pieces used in access and dyke for the Jatobá stream. Such equipment was essential for achieving stability of the stack of ore to be sorted.

Once a bench was formed, vegetation restoration was performed. In it, the material for cleaning the area was used (it had been saved) and the seeding of leguminous was performed, including calopo, sun hemp, perennial soy beans and Andu beans, which developed very well by lining the entire surface.

The goal of capturing rainwater consistently also demanded a large resloping operation in the two quarries, the reversal of all the drainage of the yard of the factory, and revegetation of the areas at work (see Photo 84). These procedures began as soon as the deposit base was ready. The sterile removed from F2 was stored at the deposit that was already prepared to receive it. For drainage, channels were built with used useless drums found in the industrial area. Ladders dissipating hydraulic energy – rainwater

[11] The calculation for the planning considered only the direct drainage, non-reabilitated area of the Jatobá basin.
[12] Technical details of these operations: mining – individual slopes with 5 m in height, with shoulders 4 m wide and an individual slope angle of 50 °C; sterile dump – banks that are 5 m high, 4m wide, berms that are 4 m wide and individual angle of 26 °C, with a total projected height of 25 m (general angle: approx. 20 °C); sterile/ore ratio: 0.18; it is therefore a low ratio, which tends to zero at the end of the recovery of these quarries.
[13] Deforestation requiring licenses issued by the IEF had already been performed before the mine was opened by Comig. Sical was fully responsible for conserving existing natural vegetation in the outskirts of the project, and it has a fire prevention brigade to avoid damage by fires, which are very commonplace in these areas during the dry season.
[14] The startup dyke is a device consisting of a heavy riprap at the base of the stack of sterile allowing its anchorage and better control of internal drainage. The mattress (or mat) is the second draining device, mounted with bricks and stones over the natural terrain, upstream of the dam start. Serves to improve drainage conditions and acts as a horizontal filter.

descending from one bench to the next – were made according to the usual technical engineering procedures [15] , but by using alternative materials available – larger pieces that were selected and then reused.

Photo 84. F2 after resloping for installation of a rainwater drainage system, followed by revegetation

For revegetation, [16] which is always implemented before the rainy season, the same variety planted in the deposit was used, plus seedlings of native species that would follow the forage cover, thus forming the permanent vegetation. Use of pioneer species succeeded by use of secondary species is arguably the most efficient method to restore degraded areas. For this, a nursery covering 100 m2 was established, covered by shade at 50%, furnished with a conduit for sprinkler irrigation. In it, seeds are scattered, plots with bagged seedlings selected by species are formed. The seeds were collected in the vicinity of the mine and from PESRM. The seedlings were produced during the dry season for planting before summer.

The mining work continued in F1. The digging of the basin to receive rainwater proceeded. The amount of water received was induced to infiltrate from the deeper side of the mountain range, where the dip of layers facing the PESRM and shown in Photo 85 made it easier for the aquifer to be recharged, and where water is most needed since this is where the sources of catchment are.

Photo 85. Sump and settling tank for rainwater, including sediments retained

[15] These procedures relate to the contribution area of the basin, the rainfall rate, the rain recurrence season, the coefficient of groundwater flow, among others. All this was designed so that drainage structures could be scaled.

[16] For the revegetation of mined areas, grasses such as Brachiaria and molasses grass – exotic species to our flora – are commonly used. Such use, however, was not recommended in the case of Sical's project, considering that this is an intervention in a listed property, where the original vegetation should be maintained.

[17] Shading is a screen placed on wooden structures to protect plants from direct incidence of light and heat from the sun.

Draining of the factory yard, until then channeled toward the Park, had to be rolled back to the basin formed in F1 in order to prevent solids, oils, grease, and other wastes from being carried into streams in this protected area. To this end, it was necessary to adjust the slope of the factory floor so that the rainwater could be conducted along a large channel that segmented the yard and received the water coming from both sides. Thus, the erosions that had previously formed on the slope of the factory due to improperly caught and misguided rainwater began to stabilize.

In order to optimize rainwater drainage with a view to increasing the potential for aquifer recharge and erosion control, reinforced fences were installed within the erosion grooves described earlier; these fences were fixed to immunized eucalyptus posts, which formed physical obstacles to water. Upstream of these fences were placed layers of blocks in various sizes between 1 and 2 m in height, which, besides allowing the infiltration of water, retained the solids, thus controlling the carrying of sediments to the river drainage – and also filled the grooves, thereby eliminating the sources of erosion. At each step formed by solid matter, new wire fence was put in place, upstream of the silted up area – from the lower levels to the top –, making it possible to control those erosions that could threaten stability of the land on which sat the plant. This type of treatment required ongoing monitoring, because of the need for continuous checking of the stability of structures deployed. At any sign of rupture, the contentions were immediately repaired.

For Sical Industrial' activities, the issue of effluents had no major problems because all of the water in the industrial process was recirculated. In this case, the only hindrance observed had to do with those effluents from the plant's boiler, which came out at temperatures higher than room temperature and, thus, were thrown into the natural terrain, which is not recommended or permitted by law. To overcome this situation, a cold box was set up through which the waste could be conducted before its release in the natural terrain. Moreover, the speed of effluent outflow was reduced to prevent new outbreaks of erosion.

As stated by the National Mineral Production Department (DNPM), for the mine to be decommissioned, one must prepare a study of future use of the area, which also includes landscape rehabilitation.

It is worth mentioning that if the recovery takes place concurrently with mining operations – as proposed in Sical –, by the end of the mining activities the area will be ready to be reused, requiring only adjustments to those areas still in operation at the time of deactivation. In this context, pits and deposits will be stabilized, with vegetation composed of species of local flora, i.e., the natural environment will have been restored. As for the industrial and administrative divisions, these should be adjusted to the new use.

The alternatives selected for future use took into account the location of the operations: tucked into the mountains, next to a protected area and natural non urbanized lands. Given this situation, the following destinations are considered to be compatible: establishment of a private ecological park or country hotel; centers for the elderly; hospital for patients with respiratory and lung problems.

It is also important to report here that when we started resloping from the high end of F1, something unusual happened. For the resloping process, remains of pruning of flower beds and gardens by the local government in the avenues and squares of

Belo Horizonte were used. This procedure provided a surprising result: unpredictable pioneer species came up, such as squash, bush, gourd, watermelon, tomato, castor, and at such speed that it was possible to follow its flowering and fruiting. Amid this pioneer vegetation were planted seedlings of native plants that would follow these rapid-growth, short-lived plants.

The appearance of these plants, complemented by the cultivation of Andu beans – whose production was so plentiful that harvest produced countless bags of grains – shows that simple and costless actions can translate into multiple, even unsuspected, benefits.[18]

Photo 86. A sight of the mine's units in 2002, with stable structures and restored vegetal cover

Finally, it should be noted that, for all those efforts to achieve success, as shown in Photo 86, regular visits paid by experts from the Belo Horizonte Municipal Secretariat for the Environment greatly contributed to this. These inspectors would monitor the activities, provide useful and relevant feedback, and strengthen the work of the management team on the environmental control and rehabilitation work of Sical's project, who felt encouraged on an ongoing basis.

As for the visits of students and teachers from schools located in the periphery of the project, they became frequent and eventually encouraged and enhanced a new activity then started at the company: environmental education. The location of Sical provided a wide view of the city of Belo Horizonte and its surroundings. This made it possible to show the essential aspects of the environment in the region to visitors. They also became interested in the environmental rehabilitation efforts being made, which became part of the environmental education program offered at several schools by the company. To this end, investments were made in providing buses to people interested in visiting the project. Thus, visits were encouraged, which were guided by experts throughout all operations. By the end of a visit, there was a get-together snack for exchange of information and more clarifications. The notion of social responsibility of the business facilitated these pedagogical actions that – one should bear in mind – virtually did not in exist at the time, at least in Belo Horizonte.

This educational effort was extended to the employees. In this case, selective collection and proper disposal of solid wastes, oils and greases were also focused. In sectoral meetings held during working hours, the rehabilitation action undertaken was explained to all; a presentation was

[18] In this case, a mining-industrial project incorporated sources of agricultural production to the delight of staff, who during lunchtime and at the end of the work day would gather fruits and grains to take home.

made on how each segment in the production process should contribute to the environmental balance goal.

This activity involving the employees has significantly improved the modus operandi of the ongoing rehabilitation, thus avoiding conflicts between individual actions and turning employees into active partners in the environmental remediation work conducted by the company. It should also be mentioned that by learning about environmental control in practice, the employees would provide details about the problems discussed, the perceived flaws in their divisions, and they would even point out their causes, and they would sometimes even suggest solutions. Hence, the Environmental Control Plan eventually became a sort of shared management mechanism, although that term was never pronounced at the company.

5 FINAL REMARKS

Throughout this account, it was clearly stated that the mining business can be operated so as to prevent and minimize a great deal of its environmental impacts, and it can be pursued without disturbing the neighboring area with extrapolations of their legal domains.

When it was demonstrated that all problems encountered in Sical's venture were due to errors made when the mine was opened, i.e., errors made by another company, the intention was to show a basic concept that should govern the mining business: it must be developed strictly according to established scientific and technical principles in areas of expertise that are devoted to issues concerning the mining industry, including engineering.

Considering also that this is an activity often performed in the wild, and that this environment needs to be respected and preserved, one can see how ecology is to contribute, mainly because it provides an overview of the physical, biotic and anthropogenic environments as interconnected realities.

As explained here, when intervening on a ridge of mountains or on the alluvial plain of a water body, an array of degradation processes is triggered that affects the components of the environment either directly or indirectly. For example, removal of vegetation cover exposes the soil, makes it susceptible to erosion which, in turn, causes siltation of water bodies and harms those who use its water downstream. At the same time, this removal supports rainwater runoff. As a result, there is no recharge of an aquifer and there is an increase in river flows that gives rise to other indirect problems, such as reduced flow of springs and floods.

