Mine Closure in Iberoamerica

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by Eng. Juarez de Oliveira Rabelo
Director of Development MBR

Editors:
Roberto C. Villas Bôas
Maria Laura Barreto

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UNIDO

MINE CLOSURE IN IBEROAMERICA

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MINE CLOSURE IN IBEROAMERICA

Request for the extra copies it should be addresses to:

Roberto C. Villas Bôas
CYTED-XIII – Tecnologia Mineral
Calle Amaniel 4
28015 Madrid, Spain

Glória J. de C. Sirotheau
Coordination of Texts

Fátima Engel
Composition and Graphic Execution

Vera Lúcia Ribeiro
Cover

Emilio Garzon
Maria Victoria Vasquez
UIA Coordination

Susana Ferrandiz
CYTED Coordination

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Roberto C. Villas Bôas
Maria Laura Barreto
Editors

Foreword

This book brings to the interested public the discussions and propositions delivered during the First Iberoamerican Seminar on Mine Closure held in La Rabida, at the monastery where Colon lived upon his return to Spain, after reaching the American Continent.

Such a Seminar was a product of an open competition among 197 candidates, from several nacionalities, all of them recognized professionals or academicians, acting upon the thematic of mine closure in these last years. From these, 101 were elegible to schollarships awarded by CYTED - Science and Technology Programme for Development - and UIA - The International University of Andalucia, since, as announced, it was open to iberoamerican citizens only.

Out of these 101 elegible candidates, 50 sent their experiences and proposals on the thematic thus proposed, Mine Closure, to this very first seminar, on an international level, that discussed the questions of mine decommissioning focusing all the angles of such question :

- from its economics and finantial angle ;
- from its social and community angles ;
- from its legal aspects ;
- from its political and psico-social angles ;
- from its environmental aspects ;
- from its technological aspects ;

From this group of 50 higly qualified people it was necessary to select 10 full schollarships and 20 partial ones ; moreover, due to the extraordinary contemporanity of the discussion it was open the possibility that officials from the mining companies could participate at their own costs ; another group of 10 people so did that way.

One very important issue of the question was the great interest aroused from engineers, scientists, lawyers, social scientists, geologists, environmentalists, community leaders, on the understandings of what is the problem related to mine closure and what this terms really means, within the new proposals and constraints of sustainable development. Thus, questions as mine rehabilitation, reclaiming, recovering of the site and more recently mine decommissioning rise, here and there, sometimes intermixing without a clear cut frontier between one and the other and even competing amongst theirselves.

Classical mining already introduced que problems of reclaiming as one of its unit operations within the orebody ; this we, mining engineers learned at our mining schools, even 30 or 40 years ago ! This is not new ! What is in fact new is to incorporate the social dimension, besides the environmental one, as well as enlarging the latter, and generating a wholly new conception of the mining enterprise : its physical, economical, social, political and ethical effects !

We, the editors, are quite sure that the subjects that are at the disposal of the reader in this book, being concepts, discussions or case-studies will well serve the purposes of stearing new discussions and proposals hopefully to reach some concensus in the way mine closure is being seen today. As immediate results of this Seminar, the following actions are under way :

- editing of a CD-R of all the presentattions, in spanish, portuguese and english and distributed by Panorama Minero of Argentina, in its October 2000 edition, coordinated by Hugo Fernandez.
- Panamerican Workshop on Mine Closure, coordinated by COCHILCO's Patricio Cartagena, in Santiago Chile, June 2001.
- Cuban Workshop on Mine Closure : its Geodynamic Approach, Moa, Cuba, June 2001, Coordinated by Roberto Blanco, of Red D - CYTED-XIII.

- establishing of a NGO in Vancouver, Canadá, february 2001, coordinated by Marcello Veiga of UBC.
- a comparative study on mining closure realities between the American Continent and the Iberian Peninsula, february 2001, coordinated by Laura Barreto.
- writting up of the La Marisma-Huelva Declaration as a guideline for mine closure concerns, coordinated by Hugo Nielson.
- and others. ..

Good reading !

Palos de La Frontera, September 2000

Roberto C. Villas-Bôas
Maria Laura Barreto
Editors

DECLARACION DE LA MARISMA
La Rabida, Huelva, España
29/09/00

En la Sede Iberoamericana de la Universidad Internacional de Andalucía, La Rábida, Huelva, España, a los 29 días del mes de septiembre de 2000, tras cinco (5) días de deliberaciones en el marco de las **I JORNADAS IBEROAMERICANAS DE CIERRE DE MINAS**, bajo el auspicio del **SUBPROGRAMA DE TECNOLOGÍA MINERAL DEL PROGRAMA DE LAS CUMBRES IBEROAMERICANAS DE JEFES DE ESTADO Y DE GOBIERNO, CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO - CYTED -,** los presentes declaran:

1) Que el principio rector de todas las políticas vinculadas con la explotación de los Recursos Naturales No Renovables debe ser el mejoramiento de la calidad de vida de la sociedad en general y, en particular, aquellos de las comunidades vinculadas con los proyectos mineros.
2) Que las responsabilidades sobre los efectos socio-económicos y ambientales negativos de los proyectos mineros, su remediación y alternativas de descomisionamiento (decommissioning) deben estar señaladas desde el inicio de los nuevos proyectos.
3) Que el concepto de "sustentabilidad minera" involucra los aspectos económicos, ambientales, tecnológicos, legales, políticos y sociales de manera indisoluble.
4) Que el desarrollo de la explotación minera debe garantizar la satisfacción de las necesidades presentes de los pueblos sin afectar las posibilidades de desarrollo de las futuras generaciones, por negligencia de usos del yacimiento y necesidad del ordinamento del territorio.
5) Que la temática abordada en las **I Jornadas Iberoamericanas de Cierre de Minas**, reviste una importancia fundamental para alcanzar una mejor contribución de la Minería al proceso de Desarrollo Sustentable de nuestras regiones.
6) Que los aspectos referidos al C**ierre de Minas** deben integrarse a las políticas y legislaciones de cada país en forma clara y precisa, procurando alentar el necesario crecimiento económico, en el marco de un desarrollo sustentable.
7) Que los Estados deben asumir un rol activo y decidido en la fijación de políticas claras para el desarrollo minero, en particular en los aspectos referidos al C**ierre de Minas.**
8) Que el **Cierre de Minas** debe considerarse una fase de los proyectos mineros desde su inicio.
9) Que sería necesario promover la incorporación de la temática del **Cierre de Minas** en los Planes de Estudio de las carreras de Geología e Ingeniería de Minas de las Universidades Iberoamericanas.
10) Que sería recomendable la realización de un inventario de Minas y Canteras abandonadas en cada país de la región.
11) Que se debería incentivar las acciones de intercambio y difusión de experiencias sobre el **Cierre de Minas**, en foros internacionales como los generados por el **CARICOM, ALCA, MERCOSUR, PACTO ANDINO**, **OLAMI,** etc. En especial los proyectos que se desarrollan en el marco de la Conferencia Anual de Ministros de Minería de las Américas (**CAMMA**) sobre la materia, que contempla para el año 2001 la realización de un Taller Panamericano sobre **Cierre de Minas**.

12) Que el **CYTED** ha contribuido de manera sustancial al intercambio de experiencias y generación de conocimiento sobre la temática minera. Que debería seguir apoyando iniciativas relativas a la organización de jornadas, seminarios y congresos que aborden la problemática de la minería y el desarrollo sustentable.
13) Que es necesario propiciar la creación de organismos que, conjuntamente con los respectivos gobiernos, analicen las temáticas vinculadas al de cierre de minas con un enfoque interdisciplinario y alejado de posiciones fundamentalistas.

POR TODO ELLO, RATIFICAN SU COMPROMISO DE TRABAJAR POR UN DESARROLLO MINERO QUE CONTRIBUYA A MEJORAR LA CALIDAD DE VIDA DE LOS PUEBLOS, GENERANDO RIQUEZA Y CREANDO FUENTES DE TRABAJO EN UN MARCO DE DESARROLLO SUSTENTABLE

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MODULE I

ENVVIRONMENTAL ASPECTS IN MINE CLOSURE

FILLING THE VOID: THE CHANGING FACE OF MINE RECLAMATION IN THE AMERICAS

Stephen Roberts, Marcello Veiga,
Department of Mining and Mineral Process Engineering, University of British Columbia, Vancouver, B.C. V6T 1Z4 Canada, veiga@mining.ubc.ca
Carlos Peiter, Glória Sirotheau, Maria Laura Barreto e Gilson Ezequiel
CETEM - Centro de Tecnologia Mineral, R.4, Quadra D. Cidade Universitária, Rio de Janeiro, Brazil, 21941-590, CPEITER@cetem.gov.br

ABSTRACT

The focus of mine closure policies and practice in the Americas has undergone considerable change since the first closure laws were enacted some three decades ago. Starting with an early emphasis on addressing human health and safety concerns, current government laws in many jurisdictions have made mining one of the most highly regulated industries in Canada and the United States. At a minimum mine closure plans must now include provisions for meeting tough water and air quality standards, the minimization of visual impact, plant and animal habitat, while creating the opportunity for other productive uses for the site. Though the technical standards for determining a successful mine reclamation project have risen considerably in the past thirty years, the public's growing hostility toward the mining industry suggests that public expectations have risen even faster. With terms such as ecological footprint, carrying capacity, and sustainable development becoming part of the popular lexicon, there is enormous pressure on the mining community to develop policies that bring their operations into line with what the public expects from a good corporate citizen. A review of industry best practice suggests that many of the more forward looking companies not only recognize the need for change, they are also taking steps that often go beyond what is laid down in the regulations. Though the results of such actions are laudable, the author's make the argument that if the mining industry in North America is to avoid the imposition of what could be potentially crippling new government regulations, it must do much more to minimize its impact on the receiving environment. With their focus on mine reclamation, the authors' highlight the need for changes in such areas as post-mine land use planning, the role of the company in assisting communities in developing transitional economic strategies following mine closure, and the importance to the industry of developing effective strategies for dealing with the many ethical and social issues that arise following closure. As more sustainable development practices begin to take hold in Canada and US, the experience gained by these two countries may assist Latin American governments in developing similar policies to optimize the economic and social return from mineral development.

INTRODUCTION

To those outside observers who are unfamiliar with the turbulent nature of the mining industry, it can often appear that mining is an industry that is always in a state of upheaval. As a sector that epitomizes the best and worst aspects of the old smokestack economy, mining seems to be permanently caught between periods of boom and bust. Even for those with closer ties to the mining community, keeping abreast of the latest technical, legal, and economic developments in the industry has been exceedingly difficult and time consuming. Working under the auspices of the Mining Policy Research Initiative (MPRI)[1], a team of researchers from the University of British Columbia (UBC), Canada, and

[1] The MPRI is a recently created arm of the International Development Research Centre in Ottawa, Canada.

the Centre of Mineral Technology (CETEM), Brazil, were commissioned to develop an informational database to assist fellow researchers who are working in the field of mine closure and reclamation. The database was compiled using source material originating from industry and academic journals, books and other electronic databases. Because mine closure and reclamation requires the involvement of personnel from many diverse fields of study, the database was developed using material drawn from a variety of disciplines including engineering, law, economics, environmental science, ethics, and political science. Since the database was specifically intended to assist academics in carrying out their own research projects, the research team made every effort to include the most up-to-date material available.

As the completed database contained over three thousand data entries spanning eleven separate themes, the research team included as a supplement an executive summary written to focus attention on those areas of interest that the team believed best described where mine closure and reclamation activities are most likely headed in the future. This article has been written to briefly highlight the main conclusions that are contained within the executive summary. As they read this some may be struck by the fact that the focus of our investigation was directed primary toward addressing socioeconomic, rather than the environmental consequences of mine closure. This approach reflects our conscious decision to highlight aspects of mine closure and reclamation that traditionally have not received very little attention[2]. It is our belief that the future direction of research on this subject will be much more holistically oriented. No longer concerned with just finding technical solutions to environmental problems, researchers will now be struggling with the more difficult task of understanding and dealing with the social and economic impacts that closure brings to a community.

At MPRI's request the database was constructed primarily from works originating from sources in the Western Hemisphere. This geographical focus of the project was taken in part to make the database more manageable by limiting its scope, as well as being consistent with MPRI's mandate to help build ties between Canada and Latin America. Given the great diversity of material written on the subject of mine reclamation, even with this limitation it was necessary to create a series of sub-themes in order to facilitate user searches of the database. To simplify the presentation of the results of our study, we have chosen to structure the remaining portions of this paper using many of the same themes that were employed in organizing the database.

LEGAL ISSUES AND INSTITUTIONAL FRAMEWORKS

The institutional and legal frameworks that govern the practice of mine closure and reclamation in North America have evolved significantly over the past twenty-five years in response to changing public, governmental, and industry expectations. As more is learned about the potentially negative long-term impact of mining on the surrounding environment, the public has become increasingly vocal in demanding that government authorities take additional steps to regulate the activities of mining companies. This section will briefly examine the regulatory and institutional structures that selected governments in the Western Hemisphere have put into place in order to ensure the reclamation of former mine sites.

How does the law specify the goals of mine reclamation? The answer to this question has evolved considerably over the last thirty years. Initially reclamation was seen

[2]These themes include such items as the law, ethics, gender issues, aesthetics, mediation and facilitation, and the social impacts on communities that are specific to mine reclamation.

in terms of addressing the rather narrow health and safety concerns that typically arise after a mine has closed (i.e., sealing of underground openings). While still interested in these twin issues, reclamation is now also concerned with protecting and restoring land to its pre-mined condition. In pursuing these new objectives, Canada and the US have instituted a series of legislative initiatives designed to create procedural and enforcement mechanisms in support of specific reclamation outcomes.

The US Model

As an outgrowth of its unique political heritage the United States has adopted a multi-layered approach to the regulation of mine reclamation. This fact has lead to a situation where US laws and institutions governing coal mine reclamation are radically different from those used to reclaim “hard rock” mines. Without commenting on the underlying political reasons for these differences, it is important to recognize how dissimilar the two systems are. When it was enacted into law in 1977, the Surface Mining Control and Reclamation Act (SMCRA) established a national set of regulations for the reclamation of coal mines. By any measure, the SMCRA is a highly proscriptive piece of environmental legislation. The regulations not only set out the precise objectives of a reclamation project, they also specify in exact detail the requirements for the construction, maintenance and final reclamation of the mine site.

Under the law the authority for overseeing the provisions of the Act may be delegated to the state level if it can be demonstrated that state laws are at least as stringent as the federal regulations. Even in those cases where the state government has assumed responsibility for administering the Act, SMCRA still allows the federal government the right to monitor the way the state operates the program. If a state fails to meet its legal obligations under the Act, the federal agency retains the right to revoke the state’s legal authority and resume control.

Though government and industry officials generally regard SMCRA as a highly successful program, there are many aspects of the Act that limit its usefulness as a model for other jurisdictions. One such limitation is that to be properly administered, there is a requirement for the government to hire a vast pool of highly skilled reclamation professionals. This makes the Act very expensive to administer. If passed on to the industry, these added costs might seriously compromise the ability of the domestic industry to compete in the global marketplace.

In contrast to the strict federal laws written to oversee the reclamation of coal mines, the regulations governing hard rock and sand and gravel reclamation are vastly different. In the US the responsibility for regulating the non-coal mine industry rests squarely at the state level. Based on the vagaries of local politics, some states have initiated well-conceived reclamation laws while others have chosen not to enact any reclamation legislation at all. The result has been to create a patchwork of laws that vary greatly in terms of the demands each state places on the industry to reclaim mined land.

If a national program of non-coal mine reclamation legislation were to be put into place, it would have to overcome the difficult problem of how to deal with the great diversity that characterizes the mining industry. Hard rock mining, sand and gravel operations, placer mines and artisanal mining are fundamentally different in terms of the mining methods employed, the products they produce, the scale of their operations, their environmental impact, and the scope of their reclamation requirements. This would suggest that governments are faced with the choice of either instituting a series of reclamation laws tailored to the demands of each subset of the mining sector, or they must adopt a unitary system that attempts to address the problem of reclamation using a single blunt instrument.

Currently in the US, only the state of Arizona maintains a unitary system for issuing reclamation permits. All other states have adopted, to various degrees, multiple permitting systems based on the type of mining operation seeking a reclamation permit.

The Canadian Model

Under the Canadian federal system, responsibility for mining falls within the exclusive domain of the provinces. Therefore with respect to mining, there is nothing in Canadian mining law that is comparable to the SMCRA. The situation in Canada is similar to the US in the sense that like the state governments, each province is responsible for developing policies and regulations governing how mined lands are to be reclaimed within their jurisdiction. Historically the laws have been written in a way that government inspectors are awarded a high degree of discretion in terms of how they can interpret the intent of the regulations (B.C. Ministry of Employment and Investment, 1997).

Abandoned Mine Lands

In both Canada and the US there has been an ongoing attempt to deal with the problem abandoned mined lands (AML). Mineral and surface title laws are inherently complex, and as such they present one of the more difficult institutional problems for addressing AML reclamation. Identification of former owners of AMLs is lengthy and expensive, and even if they can be identified these parties may be incapable of funding the required cleanup. Other problems include the need to possibly fund the long-term cleanup of the site (due to the lack of an appropriate walk-away solution), and the threat of future liability imposed on third parties that attempt to reclaim orphaned sites. The net effect of the law has been to make third party cleanup of AMLs a very risky proposition. Until the regulations are updated to include items such as a “good Samaritan” clause, little can be done to redress North America’s huge AML problem. The unique problem posed by AMLs will be further discussed in a later section dealing with *Risk Assessment*.

Latin America

In the Latin American countries studied under this project[3], the government institutions that are most closely linked to mine closure and rehabilitation are those that are responsible for the environment and/or mining. The responsibility for formulating reclamation policies and regulations are generally held at the federal level, while the control and auditing functions may, depending on the characteristics of the particular project, be the responsibility of federal, state and/or local governments.

Though the mining acts of most Latin American countries typically contain specific references to the recovery of degraded areas, it is in the complementary regulations that the more general tools for environmental management and evaluation are found. Alternative legal frameworks for managing mine reclamation are found in Argentina, Ecuador and Peru. In Mexico, the requirement for system evaluation and environmental management is contained in the regulations governing mine development.

Bolivia is the only country in Latin America that has a specific regulation for the environmental management of mine closure and rehabilitation procedures. The regulations provide specific technical guidance for how the reclamation is to be accomplished once mining operations cease. To help ensure that the intent of the law is carried out, mining companies are required to develop a closure plan beginning from initial exploration. As in North America, these closure plans must address the objectives of closure and rehabilitation, specify how the objectives are to be accomplished (tailings control, physical

[3] Argentina, Bolivia, Brazil, Chile, Ecuador, Peru and Mexico.

and chemical stabilization of tailings, rehabilitation of the area and of superficial drainage, control of erosion), and address post-closure actions (control and monitoring).

In Peru the government has produced for industry a manual for mine closure and reclamation. Unfortunately use of this manual is considered voluntary.

It should be noted that the Chilean Government is currently engaged in a process of regulatory reform that is intended to create a more holistic approach to mine closure. As the lead government agency, COCHILCO has been commissioned by the Minister of Mines to establish a revised set of technical, social and political guidelines for consideration by that country's congress. If successful, this initiative could serve as a practical model to assist other governments in formulating more effective closure strategies.

ECONOMIC CONSEQUENCES OF MINE CLOSURE

As in many other parts of the world, North American governments have attempted to manage the environmental risks from mining through a number of ways. One way is to impose financial accounting instruments that require corporations to internalize the full environmental costs of their operations. These instruments may take the form of taxes, credits, rebates, subsidies, penalties, etc. From a policy perspective an advantage to the state from using these instruments is that they encourage the industry to innovate in order to achieve the government's policy goals. The alternative is to have the government impose a system of command and control that experience has shown to be both difficult to establish and expensive to maintain.

In the absence of other regulatory requirements, industry prefers to use accounting provisions to cover their closure liabilities as this does not require them to divert any of their actual cash flow for the purpose of establishing a closure fund. The obvious problem with such an arrangement is that unless the company has chosen to set aside actual funds for closure, when the project nears the closure date the cost of reclamation is likely to exceed the company's true book value. At that point the company may choose to declare bankruptcy rather than attempt to raise additional financing to cover their reclamation liability.

To avoid the problems described in the above scenario, Canadian and US mining companies are not allowed to rely solely on accounting accruals to cover the costs of closure. Instead the government requires that they secure the necessary funding by providing some other form of financial guarantee prior to receiving their initial operating permit.

It is the typical practice of regulators to accept one or more types of financial guarantee. The issues surrounding the type, nature, and conditions of guarantees are critical if the financial assurance is to function as the regulators intend. Experience has shown that when major closure problems have occurred the result is almost always some form of negotiated settlement between the regulator and the mine owner. Typically the mine owner is strapped for cash and is seeking to scale back on his reclamation commitments. The direction these negotiations take largely depends on the "hardness" of the guarantee. As a rule, the harder the financial assurance the more flexible the regulator can be in accepting or rejecting any alternative proposals put forward by the miner. On the other hand if the assurance is soft, the regulator can exert very little leverage in its negotiations with the miner. The events surrounding the closure of Colorado's Summitville Mine are a perfect example of how powerless regulators can be in enforcing the law when confronted with the knowledge that the financial assurance it holds comes nowhere near the amount required to reclaim the site (Danielson and Nixon, 2000).

Experience in Canada and the US has shown that in order to be effective, a properly run financial assurance program should consist of three parts: permitting, inspection and enforcement, and the financial assurance itself. Lacking any one of these elements, the program may when called upon be unable to fulfill the objective of paying for the costs of reclamation without recourse to the taxpayer.

Important Issues Related to Financial Assurance

Experience in Canada and the US has shown that because mining is an industry that defies generalization, no one system of financial assurance is completely suited to meet the range of demands placed upon it. Instead regulators should focus their efforts on creating a system of financial assurance whose hallmarks are flexibility and stakeholder accountability. The system must be flexible if it is to be capable of reclaiming sites that can range from gold mines to gravel pits. In order to be acceptable to the public, the system must also be seen to hold mining companies accountable for cleaning up their operations after the valuable minerals have been extracted from the earth.

Latin America

Our review of Latin America found that there is great variability in terms of how reclamation plans are financed. It is often the case that while governments may require companies to set aside money to cover the cost of environmental clean up, few jurisdictions actually require that money be specifically set aside to cover the costs of reclamation.

To ensure the execution of the activities identified in the Plans of Environmental Management, Ecuador requires miners to purchase the necessary insurance or bank warranty to cover the costs of reclamation. This financial assurance must remain valid up to one year after the end of the mining concession.

In Argentina there is no specific financial warranty that addresses mine closure, although article # 23 of *Ley de Inversiones Mineras* does require a mining company to make annual deposits (until 5% of the costs of the extraction and dressing operations, deducible from the Income Tax) to an environmental remediation fund. If this fund remains unused, it reverts to income and is subsequently taxed at the end of the production cycle. The law does not specify if this fund must be used to support other tasks indirectly involved in closure and site rehabilitation.

The legislation in Bolivia, while not specifically addressing the subject of financial warranties does use other mechanisms to guarantee that the closure plan is adequately funded. Three years after mine closure an independent auditor is required to confirm that the company has implemented its closure plan. If the auditor approves the work, the company is exonerated from any further legal liability for the property.

In Brazil the *Plano de Recuperação de Áreas Degradadas* (PRAD*)* contains no legal provisions that require a mining company to provide any form of financial assurance to cover their closure costs. What does exist is a form of financial compensation royalty for the extraction of mineral resources. That law stipulates how the royalty (2 to 3% of mineral production) is to be divided between the state government and the federal district (23 %), the counties (65%) and the National Department of Mineral Production (12%). The revenues raised by the counties are to be applied to projects that directly or indirectly support or compensate the local community from any losses associated with the mine. In the past such projects have included measures to improve infrastructure, raise environmental quality, public health and education.

Many observers have argued that the reason behind the upsurge in foreign investment in Latin American during the 1990's is generally due to that region's less restrictive environmental legislation and lax enforcement. It is further suggested that a more rigorous application of closure laws would have the unintended effect of making much of the mineral industry in Latin America globally uncompetitive. These are valid fears and as Latin American nations continue to strengthen their democratic and economic institutions, it is likely that the imposition of additional reclamation regulations will indeed force many marginal operators out of business. While these closures may cause some initial economic problems, we suggest that over the longer term the domestic mining sector as a whole will be strengthened as the more innovative companies expand and modernize to fill the void created by the departure of the competition.

The Social Impact Of Mine Closure

What happens to a community following the closure of a mine has lately become a hot topic of discussion for social scientists, politicians, and members of the general public. In the past the primary concern of company and government officials following closure was centered on ways to minimize revenue loss, risks to public health and safety, and environmental damage. Only lately as a result of increased public pressure has the scope of these concerns widened to include steps to minimize the socioeconomic effects of closure on the health of the local community.

In our search of the literature we attempted to highlight a number of the primary issues industry, government and local stakeholders must address to mitigate the adverse effects mine closure has on the health and well being of a community. Some of the problems that we identified included loss of income, worker mobility, skills training, physical and mental well being, and alternative patterns of work. In attempting to assess the full impact mine closure has on a community; it is necessary to look beyond those people and institutions that are directly affected by the closure. Equal consideration must also be given to those whose quality of life will also be affected as a result of their indirect connection to the mine.

The Impact of Closure on the Individual

The social impact of mine closure has been well documented by behavioral scientists. The psychological impact of losing one's job can take the form of an increase in blood pressure and cholesterol levels, increased substance abuse, family violence and breakup (Warhurst et al. 2000). Further adding to the problem is that in designing transitional programs for displaced mine workers there is a need to overcome the strong cultural milieu in which most miners work. Miners have long prided themselves on their perceived physical toughness and independence of spirit. In this context, the effect closure has on a miner's sense of self-worth is particularly damaging.

The stress caused by losing one's job can also have a profound effect on how mine workers interact with their families. Repeated studies have demonstrated a link between male unemployment and the negative effect it has on the quality of life of the spouse. In attempting to cope with their husband's loss of socioeconomic status, women tend to respond by either leaving their current jobs or by postponing their return to the workforce (i.e., following childbirth). Such choices put a further strain on the already weakened financial health of family.

In advance of creating new support services for displaced workers and their families, both government and company officials need to understand the dynamics of how individuals respond to job loss. In their examination of the problem, researchers have identified three basic unemployment typologies to describe which coping mechanisms an individual will adopt and the amount of psychological stress experienced as a result of losing one's job. Because a group of laid-off mine workers will exhibit the characteristics of all three typologies, an effective support system must be capable of responding to the specific needs of each.

The Impact of Closure on the Community

Communities too experience profound change as a result of mine closure. Loss of community cohesion as a result of increased tension between employed and unemployed mine workers is one of the inevitable results of downsizing prior to closure. This tension is in addition to the traditional animosity that often occurs between marginalized locals and the relatively wealthy mine workers. In isolated regions these socioeconomic tensions are likely to become even more profound. It is important, therefore, that decision-makers initiate policies aimed at creating a suitable support infrastructure before, during and after closure.

Potential impacts of mine closure on a community will vary considerably depending on the number of jobs lost relative to the size of the affected community, its social composition and its level of internal cohesiveness. The effect of closure on spin-off industries will again be determined by the level of economic diversification that the community has achieved during the operational life of the mine.

In those isolated communities where the benefits of mining have become closely integrated into their socioeconomic structure, mine closure can be particularly devastating on the health of the local community[4]. Alternatively when mines close in towns with strong links to the surrounding region, the effects of closure can in turn have a much greater regional impact.

The life span of a mine can also play an important role in determining the degree to which closure negatively impacts a community. New mining towns in Canada and the US are constructed with a known limited life span in mind. Employing workers who recognize the temporary nature of their employment, these people typically do not form deep attachments with their community. Because these workers also tend to be on the whole younger and better educated, they are again more likely to find the prospect of finding work outside of mining less stressful. Alternatively in communities where employment in the mines has spanned several generations and when meaningful economic diversification within the community is limited, the loss of the mine is particularly stressful. Under these conditions it becomes very difficult for either individuals or communities to conceive of a future without mining. In such situations it is common for a community to be stricken by a general malaise that saps their ability to devise an effective coping strategy. According to Natural Resources Canada, some 150 communities (700,000 people) across the country have been heavily reliant on mining. When mines close in these communities the federal and provincial governments are required to spend billions of dollars to help diversify the economic structure of mining towns. To avoid these costs in the future, provincial governments are encouraging companies to adopt "fly-in-fly-out" approach to avoid establishment of new mine towns in remote areas.

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[4] This close connected can be the result of direct taxes, provision of important infrastructure, or as the result of important economic spin-offs,

Best Practice for Reducing the Social Impacts of Closure

In the same way that environmental impact assessments (EIA) were devised as a tool for measuring a mine's impact on the health of the surrounding environment, social impact assessments (SIA) are today seen by many social scientists as an equally effective device for determining the effect mining has on the social fabric of a community. More specifically, SIAs are seen as an effective device that decision-makers can use to better understand such issues as:

- How to encourage the formation of partnerships between industry, government and communities for the purpose of facilitating a more equitable distribution of the benefits and costs of mining; and
- How to formulate development strategies that will foster long-term community socioeconomic independence and sustainability.

In developing policies aimed at countering the social impact of mine closure it is important to remember that one should not think in terms of generic answers. Because every individual and the community they are a part of is the product of their own unique history, solutions must be custom made to fit the unique circumstances of each closure situation. Those tasked with providing solutions must do so only after carefully weighing the socioeconomic capacity of the community to carry on past closure. Finally, if solutions do exist they must come from the shared vision of all of the relevant stakeholders. Top down solutions, originating either from the government or the company will simply prove inadequate to the task.

Latin America

In Latin America, as in other parts of the world, the environmental effects of mining are thought by the companies to be far better understood than the comparable social effects. Most countries require companies to produce EIAs prior to receiving the necessary operating permits. Unfortunately no comparable document exists to measure the social impact of the mine, either during its operation or after closure. Some governments still abide by a set of outdated rules that do not require companies to address any of the social issues connected with their operations. An exception to the rule is found in the regulations governing the treatment of indigenous peoples. If they reside within the confines of their reserves, aboriginals are protected by law from the environmental and social impacts of nearby mines.

MINE CLOSURE AND WOMEN

Through the course of our literature review, we found that at present very little has been written on mine closure and its impact upon the quality of life of women. At least two possible explanations may account for this situation. First, women do not in fact experience unique hardships following the closure and reclamation of a mine site. Second, though women's experiences may be different this phenomenon has yet to be thoroughly researched and documented. Whatever the explanation, until further research is conducted there will be no clear understanding of the effect mine closure has (unique or otherwise) on the lives of women.

A Review of the Available Literature

While accepting that the paucity of available literature makes it difficult to formulate any conclusive statements, some general observations are still possible. These suggest that while men may shoulder the greatest direct impact, it is women who suffer most from the indirect effects of closure. In a 1987 study on the socioeconomic impact of job losses resulting from mine closure, researchers found that displaced male workers tended to transfer their negative emotions onto their immediate families (Kinicki, et al., 1987). When combined with a noted increase in the consumption of alcohol and drug use, husbands were more likely to physically and mentally abuse their wives. Even in those cases where husbands tended to internalize their emotions, women still were left to deal with the fallout. Faced with the sudden loss of self-worth, many men fell victim to physical and/or mental breakdown. In these circumstances the responsibility for maintaining the continued social and economic viability of the family unit now rested entirely with women.

Adapting to the demands of having to provide for the material needs their families, one might expect that these women would naturally seek to find gainful employment. Interesting enough this is often not the case. In response to their husbands' job loss, women were found to either delay their return to the workplace or even quit their existing jobs for fear of upstaging their husbands as the family's primary breadwinner. In either situation, women are being required to make career sacrifices in an effort to maintain social harmony in the home.

Because women in most developing countries still tend to spend a large part of their child-bearing years at home looking after the needs of their children, it is arguable that women would benefit differently from men from alternative approaches to mine reclamation. Reclamation practices that stressed the benefits of increased public health and safety and alternative productive uses for the former mine site could specifically benefit women in the following ways:

- Reduce the likelihood that former mine sites would threaten the health and safety of women and children living, working and/or playing in the area;
- Create economic opportunities for women by allowing them to engage in substance farming and/or fishing on the site.

Latin America

The connection between women and mining in Latin American countries has not received a great deal of attention over the years. With so many other issues on the table, many researchers simply did not see it as an issue of importance. Only recently has some interest been shown to consider the question of gender and the mining industry.

The mining community has traditionally looked upon women as a potential source of problems. In some cases they have even come to symbolise bad luck. Though far more widespread in the 1960's and 70's, even today some mining camps bar women from entering the property. Whether based on simple superstition or legitimate health and safety concerns, women are still confronted with a number of institutional and societal barriers that prevent them from fully participating in the economic rewards that flow from mining.

In the last twenty years some of these systemic barriers have begun to break down. While direct employment opportunities are still limited when compared to men, the mere presence of women in the mining camps is no longer automatically seen as a source of problems. In fact, the presence of women (i.e., wives) is now viewed by some as a potentially stabilising force in the camps. Unfortunately for these women, life in the camps allows them few opportunities to pursue their own career path.

REHABILITATION AND CLEAN-UP

Most discussions on the effect new government policies have had on improving mine closure practices have focused on changes to the regulations. We believe that it is necessary to go one step further by including technology in the discussion. How policy, the regulations and technology interact has taken on a new significance in recent years as resource managers have demonstrated an increased willingness to consider the value to society of new approaches for resolving the environmental problems associated with mine closure. This new approach is best characterized by a preference for policies that could be described as anticipatory and preventive, rather than reactive and corrective (Isnor, 2000). This change reflects the results of past debates over the relative merits of regulatory regimes that require mining companies to adhere to very specific technical norms (i.e., the US's SMCRA of 1977) versus more generalized performance based reclamation objectives. How this debate is ultimately decided will have a significant impact on which technologies are ultimately selected to achieve the environmental, economic and social objectives of closure.

Government Policy and Reclamation Technology

Though the main responsibility for technological innovation lies with industry, governments often play an important role in deciding the pace of technological advancement. Depending on how the regulations are written, governments can either create or remove barriers to the way industry is allowed to close and reclaim a former mine site. The most obvious example of the relationship between policy and technology is found in the US Surface Mining and Reclamation Act (SMCRA) of 1977. This national set of regulations governing the closure and rehabilitation of coal mines consists of hundreds of pages of highly detailed specifications for the construction, ongoing maintenance, and eventual reclamation of every aspect of the mine site (Danielson and Nixon, 2000). Not only did SMCRA direct that mining companies reclaim their operations, it specifically told them how it was to be done.

While SMCRA is generally regarded in government and industry circles as a success story, many observers caution against using the Act as a model for how other nations should attempt to regulate their domestic mining industries. Given the Act's highly proscriptive approach to achieving the government's policy objectives, it was necessary to create an enormous supporting apparatus of highly trained reclamation specialists. The costs of administering SMCRA are substantial and it is only because of the unique economics of coal production that the industry has been able to support the Act and still remain competitive. Given the vastly different economics that exist for hard rock mining, it would be virtually impossible for any single nation to apply a SMCRA type approach for fear that it would bankrupt the domestic industry.

Industry Best Management Practice (BMPs)

To assist the domestic mining industry to remain globally competitive, the governments of Australia, the US, and Canada have developed programs that encourage the free flow of information between public and private sector organizations[5]. Building upon the knowledge and experience of reclamation experts in government, universities, and private industry, this sharing of information has formed the basis for industry BMPs that are freely available to all interested parties. An important benefit for those participating in this

[5] Examples include MEND (Canada), IMEC and MRRP (Australia). With the demise of the US Bureau of Mines in 1995 it remains unclear how government will continue its role in fostering the sharing of information between public and private sources.

partnership is that it allows each member to leverage their limited R&D dollars by bringing together research talent from a range of disciplines to tackle common technical problems.

It is interesting to note the evolution that closure BMPs have undergone in recent years. Originally conceived to address pressing environmental issues, they have now begun to report on methods for minimizing the socioeconomic consequences of closure as they are seen to affect local communities. This shift reflects what is a growing realization within government and industry circles that social impacts have now eclipsed environmental concerns as the principal issue to be addressed when planning for mine closure.

FACILITATION AND MEDIATION IN RESOURCE MANAGEMENT DISPUTES

Until relatively recently, decisions on how to manage mineral resources have remained within the principal domain of government and the mining industry. This unspoken policy of excluding the general public from participating in decisions that directly affect their quality of life was based on the long-standing belief that public managers are technicians who worked best when insulated from unnecessary public interference. Only within the last thirty years have most public managers come to the realization that public approval is often more important to the successful implementation of a policy than just its technical merits. The most direct way of gaining public approval is by involving citizens directly in the decision-making process. Where this approach has been successfully implemented, public participation has lead to the creation of more effective decisions, increased public support for those decisions, and a strengthening of democratic institutions. Conversely, when it has failed it has led to an increase in the level of public dissatisfaction, ineffective decision-making, and a weakening of the democratic process.

North America

In reviewing the history of multi-party resource management decisions in North America, disputes between competing groups have often occurred when one party (i.e., government) fails to adequately acknowledge the concerns of another party (typically the weaker one) as being relevant to the settlement of the dispute. As a consequence many of the decisions resulting from this process have lacked the legitimacy that is necessary to ensure their eventual implementation. This issue of legitimacy becomes even more problematic when the disparity of power between groups (often government and industry versus private citizens) is greatest.

To increase the perceived legitimacy of the process, governments in Canada and the US have taken steps to actively involve the public in identifying solutions to important public policy questions. What constitutes an appropriate level of public involvement, however, is not always an easy question to answer. There are many models of public involvement to choose from. Each model has been developed to address different policy and decision-making requirements. Each model also places different demands on the government and public to work together to produce enduring solutions. To safeguard the legitimacy of the process and the decisions that flow from it, the government has an obligation to level the playing field. In the context of resolving disputes between the mining industry and private citizens, this means taking all reasonable steps to assist the latter in presenting its case.

Tailoring New Approaches to Negotiation to the Mining Industry

When practiced skillfully, the process of negotiating settlements between representatives of the mining industry and the communities they work in is often limited to the initial start-up and operational phases of a mine. Little attention has been given by the companies to build a durable relationship with communities at the initial phases of a mining project, i.e. geological exploration, when the community expectation to have large benefits from the new mine is very high. As the life of a mine draws to a close, the lines of communication between the mine and the community have traditionally been one way. The company informs the community that the mine is closing (often with very little warning) and the community is left scrambling to pick up the pieces. Unlike when the mine was initially permitted, during closure there are no formal mechanism that brings together the company and community leaders to negotiate an equitable closure settlement. Without a more systematic approach to addressing the social and economic costs of closure, decisions on post-mine land uses often fail to help the community in its transition to life after the mine.

In an effort to redress what they perceive as an unnecessary source of friction between miners and the communities in which they operate, some researchers suggest that a new approach to community consultation be considered. This approach would see both parties become much more active in developing a closure strategy that balances the legitimate needs of both sides. The onus for making this approach work falls primarily upon the industry. Rather than seeing it as just another attempt by government to download its social responsibilities onto the industry, miners should instead view it as a necessary concession for removing a major source of bitterness that has long plagued industry/community relations.

The Whitehorse Mining Initiative

In Canada important progress has been made in developing a framework for bringing together stakeholders from government, the mining industry, and community groups. This framework, known as the Whitehorse Mining Initiative (WMI) Leadership Council Accord, was signed in September 1994 and represents a critical first step in a process that would see the Canadian mining sector adopt a much more sustainable approach to the development of mineral and metal resources. The WMI sought to establish a set of guidelines for achieving stakeholder consensus in a number of areas where action was required to further the goal of a prosperous and sustainable mining industry in Canada. The Accord recognized the fact that in order to attain these goals, no element of economic, environmental or social sustainability can be pursued in isolation without it negatively impacting the whole.

Latin America

Upon a careful review of the available literature, very little has been written in Latin America on how to apply conflict resolution principles in the context of mine closure. What information is available suggests that a multi-stakeholder approach has been used with some success to build consensus on the future direction of regional economic planning. During the Amazonian gold rush in the eighties, the mining association of Brazil (IBRAM), and the Mining Federal Agency (DNPM), invited representatives from the “garimpeiros” (artisanal miners) and the mining companies to attend a forum held to try to address the simmering problem of land invasion. It was unfortunate that previous clashes between the two groups had been so acrimonious that it poisoned this attempt to resolve the issue through constructive negotiation. This would confirm the commonsense notion that negotiated settlements are only possible when they are built upon a foundation of mutual trust and goodwill.

Using a similar methodology, efforts are currently underway to assist artisanal quarry workers near Santo Antonio de Padua, Rio de Janeiro State, Brazil. The objective of the meetings is not only to try to resolve some current production and legal problems, but also to make stakeholders think about what will happen to the community once the quarries close. By thinking about these issues now, local officials are hoping to mobilize the community to develop its own vision of the future. Assuming that this is achievable, it becomes far more likely that the mine site will be reclaimed in a manner that is consistent with the community's vision of the future (Peiter et al., 2000).

ETHICS AND SUSTAINABLE DEVELOPMENT

When evaluating the efficacy of government reclamation policies and regulations it is important to consider the pertinent technical and legal issues, but what is often overlooked is how mine closure and reclamation decisions measure up against a society's dominant ethical beliefs. If government regulators and the mining industry both had a clearer understanding of the ethical consequences of their actions, we argue that much of the public's dissatisfaction with our current reclamation practices would disappear.

Ethics and Mining

Mining brings both costs and benefits to the communities that it affects. Those who stand to gain or lose from the operation of a mine are typically referred to as stakeholders (Cragg, et al., 1997). Ethics requires that a mining company take steps to identify the nature and extent of its obligations to these stakeholders. How can a company determine its ethical responsibilities to its stakeholders? Cragg et al., (1997) suggests that a company must address stakeholder concerns in four key areas:

- The development of a mine requires the voluntary participation of many different individuals. Because participation that is truly voluntary is built upon informed choice, the company is ethically bound to disclose any information that may affect a stakeholder's decision to become involved with the project;
- The company must identify all involuntary stakeholders and determine the extent to which the development will impact the quality of their lives;

Ethics requires that a company engage in a fair distribution to stakeholders of the costs and benefits that flow from the project; and

- An ethical company has an obligation to avoid actions that cause undo harm to stakeholders.

Sustainable Development and Mine Reclamation

Growing public concern over the state of the environment has proven to be a force for change in the mining industry. The highly restrictive terms and conditions that detail how a mining company is to develop, operate and close down a mine site reflect the public's heightened sensitivity to the social, economic and environmental impacts of mining (Brevik, et al. 1997, Carbon 1997, Cragg, et al. 1997, & Cordes 1997). The public's demand that the industry become more sustainable is forcing many companies to re-examine their current business practices. However for some this begs several important questions: How can mining be sustainable? and What is the relationship that exists between sustainable development and mine reclamation (Lavkulich 1991)? Answers to these questions are complex, contentious and constantly evolving in response to changing circumstances. One approach that has been taken to simplify the problem is to view mining as a temporary use of the land. In this regard mining is deemed to be sustainable only in the context that its effect upon the surrounding ecosystem and local community is sustainable. Given this understanding, it naturally follows that the act of reclamation assumes critical importance when reestablishing the sustainability of both the ecosystem and community that have been impacted by the operation of the mine (Powter, et el. 1991).

RISK ASSESSMENT OF ABANDONED AND RECLAIMED SITES

The issue of how best to reclaim abandoned mine lands (AMLs) has been a source of much heated debate between various levels of government, the mining industry and the public. By most accounts the scale of the problem is enormous; by some estimates there are over 500,000 AML sites in the United States alone (Mining Watch, 2000). Less from a technical perspective, the task of dealing with these sites is made more difficult by a regulatory system that makes third party intervention exceedingly risky.

North America

Any serious examination of the issues at play for resolving the on-going problem of how best to deal with AML sites will quickly discover that easy solutions are not forthcoming. Though each site presents its own set of unique technical problems, the real challenge facing government regulators is developing a legal mechanism that insulates third parties from potentially damaging civil and criminal liability. Unfortunately, the question of how best to amend the existing regulations is subject to much debate. This squabbling over the facts of the case has stalled most attempts by government regulators to take decisive action to resolve the problem. In contrast to the regulator's inertia, private citizens and NGOs have become increasingly vocal in their demands for something to be done. The need for immediate action appears obvious when one considers the following:

- The government presently directs mining companies to allocate enormous resources to minimize the effect of off-site pollution when a far greater benefit to the environment would be possible if a portion of these funds were directed towards reclaiming AML sites; and
- Liability concerns are preventing mining companies from going back into historic mining districts and re-mining old abandoned mine sites or doing volunteer cleanup work.

Latin America

Ordinarily the task of dealing with AML is a difficult one, however in Brazil it is further complicated by the fact that there is little cooperation between the various levels of government to tackle the problem. This is preventing any action from being taken on the important issues of financing AML reclamation and creating a public process for deciding on possible future land uses for AML sites.

Another problem that still must be overcome is the lack of information that accompanies discussions of the AML problem in Brazil. In most cases there is simply not enough data available to assess the impact on local air and water quality posed by AML sites. Without such data it nearly impossible to accurately measure risk and assign priorities for reclaiming AML sites. As a first but necessary step for correcting the problem, an abandoned and restored sites database has been proposed for Latin America.

Of the handful of AML reclamation projects that have taken place in Brazil, the mining companies have so far declined from taking a leadership role. Instead it has been left to the industrial and real estate companies and the government to propose solutions to that country's AML problem (Bitar, 1997).

WATER QUALITY

As most technical issues related to mine closure are more visible and easier to be quantified than social aspects, they usually receive more attention from companies, inspectors and legislators. Large investments have been made to generate sound solutions for problems related to mine effluents, but, unfortunately, "walk-away" solutions are not yet universally achievable.

While much has been done over the last two decades to address the problem of mine water effluent, the target of zero emission still remains just out of reach. Because aquatic systems and the biota living in them are often acutely sensitive to even minor changes in pH, heavy metals and/or suspended solids, the mining industry is under a great deal of pressure to minimize its ecological footprint. In a recently prepared document by the MPC-Mineral Policy Center (1999), a Washington based non-governmental organization (NGO) that is active in environmental issues, a series of sweeping changes were presented that, if adopted, would greatly reduce the impact of mining on surface and groundwater resources. Though the document contained many valid criticisms of current industry practice, they are nonetheless generalizations whose efficacy can only really be determined when taken in the context of a specific mine site. For example, MPC's call for a complete ban on submarine tailings disposal overlooks the fact that under the right circumstances and in specific cases, this practice has been proven to be the most effective way to prevent ARD and to reduce the aesthetic impact of tailing piles. Acid Rock or Mine Drainage (ARD or AMD) has been considered to be the industry's greatest mine closure and reclamation challenge. ARD occurs naturally in regions with high concentrations of sulfide ore. However when a mining operation exposes sulfidic rock to air and water, the process that leads to ARD is accelerated. In sufficient quantities, this acidic drainage can liberate trace metals associated with waste rocks and/or tailings.