In short, when concerns focus on the management of water resources, one must be fully aware of the interdependence of all environmental factors – physical, biotic and anthropogenic – and the need to take into consideration all aspects that contribute to the conservation of these resources.

If such issues are taken into account, it can be concluded that solutions exist to mitigate the negative effects caused by mineral extraction, but, for such an outcome, a decision must be made to find, implement and carry out proper procedures according to the specific situation involved.

From a more general point of view, this means that the development work for any mining activity must be supported by in-depth geological and geotechnical studies. Based on these, it is appropriate to adopt practices that will promote the following: progressive intervention and only over areas strictly necessary for the activity; adequate surface drainage; protection of stripped-out areas by introducing protective vegetation; recovery in parallel with mineral/sterile extraction until the pit becomes depleted, i.e., until it is time to decommission the mine.

The case of Sical was more demanding since its mine and industrial plant were located in an area with a direct influence on sources of catchment for public supply; this area is listed by the city's Artistic, Cultural and Natural Heritage; it is an environmentally protected area, a buffer zone for a restricted-use protected area; and it involves significant environmental liabilities. Apart from these tasks of a more general nature, the project had to conform to this state-of-affairs by changing the mining plan, reverting the rain drainage system to prevent the deterioration of public good – the PESRM –, and adapting vegetation to the usage situation of native species of the local flora.

Furthermore, the level of financial investment made by the company for environmental rehabilitation required the identification of low-cost alternatives for the implementation of the necessary works. The solutions – described earlier in this section – show that any mining company, whether big, medium or small, is fully capable of conducting prevention and rehabilitation of degraded areas, simply by making the decision to carry these out properly. But that decision cannot be restricted to the timeframe of the actual mining extraction. It also needs to bear in mind the future use to be assumed by the company by the end of a mine's life and operational management directed towards this specific goal.

By looking at the legislation applicable to this project, it was clear that the obligations imposed by environmental licensing represented an important factor triggering the whole process of environmental rehabilitation and reversal of the impacts on water resources. The guidelines specified in the licensing process instilled in the professionals in charge of the project an awareness of the need to implement the recommended procedures. Monitoring of the works by the relevant government agency (an additional legal requirement) also helped the works run smoothly.

One should not forget, however, that due implementation of technical procedures and compliance with the legislation are not enough when an Environmental Rehabilitation Plan is pushed through. For it to be successful, measures to promote integrated management of the whole process are critical so that all those involved in it – the board, operational management, technical team, and blue-collar workers – feel really aware of their share of responsibility for the required result: the development of a mineral extraction activity that takes into account good environmental quality that is beneficial to everyone.

In the case in point here, it was found that even the participation of the community – present in this project through visits of students and teachers – was meaningful for an enhanced understanding of the importance of the work being conducted in that, by allowing the extension of the activities to the scope of an environmental education program for schools in need of similar practices, it has raised the profile of its social relevance. The other educational activities that came into existence in the company also greatly contributed to this effect, in addition to being an incentive for employees to develop a closer relationship with their work, which came to be actively shared by many of them.

By adopting work methods that are specific to the reality on-site – which is similar to that of many Brazilian mining companies –, this case study helps show that the only way for mining activities is that its entrepreneurs assume an attitude that leads to the implementation of environmental control measures. The mining industry cannot go on making interventions that compromise diffuse rights: preserved water resources, integrity of the landscape, good air quality. Society has already been mobilized to this effect, and the government requires the fulfillment of those obligations that are established in laws. In addition, many entrepreneurs are now aware of this need, not only because non-compliance with the legislation entails hefty fines, but also because social and environmental responsibility management has become increasingly popular in the mining industry. Thus, there is no doubt that it is best to use financial resources in actions to prevent impacts on the environment, or in rehabilitation actions, in case they have already occurred, than to spend them in the payment of fines. As seen in this study, environmental degradation causes another monetary loss: the ore, when it is carried by rainwater.

Therefore, mining companies must take these issues into consideration when discussing technical proposals for the environmental rehabilitation of their projects in order not to be reluctant to implement them on the grounds that they are expensive.

With regard to those who oppose or have strict restrictions on the mining business, they need to understand that civilization is built on equipment whose raw material is the ore. Before placing a ban on the mining business, it would first be necessary to find realistic alternatives to the construction of such equipment. Before these alternatives are available, one must fight for mining projects that are committed to the implementation of environmental control measures that are capable of preventing or mitigating the impacts of mining activities on the environment. The case of Sical discussed here shows that this struggle can be successful.

IBRAM AND INTEGRATED WATER RESOURCE AND MINING MANAGEMENT

CHAPTER 6

José Mendo Mizael de Souza[1]

6.1 INTRODUCTION

The emergence of a global concern over water is, without any doubt, one of the most important and interesting attitudes of humanity in recent times.

One must always bear in mind that as the world's population grows exponentially, and considering its behavior, this vital mineral resource has become – including in Brazil –, a matter of truly genuine concern, which, to be staved off, require from us all proper management, i.e. planning, implementation and ongoing review of the results of our action, all of this with a view to having water in adequate quantity and quality and using it effectively.

This requires and will continue to require drastic changes in behavior and habits for the benefit not only of our survival, but also that of future generations, failing which we would seriously risk making matters even worse at global and even local level, which is already worrying and, in some places, dramatic.

A comparison made by an American expert is a warning for all of us, Brazilians, to the changes we need to see through.

He said: "It is interesting how you Brazilians and we Americans, in our respective countries, have a different view of rivers and watercourses: we build our houses facing the river (as if it were the garden of the house) and you have the river at the back of the backyard (generally a dumpsite)." Do you agree with this point of view? Do you think it is a realistic one?

Moreover, if we look at the state in which most of our rivers and watercourses are in, it appears that this expert does have a point...

In order to contribute to bringing about a new behavior for us all, both in the mining community and all other stakeholders – obviously, with the involvement and important inputs of the latter – IBRAM, founded in 1976, focuses on sustainable development as defined by the Rio 1992 conference, "to ensure that it (development) meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCDE, 1992).

In fulfilling its mission, IBRAM believes it is an effective instrument for environmental education to produce and publish relevant literature – updating,

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trend-setting and dissemination of best practices literature –, obviously in conjunction with participatory and field activities.

As regards our theme, IBRAM drafted, with the collaboration of experts and technical staff from its partners with substantial relevant experience, texts that we consider to be appropriate to reproduce here since the publications where they originally appeared are now out of print.

In our view, they will effectively help disseminate the basic concepts for the paramount issue of water resources and the very sustainability of the mining business so that society can have a better glimpse of the complexity and challenges of contemporary life and what can be done to overcome them successfully.

6.2 IBRAM

Founded on December 10th, 1976, the Brazilian Mining Association (IBRAM) is a private, nonprofit organization with the primary objective of bringing together, representing, promoting, and publicizing Brazil's mineral industry.

IBRAM's philosophy is to contribute to promote and expand Brazil's mining industry so that it is internationally competitive and technologically up-to-date, and that, cognizant of its social responsibility, provides their workers the most appropriate health and safety conditions so that they can perform their jobs with maximum environmental quality," and IBRAM's mission is "to act in the best interest of Brazil's mineral industry development."

In compliance with its charter and mission, IBRAM not only collaborates with the government – the Executive, Legislative and Judiciary branches, and the federal, state and local governments –, but it also supports studies, contributes to the development of the workforce in the mining industry, and disseminates the best environmental and safety and health occupational practices related to mining in Brazil.

IBRAM's members include the most prominent mining companies in the Country. Other members include organizations and entities that are either directly or indirectly involved in the Brazilian mineral industry, such as mineral and environmental engineering firms, geology firms, equipment manufacturers, technology centers, development banks, etc.

In performing its role, IBRAM strives to provide society with information and data that enable it to better understand the crucial importance of minerals to the quality of human life, all with a view to promoting mining business practices that are technically savvy and socially committed, and that will offer the Country the best of its contribution to socioeconomic development while respecting the environment. As a result of this socio-political view, IBRAM continuously monitors the work performed by the National Congress in all matters of interest to the mineral sector.

To accomplish its goals, IBRAM relies on key capabilities, in particular its Technical Committees, which consist of professionals appointed by its members. These Committees approach problems commonly facing businesses by promoting dialogue and research that help not only to disseminate the best technology available, but also to draft proposed solutions, which are incorporated into documents that are distributed to all members and submitted to government authorities where appropriate.

IBRAM's Technical Committees are as follows:

- Technical Committee on Legal, Legislative and Tax Affairs (TJLT);
- Technical Committee on Communications and Social Responsibility (CTCRS);

- Technical Committee on Sustainable Development (CTDES).

With the collaboration of directly interested members, IBRAM also has the following Special Programs:

- The Importance of Mining for Brazil's Sustainable Development;
- IBRAM AMAZÔNIA;
- Environmental Protection Area for Southern Belo Horizonte Metropolitan Region (RMBH);
- IBRAM – Committee for International Mining Standardization (Conim);
- Sustainable Development;
- Ex-Tarifários (reduction in import taxes);
- IBRAM Goiás;
- Water Resources.

The Committee on International Mining Standardization (IBRAM-Conim) was established in September 1994 with the mission of "facilitating effective participation of the Mining Industry in international standardization according to its interest and for the benefit of its development". Its philosophy is "to help the mining industry to take an active role in the development of international technical and systemic standards that have an impact on the survival and expansion of mining activity". The Committee acts in full compliance with the Brazilian Association for Technical Standards (ABNT).

Because information is one of the most important items for effective business management, IBRAM pays particular attention to this and strives to keep their members well informed.

In view of its statutory objective to "collaborate with public authorities in the study of all matters related to mining," IBRAM maintains an ongoing relationship with the federal, state and local governments, and it also a member in specific boards and bodies of the government by invitation.

Once every two years, the Brazilian Mining Conference, the Brazilian Mining Exhibition (EXPOSIbram), the Brazilian Open-Pit Mining Conference, and the Brazilian Underground Mining Conference are held. These major events include seminars and short and long training programs, and they have been used by IBRAM to foster the exchange of experiences and to update its members and other stakeholders in the mining industry in the Country.

Internationally, IBRAM has relationships with several international agencies and organizations; it is a member of the International Council on Mining and Metals (ICMM), based in London, England, and of the Inter-American Mining Society (SIM), based in Peru, representing Brazil's mineral industry in both cases. Nationally, IBRAM has relationships with significant sector organizations (many of which are also members IBRAM), State Industrial Federations and the National Confederation of Industry (CNI), among others, as well as the National Confederation of Workers in the Mining Sector (CNTSM), which is affiliated to the Unified Workers' Central (CUT).

6.3 IBRAM'S SPECIAL PROGRAM FOR WATER RESOURCES

IBRAM's Special Program for Water Resources is the industry's official stance on the Brazilian water resources management model, as provided for under Law 9,433, of January 8, 1997. IBRAM's view is that this model is a tool for promoting a true revolution in the public administration and environmental management arenas, this revolution being translated into the proposition of a new administrative framework for the management of water resources, based on the strengthening of relations between the government and the civil society, in particular the community of water users.

The Special Program for Water Resources was created in August 2000, and it purpose is to experience and develop scenarios that are conducive to the development of mechanisms for the participation of water users and water beneficiaries, especially users in the mining sector, aiming to ensure honest and competent participation in the decision-making process in water resource management, and to strengthen a management strategy on the conservation of water resources, from the perspective of the interaction of its natural cycle with the social and technological cycle, therefore according to the principle established in Dublin, i.e., an "integrating approach".

The Program has been around for five years and below is a summary of the Program's activities over this period:

a) monitoring the proposed regulatory frameworks resulting from implementation of the National Water Resources Management System.
b) organization of seminars, workshops, study groups, talks, and round tables with a view fine-tuning and creating mechanisms for broadened participation of society in the decision-making process in the management of water resources for the strengthening of federal and state water resources laws, especially as regards the basic principles of management: decentralization and participation.
c) collection, analysis and dissemination of experiences and international trends concerning water resources management system that are comparable to the national management of water resources and more akin to use in the mineral sector.
d) support and involvement in the negotiation process arising from the establishment and implementation of the water resources management system, with consolidation of IBRAM's participation in the various river basin committees already established.
e) monitoring of national and international trends concerning the definition of an economic valuation of water, considering all the particulars of the mining sector.

The following are the three main outputs derived from its activities: enactment of Resolution 29, of December 11, 2002; the National Water Resources Council (CNRH), which is the culmination of an initiative by IBRAM with support from the National Mineral Production Department (DNPM), which covers regulations on the granting of the right to use water for mining activities; publication of the book "Modelo de gestão de recursos hídricos: a posição do setor mineral na visão do Ibram" (Model for water resources management: the stance of the mineral sector from IBRAM's perspective), which was released on World Water Day in 2002 and whose excerpts are quoted here; and release of this book under a partnership with the National Water Agency (ANA), thus strengthening IBRAM's ultimate goal – responsible mining on a permanent basis for Brazil.

Also noteworthy is IBRAM's membership in the National Water Resources Council (CNRH) as (alternate) Director for the Mining-Metallurgical Representation; in the Minas Gerais State Water Resources Council and in the Pará State Water and Mineral Policy Council; in the National Confederation of Industry's Thematic Environmental Council and in the National Water Resources Council (CNRH); and in various river basin committees.

Certain of the right decision, we have chosen to follow up on our activities under IBRAM's Special

Program for Water Resources with a view to strengthening the National Water Resources Management System, as we believe and reiterate that:

a) few industries assimilated the new order of values so well, based on the premise of environmentally and socially responsible development, and so quickly and efficiently, as the mining industry, especially those companies in the private sector with a certain degree of independence in terms of resources and incentives for the development of new technologies. Billions of dollars have been invested in major projects for compliance with environmental sustainability concepts. Today, this is extended to the concept of corporate citizenship in these companies, i.e., recognition that their role is not limited to profit maximization, but where their managers should also take into account the social, environmental and ethical aspects of their business. One should bear in mind that this is an key requirement in a global market;
b) no other environmental regulation has assimilated the new ethic that emerged in this new century so well – where values are constructed by an increasingly participatory society – than the National Water Resources Policy Law, known as the Lei das Águas (Water Act), i.e., Law 9,433, of 1997, supplemented by Law 9,984, of July 17, 2000, which established the National Water Agency (ANA).

Brazil's mining industry, through IBRAM, an organization that represents its interests and acts as its voice and forum, strives on an ongoing basis to provide a tangible contribution to the improvement of a truly free and sovereign society.

It should be stressed that water use in mining operations has specific features that must be understood at a global level, and when considering the water balance in the mining industry, the small amount of appropriate water resources in each river basin becomes apparent. It is worth pointing out that the mining industry has been reusing water for decades now by continuously recycling it during the processing stage at concentration plants and tailings dams, which should be taken into consideration when enforcing mechanisms related to the granting of water use rights and charging for water use.

Similarly, groundwater level lowering in mines should be understood today as an intrinsic procedure to mineral extraction processes. This procedure translates into additional challenges to the mining industry and could bring about an extraordinary fact – an increase in the availability of a prime product, namely, premium quality water. If managed properly, this underground water that is pumped out of the mine to lower water levels in the pits can be used as an input during the processing stage at the concentration plant and it can be released into downstream drainages. In both cases, an increase in water supply to the mining project's surrounding area occurs. In the case of water being released into water courses, the most immediate benefit for nature will be improved quality standards for such bodies of water and, as a result, a significant increase in the capacity to dilute effluents.

Thus, such elements – provided that they are properly managed – can have multiple applications, or they could well become, as illustrated by the case of well established practices in countries with a significant mining tradition, reservoirs to supply drinking water to the neighboring communities, or leisure and tourism sites, or both. The master plans for river basins should consider and define the use of these elements for the benefit of future generations.

However, IBRAM appreciates and promotes all aspects and the responsibility involved in what is now commonly called closure or decommissioning of a mine, and is now discussing and developing the technical and managerial means not to leave a legacy to society, our partner, other than new socially appropriate uses for the former mining area.

Therefore, under this new approach to water resources management, IBRAM argues that the particularities of water management in the mining industry are looked at from a global perspective, considering its actual interference with the regional water balances, both today and in the future, and free from emotional attachment or bias, which could deteriorate coexistence with the communities around the mining area without bringing about the real benefits and the potential rational and integrated use of water resources, environment, society and mining, which is certainly beneficial to all parties involved.

We believe that implementation of the National Water Resources System, as per Federal Law no. 9,433, of 1997, based on participation and decentralized management, is beneficial for society in its search for balance and harmony, progress and life, with justice and freedom; this System is an effective instrument for the development of a new ethic that is associated to the challenge of achieving balance.

6.4 FINAL REMARKS

Contemporary man has a strong focus on his responsibility for the future of the planet and for the decent survival of future generations. So, man is currently challenging the traditional notion of developing at any cost, and his ideal goal is now considered to be the development that can be sustainable. The 1987 Report by the Brundtland Commission, Our Common Future, defines sustainable development as the approach to progress that "meets the needs of the present without compromising the ability of future generations to meet their own needs." It follows from this concept that this option involves ensuring that the next generation inherits a stock of wealth at least not less than that inherited by the previous generation, both in terms of the man-made and the natural heritage.

In this state-of-affairs, at first the mining industry could come to be perceived as an unsustainable business. And so the notion that mineral resources are being depleted is quite widespread. One could conclude from this that the end of resources is near, and that the future is supposed to be "sold" to meet some immediate needs of the present.

It is obvious that the earth's resources are indeed finite, but two important remarks must be made. First, the portion of the earth's crust that is known and has been explored is still very small, which suggests that the limits of mineral resource supplies are actually far from being reached. Secondly, as science and technology evolve, the extraction and processing of the mineral reserves available are becoming more efficient, maximizing them and making them more profitable, and thus extending the duration of a mine's operation. In view of this, one could ask what is the actual meaning of "sustainability" when it comes to mineral resources. The answer can be found in the interplay of three factors: geological knowledge, technology and economy.

From the standpoint of geological knowledge and technology, it is assumed that "nothing is a resource until someone figures out a way of using it for economic purposes." This fact is often overlooked when discussing the issue of finite resources. In this sense, human inventiveness literally "creates" resources, and countless examples of this are found in the past and present, and this will certainly be the case in the future. From many perspectives, the development and use of new technologies "extend" the use of our mineral resources and their exploitation in a sustainable manner. Below is some evidence of this:

- the development of pelletizing technology and the use of new furnaces in the steel industry have made it possible to greatly expand usable iron ore reserves by putting tailings to good use that would otherwise be wasted;
- the improvement of mineral processing technology makes it possible to work with low-content ores that were previously considered unfeasible. Today, for example, it is possible to process ores with gold contents around 0.6 g/t;
- today's increased scale of mining is possible thanks to large machinery and equipment, which make it possible to exploit mines that were previously unfeasible;
- with regard to the processing industry, an effort has been made over the past few years in order to produce manufactured goods with smaller quantities of raw materials, thus extending the availability of mineral resources. This is the case of aluminum cans, which are now 20% lighter than those produced in the 1970s; and cars, which currently use 30% less steel than they did thirty years ago;
- in the near future, the development of new materials such as ceramics and superconductors will provide a significant reduction in the consumption of metals such as iron, aluminum and copper in a number of prime applications.

Thus, one can set out to achieve "sustainability" by combining the effects of mineral exploration and technological development so that resources are created continuously at a rate at least as fast as that of consumption. There is no doubt that this has been happening in a competent and satisfactory manner in the mineral industry. Breakthroughs in geological knowledge and technology are, in turn, driven by the economy.