Because the mining and mineral processing often uses large amounts of water, this can be a source of conflict in places where water resources are limited. In an effort to reduce some of these conflicts, the mining industry actively promotes the use of technologies that allows for much of this wastewater to be recycled. For instance, in Canada 70% of the water used in mining operations is reclaimed. While recycling can reduce the quantity of water used by the mining industry, it is the issue of water quality that is of greater concern to the communities located near mine sites. Storage of wastewater and tailing pulps facilitates the mobility and access of pollutants to water streams. Water siltation has been a common issue when tailing dam spills occur or as a result of poor mining practices, such as use of hydraulic monitors in placer mines in Northern Canada or by artisanal mining activities in Latin America.

As particulate matter is the main pathway in which metals and other contaminants enter water systems, tailing containment is an ongoing source of anxiety for local communities. The increased turbidity caused by suspended sediments may also lead to a decrease in the growth of aquatic animals by reducing the amount of light reaching photosynthetic plants that the animals depend on as a source of food and/or protective cover.

The main effects of mining on water bodies has been listed by Bakau (1993):

- Suspended solids and sediment from runoff and processing operations;
- Acids from various processes;

Acid mine drainage during and after operation;

- Heavy metals leached from wastes and tailings around the site;
- Sulfate, thiosulfate, polythionates etc. from acid drainage;
- Arsenic and other salts from oxidized mine waters;
- Mercury, if used in the process, or from ores;

- Cyanide if used in leaching processes;
- Oil and fuels from ancillary operations;
- Other processing chemicals as may be used on the site;
- Groundwater constituents that may be pumped or discharged off-site; and
- Sewage from the site.

By themselves, the large volumes of waste produced by metal mining and mineral processing should cause minimal environmental damage. However, when surface and ground waters are allowed to interact with these wastes, metals and other potentially toxic substances can be released. When this release is uncontrolled, it can lead to serious contamination of surface and groundwater stocks.

The BHP owned Ok Tedi mine in Papua New Guinea is a striking example of how poor mining practices can seriously damage an entire watershed. Due to the rugged terrain of the area, the local Government allowed the mine to release annually over 20 million tonnes of copper-rich tailings directly into a river. The suspended sediment level is 4 to 5 times higher than pre-mine conditions and siltation is affecting 1350 km² of forest and has reduced the local fish population by 90% (BHP, 1999, Minerals Council of Australia, 1999). Riverine tailing deposition has been also practiced by Placer Dome in the Porgera Mine near Ok Tedi. In many regions of the globe riverine deposition is a standard industry practice that has led to serious long-term environmental impacts that have tarnished the image of the mining industry. This is fundamentally different from responsible subaqueous (lake or marine) disposal.

Tailings dams are among the largest structures ever constructed by man. Some of the biggest contain as much as 100 million tonnes of stored slurried tailings. With over 3500 tailings dams worldwide, these structures represent what is potentially a large and growing problem for the industry (Davies et al., 2000). The recent failure of some of these dams has resulted in loss of human life, extensive terrestrial and aquatic environmental damage, and serious economic costs to the mines. The contaminants often reported in surface and groundwater as a result of tailings impoundment failures include heavy metals, acids, cyanide and in some cases, radioactive elements.

North America

The degree of contamination of an aquatic ecosystem resulting from natural processes rather than from anthropogenic sources has been investigated by the Mining Association of Canada with the support of the Ottawa-based International Council of Metals in the Environment (ICME). The ICME represents twenty-seven major mining companies from around the world. Whether by natural or man-made causes, the contamination of water supplies near mining operations infers liability to the company. Therefore the company must endeavor to understand the physical and chemical processes that cause the transformation and dispersion of metals in surface waters in order to apply the correct mitigation procedures. In some respects, mining companies have realized that by understanding the biogeochemical cycle of trace elements in different environmental compartments, it may be possible to develop an appropriate "walk-away" solution once mining operations have ceased. Conversely, drainages from abandoned mines require "eternal" environmental monitoring or maintenance after closure due to a lack of understanding of the local geochemical reactions.

Water use by mining has been a contentious issue in those jurisdictions, like Nevada, where water resources are scarce. To sustain the operations of a mine, it may be necessary to withdraw water to aid in extraction or processing through damming or water diversion channels. These withdrawals of water may potentially deplete groundwater reservoirs and permanently lower the groundwater table. The design of the mine infrastructure may also alter the flow patterns of existing watercourses. For example, the Ekati Diamond Mine in the Northwest Territories, Canada, requires the de-watering of many lakes since the ore deposit is located beneath the water body.

Water quality is impacted by sources of ARD: discharge from open pits; waste rock dumps, tailings and ore stockpiles. Open pit operations in particular can expose very large quantities of sulfide-bearing rocks that may potentially affect water quality through the production of ARD. To put the magnitude of the problem into context, in the US about 16,000 km of streams and 12,000 ha of impoundments are estimated to be seriously affected by acid generated by sulfide-related mining activities (Canty, 1999). In 1987, it was estimated that in Canada alone ARD from active and abandoned mine sites affected an area of approximately 15,000 ha. The estimated cost for treating this problem has been conservatively estimated at Cn$ 6 billion dollars. In an attempt to address the issue of ARD, the Government of Canada created the Mine Environment Neutral Drainage Program (MEND). The principle objective of the MEND program is to provide scientific, technical and economic basis for the mining industry and government agencies to predict the long-term management requirements for monitoring and combating the effects of reactive tailings and waste rock dumps.

The placement of tailings or waste rock underwater may occur in a flooded open pit, in a lake, in the ocean or man-made impoundment. The low content of oxygen prevents propagation of sulfide oxidation and acid generation. In the most recent conference on ARD control in Vancouver, Canada (Dec. 1999) various authors have approached subaqueous deposition as the safest solution for acid-generating tailings. However, there are many public and regulatory issues related to the potential impact this disposal method may have on the health of benthic communities. Underwater disposal requires an advanced understanding of the local and regional hydrogeology and the characterization of the tailings if the sulfide-bearing rock is to be safely disposed of in a marine environment. Island Copper Mine on Vancouver Island, Canada, is an example of where this disposal technique has been successfully applied. From 1974 to 1995 between 30,000 to 60,000 tonnes of tailings were daily discharged at 50-m depth into the ocean (Welchman and Aspinall, 2000). For almost thirty years a comprehensive program of marine monitoring was conducted by an independent team of scientists to determine what effects this form of waste disposal would have on the health of the receiving environment. What the scientists found was that the site’s fish and shellfish population experienced no lasting adverse effects from the dumping, and that after closure local populations had returned to pre-mining levels (Ellis et al, 1995). In any case subaqueous discharge should not be considered as a universal solution to the problem of long-term tailings disposal. The subject deserves further investigation, as all of the relevant factors are not clearly understood.

Another alternative strategy for treating ARD is through the use of constructed aerobic or anaerobic wetlands. Extensively used to precipitate iron, aluminum and manganese from mine waste water, the US Bureau of Mines has estimated that over 400 aerobic wetlands have been constructed to treat mostly coal mine effluent. Sorption on organic matter seems to be the predominant mechanism to remove metals from the acid drainages. While the use of constructed anaerobic wetlands to treat effluents from base metals mines is promising, it is still experimental with limited application in large-scale mining operations.

Overall, the most prudent approach to ARD prevention is to reduce the production of acid in sulfide-bearing waste rock by processing the waste rock. However, the most common (and currently the most cost-effective) approach for preventing or controlling the migration of ARD is the use of dry covers to divert or impede water penetration into piles of sulfide-bearing wastes. There is a large group of environmental engineers in Canada that believe that the costs associated with the flotation of sulfides from tailings would be lower when compared against those costs associated with the construction of dry covers. The application of this approach may result in a viable "walk-away" solution for mine sites containing sulfide-bearing rock.

Latin America

Given the great diversity of climate, geology and mining activities that can be found in Latin America, it is not surprising that there is no single water quality issue that affects the continent's principal mining countries. In the case of Chile the concern shifts to addressing, still in a reticent way, the problem of ARD from that country's extensive copper-sulfide mines. Recent political changes in Chile have proven to be a catalyst for changes in that country's approach to regulating the reclamation activities of mining industry. Taking an approach that was similar to that of Canada and the US in the early 1970's, Chile in 1997 introduced reclamation regulations that were intended to address potential threats to human health and safety following mine closure. By looking at the issue of mine reclamation so narrowly, the government soon realized that it was unable to effectively manage many of the other problems that are associated with mine closure. To address problems such as ARD, the Government of Chile has recently initiated a process of regulatory reform that will eventually lead to a complete overhaul of the country's laws governing mine reclamation. As pollution does not observe national borders, Chile intends to promote through CAMMA (Annual Conference of Ministers of Mines of Americas) a process that would see the adoption of a transcontinental approach for addressing water quality problems caused by mining.

In Brazil and in almost all other countries of Latin America, the principal concern of regulators is controlling mercury pollution of water resources from that country's huge artisanal mining community. Recent estimates suggest that there are 10,000 of so small-scale mines in Brazil employing between 100,000 – 250,000 people[6]. While the mining operations themselves can serious degrade the water quality of local streams and rivers through increased siltation, the main problem occurs when mercury is added to assist in the recovery of the fine gold. Due to a lack of education amongst the miners, the low cost of mercury, and the unregulated nature of the industry, there is no concerted effort to recycle the added mercury. As a result, it has been roughly estimated that for every tonne of gold recovered, a tonne of mercury is released into the environment (Veiga 1997). Elevated mercury levels and symptoms of chronic mercury toxicity have been documented throughout the Amazon. Even in villages located far from where gold mining occurs, the wide-scale consumption of contaminated fish has led to high levels of mercury being found in the blood of human test subjects. Potential impacts of long-term consumption of moderate concentrations of methylmercury-contaminated fish can include neurological damage, visual constriction, numbness of the extremities, impairment of hearing and speech.

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[6] These estimates from various sources, including Brazilian, National Dept of Mineral Production, the United Nations and the World Bank. In 1996, UNIDO (United Nations Industrial Development Organization) has estimated that 200,000 to 400,000 artisanal gold miners were active in the Brazilian Amazon representing, that time, about 37 to 40% of artisanal gold miners in Latin America.

Mercury pollution caused by artisanal mining as well as by other sources such as wood or fossil fuel combustion, reservoirs flooding, etc. has been of great concern in all Amazonian countries (French Guyana, Suriname, Guyana, Venezuela, Colombia, Ecuador, Peru, Bolivia, Brazil). Bioaccumulation of mercury in aquatic organisms has been demonstrated in a large number of monitoring programs, but little has been done by government body to provide solutions for the problem. UNIDO, World Bank, CETEM, CIMM, Intermediate Technology, Projekt-Consult, Swedish Geological AB, CENDA Foundation, US Agriculture Dept., Geological Survey of Canada and another large number of Brazilian and international organizations have published technical and regulatory procedures to reduce mercury emissions in developing countries but these measures rarely were implemented or reached more organized sectors of the artisanal mining. Unfortunately, the reduction of the mining activities as a consequence of depletion of easily extractable gold ores, seems to be the only reason that mercury emissions from gold mining has been declining. As no clean-up effort has been carried out in Latin America, the necessity to deal with highly contaminated sites will be our legacy to future generations.

CONCLUSION

In completing this project for MPRI, we endeavored to highlight what we believe are the emerging issues that will confront researchers in the future. It is clear that as the evolution of thinking on mine closure and reclamation has made great strides over the last three decades, the future promises to usher in even greater changes. Much of the impetus for these changes comes from the public's growing awareness that our existing western approach to economic development may be incompatible with the need to maintain a healthy ecosystem. In failing to respond to public pressure, the mining industry risks the specter of public boycotts of its products and increased government regulation over its activities.

As an industry that is often harshly criticized by environmentalists, the media, and even by some members within its own ranks, mining can no longer afford to be complacent. To safeguard their continued access to large tracks of undeveloped public land, miners must be willing to take bold steps to present themselves as responsible corporate citizens. This means providing strong evidence to the public that mines can be operated, and later reclaimed, without any long-term harm to the environment. In order to provide such evidence government and industry leaders must acquire a more thorough understanding of the biophysical and socioeconomic consequences of mining. This database is intended to assist researchers in furthering this understanding.

REFERENCES

Balkau, F. (1993). Pollution Prevention and Abatement Guidelines for the Mining Industry. UNEP IE/PAC, 19p.

B.C. Ministry of Employment and Investment (1997). Health, Safety and Reclamation Code for Mines in British Columbia, Victoria, BC, Canada. ISBN 0-7726-3150-6

BHP (1999). BHP and Ok Tedi, a Discussion Paper. Aug. 1999. http://www.bhp.com.au/eac/env99/case/oktedi.htm

Bitar, O. Y. Avaliação da recuperação de áreas degradadas por mineração na região metropolitana de São Paulo. São Paulo, 1997. 183 p. Tese (Doutorado) – Escola Politécnica, Universidade de São Paulo.

Brevik, T., et al. (1997). Mining: Changing the focus for a sustainable future. *Industry and Environment*. UNEP. v. 20, n. 4, p.3.

Canty, M. (1999). Overview of the sulfate-reducing bacteria demonstration project under mine waste technology program. *Mining Engineering*, v. 51, n.6, p.93-99. Ed. SME.

Carbon, B. (1997). Sustainable Development and the evolving agenda for environmental protection in the mining industry. *Industry and Environment*. UNEP. v. 20, n. 4, p. 10-13.

Cordes, J.(1997). Mining and the Environment: Driving forces for change. *Industry and Environment* UNEP. v. 20, n. 4, p. 25-28.

Cragg, W., et al. (1997), Ethics, surface mining and the environment. *Mining Environment Management*. v. 5, n. 1.

Danielson, L. and Nixon, M. (2000). Current Regulatory Approaches to Mine Closure in the United States. In *Environmental Policy in Mining.* Warhurst, A. and Noronha, L., Ed. Lewis Publishers, Boca Raton. p. 311-350

Davies, M.; Martin, T.; Lighthall, P. (2000). Mine Tailings Dams: When Things Go Wrong. Proc. Tailings Dams 2000, p.261-274. Assoc. State Dam Safety Officials Inc. Kentucky, March 2000.

Ellis, D.V.; Poling, G.W.; Bare, R.L. (1995). Submarine Tailings Disposal (STD) for Mines: An Introduction. *Marine Georesources and Geotechnology*, v. 13 n. 1-2, p 3-18.

Isnor, R. (2000). Explicit and Implicit Technology Policies Affecting Closure: Examples from Australia, Canada and the United States. In *Environmental Policy in Mining*, Warhurst, A. and Noronha, L., Ed., Lewis Publishers, Boca Raton. p. 463 – 480.

Kinicki, A., et al. (1987). Socially responsible plant closing, *Personnel Administrator*, 32, p. 116.

Lavkulich, L (1991)., Mine Reclamation and Sustainable Development. Proceedings of the Fifteenth Annual B.C. Mine Reclamation Symposium, Kamloops, BC. June 24-28, 1991. Ed. British Columbia Technical and Research Committee on Reclamation and Canadian Land Reclamation Association.

Minerals Council of Australia (1999). Update of the Ok Tedi Miningand Environment Issue. http://www.minerals.org.au/schools/ok_tedi2.asp

Mineral Policy Center (1999). 14 Steps to Sustainability. Mineral Policy Center: Placer Dome, Sustainability Grade: Incomplete. Washington, D.C., 40p.

Mining Watch (2000). http://www.miningwatch.ca/

Peiter, C.C.; Villas-Boas, R.C.; Shinya, W. (2000). The stone forum: implementing a consensus building methodology to address impacts associated with small mining and quarry operations. Natural Resources Forum, v. 24, n. 1, p.1-9.

Powter, C.B. and Chymko, N. (1991). The Relationship between reclamation and sustainable development. Proceedings of the Fifteenth Annual B.C. Mine Reclamation Symposium, Kamloops, BC. June 24-28, 1991. Ed. British Columbia Technical and Research Committee on Reclamation and Canadian Land Reclamation Association.

Veiga, M.M. (1997). Introducing New Technologies for Abatement of Global Mercury Pollution in Latin America.UNIDO/UBC/CETEM/CNPq. ISBN:85-7227-100-7, 94p.

Welchman, B. and Aspinall, C. (2000). Mine Closure and Sustainable Development: Island Copper Mine: A Case History. Proc. of Mine Closure and Sustainable Development Workshop. World Bank, March 1-3, 2000, Washington, D.C. 16p.

Warhurst, A., et al. (2000). Issues in the Management of the Socioeconomic Impacts of Mine Closure: A Review of Challenges and Constraints. In *Environmental Policy in Mining*, Warhurst, A. and Noronha, L., Ed., Lewis Publishers, Boca Raton, p. 81 – 99.

ASPECTS OF MINE CLOSURE IN BRAZIL

Arthur Pinto Chaves
Escola Politécnica, University of São Paulo

ABSTRACT

There is a generalized opinion that the reclamation practice in Brazil is poor. As this paper tries to demonstrate, this is not true. Brazil is a huge mineral producer and the decommissioning of mining operations affects local communities to a significant extent. Therefore, much attention has been paid to these closure processes.

The decommissioning of mining operations in remote sites and in urban areas are totally different problems and need different solutions. A number of case studies are reported in this paper. Different after-mine uses are suggested according to the mined mineral.

The first conclusion is that it is necessary to work on decommissioning from the beginning of the operation. The second conclusion is that this can be a profitable practice if properly done.

In urban areas, almost any post mine use is profitable, as the real estate is high valued. In remote areas, the impacts both environmental as social are great. The non-erection of villages should be considered in order to decrease these problems.

INTRODUCTION

The international opinion about Brazilian reclamation practice is very prejudicial. *"Brazil, boasting one of the stronger economies among developing nations, has a centuries-old history of mining for gold, gems, bauxite, and other minerals. Reclamation of mined lands has never been a high-priority concern of government or the majority of its mineral producers, resulting in a landscape often marred by abandoned mine workings*" (1). This opinion has been divulged after a paper presented at a conference sponsored by the US Bureau of Mines, in 1988, by Barth, Williams and Griffith (2).

These gentlemen, two of whom were living in Brazil at that time, spent 6 weeks visiting 8 mines all over Brazil and reported their criticisms to the practice they saw. Obviously, this is a very little number of sites in view of the continental size of Brazil and its huge mineral output. Certainly their intention was to draw attention to the observed problems and to demand solutions. Therefore, their conclusion was that "*Although reclamation following mining in Brazil is a relatively new concept* (at that time, 12 years ago) *and programs are just in their infancy, <u>all of the mines visited during this study are doing a commendable job at reclamation and the results obtained are impressive</u>. ... As expected, there are problems in some areas of the reclamation process. Perhaps one of the more serious problems is a preoccupation with short-term goals that seek little more than to stablish a pleasing landscape"* (2, p. 185) (the underlining is mine).

This paper tries to offer information about Brazilian peculiarities and shed some light on Brazil's actual situation.

BASIC INFORMATION ABOUT BRAZIL

Brazil is an enormous country, having 8.5 million km^2 area and 160 million inhabitants. It is the fourth country in the world in continuous area, after Russia, Canada and China. Figure 1 is a map of Brazil and indicates the sites that will be the object of discussion.

Most of Brazil lies between the Equator line and the Tropic of Capricorn, so mean temperatures are high. 2/3 of its area is covered by rain forest and was practically unknown until 30 years ago. The demographic density in this area is very low.

Brazil has the 8th economy in the world and is growing fast. Although very diversified, Brazil's economy strongly relies on mining. Although mining production represents only 4% of the GNP, the first transformation of raw minerals increases mining participation to 27% of the GNP. For instance, Brazil is the first niobium and iron ore producer all over the world, the fourth tin producer, a major producer of bauxite, gold, gemstones, asbestos ...

41% of its people live in only 3 states: São Paulo, Minas Gerais and Rio de Janeiro. There are large metropolitan areas like the city of São Paulo metropolitan region - 19.2 million inhabitants according to UN's data (15,369,305 inhabitants according to Brazilian official data), squeezed in only 8,051 km^2. The cities of Rio de Janeiro, Belo Horizonte, Porto Alegre, Santos, Campinas, Ribeirão Preto are other considerable human concentrations.

Income distribution in Brazil is very bad. Lots of people live in miserable conditions, especially in the largest metropolitan areas.

This fact brings to us two different realities: wide regions almost uninhabited and huge metropolitan areas. Mining activities are spread all over the country, both in the uninhabited and metropolitan areas, which are absolutely diverse in terms of environmental concerns and of soil usage.

Like most Latin-American countries, military rulers led Brazil in the 60's and 70's. In a few aspects, their action was positive, as is the case of the occupation of the Amazon Basin and of the geological prospection all over the country. They believed in mining as an agent of territorial integration. Thus, they forced the installation of mining villages at each mine site.

At the same time, tens of big dams were built to provide electricity for the growing industry. A dam is a kind of work that demands a lot of workers during its construction. As a result, villages were built to host the dam-builders.

After the end of the work, the number of inhabitants of the dam villages decreased because only operational people were then necessary. Large parts of the villages were abandoned or dismantled.

The same happens to the mine villages after the exhaustion of the orebody. This is an actual problem in the remote sites where there is no other economical activity to replace mining.

A complication factor is the emergence of the so-called "satellite" villages. As company villages are built in remote areas, they bring the hope of jobs and the actuality of urban facilities like hospitals, super markets, schools and churches, as well as social interchange. All this acts as a powerful magnet, attracting people over a radius of about 150 km - fishermen, hunters, native indians and so on. A spontaneous village quickly grows around the company village. Sometimes the company is able to act over this foreign group. Sometimes it is not. Anyway, the environmental impact of the company village is multiplied. Some satellite villages are 5 times greater than the corresponding company village. All this population depends on the activity of the company if there is not an alternative economic activity in the region.

Decommissioning then becomes a painful and expensive job.

Mining in metropolitan regions is totally different. As the mine sites have a high real estate value, their reclamation is usually done at a profit.

Decomissioning In Metropolitan Areas

The São Paulo city metropolitan area

From 1995 to 1997, the author supervised a PhD research program (3, 4) about the final destination of 104 mining areas in the metropolitan region of the city of São Paulo. The purpose was to check the actual use of the areas after mine closure in the case of the closed mines (in a number of 54) and to check which reclamation procedures were being done in the case of the active mines (in a number of 50). In the case of the reclaimed areas, there was also the concern to find out who paid for the reclamation.

Out of the 54 closed mines, 41 (76%) had been reclaimed and 13 had been abandoned. The quantitative results of this investigation are shown in table 1.

Table 1 - present uses of closed mines (number of sites)

	exploited mineral				totals	
after-mine use of soil	clay	sand	crushed stone	kaolin	absolute	%
residues disposal	-	3	7	-	10	24
industry or trade	4	3	2	1	10	24
leisure, communitary leisure or sporting	1	5	2	-	8	21
real estate development	1	4	1	-	6	15
streets	1	1	-	-	2	5
schools	1	1	-	-	2	5
private clubs	-	1	-	-	1	2
hotel	-	-	-	1	1	2
fishing, fish farming	-	1	-	-	1	2
total	8	19	12	2	41	100

The use after reclamation is very closely associated to the final topography of the mine. Table 1 shows that mining in the city of São Paulo area is mainly for aggregates.

Public Authorities carried out about half of the reclamation. From this half, 2/3 have been led by municipal governments. This was to be expected, as they are the kind of authority closer to the wishes of the communities.

The remaining abandoned 13 old mine sites were occupied in a disorganized way either by poor people, or by the authorities:

- 5 were used as uncontrolled dirt disposals by municipal authorities;

- 2 were receiving sewers in addition to uncontrolled dirt disposals;

- 2 are lakes and receive hydric influents, garbage and dump.

- all these areas were partially occupied by shanty towns or by poor people housing.

For the active mines, the proposed after-mine uses are shown in table 2.

Table 2 - after-mine uses proposed for the active mines

proposed use	%
leisure, communitary leisure or sporting	19
preservation or conservation areas	22
trade or industry	17
pasture or agriculture	7
state development	10
commercial forest	1
fishing and fish farming	3
small private airport	1
hotel	1
leisure state	1
golf course	1
dirt disposition, sewage treatment	4
water recovery	3
no suggested use	11
total	100

The Águas Claras mine

This iron ore mine is located only 14 km away from the city of Belo Horizonte downtown. It has been mined since 1956 at a rate of 13.6 million tons of ROM per year. It will be closed this year.

The landscape is one of the most beautiful in Brazil: high mountains (Serra do Curral) which draw the skyline of city of Belo Horizonte. In the valley close to the mine, there is a natural reserve of remaining native forest (Mata do Jambreiro).

A real estate development project has been carried out by the offices of the famous landscape planner Burle Marx. The open pit, tailing dams and water dams will be transformed in a set of lakes and creeks. Part of the pit walls will be reforested with native species and part will be used as a housing area. This area will shelter expensive houses, hotels, leisure and culture centers and sporting activities. 65% of the 1,400 ha[*] area will be covered by natural or artificial forests (5).

The mine equipment and the preparation plant, stocking yards and other facilities equipment will be sold or dismantled and moved to other mine sites. As the city of Belo Horizonte is the center of the most important mining district in Brazil and also an important industrial district, there is a great market for used equipment.

The Mina da Passagem mine

This mine is located in an important touristic region, halfway between the historical cities of Ouro Preto and Mariana, also in the state of Minas Gerais. It is an exhausted underground gold mine with natural convection ventilation. The exhausted mine has been transformed into a touristic place. There are guided tours to the underground works, practical demonstrations of panning and a trade of ore and mineral specimens and stone artifacts. The preparation plant has been transformed into a museum. A restaurant provides fine local food (maybe the best kind in Brazil) and is part of the touristic complex.

[*] 1 ha (hectare) = 10,000 m^2

DECOMISSIONING IN REMOTE SITES

The Cachoeirinha and the Massangana mines

These are two closed cassiterite mines. The first belonged to the Brumadinho Group and the second to the Paranapanema Group. They worked with hydraulic mining and mobile pre-concentration plants. Both mines were closed in 1989 as a consequence of the tin price crash.

The mine equipment and the preparation plants are light and easy to move. Thus they have been sold or transferred to other operations in the region.

The state of Rondonia, where they lie, is a fast growing region. It is an important producer of tin, gold, topazes, cacao and coffee. Large areas of the rain forest were deforested and transformed into pastures.

Thus, in those remote sites, there is a strong alternative economy. As the mine area and its village had a good infra-structure (good roads and streets, electricity, water supply, sewage treatment or disposal, hospital, super market, school, club), it is highly attractive to the local population. As a result, part of the houses has been sold to farmers or inhabitants of the neighborhood.

In both locations the total population has decreased, but it is reported that new urban facilities improved the inhabitants' quality of life (6).

The Serra do Navio mine

This manganese mine is exhausted. It is located in the state of Amapá, in the northern boundary of Brazil. The complex consisted of mine, preparation plant, railroad to the port, port and villages at the port and at the mine sites.

The port is very close to the city of Macapá, capital of this state. So it has been transferred to the Port Authority and continues in full use. The village at the port is also very close to the town. Long ago the houses at this village were sold to the workers and now are a part of the city, as well as its satellite village (6).

The preparation plant has been dismantled and the parts have been transported by railroad to Macapá city, where they were sold as scrap iron or used equipment. The mine site, overburden and tailings deposits have been reclaimed and are now part of the forest.

The problem is at the mine village. The excellent constructions for housing, club, urban infrastructure and hospital are very good. But there is no alternative economical activity in the area.

Part of the facilities has been donated to the University of São Paulo, the most important academic center in Brazil. The condition for this donation is the establishment of an advanced campus at Serra do Navio. The University should support the academic and research activities. This initiative was implemented and by 1992, around 200 faculties and clerics worked there (6). Later on, it did not succeed as the University faces cronical lack of money to support its regular activities. The high cost of such a campus, so far from its base, is unaffordable.

The Riacho dos Machados mine

This was a small heap leaching gold operation that operated from October 1989 to March 1997. This small town is located 150 km N of Montes Claros city, once again in the state of Minas Gerais. Its main economic activity was fruit and cotton growing and cattle breeding. The region is semi-arid with savanna vegetation. There are only two watercourses and one dam, which are essential to these economic activities.

250 direct jobs plus 750 indirect ones were created. This had a highly positive impact over the existing community: 8,000 inhabitants, 4,000 of which lived in town. The immediate consequences of the presence of this operation were:

- rural emigration of workers attracted by the operation;
- urban development - supermarkets, bakeries and bars. A doctor, a dentist and a small hospital were these provided by the mining company. The company has installed a second grade school as well as reformed the rural schools;
- income increase for the population;
- real estate speculation - the cost of a piece of land increased from 120.00 US$/ha to 1,500.00 US$/ha !

In 1997, the operation closed. All environmental protective measures were duly taken. The cave was filled with water and became a lake. The overburden and tailing deposits were planted with grass. The town now has paved streets and a sewage collection system. The access road is now paved.

However, unemployment has been massive. The health system has been dismantled and the economic activity has been emptied. The most impressive consequence has been the reduction of the number of urban inhabitants upon their return to the rural area.

All this happened because the company staff was much more concerned with the environment recovery than with the community. No further use of the area has been foreseen.

ALTERNATIVE EXPERIENCES

The villages at Tucuruí, state of Pará

In 1976, the Brazilian government started to build a big dam and hydroelectric plant in the Tocantins River. The project would be done in two phases. In Phase I 4,000 MW would be implanted and in Phase II this figure would increase to 7,960 MW.

There was a small town there, named Tucuruí ("old" Tucuruí) with 3,000 inhabitants. The main economic activity was the transboard of charge from barges that sailed the upstream portion of the river to other barges that would sail downstream. Other minor activities included timbering, fishing and Brazilian nuts collection.

For the beginning of the work a village named Pioneer Village was built. In sequence 3 other villages were built: Temporary I and II villages and the Permanent village. Plans foresaw dismantling the Temporary I Village to rebuild it at another projected dam, Balbina, also in the state of Pará. This other dam would be built in the next future. Temporary II would be kept till the end of the second phase of Tucurui dam.

In 1979, in the peak period, Tucurui had 100,000 inhabitants. 55,000 lived in Old Tucuruí and the other 55,000 in the four villages.

Government changed his mind about Tucuruí's second phase. Balbina also has never been built. The total number of inhabitants today is of 60,000. 27,000 live in the villages and 33,000 in Old Tucuruí. But nor the Pioneer nor the Temporary villages were dismantled.

The availability of electric energy and the existence of the villages brought other economical activities to the region: mining and metallurgy, fishing, timber trading, some agriculture and cattle breeding. This way, part of the housing void with the exit of the dam-builders has been occupied. Although, most of the Temporary villages are now abandoned and decaying.

In contrast, Old Tucurui is a very poor city. The two urban agglomerations are 7 km away. The company town is closed and there is an entrance lane where visitors must identify. Segregation between the two villages is complete.

Urban renewal at the city of São Paulo

This town started to grow in the beginning of the last century as the result of a strong industrialization effort. Since then, lots of industries became obsolete and were renewed. Many buildings were dismantled.

Dismantling has been the most common practice, as it can become difficult or expensive to adapt an industrial building for other uses. As reported, the real estate property is high valued there. As a consequence, to find new uses for the piece of land never has been difficult.

However, some experience has been successful in adapting old buildings for new uses. An old factory was transformed in a leisure and culture center (Sesc-Pompéia), an old shoe factory was adapted to host schools, lofts and other facilities have been transformed in shopping centers, movies and restaurants.

This is done because the city of São Paulo is a strong industrial, economical and social center. There is a market for all the demolition parts, used equipment and a demand for land.

Although, the problem of contaminated must be properly evaluated. A Wal-Mart installation was built over an old asbestos plant an when this fact was realized, a complete cleaning had to be done.

The Court, because of the contaminated soils in another site, has interdicted an abandoned important industrial complex area, close to high valued areas. This makes impossible any alternative use for it until decontamination is done.

Discussion And Conclusion

As someone wrote, Brazil is a land of contrasts. So is its mining activity and so are the decommissioning activities. Remote sites and metropolitan areas present totally different problems.

It is a well-known fact that mines get exhausted and finish some day. This is happening since the beginnings of the mining activity in the world. Why then not to plan for the last day and start to work just from the beginnings to prepare for it ? The mining venture must consider the closure of the mine as a part of the business. It will much easier and cheaper to work on it in advance.

In remote sites, the environmental impact of the village usually is much greater than that of the mine, preparation plant and tailing dam. Many countries have forbidden the construction of such villages. The fly-in/fly-out (long distance commuting) concept is now often applied and is becoming consensus (7). In Brazil we have experienced it in some small gold mining ventures in remote areas and in offshore petroleum platforms. This would be the best solution for the mining activity in the remote sites in the Amazon area.

The only problem is the growing national consciousness about the international covetousness on the Amazon area.

As evidenced by the Riacho dos Machados case study, social problems are often underconsidered. The temporary character of the operation is shadowed by the immediate profits generated since the beginning. It is necessary to consider decommissioning since the very beginning of the work.

In metropolitan areas, the problem is totally different. As seen from table 1, mainly aggregates for civil construction are mined there. Clay and sand are mined in the lower terrains, close to the phreatic level or beneath it. The first suggestion for reclaiming these areas would be landscaping, leisure, fish farming or real estate developing. The high value of the real estate properties there makes anyone of these options feasible.

Quarries enable one to implement a different kind of solution. Housing, trade and industry have been successfully established in old quarries. Sanitary landfills are another possible use.

The author supervised a post-doctorate program on civil construction demolition debris recycling (8). This is a growing problem to the extent cities become old and need to be renewed. It is not proper to use expensive sanitary landfills to receive such a dump. The best solution is to recycle this dump as an aggregate for low performance concrete.

That study has demonstrated that such recycling is technically and economically feasible. It is specially suited for operating quarries, as the residue that can not be used can be disposed on the exhausted areas, and the back hauling can improve the business: the trucks that bring the dump take the aggregate - either natural or recycled. The recycled aggregate is not a competitor to natural aggregate: the first one becomes an additional product able to increase the profit of the venture as a whole.

REFERENCES

1 - CARTER, R. Reclamation grows overseas. Rock products, Feb. 1990, p. 40-7.

2 - BARTH, R.C.; WILLIAMS, D.D.; GRIFFITH, J.J. Reclamation practice at selected Brazilian mines. MINE DRAINAGE AND SURFACE MINE RECLAMATION, Proceedings. Pittsburgh, 1988. Bureau of Mines Information Circular IC 9184, Bureau of Mines, 1988, p. 179-85.

3 - BITAR, O.Y. Avaliação da recuperação de áreas degradadas por mineração na região metropolitana de São Paulo. São Paulo, 1997, PhD thesis, Escola Politécnia, University of São Paulo.

4 - BITAR, O.Y.; CHAVES, A.P. Avaliação da recuperação de áreas degradadas por mineração na região metropolitana de São Paulo. Boletim Técnico da Escola Politécnica da USP, Departamento de Engenharia de Minas, BT/PMI/062. São Paulo, 1997.

5 - MBR (informative pamphlet). Minerações Brasileiras Reunidas. s.n.e.

6 - FARAH, F.; FARAH, M.F.S. Vilas de mineração e de barragens no Brasil: retrato de uma época. São Paulo, IPT/Sama, 1993.

7 - CHAVES, A.P. Managerial aspects of mining projects in remote sites. In: SINGHAL ET AL. (eds.) Mining planning and equipment selection 1995. Rotterdam, Balkema, 1995, p. 39-43.

8 - COELHO, P.E.; CHAVES, A.P. Reciclagem de entulho - uma opção de negócio potencialmente lucrativa e ambientalmente simpática. Areia e brita, abr/jun 1998 (nr. 5), p. 31-5

ABANDONED COAL MINES: A LATENT SOURCE OF ENVIRONMENTAL CONTAMINATION IN COLOMBIA

Eng. M.Sc. *Elcy M. Córdoba T.*
Professor and Researcher, Grupo de Investigaciones en Minerales, Biohidrometalurgia y Ambiente,
Escuela de Ingeniería Metalúrgica – Universidad Industrial de Santander, Ciudad Universitaria, Bucaramanga, Colombia, A.A. 678, E-mail: elcycor@uis.edu.co,
Tel/fax:57 – 7 – 6550802.

INTRODUCTION

The universal problems of contamination and the environmental damage in general are not new, however, the problem has increased as the time pass as a result of a series of factors like the industrialization processes, which has yield an important increase in the use of combustibles and reagents, and in flow of industrial residues.

Among the industrial activities, the mining contributes significantly to the environmental contamination, especially by the residues that are eliminated from the metallurgical process that are not previously treated; by natural and/or typical phenomena of the mining exploitation, such as the erosion, the sinking and slipping of the soil (sedimentation) and the infiltration of water in the mines both abandoned and in exploitation taking place in some sectors of the mining the know acid drainages that finally contribute in high proportion to the contamination of the natural waters.

This last aspect, that is to say, the formation of acid drainages is particularly important in the Colombian coal mining, specifically in the small mining, that is not legally constituted in a great percentage, this last has hindered that the environmental authorities of the country apply a rigorous environmental control as it happens with the big and medium industry of the country.

However, and as a consequence of the growing consciousness raising about the need of all the sectors of the society to unite efforts for the conservation of the environment, different entities of the country as private as government, such as Ingeominas, Minercol, Environment Ministry, Universities and Investigation Centers work at the moment for the development of the national mining and for the decrease of the environmental impact in this sector of the industry.

Such actions tends to specific purposes as:

- Formulation of environmental politicals and the vigilance of the compliance of these politics by all the mining guild.
- Revision and improvement of the mining techniques in use at the moment in the country.
- Scientific researching on clean technologies applied to the national mining.
- Work in the consciousness raising of the small miners about the importance of the conservation of the environment.

Next, it is presented a brief summary of the results of the first investigations, which were carried out on the environmental impact caused by abandoned coal mines. The results show the importance of making a good "Mine closure".

I. Coal Mining In Colombia

The coal is without doubt the most abundant and important energy resource in Colombia (There are calculated existences for 200 years)[(1)], however, the technological degree in which the exploitations are managed; generates irresponsible affectations to the environment. On the other side, the desire of the national government of impelling politics to increase the thermic generation, supposes a demand of important volumes of coal, which is translated to a bigger offer of the mineral.

In Colombia a good part of the mining could be classified as of small industry or even as mining of subsistence, which possesses a relatively low technological degree generating a strong impact to the biophysical environment and the integral development of the communities, due mainly to that is observed a direct affectation to the system of natural sustentation, as long as a permanent modification of the landscape is given and a galloping social marginaly is observed in the mining communities without the existence of compensatory measures that guarantee a effective social – environmental restoration in the areas of exploitation.

II. Environmental Problem Caused For The Abandoned Mines

The small mining of the coal in Colombia presents considerable backwardness and obsolescence, because the mining activity is carried out without previous studies, without appropriate technology, neither adequate technical consultantship. The mining under these conditions propitiates the inadequate use of the mining resources, the contamination of the waters, the severity of the erosive processes, the destruction of the fauna and flora and affectation of the ecosystems in general.

In the last years it has been observed that the environmental contamination, mainly of aquifer near to the mining areas of coal has been increased, and this is largely owed to the production of acid drainages in abandoned coal mines (mine entrances), this phenomenon, obviously, it is increased in rain times. The location of the mines, which are located in the majority on important slopes, facilitates the step of the water of a mine to other and to the water bodies located in the hillsides of such mountains.

These waters coming from the abandoned mines are characterized mainly by a marked acidity, since it was found values of pH inferior at 3 [(2)], with high contents of dissolved and in suspension solids and with potential problems by the high iron concentrations.

Although the impact on the waters is in particular of each region, that is when the polluted rivers pour their waters to a bigger river it is not very notorious their influence, it is an important problem if it is taken into account that the different municipal aqueducts take of this water for make potable it. This carries problems as economic, for the high costs of its treatment, as technicians, due to the impossibility of removing the high quantities of iron that bring the waters, being obtained in many cases non apt waters for the human consumption.

III. Important Factors For The Environmental Contamination Control In The Coal Mining

Historically the pollution control in the mining industry has been practiced in a relatively limited scale. The waters of a mine are usually poured without treatment in the nearest place to the mine entrance that leads to a natural river bed. In some cases, not very usual, water with excessive levels of suspended solids have been treated in

"Sedimentation Wells" to reduce the load of solids before the pouring in the natural river bed. With the recent consciousness raising of the benefits of the environmental protection and the strictest application of the environmental codes, the mining industry will have to reassess its traditional practices and to look for solutions to put them in harmony with the current times.

The uncontrolled subterranean operations cause environmental damages as a result of the superficial sinking on the mining area, the pouring of waters, the creation of inadequate spoil banks, the construction and operation of access roads, construction and operation of superficial installations such as shops, machinery rooms, bathrooms and storing centers. Construction and operation of crushing plants or washing plants, they can also be sources of emissions of polluted waters, dust and noise.

The areas of more sensibility in mining operations, on which the operator should take measures of prevention and control to minimize or to eliminate the impact, are:

- Contamination of superficial or subterranean waters.
- Contamination of the air.
- Decrease of excessive flows coming from the mines with respect to normal conditions.
- Erosion of soils.
- Any activity that has impact on the habitat or the fauna, especially those in extinction roads.
- Permanent damages in the vegetation, fields or forest areas.
- Creation of dangerous conditions in spoil banks.
- Damages to recreational, cultural, historical places or in those that exist archaeological or paleontological values.
- Adverse impacts to near ground.

In the study of environmental impact of a project, the effects caused by the project in an edge water to the quality of the air and water, flora habitat and fauna, vegetation and aesthetics should be evaluated. Additionally it should be taken into account the economic, social and political impact in the humans in the proximities of the project. Individually, projects of small mining cause a small environmental impact, but an isolated small mine in a region is the exception. Usually, if a profitable exploitation has been achieved on an important deposit, it will be followed by many more to its around. Each mine contributes to the deterioration of the environmental factors maybe in a small scale, but in fact this collective of small mines, operating with very few controls, is the cause of impacts of all nature, from local levels until regional levels.

To avoid even more the degradation of the environment in the mining areas the studies of environmental impact should include minimum the following elements:

- Description of the project, their purpose and the environment that will be affected by it.
- Relationship of the project with planning concepts about the appropriate use of the properties in which the project will be developed.
- The probable environmental impact of the proposed project, including as the positive as negatives or secondary aspects.
- Any unavoidable aspect that causes an adverse impact should be mentioned.

- Alternative to the proposed project should be included.
- The relationship of benefit between the short term exploitation of a non renewable resource and the long term traditional use of the lands.
- Any irreversible action taken for the development of the project should be stood out.

IV. Recommendations For The Treatment Of The Mining Waters Before Throwing Them To The Natural River Beds

The water is an element little used in the current mining process, rather it is a natural occurrence found in the process, that has to be evacuated to allow the advance of the mine. The waters come from infiltrations from the surface or they are phreatic. Nevertheless their origin, these have to be driven to the surface. The waters found in the coal mining are relatively clean, but when they traffick the mine for its galleries they enter in contact with material of the backs, fractured coal, timbering wood, and the humans and their residues. In the whole of itinerary the water oxygenates itself and it picks up solids in suspension, solids dissolved in form of metal compounds, salts and organic material.

The most uncomfortable characteristic that is manifested as a result of the run of the waters for the mine is the acidity. This problem is increased by the presence of abandoned mines near other mines in exploitation, since having been abandoned and without works of closed of mine, the water travels them without much obstacle, being evacuated by the mine entrances the acid drainages that sooner or later will be in contact with the near waters.

Acid drainages formation

Although the mechanisms of this acidification are not completely known it is thought that when the water loaded with oxygen abundance contacts iron mineral in form of Pyrite (FeS_2) or other ferrous compounds the process of oxidation is accelerated tremendously, beyond the normal thing. In the following reactions it is shown the oxidation of the pyrite and its compounds:

$$2FeS_2 + 2H_2O + 7O_2 \rightarrow 2FeSO_4 + 2H_2SO_4 \quad (1)$$

$$FeS_2 + 14Fe^{3+} + 8H_2O \rightarrow 15Fe^{2+} + 2SO_4^{2-} + 16H^+ \quad (2)$$

$$4Fe(SO_4) + O_2 + 2H_2SO_4 \rightarrow 2Fe_2(SO_4)_3 + 2H_2O \quad (3)$$

$$Fe_2(SO_4)_3 + 6H_2O \rightarrow 2Fe(OH)_3\downarrow + 3H_2SO_4 \quad (4)$$

Of the previous reactions it can observed that there is formation of sulfuric acid and iron presence in form of precipitate, then when a water presents a precipitate of reddish color (as the color of the bricks), it is very probable that that water is acid.

In these acid waters can only exist certain types of mold and algas that are tolerant to low pH values. Therefore, these waters will have a negative effect on aquatic species, and it will impact in their potability for human consumption, livestock or other fauna, and they will cause increases in the treatment costs of waters for human consumption, equally they can destroy metallic structures for the high effects of corrosion; also, they leave unacceptable the waters for recreational use.

The load of pollutants of a mine to another is supremely variable, then in mining a typical load of pollutants does not exist as in other industrial sectors, therefore the concept of typical treatment plant neither exists. A methodology is generally selected for treatment and then, according to the characteristics of the water, an appropriate plant is designed. For this reason, several treatment technologies have evolved.

The quantity and quality of the mine waters depends on many factors that are outside of the control of the mining operator, and in general they are not related with the production of the mine, then it is not possible to establish a direct relationship among the production and the quantity or quality of waters that should be treated.

1. Sedimentation for gravity

The most common treatment for the waters of a mine is the use of a sedimentation well. The size of the well should be based on the characteristics of sedimentation of the particles in the water. The design of the well should be such that the maximum percentage of the area of the well is used during the traffic of the waters by the well and also that the time of permanency must be enough to allow an appropriate sedimentation before the pouring.

It is possible to increase the efficiency of a sedimentation system with the flocculants use. The flocculants are of several types, including compound ferric, lime, aluminum sulfate and anodic or cathodic polyelectrolytes. But, for their cost, the flocculants use is not common.