Thus, given the combination of these three factors – geological knowledge, technology and the economy –, there are more resources available for the welfare of humanity at present than in the past (economically demonstrated resources for most minerals have increased much more rapidly in the last forty years than the corresponding rate of global use). In other words, one must take into consideration the fundamental fact that today more non-renewable resources are available than they were for the previous generation when discussing the principle of equity between different generations, which underlies the concept of sustainable development.

From a different perspective, the concept of sustainable development is a requirement for the mining industry when its implementation involves a choice between development of a mine and preservation. In this case, the general tendency is to give preservation a greater weight. However, the balance point should be closely related to the use of best practical technology available to reduce and control the generation of effluents, which are likely to be found in all human endeavors. Even in cases where the best available technology is used, but still, pollution remains significant, it is imperative and indispensable that this situation be immediately clearly presented to society for it to always opt to strike a balance based on an analysis of actual costs and benefits.

An additional – and also fundamental – aspect to be considered for the sustainable use of earth's resources is wastage. In the mining industry, this takes on the most varied forms, such as an inefficient ore processing procedure; the mining operation focusing entirely on high grade ore and leaving aside the low content matter that could only be economically exploited together; or tailings disposal conducted without an assessment of the potential for its reuse in the future.

Wastage has a number of causes, ranging from managerial unpreparedness and lack of technical knowledge on the part of the mining companies to government interference through taxes, subsidies or regulations that result in inappropriate environmental practices.

It is worth remembering moreover that Chapter 18 of Agenda 21, "Protection of the Quality and Supply of Freshwater Resources: Application of Integrated Approaches to the Development, Management & Use of Water Resources," as we know, has the following introduction (only the first three items are quoted here):

> [...]
>
> 1. Freshwater resources are an essential component of the Earth's hydrosphere and an indispensable part of all terrestrial ecosystems. The freshwater environment is characterized by the hydrological cycle, including floods and droughts, which in some regions have become more extreme and dramatic in their consequences. Global climate change and atmospheric pollution could also have an impact on freshwater resources and their availability and, through sea-level rise, threaten low-lying coastal areas and small island ecosystems.
>
> 2. Water is needed in all aspects of life. The general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases. Innovative technologies, including the improvement of indigenous technologies, are needed to fully utilize limited water resources and to safeguard those resources against pollution.
>
> 3. The widespread scarcity, gradual destruction and aggravated pollution of freshwater resources in many world regions, along with the progressive encroachment of incompatible activities, demand integrated water resources planning and management. Such integration must cover all types of interrelated freshwater bodies, including both surface water and groundwater, and duly consider water quantity and quality aspects. The multisectoral nature of water resources development in the context of socio-economic development must be recognized, as well as the multi-interest utilization of water resources for water supply and sanitation, agriculture, industry, urban development, hydropower generation, inland fisheries, transportation, recreation, low and flat lands management and other activities. Rational water utilization schemes for the development of surface and underground water-supply sources and other potential sources have to be supported by concurrent water conservation and wastage minimization measures. Priority, however, must be accorded to flood prevention and control measures, as well as sedimentation control, where required."
>
> [...]

In spite of Agenda 21, we know we have a long and arduous way to go in order to achieve a new level of maturity as a truly organized society. We believe that the water resources legislation gives us the tools to facilitate this new path, paving the difficult path of negotiation, balance and understanding across such different segments in society. We are standing not for privileges, but for rights.

The mining industry puts itself forward as a partner on this road, and tries to show that despite being misperceived as the great villain in the environmental arena, and especially when it comes to water resources management, it is an essential economic activity to the Country and to humanity. All of our cultural manifestations are expressions that have mining as one of their building blocks. For example, cultural manifestations include magnificent sculptures in marble, bronze and steel; in poetic manifestations, various parts of musical instruments include minerals; in religious manifestations, the beautiful monuments and cathedrals are a case in point; and it is also found in technology – the ultimate representation of modern age –, which results in the creation of instruments for the comfort and extension of our lives. So, repudiating or banning the mining business means, therefore, repudiating or banning the History of mankind on this planet altogether. A rational production, however, with effective management of the environmental variables associated with the use of advanced technologies and the relentless pursuit – with investment in new research – for an increasingly rational use of mineral resources, including recycling of products, is currently an inherently critical matter of survival for the mining business. Likewise, it is vital that water resources are used rationally as they are a basic input in mining operations.

We cannot emphasize enough that "In fact, the world today seems to beckon with an ideological movement, which seeks to feature man with no right or left inclinations; a man with two arms and one heart, one head, trying to act towards earthly happiness harmony" (BOSON, 1990).


Photo: Ecotrópica

THE NATIONAL WATER AGENCY'S INSTITUTIONAL MANDATE AND THE MINING INDUSTRY

CHAPTER 7

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7.1 INTRODUCTION

The purpose of this chapter is to present the mission of the National Water Agency (ANA) and outline the interrelationship between its jurisdiction and activities in the mining sector based on potential changes to the water body system, and water quantity and quality from the industry's production approach.

It is also the purpose of this chapter to provide up-to-date information to the Brazilian society on this arrangement, with a focus on ensuring multiple water uses, especially for human supply and the watering of animals, given the strategic and utility-related importance of the mining sector for the Country.

7.2 WATER MANAGEMENT AND THE ESTABLISHMENT OF ANA

ANA is responsible for implementing the National Water Resources Policy (PNRH), and it is a special self-governing agency with administrative and financial autonomy. ANA was established on July 17, 2000 in accordance with Law no. 9,984, and became operational on December 19, 2000, pursuant to Decree No. 3,692, 2000. It is attached to the Ministry of the Environment[3] and is a member of the National Water Resources Management System (SINGREH) provided for in the 1988 Constitution and established as the National Water Resources Policy (PHRH) in accordance with Law 9,433, of January 8, 1997, i.e., the so-called Water Law.

The establishment of public regulatory agencies is part of the restructuring of the Brazilian State; it is based on a facilitating and regulatory model, and intends to break the grip of State monopoly, marking the partial withdrawal of the State from the economy so that its interference is maintained only through regulatory agencies.

In the case of ANA, an important difference in its mandate compared with other agencies designed under this new State structure is noteworthy. While other agencies are also established as special self-governing agencies with administrative and financial autonomy, and work on the regulation of the use of public goods and related services – for example, ANEEL[4] –, ANA's mission is solely to regulate the use of "water" as a public good, in particular providing

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[3] ANA's Management Report, 2003.
[4] Under Article 2 of Law No. 9,427/96, the National Energy Agency's mandate is to "regulate and supervise the production, transmission, distribution and sale of electricity in accordance with the Federal Government's policies and guidelines and its Article 3 (including subsequent amendments to Law No. 9,427/96) which provides, inter alia, for their jurisdiction in relation to the provision of services.

for its multiple uses, which until a few decades ago was considered to be an infinite, easily available "free resource from nature," even when considering those regions where it is scarce and increasing pollution.

As far as the implementation of the National Water Resources Management System is concerned, it is up to ANA to regulate the use of river waters controlled by the Federal Government in order to maximize the allocation of this water for the development of the Country while supporting water sustainability through PNRH's mechanisms and pursuing the change of the current water picture of water pollution and wastage, so as to ensure availability of good quality water for human consumption across generations, as well as the multiple use of water resources.

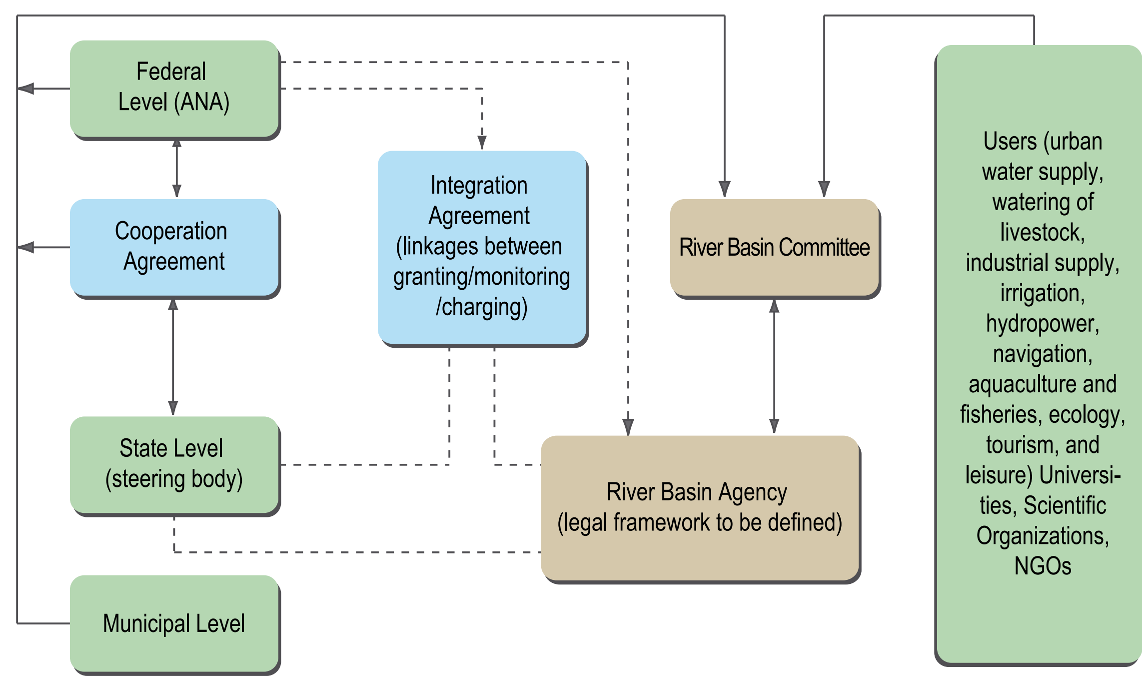
Decentralized and participatory water resources management is at the heart of the Water Act. This could not be otherwise, considering that what is at stake is a natural resource that is essential to support life on Earth and that is irreplaceable and therefore must be maintained. That is the question: we are not mere users of a resource that is simply "renewable"; much more than that – we are all especially responsible for its conservation as a shared good, [5] whatever the use, however noble it is.

According to GRANZIERA (2001), in the Water Act decentralized management has a sense other than the one provided for under administrative law. That the author mentions that [...] the concept of decentralization in construing Law No. 9,433, of 1997, can be considered from two different perspectives. First, from the perspective of society's participation, as a feature of contemporary public administration in the decision-making process [...]. Hence, decentralization would mean democratization of administrative decisions [...]. The second approach to decentralization lies in the management, which builds on the concept of a river basin. Within Committees, some decisions are made that will be the basis for the administrative acts under the jurisdiction of the Government.

MACHADO (2003) argues that "the introduction of participatory management of water as a public good is an innovation, because the Government will not have the majority of votes within River Basin Committees. In order not to nullify participatory management or make it ineffective, social control must find the means for continuous and organized information." Adds GRANZIERA (2001): "The fact that users and the civil society, and also municipalities, participate in Committees is the only condition capable of securing the commitment of each stakeholder in the process (development and operation of the Water Resources Management System, which is construed as the sequence of events and actions that evolve over time). Failing this, the law cannot be effective".

Figure 73 illustrates the interaction of several institutions that take part in the river basin management process.

[5] Article 225 of the Federal Constitution. Everyone is entitled to an ecologically balanced environment, as well as the common use that is essential to a healthy quality of life, necessitating the government and the community to uphold it and preserve it for present and future generations.



Source: Adapted from ANA's Management Report, 2003

Figure 73. River basin management workflow

The mining business, whatever the segment or objective considered, even when its most typical feature is considered, i.e., locational constraint, always develops within a river basin, which is the territorial unit for implementation of both PNRH and SINGREH, one of the foundations of Law No. 9,433, of 1997. Therefore, it is always subject to water-related regulations, whether surface or underground water is involved, as far as use of water resources concerning the operation underway and its scope (federal or state).

A brief discussion on water domains follows. The water bodies under Federal jurisdiction are those lying on more than one state, border water bodies, as well as cross-border water bodies and those resulting from works undertaken by the Central Government. Established pursuant to Law No. 9,433, of 1997, the National Water Resources Policy applies to the entire Brazilian territory and its implementation is up to the ANA, as defined under Law No. 9,984, of 2000.

Machado (2003) clarifies that the public dominion of waters, as enshrined in Law No. 9,433, of 1997, does not convert the Federal, State and Federal District's Governments into owners of the water, but makes them managers of this good in view of the collective interest.

Those bodies of water that are bordered by only one state are under this state's domain, and they are governed by a specific law by that state, although they generally have backgrounds that are similar to that of the Water Act, even in order to support integrated water resources. It should also be pointed out that Section IV of Article 22 of the Federal Constitution provides that it is solely up to the Federal Government to legislate on waters in such a way that there should be no legal or managerial asymmetries between the Central Government and the individual states in this context.

With regard to groundwater, Section I of Article 26 of the Federal Constitution defines it as the property of states. Where the uses of the water in an aquifer shared by more than one state could give rise to disputes – which are all the more difficult to solve the greater the scarcity of surface water and the need to exploit aquifers –, the legislation providing for the National Water Resources Management System stipulates that the National Water Resources Council (CNRH) shall act as the arbitrator. In this case, ANA, considering its statutory mandate, acts as the public agent to provide the necessary technical support to assist the CNRH in its decision on the allocation of groundwater between the two states sharing it, with a view to resolving the dispute.

Anyway, the mining business will always be subordinated to the general guidelines for action and instruments enshrined under the Water Act and its state-level counterparts as it will be closely associated to the use of water resources.

Photo: ANA Archives

7.3 ANA'S ORGANIZATIONAL WORKFLOW

ANA is run by a Board of Directors comprised of five members appointed by the President of the Republic, upon approval by the Senate, with non-overlapping four-year terms. The Chief Executive Officer is chosen by the President of the Republic from among the Board Members appointed and invested in the office for four years or the remaining term of his mandate.

The Board decides based on a simple majority vote rule, and meetings are convened with the presence of at least three Board Members, among them the Chief Executive Officer or his legal alternate. All decisions related to ANA's mandate are made collectively. With regard to ANA's Bylaws and its amendments, as stipulated under Decree No. 3,692, of December 19, 2000, approvals may only take place with the presence of all Board Members and on an absolute majority of votes basis.

ANA's organizational structure is outlined in the following chart.

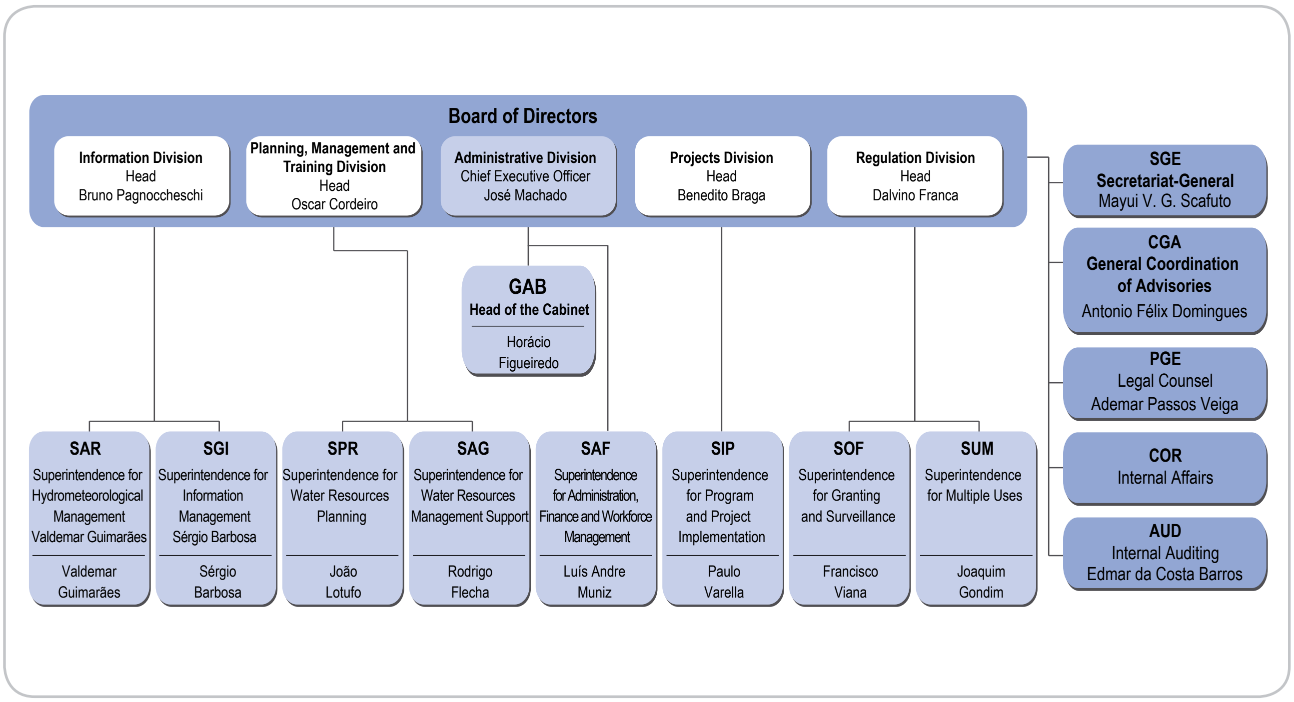


Figure 74. Organizational Workflow for the National Water Agency – ANA (06/2006)

ANA's Bylaws outline the nature and purpose of the Agency, as well as its mandate and organization, among other measures that include the common and specific powers and duties relating to its organizational structure. It was approved through Resolution No. 9, of 17 April, 2001, and amended by subsequent resolutions. Resolution No. 223, of 12 June, 2006, is currently in force, and it established the organizational structure shown in Figure 74.

Regarding institutional coordination arrangements, provided for in Decree No. 3,692, of 19 December, 2000, and in accordance with Law No.

10,881, of 9 June, 2004, ANA may sign a management agreement or a partnership agreement with river basin agencies for implementation of services relating to water agencies enshrined in Law No. 9,433, of 1997, with fund appropriations to these agencies for the performance of the agreements. Management agreements may be executed with river basin intermunicipal consortia and associations, which may receive delegation of authority from the National or State Water Resources Councils, for a definite term, to perform duties under the mandate of river basin agencies while these entities have not yet been set up.

ANA can also enter into technical cooperation agreements with public bodies or agencies at state level (including the Federal District) for cross-institutional coordination purposes with a view to managing water resources of common interest. These cooperation agreements shall seek the understanding between the parties on equivalent criteria for charging for the use of water resources in a particular river basin, regardless of the dominion of the water bodies that comprise it. It should be noted that this agreement will always be conditioned to the decision of the River Basin Committee regarding the appropriateness of the implementation of a "charging" mechanism and regarding the amounts to be charged.

7.4 REGULATING "WATER" AS A PUBLIC GOOD

AANA's regulatory mandate is based on PNRH's fundamentals, objectives, guidelines and instruments in order to ensure proper fulfillment of the needs and priorities for water resource use regarding bodies of water controlled by the Central Government, including through the definition of a minimum flow and maximum concentration of pollutants in the transition from bodies of water controlled by the state into those under federal jurisdiction.[6]

The autonomy and independence granted to regulatory agencies – since these are special self-governing agencies – are key for them to properly perform its duties, considering that the greater good at stake is the common good, and they cannot be subject to constant political instabilities (CARVALHO, 2002).

Noteworthy is the fact that the regulatory function is not repelled and that ANA has been established to assist in implementing a policy to be dictated by the National Water Resources Management System, since the regulation is limited to enacting orders of a primarily technical – and never political – nature, so it does not conflict with the principle of a legal reserve described under Section II of Article 5 of the Brazilian Constitution (MOREIRA NETO, 2000 apud MADEIRA, 2002).