2. pH neutralization

The most common methodology of treatment of acid waters is by neutralization or pH adjustment. The neutralization is achieved by adding basic compounds to the acid water that change the behavior as of materials in suspension as of the materials in solution. The solubility of the metallic ions is a function of the pH. In highly basic solutions, many of the heavy metals inclusive cadmium, copper, chromium, iron, manganese, nickel, lead and zinc form insoluble compounds which precipitate for gravity.

3. Precipitation with lime

The use of lime to regulate the currents of acid residuals and to originate chemical precipitations has been spread thoroughly in the mining industry due to its easy handling, economy and to its effectiveness in the treatment of a great variety of dispersed materials.

Other bases such as limestone, dolomite, magnesite, sodium hydroxide, caustic soda, ammonium hydroxide and other basic components can also be used to elevate the pH from the currents of acid residuals to the wanted level. However, the use of lime is probably the better known and studied method.

In a typical treatment with lime the water is pumped or evacuated to the sedimentation well where are decreased the levels of solids. The conditions of repose in the well allow that the biggest particles settle. The lime and the water are liberated either in the primary well or in a mixed lagoon where they are mixed with the water – wastes current. The increment in the pH causes that many of the solids in suspension settle when breaking the electric load that sustain the particles in suspension. The dissolved metals precipitate as insoluble hydroxides, sulphides, or free ions, depending on the characteristics of the mine water. The sedimentation dam is used to pick up the volumes, usually high, of muds that are produced. These dams can be periodically dredged to remove the muds, or with them the sides of the lagoon can be reconstructed to increase the effective volume. The water is generally discharged through a class of pouring device to minimize the agitation. In some cases can be necessary to reduce the pH adding acid before the discharge to fulfill with the pouring laws.

The conditions of the treatment, dosage and final pH should be optimized for any waste current, but in general to achieve a pH of at least 9 is necessary to assure the removal of heavy metals. To obtain the wanted levels of control for some heavy metals, it can be necessary to achieve a pH from 10 to 12. However, it is necessary to be careful not to dissolve not wanted metals when elevating the pH again.

The following reactions illustrate a typical series of reactions that can happen during the process of precipitation with lime. If the system of granular lime is used, adding the lime directly to the residual water, the hydration reaction or of lime slaked happens simultaneously with the neutralization reaction:

$CaO + H_2O \rightarrow Ca(OH)_2$ (Hydration of the lime) (5)

$Ca(OH)_2 + H_2SO_4 \rightarrow CaSO_4\downarrow + 2H_2O$ (neutralization) (6)

When continuing adding lime, the pH continues increasing and the solubility of the dissolved metals falls. The following reaction shows the precipitation of a metallic hydroxide for the dissolution of any metal M:

$M + H_2SO_4 + Ca(OH)_2 \rightarrow M(OH) + CaSO_4\downarrow + H_2O$ (7)

The recarbonation of the water tried before the discharge can be necessary to convert the carbonates to bicarbonates, which the solution is stabilized against the precipitation of carbonates. The recarbonation consists on the diffusion of the carbon dioxide (CO_2) through the tried water for replacing the carbon dioxide removed by the addition of lime.

4. Disposition of solid residuals

The solid residues generated in the mining industry during the treatment residue – water are a serious problem. The treatment includes the removal of dissolved and in suspension components, of the residual water and of the removed material, for which should be recognized as a liquid – solid problem.

Most of the sedimentation wells collect considerable quantities of precipitate solids, frequently generating the necessity of cleaning. These solid wastes should be deposited in a sanitary filling or they should be returned to the mine for their disposition in areas already abandoned.

In the event of disposition in a sanitary filling measures should be taken to prevent the leaching. Filtrations and infiltrations of residual waters coming from deposits of brashes or sedimentation wells, if they are not designed appropriately they can contribute additionally to the contamination of the waters of the river basin where the deposit is located.

V. Recommendations To Avoid The Environmental Contamination For Abandoned Coal Mines

An important aspect in the control of the quality of the water in the small subterranean mining of the coal is to look for the minimization of the quantity of the water that should be evacuated of the mines and on the other hand, to manage the water inside the mine and outside of it for minimizing the contamination. To solve these aspects it was proposed, among other, the control of the infiltrations.

To minimize the quantity of waters of mines, the entrances of waters should be controlled appropriately to the subterranean works, looking only for pumping the sub-superficial water (water of aquifers that inevitably will enter to the galleries and tunnels that are below the phreatic level and that are practically all the cases). These entrances of water can be classified in four:

- Rain waters entering through abandoned mine entrances.
- Rain waters entering through mine entrances in operation.
- Rain waters or water of superficial currents that enter through cracks caused in the sedimentations.
- Subterranean waters.

For each case it was proposed to implement the following procedures:

1. Abandoned mine entrances

They constitute an important source of entrance of water to the mines, because, when they are outside of use, the covers that avoid the entrance of rain waters (or that do not have this protection) are generally under bad conditions. They will be plugged using wood to carry out a lattice in the superior part, and a mound will be formed at a superior level of the land with the purpose of avoiding as the direct entrance of the rain water as the entrance of the runoff water.

In the Figure 1 it is presented an outline of the basic procedure with the recommended dimensions.

It is necessary to stand out that in some visited areas, which have small subterranean mining of coal, where the mantles of coal are very inclined or vertical, is carried out in several cases, a plugging of the abandoned mine entrances. In these cases the recommendation is plugging this entrances with a mound of superior level to that of the land.

It is recommended to sow on the mounds herbaceous vegetation with the purpose of to avoid erosive processes in these works for give then stability.

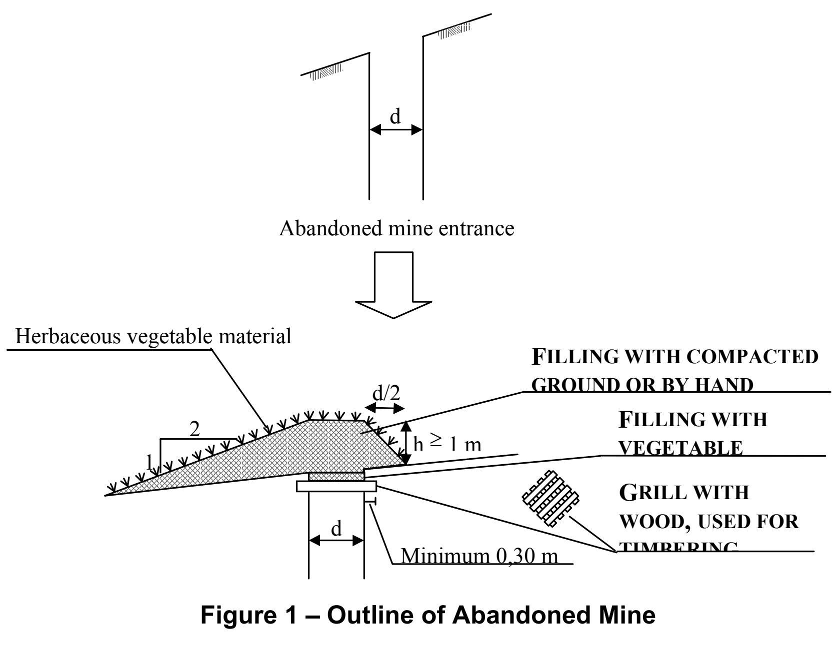


Figure 1 – Outline of Abandoned Mine

2. Mine entrances in operation

It is necessary always to have protection systems against the rain waters and of runoff in the works of the small subterranean mining of the coal that are active. A cover that protects these entrances should have an appropriate maintenance and to cover around at least one (1) meter more than the net area of the mine entrance. Also, it should be avoided that the water deviated by the roof returns to the entrance (it is necessary to give the slope toward the place near to the entrance that has a lower elevation that the entrance). Lastly, a perimetrical channel should be build to deviate the runoff waters. This basic procedure is shown in the Figure 2.

When the slope of the land is very inclined, the solution shown in the Figure 3 could be taken for the direct control of the rain water.

3. Sedimentations

The sedimentations caused by the natural landslide of abandoned mining works (or tunnels already exploited), as consequence of the failure of the wood with which the roof of the mine is propped, in some cases they arrive until the surface and they cause depression areas for where is infiltrated big quantities of water, either directly when it rains, for later runoff or for infiltrations of superficial current waters.

When this happens, a treatment should be given to the affected area, stuffing the sedimentation trenches with near material, in the possible clayey or muddy, and looking for forming a mound, that is, that the whole of area of treated sedimentations is with a superior elevation to that of the rest of the land. In the Figure 4 is presented the form of developing this basic procedure.

On the areas some plants of type shrubs and herbaceous should be sowed, taking into account the species recommended in particular for each region.

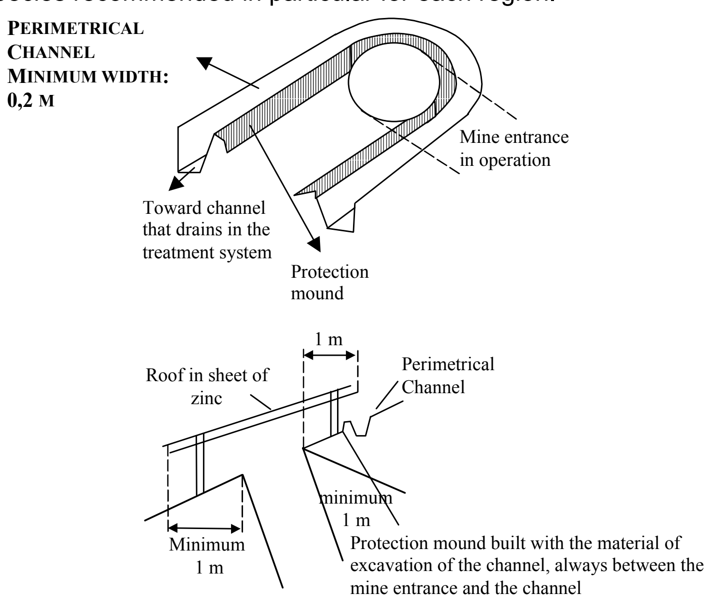


Figure 2 – Outline Control of Infiltrations in Mine Entrances in Operation

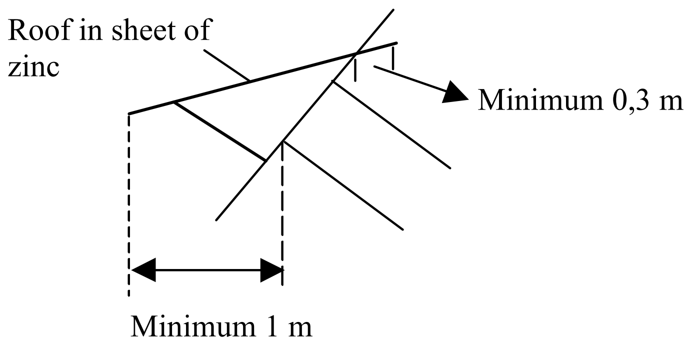


Figure 3 – Outline of Control of Infiltrations un Mine Entrances in Operation in Lands of High Slope

4. Natural river beds

When they exist near mining works or below of river beds of superficial currents and the bottom of the bed of the current is not sufficiently waterproof, the infiltrations of water toward the mines are evident. This mining works should be prohibited, because besides being dangerous, they make that a percentage of the water of the superficial current penetrates until the works of subterranean mining, and although this flow is returned again toward the superficial current by pumping, the water leaves the polluted mine. When not being able to deviate the current of their natural bed (because, in most of the cases, it is a current of appreciable flow) the works of exploitation should be canceled.

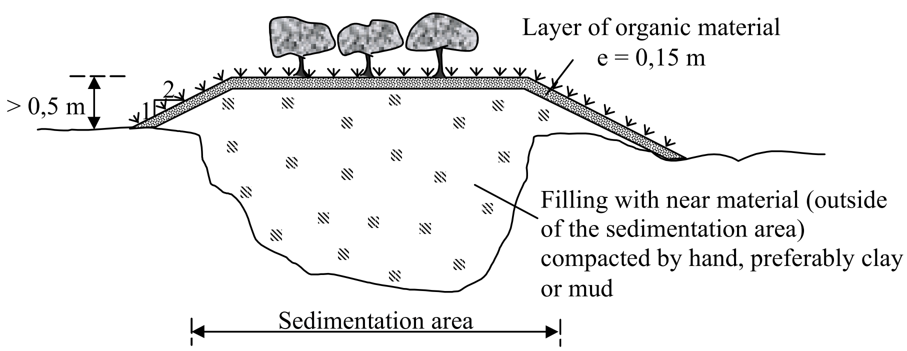


Figure 4 – Outline of Treatment of Sediments for Control of Infiltrations

VI. CONCLUSIONS

Of the diagnostic carried out and based both on bibliographical information and on the gathered field data it is possible to conclude the following:

- The small subterranean mining of coal impacts in the quality of the waters at a local scale, at level of the microbasins where the mining activities are carried out. In the big water receiving bodies, where the waters of the small polluted currents are poured with waters of mines.
- The problems of water in the mines are caused mainly by infiltration waters. These flows of water can be presented by the same mine, or for sedimentations areas (caused by the

subterranean mining activity), or for abandoned mining works in the area, which can be minimized by taking the recommended actions.

- It is urgent to take measures that allow exercising a more effective control on the mining work to small scale establishing execution norms for the control of negative environmental effects.
- To minimize the contamination of aquifer near the mining areas is indispensable that the government entities make a rigorous control in the tasks of "Mining Closure".

VII. Bibliographical References

1. Memoirs, IV national and II international congress of science and technology of the coal. Ecocarbón, Colciencias and UPTC. Paipa, Colombia. 1998.
2. Final report, Control of contamination of the water in the small subterranean mining of the coal. Ecocarbón. Bogotá, Colombia, 1995.

MINE CLOSURE-RELATED GEOCHEMICAL ASPECTS

Saulo Rodrigues-Filho[a,b,d], Eurico Zimbres[b], Marilu de Meneses Silva[b], Anderson Rocha[c], João Felipe Mitre[c] and Roberto C. Villas Bôas[a,d]

[a]Centro de Tecnologia Mineral CETEM/CNPq, Rua 4 Quadra D, Cidade Universitária, 21941.590 Rio de Janeiro, RJ, Brazil. E-mail: srodrigues@cetem.gov.br, villasboas@cetem.gov.br

[b]Universidade do Estado do Rio de Janeiro, Faculdade de Geologia, Rua São Francisco Xavier 524, 20550.013 Rio de Janeiro, RJ, Brasil.

[c]Universidade Federal Fluminense, Instituto de Química/Engenharia Química, Outeiro São João Batista, s/n, 24020.007 Niterói, RJ, Brasil.

[d]CYTED, Ciencia y Tecnologia para el Desarrollo, Subprograma XIII, Calle Amaniel 4, 28015 Madrid, Spain.

ABSTRACT

The increasing societal demand for actions and strategies towards mining sustainability has led experts to face the challenge of managing the potential harzards associated with mine closure and abandoned mine sites. Surface and groundwater pollution, acid mine drainage, land mass slide and dam failure, among others, are frequent subjects related to projects dealing with mine closure and reclamation worldwide. Also, filling of drainage beds with mineral matter originated from erosion and downstream runoff of abandoned mining waste piles and tailings generally causes both silting of waterways and elevation of metal concentrations in sediments.

This paper proposes a geochemical evaluation methodology applied to the receiving environmental compartiments under a historical perspective which takes into account the sources and the fate of heavy metals. It is thought to constitute a valuable tool in choosing alternatives for site rehabilitation and hazards prevention, since it reconstructs the geochemical dinamics on the mine site prior to mining operations.

INTRODUCTION

For a better understanding of current environmental changes, namely those caused by mining operations, it is required to investigate the existing geochemical patterns prior to the establishment of a mining activity. The environmental history of a drainage system is commonly achieved via analyses of sediment cores taken in low-energy deposits, such as overbank and lake sediments.

However, the use of common geochemical and mineralogical records as paleoenvironmental indicators might introduce some uncertainties with regard to the partitioning of anthropogenic and lithogenic components. These uncertainties are derived from the difficulties in determining the source of the mineral matter found either in fluviatile or lake sediments, as well as from early-diagenetic chemical changes that take place in sediments after deposition.

Based on observations from temperate regions, several authors pointed out that definitive evidence for soil erosion may be difficult to obtain from sediment chemistry because changes in soil mineralogy are too subtle to detect (Engstron and Wright Jr., 1984; Chesworth, 1972). However, this seems not to be the case in tropical regions, where chemical weathering causes marked mineral transformations and the relative accumulation of less mobile metals in surface horizons under neutral or oxidizing conditions, such as Al, Ti, Fe, Mn, Be, Ti, Cr and Ni. Thus, geochemical contrasts among soil horizons favor the reconnaissance of source imprints in sediments (Wasserman, Silva-Filho and Villas Bôas, 1998).

Mineralogy of tropical soils also helps a great deal in identifying sediment provenance, since contrasting accumulation of quartz and secondary minerals within weathering profiles is a well documented fact (Lucas et al., 1993; Nahon, 1986; Kopp, 1986; Irion, 1984; Curi and Franzmeier, 1984). Goethite and gibbsite generally occur in the uppermost soil horizon as a result of hydration of hematite and leaching of silica from kaolinite, respectively.

The environmental history of the Holocene sedimentation (last 10,000 years) in Lake Silvana, southeastern Brazil, was reconstructed by tracing back the source of sediments based on contrasting geochemical and mineralogical patterns within the pedologic mantle of the catchment (Rodrigues-Filho and Müller, 1999).

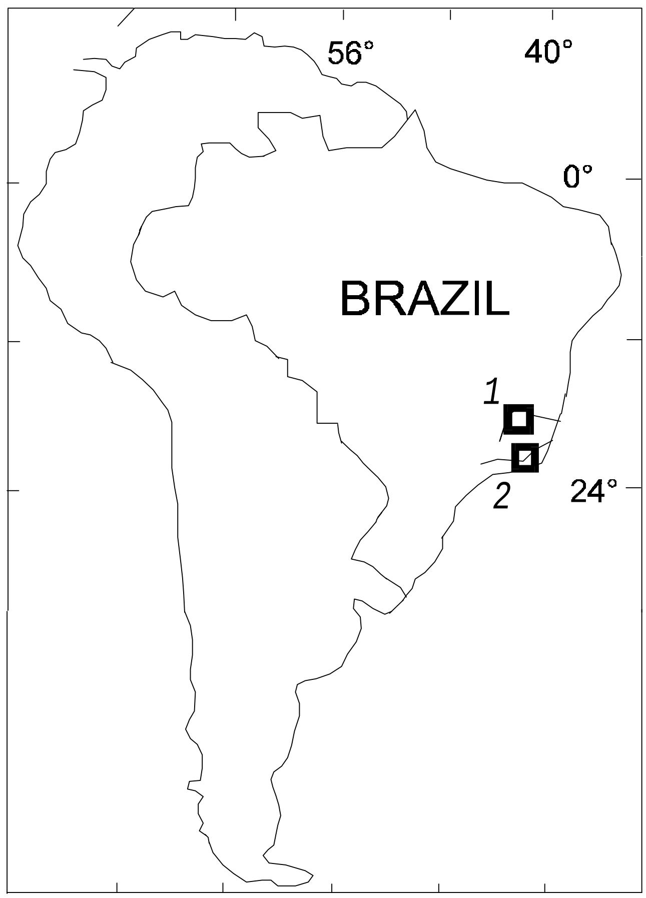


Figure1 - Location of the study areas. (1) Lake Silvana; (2) Paraiba do Sul river

A similar methodology has been applied to reconstruct the heavy metal pollution history in the Paraiba do Sul river basin, southeastern Brazil, where steel industries and metalurgical plants have been in operation since the 50‘s (Rocha and Rodrigues-Filho, 2000). In addition to the determination of total metal concentrations in sediment cores, this study investigates the partitioning of metal concentrations bound to different mineral species through a sequential extraction procedure (Fig. 1).

The Lake Silvana Case (Rodrigues-Filho and Müller, 1999)

The study area includes Lake Silvana (19° 31' S and 42° 25' W) and its catchment, situated on the right bank of Rio Doce, approximately 10 km downstream from the town of Ipatinga The Rio Doce Valley is situated in the eastern part of the State of Minas Gerais, southeastern Brazil, in one of the world´s most important mining regions for iron. Both Rio Doce and Rio Piracicaba form the so-called *Steel Valley*, where three steel-producing companies have been in operation for the past 40–50 years. Gold mining activities exist in the region since the late 18^{th} century.

Lake Silvana is one of almost forty dammed-valley lakes occurring in the middle course of Rio Doce. Several lakes are surrounded by Atlantic Rain Forest and semideciduous forest, where the primary vegetation was preserved.

One sediment core and two soil profiles were collected in Lake Silvana and its catchment. Core SB1 is 12.7 m long and was collected using a piston corer capable to reach great depths with excellent recovery rates. This has been assessed through the length of each core section after extrusion, which indicated negligible loss of material.

Two profiles of the weathering mantle (EG1 and EG2) were sampled, providing 21 samples, where road cross-sections enabled the exposure of the entire pedologic cover. Sampling points within the weathering profile, which may reach a thickness of 30 meters, were selected according to changes in macroscopic features, such as color, texture and pedological and lithological structure.

Costa and Schuster (1988) carried out a worldwide survey on the numerous kinds of dams that form by natural processes, including volcanic, landslide, glacial and fluviatile dams. The most common constraints that lead to dam-forming landslides are excessive rainfall and snowmelt and earthquakes. The types of mass movements that form landslide dams are rock and debris avalanches; rock and soil slumps and slides; and mud, debris and earth flows. A significant percentage of landslide dams consists of mud, debris and earth flows. Most of these dams have been caused by relatively high-velocity debris flows derived from tributary valleys. The authors observed that dams formed in this manner are not high, and if composed of noncohesive material, they commonly overtop soon and breach rapidly. In the case of slower debris flows and/or flows of cohesive materials, longer-lived dams may form.

Chemical weathering in humid tropical regions leads to the formation of typical mineral assemblages made up of secondary minerals, commonly represented by kaolinite, gibbsite, hematite and goethite and residual quartz, while anatase and zircon are common trace constituents (Irion, 1984; Lucas et al., 1993; Curi and Franzmeier, 1984). Dissolution of soluble minerals and geochemical reactions within the pedologic mantle is mainly controlled by hydrolysis, which in turn is climate-dependent (Chesworth, 1992). Microbiological activity in topsoils appears to be a further relevant factor controlling the surficial accumulation of silicon in equatorial ecosystems (Lucas et al., 1993).

Four distinct sedimentary sequences represent major paleoenvironmental zones within the core SB1. Different phases of the hydrological cycle in Lake Silvana were inferred from contrasting geochemical and mineralogical patterns, which are consistent with changes in vegetation indicated by pollen data since the early Holocene. XRD analyses in the <20 µm fraction of samples collected at regular core intervals revealed a dominance of poorly crystallized kaolinite, followed by goethite, muscovite and quartz. Varying contents of gibbsite and siderite occur since the transition from zone I to zone II (Fig. 2).

Mineralogical and geochemical contrasts within the 29-m-deep weathering profile EG2 allow to a certain extent to identify the source of terrigenous sediments in Lake Silvana (Fig. 3). The lowermost C2 horizon consists of brownish-ochre saprolite without banding, indicating a somewhat isotropic fabric of the parent rock (amphibolite lens). Samples are composed of poorly crystallized kaolinite, goethite, hematite and quartz. Trace metal concentrations revealed the highest values for Ni, Cu, Zn, Ti and Fe, while Hg was near the detection limit.

The C1 horizon is composed of reddish-brown saprolite showing the original macroscopic structure of a biotite-rich gneiss. Samples are composed of well ordered kaolinite, hematite, quartz and goethite. The highest Cr and Pb concentrations have been detected in this unit.

The B horizon consists of yellowish latossol composed of poorly crystallized kaolinite, quartz, gibbsite and goethite. It is noteworthy the relatively high Hg concentrations and gibbsite contents in the B horizon.

Relatively high background concentrations of Hg (average of 0.15 μg/g) were recorded in B horizons of undisturbed soils in Central Brazil, which have been demonstrated to be derived from the oxidation of Hg-containing pyrite (Rodrigues-Filho and Maddock, 1997). There, Hg concentrations tend to decrease from the saprolite to the top of profiles, demonstrating that Hg concentrations have been depleted through leaching (Rodrigues-Filho, 1995).

A first flooding of the lake basin is indicated for the early Holocene (9400 yr B.P.), when the gibbsite-rich, Hg-containing B soil horizon started to be accumulated in the lake. Four distinct phases of the hydrological cycle are consistent with vegetational changes indicated by pollen data. Phases of slope instability (colluviation) and low lake level correspond to pollen-free intervals and point to a severe retreat of the vegetation cover. The rapid sedimentation of a 7.8 m-thick sequence of slope-wash sediments appears to be related to the damming of the Lake Silvana Basin, that culminated at 8500 yr B.P., probably as a response to a drastic increase in precipitation rates (Fig.2).

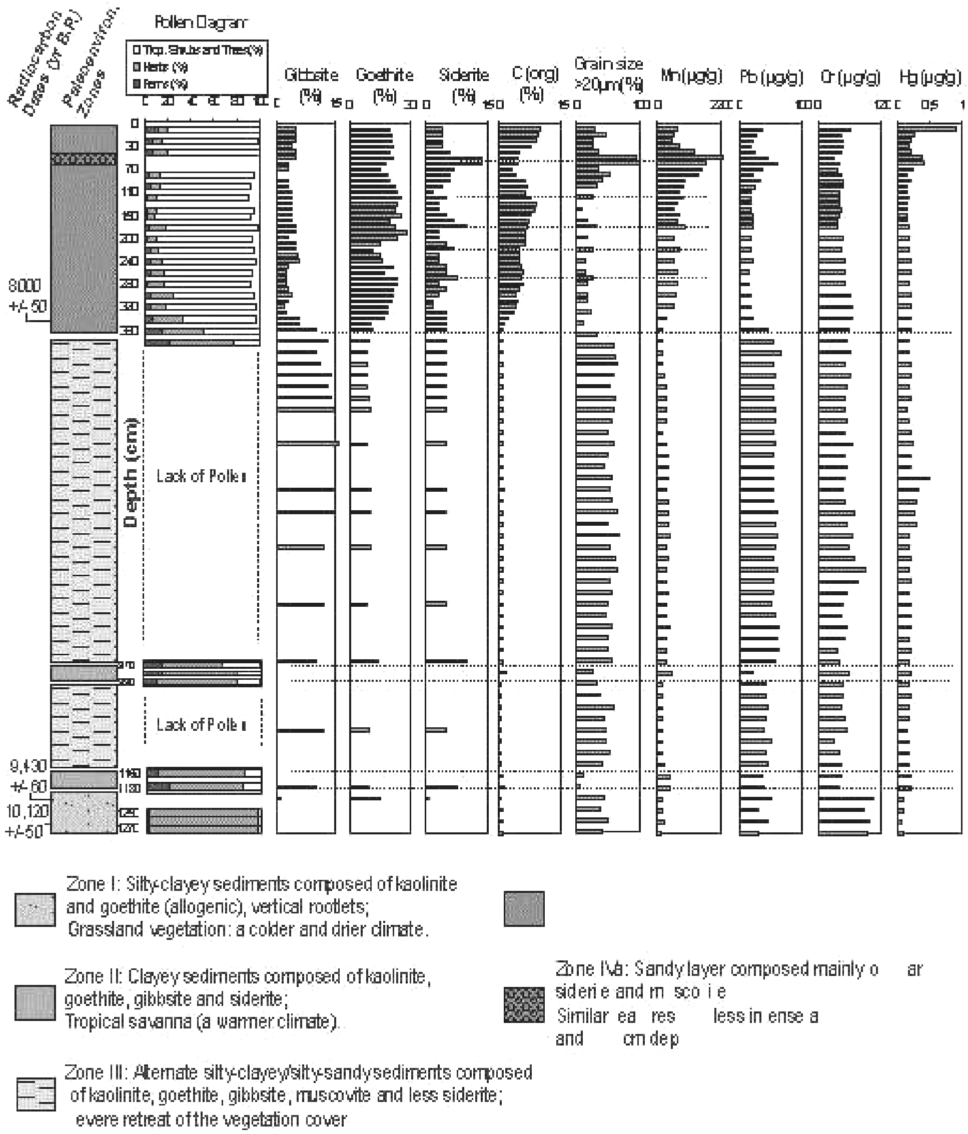


Figure 2 - Summary diagram of sedimentologic and palynologic data – Core SB1, Lake Silvana.

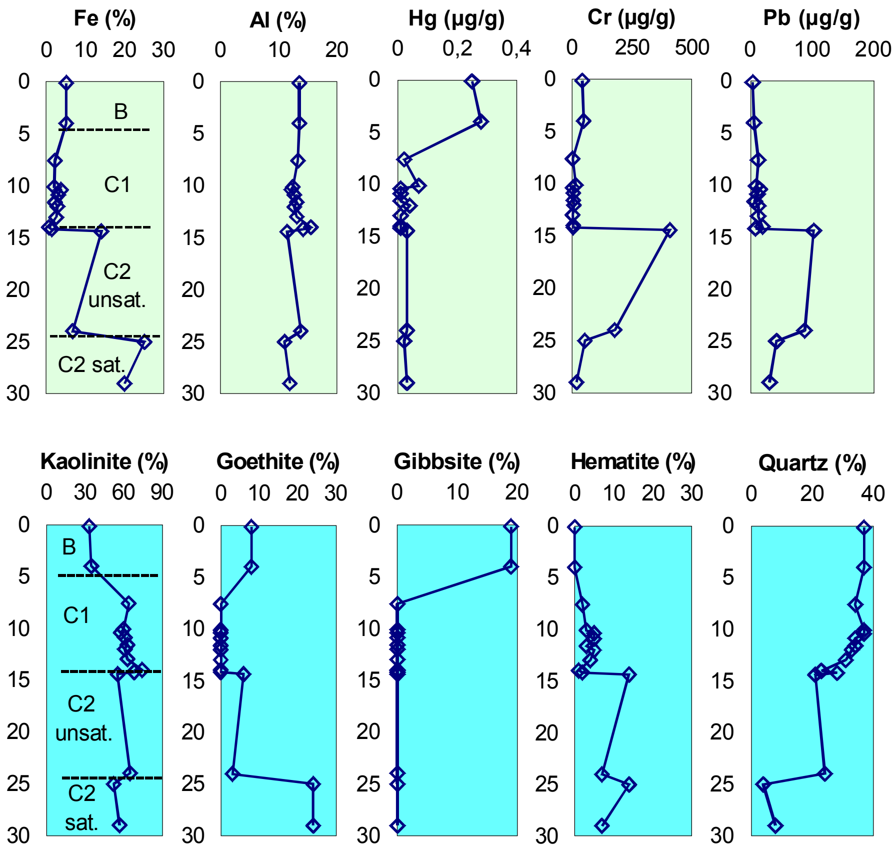


Figure 3 - Metal and mineral distribution within soil profile EG2, Rio Doce Basin.

The Paraiba do Sul Case

Another sediment core - PPS1 - was collected in an overbank deposit of the Paraíba do Sul river, downstream to the industrialized area. PPS1 is a 36 cm long core taken with a PVC tube.

Overbank and lake sediment cores have been successfully used for reconstructing pollution history in drainage systems, as well as for determining background levels of hazardous substances (Renberg et al., 1999; Swennen et al., 1998; Shotyk et al., 1998; Xie and Cheng, 1997; Skei et al., 1988; Smith and Loring, 1981). In Brazil, however, this methodology has been not fully stressed, with just few examples of its application (Rodrigues-Filho et al., 1996; Lacerda et al., 1991; Patchineelam et al., 1988, among others).

The sediment core PPS1 represents an overbank deposit located downstream to the most significant industrial area of the State of Rio de Janeiro. Measures toward pollution control by means of end-of-pipe cleaning technologies, as effluents and gaseous emissions treatment, have been adopted in a recent past following the strengthening of the environmental legislation.

Previous to the partitioning of heavy metals concentrations through sequencial extractions, 2-cm intervals of the core have been digested with aqua regia for determination of pseudo-total concentrations (Fig. 4).

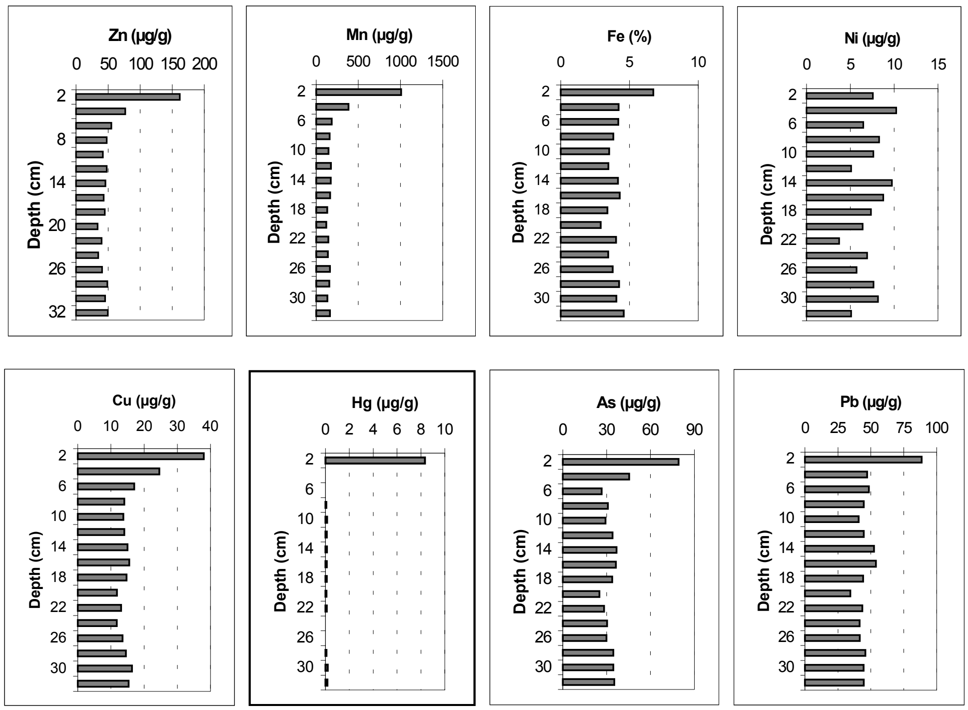


Figure 4 - Vertical distribution of heavy metals within the core PPS1

Heavy metal profiles show the highest concentrations near the surface, which are probably derived from metal remobilization through dissolution of Fe and Mn oxi-hydroxides in the reducing zone, rather than an indication of pollution. Nevertheless, despite of the well known enrichment of metals in the zone of organic decay in sediments, the formidable elevation of Hg on the surface possibly indicates an anthropogenic source. Likewise, the increase of Pb, As, and Ni in the interval between 14 and 18 cm depth indicates a period of higher industrial emission rates to the environment in the recent past, probably during the 70's (Fig. 4).

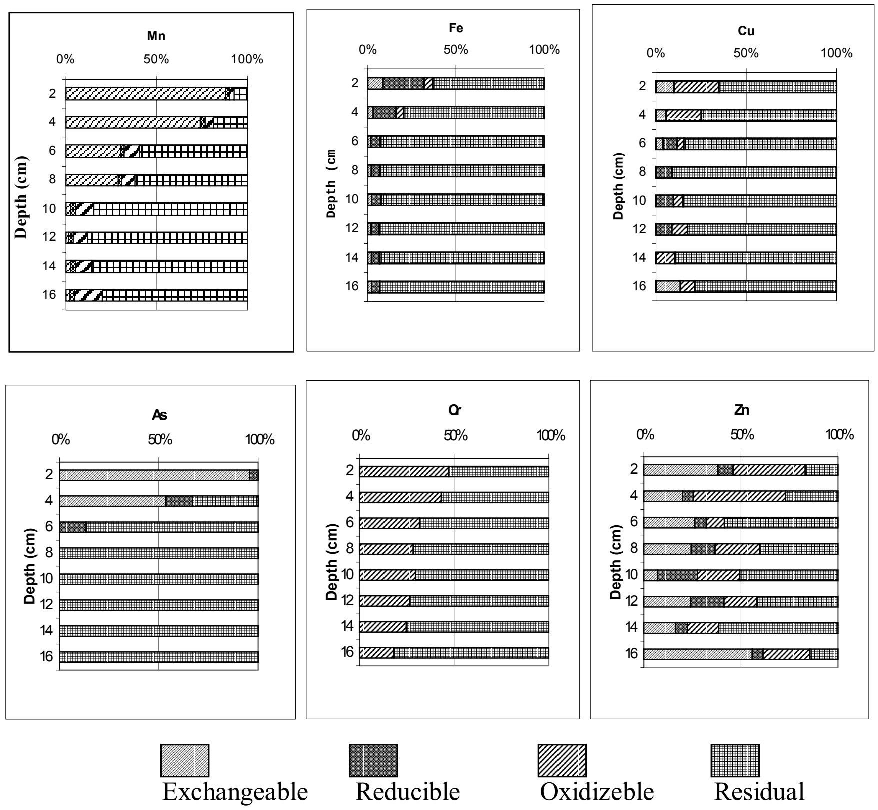


Figure 5 - Vertical distribution of geochemical phases within the core PPS1

Sequential extraction analyses were performed in the first 16 cm of the core PPS1. Hg, Cd and Cr have been below the detection limit for all extraction phases. The highest Fe and Mn concentrations at top of the profile for the exchangeable fraction seems to confirm the above mentioned hypothesis, that is a reducing system with high contents of organic matter leading to the reduction of Fe and Mn oxi-hydroxides and releasing oxide-bound metals, in this case As, Cu and Zn. Moreover, somewhat elevated Cu and Zn concentrations in the exchangeable fraction at 16 cm depth indicate an anthropogenic source (Fig. 5).

Conclusions Towards Mine Closure Evaluation

The Lake Silvana study indicates the feasibility of using geochemical and mineralogical records from lake sediments as paleoenvironmental proxies, at least for tropical regions, where the chemical weathering yields contrasting patterns among soil horizons with regard to their mineralogical and chemical composition. Thus, the history of environmental changes becomes achievable, including a wide range of aspects, such as geochemical background, water quality and landscape evolution.

As a preliminary assessment of pollution history, the in progress study from Paraiba do Sul river indicates the applicability of the core methodology for investigating fluctuations in pollution levels in a shorter time frame, in this case decades. In progress radiometric dating using the ^{210}Pb isotope in varying sediment dephts is going to indicate sedimentation rates in overbank deposits of the river, revealing the relative ages of each profile interval.

Therefore, the methodology herein exposed is a valuable tool in assessing the prior history of a mining place since it enables the comparison between different time periods , for instance, previously to any mining activities , but with some natural geochemical anomalies. Thus, the entrepreneurs would be able to identify waste-containing, mining-derived anomalies from those generated by erosion of high background soils and rocks.

REFERENCES

Chesworth, W. (1992). Weathering systems. *In*: Martini, I.P. and W. Chesworth (eds), Weathering, Soils and Paleosols. Elsevier, Amsterdan. Developments in Earth Surface Processes, vol. 2, pp. 19-40.

Costa, J.E. and Schuster, R.L. (1988). The formation and failure of natural dams. *Geological Society of America Bulletin*, 100: 1054-1068.

Curi, N. and Franzmeier, D.P. (1984). Toposequence of oxisols from the Central Plateau of Brazil. *Soil Science Society of America Journal*, 48: 341-346.

Engstrom DR and Wright Jr. HE. Chemical stratigraphy of lake sediments as a record of environmental change. In: Haworth EY, Lund JWG, editors. Lake Sediments and Environmental History. University of Minnesota Press, 1984, pp. 11-67.

Irion, G. (1984). Sedimentation and sediments of Amazonian rivers and evolution of the Amazonian landscape since Pleistocene times. *In*: Sioli, H. (ed.), The Amazon: Limnology and Landscape Ecology of a Mighty Tropical River and its Basin. Dr. W. Junk Publishers, Dordrecht, pp. 537-579.

Kopp, D. (1986). Mineralogische, geochemische und geophysikalische Untersuchungen von Verwitterungsprofilen in Minas Gerais, Brasilien. Ph.D. Dissertation, Universität Freiburg, 213 pp.

Lacerda, L.D.; Salomons, W.; Pfeiffer, W.C. & Bastos, W.R. (1991). Mercury distribution in sediment profiles of remote high Pantanal lakes, Central Brazil. *Biogeochemistry*, 14: 72-79.

Lucas, Y., Luizão, A., Chauvel, A., Rouiller, J. and Nahon, D. (1993). The relation between biological activity of the rain forest and mineral composition of soils. *Science*, 260: 521-523.

Nahon, D.B. (1986) Evolution of iron crusts in tropical landscapes. In: Colman SM, Dethier DP, editors. Rates of Chemical Weathering of Rocks and Minerals. Academic Press, London, pp. 169-191.

Patchineelam, S.R.; Leitão-Filho, C.M.; Kristotakis, K. and Tobschall, H.J. (1988). Atmospheric lead deposition into Guarapina Lagoon, Rio de Janeiro State, Brazil. In: U. Seeliger; L.D. Lacerda and S.R. Patchineelam (Eds.). Metals in Coastal Environments of Latin America. Springer-Verlag, Heidelberg, New York, Tokyo. P. 65-76.

Renberg, I.; Bindler, R.; Brännvall, M.A.; Emteryd, O.; Bartnicki, J. and Billström, K. (1999). The medievalmetal industry was the cradle of modern large-scale atmospheric lead pollution in Northern Europe. *Environ. Sci. Technol.*, 33: 4391-4395.

Rocha, A. e Rodrigues-Filho, S. (2000). Avaliação preliminar da evolução histórica da poluição por metais pesados no rio Paraíba do Sul, Estado do Rio de Janeiro. Anais da VIII Jornada de Iniciação Científica do CETEM, Rio de Janeiro (In press).

Rodrigues-Filho, S. (1995). Metais Pesados nas Sub-Bacias Hidrográficas de Poconé e Alta Floresta (MT). CETEM/CNPq, Rio de Janeiro. Série Tecnologia Ambiental, vol. 10, 92 pp.

Rodrigues-Filho, S.; Andrade-Ramos, J.L. and Oliveira, C.A. (1996). Diagnóstico Ambiental das Áreas Submetidas à Garimpagem de Ouro em Rio Preto – MG. Série Tecnologia Ambiental, Vol. 11. CETEM/CNPq, Rio de Janeiro. 31 pp.

Rodrigues-Filho, S. and Maddock, J.E.L. (1997). Mercury pollution in two gold mining areas of the Brazilian Amazon. *Journal of Geochemical Exploration*, 58: 231-240.

Rodrigues-Filho, S. and Müller, G. (1999). A Holocene Sedimentary Record from Lake Silvana, SE Brazil: Evidence for Paleoclimatic Changes from Mineral, Trace-Metal and Pollen Data. Lecture Notes in Earth Sciences, Vol. 88. Springer-Verlag. Heidelberg, New York, Tokyo. 96 pp.

Shotyk, W.; Weiss, D., Appleby, P.G..; Cheburkin, A.K.; Frei, R.; Gloor, M.; Kramers, J.D.; Reese, S. and Van der Knaap, W.O. (1998). History of atmospheric lead deposition since 12,370 yr BP from a peat bog, Jura Mountains, Switzerland. *Science*, 281: 1635-1640.

Skei, J.M.; Loring, D.H. and Rantala, R.T.T. (1988). Partitioning and enrichment of trace metals in a sediment core from Framvaren, South Norway. *Marine Chemistry*, 23: 269-281.

Smith, J.N. and Loring, D.H. (1981). Geochronology for mercury pollution in the sediments of the Saguenay Fjord, Quebec. *Environm. Sci. Techn.*, 15: 944-951.

Swennen, R.; van der Sluys, J.; Hindel, R. and Brusselmans, A. (1998). Geochemistry of overbank and high-order stream sediments in Belgium and Luxembourg: a way to assess environmental pollution. *Journal of Geochemical Exploration*, 62: 67-79.

Wasserman, J., Silva-Filho, E.V. and Villas Bôas, R.C. (1998). Environmental Geochemistry in the Tropics. Lecture Notes in Earth Sciences, Vol.72. Springer-Verlag, Heidelberg, New York, Tokyo. 305 pp.

Xie, X. and Cheng, H. (1997). The suitability of floodplain sediment as a global sampling medium: evidence from China. *Journal of Geochemical Exploration*, 58: 51-62

MINING ENVIRONMENTAL MANAGEMENT IN COLOMBIA: CHALLENGES AND OPPORTUNITIES FOR THE AGGREGATE INDUSTRY

Carlos Fernando Forero Bonell
Executive Director
COLOMBIAN SAND AND GRAVEL ASSOCIATION – ASOGRAVAS
asogravas@col-online.com - Santa Fe de Bogotá D.C. - COLOMBIA

INTRODUCTION

According to the National Stone Association in the United States of America if the aggregate industry has one major failing it is and has been its willingness to accept its role as quiet, unassuming supplier to the construction trades. Aggregate producers have long been willing to let others take the credit for the ribbons of highways, for the bridges over which we drive daily, and the rural, blacktop roads as well as the dams that help generate electricity for power supply.

A country of great geographical and ecological diversity, Colombia is one of the most densely populated countries in Latin America with 42 million inhabitants, of which 70% live in urban areas.

The history of the Colombian mining dates back to the sixteenth century, when the region was the most important supplier of gold to Europe. Most recently Colombia only began to participate in the mining world market in the 1980s, with important volumes of oil, coal, nickel and emeralds, in addition to gold. With the beginning of some large-scale mining operations, the sector's participation in GNP grew from 3.3% in 1986 to an estimated 5% in 1997 (including oil).

Annually Colombia produces about 50 million tons of natural aggregates. Most of this natural aggregate material goes into construction, specifically as a sand and gravel for the cement concrete and asphalt concrete mixtures, as well as aggregates used as roadbase material as construction fill.

Since natural aggregates are a vital ingredient in all concrete and asphalt products, the aggregate industry is a major contributor to the physical well being of Colombia. The geographic diversity of the aggregate industry is unique among business mining and producing natural materials because aggregate producers operate in most cities in Colombia.

There is definitely a trend on the part of aggregate operators to be more sensitive to, and aware of, the needs and wishes of the general public. Today's the aggregate industry is extremely concerned about public opinion. Noise, dust, air, and water pollution are four areas where the formal and legal industry has tried hard to develop more effective measures.

Sustainable development thinking is and will be a central component in the industry corporate policies during this century. Many have worked hard to win trust and support of their residential and commercial neighbors, radically reducing air, water and solid wastes as an important part of the equation, but there is much more. It is coming to mean how industries interact with all their stakeholders in all spheres of influence. This includes companies' impact on public policy and their role in civil institution building.

The Colombian Sand and Gravel Association – ASOGRAVAS develop a series of environmental and social programs to promote stakeholder dialogue and partnership based upon their corporate responsibility, a key challenge that businesses purporting to be sustainable have to address.

To support the improvement of the environmental performance, promoting an environmental culture in the aggregate industry and create public recognition to companies who are leading the path to sustainable mining development, Colombia is in the process of developing an initiative called CANTERA VERDE which we are going to describe in detail this paper.

THE LEGAL ASPECTS

The Ministry of Mines is responsible for the administration of natural non-renewable resources, based upon the legislation established in the Code of Mines (today in the process of reformation), with the state as the legal owner of the country's natural resources. Therefore a mining company needs to apply for a *Título Minero* (mining title) that is issued by the national government and entitles the company to explore and exploit minerals.

Once the company is issued with a mining title, it needs to obtain all legal permits granted by the Ministry of the Environment, in the case of a large mining operation, or by the regional and local authorities for a medium and small scale operations.

In many developing countries the aggregate industry are not done according to prospective planning. Although most of the countries have legislation for mining activities in some of them it is not strongly enforced by the mining and environmental authorities.

Colombia has one of the oldest environmental laws in Latin America. In 1974 the Code of Natural Resources became a law, resolutions and decrees to protect the environment followed this. However enforcement has been significantly complicated due to the informal sector. It is estimated that the informal sector accounts for around 65% of all activities and more than 80% of the environmental impact.

In 1993, in part as a consequence of the Rio Summit, the government reorganized the National Environmental System and created the Ministry of the Environment based upon law 99-93. To enforce that law since 1994 there have been a great deal of new resolutions, decrees, agreements, consultation processes, public audiences, and fines as well as sanctions to improve the quality of water, air and waste management.

Mining was specially restricted in the *Sabana de Bogotá D.C.* (around the capital city), declaring its valleys, rivers, savannas, mountains, and all ecosystems around Bogotá of special ecological interest with main destination for agriculture and forestry and very limited options to mine aggregates sites.

Law 99-93 also establish that all open pit mining operations must reclaimed the land and also It must have a bank policy and guaranty for 30% of the total cost of the environmental management plan.

There is a law which will be pass by the congress by the end of this year to modernize the Code of Mines. The law recognized that mining industry is of national interest and will redefined the role and responsibilities of both the regulators and those organizations subject to regulations, outlines a formal and faster environmental permitting process and presents specific regulations regarding communities and ethnic minorities.

Some of the key environmental issues addressed in the New Code of Mines include:

The principle of sustainable development for any mining activity in the country.

The instruments to enforce the environmental regulations are environmental management plans, environmental alternative assessment, environmental impact assessment, environmental license, permits, and authorizations or requirements, as well as terms of reference for environmental studies and technical guides for environmental protection.

Mining and environmental authorizations should be process simultaneously by the mining and environmental authority.

Mineral prospecting, evaluation and exploration are exempt from the requirement to follow the licensing process as defined in law 99-93.

The environmental license for mining operations is deemed to include all of the authorizations, permits or requirements for environmental protection legally established for such activities.

The validity of the environmental license for a mining activity is not limited in time but will relate to the life of mining title (50 years).

Mining operations are required to have a legal policy as a guaranty the company will comply with all mining and environmental regulations.

In all cases when mining title ceases, the mining industry must put in practice all environmental measures to close the operation and reclaimed the abandoned land. The guaranty shall be extended for three year after the title ceases.

Technical review of the documentation, site evaluation and monitoring relating to all environmental impacts would be undertaking by a specially created group of external auditors to support the environmental authorities. Although the issue of approvals, licenses, penalties and sanctions would still remain with the environmental authorities (Ministry of the Environment for large mining operations and Regional Environmental Authorities for small and medium size operations).

Some concerns arose within the mining community as a result of the future introduction of this legislation, specially the application and enforcement to small-scale and informal operations. That has led off to fears of closure of many operations owing to their lack of technical knowledge for the mining design, mineral planning and environmental management plans and the lack of funds for their implementation.

NEW APPROACH TO THE ENVIRONMENTAL REGULATIONS

The government of Antioquia (Region in the west part of Colombia) represented by the Secretariat of Mines and Energy, has initiated a program which aims at improving the environmental performance of the aggregates industry in that region. The idea of the program was to establish a voluntary control system, which after having reached certain coverage should enforce other companies to improve its environmental performance.

The National Cleaner Production and Environmental Technologies Center (CNPML) in Medellín-Colombia was selected to coordinate and prepare the program which was called *CANTERA VERDE* (Green Quarry).

The CNPML which is supported by the Swiss Federal Laboratories for Material Testing and Research – EMPA in St Gallen through funds of the Swiss State Secretariat for Economic Affairs has further developed the *CANTERA VERDE* program and has asked EMPA support through international consultancy. As a result, Ecopartner Ltd. of St Gallen, a specialized engineering and consulting firm in resource management, has been selected to develop the program.

Due to the interest of the aggregate industry in the country the program became a national initiative supported by associations such as the Colombian Sand and Gravel Association – ASOGRAVAS.

The objective of the program *CANTERA VERDE* (green quarry) is to recognize and give benefits to the companies who manage in a systemic way their environmental responsibilities and who could exhibit positive environmental results to society based upon self-regulatory practices.

Before we set the program

For the preliminary phase two sites were selected in the region of Antioquia. An initial visit was conducted to assess general conditions of the sites. Based upon a general checklist of environmental impacts, a first assessment was done. That has become in the basis for an action plan for both sites to improve their environmental performance.

In the extension phase the methodology for the assessment has been verified and further developed with 5 additional companies.

The program

The *CANTERA VERDE* program is a tool to support the continuos improvement of the environmental performance of the industry reducing the negative impacts to the environment and standardizing procedures and enforcement protocols among the environmental and mining activities through the use of indicators.

The *CANTERA VERDE* includes all activities aggregate mining and plant operators and developers are required to conduct in an environmentally acceptable manner in compliance with all the standards, regulations and permit conditions of the exploitation process.

The objectives of the program

- To promote the use of new strategies to enforce environmental regulations in a more cost-effective manner based upon the environmental performance;
- To create market incentives for *CANTERA VERDE* companies and to motivate other companies especially those informal actors to participate in the program;
- To increase the level of legal compliance of the sector and to continuously improve the environmental conditions in and around exploitation areas;
- To promote the adoption of environmental management systems in the aggregate industry as a complementary route to environmental continuous improvement;
- A driving forward for processes and products to become cleaner;
- Establish a national environmental information system for the aggregate industry in Colombia;
- To help companies during mining closure activities.

Legal compliance is a prerequisite to enter the *CANTERA VERDE* program, which implies that a company should have the necessary mining and environmental licenses

The participation in *CANTERA VERDE* is voluntary to the companies. The program was designed as a self-control program for the aggregates sector with participation of the environmental and mining authorities.

The program believes in the framework of pollution prevention, that is why the activities are presented in a manner that all the disturbances caused by mining can be minimized by planning and using safeguards practiced throughout exploration, mining and reclamation.

Self-control on one hand means that the sector itself is taking responsibility for increasing the level of environmental performance by setting and controlling the *CANTERA VERDE* standard, but on the other hand it also means, that the companies themselves have take responsibility, because some measures are out of regular control by the auditor.

CANTERA VERDE must have high credibility among mining and environmental authorities and the general public.

ISO 14000 standards and *CANTERA VERDE*

The general requirements of ISO 14001 "Environmental Management Systems" are considered in the program. They include the aspects of legal compliance and continuos improvement of the environmental performance (Plan-do-check-act cycle).

Although it is in the initial stage not intended to establish *CANTERA VERDE* as a certified label. It is recommended to respect ISO 14020 "Environmental labels and declarations-General Principles"

Standard 14031 "Environmental management – Environmental Performance Evaluation Guidelines is of relevance for *CANTERA VERDE*. Environmental performance evaluation is an internal management process and tool designed to provide management with reliable and verifiable information that uses indicators to compare an organization's past and present environmental performance with its environmental performance criteria.

In the *CANTERA VERDE* program it is intended to determine the environmental performance of a company operating a quarry or gravel pit by external auditors and to compare the environmental performance with the standard set by the *CANTERA VERDE* program. Despite ISO 14031 criteria and guides, the indicators system in *CANTERA VERDE,* today is mostly qualitative.

***CANTERA VERDE* system indicators**

The goal of environmental Indicators is to communicate information about environmental impacts generated by aspects related to the aggregates operation that affect it in ways that highlight emerging problems and draw attention to the effectiveness of current environmental practices in the industry. Indicators must tell us, in short whether things are getting better or worse. To tell this an indicator must reflect changes over a period of time keyed to the problem. It must be reliable and reproducible, and whenever possible, it should be calibrated in the same terms as policy goals of the company.

The indicator system that has been developed for CANTERA VERDE program consists presently out of 25 indicators. These indicators are distributed among the 6 main environmental areas: soil (8 indicators), water (8 indicators), dust, noise and vibrations (4 indicators), energy (2 indicators) and ecology and landscape (3 indicators).

Experts in the aggregates industry are still studying this indicators system and we expect to release the final version by December 2000.

Environmental aspect: **Soil** (8 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance Indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Soil deterioration	Soil handling during exploitation	**S1**	Excavation and storage of topsoil and subsoil	The *topsoil* has a high organic content and is the major zone of root development. It carries much of the nutrients and it supplies a large share of the water to plants. The *subsoil* is the nutrient, water and air reservoir of the soil for plant growing. Inadequate handling of top- and subsoil might destroy soil characteristics and lead to a loss of soil fertility.	(1) use of adequate machines to avoid compaction during excavation and handling of soil in particular of topsoil; (2) immediate reuse and/or adequate storage and protection of soil against erosion and sludgeing (topsoil-heap max. 3 m; basis slope 4-5%; ensure drainage) (3) minimization of transport distances for soil between excavation, storage and reuse
		S2	Disposal and reuse of overburden	Material which is below the quality for selling can either be piled and/or dumped or used to reduce other impacts of exploitation activity, for example dust and noise from exploitation and/or processing activities to residential areas.	(1) adequate reuse of overburden to reduce other impacts of exploitation activity; *if not possible:* (2) adequate disposal of overburden by proper dumping
Soil deterioration	Handling of sludge from processing activities	**S3**	Sludge handling and disposal	Sludge from processing can in some cases be sold or has to be disposed off. Sludge is of limited permeability and can cause drainage problems, destroy soil texture or limit soil fertility if not disposed off properly.	Sludge reuse and/or proper disposal (pre-drying out; maximal layers of 0.5-1m)
	Refilling with excavation and waste material	**S4**	Planning and operation of refilling with excavation and waste material	In certain cases an exploitation site is used for disposal of excavation and/or waste material. For refilling material of different quality will be brought in and disposed off. The quality of this material has an impact on stability aspects, drainage of exploitation area and water quality in underlying areas.	(1) adequate planning and operation of refilling (2) disposal of adequate material according to risk of water and soil contamination and stability criteria; (3) control of origin and quality of material prior to disposal and adequate separation for disposal; (4) monitoring of refilling process; (5) adequate drainage, control and disposal of drainage water; (6) protection of site to avoid unallowed disposal
	Restoration of soil for preparation of after-closure use	**S5**	Technique of soil restoration for after-closure use	Soil restoration is important to ensure fertility in those areas where a reforestation or recultivation is foreseen. Adequate soil restoration includes preparation of soling level and replacement of subsoil and topsoil and allowing drainage. Poor drainage can lead to permanent wetlands and therefore limited fertility.	(1) ensure drainage of soil by keeping adequate slope on soling level; (2) adequate restoratioin by use of well graded soil (subsoil thickness around 80 cm); (3) use of adequate machines to avoid compaction in particular of topsoil; (4) ensure start of biological activity and avoid erosion of topsoil;

Environmental aspect: **Water** (8 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance Indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Soil deterioration	Erosion or landslide of exploitation area	**S6**	Protection of exploitation area against erosion and landslides	Surface water in an exploitation site can cause erosion within the site and create landslide risks to underlying areas. In certain cases, exploitation can require permanent or temporary brook or river relocation that - if not done properly - can increase erosion risk.	(1) adequate topographic arrangement to minimize erosion and landslide risk; (2) adequate drainage and water disposal (along roads, slopes etc.); *if relevant:* (3) proper relocation of brooks to avoid erosion or landslide risk
	Erosion or landslides of external slopes	**S7**	Protection of external slopes against erosion and landslides	External slopes created by the exploitation can get eroded and loose their fertility or pose a landslide risk to roads, electricity lines, power stations, residential areas etc.	(1) adequate slope, drainage and replanting to avoid erosion or landslide risk; (2) reduction of landslide and erosion risks of steep slopes by placing benches every 10-20 m height
Soil deterioration	Erosion of river banks through unadequate exploitation	**S8**	Technique for exploitation of river banks	Inadequate exploitation of riverbanks can change existing balance between erosion and deposition of river sediments and/or increase risk of floods in underlying areas. In addition increase of suspended solids and or water pollution by machines can endanger fishing properties.	(1) balanced exploitation within amount of material deposited by river; (2) no lowering of riverbed in and besides the exploitation site; (3) protection to avoid endangerment of fishing properties
Water pollution	Water quality endangerment through exploitation activities	**W1**	Protection against water pollution from exploitation activity	During exploitation activity machines or vehicles might loose hydraulic and/or diesel oil. Exploitation above or within water extracting area increases the risk of water contamination, if no preventive measures are taken.	(1) limited and adequate storage of water endangering liquids in exploitation site; (2) regular maintenance and repair of machines and vehicles as much as possible outside exploitation area; (3) immediate removal and proper disposal of oil losses (use of oil bindings materials) *in high risk zones:* (4) keeping of machines during non operation times out of exploitation area; *optional:* (5): use of easily-degradable oil in machines and vehicles (on plant basis)
	Water quality endangerment through processing activities	**W2**	Protection against water pollution from processing activity	Processing areas can pose a risk of ground and surface water through the use of diesel oil for engines or by use of lubricates for conveyor belts etc. In addition disposed water can endanger surface water if quality of disposed water is insufficient.	(1) proper condition of processing area by regular maintenance and repair of processing devices; (2) adequate water treatment and disposal to ensure quality in run-off water
	Storage, handling and disposal of waterendangering liquids	**W3**	Storage facilities, emergency protection schemes and disposal of waterendangering liquids	Water endangering materials like diesel oil, new and/or used hydraulic and engine oil or lubricants are mostly stored nearby the exploitation site and pose a potential risk to ground- and surface water resources if not stored and handled properly. In addition most of the sites have a diesel oil pumping station for refilling of vehicles and trucks.	(1) adequate location, condition and protection of storage facilities for grease, machine oil and lubricants (2) adequate location, condition and protection of diesel tanks and diesel oil pumping station (3) adequate disposal of collected contaminated liquids

Environmental aspect: **Water** (8 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Water pollution	Vehicle and machine maintenance and repair area	**W4**	Protection against water pollution from maintenance area	Vehicle and machine maintenance is mostly done within or nearby the exploitation site. This can pose a potential risk to water resources due to the use of water endangering liquids.	(1) adequate condition and protection of maintenance and repair areas (sealing of ground and manholes; existance of grease and oil trap); (2) adequate retention of spoiled waterendangering liquids; (3) quality control of disposed water
	Solid waste collection, storage and disposal	**W5**	Solid waste collection, storage and disposal	Inadequate waste collection and storage in a quarry or gravel pit is a pollution risk to water resources. Waste can include barrels, oily metal parts, oil filters, damaged machines, tires etc.	(1) proper waste collection and storage with distinction of waste quality; (2) adequate disposal of collected waste
	Water quality endangerment through disposal of domestic wastewater	**W6**	Disposal of domestic wastewater	Wastewater from toilets, kitchen and bathrooms in the premises of the exploitation company are polluted and need to get disposed of into a sewerage system or have to be pretreated by septic tank and infiltration prior to the disposal.	Disposal of household wastewater in sewerage system or disposal by adequate designed septic tank and soil infiltration system.
Water dissipation	Inefficient use of water in the material processing	**W7**	Water use efficiency in material processing	The processing unit needs water for gravel washing and recovering of sand fraction. Water use efficiency is environmentally relevant. Adequate layout and operation of the processing unit and the water system can reduce water consumption.	(1) adequate design of processing unit; (2) minimization of water use in processing through water-reuse; (3) prevention of water losses
River flood risks	Flood risk of exploitation site by river	**W8**	Protection of exploitation site against flood risks by rivers	A river can pose a risk to exploitation areas, if exploitation is within flood risk zone of river and no or non-adequate protective measures are taken.	(1) keeping of adequate distance from rivers; (2) adequate protection against flood risks (construction of dams etc.); (3) existance of emergency scheme and measures

Environmental aspect: **Dust, noise and vibrations (**4 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Dust emissions	Dust emissions from processing	**A1**	Protection against dust emissions from processing	Material processing and handling lead to dust emissions that can endanger residential or natural conservation areas.	Protection to avoid or reduce dust emissions (covering of processing devices, construction of dams, plantation of trees, sprinkling of dust emission spots etc.)
	Dust emissions from transportation	**A2**	Protection against dust emissions from transportation	Internal and external transportation of materials lead to dust emissions that can endanger residential or natural conservation areas.	Protection to avoid or reduce dust emissions (wheel washing, road irrigation, paved roads etc.)
Noise emissions and vibrations	Noise/vibrations from exploitation	**N1**	Protection against noise and vibrations from exploitation	Exploitation activities (operation of vehicles and machines as well as blasting) cause noise and can have a negative impact on the environmental conditions.	Protection to avoid or reduce noise emissions (dams, trees, adequate operation times etc.) *blasting:* warning system for blasting units, blasting plan; measurements of noise and vibrations
	Noise from processing	**N2**	Protection against noise from processing	Processing activities through machines cause noise and can have a negative impact on the environmental conditions.	Protection to avoid or to reduce noise emissions (dams, trees, adequate operation times etc.)

Environmental aspect: **Energy** (2 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Energy dissipati-on	Energy consump-tion in exploi-tation process	**E1**	Energy use efficiency in exploitation	The exploitation process like area preparation, excavation, and internal transportation (in certain cases) lowering of watertable needs energy. Efficient use of energy is environmentally and economically relevant.	(1) minimization of energy consumption through adequate *planning of exploitation* (2) minimization of energy consumption by optimi-zation of vehicle and machine use for excavation, optimization of exploitation concept and techniqueand internal transportation
Energy dissi-pation	Energy consumption in processing machinery	**E2**	Energy use efficiency in processing	The processing of the material needs energy (hauling, crushing, washing, separation, storage). Efficient use of energy is environmentally and economically relevant.	(1) minimization of energy consumption through adequate planning of layout of processing unit (distances, level differences etc.); (2) minimization of energy consumption during processing through use of adequate processing machinery (according to quantity and quality of material)

Environmental aspect: **Ecology and landscape** (3 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Damage of eco-systems	Damage of ecosystems during exploitation process	**ES1**	Measures taken to protect and create ecosystems during exploitation	Exploitation activities are interventions in the existing ecological conditions. On one hand they can hamper ecological exchanges. On the other hand they can create new ecosystems which are gradually populated by vegetation and animals.	(1) inventorizing of species and ecosystems prior to exploitation activities; (2) protection of valuable ecosystems during exploitation; (3) stepwise creation and movement of ecosystems according to exploitation process.
Deterio-ration of land-scape	Visual impact during exploitation	**ES2**	Measures taken to reduce visual impact during exploitation	Final or provisional reforestation measures as well as provisional or final construction of dams and adequate exploitation concept can reduce visual impact during operation period.	Adequateness of *exploitation planning* and operation to reduce visual impact

Environmental aspect: **Ecology and landscape** (3 environmental performance indicators)

Issue	**Environmental aspect**	**Environmental performance indicator**		Description of environmental relevance	Requirements for **CANTERA VERDE**
Deterio-ration of land-scape	Landscape rearrangement for after-closure use	**ES3**	Reforestation and/or renaturation measures for after-closure use	After closure of an exploitation site, the landscape has lost its initial shape. The landscape has therefore to be rearranged in accordance with the intended after-closures uses. This rearrangement has to be integrated in the planning and operation of the exploitation. Reforestation and renaturation measures reduce damage to ecosystems and can progressively improve quality of the extraced areas.	(1) adequateness of *landscape arrangement, reforestation and renaturation planning;* (2) preparation of planting (nursery) and planting of habitat adapted bushes and trees; (3) stepwise rearrangement of planned landscape according to exploitation progress

This group of indicators was extracted from the technical report prepared by ECOPARTNER LTD a company based in St Gallen, Switzerland, specialized in waste and resources management, contaminated site remediation and environmental management.

Module II

Juridical and Legal Framework

MINE CLOSURE: THE SEARCH FOR A LEGAL FRAMEWORK

Maria Laura Barreto
LBARRETO@CETEM.GOV.BR

SUMMARY

This paper seeks to analyze the ambiguity and flexibility currently prevalent in legal systems and in related literature regarding mine closure and proposes an approach based on stages in the mining process.

It also seeks to deal with the main controversial aspects of regulation, based on critical analysis of the legal systems of various Latin American and North American states. The focus of research was mine closure as a new phase in mining operations, legal/technical and economic instruments, and regulatory and monitoring bodies responsible for this new stage in mining. This second aspect (instruments) is examined with an emphasis on responsibilities and guarantees.

LEGAL CONCEPTS: REFLECTIONS

Up until the 1980's, legal codes governing mining were principally concerned with regulating the various methods of mineral resource exploration, establishing administrative procedures and the rights and obligations of the mining entity. In addition, these regulations were concerned with defining the jurisdiction and authority of the various bodies responsible for the licensing and inspection of mining activity. The objective of the legal codes was the optimization of the exploration and use of mineral resources. As a result, mining activity was divided into phases: prospecting; research; mining (extraction)/refining.[1]

The focus of the laws and regulations was therefore on the exploitation of mineral resources and activities directly related to it. Public authorities were not concerned with, for example, the project pre-planning, or the project planning and did play a part in addressing the process of mine-closure or environmental revitalization of areas affected by mining. These were regarded as activities related to the commencement and development of the mining process, which should be left entirely up to the mining entity.

So far as the mineral project is concerned, in Brazil for example, only the research work plan (together with the budget, chronology and economic operational plan for site excavation, including a description of the refining process), needs to be submitted to the National Mineral Production Department – DNPM, when applying for permission to excavate. All other studies undertaken by the mining entity, are not analyzed during the licensing process. These unanalyzed studies include those relating to the socio-economic evaluation of the area, and form the actual basis for the investment decision.

This procedure is being gradually modified by the introduction of environmental variables. The Environmental Impact Study - EIA/RIMA and the Environmental Control Plan are indicative of this change. In other words, current government interest in mining activity is no longer limited to mining operations *stricto sensu* in isolation from its socio-economic and environmental reality. Rather, mining activity is seen as an activity which can generate national wealth and promote environmentally-friendly regional development; an essential component of sustainable development. Mine-closure is an important issue in this new vision.

[1] Some minor differences in the denomination of mining phases may occur as a result of the aggregation of some phases or simply because of differential denomination of the same process.

Given that this is a relatively new area it is perhaps not surprising that the related literature is full of apparently synonymous terminology, e.g. mine decommissioning, revitalization of affected areas, pit closure; mine closure, etc. In fact, it seems that these terms relate to different procedures, which occur at different times in the production process.

The process may be diagrammatically represented as follows:

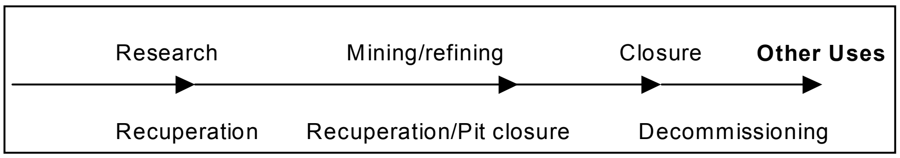


Figure 1: Stages of mining activity versus environmental processes

Several matters merit consideration. Mine closure is a phase, which should be borne in mind from the outset, as part of the mineral project stage, with a view to assessing the environmental impact and costs of this stage. The revitalization of affected areas should be considered during the research stage whether or not the mining entity intends to remain operational in the location after closure.

Revitalization of affected areas is, during the mining process, related principally to pit closure. It is important to note that pit closure has historically been seen by the mining entity in terms of safety and the continuation of mining activity, and not in the wider sense of environmental recovery. In addition to issues of safety and continuity of operations, this involves the cleaning up of contaminated areas and finding alternative uses for deactivated areas.

Mine closure, on the other hand, should be seen as a mineral phase, which commences when the mine has been completely excavated or when continued mining of the site is no longer technically/economically viable. Mine closure involves a complex decommissioning process with various aspects:

- technical;
- environmental;
- socio-economic;
- political.

The basic question to be posed is: What is the destiny of the area? It is in order to satisfactorily answer this question that the process of decommissioning is begun, and culminates with the area being returned to those legally entitled to it in conditions which permit its future use.

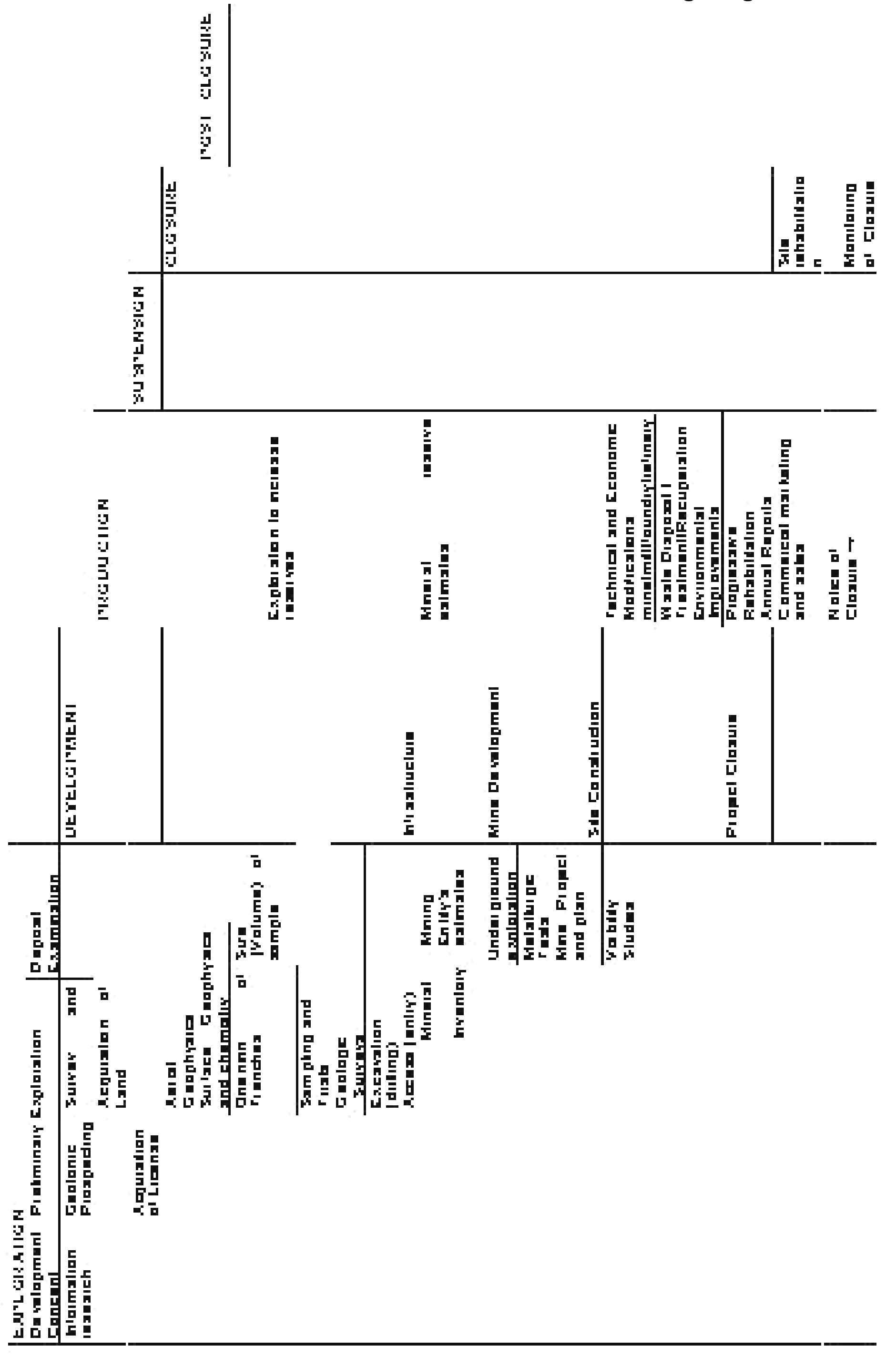
Diagrammed out below in **Box 1 and 2** below contain diagrams

Box 1
Canadian View of "Key Activities and Potential Environmental Impacts of Each Phase Of Mining"

Mining Phase	**Key Activities**	**Potential Environmental Impacts**
Exploration	Prospecting Geochemical and geophysical surveys Drilling and trenching Staking mining claims	Generally low or no impact When exploration reaches a stage of requiring, drilling, or road access, habitat disturbance increases and the discharge of contaminants can occur
Mining and milling	Feasibility and engineering design studies Public review Mine construction and pre-production Extraction and crushing and/or grinding of ore Flotation or chemical concentration of ore	Discharge of acid mine drainage that contains contaminants that are released to surface water and groundwater; particular concerns are related to: - heavy metals originating in the ore and tailings (can be accelerated by naturally occurring acid generation) - organic compounds originating in the chemical reagents used in the milling process - cyanide, particularly from gold milling processes - ammonia Alienation of land as a result of waste rock piles and tailings disposal areas Increased erosion; silting of lakes and streams Dust and noise
Post-operational waste management	Mine reclamation and abandonment	Continuing discharge of contaminants to groundwater and surface water (particularly heavy metals when naturally occurring acid generation exists) Alienation of land and one-time pulse discharge of contaminants and sediment to water as a result of dam failure

Source: Canada. House of Commons. *The State of Canada's Environment.* Environment Canada. Standing Committee on Natural Resources, Ottawa: Government of Canada, 1996. Chapter 11, tables 11.14 and 11.15, em BARRETO (1997)

Box 2:Canadian Government View of Mining Stages



Permanent Maintenance Source: Intergovernmental Working Group on the Mining Industry of Canada (1996), in BARRETO (1997)

THE MAIN ASPECTS OF A LEGAL APPROACH TO THE MINE CLOSURE

Roberts & Others (2000), Zenteno (1999), Sirotheau (2000) e Menezes & Barreto (1997), discuss many experiences related to mine closure in other countries. Three aspects were selected based on this discussion as being crucial to a legal approach to mine closure: the treatment of mine closure as a new phase in the mining process; legal/technical and economic instruments and regulatory/inspection agency.

MINE CLOSURE AS A NEW PHASE OF THE MINING PROCESS

Mine closure should be seen as another phase or step in the mining process. This already occurs in some countries, particularly in the traditional mining countries of the Northern Hemisphere. The concept is not always present in Latin American countries and is frequently confused with mere environmental revitalization of the area.

The dangers of this latter approach are twofold. Firstly, the fact that recuperation of the area affected by mining is a process which occurs only at the end of mining activity and not a continuous process beginning at the research stage and ending with the mine closure stage. Secondly, mine closure is seen merely as an environmental issue and not as a socio-environmental process.

Canada was chosen as an example of a country where mine-closure is regarded as a new mining phase as illustrated in **Box 2** above.

As all other stages, it should have a beginning and pre-established duration period, which should be communicated to the control and inspection agency. This period, according to the experience of some countries, should be from 3 to 6 years depending on the type of operation. The estimated duration should be reviewed and altered as and when necessary.

The rights and obligations of both the mining entity and the relevant public authority should be clearly established. Examples include the need to present a mine closure plan for approval; annual reports designed to aid the public authority in its monitoring capacity and inspection visits.

TECHNICAL/LEGAL AND ECONOMIC INSTRUMENTS

Mine Closure Plan

This is an important legal/technical instrument which on the one hand aims to plan the activities and on the other to provide the mining entity with guarantees. This is because, like all other mining activity, mine closure involves a series of different actions, which must be planned and co-ordinated, for example:

Technical/Environmental Actions

- Dismantling/re-use of the infrastructure of processing and refining units, support installations, maintenance and access equipment (hydraulic and ventilation system);
- Technical solutions for the pit, envisaging future use for the same and its surroundings;
- Cleaning of containment dams and other types of waste, particularly when it contains heavy metals or dangerous substances such as those involved in acid drainage;
- Restocking and re-forestation of deforested areas;
- Future monitoring;

Socio-Economic Actions

- Economic alternatives for the region: other mining projects or other economic activities;

- Redeployment of the workforce;

- This plan should be based on a realistic diagnosis of the mining undertaking's socio-environmental and local/regional situation. The plan should be elaborated by the mining entity, and approved by the relevant public authority.

The community affected should be involved in the elaboration of the plan and should have an opportunity to discuss and debate its proposals, as well as playing a part in its implementation. This objective may be achieved in different ways: such as the establishment of a council including community representatives, which takes decisions, monitors the elaboration of the plan, approves it prior to its presentation to the public authorities and holds public meetings to discuss the project and its execution.

Responsibilities

Issues relating to responsibility are crucial, both from the point of view of the mining entity and the public authorities, in the sense of providing security in the sense of the work to be undertaken by the former and with a view to ensuring that the later does not may unreasonable demands. It is therefore important that all the obligations of the parties involved in the process be defined in relevant legislation. The legislation should be as detailed, as possible, and generic formulae should be avoided. The educational and informative role of legislation should be borne in mind with a view to attaining its ultimate objective: compliance.

In most mining countries, the determination of the person/entity responsible for the mine-closure phase is complex. For example:

- New projects. The mining permit-holder is responsible;

- Projects already underway. In principle, the original mining permit holder is responsible, however the extent of responsibility requires analysis given that this new phase was not considered at the technical/economic viability stage, or if it was, it was probably not analyzed in the way required by the current system;

- Previously terminated operations, the so-called abandoned mines;

- Previously terminated operations in which the previous permit holder is unknown, the so-called orphan mines.

- These last two situations are the most complex given that the public authorities and society in general cannot ignore the impact (particularly in terms of the environment) of these projects, which despite having been terminated did not undergo any decommissioning process or previous preparation for closure, and which may continue to have a negative impact on the environment. In the case of orphan mines there appears to be no viable alternative to the State assuming responsibility for the environmental rehabilitation of the area, given that the identity of the permit-holder is unknown.

- In the case of projects previously terminated, where the identity of the title-holder is known, there is the possibility of requiring the previous title-holder to arrange environmental rehabilitation of the area. In any event, regulation of mine closure requires clear directives covering the two items referred to above. Further, it is important to bear in mind the various types of responsibility; administrative, civil and criminal. The current trend in environmental law is the imposition of criminal responsibility on the basis that the threat of severe punishment induces compliance with the law. However, at times, administrative punishment can be quicker and more effective, since it is free of procedural delays characteristic of criminal proceedings.

Guarantees

Almost all legal systems find it necessary to require economic guarantees for the mine closure phase. This is due to the fact that the activities to be undertaken may have a high cost, which it may be difficult for some companies to bear, resulting in problems in meeting future obligations.

When legal systems regard financial guarantees as necessary they tend to use financial/economic mechanisms which can be triggered if and when necessary. Such measures, according to ROBERTS & OTHERS, include:

- Letters of credit;
- Payment of Deposit;
- Insurance;
- Guarantor.

There are advantages and disadvantages to each of these guarantees, and the legislator should select that which is most appropriate in the particular country and mining situation. A guarantee should never be used as another form of taxation on mining activity. This is crucial if the system is to maintain credibility. The example of Argentina is instructive in this context.

The magnitude the sum guaranteed is a delicate issue in that each project has its own specifics, depending on the type of mine and pit, dimensions, locale, the technology used and other variable factors which may have varying socio-economic and environmental effects. It falls to the legislator to be aware of the specifics of each type of operation and establish appropriate conditions based on:

- Type of mine/pit;
- Size of undertaking;
- Locale: urban/rural area; vulnerable ecosystems; culturally sensitive areas (e.g. Native Indian Reserves).

It should be borne in mind that the level of the guarantee is a factor, which will feature in analysis conducted by national and foreign investors.

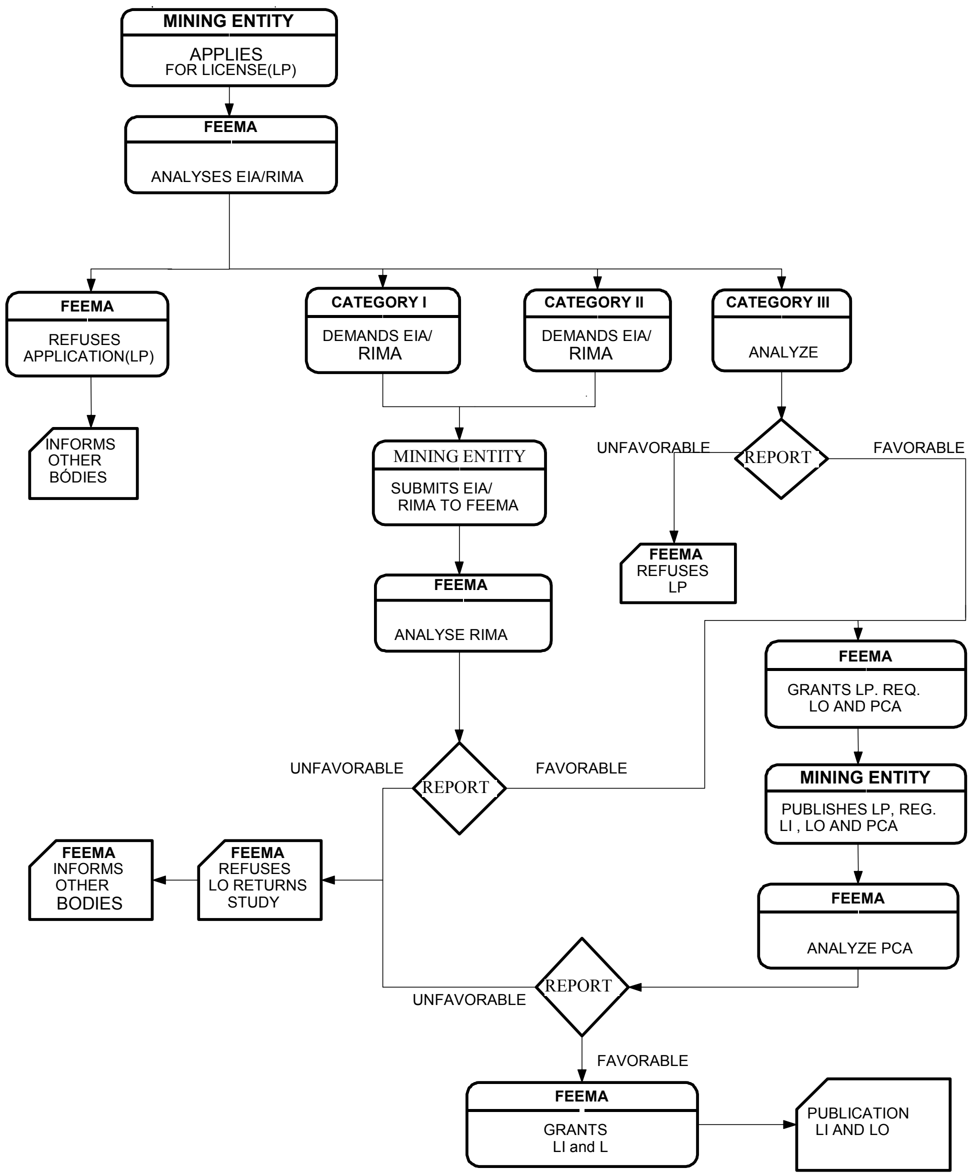
REGULATORY AND MONITORING AGENCY

The mining sector has special characteristics, and is as a result considered an economic activity worthy of State control, as is the energy sector. As such, mining is regulated by an agency, which is responsible for issuing permits, inspection and control. This occurs in almost all Latin American countries.

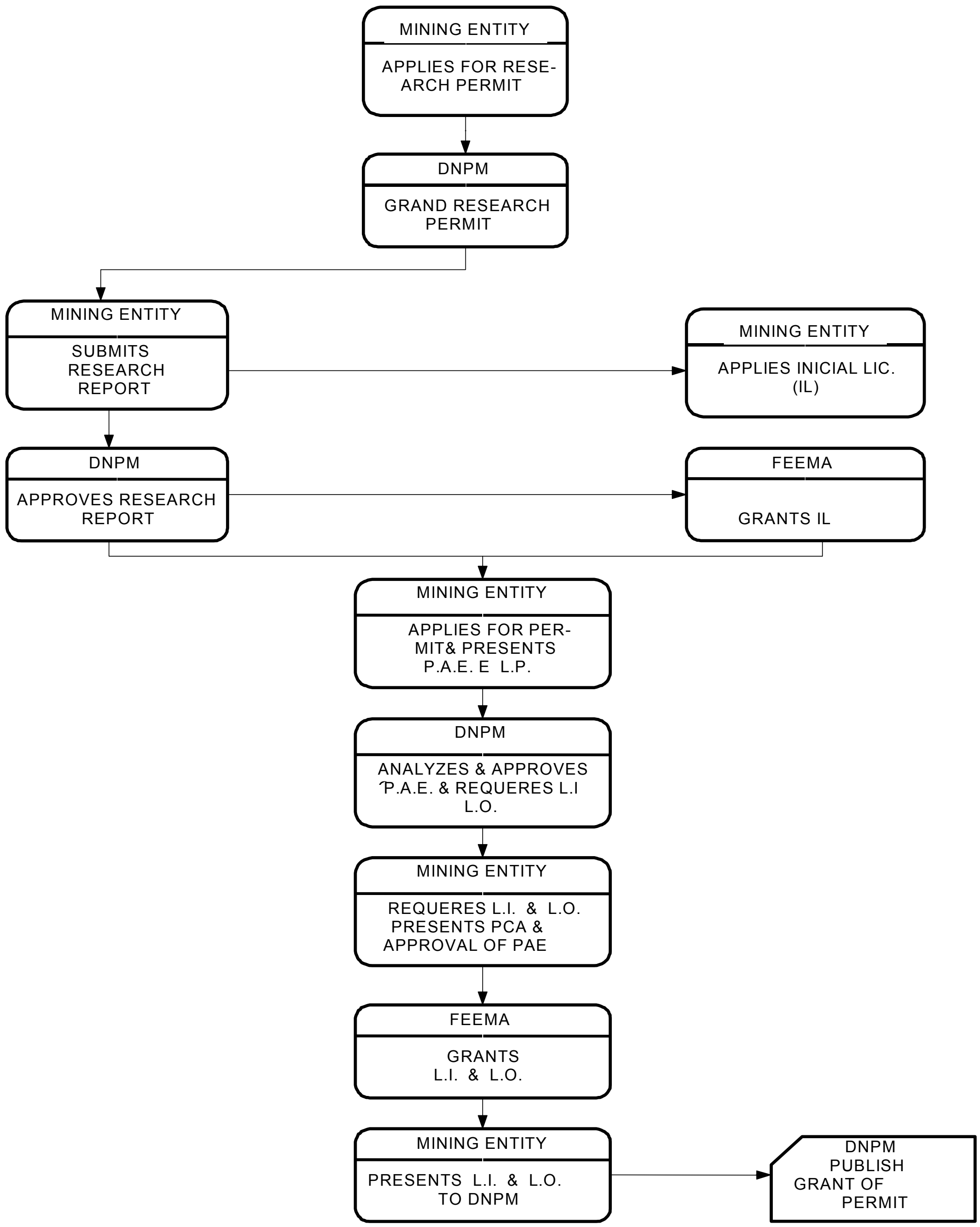
Environmental concerns have been high on the national and international agenda of most countries since the 1980's. As a result, economic activity is subject to environmental policies, regulated by federal, state and municipal agencies.

The large number of mining regulatory agencies has resulted in some cases in duplication and in problems arising out of excessive bureaucracy in relation to the issue of mining permits as set out in **flowcharts 1 and 2,** where the example of Brazil is examined.

In practice, there are two simultaneous and inter-linked procedures, for example, municipal licensing requirements frequently assume certain environmental measures have been complied with, and vice-versa (see **flowchart 2**)



Flowchart 1: Environmental Licensing Procedure



Flowchart 2: Mineral and Environmental Licensing

At the heart of this problem lies a theoretical and philosophical question. The current view of the regulatory function of the State in relation to the economic activities cited above is that the regulatory function should not be exercised separately in relation to economic development and the environment. The aim is sustainable development of all economic activity, including mining. The agencies responsible for regulation and inspection of the mining industry should base their activities on the goal of sustainable development.

In this context, there is no sense in having on the one hand governmental regulatory and development agencies and on the other environmental regulatory and control agencies. It does make sense to maintain the environmental regulatory agencies in respect of economic activities which are not subject to any form of regulation other than environmental, which in reality means most of the economic activities of any given country.

This issue is clearly relevant to the mine-closure phase. Which agencies should be responsible for establishing norms, for monitoring and inspecting this phase? Environmental agencies or mining regulatory agencies? The mine-closure phase is clearly hybrid; part environmental, part mining. On the one hand it is necessary to minimize the local, regional and national impact of the closure of an undertaking which generated wealth for the nation, and on the other, to reduce the present and future socio-environmental impact of the cessation of activities. This reinforces the argument presented above that there should not be any dichotomy between economic development and the environment, and there should be no agencies, which reflect this dichotomy.

3. Bibliography

BARRETO, Maria Laura. **A Experiência Canadense de Desenvolvimento Sustentado:** A Política Reguladora Mineral. CETEM/CNPq. Rio de Janeiro: 1997. MIMEO.

MENEZES, MÔNICA& BARRETO, MARIA LAURA. **Decommissioning of Mines, Sustainable Development Policies and Environmental Solutions**: Brazil and Canada. 1997. MIMEO.

ROBERTS, Steve and OTHERS. **Overview of Mine-closure in the Americas**. Executive Summary. Mine Closure Bibliographic Database Project. UBC/CETEM/MPRI/IIPM/IDRC. Vancouver: April 2000.

SIROTHEAU, Glória; BARRETO, Maria Laura; PEITER, Carlos e FERREIRA, Gilson. **Overview of Mine-closure in Latin America**. Executive Summary. Mine Closure Bibliographic Database Project. UBC/CETEM/MPRI/IIPM/IDRC. Rio de Janeiro: 2000. MIMEO.