Hence, in its legal mandate as a regulatory agency, ANA aims specifically at regulating (from the Portuguese verb 'regular') activities relating to the use of water resources, and this power, as explained by Mello (2000) and quoted by Heinen (2004), cannot be distorted so that it becomes a regulating (from the Portuguese verb 'regulamentar') power that would be comparable to that of the Legislative branch.

In this regard, vitally important is the semantic value of the Portuguese term 'regular' and the Portuguese term 'regulamentar', which are often neglected in the legal doctrine. The meaning of the Portuguese term 'regulação' is primarily related to technique and the economy, while 'regulamentação' has an eminently political conotation. In other words: one

[6] Articles 16 and 17 of Decree Nº 3692, of 2000.

must not take regulação, which is an economic concept, for regulamentação, which is a legal (political) concept (HEINEN, 2004).

In this context, ANA's mandate is described under Section II of Article 4 of Law No. 9,984, of 2000, which establishes that it is up to ANA to normatively control the implementation, operation, monitoring, and evaluation of instruments under the National Water Resources Policy.

The power to regulate has a very clear-cut legislative jurisdiction: the so-called normas legais em branco (blank legal norms)[7] (BRUNA, 2003 apud HEINEN, 2004). Along these lines, the regulations will play a clarifying role for the norm by adapting it to changing national circumstances, and it is governed by changes in social reality (HEINEN, 2004).

7.5 ANA'S MANDATE

The role of ANA as a member of the National Water Resources Management System is that of a steering body at national level. SINGREH is comprised of government and civil organizations properly defined under legal instruments, including Law No. 9,433, of 1997. The important thing is that the structure of the System has room to aggregate wide and diverse decision-making

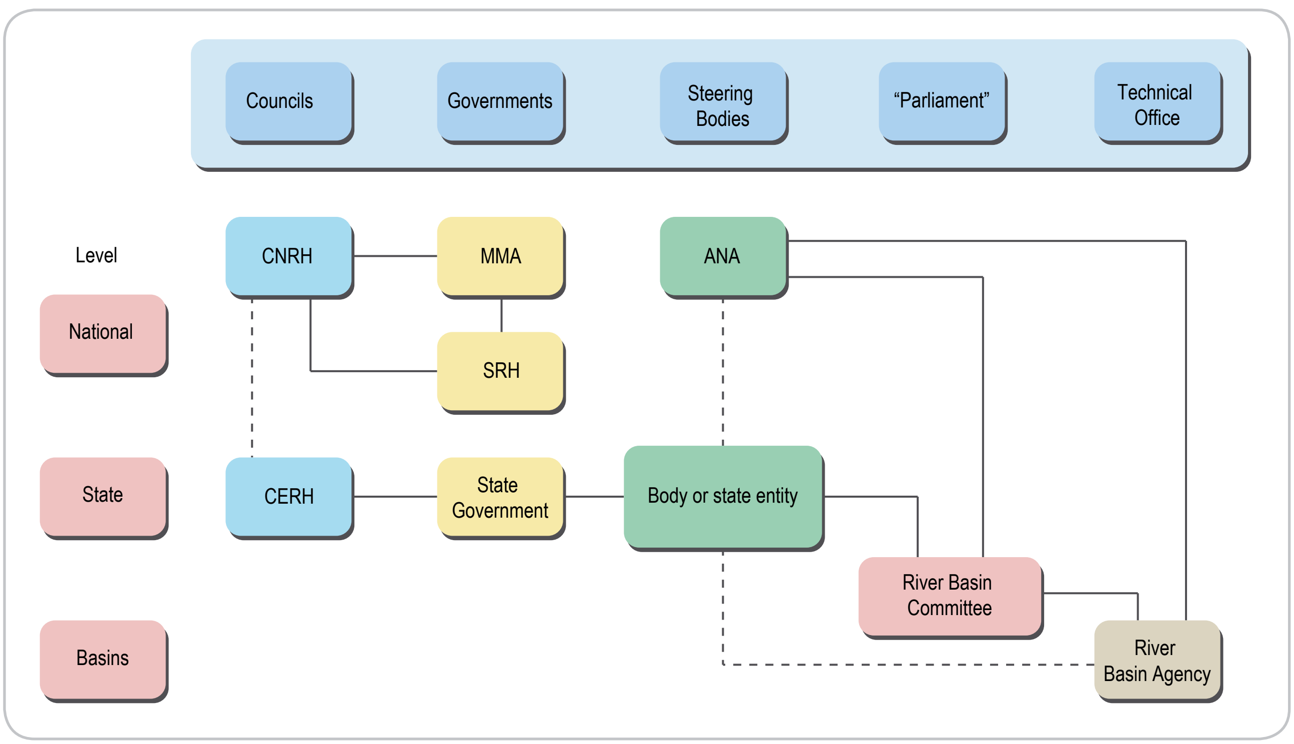


Figure 75. SINGREH's Operating Workflow

[7] MATTOS (2005) explains that (...) for all branches of law, the so-called "normas em branco" (blank norms) are "non-autonomous legal rules," or equivalent to incomplete draft laws, which make it possible to complement and explain them through another norm, which derives from the Executive Branch..

capacities, aiming at decentralization and active participation of civil society in issues involving water as a public, common-use good.

One element that stands out in this structure is the role played by the National Water Resources Council (CNRH), which is required to coordinate planning arrangements at national, regional, and state levels, and from segments of users developed by the entities in the National Water Resources Management System, and it is required to design the National Water Resources Policy pursuant to Law No. 9,433, of 1997. "It is recognized by society as the facilitator of a transparent dialogue in the decision-making process related to water resources legislation for coordinating the integration of public policies in Brazil."[8] At the heart of SINGREH and with a mandate akin to "water resources", many questions have reflected a desire to draw a line between ANA and the Secretariat for Water Resources (SRH), which belongs to the core structure of the Ministry of the Environment, and to SINGREH itself. It should be noted therefore that the basic distinction between the SRH's and ANA's powers is that, while it is up to the former to propose development of PNRH, the latter is the federal agency in charge of implementing the PNRH.[9]

This condition makes the two entities complementary to each other, so to speak, and it turns out to be extremely timely in view of the impossibility of reconciling these powers on democratic terms.

Moreover, the ideal structure of a modern state is to have the policy-making and implementation process in different government entities in order to make it easier to assess an administration.

Another distinction that must be brought to light derives from the fact that water is primarily an element of nature and as such belongs to the environment, so without proper clarification of the matter, an overlap of mandates is often supposed to exist for the sole purpose of the duties performed by entities that are administratively and financially subordinated to the Ministry of the Environment.

When the mining business is concerned, it is assumed, as mentioned earlier, that its operations will always take place within a river basin and, in view of the need to obtain or catch water for final consumption or use as a production input or effluent discharge in water bodies, it will also always be bound to water resources regulations, whether the body of water is under federal or state jurisdiction. It should be pointed out in particular that the mining business may require water uses that will alter the system, quantity or quality of the water existing in a body of water, or the extraction of water from an underground aquifer for final consumption or use as a production input, these cases being more directly associated to the mining business.

In principle, there is consensus that the mining business will impose some kind of change to the landscape; mineral extraction and processing activities may require the catchment of surface or underground water, involve effluent discharges, or directly or indirectly affect the watercourse system and its quantity or quality.

To make way for mining, it may be necessary to remove the vegetation covering the soil and, because of the direct relationship between soil and water, this might entail some sort of change to adjacent water

[8] Excerpt from the website of the National Water Resources Council: http://www.cnrh-srh.gov.br/
[9] Article 11 of Decree No. 4,755, of June 20, 2003, outlines the powers of SRH.

bodies driven by the action of rainwater and the wind, which are natural carriers of sediments, which would normally be carried to the lower level of the terrain and could reach a body of water.

This is a type of diffuse and physical pollution, causing the siltation of water bodies and increased water cloudiness. There are also situations where human action can lead to biological changes and chemical pollution of water from elements used in human activities, including mining.

However, whatever is not associated to the catchment of raw water or effluent discharge [10] or change to the system, quality or quantity caused by its users, and although it is clear that damage may result from the mining activity and indirectly affect water bodies, if there is no direct relationship with water use in mining operations, regulatory action by ANA or state-level water resources agencies – depending on the relevant jurisdiction – is not applicable.

Hence, this is where ANA's mandate is distinct from that of other entities in the National Environment System (SISNAMA),[11] whose jurisdictions can be at federal, state or municipal level. However, facts such as the one above also highlight the need to integrate environmental management with the management of water resources and the need to associate water resources management with land use management, which are both elements of the general guidelines for the implementation of the PNRH.

With regard to surveillance of the use of water resources, ANA's regulatory powers are based on Law No. 9,433, of 1997, and these aim to ensure adequate fulfillment of water use needs and priorities so that any offenses are reviewed against the relevant regulations and refer to the breach of any legal or regulatory provisions concerning the activities involved; performance of hydraulic works and services; derivation or use of water resources controlled by or under the dominion of the Central Government; or non compliance with requests or requirements made by ANA,[12] which can be described as minor, serious or critical and give rise to fines. Upon concurrent occurrence of more than one offense regarding the use of water resources by a particular user, simultaneous or cumulative penalties shall apply according to the individual violations.

Additionally, IBAMA's surveillance mandate[13] – which aims to ensure that the Country's natural resources are exploited rationally in accordance with standards and regulations for their sustainability in order to reduce human predatory action over nature – promotes Special Surveillance Actions in the Field of Environmental Degradation and Pollution, which includes the fight against environmental degradation and pollution caused by mining or prospecting activities. In this context, any violations will be duly acknowledged and the respective criminal and administrative penalties pertaining will be applied, based on Law No. 9,605, of February 12, 1998, i.e., the Environmental Crimes Act.