ZENTENO, Patricia González. **Tratamiento Normativo de la Fase Minera Pos Operacional en los Países Latinoamericanos y la Planificación del Cierre**. Informe Internship. IDRC/CIID. Canada: Noviembre 1999.

CLOSING MINES IN MEXICO

Ing. *Margarita Lozada Nava*
Ecology Sub Director - General Mining Office

Mexico counts with more than 400 years in mining and the mining industry had been closely linked to the history and development of the country, contributing to the foundation and growing of many of the main cities, like Zacatecas, Durango, Chihuahua, Hidalgo, Guanajuato, San Luis Potosi which are still having great deal of participation in the mining-metallurgical national production.

The mining resources in the national territory had allowed Mexico to be placed among the main producers of 18 metals and minerals where we can find silver, celestite, fluorite, arsenic, bismuth, cadmium, graphite, molybdenum, zinc, antimony, barium oxide, lead, manganese, salt, gypsum, copper, feldspar, and sulphur. Mexico stands up for its importance in the sustained production of silver well known world wide.

As the majority of our countries, the mining sector importance in the mexican economy lays in the amount not only of the metals and minerals but also in the thousands of employees direct or indirect generated particularly in remote locations where another kind of different industries than mining could not be developed because of the infrastructure.

From its conception mining had found challenges of all kinds, which had been sort through development of technical skills and/or practising human resources. On time this challenges are more complex and required more skills to be overcome among them is the environmental challenge.

In the XXI century mining will face less real costs of metals and the necessity to process minerals of less quality and major mineralogical complex. Also will require to elevate the recuperation of values in the process, a production of concentrate and metals of best quality, a major productivity, the development of more sophisticated technologies but efficacious and above all its compromise for a better tilt and rehabilitation in mining sites.

Nowadays among the main environmental problems that our activity faces is the high energy consumption, the generation of important volumes of residues (tailings) the emissions to the atmosphere (gases and particles) the biological diversity deterioration in the mining sites, the risks of ground and water contamination the process of closing and abandoned of mines as well as a growing negative social perception.

In this context the “prints” of the mining activity in a country like Mexico are found at peoples sight. The residues generated and deposited in tailing ponds represent environmental risk that worries the population and authorities. But before we are completely in the mining subject and environmental we would point some important aspects in both legislation as well as its relations.

In Mexico the mining resources are nation property and is this who gave particulars through a concession the possibility to explore (even 6 years without an extension) a mining lot, having the right to substitute this concession for an exploitation one (for a period of 50 years and extensions).

The Political Constitution of the United Mexican States designated mining the quality of public nature that is why, the rights given from the State to particulars through The General Mining Direction of the Secretary of Commerce and Industrial Foment (SECOFI) oblige to establish agreements with the superficial owners where the fund is located it can be through different ways like temporarily occupation (indemnification and monthly rent) a pass right of way (indemnification and monthly rent) or via presidential expropriation (indemnification) only if it fulfil the Mining Law conditions for this case.

According to the present Mining Law, this had been from 1992 and was modified in December 1996 its regulations was actualised and published for its application in February 1999 contemplate in different articles that following are described and all of them with responsibility for the mining concessionaire to obtain the rest of the permits that the activity requires among them the environmental.

Art. 20 " ..... The work and labour in exploration and exploitatio within the federal zone ground of maritime and the protected natural areas can be only authorised by those who have the mentioned goods zones or areas in the dispositions and terms pointed applicable."

Art. 55 Will be punish with cancellation of the mining concession for whatever of the followed:

VII.- Do work or labour for exploration or exploitation without the authorisation pointed in the 20 article of the present law.

In the case of the Regulation of the Mining Law established in the 62 article that for the realisation of work or activities in the exploration or exploitation and benefit of minerals the interested will fulfil with the dispositions of the LGEEPA its regulations, official Mexican norms and rest of norms applicable in this matter.

Reference to the required in the environmental legislation even the first preceding in the 60 decade, was not till the emission of the General Equilibrium Ecological Law and Environmental Protection (LGEEPA) in 1988

The LGEEPA counts with some rules in the Evaluation of Environmental Impact, Prevention and Contamination Atmosphere Hazarous Residue Control, matter and to protect the ambience against contamination derived from noise. Actually is working with the Natural Protected Areas (ANP's) that results a special interest in the mexican mining activity.

The regulation that in a special way leads the mining activity is The Environmental Impact Evaluation in it is establish the evaluation procedures that all the mining activities such like exploration and exploitation have to follow.

For the first case, we have an official mexican norm (Obligatory fulfilment) that establish the environmental protection conditions that can be carry out when exploring, in the case of exceed the parameters of reference that the norm contains should elaborate a preventive inform that includes a major amount of information that allows the environmental authorities to evaluate the impact potential that can be caused in the ecosystem where the projects are located.

When the activities are exploitation, must be elaborated an environmental impact manifest (MIA) that included studies and information in the most amount and details. Is here where can find the first antecedent of the activities of closing mines, because the miners or companies should present an estimate of what their plans are for when the useful life of the mine expires.

The authority in charge to supervise the fulfilment of the terms of the opinion of the environmental impact is The Federal Agency of Environmental Protection (PROFEPA) meanwhile the authority that effects the evaluation is the National Institute of Ecology (INE) both assigned to the Environmental Natural Resources and Fishing Secretary (SEMARNAP)

The mining concessionaires should give PROFEPA a periodically inform of the advance in the fulfil of the operation conditions pointed by INE in the opinion of its MIA and at the present is lot of cases in Mexico where companies are working in restoration and closing of its mines.

Nevertheless the above, the main worry of the environmental authorities is centred in those mining installations that left operations many years ago, that are abandoned and where the environmental passive are really high.

The State does not count with enough resources to restore the contaminated site and look for some alternatives to resolve the situation, in the other hand, in the case of the mining installations in cooperation, regulations are establish and warranty that allows reasonably assure that when it is stop cooperating will effect actions that take care of the abandoned aspects of the same.

In special in the 48 article of the LGEEPA regulation in matter of Evaluation of the Environmental Impact, foresighted in the cases of conditioned authorisations, the SEMARNAP will point the conditions and requirements that should observe in the step previous to the start of activities as well as in the construction, operation and abandon stages.

In the other side in its 51 article the cited regulation, is establish that SEMARNAP could demand the issuing of insurance or warranties regarding the fulfil of the conditions establish in the authorisations, when during the realisation of the work could produce big damage to the ecosystem. Must understand this last concept, when:

- Could freed substances that in contact with the ambience will transformed in toxic, persistent or bio-accumulated,
- In the places where planing to realise the work, exist water bodies, wild endemic flora and fauna species, menage, in extinguish hazarous or tied to special protection,
- The projects implicated in the realisation of activities considered highly risk according to the legislation and applicable dispositions; and
- The work or activities carried in ANP's.

Complementary, the articles 52 and 53 prevent that the SEMARNAP set the amount of the insurance and warranties attending the value of the damage reparation that could derived from the no performance of the conditions imposed in the authorisations, meanwhile the promotes of the projects should renew or actualised annually, the amount of the same.

Is good to point that when its accredit to SEMARNAP, to fulfil with all the conditions that gave origin to all the warranties, previous application, will order its cancellation.

In our country, the schemes of the economic instruments are of recent application and still does not count with enough experience to evaluate its effectiveness, notwithstanding, take part of the present environmental mexican policy.

Considering the exposed panoramic, I should point to you that mexican mining continues in a change process, the present way to work is already considers the ambience variable within the costs of the operations; nobody can denied the way of work of the miners had been improvement technologic and socially in many of our countries.

In the special case of Mexico, before the 60 to 70's decade the mine and industrial activity in general, were not worried to do its activities taking care of the environmental surrounded them, nevertheless as time passed the challenge of mine were extended farther of the international quote pressure of metals and minerals, but international tendencies in health and environmental matter, to the influence of the social perception of the mining projects and to the environmental impact direct or indirect that generates.

It is clear now that the technical problematic of operation could never again be done without environmental responsibility from here that the liability of the mining projects will also be in function of the environmental costs that should considered to execute the closing of mines.

The experience from mines that up to date worked or still working in process of abandon and close, is coming from Peñoles Company, Luismin Industries and North Steeler Group, three of the most important national mining groups to whom I really thank for let it me have this information to make this presentation to all of you.

Peñoles Industries Case: Sultepec Unit in the State of Mexico, Cuale Unit in the State of Jalisco and La Minita Unit in the Sinaloa State.

LUISMIN INDUSTRIES CASE: SAN MARTIN UNIT IN THE STATE OF QUERETARO.

North Steeler Group Case: Minera Carbonífera Río Escondido in the State of Coahuila.

Conclusions:

The mining-metallurgic mexican sector contributes in an important way to the national economy, what makes necessary to attend its operation under a strategic view of modernisation to continuing being competitive in the international ambit.

The mining activity involves itself, physic-chemistry process that represents a potential risk of the environmental impact, these alterations should be attended in a legal way in each of our countries, such way that warranty the profit of the mining resources with which it counts and adequate quality of life for the towns where mining exists, it is fundamental in this process the mitigation of environmental impact generated, only that way could be a reality the maintainable mining.

The activities for closing a mine results of main importance for mining, because is also that the communities accept the presence of the operations in the surrounding area. An adequate environmental performance not only is a moral responsibility of the Enterprises but a tool more with which its activities develop a better social acceptance.

In the other hand the control and environmental instruments designs and apply for the activities when closing mines should walk and be applied gradually taking care its impact how the costs of a project could affect its feasibility.

ENVIRONMENTAL POLICY IN PERU AND LEGISLATION ON MINE CLOSURE

S. Rocío Gordillo Ruiz
UCP, Peru

INTRODUCTION

The Mining Industry plays an important part in the economy of many countries, so much industrialized as in development. However, they also figure among the industrial sectors whose activity involves the emission or discharge of enormous quantities of pollutants in the environment. Each stage of the production of a metal can be associated, to a certain extent, with an impact for the environment. This effect can even be bigger for the same magnitude of the industry and for the type of pollutants that generates.

The new technologies reduce the quantity of pollutants or they allow to transform the pollutants into inoffensive chemical products, preserving the environment.

The application of new and rigorous environmental norms in the world, has stimulated the development of new technologies which have rebounded positively in the environment.

In the last years, in the Peru, the Ministry of Energy and Mines has been placed to the vanguard of the other sectors concerning environmental topics and care of the environment. In these last five years, the mining sector has being adapted to the new environmental demands and the execution of the environmental normativity of the sector that tends to reach the international standards. The opening of the government to foreign investments in the Peru, has promoted the development of new technologies that try to mitigate to the maximum the impacts to the atmosphere.

Environmental norms in Peruvian Mining

1. CODE OF THE ENVIRONMENT AND THE NATURAL RESOURCES

This Code, approved and promulgated the 08/09/90 according to Legislative Decree No 613, expresses in a general way the necessity to protect the environment and the natural resources, leaving clear that is the competent authority (as it is the sector) the one in charge of the technical evaluation of the atmosphere.

In chapter III of this Code (of the Protection of the Environment) the Studies of Environmental Impact are already mentioned (EIA) indicating that the same ones could only be able to be elaborated by the properly qualified public or private institutions and registered in front of the competent authority, indicating also that the cost of its elaboration is of responsability of the holder of the project or activity.

Also in this chapter it is clearly defined that the EIA will contain a description of the proposed activity and of the foregone direct or indirect effects of this activity in the physical and social environment, to short and long term, as well as the technical evaluation of the same ones. They will indicate, equally the necessary measures to avoid or to reduce the damage at tolerant levels.

In the XII chapter (of Mining Resources) and their modifications according to the D.L. 708 published the 14/11/91 the following points were established:

- That the holder of a mining activity requires of approval of his project by the competent authority to carry out it, with the obligation of the defense of the environment and natural resources according to the parameters settled down by the competent authority.

- The new applications of benefit concessions will include a study of environmental impact.

- The Study of Environmental Impact in exploitation labors, will be dedicated to the control of the solid and liquid effluents.

- When requesting miner metallurgical waste deposits (tailings dam) the Construction Project, in order to avoid the contamination of water in particular and of the environment in general will include the following aspects:

a) That the technical conditions guarantee the stability of the system.

b) That the operation of the system is specified technically.

c) That the technical measures of abandonment of the deposit are explained.

- Obligation of the holder of including equipment for controlling pollutants in their installation.

- The exploration and exploitation of mineral resources will be adjusted to the following dispositions:

- In Open Pits measures that guarantee the stability of the land will be adopted.

- All water used for processing minerals must be recirculated as much as posible.

- All mining operation with use of explosive in the vicinities of populated centers will maintain the levels settled down by the competent authority, the noise impact, the dust and the vibrations.

- The residues and discharges to the atmosphere of processing plants and/or refineries will undergo a discharge control before treatment, so that it wont contamine.

- The radioactive residuals evacuated from the miner-metallurgical installations won't overcome the passable limits settled down by the competent authority.

- The competent authority will make periodic samplings of soil, water and air in order to preserve the environment and to take in case of being necessary the corrective measures.

As can be seen in this Code, it is framed in a general way the conditions in which the mining activity will be developed in order to take an appropriate environmental handling, inside obligations that concern the holder of the mining activity so as the authority of the sector.

Later on in the Orderly Unique Text of the General Law of Mining (D.S. 014-92-EM) approved the 04/06/92, in their Title Tenth Fifth on environment (art. 219 at the 226) this one reaffirms that what has been settled down by the Code of the Environment and Natural Resources and their modifications refering to the chapter of Mining Resources . This also adds that the competent authority for this sector will be Energy and Mines.

The Code of the Environment and Natural Resources, frames in a general way the obligations of the holders of mining concessions, and is the Sector of Energy and Mines which regulated in detail the environmental obligations that govern to date, and established the Regulation that is detailed next :

2. Regulation of the General Law of Mining refering to the Environment

In this Regulation (D.S. 016-93-EM of date 28/04/93) were clearly defined the obligations of the holders of the mining activity in order to fulfill the environmental protection in the mining-metallurgical activity and the measures of control of the sector that guarantee their execution.

This Regulation, contains obligations programmed by stages, and for that reason a series of mensurements and establishment of periodic monitoring programs were requested initially, to be able to have a starting point and this way the mining companies could go focusing the environmental problem in a reliable way gradually and then present an adaptation program that would allow them to fulfill the required standards.

To the date some of them have already concluded, having achieved their objective. Inside the obligations proposed in this regulation these are the following ones :

2.1 Anexo 1:

This is the Report about Emissions and/or flows of residuals of the Mining_Metallurgical Industry that will be presented annually, before June 30 and enclosed to the Consolidated Annual Declaration.

This report has character of juridical declaration and initially it has been good to know the kind of activity developed by the holder as well as the emissions and flows it has to have a starting point; later on it has been good to make a pursuit to the EIA or the PAMA as it is the case. Case

2.2 Monitoring Programs

Systematic sampling of the effluents of a mining operation that was carried out from March 94 to February 95, based on two guides published by the General Address of Environmental Matters of the Mining sector (protocol of water monitoring and protocol of air monitoring) and whose results were presented quarterly to the Ministry (June, September and December of the 94). With this program it has been possible to be able to take a registration of results that reflect in a real way the quality of the emissions.

2.3 Preliminary Environmental Evaluation(EVAP)

The EVAP constituted the final part of the Monitoring Program , and identified the problems in the atmosphere caused by the mining activity. This Preliminary Environmental Evaluation (EVAP), subscribed by a registered Environmental Auditor was presented to the Ministry in marzo-95, in the following month to the end of the Monitoring Program . This study included in addition the results of the monitoring program, the identification of the environmental problems and probable solutions.

As can be appreciated in the regulation, specific obligations were detailed and they served as starting point for the programs that are detailed next.

2.4 Program of Adaptation and Environmental Handling (PAMA)

Program that contains the actions and necessary investments in order to reduce or to eliminate the emissions of a mining metallurgical operation , at passable levels. The PAMA, obligation of all mining Company in operation, should be subscribed by a Environmental Auditor and presented to the MEM in one period that didn't exceed of 12 months of having approved the EVAP. To the date all the mining companies have fulfilled the presentation of the PAMA that represents an investment commitment, having as main objective to reduce the levels of environmental contamination diagnosed by the EVAP until reaching the permissible maximum levels. The pursuit of the PAMA, is carried out by the Ministry through the inspectors (auditors) whose existence is normed as it will be seen later on.

The PAMA has an execution chronogram that won't be smaller than 5 years neither bigger than 10 respectively, depending on, if it is an operation that doesn't include processes of sinterización y/o foundry or if it includes them. Also the annual investment that this PAMA represents won't be smaller to 1% of the annual sales of the company that presents it. In the PAMA, the holder commits to execute a chronogram of activities whose objective is to mitigate the impacts and to apply the necessary technology to have processes that don't contaminate the environment.

To the date there are 69 presented PAMA's that correspond to different mining operations or foundries and that include a commitment of total investment of US $928´038,495. Depending of if it is a mining operation or foundry the terms to be adapted to the commitments assumed in the PAMA vary from 5 to 10 years, and the investment distribution according to the operation type is shown in the following square:

PAMA's	Tipo de Operación	Inversión US $	%
55	Operation of Metallic minerals	117'619,668	12.7
05	Foundries and Refineries	809´528,350	87.2
09	Operation of Non Metállic minerals	890,477	0.1
69		**928´038,495**	**100**

The biggest investment percentage corresponds to foundries and refineries having in consideration the commitment assumed by Southern Perú in implementing a new copper foundry, with clean technology that ensure the conservation of the environment.

To the date, the committed investments for foundries and refineries and no-metallic operations have been completing according to the previously established chronograms, in a same way for the case of metallic operations of old mining holders, however there are medium metallic operations that have been privatized, this is the cause for which there is a small delay, having achieved an advance of 60 to 70% on the originally committed thing, but it is necessary to highlight that the assumed commitments will be completed in their entirety.

At the moment there are already concluded PAMA's , in those that in some cases the required investment has been bigger to the committed one in the PAMA and it is through the Inspection of activities whose norm will be explained later on that the Ministry verifies its execution.

2.5 Studies of Environmental Impact (EIA)

The EIA comes to be the integral study that should be made in projects for the realization of activities in mining concessions, of benefit, of general work, and of mining transport, that should evaluate and describe the physical-natural, biological, socio-economic and cultural aspects in the area of influence of the project, with the purpose of determining the existent conditions and capacities of the means, to analyze the nature, magnitude and to foresee the effects and consequences of the realization of the project, indicating forecast measures and control to apply to achieve a harmonic development between the operations of the mining industry and the environment.

This study will be presented by the applicant of a mining and/or benefit concession (new project), as well as those that carry out production amplifications in its operations or size of benefit plant superiors to 50%. Also, this study will be carried out by some of the registered entities and authorized to carry out studies of Environmental Impact in the General Address of Environmental Matters of Mining.

The objectives of a Study of Environmental Impact are:

· to Determine the environmental conditions around the area of the project

· to Identify the possible potential impacts

· to Identify the mitigation measures or elimination of the environmental impacts

· to Elaborate the plan of environmental handling

· to Elaborate an appropriate closing plan

· to Elaborate the respective contingency plans and of security

· to Carry out the cost/benefit of the project

The closing plan also constitutes an element of the EIA,.The new projects must consider from a beginning the plans for a technical abandonment once the the project has finished so that it could be able to restore the impacted areas as much as possible or in certain cases to assign them another use. Also in this case it is through the Inspection that the energy Ministry and Mines verify their execution.

3. Registration of Entities authorized to carry out Studies of Environmental Impact in the Sector of Energy and Mines

According to R.M. 143-92-EM/VMM of date 03/07/92 it was created in the General Address of Environmental Matters the registration of entities authorized to carry out Studies of Environmental Impact in the sector Energy and Mines. Being the EIA, a study that implies the interrelation of several disciplines, one of the requirements to be able to register is having a team integrated for not less than 5 professionals in some of the disciplines corresponding to the natural sciences, social sciences, sciences of the health, economic sciences and specialties related with the scientific or technological development in general.

4. Inspection of mining-energy activities by third

Starting from the 01/10/92, according to D.L. 25763 it was established that the obligations related to the mining activities, of electricity and of hydrocarbons would be investigated through Auditor and Inspection Companies. The obligations to which reference is made are: 0bligations derived of contracts taken place with the State, security norms and hygienic, technical norms and norms for environment conservation. This way, the Inspection passes at the hands of companies or private consultants, previously inscribed in the Address of Mining Inspection. Through these Inspectors or Auditors, pursuit is made to the execution of that settled down in the PAMA's or EIA's, as it is the case. So these Inspection Companies are hired by the mining companies, and there are carried out two annual inspections at the end of which there is a report presented to the Ministry of Energy and Mines. However, this system appeared like a necessity to exercise control on the mining activities and it is susceptible of being improved. At the moment a proposal modification of this Law exists, in way of improving this system that has reported some deficiencies.

5. Legislation on standard and permissible limits

With this whole existent normativity and being the objective of the same one not to contaminate, it was necessary to get adapted to certain standards and although in a first moment, there were some devices of other such sectors as the Law of Waters and the Law of Health, in all the measurements and samplings carried out in the different mining operations, (was to make) comparisons with international standards were made,in cases that the Peruvian laws had some hole in reference to the contents of some metal either in water or in air.

Finally in 1996, through ministerial resolutions of the Ministry of Energy and Mines this is achieved:

- To approve the permissible maximum levels of emission of liquid effluents for the mining metallurgical activities. According to this the following parameters are regulated: pH, suspended solids, lead, copper, zinc, iron, arsenic and total cyanide.
- To approve the permissible maximum levels of emissions of gases and particles for the minig metallurgical activities , regulating the emissions of sulfurous anhydride, particles, lead and arsenic present in the gassy emissions.

6. Legislation on Mines Closure

The mine closure is a wide and varied topic that do not only understands the physical atmosphere and the operative aspects of the mine but also the measures for contrarestar the economic impact in the hard-working population that rotates its economy around the mining operation.

Most of the mining operations in Peru consist of all or most of the following components:

- Underground and Open Pit mines.
- Waste Dumps.
- Mineral Processing Plants.
- Tailings Dam.
- Heap Leaching.
- Ponds, treatment plants and discharge points of residual waters.

Previously, the practices of mine closure in mines in Peruvian, included in general the abandonment of the operation without considering expenses to avoid environmental consequences. It is as well as they have left accumulating the environmental passive, for lack of technical planning for the closing. This has changed, and for the new projects it is required to include inside the EIA, a closing plan that identifies the problems, the focus, the objectives and the costs of the closing.

The acid drainage is a problem that all the mining industry faces. In Peru this is of particular importance, being necessary the appropriate characterization of mine rock and of waste material to incorporate inside the design of mine closure appropriate measures for the prevention of the generation of acid water.

In July of 1995, a guide of limits was published for considerations of closing of mining operations that describes the design mine closure like an specific activity for each deposit and which should take into account the climate, the hydrogeology the sensibility of the environment and the final use that the land will be given once to the mining activities have concluded.

The environmental guide for the Closing and Abandonment of Mines published by the Ministry of Energy and Mines of Peru and by the other side the international environmental guides, as well as specialized information of the topic coincides in establishing that all plan of mine closure should consider the following:

- Protection of the life and the population's health located in the influence area.
- Prevention of the environmental deterioration, avoiding negative impacts in courses of water, air and floors.
- Reclamation of the disturbed area trying as much as possible to return to their original conditions and in case it cannot be this possible, to give them an use so that it will be useful for the population of the area.

ANALYSIS OF THE CHILEAN LEGISLATION ON THE CLOSING AND ABANDONMENT OF MINING TASKS AND A CASE OF APPLICATION

Omar Gallardo G., Francisco Ramenzoni B.
UC, Chile

INTRODUCTION

In the Chilean mining a group of laws exists, supreme ordinances, ordinances with law force and norms that regulate the one that to make of the exploration work and exploitation of locations. In it finishes it decade laws they have been dictated it has more than enough medioambiente and norms that link to this with the work in the mining industry, this has been applied to the new projects, but it is necessary that it is applied to the old tasks that a they are operating those that the law has given them term so that they are adapted to the new demands, inside these they are the closing plans and abandonment of the tasks, point of which we will make an analysis of the existent thing in legal matter.

STAGE OF CLOSING AND ABANDONMENT

The closing stage and abandonment, respond to the idea that the mining activity involves a temporary use of the floor and underground, Well-known as rehabilitation or restoration of mining tasks, it is that activity that has for purpose the repair or restoration of the areas affected by the extractive mining activity, in terms the next thing possible to the good economic and ecological values.

The main objectives of this activity are the reduction of the risk for contamination, the recovery of the floor and of the landscape, the improvement of the aesthetic aspects of the area and the prevention of future degradation.

For that exposed, it should be considered the physical stability, chemistry of the area, I eat **THE FUTURE USES OF THE FLOOR ALSO.**

The restoration of mining tasks in the Chilean right

The restoration as long as own and independent instrument, endowed with their own foundation, not yet this present in the Chilean mining legislation.

A first approach is verified from the system of evaluation of environmental impact (SEIA) according to what prescribes the articles 2 letter s, 12 letter and, 16, 24 and the paragraph I of the I Title III of the law 19.300, (Law on general bases of the environment, published in the official newspaper March 1994 09), which makes synonymous repair and restoration, in spite of constituting slightly different concepts, since they have a gender relationship to species.

The treatment that this law and the regulation of the SEIA make of the topic, they place it inside the minimum contents of the studies of impact environmental, when this plan it is reasonable. Likewise they include it inside the requirements that it should complete the project and that it should be certified in the resolution of favorable qualification.

The measures of repair y/o restoration should be expressly in a plan of measures of repair y/o restoration. This plan in the context of the study, is conjugated with the plans of mitigation measures and compensation, which should describe the measures that were adopted to eliminate or to minimize the adverse effects of the project or activity and the actions of repair y/o compensation that were carried out, when it is reasonable.

Now then, to the margin of the considerations that you/they can be made of these plans from the perspective of the System of Evaluation of Environmental Impact, the legislation sectoral mining Chilean counts alone with an artificial norm that is related with the abandonment of tasks that corresponds to the Regulation of Mining Security (I Decree supreme Nº 72, ministry of mining of October 21 1985) text that in its I articulate 22 it establishes the obligation of the company or mining task of informing to the mining authority in writing SERNAGEOMIN, of the abandonment of the works or mining tasks in terms that when the mining company decides to abandon an exploration work or tasks of exploitation, this forced to give written warning from this decision to the Service, before the works have become inaccessible, and in case it doesn't Complete this obligation, the Director of Sernageomin he/she will be able to order that the laboreo is rehabilitated to coast of this company.

As it is of manifesto, the holder's only obligation is the one of notifying in writing to the service to effect of maintaining it properly informed on the mining economic activities of the country.

It is in any event legally excellent the sense and reach of the I finish of mining tasks, which are defined by the one mentioned Regulation settling down that these they understand the group of facilities and places of work of the mining extractive industry, such as mines, plants of benefit, foundries maestranzas, houses of force, shops, shipment activities in earth and in general, the entirety of the necessary support works to assure the operation of the extractive mining industry.

On the other hand THIS SAME Regulation prepares the reach of the I finish extractive mining industry designating to the whole activities corresponding to prospecting of locations extraction, transformation, concentration, foundry of minerals and intermediate products, transport, storage of waste and shipment of metallic and not metallic minerals, rocks, natural deposits of fossil substances and liquid or gassy hydrocarbons and fertilizers.

It is the own SERNGEOMIN the one that incorporates to the concept of mining tasks, the exploration works in a mining concession. This implies the obligation therefore of informing in writing to this service of the tasks, giving their location, the proprietor's name and of the administrator, to the fifteen days before beginning the works. The same reason should be applied being abandonment of mining tasks, when these they have implied single exploration tasks.

The only direct reference of the Regulation of Mining Security regarding the obligation of making a closing of the mine, is the one that you points to the escombreras or botaderos of sterile for whose localization and construction, without the letter of the law makes reference to the abandonment, if he/she mentions the exhaustion of the location, that which impacts evidently in direct form in its appropriate abandonment.

Indeed the one mentioned Regulation points out that the botaderos should be established according to a project carried out by the administrator and to approve for the director. To get the stability of the I deposit, they will be kept mainly in mind in their design the resistance of the land where it will locate, the materials that will be employees and their characteristics, the bank angle that should be stable even after the exhaustion of the location, the appropriate natural or artificial drainage and the seismic movements.

The expressed mention of the long term stability of I deposit them after the exhaustion of the location, it involves a concern regarding the abandonment of the tasks, including like it expresses, not alone the angle of the bank, but also such factors as the natural drainage, that is to say eventual contamination of superficial or underground waters and the seismic movements, aspects that it is linked with a plan of forecast of risks.

It is possible to point out that the same guideline is the one that guides the articles 40 and 44 of the º Nº 86 of August of 1970, 13 that approves the construction regulation and operation of Tranques of Relaves decree (prey of residuals), text that doesn't mention in expressed form the abandonment of these works, but that if it demands measures of security and such stability that it doesn't generate risks for the population seated in the valley hidrográfica, at a dangerous distance in the event of spill for earthquakes, risks that evidently diminishes once concluded the mining tasks, but that he/she stays regarding eventual avalanches, torrential or grown rains of waters that can cause breaks in its structure and material haulage.

This risk is focused fundamentally in function of the life and the population's health during the operation of the tranque. In fact one of the emergency measures of the I articulate 34 of the respective regulation (letter d) it is the suspension of the tranque. However it is necessary to point out that at the moment it is also considered their localization to effect of avoiding a future contamination of underground or superficial waters.

Other linked norms are those that say relationship with the closing and demolition of hydraulic works of the I Title I, book third, of the Code of Waters, which are particularly prominent since demand from those that build this type of works, enough guarantees to finance the cost of their eventual modification or demolition, so that they don't constitute danger, if was you abandon during their construction.

To conclude this point it is necessary to highlight the distinction that can be made about physical abandonment and legal abandonment of a mining task, focusing this I finish from the perspective of the legal finalización of the possession of a mining task on the part of the holder of the project or activity and of the responsibility for environmental damage that this possession generates during the validity of the mining concession, as well as the one that lasts later on to the closing.

Parallelly to that exposed and from the perspective of the environmental value of the territory, in the measure that is not defined regionally or nationally, the tourist value, paisajistico or environmental of the territory in that is sought to summon a project of this nature, difficult it will be to find a support juridical solid so that the competent authority not bases the demand of restoration measures endorsed legally by the sectoral legislation.

CASE OF APPLICATION

Project of Mining Expansion The Hides

The following one is an example of the application of the closing norms and abandonment to which should undergo the Project of Expansion of Production of Mining The Hides, according to that had by the effective Law, and their necessity to present the Study in the face of the authorities of the corresponding COREMA.

Plan of Closing and Abandonment

The Plan of Closing and Abandonment specifies the measures that will be adopted at the end of the useful life of the project, with the objective of leaving controlled mitigated y/o the situations that can give origin to impacts environmental indeseados during the abandonment, granting a condition environmentally sure in the long term.

In the Project of Mining Expansion The Hides 85.000 tpd whose useful life is of 30 years, the plan of previous elaborated abandonment to its construction cannot foresee a series of situations that you/they can modify the conditions and measures of abandonment in the future that finally will be adopted, among those that highlight:

New technologies that allow to improve at a cost reasonable problems that at the moment are not feasible of solving;

- Development of later projects that use total or partially the built infrastructure;
- use of the infrastructure on the part of third (State, matters).

For such a reason, the measures that intend in this plan are of preliminary character and in the conceptual environment.

Next a listing of closing measures and abandonment contemplated by the expansion project is presented. These measures are described with the following order:

- applicable measures of general character to facilities and process teams, separated by area;
- specific measures for him rend;
- specific measures for the deposits of sterile The Hides and Hualtata;
- specific measures for the relave deposits.

Process teams and facilities

The works that The Hides can leave enabled for later use in projects characteristic of the company or in activities that can carry out third, they are the following ones:

- bocatomas for receptions of superficial waters (The Cascade, rivers The Hides, Cuncumén and Totoral and Esteros Piuquenes and Chacay);
- pipe for conduction of fresh water from the previously signal points;
- electric substations The Chacay and The Hides;
- Electric line between The Hides and The Chacay-Piuquenes.

In case that these works are not dedicated to another use, the company will proceed to retire the surface structures and to recondition the lands if was necessary, avoiding mainly that they are material exposed to erosion hídrica.

The new facilities specifically mining that will be able to be good for later operations of the company they are:

- chancado team;
- teams and mill circuit;
- teams and flotation circuit;
- molybdenum plant;
- auxiliary facilities.

Of equal it forms, in case that these teams are not dedicated to another use, the company will proceed to retire them next to the associated surface structure; complementarily they will be carried out the following measures:

- Remodeling of the surfaces of the land in the sector The Piuquenes corresponding to the abandoned areas of the plant to soften the topographical contours.

- To improve the control of the erosion and the reinstatement from the land to the atmosphere, they will cover exposed areas to erosion and mainly those that are visible from sectors trafficked inhabited y/o, with vegetable earth of it escarps and adapted vegetable species will be planted, being given priority to native species.
- Finally they will settle signs with information of prevention inside the area of the project.

I rend

The condition of abandonment of the I rend it will be the following one:

- The final configuration will correspond that of the last year of exploitation. The Hides won't execute restoration measures or special remodeling.
- The company will analyze the final security of the I rend, and it will adopt the technical measures that it corresponds to grant stability of long term to the banks and banks.
- Also the company will install the necessary signalings preventing about possible entrance risks to the I rend.

As measure to reduce the generation of sour waters the following ones will be analyzed alternative:

- Construction of a channel perimetral that intercepts the superficial flows of melted snow and it drives them waters under the I rend, avoiding that he/she enters in contact with rusty rock of the mine;
- qualification of a system of horizontal or inclined drenes (type sondaje) that depress the napa in the environment of the I rend, in which case the intercepted flow would be driven gravitacionalmente through a canaleta waters under the I rend.

The objective of these measures is to minimize the entrance of waters to the I rend, its possible acidification and the creation of a sour lagoon.

Deposits of sterile The Hides and Hualtata

As first measure the company will evaluate the final stability of the deposits to verify that the condition of abandonment will be the one contemplated in the designs.

On the other hand, the deposits of sterile will have channels interceptores of waters rain built in the exposed perimeters to superficial flows of water to evacuate these flows. These channels will be adapted (they will enlarge y/o they will deepen) to be able to evacuate flows associated to a condition of long term. The objectives of this measure are basically the following ones:

- to avoid that the exposed banks you erosionen;
- to avoid that the waters enter in contact with deposited materials.

This way, the only contributions hídricos that you/they will be able to receive the deposits corresponds to the direct precipitation (it snows) and blooming that can take place in the bottom of the involved gulches. They are these flows those that will be able to be exposed to acidification during the abandonment, for their contact with the rock.

In case that the operational monitoreo reveals that the acid generation is significant and that this can stay lingeringly during the abandonment, they exist as alternative applicable mitigadoras to the deposits of sterile the following ones:

- installation of a layer of material of low permeability in the final surface of the deposit, either of a single time after the useful life, or in the measure that this he/she leaves completing;
- compactación of the final surface and readecuación of the slope to facilitate the superficial drainage.

This measures are dedicated to reduce the possibility of infiltration of precipitations (it snows).

Complementarily, the system of basal dren (type "it pricks with thorns of fish") of the deposit of having broken Hualtata will be able to be connected to the I rend, for it avoids any sour precolación that arrives to the base of the deposit, for their evaporation in the bottom of the I rend.

Finally, the company seeks to continue with the monitoreo of quality of waters in the river The Hides and The Cascade, for a 3 year-old period after the closing.

Deposits of Relave

An important aspect of having in all in connection with the abandonment of the relave deposits, is that they will go concluding its useful life before The Hides conclude their operations; for example the deposit The Quillayes its operation will culminate a year 8 or 9, that is to say, but of 20 years before it finishes the project. This advantageous situation will allow to The Hides to maintain a control of the condition post-operation of the first two relave deposits, in such a way that its condition of definitive abandonment will be able to be verified as for its security. Any accidental situation that is generated in the first deposit "abandoned" he/she will be able to be solved by the company, in which case it will adopt the pertinent preventive measure in the other deposits.

The measures of abandonment considered a priori for the relave deposits refer to the following aspects:

- The superficial escorrerías generated by precipitations will be intercepted and evacuated by means of the works of deviation perimetrales (ataguías and canales/túneles). In case that a part of the escorrerías enters to the deposit, this will be evacuated through the drains of grown. These works will be designed for an extreme hydrological condition.
- In order to producing the permanency of waters rain in the deposit, the deposit of the relave at the end of the operation will be managed in way of generating a surface lightly bowed in address to the drain. This geometry of the relave will avoid the generation of a lagoon in the later part of the deposit, allowing the practically total evacuation of the water entered to the few days of having happened the precipitation.

The transitory formation of a lagoon during the grown ones that it can be in contact with the wall of sand makes necessary to design a wall crowning that doesn't allow filtration from the lagoon. For this end a clay nucleus has been designed protected by a rip-rap. Also, the wall considers an additional revenge of abandonment of 2 m (on the 5 normal m) and a width of crowning of 10 m to compensate possible establishments of seismic solicitations.

The final surface of the walls of the deposits will be protected with a layer of thick material (it burdens sandy or similar) to minimize the eolic erosion.

Complementarily he/she will settle a layer of floor vegetable in the final surface of the walls to allow the plantation of appropriate species, as much as possible native. This measure will be applied to the visible walls from trafficked sectors and inhabited. The company will have enough time to prove spices that give success to this objective.

During the operation of the deposits he/she will have a line of wells to capture eventual infiltrations from the deposits. In case that is verified significant infiltrations, the wells will continue operating once concluded the operation of the respective deposit, until the quality of the water reaches acceptable ranges. The water captured by these wells will be pumped toward the own relaves deposit for its evaporation.

Plan of Actions of Repair and Compensation

Next the measures are presented that The Hides have considered to execute in the time, starting from the first years of operation, to restore the original condition of the affected components insofar as possible that they require it, as well as the actions and measures that it will execute to compensate the irreversible significant impacts.

The impacts that it is considered should be in some measure compensated to be them significant and irreversible they are the following ones:

- Alteration of the hábitat of gumps in having Broken Hualtata, product of the deposit of sterile in a sector of this gulch.
- Floor loss in the half valley and under of the one it Maims and their associate biodiversity, product of the construction of 2 relave deposits.
- In both cases they are not applicable the restoration measures in the intervened sectors, due to the characteristics and span of the involved works.

Broken Hualtata

In the Quebrada Hualtata a population of Gumps residents has been verified, for what constitutes an excellent hábitat for this species. As compensation measure to the impact generated by the hábitat loss intends the following plan:

- The Quebrada Hualtata will be used as deposit of sterile for a 6 year-old period, starting from the setting in march of the project; during this lapse of time he/she will be carried out a monitoreo of gumps in the gulch and sectors bordering, in order to make a pursuit of the species and to identify near places in those that it can apply a handling plan and protection of the species later on. The monitoreo in detail will remember with SAG and CONAF.
- At the end of the period of 6 year-old intervention he/she will start a protection plan and handling of the Quebrada Hualtata and of some other eventual place bordering, guided to potenciar the not altered hábitat and to generate appropriate conditions for the reintroduction of Gumps (access restricted people, veranadas prohibition, among other).

Fence of the one it Maims

As compensation of the loss on behalf of the existent natural community in the Valley of the one Maims, The Hides propose the following measures:

- To consider the high part of the valley (not intervened by this project) as a protection area and ecological recovery, under the form of a plan coordinated among SAG, CONAF and The Hides. You will also proceed to an improvement of the hábitat by means of the transfer and plantation of species that will get lost with the development of the deposits. Also, with this plan it will be possible to recover the ecological system, the one which at the moment is degraded by agricultural activities developed in previous times
- In the low part of the valley (you dilute under the deposits) a plan of afforestation will be made with native species of the one it Maims; this sector would be visible from the road, with that which an improvement of the quality paisajística of the place would be obtained.

- To support and to collaborate with programs of conservation of the wild life of the IV Region that are carried out in their Protected Wild Areas.
- Realization of the pejerreyes population's studies (Basilichtys microlepidotus) and bagres (Trichomycterus areolatus), species in extinction danger and vulnerable, respectively that exist in the River it Maims and in the Río Choapa. He/she intends to settle down their space and temporary distribution, abundance, characterization of its hábitats, structures of the population and reproductive aspects of the species, particularly its reproductive fenología. With the results of a program of this type he/she will be able to be defined together with the authority a program of conservation of the species inside the system hídrico of the Choapa.

Plan of Monitoreo

Objectives

The objectives of the monitoreo program are the following ones:

- To validate in he/she practices it the real effect caused by the activities of the project that have bigger predicted impact or potential, through the mensurations from the susceptible environmental components to be affected;
- To verify the effectiveness of the mitigation measures and proposed prevention;
- to verify the execution of the applicable environmental measures; and
- To detect in an early way any not foreseen effect and not wanted, so that it is possible to control it taking measures or appropriate actions.

Effective Monitoreo

The Hides maintain a monitoreo of the quality of superficial and underground water of the rivers the Hides, Cuncumén and Choapa, which is associated to specific permits obtained at the moment for works in operation (General Address of Waters). This monitoreo began in March of 1992 and he/she understands samples of water superficial and underground waters under the industrial facilities of The Hides in the sector of The Hides and The Chacay.

The current monitoreo of superficial and underground water is carried out monthly, and it considers the determination of the physical quality and chemistry according to the following parameters:

- pH
- temperature
- get paid (Cu)
- molibdeno(Mo)
- calcio(Ca)
- sulfates (SO2--)
- dissolved total solids (STD)
- iron (Faith)
- manganese (Mn)

The samples of water are obtained along the Rivers The Hides, Cuncumén and Choapa

The sampling, the preservation of samples and the laboratory analyses are carried out according to the procedures of the Standard Methods for the Examination of Water and Wastewater.

Content of the Program of Monitoreo of the Project

The program of monitoreo of the expansion project specifies the following aspects:

Environmental component: it corresponds to the resources or constituent elements of the environment like air, it dilutes and floor that you/they will be monitoreados.

Parameters: they correspond to the physical and chemical variables that will be, measured y/o registered as indicators of the behavior of each environmental component.

Places of Monitoreo: it corresponds to the mensuration places and sampling selected for each parameter.

Frequency: he/she refers to the rhythm with which the mensurations, takings of samples y/o analysis of each parameter will be made.

Methodology: it is indicated the mensuration procedure and analysis of the information in each case.

Environmental components

The program of monitoreo of the expansion project considers the following environmental components:

Air

It dilutes superficial

It dilutes underground

Floors

Noise flora and fauna

THE ABANDONMENT OF MINES IN MEXICO UNDER THE NEW ENVIRONMENTAL LEGISLATION

Luis R. Vera Morales
México

The abandonment of mines in Mexico is a severe problem that has not been sufficiently studied. To this date, there does not exist a single documented case of planned closure of any mine that has been exhausted, neither before mining nor environmental authorities. This can be explained by the absence, until very recently, of specific instruments for the control and regulation of these activities and that the authorities lack creativity in the use of instruments of environmental policy within their reach. This document will explore the different legal ordinances existing in Mexico and the difficulty in their application to this worrisome matter.

I. DEFINING THE PROBLEM

The mineral wealth of Mexico has been a guiding line for the development of the people and nations, which have settled this territory for more than three thousand years, but sometimes to their detriment. During the pre hispanic period mining activities focused primarily on the extraction of metals and precious stones, since the Conquest and through out the colonial times, mining was, without any doubt the primary economic activity of New Spain. In fact, the history of its colonization can be almost totally explained by two phenomenons: mining exploration and the evangelistic catholic crusades. Consequently, a great many of our colonial cities are or were mining centers or transitional points of them. During all this time, the law as well as mining institutions gave order and direction for the prosperity of New Spain and that of the Spanish Crown.

By the end of the colonial period, mining activity in Mexico had decayed due to the fight for independence and the consolidation of the new State. This lethargy lasted practically the whole XIX Century. In the last quarter of this century, the new country saw the arrival of foreign companies, mainly English and American, bringing with them the economic means and technical personnel to exploit its riches. It was not until 1932 that the government of Mexico ordered the nationalization of gold, silver, copper, mercury, aluminum, iron, bismuth, and platinum mines.

In this century the extracting industry has been one of the most important economic activities in the country, although the exploration and exploitation of its mineral deposits has kept practically to the same proportion as that during colonial times. In this sense, the numbers are quite revealing: the actual area of Mexico is almost two million square kilometers, and an estimated 80% or 1.6 million square kilometers of this, meet the appropriate geological conditions for metallurgic processes. Regardless of this, the government has granted concessions for the exploration and exploitation of only 3,500 square kilometers or 2.2% of this area.

As an obvious result, accompanying the activities of discovery and mining operations we eventually encounter their abandonment, along with the effects of each of these stages on the environment. It is important to indicate that we have evaded the term “closure” when referring to the post operative mining stage, because it encapsulates the idea of being a planned activity. The habitual indifference to legislate for this phase has not resulted in the development of planned systems for the closure of mines. In reality, the legislation recently enacted, which we will analyze in depth in this work, has adopted the term commonly used in these cases, that of “site abandonment”.

II. THE PROTECTION OF THE ENVIRONMENT WITH RESPECT TO THE EFFECTS ON THE MINING ACTIVITIES

As previously mentioned, traditionally, Mexican legislation has not bothered to establish *ad hoc* norms to counteract the impacts from the post operative or abandonment phases on the environment, wild life or human health. Although there have been recent attempts to correct this omission, there are instruments which have not yet been identified by legal analysts, which could both allow the holders of mining concessions to limit their liabilities, as well as provide the environmental authorities with means to comply with the purpose for which they were created: the preservation of the ecological equilibrium and the protection of the environment. In the following we will analyze those legal ordinances and instruments.

A. Mining Law (LM)[2]

This Law, fundamentally productive in nature, contains scarce regulations with respect to the protection of mining resources and does not contemplate legal provisions regarding the protection of the environment from the effects of the exploration, exploitation, smelting and refinement of minerals. Moreover, it mandates that these activities will be preferable over any other use or usage of lands (art. 6), whether agricultural, cattle raising, forestry, conservation, etc., except to those cases expressively considered as exempt (arts. 13 and 14).

Notwithstanding the above, according to the LM the holders of exploration and exploitation concessions are obliged to comply with the general provisions and specific norms on mining safety, ecological equilibrium and environmental protection applicable to the metallurgic industry (art. 27, section IV). Likewise, in accordance with the mining legislation, the holders of concessions for the exploration, exploitation and smelting of minerals or substances, must procure the conservation and protection of the environment (art. 39). Finally, exploration and exploitation activities that are undertaken within properties (real estate), zones or areas under the control of other authorities (dams, channels, population centers, federal maritime zone, natural protected areas), require the previous authorization from the latter (art. 20).

B. General Law on Ecological Equilibrium and Environmental Protection (LGEEPA)[3]

LGEEPA does not establish any specific provision for the abandonment of mines, but, initially, it does contemplate the use of instruments of environmental policy, that is, Official Mexican Norms and the environmental impact evaluation procedure (EIEP), in order to prevent and control the effects caused by mining exploration and exploitation activities. Furthermore, it is possible to find generic provisions on the conservation of soils, which could be applicable to the site abandonment stage.

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[2] *Mining Law*, Official Gazette of the Federation, June 26th, 1992.

[3] *General Law on Ecological Equilibrium and Environmental Protection*, Official Gazette of the Federation, January 28, 1988. Amended by Decree published on the Official Gazette of the Federation on the 13th of December 1996.

1. The use of environmental policy instruments for control

a. Official Mexican Norms (NOMs)[4]

In accordance with the LM, LGEEPA provides that, in order to prevent and control the effects generated by the exploration and exploitation of non-renewable resources, the Ministry of Environment, Natural Resources and Fisheries (SEMARNAP) will issue NOMs which may allow: i) the control of water quality and the protection of that which has been used or that which results from these activities so as to permit their use for other purposes; the timely and proper protection of soils and of wild flora and fauna from the topographic alterations caused by these activities, and iii) the adequate locations and the forms of deposits from clearing activities, cuttings and slag from mines as well as establishments for the smelting of minerals[5]. The holders of concessions, authorizations and permits for the use, advantage, exploration, exploitation and refinement of non-renewable resources[6] must comply with these norms.

Environmental Impact Evaluation Procedure (EIEP)

Even though NOMs, which regulate the effects of the exploration, exploitation and abandonment of mines, do not exist, there is however an instrument in the LGEEPA which can contribute significantly to the protection of the environment in respect to the effects of mining activities: the EIEP.

i). Jurisdictional problems

Article 28 of the LGEEPA lists the works or activities that prior to their development[7] require an environmental impact authorization from SEMARNAP, among those the exploration, exploitation and refinement of materials and substances are reserved to the federation (section II)[8]. There are other sections related to mining activities such as

[4] NOMs regulating environmental matters are technical provisions whose purpose is to: i) establish the requirements, specifications, conditions, procedures, goals, parameters and permissible limits which must be observed in regions, zones, basins or ecosystems, for the exploitation of natural resources, the development of economic activities, the use and destiny of real estate, input and processes; ii) consider the necessary conditions for the well-being of the population and the conservation and restoration of natural resources and the protection of the environment; iii) to boost or induce the economic agents to reorient their processes and technology for the protection of the environment and a sustainable development; iv) grant certainty, in the long term, to investments and induce economic agents to assume the costs of the environmental affectations that they may cause, and v) to stimulate efficient and sustainable productive activities (LGEEPA, Art. 36).

[5] LGEEPA, Art. 108.

[6] LGEEPA, Art. 109.

[7] It is important to indicate that notwithstanding the fact that the Regulations of the LGEEPA on the Evaluation of Environmental Impacts excludes several works or activities from the environmental impact procedure this should not be understood as a renouncement from the federation to the jurisdiction granted by article 28 of the LGEEPA to regulate them, neither does it constitute a competence gap which could be solved with the intervention of the States, as provided in article 124 of our Constitution (*"Those faculties which have not been expressively granted by this Constitution to federal officers, should be considered as reserved to the States"*). Thus, the States may not regulate any of those activities, which have been excluded from the environmental impact evaluation procedure in terms of the Regulation of the LGEEPA on the Evaluation of Environmental Impacts, but only those activities, which have not been listed in the first paragraph of article 28 of the LGEEPA.

[8] According to article 6 of the LGEEPA, States and Municipalities have the authority to regulate the exploitation of minerals and substances not reserved to the federation, constituting natural deposits of materials similar to the components of the lands, such as rocks and products of their decompose which can

the one regarding installations for the confinement of hazardous waste (section IV), land use modifications of forestry lands, jungles and arid zones (section VII), and generic works competence of the federation which have not been specifically listed (section XIII).

Furthermore, article 28 provides in its second paragraph that the Regulations to this Law (that is, the recently enacted Regulations on the Evaluation of Environmental Impacts or REEI) will define the works or activities which due to their location, dimensions, characteristics or scope: i) **do not produce significant environmental impacts**, ii) **do not cause or might not cause ecological imbalances**, iii) **do not exceed the limits and conditions set forth in the legal provisions referring to the preservation of the ecological equilibrium and the protection of the environment**, and therefore do not need to submit the EIEP.

In a nutshell, mining activities in general are subject to the EIEP (article 28, first paragraph, section III, of the LGEEPA) except those, which are expressively exempted and listed by the REEI (article 28, second paragraph, of the LGEEPA).

On the other hand, article 5 of the REEI details the works or activities of federal jurisdiction which are subject to the EIEP, as well as those which are exempt from this procedure; particularly section L), lists the works which must submit the environmental impact procedure provided for in the LGEEPA, as well as its exemptions: I. Works for the exploitation of minerals and substances reserved to the federation as well as support infrastructure, II. Exploration works, **except those**, with gravity, superficial geology, geothermic, magnetic-telluric, magnetic susceptibility and density prospecting; as well as those involving drilling, ditches or rock exposure, when carried out within agricultural, cattle raising or uncultivated lands or in zones with dry or warm climates in which flora such as: xerophiluos scrub, deciduous tropical forest, coniferous forest or holm oaks grove, grows and which are located outside of natural protected areas, III. Refining of materials and the final disposal of their waste in tailing reservoirs, excluding refining plants not using hazardous substances and the filling of water carried out in underground mining works[9].

Even though neither article 28 of the LGEEPA nor article 5 of the REEI, establishing that the works and activities are subject to the EIEP at the federal level, include nor exempt the abandonment of mines, the latter provides that any resolution that the SEMARNAP may issue on the projects submitted to the EIEP may establish conditions to the authorization addressed to avoid, mitigate or compensate the negative environmental impacts caused during the **construction** or **normal operation** of the project and **in the event of an accident as well as the abandonment or end of the project's useful life**[10]. The REEI however pretends to extend the reach of those resolutions subject to conditions that according to the LGEEPA only include the construction, normal operation and in the event of accident[11], but not abandonment. We consider that besides the fact that REEI could be in violation of principles of legality by pretending to increase their faculties expressively established in the LGEEPA for SEMARNAP, it disregards the preventive character of the instrument as well as the purpose for which it was designed: the reasonable making of decisions, not the control (correction) of consequences.

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only be used for the production of construction or ornamental materials, for environmental protection purposes.

[9] We must assume that the term "exploitation" does not include the concept of "site abandonment", neither in its literal nor legal context (the REEI differences the "abandonment" and "exploitation" concepts. *Supra* footnote 10.

[10] REEI, Arts. 45, section II and 48.

[11] LGEEPA, Art. 35, fourth paragraph, section II.

Another position complementary to that of the aforementioned would be the following: Due to the fact that the "site abandonment" was not expressively included in the mining activities listed in the above-mentioned articles, there are two possibilities: that they fall under State jurisdiction or that they maintain their federal jurisdiction but that the federation has decided to exempt them from the EIEP. The former case is easily discarded as that the LGEEPA establishes those cases of State jurisdiction (*see* footnote 8). The second case is more defendable from a technical jurisdictional point of view even though it apparently impedes the SEMARNAP from revising the impacts of said activity. Notwithstanding the aforementioned the LGEEPA and the REEI contain a mechanism through which the impacts of unlisted activities can be revised at the discretion of the federation.

ii) Exception to the Exception: The evaluation of the abandonment of mines

Section XIII of article 28 of the LGEEPA allows for the possibility that SEMARNAP can evaluate the environmental impacts of works or activities that correspond to matters under federal jurisdiction that could cause serious and irreparable ecological imbalance, harm to public health or to ecosystems, or exceed the limits and conditions established in the legal provisions relating to preservation of ecological equilibrium or protection of the environment.

It is noteworthy that this section permits two interpretations, in our opinion, as equally valid and furthermore, compatible: the first is that the SEMARNAP can attend matters listed in the first two sections of article 28 of the LGEEPA, between them the III referring to mining, **but subject to evaluation by virtue of article 5 of the REEI, whether by exclusion or express exception,** this faculty constituting a literal exception to the exception; and the second can attend to matters apart from those listed under federal jurisdiction in general, with those being added to the list on article 28 of the LGEEPA, those matters under federal jurisdiction which are detailed in article 5 of the same LGEEPA, allowing for wide discretional possibilities in the type of matters that can be evaluated by the authority[12].

In all cases, the limits of this faculty to evaluate works or activities, otherwise exempted or excluded (under the first interpretation), or in the case of the so called "extended or added jurisdiction" (under the second interpretation), will be those indicated in section XIII: to cause serious and irreparable ecological imbalance, harm to public health or to ecosystems or exceed the limits and conditions established in the legal provisions relating to preservation of ecological equilibrium or protection of the environment. It is evident that the abandonment of mines could cause or maintain one or more of these effects.

The REEI establishes the following procedure for exercising this faculty: (i) when the possible development of any work or activity under federal jurisdiction comes to the knowledge of SEMARNAP in any way (under any of the above-mentioned interpretations), this agency must notify the interested party of a justifiable resolution to submit them to an EIEP; (ii) Within a term not greater than 10 working days the interested party must present reports, opinions and considerations that are deemed convenient; (iii) within the following 30 days of receiving the documentation SEMARNAP will notify the interested party of their

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[12] This last interpretation in particular will only reinforce our conclusion that federal jurisdiction is not limited by the list contained in article 5 of the REEI, as the federation could always subject all types of works and activities under their jurisdiction to the EIEP, including not only those listed under article 28 of the LGEEPA, excluded or not of the EIEP, but inclusively others where the jurisdiction of the federation is not derive from the cited article but from article 5 of the same legal ordinance.

decision on the requirement to present an environmental impact statement (EIS) or not and the term for its filing; (iv) the silence of the SEMARNAP implies that it is not necessary to present the above-mentioned EIS[13].

The reparation of damages under the REEI

Once the way in which the authority may access to the evaluation of the effects that must be counteracted due to the mining abandonment works has been explained, and having established that, as a result of the EIEP, SEMARNAP may conditionally authorize the development of a work or activity, we consider it necessary to analyze in depth the standards of mitigation to be observed.

In accordance with the REEI, "mitigation measures" are defined as the "combined actions to be undertaken by the applicant to **diminish** the impacts and to **re-establish or compensate the existing environmental conditions prior to the disturbance** originated by the development of a project in any of its stages[14]. This concept constitutes a radical change for the repair of environmental damages from an administrative perspective, as it differs from the rules that the LGEEPA or the National Waters Law establish in relation to the affecting of natural resources, approaching the civil regulation for compensation[15].

2. Control by generic rules

The LGEEPA contemplates several provisions which contain criteria regarding the control of the effects of activities which affect the environment and can be applied by the SEMARNAP in the event that the aforementioned instruments turn out to be inefficient or should a restriction to the application, such as those already mentioned, arise. Each of these alternatives present difficulties in their application or otherwise have a limited scope.

Restoration Zones

The LGEEPA provides that in those areas that display processes of degradation or desertification or severe ecological imbalances, SEMARNAP must prepare and implement, with the participation of owners, occupants, social organizations, whether public or private, etc., ecological restoration programs for the purpose of undertaking the actions necessary for the recovery and re-establishment of conditions that favor the evolution and continuity of the natural processes developed therein[16]. Conceptually, nothing would impede SEMARNAP, in the use of this faculty, to issue restoration programs for zones that may have been affected by mining activities. The transaction costs (negotiations with proprietors and other social parties), would constitute the most relevant obstacles for their implementation, depending on whether the liabilities of any of the parties involved in this problem have been limited or not.

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[13] REEI, Art. 16.
[14] *Ibid,* Art. 3, section XIV.
[15] See Civil Code for the Federal District in common matters and for the entire Republic on matters of federal nature (CC), Art. 1915.
[16] LGEEPA, Art. 78.

b. Measures for soil remediation

Within the LGEEPA there is only one criterion for the remediation of soils, which only applies to sites, which have been contaminated by hazardous waste and materials. In these cases, LGEEPA establishes that the responsible party must undertake the necessary actions to recover and re-establish its conditions so that it may be used in any of the activities provided for in the urban development or ecological ordinance program applicable to that site or respective zone[17]. The future use of a site contaminated by hazardous waste or materials, as established by the administrative criteria for damage repair, in opposition to its **prior use**, has been interpreted as legal acceptance (*strictu sensu*, as the criteria is provided in the Law) of an environmental loss, that which opposes the civil and REEI rules, which demand the repair to the condition existing prior to its affectation, including, in the case of the civil rule, the indemnity from any foregone gain or earning that could have legitimately been obtained by the affected party, without allowing any losses, should the damage have not have been caused.

The remediation standards, that is, “how clean is clean?”, have not yet been established, conversely, the efforts of the government to impose sanctions that have been easily truncated in court (although the obligation is indisputable). On the other hand, even though article 152 Bis clearly establishes that the generator and the company or person in charge of the handling or final disposal of those hazardous waste or materials are liable, it does not give a solution in the event that the responsible party cannot be identified. In the latter case, SEMARNAP has applied article 134 section V, of the LGEEPA, establishing for the prevention of soil pollution, in soils contaminated by hazardous materials or waste, that the actions necessary to recover and re-establish its condition, must be undertaken in order to allow their use for any of the activities provided for in applicable urban development or ecological ordinance program. Hence, the general criteria does not define who should bear the responsibility for the remediation of the soil. Moreover, this criterion applies to pollution currently present, regardless of when, how or the party responsible for its presence. Based on the aforementioned, this criterion is applicable to the present owners and occupants of the polluted soil (plot), regardless of their intervention in the process (of contamination).

The aforementioned is of great relevance for the definition of the repair obligation that may derive from the acquisition of a contaminated plot due to the historic undertaking of mining activities. Another interesting fact is that there is no obligation to notify the authority of the existence of soil pollution. Hence, in the event that the owner of the land becomes aware that his or her land is polluted, he or she is not compelled to appear before or to inform SEMARNAP or any other authority of said circumstance. However, the law obliges him or her to clean up the soil. This obligation arises from the moment that the owner or possessor becomes aware of the existence of the contamination.

III. Conclusions

Even though both the LM and the LGEEPA contemplate provisions to protect the environment against the effects from the mining activities, to this date, the ad hoc instruments, that is, the NOMs, have not yet been developed.

Due to the aforementioned, it is feasible to regulate the effects of the abandonment of mines through other instruments of environmental policy, such as the EIEP. Nevertheless, their successful application will be subject to the correct interpretation of the REEI within the context of the LGEEPA.

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[17] LGEEPA, Art. 152 Bis.

Regardless of having other criteria, which bring attention to the negative effects that mining activities may cause to the environment, including site abandonment, those criteria are insufficient in that they only refer to soil and not to the elements of the affected ecosystems as a whole.

Finally, the difference that the remediation standards present with regard to environmental damages, resulting from the application of the REEI or of the criteria established in the LGEEPA lead to violations and to a legal defense from the holders of concessions against the authority's intentions to apply any instrument or criteria for remediation, causing inefficiencies in the system and as a result, the deterioration of the environment.

Module III

Social Aspects and Communities

PLANNING FOR CLOSURE & SUSTAINABILITY INDICATORS

Professor *Alyson Warhurst*
WCCU, Warwick Business School, University of Warwick
Cristina Echavarria
Director, Mining Policy Research Initiative, IDRC, Uruguay

Can minerals development and metals production be undertaken without damaging the environment or undermining the socio-economic development opportunities of civil society; and, can the benefits of minerals and metals production and use be distributed amongst stakeholders equitably?

A key imperative is planning for closure from the outset and responsible closure implementation.

How can Sustainability Indicators help?

- Corporate Citizenship Unit/MERN research agenda - Planning for Closure and Sustainability Indicators
- Public Policy provides the framework but companies have the capacity, opportunity and responsibility to make the requisite changes in strategy to ensure responsible closure
- Research, community action and societal pressure can provide the impetus, arguments and tools to support business to make those changes to ensure responsible closure
- Sustainability Indicators can help to direct those changes, evaluate progress and communicate sustainable i.e. closure activities to stakeholders

Point of Entry

Sustainable Development - an intra-and inter-generational development process defined by sustained improvements in human health and well-being, quality of life and ecosystem health (8th MERN - TERI - INER Research Workshop 1998)

Corporate strategy - the prime-mover in ensuring minerals and metals production and use contributes to, and does not detract from, these constituents of sustainable development (MERN Research 1991-2000)

Corporate social responsibility (CSR) - key to operationalising the strategic role of mining and metals companies in sustainable development

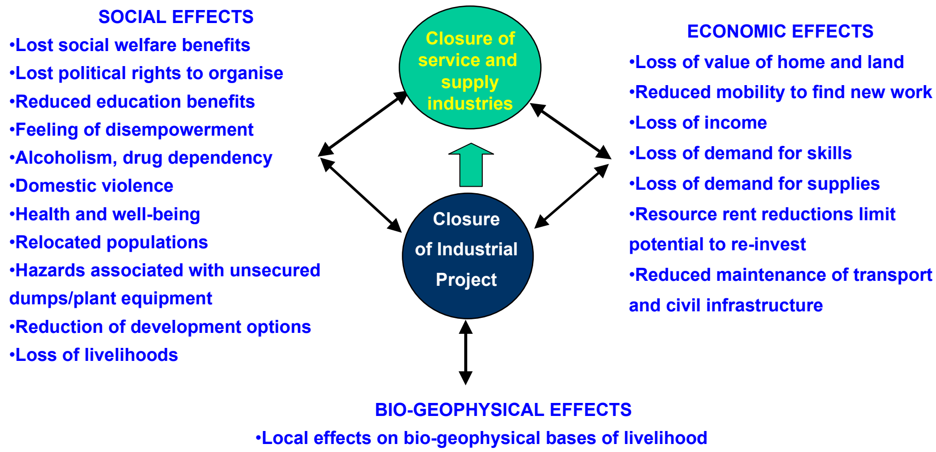
Implies responsible planning for closure strategy:

– Sustainability Indicators can help define and communicate progress

Sustainability Indicators: MERN - TERI - INER Research Challenge

- To develop indicators that are meaningful, credible and relevant to different stakeholders and that are sensitive to varying perceptions and values
- To design an indicator development methodology that suggests strategic options, that is also an internal learning process, and that evaluates and communicates progress towards sustainable development according to meaningful, credible and relevant milestones
- To contribute to knowledge about corporate strategy and performance, and impact on workers and local communities

Plant Closure Socio-Economic Effects



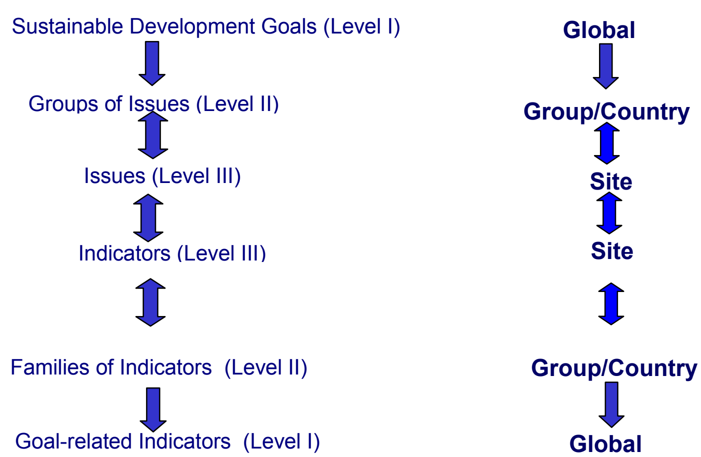
Key Advantages of Planning for Closure from the Outset

- Prevents Pollution
- Establishes effective environmental management strategy
- Facilitates ongoing social adjustment of local community and workforce
- Spreads costs and helps identify future benefits e.g. alternative economic land use
- Improves chances of generating increased well-being and sustainable development of mining regions throughout mine life-cycle and after closure

Sustainability Indicators and Planning for Closure

The following sets of indicators establish some of the issues that a pro-active closure strategy should address and relevant performance indicators.

Sustainability Indicators Framework



Global Sustainable Development Goals (Level I)

Social Sustainability

- Enhanced health, well-being and quality of life; social equity and human rights protection and promotion

Environmental Sustainability

- Environmental Protection and clean technology diffusion

Economic Sustainability

- Sustainable economic growth and enhanced intra- and inter-generational equity with respect to economic welfare

Level I, II and III Issues/Indicators

Goal (Level I)	Social Sustainability - Responsible Planning for Closure
Family/Group (Level II)	Social Legacy
Issue/Indicator (Level III)	Sustaining Local Community Development and Education Programmes
	Lasting Partnerships
	Participatory Monitoring System

Level I, II and III Issues/Indicators

Goal (Level I)	Environmental Sustainability -
	Responsible Planning for Closure
Family/Group (Level II)	Pollution Prevention/Containment
Issue/Indicator (Level III)	Mineral Recovery Process
	Tailings Disposal Process
	Monitoring Performance Plan
	Mitigation Plan
	Process & Storm Water Management System
	Waste Rock Management System

Level I, II and III Issues/Indicators

Goal (Level I)	Environmental Sustainability - Responsible Planning for Closure
Family/Group (Level II)	Reclamation / Rehabilitation
Issue/Indicator (Level III)	Quality of Baseline Data
	Quality of Impact Assessment
	Biodiversity Conservation
	Site Reclamation
	Revegetation

Level I, II and III Issues/Indicators

Goal (Level I)	Environmental Sustainability - Responsible Planning for Closure
Family/Group (Level II)	Stewardship and Post-Mining Land Use
Issue/Indicator (Level III)	Overall Restoration of Land Area
	New Habitats Created
	Post Mining Land-Use Benefits

Level I, II and III Issues/Indicators

Goal (Level I)	Economic Sustainability - Responsible Planning for Closure
Family/Group (Level II)	Economic Retrospect
Issue/Indicator (Level III)	Socio-Economic Benefits to Local Communities
	-Services
	-Supplies
	-Jobs
	-Economic Diversification

Level I, II and III Issues/Indicators

Goal (Level I)	Social Sustainability Responsible Planning for Closure
Family/Group (Level II)	Indigenous Peoples Ethic Integrity
Issue/Indicator (Level III)	Proper consultation (ILO 169)
	World Bank OD 4.20 applied
	Intercultural EIA/SIA/EMS
	Intercultural Compensation System
	Participatory / intercultural Monitoring System
	Training / Employment opportunities
	Culturally compatible development programs

MINE CLOSURE - THE 21ST CENTURY APPROACH

Wanda M.A.Hoskin
Senior Programme Officer (Mining)
United Nations Environment Program, Division of Technology, Industry and Economics

1. INTRODUCTION

Mining is an economic activity that has been occurring for hundreds, and in some cases thousands of years, and mine closure is an aspect of mining where historic practices and evolving community expectations do not meet. Some closed mine sites do not meet the standards now expected by the community, governments and best industry practices. It is a topic whose relevance has emerged in the past decades due first to increasing awareness of public health and safety issues and, more recently to increased awareness of environmental contamination and environmental preservation.

Unlike other industrial operations where buildings are frequently torn down after their economic life is past and so are not reminders of past practices which would not be acceptible today, mine closure problems from the past are visible today. Mine closure is also an area of operations where institutional and legal frameworks have evolved significantly over the past decades in response to changing public, government and industry expectations. Mine closure is an area where blame for problems is easy. As well, it is an issue that brings industry practices, government policy and regulations with respect to environmental protection and community expectations together. Standards have and will continue to evolve, but this doesn't mean ever changing yardsticks.

What is mine closure? Essentially the objective is to leave a mine site in a condition which is safe and stable, limiting further environmental impact so that the mining tenements can be relinquished for alternative land use. Mine reclamation refers to the restoration of land affected by mining for further economic use. Mine closure and mine reclamation are not after-thoughts. They need to be planned from the beginning of an operation.

2. OVERVIEW OF INTERNATIONAL CONSIDERATIONS RELATED TO MINE CLOSURE

Mine closure has become a topic of broader discussion in the past 20-25 years during which time the institutional and legal frameworks that govern the practice of mine reclamation have evolved in response to changing expectations.

In 1987, the Brundtland Commission resulted *inter alia* in the well-known definition of sustainable development namely that meets the needs of the present without compromising the ability of future generations to meet their own needs. The Brundtland report provided material for environmental groups, pressure from which has resulted in a more vocal public demanding that governments create stronger legislation to compel the mining industry to be more environmentally sensitive.

In June 1991, an International Round Table Conference on Mining and Environment was organized in Berlin. Although mine closure was not broadly discussed, the *Berlin Guidelines* provided an initial outline of "necessary environmental guidelines and strategies on mining with emphasis on developing countries". In many countries, environmental impact assessments, now required by law, are the vehicle under which companies are required to produce a closure plan in significant detail.

In 1992, United Nations Conference on Environment and Development (also know as the Rio Conference), produced Agenda 21, the programme for environmental management for the 21st Century. It emphasized the need for adoption of environmental guidelines for natural resources development. Since 1992, UNEP and other international agencies have been asked to provide environmental guidelines for the mineral sector. In 1997, DESA and UNEP compiled *Environmental Guidelines for Mining Operations* and these discussed approaches to implementation, monitoring, enforcement and participation.

In 1994 an International Conference on Development, Environment and Mining was co-sponsored by the World Bank, UNEP and the International Council for Metals and the Environment (ICME). The purpose was to share ideas, perspectives, information and solutions with respect to the challenges surrounding sustainable mineral development. Key conclusions, *inter alia*, were that:

Environmental regulations do not act as a disincentive to investment provided that the regulations are realistic, transparent and stable.

The objective of rehabilitation of mine sites should be to restore them to a self-sustaining ecosystem that is as close as practical to its original state prior to mining activity. There is a need for mechanisms that ensure the availability of funds to finance rehabilitation.

Principles of environmental management are being adopted by industry and these are seen as a vital part of efforts towards continuous improvement. The management systems being adopted depend on regulations and on corporate cultures. These systems are part of the industry's efforts to demonstrate that mining is compatible with environmental protection.

In 1998, UNEP produced *Case Studies on Tailings Management* in partnership with the ICME. UNEP also developed a training manual on *Mine Rehabilitation for Environment and Health Protection: A Training Manual* with the World Health Organization to introduce mine personnel to new skills as information and training are at the heart of any new approach.

3. Environmental Liability and Site Rehabilitation

Every phase of the mining sequence involves some degree of ground disturbance. The objective of site rehabilitation is protection of public health and safety and the return of the site and its surroundings to economic use and/or a sustainable ecosystem. In many dry countries, we can see the tracks and scars of exploration covering many square kilometres of land that will never be mined. Techniques can now be used to reduce the extent of disturbance, but some rehabilitation will always be needed.

During mining operations, much ground is exposed to the elements. Closure usually involves sealing underground mines and rehabilitating, regrading, stabilizing and revegetating open pit operations.

New operations try to minimise land disturbance, plan for soil and waste storage, undertake progressive revegetation and land management. In fact, experience has demonstrated that a well managed mine that follows strict environmental stewardship principles throughout its operations will be easier and less costly to reclaim. A key issue is where, when and how to dispose of mine spoil, tailings and other mine waste so that these operations are both safe and have a minimal environmental impact now and in the future.

Following closure, the site needs to be restored to some predetermined plan. Today, the more progressive mining companies start planning for closure before the first operations commence so that the costly need to re-handle material, reshape landforms and restore degraded environments at the last moment is minimised.

At many sites however, the damage has already been done, in which case rehabilitation in a post-project sense is required. These situations are invariably expensive, often with no clear view of where the funds will come from. Post-project rehabilitation needs to be intensely practical and cost-effective. In many cases the objective will be to make a site physically and chemically secure rather than planning for a productive after-use. Time may be one of the tools relied upon to do over many years what technology and intensive care could otherwise achieve in a few months at more active sites.

One issue, however, is that in many cases there are no final standards to which a site must be returned to and every mine and mine environment is unique. Increasingly, consultations need to occur between the company, the community and its stakeholders and the government as to what the final site plan should look like. Ultimate relinquishment of the mine site by the company is impossible unless closure standards are established.

The issue of legal and financial responsibility is at the heart of many rehabilitation projects. For new projects, legislation may set performance targets in terms of environmental impacts and long-term land-use, perhaps enforced through financial bonds or securities that guarantee the public purse against defaulting companies. The rehabilitation procedures may already be evaluated at the EIA stage and stipulated as obligations in the project permit.

Many companies now see their relationships with the public as being at least as important as regulatory compliance. Public acquiescence of mining as a future activity is strongly influenced by its vision of ecological performance at today's sites. The rehabilitation of sites which leaves a public asset in terms of farmland, recreation reserves or nature habitat has become an increasingly common policy of mining companies. Site rehabilitation in these cases goes beyond the mere physical stabilisation of slopes and pits and providing a vegetation cover at the least cost.

Health and safety has long been regarded as a workplace issue, with objectives being limited to physical safety and protection from exposure to toxics. While these are still important, additional concerns include public safety from structures during and after operation, the fate of hazardous materials and wastes which may have been buried at the site, and about public security of the land after closure.

Beyond the confines of the mine, mining wastes, if not properly contained, can potentially affect public health in both nearby communities and surrounding ecosystems. Mine wastes may include cyanide compounds, heavy metals, radionuclides and asbestos (though never all in one waste stream). These can become solubilised or carried as suspended particles in waters leaching from the waste sites. This leachate, together with drainage from the mine, is often highly acidic or saline, and may also carry a high sediment load. The common incidents of contamination, which could ultimately affect public health or well-being, are pollution of drinking water supplies, aquatic ecosystems including fishing grounds, agricultural soils and urban areas.

As environmental and safety issues continue to evolve, all aspects of mine management must be reviewed from time to time to see if they are still relevant. Old practices may no longer be acceptable, as in the use of certain chemicals or in the standards of disposal. New techniques become available in slope stabilisation, in revegetation and in monitoring. It is necessary for supervisors and managers to remain up-to-date with the latest techniques in order to constantly improve environmental performance. For this, a constant link with environmental and technical research and development as well as with the changing environmental priorities of governments is an absolute necessity for all managers.

4. The Legacy of Inappropriate/Insufficient Mine Closure – Abandoned Mines

One of the major outstanding environmental problems is that of abandoned mine sites, a legacy of centuries old practices, of inadequate, insufficient or non-existent mine closure. The potential costs of rehabilitation, the lack of clearly assigned (or assumed) responsibility, the absence of criteria and standards of rehabilitation as well as other factors have delayed action by all parties - industry, governments and communities. Yet, land degradation from old mine operations is well known in almost all countries.

While many have seen these derelict sites, and there are many references in the literature, there have been few systematic surveys to quantify how many sites need attention. There has been even less work on trying to quantify the nature of associated problems so as to priorize remediation efforts.

UNEP has begun to compile information associated with the few national or regional inventories that exist although these are mostly in developed countries. These surveys are still ad-hoc and based on internal data collection in only some agencies (eg. abandoned sites on national park lands).

This is an important environmental issue on which we hope to make progress over the next year. In the meantime, if Workshops such as this one on mine closure can contribute to the development and implementation of good closure plans and technologies, the number of future abandoned or orphaned mines will surely diminish over time.

5. Mine Rehabilitation for Environment and Health Protection - Training

Building capacity to implement new policies in government and industry has been a major activity for UNEP. The work includes making information available to a wide range of professions, preparing trainers manuals, stimulating the upgrading of training curricula in institutions, and holding training workshops. In 1998, UNEP produced a training manual on *Mine Rehabilitation for Environment and Health*

Protection. The manual is designed as an applied, hands-on guide to address the rehabilitation of disturbed land, particularly as it applies to mining lands. It is a practical, factual method whereby rehabilitation techiniques can be applied.

When the decision has been made to decommission and close down a mine, the site rehabilitation plan should be brought to its final stages. In many countries and for many companies, rehabilitation is an on-going process as part of their operations. Unless an alternate use has been agreed upon with the nearby community, all physical facilities such as buildings, conveyor belts, silos and chimney stacks should be removed and all logistics features such as roads and power lines should be appropriately rehabilitated. Also, closure monitoring needs to be established and continued into the next stage, namely the post-closure period.

Post closure is the period following the shut-down and rehabilitation of the mine. If all environmental impacts have been appropriately and acceptably addressed, there may be a situation where the owner can ``walk away`` from the site. Monitoring however, will be required over a specific period of time to ensure that all the remedial work that has been carried out is stable and secure and functioning. Given that mining companies have little interest in their closed mine sites, there may come a time when this post-closure monitoring becomes the responsibility of a third party with funding from some type of insurance bond.

Under other active care conditions, a site may have to undergo perpetual maintenance. This would be in addition to the post closure monitoring. Even under passive care conditions, continual or periodical inspections and monitoring should take place.

6. Financial Issues

As with all mining operations, there are real and significant financial considerations with respect to mine closure and site rehabilitation, especially given that closure and rehabilitation occur at a time when the operation is no longer financially profitable. This is one major reason why governments are increasingly requiring companies to provide guarantees for mine closure, sometimes referred to as reclamation funds prior to a mine opening. It is important that these funds be established in accordance with both best accounting practices and in accordance with the tax provisions in the mine’s jurisdiction (in some jurisdictions, these funds are required by law).

There are a range of financial surety instruments ranging from irrevocable letters of credit, performance bonds, trust or reclamation funds, insurance policies or other guarantees. It is important that these funds become auditable items on a company’s books so as to be reported on. It is recommended that these funds be established under law and receive monies from the earliest days of operations. Company closure plans should be updated regularly so as to be prepared in the event of the need for a mine to be put under care and maintenance or in the event of premature closure. Governments have a role in setting the policy and tax frameworks for these financial instruments.

7. Social Issues

Although often neglected, the social effects of mine closure are often as adverse as the environmental and economic effects. In many countries in recent years, mine closures have exceeded new mine openings resulting in a significant number of workers being displaced. This situation is expected to continue in many countries including South Africa, Canada and China over the next decade. With hundreds of thousands of workers displaced, consideration needs to be given to issues of income, skills training, worker mobility (although many workers do not want to move), physical, and mental well-being and alternative patterns of work. Mine closures represent a significant social and cultural upheaval as well as having financial implications for the country.

While there are no easy answers to these challenges, many companies are starting to discuss mine closure impacts with the community in advance of mine construction and operation. This is the case for the new copper zinc mine of Cia Minera Antamina (CMA) in Peru. Antimina, a consortium of Rio Algom, Noranda, Tech and Misubishi Corp has discussed with the community elders what they would like to see left in their community after the mine operators remove their equipment. Even now, certain mine facilities are being designed and built with community after use in mind.

8. Institutional and Legal Issues

While current policy and legislative frameworks vary widely around the world, it is increasingly important that countries formulate clear, stable and predictable policies for industry to follow. These policies can evolve but should not fluctuate nor be unequally applied. It is equally important to recognize that each mine is unique, that some flexibility will be required as the mine operates and that artisinal, hardrock and coal mines and aggregate operations are different.

9. Future Issues

While it is clear that current best practices and regulations in many countries require mine closure plans, the challenge remains as to how to ensure that some companies don't cut corners in an effort to remain competitive. Further, what is the best way to ensure that small and medium sized companies, of which there are many more, also commit themselves to environmental stewardship and best practices. Globally, government environmental policies vary greatly and, it is important to recognize the contribution mining makes to national economies.

Abandoned mines present more legal and financial challenges than technical ones. The threat of future liability imposed on third parties that attempt to clean-up sites is a deterrent to progress. Under the laws of several countries, liability for toxic pollutants is retroactive with no statute of limitations meaning that present owners are responsible for the property in perpetuity even if they were not involved in the original mine. Work is underway in some countries to address this problem through "good Samaritan" clauses or other similar mechanisms.

There are several outstanding financial policy issues including: how can mine closure and reclamation funds be integrated into artisinal, small and medium sized operations? How can financial surety options be realistic, flexible and sufficient to address mine rehabilitation yet not so burdensome as to push companies into bankruptcy or deter them from commencing operations? What are the options to meet the financial burden of reclaiming abandoned mine sites, many from more than one hundred years ago?

The social challenges are also very real. Just as environmental impact assessments became the tool for measuring a mine's environmental impact, social impact assessments may become the tool to address social impacts. Perhaps these two mechanisms may become juxtaposed into socio-environmental impact assessments which *de facto* occurred recently in Canada with the proposed Voisey's Bay project.

10. CONCLUSIONS

It is possible that mining in the 21st century could become a model of an economically viable, environmentally sensitive, socially responsible industrial sector producing sustainable and decentralized benefits to foster other activities and increased capacities in the communities which will endure long after a particular mining operation closes.

In order for this to occur, a true partnership needs to emerge in association with each individual mining operation. Industry is challenged to assume greater environmental stewardship and communicate with nearby communities in all aspects of their operations. As the mining industry is often judged by its weakest member, good companies are urged to pressure those which give the industry a bad name to improve their environmental and social performance. National governments need to articulate clear policies and rules for environmental impact assessments including mine closure and site rehabilitation.

And what is UNEP's role? We are working with mining schools trying to ensure that the broad range of environmental issues are incorporated into the different subject curricula. We are currently improving access to environmental information primarily through the environment portion of the joint UNCTAD-UNEP website (www.natural-resources.org/environment). We are partnering with the Coalition for Environmentally Responsible Economics (CERES) in the Global Reporting Initiative which represents

The first global framework for corporate sustainability reporting encompassing environmental, social and economic issues – the *triple bottom line*. Should we consider insisting that companies must always report on closure planning and actual closure in their environmental report?

UNEP's mission is to provide leadership and encourage partnerships with the private sector and help decision makers in government and local authorities and industry develop and adopt policies and practices that are cleaner and safer, make efficient use of natural resources, incorporate environmental costs and reduce pollution and risks for humans and the environment. We try to stimulate policy debates like this one on mine closure as this is a critical environmental and social component of mining operations and remains a challenge for us all.

SELECTED BIBLIOGRAPHY

Case Studies Illustrating Environmental Practices in Mining and Metallurgical Processes; International Council on Metals and the Environment and United Nations Environment Programme, 1996

Case Studies on Tailings Management; International Council on Metals and the Environment and United Nations Environment Programme, 1998

"Closure Concepts", Mining Environmental Management (November 1998)

Environmental Aspects of Selected Non-Ferrous Metals (Cu, Ni, Pb, Zn, Au) Ore Mining: Technical Report Series No. 5; United Nations Environment Programme, International Labour Office, 1991

"Financial Provisions for Mine Closure", Mining Environmental Management (May 1999)

Mine Rehabilitation for Environment and Health Protection: A Training Manual; United Nations Environment Programme, World Health Organization, 1998

CORPORATE SOCIAL RESPONSIBILITY AND THE CASE OF SUMMITVILLE MINE

Professor *Alyson Warhurst*
Director, Mining and Energy Research Network, Corporate Citizenship Unit, Warwick Business School, University of Warwick, Coventry CV4 7AL, UK
and Dr *Paul Mitchell*
Technical Director, KEECO (UK) Limited, Rosemanowes, Herniss, Penryn, Cornwall TR10 9DU, UK

ABSTRACT

A growing literature is developing parallel to increasing “voice of society” concerns about corporate social and environmental responsibility. Emerging research suggests that, while public policy might provide the framework for the internalisation of previous external environmental damage costs, it is corporate strategy that can make the difference between environmental disaster and pollution prevention, and responsible business practice is defined by its anticipative and pro-active approach to ensuring that pollution is prevented and mine closure us accompanied by clean-up and reclamation. The Summitville gold mine, an abandoned open pit and underground operation in Colorado is often described as an ‘environmental disaster’ and the most notorious example of inadequate design, poor operation and failed environmental management at a mining operation in the US, past or present. Now a Superfund site, and the subject of numerous legal suits and counter-suits, its unplanned and sudden closure and abandonment in December 1992 has had profound implications for environmental protection, the costs and benefits of remedial treatment, technology issues and the regulatory process in both the USA and globally.

Of great import are the factors that influenced the development of events at Summitville, and these are discussed in two broad areas: corporate strategy during the development and operation of the site; and, the regulatory framework within which the mine was permitted, operated and abandoned. Finally, the implications of the abandonment of Summitville mine for the wider mining industry, regulatory authorities and the policy literature in this field, are discussed.

Keywords: Corporate social responsibility; Mine closure; Superfund; Environmental management; Acid rock drainage.

CORPORATE SOCIAL RESPONSIBILITY

While in financial terms, the designation as a ‘disaster’ is probably true, with in excess of $150 million so far being spent from public monies on remedial work at the site since its abandonment, it is less clear as to whether the site is a ‘disaster’ in terms of impacts on the physical environment and potential risks to human health. It is not the purpose of this paper to merely review the wealth of technical, regulatory and legal literature that relates to Summitville. Instead, it analyses the chain of events that culminated in the abandonment of the site in 1992 and post-abandonment remedial work by the US Environmental Protection Agency (USEPA); and draws out the implications for corporate strategy. This is undertaken within the context of growing demands from society for the mining industry to be more socially and environmentally responsible for its long-term indirect as well as direct effects.

The development of the concept of corporate social responsibility has fast expanded since the days when it was considered that: "… the social responsibility of business is to increase profits…" (Friedman, 1970). For example, Andrews (1988) argued: "… corporate strategy …is the pattern of decisions in a company that determines and reveals its objectives, purposes, or goals, produces the principal policies and plans for achieving those goals, and defines the range of business the company is to pursue, the kind of economic and human organisation it is or intends to be, and the nature of the economic and non-economic contribution it intends to make to its shareholders, employees, customers and communities…". And, more recently, Drucker (1993) stated "….[corporate] citizenship means active commitment. It means responsibility. It means making a difference in one's community, one's society, and one's country…..".

Corporate social responsibility is defined here as the internalisation by the company of the social and environmental effects of its operations through pro-active pollution prevention and social impact assessment so that harm is anticipated and avoided and benefits are optimised (Warhurst, 2000a). The concept is about companies seizing opportunities and targeting capabilities that they have built up for competitive advantage to contribute to sustainable development goals in ways that go beyond traditional responsibilities to Shareholders, employees and the law.

The drivers of these changes include (Warhurst, 1998):

- Globalisation, liberalisation and increased foreign direct investment world-wide
- Societal pressures, which are increasingly expressed as demands to address quality of life impacts, consultation, accountability and disclosure, and are sometimes pushed by special interest groups (e.g. NGOs)
- Regulation, which is increasingly becoming more integrated across the three environmental media of land, water and air and covers impact assessment and planning for closure
- Financial drivers, that is environmental and social conditionality applied to the granting of credit, equity investment or political and environmental risk insurance
- Supply chain pressure, which includes purchaser's growing requirements for audited and verified environmental and, more recently, social proficiency
- Peer pressures from other companies and reputational management
- Internal pressures from employees and shareholders; and finally
- The natural dynamic of environmental change itself, such as climate change and rising sea levels.

It is in the context of the evolution of these drivers for enhanced corporate social responsibility that the Summitville mine operation was developed, operated and closed which, in part, accounts for the world-wide critical appraisal that accompanied its acquisition of "superfund" status.

As mining has continued along the path of mechanisation and automation, the direct links *via* employment and financial benefits for local communities have diminished, reducing the acceptability of mining in the eyes of local stakeholders and posing new challenges to companies in terms of preventing pollution affecting local communities' livelihoods and health and finding new ways to deliver benefits in the form of social development or community projects[1]. In a more general sense, the image of the industry has become increasingly battered since the rise of general environmental awareness in the 1970s and 1980s, with each new environmental incident adding a further dent. This has left the industry prey to small but vociferous pressure groups, which are able to command the environmental and ethical high ground, and as public opinion continues to swing against the industry, so this is increasingly reflected in regional and central governments' attitude towards the sector as a whole, particularly as the role of mining in generating GDP declines. This has become apparent in the past 3-4 years in the US, with the federal government taking an increasingly confrontational attitude towards the industry despite the major bridge building that has occurred between environmental regulatory agencies and the industry during that same time. Summitville mine is an operation that is often quoted by pressure groups to represent much that needs to be addressed by today's mining industry. However, the real situation is more complex than any such simplistic assessment, and involves broader elements of corporate strategy and regulatory control that must also be considered. This paper seeks to contribute to that process through:

- Reviewing of the events leading up to and taking place during the operation and post-abandonment at Summitville and their environmental consequences
- Suggesting some implications for corporate management and strategy
- Drawing some conclusions of relevance to the emerging field of corporate social responsibility.

Overview of Events – From Permitting to Abandonment (1982-1992)

Summitville mine is located in Rio Grande County, Colorado (USA) at an average elevation of 11,500 feet. Surrounded by the Rio Grande National Forest, the site is bounded to the north by the Wightman Fork of the Alamosa River and to the east by Cropsy Creek. Cropsy Creek meets Wightman Fork near the north eastern perimeter of the site. This also represents the downstream boundary of the site (Pendleton *et al*., 1995). Wightman Fork enters the Alamosa River approximately four and a half miles downstream of the confluence with Cropsy Creek. Annual precipitation at the site (1,400 mm, mainly as snow) significantly exceeds water lost through evaporation (610 mm per annum).

Before 1870, when mining for gold began, the site consisted of uplands, wetlands and South Mountain. Since that time, mining has radically altered the local topography and biophysical environment. Although placer mining took place on Cropsy Creek and Wightman Fork from 1870 to 1873, it was extensive underground mining of the north-eastern flank of South Mountain between 1873 and 1940 that had a far greater disruptive impact due to the creation of access roads and waste disposal sites. In the late 1960s, Wightman Fork was also diverted to the north of the site to enable

[1] Natural Resources Cluster of the World Bank: Business Partners for Development Papers produced by Mining & Energy Research Network, Corporate Citizenship Unit, Warwick Business School, UK: Carter, 2000; Carter & Kapelus, 2000; Molloy, 2000; Warhurst, 2000b, Warhurst 2000c.

the construction of a large tailings pond. Consequently, by the 1980s, when the chain of events that lead to the eventual abandonment of the site and its classification as a Superfund site, there already existed a considerable legacy of land and water contamination over and above that resulting from the occurrence of natural mineralisation in the region (as detailed by Posey et al. (2000), natural mineralisation upstream of Summitville has an impact on water quality of the Alamosa River downstream of the site).