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[10] Resolution ANA No. 219, of June 6, 2005, stipulates "that the technical review prior to granting the right to use water resources for the purpose of discharging effluents into watercourses controlled by the Central Government, the Licensing and Surveillance Superintendence reviews the parameters for Temperature, Biological Oxygen Demand (BOD) and, in locations subject to eutrophication, for Phosphorus or Nitrogen".

[11] The National Environment System (SISNAMA), established under Law No. 6,938, of August 31, 1981, enacted through Decree No. 99,274, of June 6, 1990, consists of agencies and bodies in the Federal, State, Local, and Federal District levels, and the public foundations responsible for protecting and improving environmental quality.

[12] Article 19 of ANA Resolution No. 082, of April 24, 2002.

[13] IBAMA – Brazilian Institute for the Environment and Natural Renewable Resources is subordinated to the Ministry of the Environment and the implementing agency for SISNAMA.

Thus, ANA's mandate does not exceed its powers and focuses on aspects related to the actual use of water resources pursuant to any of the specifications listed under Law No. 9,433, of 1997, and under Law No. 9,984, of 2000, in addition to other regulations enacted by the National Congress – modifying or supplementing regulations –; the CNRH – regulations that define general criteria – and ANA's technical regulations.

The granting of a right to use water resources, in turn, is clearly part of ANA's mandate with regard to bodies of water controlled by the Central Government; this grant is stipulated under Law No. 9,433, of 1997, as one of PNRH's instruments, and it aims to ensure quantitative and qualitative control of water use and the effective exercise of the right to access it. Uses subject to this granting process are considered, as well as those which, though classified as "uses", are exempt from it, such as those uses intended to cater to the needs of small settlements in rural areas, and accumulations of water, derivations, catchments, and discharges that are deemed minor. The size limit for minor uses for bodies of water controlled by the Federal Government is determined by their respective river basin committees.

Charging for water use, which is also a mechanism under the PNRH, will always be linked not only to the granting of the right to use water resources, but also to the river basin committees, the understanding of the appropriateness of charging for use of water resources and the availability of water in bodies of water, so that this instrument may be added to the two aforementioned functions of the Agency regarding water catchment or derivation, effluents discharge, and uses that alter the system, quantity or quality of water, which in this case are associated to the mining business.

7.5.1 THE GRANTING PROCESS

The granting of water use rights is one the PNRH's mechanisms to which the charging scheme is fundamentally associated.

According to Machado (2003), Law No. 9,433, of 1997, clearly outlines the granting process as an affair that cannot be left to the private sector. The author evokes Section XIX of Article 21 of the Federal Constitution, which states that it is up to the Federal Government to establish criteria for granting rights to use water resources, so one of the relevant criteria is that this grant is under the government's mandate.

Law No. 9,984, of 2000, describes ANA's mandate regarding the granting, through an authorization, of the right to use water resources from bodies of water controlled by the Federal Government, within certain timeframes, the possibility of issuing preventive grants for the purpose of declaring the availability of water for the required uses, the need to supply a declaration of reservation of water supply for use of hydropower potential and mandatory disclosure for applications for grants and the ensuing administrative actions. Decree No. 3,692, of 2000, reiterates this mandate for ANA, and so does its Bylaws.[14]

The CNRH, which is responsible for establishing general criteria for the granting of the right to use water resources and for charging for its use,[15] issued four resolutions on the granting,

[14] Annex I of ANA Resolution No. 09, of April 17, 2001.
[15] Section XI of Article 1, Directive No. 377, of September 19, 2003, approving CNRH's Bylaws.

which cover all the granting bodies that comprise SINGREH, two of which being closely related to the mining practice.

CNRH Resolution No. 16, of May 8, 2001, is a general regulation, to ensure uniformity, which describes its nature; the types of use subject to the granting process and those exempt from it; the timelines; the linkages with the water resources plans; the priorities; the minimum details required for the application; the administrative act of granting; the register of users; among others.

Resolution CNRH No. 29, December 11, 2002, is specific in relation to mining and its preamble emphasizes the need for integration of procedures and concerted action between agencies and entities whose responsibilities are related to water resources, mining and the environment; and that the mining industry has specific uses and water consumption that could lead to changes in water body systems, both in quantitative and qualitative terms.

The Resolution mentions derivation or catchment of surface water, or underground water extraction for final consumption or as an input for production; effluents discharge, and other uses and interferences as types of use of water resources related to the mining business that are subject to the granting process.

There is one detail in this Resolution that spells out sections of Article 12 of Law 9,433, of 1997, to adjust them to the particularities of the mining practice, which are listed in Section III of Article 2 of CNRH Resolution No. 29, of 2002, which covers other uses and interferences and includes: a) catchment of groundwater for water level lowering purposes; b) diversion, correction and channelization of water bodies necessary to exploration and mining activities; c) damming for settling and retention of tailings in water bodies; d) damming for normalization of water level or flow; e) sterile and tailings disposal systems; f) use of minerals in bodies of water; and g) water catchment and effluent discharge associated to the transportation of mining products.

Item "e" in this Resolution deserves special mention since it conditions systems for the disposal of tailings and waste to the granting system.

The list of concepts set forth in CNRH Resolution No. 29, of 2002, contains two concepts directly related to this item:

> [...]
> VIII – spoils disposal system: facilities that are designed and implemented to collect materials, either temporarily or permanently, that are disposed of in a planned and controlled manner under geotechnical stability conditions and are protected against erosive effects;
>
> IX – waste disposal system: engineering facilities for retention and disposal of waste derived from ore processing, water catchment and effluent treatment;
> [...]

In the first case, no mention is made of the use of water resources, while in the second the conditions of use are explained as "waste derived from [...] water catchment and effluent treatment," which refers to required granting for these uses, both having been already covered in Law No. 9,433, of 1997, but not necessarily associated to the mining tailings disposal system.

From a more restrictive perspective, one can construe that this subordination refers to Section V of Article 12 of Law No. 9,433, of 1997, regarding water quality, which might be adversely altered by the percolation of polluted water along the soil and, depending on the location of the sterile and tailings disposal systems in relation to the body of water, could reach it along its subsurface or underground way and thus cause pollution.

As far as the granting process is concerned, this provision is consistent with Section IV of Article 15 of Law No. 9,433, of 1997, which provides for partial or total suspension of the grant in those cases where severe environmental degradation needs to be prevented or corrected. However, the essential condition for the suspension of the granting of water use is that it must have been issued and, therefore, there must be a grant that binds water use to the tailings disposal system in mining operations or even the sterile disposal system. Failing this, the need for a grant to use water resources should undergo specific technical review, given the polluting nature of the activity and the potential to affect water bodies located in the surrounding areas, with varying impacts.

Section II of Article 49 of the Water Act provides that "starting the setup of, or setting up a new project involving the derivation or use of surface or underground water resources that entails changes to the system, quantity or quality thereof, without authorization of the relevant agencies or authorities" is a violation of regulations on the use of surface or underground water resources.

Relevant analysis shows that, on the one hand, there is the potential for changes to water quality; however, on the other hand, it is not properly clear which sterile and tailings disposal systems are bound to a sort of special use of water resources, as indicated in item e of Section III of Article 2 of CNRH Resolution No. 29, of 2002, other than that, clearly related to the catchment of water for consumption or as an input to the production process.

This goes to show the importance of this matter when considering the regulation as a means of "security" for cases of conditioned use, where the condition of "requiring a grant" is appropriate and relevant, since this condition is not mandatory, since there are cases in which there is no causal relationship. However, if the mechanism is fit, it will certainly be applied, but for the specific use of water, just as established under CNRH Resolution No. 29, 2002.

It should be pointed out that Resolution CNRH No. 29, 2002, requires submission of a water use plan exclusively for mining projects and whenever necessary. For purposes of reviewing applications for a grant of water resources use, this plan must contain, among other details, quantitative and qualitative details for the water balance in the affected area, and the balance's variations over time.

In view of this, the review of water use for granting purposes, given the locational constraint of mining projects, takes into consideration all uses related to that business, hence the need for a water balance on the affected area, which will seamlessly cover all uses of water resources and interventions pertaining to it.

The potential pollution of an adjacent river will be covered by the surveillance team, who, by complying with the guidelines for integrating the management of water resources to environmental management, must formally submit to IBAMA or the relevant environmental authority, the details relating to the actual environmental damage so that it may qualify the offense and its perpetrators under the Environmental Crimes Act and proceed to impose the applicable penalties.

It is noteworthy that, because it covers all granting authorities under the SINGREH, Resolution CNRH No. 29, of 2002, will all-inclusively cover the preventive grant or the grant of the right to use water resources both for waters controlled by Central Government and the waters under the jurisdiction of states and the Federal District.

As part of its mandate, ANA also issues regulations on the grant, which affect only the rivers under the jurisdiction of the Central Government and outline criteria and procedures of a technical and administrative nature.

7.5.2 THE DUTY OF SURVEILLANCE

Law No. 9,433, of 1997, does not include surveillance as one of PNRH's mechanisms, but does include it in Section II of Article 29, and Section I of Article 30, which describe the regulation and surveillance of the uses of water resources as one of the duties of public authorities[16] in relation to the implementation of PNRH, considering that the civil, administrative and criminal liability of the public agency issuing the grant is not limited to this duty.

Machado (2003) argues that surveillance of the use of water should include periodical inspections, otherwise the grant becomes an act devoid of any benefits for the environment and users in good standing.

While Law No. 9,984, of 2000, on the establishment of ANA, provides for surveillance as part of its mandate (Article 4, Section V), Decree No 3,692, of 2000, which regulates its establishment, is more specific, and includes a surveillance competency, with law enforcement powers, regarding uses of water from bodies of water controlled by the Central Government (Article 2, Section VI).

The legislation issued by ANA is Resolution No. 082, of April 24, 2002, which on the matter of surveillance explains that it is up to ANA to inspect the use of water resources through monitoring and controlling, investigation of violations, imposition of penalties, and enforcement of remedial actions for the activities, works and services by the users of water resources under the jurisdiction of the Federal Government (Article 8).

The framework for this regulation brings together all uses subject to surveillance and makes up a broader universe than that of the grant, since not all uses subject to surveillance are subject to the PNRH's mechanism.

Regarding the use of water resources by the mining industry, surveillance covers[17] industrial supply, including mining operations involving water catchment and effluents discharge into water bodies under the jurisdiction of the Central Government; ducts and tunnel crossings bodies of water controlled by the Central Government involving uses without water derivation; cleaning of river banks and protection of river beds in relation to miscellaneous services in rivers, streams and lakes; and the extraction of grade II ores from beds or banks of water bodies or reservoirs.

Other situations not covered explicitly under ANA's surveillance categories were included in Annex I of ANA Resolution No. 082, of 2002, under the title "Others". It applies also to catchment and discharges, and uses without water derivation, in this case in the context of hydraulic works, with a mention to dams; channeling, rectification

[16] Articles 29 and 30 of Law No. 9,433, of 1997, deal with the jurisdiction of the Federal Executive Branch and the Executive Branches for the States and the Federal District, respectively, regarding implementation of the PNRH.

[17] Resolution No. 082, of April 24, 2002 – Annex I, item 3.

and protection of river beds; and crossings – air, intermediate or underground – of bodies of water controlled by the Central Government.

Subject to surveillance, the "Other" item can accommodate a number of activities involving less common uses of water resources or the interference with them, but it does not exceed ANA's surveillance mandate. However, CNRH Resolution No. 29, of 2002, once again is applicable in those cases where sterile and tailings disposal systems, which are not always covered by the grant, come to damage the quality of water bodies in their surroundings. The determination of the damage by ANA's surveillance action will identify whether or not there is a connection to Agency's mandate. If a condition exists, the business will be liable to penalties and other sanctions provided for in Law No. 9,433, of 1997, and Law No. 9,605, of 1998. Once an environmental damage has been verified, the business will be administratively and criminally prosecuted for actions detrimental to the environment, according to the provisions of Law No. 9,605, of 1998,[18] whose applicable penalties will be imposed by the relevant environmental agency.

It should also be pointed out that the minor uses that are not subject to the grant must be entered in the National Register of Users of Water Resources (CNARH) and will be monitored, since the fact of having been classed as such at any given time does not imply that they remain so over time, both due to increased user demand and because the statutory minor amount of water established for each river basin can vary in relation to the water available in the body of water.

7.5.3 THE CHARGING SCHEME

The 1934 Water Code assigned an economic value to water, and pursuant to paragraph 2 of Article 36, the common use of water may be either free or paid, according to the laws and regulations of the administrative district to which it belongs. Granziera (2000) mentions that this approach stems from the 1968 European Charter on Water Resources, which stated the economic value of water, albeit not having addressed the issue of charging. In 1972, the OECD Council[19] established the need to charge for water use.

However, this matter came to the global forefront on the International Conference on Water and the Environment held in Dublin in 1992, when four basic principles were adopted to express the core elements of the interplay between water and the environment, and specifically the following:

> Principle #4: "Water has an economic value in all its competing uses and should be recognized as an economic good".

This was an additional boost for the Brazilian technical and scientific sectors focused on the development of legislation to manage the use of water resources to ratify the need to include the charge within the legal framework, which was then being developed for the country.

Hence, Law No. 9,433, of 1997, secured the charging for the use of water resources in its mechanisms, where water is recognized as an economic good, with the primary purpose of encouraging rationalization of its use while providing funds to finance actions properly set forth in the Water

[18] Articles 33; 53, Section I; and 54, Section III of Law No. 9,605, of 1998, cover this specific matter.
[19] Organization for Economic Cooperation and Development.

Resources Plan – which is also one of PNRH's mechanisms – in relation to the river basin[20] for which the fund will have been collected.

It should be noted that the fact that water be deemed as an economic good also allows users to have a notion of its actual value and makes it possible, in legal terms, to charge for the use of water resources, but without interfering with the inalienable nature of this public good.

The "collective interest" is enshrined in the very foundations of the Law and is reflected through the priority use for human consumption and for watering livestock, but without limitation, since the management of water resources should always allow for multiple uses of water, and this is also one of its foundations.

As the manager of the public good called "water", ANA operates according to tenets, objectives, guidelines, and mechanisms set forth in the PNRH, and in collaboration with public and private bodies and organizations that are members of the SINGREH. It also includes, according to Granziera (2001), the principles of "poluidor-pagador" (pay-per-pollution) and "usuário-pagador" (pay-per-use), introduced by Law No. 6,938, of August 31, 1981,[21] which establishes under Article 4, Section VII, that the National Environmental Policy shall aim to impose on polluting and predatory parties the obligation to rehabilitate and/or compensate for the damage caused, and shall impose on users a contribution for the use of environmental resources for commercial purposes.

Law No. 9433, of 1997, provides that charges apply for the use of water resources subject to the granting process, and that the pricing process should consider, among others, the amount of water removed and its variation system in the context of water derivations, catchments and extractions; and the released portion and its variation system and the physico-chemical, biological and toxicity properties of the effluent in relation to sewage discharges and other waste liquids and gases.

It is important to note that the income from charging for the use of water resources may be invested, as non-refundable resources, into projects and works that change the quality, quantity and flow rate of a body of water in a manner that is deemed beneficial to the community and primarily in the river basin in which they were generated.

The term "primarily" has caused some uncertainty as to the specific destination of resources, since it could give leeway for the funds to be invested in a different river basin. As a result, Draft Law No. 240, of 2002 was submitted to the National Congress; it gives a new wording to Article 22 of Law 9,433, of 1997, compared to the income from the charging system. The final version of Draft Law No. 240, of 2002, requires that the income from charging for the use of water resources that are established under Section VI of Article 38, and from the fines resulting from failure to comply with the provisions of this Act shall, without prejudice to the legislation in force, be fully implemented in the river basin in which they were generated, [...], which makes it mandatory to invest the funds generated from charging exclusively in the river basin in which it was created.

Another fact of great importance for the operation of SINGREH was the enactment of Law No. 10,881, of June 9, 2004, which regulates the

[20] Law No. 9,433, of 1997, stipulates under Article 22 that the income from charging for the use of water resources shall revert primarily to the river basin in which they were generated.

[21] Law No. 6,938, of 1981, provides for the National Environmental Policy, its purposes and development and implementation mechanisms, and makes other provisions.

management contracts between ANA and entities that take on Water Agency duties for the management of water resources under the jurisdiction of the Central Government, among other measures.

Backed by Supplementary Law No. 101[22], of May 4, 2000, which in paragraph 2 of Article 9 emphasizes that no limitations shall apply to expenses that qualify as constitutional and legal obligations for the entity, including those intended for the payment of debt service, and those that qualify as exceptions in the budgeting guidelines law, this law ensures that the entities taking on ANA's duties shall be entitled to appropriations from the proceeds from charges on the use of water resources in rivers under the jurisdiction of the Central Government, i.e., there can be no curtailment of the amount of funding raised through the charging mechanism. This guarantee is extremely timely so that the funds collected can be used as soon as available in wide-ranging improvements at the river basin in which they were generated, according to the contents of the relevant Water Resources Plan.

One should bear in mind that charging for the use of water resources is not a mechanism that can be implemented as the result of an exclusive decision made by ANA. A number of powers to this end is held by the entities that make up the SINGREH.

CNRH's powers include the establishment of general criteria for granting the right to use water resources and charging for their use, and setting amounts to be charged for the use of water resources controlled by the Central Government.[23] It is up to ANA to prepare technical studies to support the definition, by CNRH, of the amounts to be charged for the use of water resources under the Central Government Jurisdiction, based on the mechanisms and quantities suggested by the River Basin Committees, as per section VI of Article 38 of Law No. 9,433, of 1997; to implement, in collaboration with the River Basin Committees, charging for the use of water resources under the Central Government jurisdiction; and to collect, allocate and invest proceeds from the charging for the use of water resources that are controlled by the Central Government.[24]

7.6 FINAL REMARKS

There is no doubt about the importance of water resources in the mining industry, which, in most cases, at some stage of its production chain will establish an interface between them, whether on demand or due to the need to remove the groundwater flooding the mining pits which, for the continuation of mining operations, must be pumped into the nearest body of water or stored in pits or retention facilities.

The development of an innovative legal framework for water resources management has also prompted the establishment of a robust national management system, which brings together representatives from the civil society, water users and public authorities, assigning them powers and duties to agree on the management of river basins with water organizations and managers, with details of their problems and their strategies for rehabilitation and revamping – this places Brazil at the forefront of water management.

[22] Fiscal Responsibility Law.

[23] Bylaws of the CNRH, Article 1, Sections XI and XIV (Annex to Directive No. 377, of September 19, 2003, adopting the Bylaws of the National Water Resources Council).

[24] Law No. 9,984, of July 17, 2000, Article 4, Sections VI, VIII and IX.

The regulatory framework at various levels – from the constitutional provisions to enactment of an operating regulatory framework – incorporated a number of prominent principles for the rationalization of water use and to reduce the inflow of polluting effluents, especially the recognition of its economic value and the development decentralized and participatory management regulations, thus securing to SINGREH a strategy that is virtually revolutionary in terms of managing public affairs.

The objective is to rise to the challenge of regenerating our waters both quantitatively and qualitatively, ensuring proper care for this priceless asset and, under the assumption that water and society are inseparable, the duty of the community to conserve and protect water resources in tandem with the government should be stressed, which accounts for the shared responsibility of the Brazilian people in performing this task that will shape the desired future for the Country, whatever the intended use of water resources.

Photo: Arquivo Ana

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CHAPTER 8

Photo: Arquivo Vale do Rio Doce

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