The principal owners of the surface and mineral estates of the area that encompassed the Summitville mine at the time of the events described in this paper were Aztec Minerals Corporation, Gray Eagle Mining and South Mountain Minerals Corporation. In 1984 the owners leased the property on which Summitville mine is located to Galactic Resources Inc. (GRI), and its wholly owned subsidiary Summitville Consolidated Mining Company Inc. (SCMCI), which designed, built and operated the final mine facility.

Operational design and environmental management in the context of declining gold prices.

Groundwater at the site occurs in a number of discontinuous and shallow perched aquifers. Some of these shallow systems discharge waters to the surface on a seasonal basis. Bedrock throughout the site is highly fractured and numerous springs and seeps occur, linked to the annual precipitation cycle (Pendleton et al., 1995). Rainstorm-related seeps also arise, particularly during the month of August. Therefore, it is clear that water management was always going to be a serious issue at the site.

In terms of setting the environmental baseline, SCMCI were required to create no incremental impacts in addition to those already in existence. They met the permitting requirements set at the time, and were not required to clean up prior mining impacts. The baseline conditions were assessed at the site and submitted to the Colorado Mined Land Reclamation Board (CMLRB) and were accepted as being adequate as judged against the standards across the state operating at the time of the submission. From the outset, the decision not to address past pollution suggests that a potential future problem was being built into the project and; from a corporate social responsibility perspective, we can note a regulatory framework that did not require past pollution to be addressed that could be interpreted as storing up problems for the future.

Beginning in 1984, SCMCI, the designer and operator of the final mining operation at the site, excavated waste rock and ore to create an open pit on the northeastern flank of South Mountain. The excavated material was either dumped in waste piles along with fines (undersize material) or placed on heap leach pads prior to the recovery of gold. Waste rock was also used extensively in the construction of roads, embankments and parking areas on the site (Pendleton et al., 1995).

Initially, there were plans to process separately the two types of ore found in the deposit: clay ore and vuggy silica ore. Indeed, a separate crusher and conveyor system was installed for each ore type. However, plans to agglomerate and leach the clay ore never came to fruition, and the ore remained stockpiled with the dedicated crusher and conveyor almost unused (Pendleton et al., 1995). One explanation for the latter was the high cost of the process in the context of the decline in gold price from nearly US$800 in 1982 to half that amount by the time operations began in 1986. The decline in gold price also exerted pressure on the operator to begin production as quickly as possible, without a fully detailed plan. Further problems arose as SCMCI changed consultants during the construction process, compounding continuity and management problems.

Although the abandonment itself was sudden, with the benefit of hindsight, there were indications of trouble ahead before the dramatic fall in gold price. For almost one and a half years before the abandonment, GRI and SCMCI had been subject to State agency mandates, requiring them to evaluate contaminants being released from the site. They were also required to develop remedial measures with the aim of eventual site reclamation (Pendleton et al., 1995).

In the period prior to the abandonment, other state and federal agencies were also involved in the monitoring of the mine site and the surrounding areas. Environmental and operational management issues identified at the site included:

- The permit was issued and construction commenced before a number of critical issues were fully resolved, on condition that they would be resolved later on. In a very real sense, planning never caught up with what was happening on the site. This particularly relates to closure planning.
- Difficulties in maintaining the integrity of the liner system under the heap leach pad, following its construction during the winter. Concerns regarding bank financing of the operation and the fear of reducing the potential profitability of stock options made to senior staff appear to have generated significant pressure on contractors to remain on schedule with the liner construction despite extreme weather conditions (Wilkinson, 1997). Deadlines that related to bank loan commitments also appear to have been a contributing factor (Danielson, *pers. comm*). Moreover, a number of changes were also made to the design of the liner system that were neither submitted to the state regulators for approval nor properly considered prior to implementation (Danielson *et al*., 1994).
- Leaks were detected between the upper and lower liners, and through the lower liner within a week of beginning heap leach operations in June 1986. This leaked effluent was subsequently pumped back onto the heap leach, further aggravating the overall water imbalance (1,400mm per annum precipitation against 610mm per annum evaporation) at a site where the leach portion of the project was initially envisaged as being zero discharge (Colorado Court of Appeals, 1996) through water entrainment in the leach material, enhanced evaporation and "aggressive" surface water management.
- Failure to stop construction and repair the liner when significant leakage became obvious also contributed to the unfolding environmental impacts and liabilities.

In 1989, SCMCI obtained approval for a process water treatment plant. However, this plant was unable to meet the water treatment standards required, and SCMCI then sought and obtained permission to allow for land application of the treated process water. This application was to be undertaken at a controlled rate to allow evaporation and percolation into the ground and attenuation of the contaminants. However, the company obtained approval for a land application system as an interim response without making it clear that it did not own all the land that it wished to use for the application. When the company failed to obtain permission to use the neighbouring land, it increased the rate of application on the land that it did own, contributing to overload flows to Wightman Fork and Cropsy Creek (Colorado Court of Appeals, 1996). It is worth noting that many of the clean-up standards were considered futile at the time by SCMCI due to the existing contamination from historical mining activity and natural mineralisation.

Each of these issues reflects significant failures in planning, and operational and environmental management in the face of increasing financial pressure to enter and continue the production phase in the context of declining gold prices.

Site abandonment and crisis management

The day before SCMCI petitioned for bankruptcy, the company submitted a revised reclamation plan to the Colorado Division of Minerals and Geology (CDMG) and the Colorado Mined Land Reclamation Board (CMLRB) that included additional costs ranging between $20.6 and $38.6 million. Had this plan been accepted, the company would then have been required to provide additional funds in the form of a bond amounting to the projected costs of reclamation (Pendleton et al., 1995). In the aftermath of the abandonment, some of the remedial measures presented in the plan were actually implemented by the USEPA (Miller *et al*., 1995) (see below).

On 1 December 1992, GRI alerted authorities of the State of Colorado that they intended to declare bankruptcy and abandon operation of the site on 16 December, 1992 (Pendleton et al., 1995). At this time the fluid level in the cyanide heap leach pad was five feet below the emergency spillway (giving a storage capacity, assuming normal precipitation, of 2-3 months) and contained an estimated 160 million gallons of cyanide and metal-bearing waters. It was also anticipated that any failure in pumping capacity from the heap leach underdrain would result in the direct discharge of acidic cyanide-bearing effluent into Cropsy Creek and subsequently Wightman Fork, a tributary of the Alamosa River, (Pendleton et al., 1995). These two immediate threats apparently could not be dealt with at State level and a request was made for emergency response assistance from Region VIII of the USEPA on 4 December 1992, under the Emergency Response Fund of the Superfund. USEPA personnel and contractors, working with SCMCI staff ensured that the necessary water circulation and treatment were continued to remove the immediate threat of direct effluent discharge (Pendleton et al., 1995).

Bonding as a mechanism to assure environmental responsibility

In retrospect, reclamation bonds at the site could be deemed to have been inadequate. Indeed the initial bond was set in 1984 before the Superfund system was sufficiently understood by the mining community and before Colorado had an effective mine permitting structure. The mining permit issued in 1984 required a reclamation bond of $1.3 million This applied to the grading, shaping and capping of surface wastes, but did not include a component for heap detoxification, water treatment or remediation. An additional surety of $0.9 million posted in August 1989 covered a "one-time" rinse of the heap, but this still did not include water treatment costs. An additional bond of $5 million was posted on June 21, 1992 following the realisation that major revisions would be required to the reclamation plan. By the autumn of 1992, with site grading completed, and the commencement of water treatment, the company requested and obtained the release of $2.5 million. On site abandonment, therefore, the surety bond was approximately $4.7 million (Filas and Gormley, 1997). However, this was effectively to guarantee performance of a predefined reclamation plan, rather than to address potential "disasters" or sudden site abandonment. Additionally, much of the bond was effectively worthless as it was in the form of equipment (such as the water treatment plant) which could not be removed from the site. Also, the non-payment of taxes led to tax liens senior to the reclamation lien.

Long-term environmental issues

In terms of pollution issues, the post-closure environmental concerns largely mirrored the concerns that were extant prior to abandonment (e.g. water contamination by cyanide and heavy metals); rather it was the scale of potential impact that changed following abandonment by SCMCI. The environmental issues of concern are summarised below:

Acid Rock Drainage

Surface drainage from the site ultimately reported to Terrace Reservoir, approximately 17 miles downstream of the confluence of the Wightman Fork and Alamosa River. From there it continued to the San Luis Valley where homes, farms and ranches depended on wells or river water for potable drinking and agricultural water supplies (Pendleton et al., 1995). As such, the movement of contaminants into surface and ground waters was the principal concern. Prior to mining, shallow water flow was controlled by non-mineralised faults in the rock mass and the permeable vuggy silica zone (Plumlee *et al*., 1995b). Sub-surface workings then became the major controlling factor via the creation of drainage adits. These were in turn modified by the creation of the open pit, which aided the transfer of water into the sulfide-rich mine workings below (Plumlee et al., 1995b).[2]

Although it was the potential release of cyanide that catalysed the mobilisation of state and federal staff and the involvement of the USEPA at the site, it was the generation of acid rock drainage (ARD) that represented the most significant of the long-term environmental risks. ARD at Summitville is among the most acidic and metal-contaminated in Colorado (Plumlee et al., 1995a) and has been an issue for many decades. The situation was aggravated by water-soluble secondary salts (e.g. iron and copper sulphates) formed by the evaporation of metal-contaminated acid waters during dry periods in summer and autumn. These salts subsequently re-dissolved in rainwater and snowmelt to form highly acidic, metal-rich waters. Therefore, the major long-term challenge was ultimately to prevent the oxidation of sulphides and dissolution of secondary metal salts, particularly from the numerous waste piles situated on the site (Plumlee et al., 1995a).

Waste rock piles

The initial assumption that since the ore body was in the oxidised zone associated wastes would not generate acid, was proved to be incorrect. Substantial quantities of sulphide minerals were present in the oxidised zone as pockets, and these were removed along with the gold-rich oxide mineral assemblage. Failure to properly identify potential acid-generating material inhibited the implementation of

[2] Part of the remedial plan submitted the day prior to notice of abandonment was to assess the possibility of reconfiguring the pit to increase surface run-off, and reduce infiltration to ground water (Miller et al., 1995).

pollution prevention from the outset and also had severe detrimental impacts on the capacity of the waste management plan to deliver an appropriate level of environmental protection. As gold present in sulphide minerals was not amenable to cyanidation, SCMCI limited the amount of sulphide-rich material reporting to the leach pads, instead dumping it on waste piles. These extensive sulphide-rich waste piles became a major source of ARD, exacerbated by poor and haphazard waste management practice. For example, at least one of the waste piles was dumped on a spring-fed bog, which increased the volume of ARD generated and the release of metals into solution (Pendleton et al., 1995).

Waters from the waste piles and adits ranged in pH from 2.3 to 3.2 and contained extremely high concentrations of metals and other elements. In general, the waters from the waste piles were of lower pH and higher metal concentrations than the discharges from the adits (Plumlee et al., 1995a).

Reynolds Adit

Although there are other adits on the site, Reynolds Adit was the most significant as it was the lowest of the historic underground workings (Roeber *et al*., 1995) (approximately 200 feet lower than Chandler Adit, and 550 feet lower than Iowa Adit). Reynolds Adit was used to lower the water table at the Summitville site and thus reduce the costs of pumping. Flow-rates varied between 380 l min^{-1} up to an average peak of 1,500 l min^{-1} during the spring when snowmelt was occurring (Pendleton et al., 1995).[3] As it drained the mineralised zone of South Mountain, dissolved metals in the discharge from the adit were relatively high. Prior to 1988, copper was present at 20-30 mg l^{-1}. However, it appears that the excavation of the open pit (the floor of which was about 300 feet above the adit) promoted infiltration of water and oxidation of the ore, and in 1989 the concentration of dissolved copper began to rise, reaching approximately 130 mg l^{-1} by 1992. In June 1993, copper reached its highest documented concentration of 650 mg l^{-1}. Work by Plumlee et al. (1995a) indicated that iron, aluminium, zinc and arsenic showed a similar increasing trend in concentration. The quantity of metal discharged from Reynolds Adit was equal to that discharged from the remainder of site, including the waste piles.[4]

REMEDIAL ACTION AT SUMMITVILLE: RETROSPECTIVE RESPONSIBILITY

Cropsy Waste Pile, Cleveland Cliffs Tailings Pond, the Beaver Mud Dump, the open pits and the underground workings were identified as the major sources of ARD on the site (Ketellapper *et al*., 1995). These were the priorities for a three phase programme[5] of remediation which was chosen on the basis of cost effectiveness and potential efficacy from five alternatives (Ketellapper et al., 1995; Ketellapper and Christiansen, 1998).

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[3] Although undocumented flows up to 6,000 l min^{-1} have been reported.

[4] The amount of copper released from the entire mine site was up to 4.1 t day^{-1}, approximately half of which was discharged from Reynolds Adit prior to its plugging in 1994.

[5] Each phase of the remedial plan had a voluntary contribution of 10% from the State of Colorado (Williams, 1995). Phase III also involves a potential nine year period of flushing of contaminants from the areas beneath the sites of Cropsy Waste Pile, Cleveland Cliffs and Beaver Mud Dump prior to their removal to the open pits (Williams, 1995).

Waste backfilling

The three phases were designed in order to remove acid generating rock from saturated areas, to backfill the open pits and also reduce infiltration into the underground mine workings (Ketellapper and Christiansen, 1998).

- Phase I and Phase II consisted of the lining of the north and south open pits with a clay liner and two feet of lime and subsequent removal of the majority of Beaver Mud Dump, Cropsy Waste Pile and Cleveland Cliffs Tailings Pond to the lined pits. Approximately 3.6 million m^3 of acid generating waste were relocated to the pits during the period 1993-1996.
- Phase III included capping and vegetation of the infilled south pit in 1995 and revegetation of the sites from which waste had been removed (Ketellapper et al., 1995). The north pit backfilling is continuing (Ketellapper and Christiansen, 1998) and eventually it is planned that this will also be capped.

Active treatment of ARD from Reynolds Adit in the form of a portable interim treatment system (PITS) using caustic soda solution as the precipitating agent, was installed in July 1992 (Logsdon and Mudder, 1995; Roeber et al., 1995). The coagulated and flocculated sludge was disposed of on the heap leach pad. This was subsequently backfilled to the open pits.

In 1995, the area around the tailings pond was excavated and re-designed as the Summitville Dam, which was to serve as a catchment area for the majority of flows generated on the site and to facilitate water treatment through a single central facility (Ketellapper and Christiansen, 1998). At present, the Dam has a capacity of 3.4×10^8 L and the treatment facility a capacity of 3,400 L min^{-1}.

Adit plugging

In January 1994, Reynolds Adit was plugged in order to reduce the discharge and re-establish pre-adit hydrologic conditions (Plumlee et al., 1995b). Some discharge continues from the adit due to fractures in the rock around the plug (Plumlee et al., 1995b). Plugging was suggested in the remedial plan lodged by SCMCI the day before abandonment as a means of saturating the workings and controlling the ingress of oxygen (and oxidation of sulphides) (Brown, 1995). The assumption that saturation will control sulphide oxidation is not necessarily correct due to the presence of ferric iron (a strong oxidant) in secondary salts. However, plugging is also expected to promote the movement of water through the rock mass, increasing the opportunities for attenuation.[6]

The full effects of plugging and pit capping have yet to be determined in terms of source reduction of acid, metal-laden waters. However, it is assumed that if land reclamation and revegetation on site is successful, that water treatment may no longer be a continuous necessity as preventative measures improve water quality (Ketellapper and Christiansen, 1998) due to the reduced infiltration of water and the

[6] Based on batch tests, the attenuative capacity of the rock mass (assumed to act as a porous body) for copper was calculated as at least 123,000 t and for zinc at 11,000 t. This capacity could theoretically hold all the copper present in the ore body above the elevation of Wightman Fork and 25% of the total zinc present in the same portion of the ore body (Brown, 1995).

return of the sub-surface environment to its pre-mining anoxic state.[7] This preventative approach is potentially important when it is considered that to date nearly 55% of the project costs (approximately $65 million) have been spent on water treatment (Ketellapper and Christiansen, 1998). By way of comparison, adit plugging has accounted for approximately 1% of the total project cost, yet may well have contributed significantly to source reduction in the short-term.

However, capping and flooding of the workings above the Reynolds Adit will not completely stop water flow into the pit area as cavity-bearing silica outcrops and faults outside the backfilled and capped area may allow groundwater recharge of the area beneath the cap (Plumlee et al., 1995b). Therefore, any cavity-bearing or faulted areas may also have to be isolated or capped.

Equally, adit management through the use of plugs may only reduce the metal loading in the short-term, depending on the future movements of subsurface water and their expression at the surface via seeps, springs and streams. Water may also exit through adits at higher elevations as the head of water builds. Redirecting water from one route (e.g. by adit plugging) may lead to greater metal loading if that water is forced through more highly mineralised wastes or in-situ workings. At Summitville this occurred when seeps reappeared on the north side of the site (due to the plugging of adits) and water passed through the North Waste Dump (waste rock pile).

Seeps and springs

Prior to backfilling of the wastes to the open pits, seeps and springs drained the various waste dumps (with at least one waste dump positioned on a spring-fed bog). Historic (pre-mining) seeps and springs are marked by deposits of ferricrete (precipitates of iron oxide/hydroxide minerals that occur as iron-rich acidic groundwater flowed to the surface) (Plumlee et al., 1995b). These gave some indication of the possible discharge points that might re-activate when Reynolds Adit was plugged (in 1994). Since the plugging of the adit, seeps east and north of the open pit have either started or increased in flow rate (Plumlee et al., 1995b), typically at sites of historic flow. In particular, seeps bearing increased metal loads appear to be the result of water passing though the North Pit Waste Dump

The removal of the priority waste dumps to the open pits was considered likely to reduce the significance of new seeps and springs. However, with the plugging of Reynolds and Chandler Adits, the historic seeps and springs along the northern site boundary are considered likely to be of greater significance as groundwater flow returns to its pre-mining pathways. These discharges, however, need to be viewed in the context of other natural sources of acidity and dissolved metals in the Alamosa River basin (Plumlee et al., 1995a) et al et al et al

ANALYSIS: CORPORATE STRATEGY AND ENVIRONMENTAL IMPLICATIONS

The legacy that SCMCI inherited was, in retrospect, a considerable one - with Summitville a site that had been subjected to massive and continuous surface disturbance, accompanied by fundamental changes to ground and surface water flow paths. There existed little historic documentation of the nature of wastes disposed of

[7] Equally important of course are any changes in the acceptable concentration of metals in waters discharged from the site.

around the site. Undoubtedly, changes in operational responsibility since the site was first worked in 1872 were an important factor in determining the final environmental impact of the site, as contaminating wastes were deposited or discharged and responsibility for them was “lost” by subsequent owners and leasing companies.

From the perspective of SCMCI and GRI, inheritance of a legacy of on- and off-site environmental problems could have been mitigated in part by a proactive and thorough baseline survey of existing conditions from the outset of their involvement. More importantly, the leasing of the site itself might have been reconsidered had GRI considered environmental liabilities previously identified in a mine feasibility study undertaken by Anaconda in 1983 (Anaconda, 1983). This had contributed to Anaconda's assessment that the mine development was not economically viable. The issue of environmental liabilities appears to have been ignored by GRI.

Irrespective of the fact that it inherited a significantly contaminated and disturbed site, SCMCI failed to address the issue of social responsibility and its environmental implications. It had in its power the capacity to predict potential ARD generation from waste piles (through, for example, the application of static and kinetic leach tests). It also had the opportunity to take the necessary steps to avoid acid generation by implementing various waste management control options (e.g. isolation of sulphidic material and minimisation of the exposure of sulphide-rich altered clay zones in the open pit). Evidence suggests it followed neither of these routes.

Furthermore, SCMCI did not appear particularly adept at meeting the requirements of day-to-day operation and rehabilitation on-site. Although permits require reclamation on closure, no studies are required to prove that the company involved can actually achieve the proposed reclamation targets (Williams, 1995). This gap between apparent capacity and reality seems to have been a significant factor for SCMCI. Radical changes were made to Colorado’s mine permitting laws as a result of this (see Danielson and Nixon, 1999 for further details relating to changes in permitting and bonding in Colorado).

There has been a considerable debate as to whether Summitville is sufficiently different from other mine sites to justify the higher level of expenditure that has occurred, as summarised in Table 1, and if the risks to human or wider ecosystem health were as large or significant as originally anticipated. According to Williams (1995), Summitville is far from unique in terms of type and location. Neither is it the only mine being addressed under the USEPA’s Superfund programme. However, it is the first of the modern heap leaching gold mines to be addressed in this way, and it is also the sole mine on the Superfund list for which the associated watershed has not been irretrievably degraded by historic mining activity. Notwithstanding, it should be noted that other factors such as local geochemical conditions, construction of logging roads, accelerated erosion and tourism have also been quoted as significantly degrading the quality of the river (Mendonca, in NAM, 1997).

Table 1. Costs of remedial action at Summitville mine (data from Ketellapper and Christiansen, 1998)

ACTIVITY	COST	COMMENTS
Water treatment	US$65 million (to end of 1997)	Includes treatment of cyanide bearing water from the heap leach pad and ARD
Source removal and pit capping	US$32 million (to end of 1997)	Does not include cost of capping the north open pit
Adit plugging	US$1.7 million	Total cost – plugging programme completed
Recontouring and reclamation	US$45 million (estimated)	Cost of recontouring and capping the heap leach pad was US$15 million. Estimated cost to complete site reclamation is US$30 million

Therefore, relative to other mining-related Superfund sites, the Summitville Mine is a potential long term economic "sink" as more money is poured in to prevent deterioration of water quality in the Alamosa River basin.

Some researchers have questioned whether the total estimated investment of $150 million in remediation will ultimately prove worthwhile given the other non-mining related pressures on water quality in the region (Mendonca, in NAM, 1997). This seems to be borne out in part by the recent work of Posey *et al*. (2000) that defines the significant contribution to water quality deterioration of natural acid drainage formation (*i.e.* that which is not anthropogenic in origin) and earlier work by Bove *et al*. (1995) indicating that acid generation in the Alamosa River basin predated mining activity by millions of years based on the local and regional geology. Other researchers have stated that considerably less investment was required to achieve an acceptable level of remediation. This last point may have some justification, given that the purpose of Superfund clean-ups is to reduce or eliminate risk to human or ecosystem health, not to return a site to its pre-industrial condition (Wilkinson, 1997). Notwithstanding any of these points, the Superfund programme cannot have clean-up goals at Summitville beyond pre-mining water quality conditions.

The events leading up to the incidents at Summitville are generally well understood (although as with any human endeavour, the written word can only paint a rough picture of cause-and-effect relationships). It is accurate to say that none of the different actors were entirely blameless and that none were entirely to blame, and that the permitting and regulatory frameworks shaped events as much as the mismanagement at the corporate strategy level that occurred during site development and operation. The regulatory framework as it existed at the time could be considered in part a catalyst for the events that followed – leeway and loopholes combined with a lack of a strategy of corporate social responsibility will often lead to unforeseen and undesirable effects. However, the design, implementation and enforcement of regulations are complex procedures, and as with many human activities, can be undermined by human fallibility. Regulatory frameworks must evolve, as must the industry, to incorporate lessons from past shortfalls in compliance and performance. In Colorado at least there are clear signs that the regulatory framework has adapted to ensure a greater degree of regulatory control over all stages in the mining process – from permitting through to eventual closure.

SCMCI has been the subject of a great deal of 'retrospective criticism' (based, in part, on applying 1990s standards to a 1980s operation) as a result of its corporate strategy and inability or unwillingness to remain with the confines of the regulatory framework. Although regulation (in the form of the Colorado Mined Land Reclamation Act of 1976) was limited in its scope and relatively lenient, SCMCI was deemed to have violated a number of key provisions under the Act, for example, partially or completely changing or omitting design features outlined in its permit application without consulting either the CDMG or CMLRB (Danielson et al, 1994). Indeed, on 2 May 1996, SCMCI pleaded guilty to 40 felony violations of federal environmental laws at the Summitville site, and was fined $20 million. SCMCI entered guilty pleas to charges of conspiracy, unauthorised discharge of pollutants, failure to make required reports and making false statements or documents. The company was indicted in June 1995 along with the mine's environmental manager Tom Chisholm. Additional charges were filed against the mine, Chisholm and the general manager Samye Buckner in November of the same year.

Although the SCMCI operation did undoubtedly cause greater oxidation of sulphides and release of metals (see, for example, water quality data in Van Zyl, 1996), it begs the question of whether it is appropriate to criticise the company for that increased ARD generation at the time when the mining, regulatory and environmental communities did not have the same awareness of acid drainage as is nowadays the case. Against this must be balanced the fact that neither a pro-active nor an integrated approach to environmental management and pollution prevention was apparent in the strategy of SCMCI at Summitville. All this, of course, is in the context of a regulatory framework that limited the regulators' capacity to intervene directly.

There are, in any case, specific lessons to be learned from Summitville, including the necessity of effective isolation of sulphidic wastes from water and oxygen in wet climates[8] and the need to reduce the effects of wet-dry cycles and the concomitant build-up of secondary metal salts. Seeps and springs need to be properly documented before mining takes place to ensure acid-generating wastes are not placed near them (Plumlee *et al*., 1995b). Perhaps the most pertinent fact is that these points are largely accepted as being in line with definitions of "best practice" and - based on years of costly experience within the industry – common sense approaches to water and waste management. However, it appears that dissemination of best practice within the industry in the area of ARD is not as effective as it could be. This could be considered to typify the whole issue of ARD; an increasing knowledge base is being generated about preventative and control methods, yet it continues to feature as a major environmental problem.

Conclusions: Corporate Social Responsibility: Towards Environmental Performance Beyond Compliance

Summitville is proof that the potential for substantial environmental impact remains a reality even at modern mine sites, as indeed, Danielson *et al*. (1994) note.

[8] In wet climates, the absence of neutralising minerals in the ore or host rock indicates that the risks of ore exploitation may be high in the context of ARD generation. The movement of ARD off-site in the absence of buffering capacity is also aggravated (Plumlee et al., 1995b). One could question whether such deposits should be worked at all.

But equally, it can be used to demonstrate that a number of discrete factors need to occur in sequence for such disastrous pollution events to occur, and in the majority of cases most mining operations in well regulated and enforced regimes cannot truly be considered “the next Summitville waiting to happen”. There is however a risk that the resultant “over-regulation” of operations in certain countries (e.g. the USA, Canada and Australia) may cause the problem to be transferred to countries where regulation is less stringent, or cannot be enforced.

Moreover, the Summitville case demonstrates that there were other strategies that SCMCI and GRI could have followed that would have been more socially responsible and have yielded fewer negative implications

Mining – barring a paradigm shift in technology – by its very nature will continue to have impacts on the physical environment, be they transient, temporary or permanent. It is perhaps easier now to envisage a time when negative environmental and social impacts can be properly managed, minimised or eliminated throughout the industry. Technological change and the development of effective environmental management systems have contributed significantly to merit this optimism. Against this must be balanced the benefits that the extraction and processing of mineral resources can bring. Although impacts continue, the mining industry is largely unlike that of 50 or even 25 years ago. However, the relationship between most stakeholder groups and mining companies is based largely on past, rather than present, performance and impacts. It is unreasonable to suggest that every mining site is a “Summitville waiting to happen” – although undoubtedly there are many that represent a serious environmental and/or social risk beyond that which is acceptable. Equally, it is problematic to criticise retrospectively or prosecute companies that can be shown to have met regulatory obligations in place at the time of starting operations. Notwithstanding this view, the new concept of a corporate strategy of social responsibility does address the fact that there indisputably exists a pro-active role that can be played by business; and, the Summitville case illustrates how, in one situation, corporate strategy might have been implemented differently, The burden of responsibility, however, may need to be shared with government (Tilton, 1994). Where voluntary initiative has not been taken, in those cases where companies have actively sought to exploit loopholes in regulation or have stepped outside of the regulatory process as part of a purposeful policy to achieve internal strategic or operational targets, there is still a need for strict regulatory enforcement. It is not always easy, or even possible, to differentiate between these two scenarios of “responsible but misconceived compliance” or “opportunistic compliance”. Even in the case of Summitville, some would argue that the nature of the regulatory framework aggravated the likelihood of a pollution event.

The task that the industry faces, it is suggested here, is communicating effectively the difference between these two scenarios to stakeholder groups by pro-actively addressing pollution that has resulted in cases of “misconceived compliance” and by isolating, rather that protecting, opportunistic polluters.

How can the wider industry distance itself from specific incidents as they continue to occur at various locations around the globe? One potential answer lies in the emerging capacity to allow consumers (via intermediaries such as manufacturers and fabricators) to differentiate between sources of metals, and apply pressure through the supply chain on poor performers. Through an overarching framework of environmental and social performance indicators (ESPIs), it would be possible to audit companies at corporate and site-specific levels. This auditing process might be undertaken by an independent body, for which funding could be partially derived from a premium applied to metals from “quality assured” sites (with part of the premium also passing to the company in question). This approach is of course open to abuse, particularly in countries where regulatory frameworks and enforcement are weak, or where corruption is endemic, but the concept is not without precedent (e.g. the accreditation of timber producers under a general theme of “sustainability”).

The Proceedings of Summitville Forum ’95 contains a whole gamut of opinion and evidence from the narrowly technical and scientific, through to the sociological which could be considered to be more value-laden. What is almost more important than the content of the proceedings is that this range of opinion exists as it does, demonstrating that the same incident when viewed from different perspectives can lead to so many diverse assessments.

Events such as occurred at Summitville will undoubtedly occur again sporadically and it is important that lessons be drawn from this case to reduce the likelihood of future pollution.

In a more general sense, conclusions that can be drawn from this case include:

- Modern as well as historic mining may be associated with environmental problems.
- Proactive baseline monitoring and ARD prediction, monitoring and management from the outset are of paramount importance.
- Environmental liabilities need to be assessed and addressed before new mining begins or when ownership of a site changes - responsibilities need to be defined from the outset.
- Management capacity, as much as technical expertise, is paramount in putting together the elements of what could be considered good practice in ARD and other pollution prevention and management.
- A cost-effective approach by the industry must be to anticipate and plan effectively, proactively preventing environmental damage rather than reacting to *post-facto* damage.

Todd and Struhsacker (1997) contend that the past performance of the mining industry as represented by old or abandoned operations does not represent what will happen at new and modern sites. This point is certainly borne out by the results of their (limited) survey. However, it is interesting that a notable absentee from the mines that they considered was Summitville. While using Summitville as a “stick” with which to beat the industry cannot be justified, on account of the specific circumstances of that site, neither can the experience of such modern sites, where significant errors have occurred, be ignored. By failing to analyse the problems the industry runs the risk of failing to learn from past experience and meet its societal obligations to plan for optimal and acceptable environmental performance at future sites.

The Summitville story is a useful demonstration of what is meant by corporate social responsibility in operational terms. It demonstrates first, that regulatory weakness - the failure of the public policy framework – is not the sole cause of environmental pollution. It shows that there is not "one way" to do mining. It suggests that different companies can achieve good or poor performance. It demonstrates, secondly, that companies can take different strategic options. They are neither bound by regulation nor need to be limited by it, where experience dictates superior strategies to prevent pollution or manage environmental impacts in innovative ways.

Therein lies the operationalisation of the concept of corporate social responsibility – the pro-active implementation of a strategy of internalising responsibility to protect the environment and mitigate negative social impacts, even where the regulatory framework has not anticipated a problem and the safeguards put in place wouldat the outset have been considered, albeit erroneously, as adequate.

At present the mining sector is judged by its worst performer, therefore, the Summitville story warrants analysis; and, we are not suggesting our conclusions are the only ones that could be drawn. There is a misconception, within a broad sector of society, that mining is necessarily polluting and that this is the only way it can be done. The analysis above suggests the industry needs to address how best to differentiate between three key categories of corporate strategies and to demonstrate their different implications to a critical public:

- Poor environmental performers exhibiting mismanagement, technical blunders and an abuse of a weak regulatory regime or regulatory loopholes
- A compliant performer that is within the law but exhibits poor performance on account of regulatory weakness or failings and a genuine failure to predict pollution in spite of best efforts
- Good environmental performers that endeavour to select socially responsible corporate strategies irrespective of regulatory requirements so as to prevent pollution, avoid disaster and ensure mining truly contributes to sustainable development goals.

It is in the power of individual companies to choose which category they operate in, and clearly we have a situation world-wide where companies can be empirically located by virtue of their performance in each of these categories. The first step forward for business, however, is to define which strategic option is to be pursued and, secondly, those companies following the third "strategic option" may need to differentiate themselves from other companies and report comprehensively to interested stakeholders on their performance beyond compliance. By the same token, it is becoming even more important for a discerning public and for critical special interest groups to encourage and recognise those companies that are distinguishing themselves and are behaving responsibly, so as to help ensure an upward trajectory of improvement continues.

References

Anaconda. 1983. Summitville open pit pre-feasibility report. September 28, 1983.

Andrews, K.R. 1988. The Concept of Corporate Strategy. In: Quinn, J.B., Mintzberg, H. & James, R.M. *The Strategy Process; Concepts, Contexts and Cases*. Prentice-Hall. Englewood Cliffs.

Bove, D. J., Barry, T., Kurtz, J., Hon, K., Wilson, A. B., Van Loenen, R. E. and Kirkham, R. M. 1995. Geology of hydrothermally altered areas within the Upper Alamosa River basin, Colorado, and probably effects on water quality. In: Proceedings of Summitville Forum '95, pp. 87-98, Colorado Geological Survey Special Publication 38.

Brown, A. 1995. Geohydrology and adit plugging. In: Proceedings of Summitville Forum '95, pp. 87-98, Colorado Geological Survey Special Publication 38.

Carter, A. S. 2000 Delivering Social Investment Programmes through Corporate Foundations Mining & Energy Research Network, Corporate Citizenship Unit, Warwick Business School, UK, February 2000

Carter, A. S. & Kapelus, P. 2000 Cost Sharing/Cost Saving in Strategies Relating to Social Issues at Natural Resource Projects Mining & Energy Research Network, Corporate Citizenship Unit, Warwick Business School, UK, February 2000

Colorado Court of Appeals. 1996 . No. 95CA1108, 24 October.

Danielson, L. J., Alms, L. and McNamara, A. 1994. The Summitville story: a Superfund site is born. Environmental Law Reporter, July, pp. 10388-10401.

Danielson, L. J. and Nixon, M. 1999. Current regulatory approaches to mine closure in the United States. In: Planning for Closure: Best Practice in Managing Ecological Impacts from Mining, eds Warhurst A.C. and Noronha L., CRC Press.

Drucker, P. F. 1993. Post capitalist Society. Butterworth-Heinemann, Oxford.

Filas, B. A. and Gormley, J. T. 1997. The Summitville mine: build-up to crisis. In Marcus, : J. J. (Ed), Mining Environmental Handbook: Effects of Mining on the Environment and American Environmental Controls on Mining, London: Imperial College Press, pp. 687-697.

Friedman, M. 1970. The Social Responsibility of Business is to Increase its Profits. New York Time Magazine. 32-33, 122, 126.

Gray, N. F. 1995. Influence of secondary sulphate mineral formation on the impact of acid mine drainage to surface waters. Water Technology Research Technical Report: 16, February 1995, University of Dublin, Trinity College.

Hutchison, I. P. G. and Cameron, D. P. 1995. Remedial alternatives identification and evaluation. In: Proceedings of Summitville Forum '95, pp. 121-126, Colorado Geological Survey Special Publication 38.

Ketellapper, V. L., Cressman, J. E. and Carmody, C. 1995. Cropsy Waste Pile, Beaver Mud Dump, Cleveland Cliffs and Mine Pits response action. In: Proceedings of Summitville Forum '95, pp. 121-126, Colorado Geological Survey Special Publication 38.

Ketellapper, V. L. and Christiansen, J. W. 1998. The effectiveness of acid rock drainage control strategies at the Summitville Mine. In: Proc. 1998 Annual Meeting of the American Society for Surface Mining and Reclamation, May 1998

Kirkham, R. M., Lovekin, J. R. and Sares, M. A. 1995. Sources of acidity and heavy metals in the Alamosa River basin outside of the Summitville mining area, Colorado. In: Proceedings of Summitville Forum '95, pp. 121-126, Colorado Geological Survey Special Publication 38.

Logsdon, M. and Mudder, T. 1995. Geochemistry of spent ore and water treatment issues. In: Proceedings of Summitville Forum '95, pp. 99-108, Colorado Geological Survey Special Publication 38.

Miller, S. H., Van Zyl, D. J. A and McPherson, P. 1995. Summitville site water quality characterization and modelling. In: Proceedings of Summitville Forum '95, pp. 75-98, Colorado Geological Survey Special Publication 38.

Molloy, E. 2000 Tri-Sector Partnerships for Equitable Resource Rent Distribution: A Review of Potential. Mining and Energy Research Network, Corporate Citizenship Unit, Warwick Business School, UK, February 2000

NAM. 1997. Summitville costs may be unreasonable. North American Mining, March, pp. 13-15.

Orava, D. A. and Swider, R. C. 1996. Inhibiting acid mine drainage throughout the mine life cycle. CIM Bulletin, 89, No.999, pp. 52-56.

Ortiz, R. F., von Guerard, P. and Walton-Day, K. 1995. Effect of localized rainstorm on the water quality of the Alamosa River upstream from the Terrace Reservoir, South-Central Colorado, August 9-10, 1993. In: Proceedings of Summitville Forum '95, pp. 13-22, Colorado Geological Survey Special Publication 38.

Pendleton, J. A., Posey, H. H. and Long, M. B. 1995. Characterizing Summitville and its impacts: setting the scene. In: Proceedings of Summitville Forum '95, pp. 1-12, Colorado Geological Survey Special Publication 38.

Plumlee, G. S., Gray, J. E., Roeber, M. M., Coolbaugh, M., Flohr, M. and Whitney, G. 1995a. The importance of geology in understanding and remediating environmental problems at Summitville. In: Proceedings of Summitville Forum '95, pp. 13-22, Colorado Geological Survey Special Publication 38.

Plumlee, G. S., Smith, K. S., Mosier, E. L., Ficklin, W. H., Montour, M., Briggs, P. and Meier, A. 1995b. Geochemical processes controlling acid-drainage generation and cyanide degradation at Summitville. In: Proceedings of Summitville Forum '95, pp. 23-34, Colorado Geological Survey Special Publication 38.

Posey, H. H., Renkin, M. L. and Woodling, J. 2000. Natural acid drainage in the Upper Alamosa River of Colorado. In: Proceedings of Int. Conf. on Acid Rock Drainage, Denver, May 2000 (in press).

Roeber, M. M., Carey, A. J.,. Cressman, J. E, Birdsey, R. S., Devarajan, T. S. and Trela, J.A.. 1995. Water treatment at Summitville. In: Proceedings of Summitville Forum '95, pp. 134-145, Colorado Geological Survey Special Publication 38.

Tilton, J. E. 1994. Mining Waste and the Polluter-Pays Principle in the United States. In: Mining and the Environment: International Perspectives on Public Policy ed. Eggert, R., Resources for the Future, Washington DC.

Todd, J. W. and Struhsacker, D. W. 1997. Environmentally responsible mining: results and thoughts regarding a survey of North American metallic mineral mines. Proc. Environmentally Responsible Mining: the Technology, the People, the Commitment. Milwaukee, Wisconsin, USA, February 17-18, 1997.

Van Zyl, D. 1996. Understanding the reasons for environmental problems from inactive mine sites. In: Managing Environmental Problems at Inactive and Abandoned Metals Mine Sites, US Environmental Protection Agency, Office of Research and Development, Washington DC, EPA/625/R-95/007, pp 4-7.

Warhurst, A. 1998. Corporate Social Responsibility and Human Rights: A Pro-active Approach. Paper presented to the Royal Institute of International Affairs, April 1998, London.

Warhurst, A. 2000a . Issues in the Management of the Socioeconomic Impacts of Mine closure: A Review of Challenges and Constraints. In: Environmental Policy in Mining: Corporate Strategy and Planning for Closure eds. Warhurst, A. and Noronha, L., CRC Press.

Warhurst, A. 2000b. Drivers of Tri-Sector Partnerships, Mining and Energy Research Network, Corporate Citizen Unit, Warwick Business School, UK, February 2000

Warhurst, A. (Ed) 2000c Mining and Energy Research Network Bulletin 15 "Sustainable Development" Special Issue, Warwick Business School, UK, May 2000.

Wilkinson, T. 1997. Who pays the bill for mining leftovers? The Christian Science Monitor, 17 April, p. 4.

Williams, L. O. 1995. Is Summitville really unique? In: Proceedings of Summitville Forum '95, pp. 362-368, Colorado Geological Survey Special Publication 38.

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ENVIRONMENTAL SITUATION OF OPEN-PIT MINING IN BUENOS AIRES PROVINCE, ARGENTINA. CASES ANALYSIS

Mario Tessone and *Daniela Marchionni*
INREMI (UNLP)

INTRODUCTION

Buenos Aires Province have a privilege place in the Argentinean mining activity, contributing with a 37% to the national production. This prominent place responds so much to the good quality of its materials as to the geographical location of the deposits, near the big consumption centers.

The mining activity of the province is sustained fundamentally by the item application rocks (90%), to which they continue in order of importance the non metal-bearing minerals (10%), being insignificant the metal-bearing production. The application rocks (granites, limestones, dolomites and clays) concentrate mainly on the mountainous ridge denominated Sierras Septentrionales or Tandilia System (Figure 1).

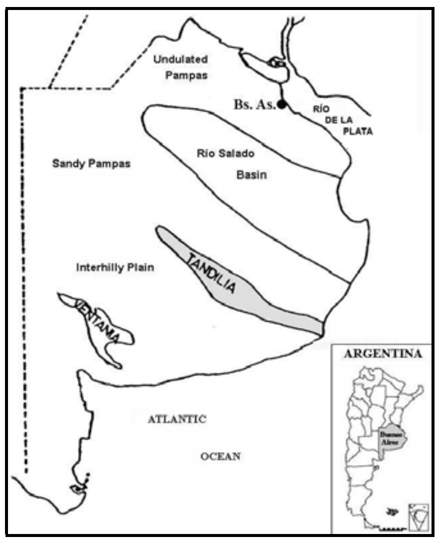

Figure 1. Geologic environments of Buenos Aires Province.

The mining productive structure in this area is essentially linked to the construction industry. The extracted materials respond to three different uses: as basic materials, as ornamental elements and as raw materials for other materials production. These application materials are extracted in open-pit quarries of big dimensions, being the current centers of exploitation restricted to a few sectors, close to the urban centers. A growing require in the national and international markets, actually offers interesting possibilities for the activity expansion.

The consequences that the extractive activity has on the environment can be considered from two different points of view. On one hand, it is a non renewable resource, for the human scale of time, that is wasting away to a high rate. On the other hand, they take place a series of negative and/or positive effects on different components of the environment (air, water, soils, vegetation, fauna, landscape) and human populations. According to the rate of extraction of the resource, the impacts on the landscape prevail because of, in most of the cases, the areas are not subjected to rehabilitation processes in the mine closing stage.

The areas of main production of granitic rocks are located in Tandil and Olavarría, those that represent 80% of the provincial production (fundamentally of broken stone). In this contribution they will be analyzed as examples these two districts that have a different environmental problematic: 1) Tandil case: a conflict with an important social component generated by the presence of quarries in a residential and tourist area; 2) Olavarría case: development of exploitations in an area with an important industrial and mining activity.

GEOLOGICAL SETTING

In Buenos Aires province emerge two mountainous ridges of general orientation NW-SE: Sierras Septentrionales (Tandilia System) and Sierras Australes (Ventania System), of different geological characteristics and ages, and separated to each other by a wide inter-hilly plain (Figure 1).

The Tandilia System is located among the parallel 36º30' and 38º00' of south latitude and among the meridians 58º00' and 62º00' of west longitude. It extends along about 350 Kms, with a maximum width of about 60 Kms in the central part (Figure 2). It is constituted by a precambrian crystalline basement: Buenos Aires Complex (Marchese and Di Paola, 1974), on which rely on, unconformitly, sedimentites of the Upper Precambrian (Sierras Bayas Group; Poiré, 1987) and Lower Paleozoic (Balcarce Formation; Dalla Salda and Iñiguez, 1979). Its structural style is of blocks limited by faults (Borello, 1969). Several authors have carried out works referred to the mineral resources of the county, among them: Angelelli (1975), Angelelli et al., (1973; 1976) and, among the most recent: Dominguez and Schalamuk (1992; 1999).

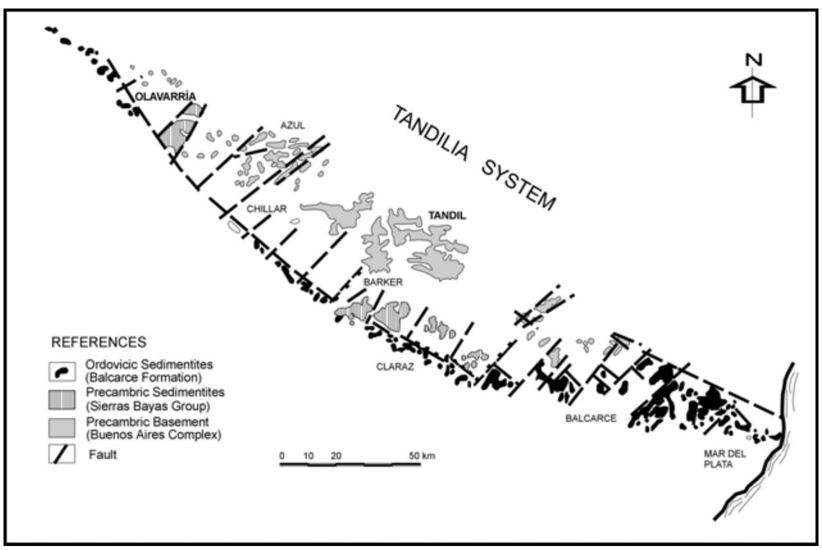

Figure 2. Simplified geological map of Sierras Septentrionales.

The extractive activity of Buenos Aires Province (Table 1) registers their biggest development in different localities along the Sierras Septentrionales: In Olavarría and Tandil granites and dolomites are exploited in blocks (as ornamental materials) and crushed (for the construction industry and as fusing). Limestones are extracted in Olavarría and Barker (for the cement industry and lime elaboration). Refractory and other clays are also exploded in this area (for common bricks, cement and light aggregates) in Olavarría, Balcarce and in the belt Chillar-Barker-Claraz. Quartzite exploitations are concentrated in Balcarce-Mar del Plata area (for construction arid use and as abrasives), and also in Barker area.

Table 1. Mining production of Buenos Aires Province (measure unit: tons)

	1993	1994	1995	1996	1997
Clays	2.557.487	1.974.786	2.535.852	2.981.428	2.828.921
Limestone	4.807.869	4.624.360	4.361.020	5.132.920	4.749.539
Blocky dolomite	381	725	250	277	—
Crushed dolomite	59.432	132.100	538.990	792.700	77.545
Blocky granite	38.972	47.644	85.390	89.377	50.214
Crushed granite	2.968.760	3.209.200	4.210.540	5.290.000	6.779.084

The Ventania System has a longitudinal development of 150 Km, with a maximum width in the central area, of 60 Km. The dominant structural style is folding, with subordinate faults, and it is geologically integrated by paleozoic sedimentites and granitic intrusions. Until the present the mining activity of the Sierras Australes is poor and it is limited to the exploitation of granites for broken stone, gravels and sands.

In the whole Pampean Plain, it is necessary to mention the exploitation of the saline bodies for sodium chloride (common salt) and sodium sulfate (for the chemical industry, tanneries, refrigerators, etc.). The exploitations of hardpan and selected soils are also important in several sectors, sands are extracted in the coastal area while shell sands and calcareous in Magdalena-Cerro de La Gloria area.

LEGAL ASPECTS

The legislation that governs the open-pit exploitations in Buenos Aires Province is framed in national and provincial dispositions, also existing some municipal ordinances.

National dispositions:

Mining Code, sanctioned by the National Congress in 1886 (Law 1919): it governs the rights, the obligations and the procedure for the acquisition and exploitation of the mining properties in the Argentinean territory.

Mining Bring up Law, sanctioned by the National Congress in 1995 (Law 24.498): it incorporates important reformations to the Mining Code as for the domain of the mining properties.

Environmental Protection Law for the Mining Activity, sanctioned by the National Congress in 1995 (Law 24.585): it establishes the necessity to present an environmental impact and restoration report, with a detailed analysis of the transformations that can cause the project in the earth, water, air, flora and fauna and a proposal for the mitigation, rehabilitation or restoration of the altered environment.

Provincial dispositions:

Environment Law of Buenos Aires Province, sanctioned by the Provincial Congress in 1995 (Law 11.723): its objective is the protection, conservation, improvement and restoration of the natural resources and of the environment in general in Buenos Aires Province.

Regulation Decree Nº 3431/93 of Buenos Aires Province Government. It establishes the presentation and periodic bring up to date of a plane of mining works and plan of exploitation for the inscription in the Registration of Mining Producers.

Disposition 068/99 related to the Art. 4º Inc. F of the Regulation Decree Nº 3431/93 of Buenos Aires Province Government. It establishes the presentation of a Project of Technical Feasibility for the mining exploitations.

I. Tandil Case

Tandil city is located at the bottom of the Sierras Septentrionales, at about 400 kms of the Federal Capital, with a population of 150.000 inhabitants, being the traditional economic activity the agricultural-cattleman, followed by mining activity.

The exploitation of the granitic stone is a centennial activity in the Tandil district. Toward the beginning of century it constituted an important activity for the local economy, because of the excellent quality of the materials and the presence of qualified manpower in the area. Most of the production was dedicated to the paved of streets and, in smaller proportion, to the public buildings ornamentation. The handmade activity required intensive manpower and the extraction capacity was relatively low, for such reasons it was valued positively by the community. The mechanization reached by the middle of this century was diversifying the uses given to the stone: construction of railroad embankments, arid for the asphalt production, support for asphalt streets. The generation of polished plaques of granite allowed its use in buildings and interiors lining.

At the moment the mining productive structure in this sector is essentially linked to the construction industry. The production of Tandil district corresponds basically to the extraction and benefit of "granites". These last ones constitute the basic materials of the Tandil mining activity, having about 9 stone quarries with mill and classification plants, several of them along the access roads to the city.

In the last decade a very promising alternative activity has appeared: the tourist industry, because of the natural beauties of the mountains and their landscape. At the moment the Tandil community is passing by a social conflict that faces to the mining sector with the rest of the local society.

Problem Description

The urban growth of Tandil determined that quarries that originally were located in rural or suburban areas, they have remained within or adjacent to residential areas and in the visual basins of the main tourist circuits. The evolution of the environmental conscience and the development of conservative attitudes of the environment, on one hand, and the peak of the tourist activity based on the natural beauties, for the other one, they have determined a growing valuation of the mountains by the community. At the same time, the emergence of new extraction centers (Olavarría) with lower production costs, originated a substantial decrease of the production of broken stone, with the consequent decrease of manpower occupation by this industry.

The municipal authorities, as a response to the generated problem, have dictated a series of legal dispositions:

1. *Municipal Decree 348/72*: it establishes an Area of Conservation of the Landscape defined by the polygonal traced at the back part and at a thousand meters of the routes 30, 74 and 226. This norm prevents to enable exploitations that modify the hills profile that can be observed from any point located in the interior of the polygonal or that they affect to the superior third of the hills.

2. *Municipal Decree 1085/79*: it prohibits the installation of new exploitations inside the area defined by the polygonal and fixed a 10 year term for the definitive eradication of the existent quarries.

3. *Municipal ordinance 4133/87*: abolish the previous ordinance, but it maintains the prohibition of installation of quarries in the area and the impediment of taking the quarry fronts to heights that reach the superior third.

4. *Municipal ordinance 6543/94:* establish a differential tax to the stone, with higher values inside the polygon.

From the actual municipal normative the local authorities impel a clear politic of relocation of the extractive activity. The affected managers, at the moment in fiscal rebelliousness and ignoring the municipal competition in the topic, they have to find an alternative solution to this conflict that extends in the time and reach every time bigger importance.

II. OLAVARRÍA CASE

The Olavarría city is located in the most western part of Sierras Septentrionales, at about 370 kms of the Federal Capital, with a population of 120.000 inhabitants, being the traditional economic activity the industrial and mining followed by agricultural-cattleman activity.

Since 1880 the calcareous rocks of Olavarría have been used in a rudimentary way for lime production. In 1919 the industrial cement production begins and continues until the present time with a sustained rhythm. The use of the granite in this area began in 1885 with the production of paving stones and blocks, being mechanized in 1911 for the obtaining of broken stone. Around this exploitations several mining settling arose (current cities of Sierra Ghica, Sierras Bayas, Villa Fortabat).

Actually about 30 quarries of diverse materials are in exploitation (limestone, clay, dolomite, crushed and blocky granite, etc.) far from Olavarría city, as well as different industrial plants: elaboration of polished plaques and tiles, lime and cement factories, all of them located in the Industrial Park of Olavarría.

In this case, contrary to the one outlined for the Tandil district, social conflict are not registered because of the characteristics of the main activity in the area.

Problem Description

The aspects to be considered in this case contemplate two basic questions. On one hand the optimization in the exploitation of a non renewable resource that represent an important work source for the local population. On the other hand the control of the negative effects that the activity has on the different components of the environment: air, water, soils, vegetation, fauna and landscape.

On these components the effects depend in great measure on the type and applied method of exploitation. In the case of the application rocks, with surface mining activities, there exist impacts on the atmosphere by emission of powders, gases and smoke; impacts by noise and vibrations of the detonations; impacts on the water by contamination with particulate material and chemical substances; impacts on the vegetation by the removal of the same one, on the fauna by the habitats alteration and on the landscape by the modification of the vegetation and the geomorphology, the generation of big holes and accumulations of residual material.

Discussion

Tandil Case: existing the technical possibility to transfer the quarries to areas far from tourist and residential areas, the companies of the sector have the possibility to continue with their activity in other areas, being adapted by this way to the municipal requirements. But they find several obstacles of economic nature: opening of new fronts of exploitation, increment of the cost of the freights, relocation of the infrastructure, etc. Therefore, to carry out the relocation in a real form a political and economic decision that accompanies it, is necessary.

At the same time it should be foreseen the use to be given to the holes after the abandonment of the areas in exploitation, either integrating them to the tourist circuits (as old mines visits) or to diverse recreational activities.

Olavarría Case: since the activity has a strong influence in the development of the regional economies, mainly in the generation of work source, as much the companies as the population present a good predisposition in the acceptance and effective execution of the normative that take to a rational and appropriate exploitation of the natural resource.

Being the extractive mining one of the bases of the local economy in this area is indispensable the execution and pursuit of the effective norms making special stress in the measures of security and restoration of the abandoned places.

Of the outlined problems it comes off the strong influence of the society in the development of the regional economies and their disposition to face and/or to solve the problems related to the affectation of the environment. The Tandil case, in contrast with the Olavarría case, show a typical case where the mining activity is being displaced by an alternative activity as the tourist one, without existing, for more than ten years and so far a solution to the problem.

Therefore it is outlined the necessity of planning and ordination territory measures of long term so that, it will not be necessary in the future to improvise solutions facing similar situations.

REFERENCES

Angelelli, V., J.R.Villa, & J.M.Suriano,1973. Recursos Minerales y Rocas de Aplicación de la provincia de Buenos Aires. LEMIT, Anales, 2, pp.1-201. La Plata.

Angelelli, V., I.Shalamuk & A. Arrospide, 1976. Los yacimientos no metalíferos y rocas de aplicación de la región Patagonia-Comahue. Secretaría de Estado Minería, Anales, 17. Buenos Aires.

Borrello, A., 1969. Los geosinclinales de la Argentina. An. Dir. Nac. Geol. Min. 14, 1-188, Buenos Aires.

Dalla Salda, L.H. & M. Iñiguez Rodriguez, 1979. " La Tinta", Precámbrico y Paleozoico de Buenos Aires. VII Congr. Geol. Arg., I, 539-550, Neuquén.

Di Paola, & H. Marchese, 1974. Relación entre la tectosedimentación, litología y mineralogía de arcillas del Complejo Buenos Aires y la formación La Tinta. Asociación Argentina de Geología, Mineralogía y sedimentología, Revista, 5: 3-4. Buenos Aires.

Dominguez, E., & I. Shalamuck, 1999. Recursos minerales de la Sierras Septentrionales, Buenos Aires. En: Recursos Minerales de la República Argentina(Ed.E.O. Zappettini) Instituto de Geología y Recursos Minerales SEGEMAR, Anales 35: 183-190, Buenos Aires.

Poiré, D.C., 1987. Mineralogía y Sedimentología de la Formación Sierras Bayas en el núcleo septentrional de las sierras homónimas, Olavarría, Prov. de Bs.As. Tesis, Mus. De la Plata (inéd.)

MINING WITH COMMUNITIES

Marcello M. Veiga, *Malcolm Scoble*
Department of Mining and Mineral Process Engineering,
University of British Columbia, Vancouver, B.C. V6T 1Z4 Canada
Mary Louise Mcallister
Department of Environmental and Resource Studies,
University of Waterloo, Ontario N2L 3G1 Canada

A "sustainable mining community" needs to be considered in terms of the principles of ecological sustainability, economic vitality and social equity. These principles apply over a considerable time span, covering both the life of the mine and post-mine closure. The legacy left by a mine to the community after its closure is emerging as a significant consideration in its planning. Progress towards sustainability is made when value is added to a community with respect to these principles by the mining operation. A series of case studies are presented to demonstrate the diverse potential challenges to achieving a sustainable mining community. These are drawn mainly from overseas developments, where many Canadian companies are now building mines. The paper concludes by considering various approaches to foster sustainable communities and the role of community consultation and capacity-building.

1. Introduction

Globally and domestically, the politics of mining are increasingly being played out at the local community level, monitored closely by a diversity of media and non-governmental organizations around the world. Investors, insurance companies, banks, governments, and citizens will want little to do with an industry that is seen as indifferent to the present and future socio-economic and biophysical welfare of local communities. This is a message that has been communicated loudly by international organizations such as the International Council on Metals and the Environment and the World Bank to individual mining companies themselves. Mining companies must now pursue their interests in a way that also promotes those of the local communities in regions where they are operating. The long-term sustainability and viability of both the mining industry and its related communities justifies attention. Improving environmental performance is critical to ensure that the environment is protected but it does not necessarily ensure the social health and welfare of any associated mining community.

2. Sustainable Mining Communities

A mining community is one whose population in some part is significantly affected by an associated mining operation. This may be through the provision of direct employment or some other impact arising from mining, albeit environmental, social or economic impact. The community can range in size from a city (which for example could be serving as a base for distant fly in-out operations, or a centre for supplies and financing) to a village (which relies extensively on local mining). Communities vary in their profile and perceptions about mining and needs. In Canada alone 128 communities rely on mining[1]. They share several common characteristics. Many have faced the impact of reduced employment in their mines. This trend has been associated with increasing mechanization and automation, economies of scale, declining commodity prices, and depleted reserves as exploration and mining companies tend to move offshore. In Canada, and offshore, many mining communities are based in remote regions and have few opportunities for diversification. There are, therefore, numerous challenges to achieving a viable mining community.

A sustainable mining community is one that could realize a net benefit, from the introduction of mining through to the closure of the mine and beyond. In practice, this would mean that a community was supported by "three fundamental pre-requisites for sustainable societies" outlined by George Francis[2]:"ecological sustainability, economic vitality, and social equity. As an ideal, sustainability meshes well with the desires of most people to achieve decent levels of health and well-being, in pleasant surroundings, with strong community networks, and a diversity of opportunities for work and fulfillment."

The challenge for any mining company is to engage in an equitable partnership with the associated community that leaves a lasting legacy of sustainability and well-being for the community, avoiding environmental degradation and social dislocation. Mining communities differ significantly in terms of culture, political orientation, geographical location, environmental characteristics and collective attitudes towards resource development. Nevertheless, there tends to be a common characteristic shared amongst communities that have had a poor relationship with a mining company: this is the perception that miners are intruders into their environment, culture and history. Such a feeling may particularly be the case where the community has no mining tradition and the benefits from mining have not been cooperatively determined nor equitably shared. How this perception can be minimised and a durable relationship created is key to building a sustainable mining community. The following case studies suggest that while mining companies are increasingly aware and taking initiatives, particularly in the area of remediation, the industry still needs to continue to develop and address appropriate principles of sustainability.

3. Case Studies of Mining Community Development

A widespread perception in the mining industry is that the public sees it as a low-tech, polluting and avaricious industry. In 1994, a US opinion survey conducted by Roper Research, ranked the mining industry in 24th place in terms of public popularity, behind the tobacco industry[3]. A large contingent of society sees mining primarily as a hazardous activity, accompanied by an acute environmental impact. This view is perhaps strongest amongst urban dwellers who experience little direct benefit from mining, despite being the largest consumers of its products. Rural communities may welcome mining activities as a means to improve their quality of life. It is important, however, that the environmental impact of the mining activity does not pose any unacceptable risk to the associated communities.

A prominent case study has been the mining operation of Ok Tedi Mining Ltd. (OTML), which has been operating since 1984 in Papua New Guinea (PNG). It is owned by BHP Ltd. (52%), the PNG Government (30%) and Inmet Mining Ltd (18%). BHP reported in 1999 that "Since the project began, it has not been able to construct planned tailings or waste rock storage facilities. As a consequence, these materials have been progressively discharged to the river system under Government permit. During the reporting period, a total of 83 million tonnes of material entered the river system from the mining operation, of which 15 million tonnes was subsequently removed in the course of the dredging trial in the Lower Ok Tedi"[5]. ENGOs and community leaders have taken a strong and united stance against what they have termed one of the "World's Worst Mining Disasters" [*]. They noted that these kinds of mining practice would not be allowed to take place in Canada or Australia; as such they questioned why it was allowed to take place in PNG. A recent OTML Mine Waste Management Project considered the possible means to reduce the mine's environmental impact with engineering, social and environmental evaluations, including a risk assessment. It studied four options offering potential solutions, including closing the mine in 2000. It concluded that: "the issues are complex, and none of the options have identified a way to prevent mine waste causing environmental damage. For example, the studies show that:

The current projected environmental impacts in the river system exceed those previously expected.

Dredging will not have the environmental benefits originally expected and impacts in the river system will continue to worsen with or without dredging.

Early closure of the mine appears to be the only option that will significantly limit the projected environmental impacts of the mine.

From a social perspective, early closure appears the least attractive option, effectively stopping the social and economic benefits that would accrue from continued operation and orderly closure in 2010."[5,6]

Through the process, the communities have been provided with employment, land rent, royalties and the provision of educational facilities as well as other community development projects, but are the tradeoffs acceptable? Must immediate improvements in the physical health of a community and the provision of employment come at the cost of long-term ecological consequences to the environment? Achieving a balance between ecological and social health can be a complex challenge, particularly in communities where there is little opportunity for economic diversification. This is not to say that the resolution of such problems will be easily achieved. Some governments anxious for revenues may encourage mining in unsustainable circumstances or where it is difficult to find technical solutions to environmental problems. In such situations, it would be sensible to either await technical solutions to eliminate the problems or pursue political or social alternatives. In spite of the significant social benefits provided to communities, companies need to adopt an approach to integrated environmental and social assessment.

Another case study in the Pacific region is the Porgera mine, operated by Placer Pacific since 1990, that has adopted a similar practice of mine waste disposal,

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[(*)] The ENGOs (Environmental Non-Governmental Organizations) included the Mineral Policy Center, MiningWatch Canada, Mineral Policy Institute, MineWatch UK, Calancan Bay Villagers Support Coalition, the Environmental Mining Council of British Columbia, Friends of the Earth, Pacific Environment and Resources Council, Project Underground, and others endorsed the position of Pacific-based NGOs. Source: Mineral Policy Centre, "One of World's Worst Mine Disasters gets worse; BHP admits massive environmental damage at Ok Tedi Mine in Papua New Guinea, says mine should never have opened" Press Release, August 11, 1999, http://www.mineralpolicy.org/media/index.php3?nav=3&inc=release&release=11

discharging about 17,000 tonnes of tailings per day into a tributary of the Porgera River. Treated tailings and waste rock are discharged, predominantly as fines (80% minus 0.065 mm). At a monitoring station 160 km downstream from the mine, the total concentration of heavy metals in water is very high but the dissolved metals "do not exceed the PNG Government compliance criteria"[8]. As the area close to the mine is scarcely inhabited and because the local population does not currently use the rivers for food and water, the mine and independent consultants do not see health risks associated with riverine disposal practices. This perspective, however, does not include consideration of the cumulative environmental impacts of such practices. In addition, multinational firms claim that they apply the same environmental practices in less developed economies that they do in their own country. It is no longer considered enough to ensure that the compliance criteria meets that only of the host country; a country that urgently needs foreign investment. According to one member of an ENGO: "Now that BHP finally acknowledges the severity of the damages it has caused at the Ok Tedi mine, an ecological disaster the company has for years denied in engagements with concerned NGOs, it will be interesting to see whether Placer Dome Inc. will finally respond to calls for that company to stop dumping its tailings from the nearby Porgera Mine into the same river system," said Catherine Coumans of the Calancan Bay Villagers Support Coalition and Mining Watch Canada.

Placer Dome is engaged in monitoring the environment and providing social benefits similar to those at the Ok Tedi mine. About 1900 people are directly employed by the mine and Porgera's Community Affairs Department has actively been developing a set of social and business programs such as: professional training, business development, retail and wholesale supermarket, bakery complex, community schooling, health services, sports, community consultation, youth and women's assistance[9]. This level of assistance is not something the government and communities can easily give up despite the long-term environmental implications. The issues relating to a mine and its community are broad and complex. Who is ultimately responsible for making the decisions about whether a mine should go ahead, or whether or not it should remain open: the host central government, the company, or the local community? Mining companies often refer to their application of the same standards and approaches to mining in poorer, less industrialized countries as are applied in highly developed industrial countries. If such intentions are to be credible in the eyes of the watching international community, then responsible decision-making cannot be abrogated by the companies to governments or communities. This is not what is meant by encouraging community participation. Companies themselves need to take a precautionary approach, use their expertise, and make the decision about whether or not the geological and other conditions are in place to ensure that a property can be operated and closed in an environmentally safe manner.

In contrast to its Ok Tedi situation, BHP has introduced a holistic life cycle management approach to its Island Copper mine on Vancouver Island, Canada. This mine, started in 1971 and closed in December 1995. It employed as many as 900 people with an annual payroll of US$ 25 million, producing 1.4 million tonnes of copper, 1.1 million ounces of gold, 11.8 million ounces of silver and 59 lb of rhenium. The mine had a distinct approach to tailings disposal. Its daily production of 50,000 to 60,000 tonnes of tailings was disposed over the ocean floor, 650 feet below sea level. The mine's economic contribution to the community and region was generated from a payroll of US$ 650 million, with spending on supplies and services of US$1.5 billion over its twenty five year life. The mine was instrumental in promoting the availability of the physical assets (power, water, building, dock and cleared land) for other commercial and industrial uses. As well, the mining company provided to the community a US$ 1.3 million sewage treatment plant, 400 houses, support to build a new hospital, an ice arena, swimming pool, theatre and parks. The flooded 530 acres, 1320 foot deep pit has been used for commercial production of Atlantic salmon smolt. A company has purchased the buildings and dock facilities to establish the commercial production of crayfish and sturgeon. With almost half the population of Port Hardy directly dependent on Island Copper's payroll, most mine employees became actively involved in all aspects of community life. This helped to ensure that common goals were met. The company implemented two programs to assist employees in job retraining and educational upgrading. A total of 155 employees found jobs through the training program. Other sustainable local initiatives took place to create new businesses opportunities such as: tourism, a seaplane base, wood processing, fish processing and a marina. About 800 acres of land have been returned to the Crown that is negotiating this with various companies, such as pulpwood chipping plant, copper processing plant, etc. The main lesson learned by the company was that the personnel employed during the operation as well as the community should be involved in the closure process[10].

In other parts of the world, particularly in developing areas, some remote communities may not be prepared to change their life styles to accept new concepts of development, if they perceive a loss of important cultural and spiritual values even when this may represent improvements in material standards[11]. Community antagonism is often most intense when foreign exploration companies start to work on such sites. Thomson and Joyce[12] have explored the complex relationship between the community and geological exploration companies. The local community quite naturally, views exploration companies (usually junior companies) in isolation, with little knowledge or interest of the larger picture within the mining industry and its competitive challenges. The level of expectation created in a community usually does not follow the company's expectation or ability to invest. Not infrequently, in the initial phases of a project, the community views the drilling step as ore production. The expectation of having jobs and benefits from "the company" may well be frustrated within a matter of months.

A recent example of such a misunderstanding occurred in the Brazilian Amazon region, related to the village of Cachoeira do Piriá, 250 km from Belém, capital of the State of Pará. This region experienced a significant gold rush that lasted from 1980 to 1990. The area attracted 10,000 people that included 5,000 miners. A junior mining company, Brazilian International Goldfields (BGZ), with headquarters in Vancouver, secured an option in September 1998 to purchase two granted mining concessions at Cachoeira Para State from the Toronto based TVX Gold and CCO Mineração. BGZ started an intense drilling program (2200 m) conducted by Brazilian geologists. For the 2000 inhabitants of the recently created municipality of Cachoeira, the reactivation of the "mining" camp was a spark of hope for the community. This was originally generated in the eighties by the gold rush in which about 5,000 artisanal miners extracted almost 4 tonnes of gold from superficial ore. Currently the village is struggling from the aftermath of mining activity with few employment opportunities. Most of the easily extractable soft ore has been depleted and a handful of miners are producing minor quantities of gold through the reprocessing of tailings. Sparse crops of rice, cattle farming and timber cutting and milling are now the main economic activity of the village. With an enormous potential for gold, major international companies are exploring the Greenstone belt in the region. The main geological targets are peripheral to the town with 700,000 oz of gold defined to date. Prior to the company's discussions with the Mayor of the Cachoeira municipality, there was a plan to build houses over old informal mining pits, shafts, adits and tailing sites left by the previous miners. BGZ reached an agreement with the Mayor for a moratorium regarding any further urban development within these areas until exploration was conclusive and to select alternative sites suitable for urban habitation. As part of establishing a community relationship program, the company employed over 20 people to help in site preparation and geological sampling. Their salaries were 30 to 50 per cent higher than the norms for that region of Brazil. After 3 to 6 months, the work was completed and most employees were laid off, as expected. Unfortunately, when the drilling activity stopped and the company turned to compiling the data, the local people lost hope in the possibility of having a mining operation in the short term and re-started building houses on top of mercury-contaminated tailings ending the moratorium.

In the discussions with the Mayor, mining had been openly supported by the municipality and the community because they expected that it could bring long term economic benefit to the town. The mining company would, for example, provide water to the town from the local Piria River. This generated particular interest. The water supply would be a lasting benefit from mining activity. However the desire was for it to happen immediately. There was little understanding of the process and steps that are required to establish a company sponsored operation. The drilling and feasibility studies would have to precede any investment in infrastructure. Drilling has recommenced on the Cachoeira property under a joint venture between BGZ and major gold producer Gold Fields Limited. Discussions with the community continue. Some artisanal miners are still struggling to survive by extracting gold from tailings and small ore bodies on the property[13].

The behaviour of local people in the remote areas of the Amazon is not atypical of communities when faced with "foreign-owned" mining operations that do not appear to bring long-term benefits. In the case of Cachoeira, local people do not want to invade the cattle farms of the region, since the latter are viewed as "productive" and are associated with the local landowners. In contrast, foreign companies are seen as rich "gringos" with an obligation to provide jobs for all community members. In the case of mining, the community does not distinguish between a major and a junior company. Even domestic companies from outside the region can be viewed as intruders.

As noted in the case above, the reaction of a community to the prospects for a mining operation in its vicinity may be volatile and unpredictable, particularly when the level of poverty is high and mining is the only potential economic activity. This is a serious problem for sustainability, particularly when one considers the huge numbers of people dependent on marginal forms of mining employment. In 1993, for example, it was estimated that about six of the world's 30 million mineworkers were engaged in artisanal mining in more than 40 countries, extracting over 30 different types of mineral substances[14]. The International Labour Organisation estimates that currently the number of artisanal miners is around 13 million in 55 countries and rising, which leads to the belief that 80 to 100 million people worldwide depend on this activity as a livelihood[15] (Table 1). Gold, due to its ease of trading and independence from any government monetary instability, is by far the main mineral being extracted. Experts have estimated that 1 in 900 Latin Americans are employed in gold and silver artisanal mining[16]. Some countries are facing severe social and environmental problems derived from poor mining and processing practices associated with a lack of economic alternatives[13].

Table 1. Employment in artisanal mining.[15]

Continent	Number of Miners (million)
Asia/Pacific	6.7 - 7.2
Africa	3.0 - 3.7
Latin America	1.4 - 1.6
Developed countries	0.4 - 0.7
Total	11.5 - 13.2

It is difficult for developed countries to grasp the scope and scale of the artisanal mining problem in developing countries. Concepts such as conservation, heritage values and aesthetics that are commonly established principles in developed countries, are superseded by concerns for survival and employment in poorer countries where choices are few and there is no luxury to plan beyond the immediate future. In December 1999, the World Trade Organisation meeting in Seattle, brought to the public's attention many important points related to the fragility of developing countries in establishing their trade protocols. The International Labour Organisation (ILO)[17] estimates that 250 million children between the ages of 5 and 14 work in developing countries, half of them full time, and tens of millions of them do so in exploitative and harmful conditions. In the mining sector, particularly in artisanal mining operations, ILO estimates that the number of children could be as high as 250,000. Most children work to support their families. Their parents are aware of the hazards and risks associated with the rudimentary mining activity but see no economic alternative. In some cases this is the way to keep the families together. Jennings[17] reports that the main reasons for child labour in small-scale mining are: poverty, lack of incentives to go to school, no prospects for regular employment, lack of co-ordinated policy to stop child labour, lack of enforcement, a reluctance to invest in small-scale mining to improve performance and social benefits for rural communities. Governments and mining companies all over the world are generally not well prepared to deal with issues related to artisanal mining, let alone those related to child labour in potentially marginal/illegal activities. The World Trade Organisation meetings also highlighted another important point; many powerful and vocal organizations are no longer prepared to allow trade and development to take place without equal attention being paid to such adverse social (and environmental) impacts.

The conservative tradition of rural politics in developing countries also poses a considerable obstacle to the creation of a trusting environment between governments and miners. Many governments impose rules on artisanal miners trying to force them to be part of the formal economy. Rarely is assistance provided to help these miners to employ legally and technically sound practices. Cultural, social and political constraints serve as barriers to meaningful consultation exercises with stakeholders and in developing a consensus approach to common concerns. These problems are part of the historical legacy of developing countries.[18]

One of the most interesting projects in communities with a traditional history of artisanal mining has been evolving in the interior of Venezuela, in the preparation of a project to extract 48,000 tonnes of gold ore daily from the Las Cristinas deposit. Placer Dome Ltd. faced significant social tension when they became a partner with a Venezuelan public company in 1994 to develop the project. The community of 2800 people, mostly artisanal miners and families, had already suffered some significant economic destabilisation from the relocation to new settlements out of the property in 1992. Unauthorised mining became evident as a potential problem. This also represented, however, a livelihood for 40% of the active population. With the escalation of the tension in the area, the company proposed a co-habitation program, establishing a project with the participation of the local community to create 126 ha within the company's property to initiate a small-scale mining operation. The company invested US$ 1 million in this project to foster a stable relationship between itself and the community. After an extensive effort to organise the miners and provide a legal framework for the operation, a training program was started. This program focused on the introduction of safety and environmental considerations and the improvement of life quality. A Mining Centre was created in 1997 including: a recreation area, cooking facilities and infirmary. Mercury was banned from the property and in 1999 the individual work of 200 miners changed to a more co-operative organisation with 50 miners receiving salaries and establishing production goals. Currently about 2 kg of gold is being produced per month and the mine is managed by a Miner's Association[19,20]. Unfortunately, the co-habitation solution has only involved a small contingent of people and, as yet, it does not provide economic diversity for the community, during and after mine closure. These efforts at this mine should be carefully examined. This case demonstrates that companies do see community participation as an important and viable approach to contemporary mining practices. Moreover, this company is recognizing that social instability and discontent (an important factor in political risk assessment) can play a far greater role in determining the ultimate success of a mining operation than has been historically calculated in mineral investment decisions.

4. Sustaining the Community

Today, as any mining company knows if it has experienced poor relations with local communities, sustaining the community is integral to sustaining an effective and respected operation. As noted earlier, a sustainable mining community should be based on the principles of ecological sustainability, economic vitality, and social equity. Examination of case studies shows a wide variation in circumstances and approaches taken historically.

The traditional route to a sustainable mining community has tended to focus on a three-step approach. The first was to establish infrastructure to support and nurture the workforce. Mining companies in Canada, for example, set high standards in being the driving force to create towns and infrastructure with medical, educational and utilities support. Noted examples of towns, planned specifically to support mining operations, include Leaf Rapids in Manitoba and Fermont in Québec. Some of the communities that grew within such towns and infrastructure have evolved further through diversification, whilst others have wilted after the departure of the mine on closure. The second step was to generate sustained employment through discovering and mining all available ore deposits in the locale. Communities such as Flin Flon and

Snow Lake in Manitoba, for example, have been sustained by the continued discovery and operation of many ore deposits within reasonable proximity to these towns. The third step generally was to leave infrastructure such as roads, power, and housing to local communities when the mine was closed or in remote areas to demolish it. The planning for mine closure has been only a relatively recent development and its scope and practice is still evolving. In the past, contributing infrastructure has been viewed by many companies as leaving a major asset and donation to the communities. While the hard infrastructure remained, the soft infrastructure (social considerations) and the environmental residues were left primarily as responsibilities of government. Experience has shown, however, that bricks and mortar are no substitute for enlightenment, education and organization. Villages left behind by mining companies can become shanty towns, as the example in the Amazon region has demonstrated. If their location is appropriate these may be fortunate enough to become tourist destinations as resorts or heritage sites, such as New Denver or Barkerville in British Columbia. Today, in both highly developed and developing economies, the approach to creating a sustainable mining community has changed. There is now a requirement to contribute to the ecological integrity or viability of the local bio-physical environment, to diversify the economy into different areas, and to consider long-term community sustainability.

The advent of developing mines as long-distance commuting (LDC) or “fly-in fly-out” operations has added a further dimension to planning for sustainable mining communities. The first use of LDC in Canada was at Asbestos Hill in Quebec in 1972. In LDC operations, remote mineral deposits are mined without the development of the traditional mining town. It brings its own set of implications for rural and remote communities. LDC work cycle rotations have an impact on small communities and family life, particularly if that community has not experienced this type of mine employment previously. A greater concern for declining mining communities is the prospect that they may be “flown-over” by companies that may choose to hire mine employees from larger regional centres rather than from the smaller, more remote towns. On the other hand, LDC operations can be far less environmentally disruptive if the alternative is to build a new mine town. Significant environmental (socio-economic and biophysical) costs accompany the building of a mining community with its requirements for extensive infrastructure, schools, social and health programs needed to sustain people in a remote setting. A LDC operation can avoid many of these costs by flying in workers from established towns. The opportunities and costs posed by this type of operation for the company as well as for the affected mining towns need to be carefully weighed on a case-by-case basis. In developing countries there may be a reluctance to support LDC rather than promote the enhancement of a local workforce, for example, Placer Pacific's Porgera mine was originally intended to be operated on a fly-in, fly-out basis, but these plans were dropped at the request of the PNG government[21].

The attention of mining companies to the surrounding social environment has historically been devoted to the reduction of conflicts or compliance of legal requirements rather than its long-term sustainability. Sassoon[22] highlights the importance of a serious Environmental (and Social) Impact Assessment (EIA) as a commitment for companies to establish environmental management, not use it as a simple document to pay lip service to legislation. One will often hear of community consultation and it has increasingly been practiced throughout the world. Consultation has been intrinsically part of Environmental Impact Assessment in many countries as a way to provide companies with some thoughts and guidelines about how to interact effectively with communities. Basic strategies are offered by social scientists to reduce the difficulties companies have when dealing with the public[23]. The community needs to fully understand the mining project and its costs and benefits. This type of communication can serve as a basis for its involvement in a joint problem-solving process. From the community's perspective, such a consultation can result in a far better understanding of the proposal issues covered in the EIA and can contribute to a successful working partnership[24].

5. COMMUNITY CONSULTATION AND CAPACITY-BUILDING

Consultation, can make the life of a company somewhat easier but it will not in itself achieve community sustainability. What is being suggested here is a significantly more fundamental change, a change that is related to questions of power, resources, and control. Resource-based communities throughout the world, including those in Canada, have historically been at the mercy of events and decisions happening outside their control; whether it be fluctuating world prices, foreign-owned companies, international trade organizations, or domestic governments that primarily serve the interests of the politically influentially urban, metropolitan regions. At the heart of the problem then is a question of social equity. Until community members themselves feel that they are partners in decisions that intimately affect their own lives and the environment in which they live, little progress on the path to sustainability will be achieved. As some analysts have pointed out, what is required is "resilience through local governance"[25]. With "volatility, uncertainty, unpredictability and at time incalculability" the norm, then a flexible, adaptable local process is needed, where communities can "withstand the periodic or sporadic economic misfortune that besets all resource communities at some point in time"[25]. Rather than having companies or state governments determine the future and structure of communities, a system of local governance needs to be established. This system of local governance is one that should include all community groups and actors not just the local political representatives. This participation takes place before, during and after mine development. Warhurst et al.[26] have stressed that the socio-economic impact assessment needs to be an ongoing process throughout the life phase of the mine and decommissioning. The authors suggest that the consultation process needs to move from an almost exclusive focus on the operational period of a mine to have similar emphasis during both exploration and closure phases. This pro-active approach reduces misinterpretation in expectations during the exploration and reduces impacts of a mine closure on the communities. The problems of coping with closure at the community level ranges from unemployment and family disruption to destruction of the environment and consequent loss of economic opportunities for communities after closure.

The first step to community sustainability, then, may relate to local capacity-building and local governance. Community members are given choices about how the mine is developed within the community, and how tradeoffs can be made within the constraints of the available financial, social or natural capital. Developing a sense of efficacy and control within the community leads to political, local and social stability. For a community to have long-term resilience in Canada or abroad, Paget and Walliser[25] suggest that local governance can achieve several benefits including:

- embrace and foster a broader concept of community governance;
- elevate social development to a position of at least equal prominence to development efficiency;
- actively involved local residents in the process of making decisions for themselves.

With such an internal capacity, communities are in a stronger position to respond to rapid economic changes and the prospect of uncertain futures generated by external forces.

6. Planning to Add Community Value

The next step is to consider what benefits the community might gain from the development of a mine in the region. If it acts according to principles of sustainability a mine represents an opportunity to add value to its community. Value may include many of the safety, health, and economic benefits mining companies traditionally consider, such as:

- direct employment;
- ancillary economic activity, supporting the mining activity (e.g. mining suppliers);
- water, power supply, transportation and other infrastructure;
- enhanced land quality and agricultural opportunity;
- healthcare, safety improvements;
- educational facilities, programs, scholarships;
- communications and information systems;
- recreational facilities;
- fostering cultural activities;
- alliance with other natural resource or manufacturing activity in the locale;
- diversity: through sponsorship of new economic activity.

Beyond that, however, companies need to think about how introducing a new mine could bring about long term biophysical and socio-economic improvement to a region that is consistent with holistic principles of sustainability. This means that sustainable decisions are not ones that result in zero-sum equations where there is a dramatic trade off between immediate jobs and long-term ecological integrity. As the earlier mine case studies demonstrate, the issues are complex and may not be readily resolved. They will require attention at the level of international trade organizations and decision-making bodies, involving financial institutions, governments, non-governmental organizations, and influential mining associations. It is often at this level where the preconditions are established for local sustainability. Given the current prominence of concerns about tailings dam failures, companies will need to establish their credibility in terms of both the management and design of waste disposal systems. Instituting mechanisms of independent environmental audits and independent environmental reporting would go a long way toward convincing communities and ENGOs that a company is committed to environmental protection[27].

It is not suggested here that the quest for a sustainable community can be readily resolved. An important first step would be to define a general goal. For example, a fundamental decision-making principle for any sustainable mining community development might be: does the mining company operate on an ethical basis in a way which contributes to the well-being of the present community and leaves a sustainable legacy for future generations? In the words of George Francis[2]: "Sustainability is ultimately an ethical commitment based on a belief that the natural world and its component life forms, including humanity, have value in and for themselves".

7. Conclusion

The world's mining industry is facing many challenges with respect to dealing with human interaction with physical and social environments. Many companies have invested considerable resources in technological innovation to increase productivity and competitiveness. Benefits also relate to improved health and safety, as well as quality of the environment. Attention still needs to be given to finding innovative approaches to establishing long-term benefits for the communities created or enhanced by the presence of the mining operation. Developing resilient communities, long-term benefits, and shared decision-making processes may not come easily to mining companies but experience indicates that the diverse needs and requirements of communities must be acknowledged and respected. Such an approach recognizes that community sustainability is not simply another management problem: something that needs resolution much in the way that a technical difficulty might be tackled. It is a completely different philosophy based on a concept of sharing benefits and responsibilities with local communities. This is a philosophy that goes beyond mere co-existence; it is one that promotes concepts of industry-community co-participation in the mine building process. As Canadian mining companies are moving to underdeveloped regions it is paramount to understand how the singularities of poverty and lack of power affects the long-term health of the mining community. Built into that understanding is a recognition that local people need to make decisions about what "benefits" they would like to see to fit their own cultural needs and physical requirements. As such, there is no unique formula. Adaptability, flexibility, responsiveness, and mutual respect for people and the biophysical environment on which we all depend are the principles upon which future mines need to be built if they are to follow a more sustainable path.

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References

Natural Resource Canada, (July 20, 1999). Canadian Mining Facts http://www.nrcan.gc.ca./mms/efab/mmsd/facts/canada.htm.

Francis, George (December 1999). Personal Communication, University of Waterloo, Waterloo. See also, "Making Sustainable Development Happen: Institutional Transformation" (with S.C. Lerner), Chapter 6, (pp. 214-233) in: John Robinson and Ann Dale (Eds.). To Serve the Future Hour: Achieving Sustainable Development. Vancouver: University of British Columbia Press.

Prager, S. (1997). Changing North America's Mind-set about Mining. Rock Products, 100, 8, pp.34-39.

Friends of the Earth Canada (August 1997). Media Release: "Environmental NGO's join forces to clean up mining in Canada and South America". http://www.foecanada.org/media/970800-m.htm.

Broken Hill Proprietary Co. Ltd. (1999). Environment and Community Report 1999, Case Studies, Ok Tedi, http://www.bhp.com.au/eac/env99/case/oktedi.htm.

Mineral Policy Center (1999). "One of the World's Worst Mining Disasters Gets Worse." Joint Press Release (August 11, 1999), Mineral Policy Center, Washington, DC. http://www.mineralpolicy.org.

Minerals Council of Australia (1999). The Ok Tedi Mining and Environment Issue, Ok Tedi - Update August 1999. National Education Program. http://www.minerals.org.au/pages/page8_164.asp.

CSIRO Environmental Projects Office (1996). Porgera Joint Venture: Review of Riverine Impacts. Report contracted by PJV, December 1996. Dickson Act, Australia.

Placer Dome Asia Pacific (1998). 1998 Sustainability Report: Porgera Mine. Western Highlands Province, Papua New Guinea, 20p.

Welchman, B. and Aspinall, C. (2000). Mine Closure and Sustainable Development: Island Copper Mine: A Case History. Proc. of Mine Closure and Sustainable Development Workshop. World Bank, Washington, D.C., March 1-3, 2000, 16p.

McAllister, M.L., Scoble, M. and M.M. Veiga (1999). Sustainability and the Canadian Mining Industry at Home and Abroad. Bulletin Canadian Institute Mining, Metallurgy and Petroleum, 93, 1033, p.85-92.

Thomson, I. and S. Joyce (1997). Mineral Exploration and the Challenge of Community Relations. Paper presented at the International Conference and Roundtable on Mining and the Community sponsored by the World Bank in Quito, Ecuador, May 6-8, 1997. Also published in *PADC Communiqué*. Prospectors and Developers Association of Canada, 8p.

Veiga, M.M. (1997). Introducing new technologies for abatement of global mercury pollution in Latin America. Rio de Janeiro: UNIDO/UBC/CETEM. 94p. ISBN: 85-7227-100-7.

Noetstaller, R. (1995). Historical perspective and key issues of artisanal mining. International Round Table on Artisanal Mining, Washington, DC, May 1995.

ILO-International Labour Organization (1999). Social and Labour Issues in Small-scale Mining. Geneva, 99 p.

Inter Press Service (1995). Development-Mining: Small-Scale Miners Get World Bank Attention. Lead Int. Inc., New York. http://www.lead.org.

Jennings, N.S. (1999). Child Labour in Small-scale Mining: Examples from Niger, Peru and Philippines. International Labour Organization, Working Paper SAP 2.78/WP.137. Ed. N.S. Jennings, Geneva, 74p.

Peiter, C.; Villas Boas, R.C.; Shinya, W. (2000), The stone forum: implementing a consensus building methodology to address impacts associated with small mining and quarry operations, Natural Resources Forum 24 (1), p. 1-9.

Davidson, J. (1998). Building partnerships with artisanal miners. Mining Environmental Management, 6, 2, March 1998, p. 6-7.

Davidson, J. and Veiga, M.M. (1999). Developing Strategies for Mercury Abatement in a Zone of Uncontrolled Mercury Use: km 88 District, Venezuela. Proc. 5th Int. Conf. on Mercury as a Global Pollutant. p. 493, Rio de Janeiro, May 23-28, 1999 (abstract).

Mining Journal (1989). Long-Distance Commuting. Mining Journal, London, vol. 313, no. 8046, 2p.

Sassoon, M. (1999). Effective Environmental Impact Assessment. In: Environmental Policy of Mining, Corporate Strategy and Planning for Closure, Ed. A. Warhurst and L. Noronha. Lewis Publ., Boca Raton, USA, p. 101-116

Connor, D. M. (1997). Public Participation: A Manual. How to Prevent and Resolve Public Controversy. Victoria, BC: Development Press, Canada. 38p.

Environment Protection Agency (1995). Community Consultation and Involvement. Series on Best Practice Environmental Management in Mining, Australia, 28 p.

Paget, G. and B. Walisser (1983). "The Development of Mining Communities in British Columbia; Resilience Through Local Governance," *Mining Communities: Hard Lessons for the Future*, Centre for Resource Studies, Proceedings No.14, Queen's University at Kingston, p. 96-130.

Warhurst, A., Macfarlane, M. and G. Wood (1999). Issues in the Management of the Socioeconomic Impacts of Mine Closure: Review of Challenges and Constraints. In: Environmental Policy of Mining, Corporate Strategy and Planning for Closure, Ed. A. Warhurst and L. Noronha. Boca Raton, USA: Lewis Publishers, p. 81-99.

Mineral Policy Center, (August 9, 1999) "Fourteen Steps to Sustainability". Mineral Policy Center, Washington, DC: http://www.mineralpolicy.org.

Background information on the authors:

Marcello Veiga is an assistant professor in the Department of Mining and Mineral Process Engineering at the University of British Columbia. He holds a Bachelor's degree (1977) in metallurgical engineering, Catholic University of Rio de Janeiro, Brazil, an MSc. (1984) in environmental geochemistry from the Federal Fluminense University (UFF) Niteroi, Brazil, and a PhD. (1994) in mining and mineral processing engineering from the University of British Columbia. He has extensive experience in Latin America as a consultant and researcher on a number of projects, particularly in the Amazon. The primary focus of his work has been on gold mining and mercury pollution and remediation.

Malcolm Scoble is a professor of mining engineering and Head of the Department of Mining and Mineral Process Engineering at the University of British Columbia. He is a graduate of the Camborne School of Mines (1966) and holds a M.Sc. in Mining Geology and Exploration from Leicester University (19971), and a Ph.D. in Rock Mechanics from Nottingham University (1981). Prior to joining U.B.C. in 1997, he was the Director of Mining and Webster Professor of Mining Engineering at McGill University in Montreal. His current research, teaching and consulting activities primarily lie in the fields of sustainable mining, mine design and automation.

Mary Louise McAllister is an associate professor in the Department of Environment and Resource Studies, University of Waterloo, Waterloo, Ontario. She holds a B.A. (Hons.), M.A. and Ph.D. from Queens University at Kingston, Ontario in the Department of Political Studies. At Queen’s she taught and worked as a researcher in various research institutes including the Centre for Resource Studies. Before coming to Waterloo, she was an assistant professor at the University of Northern British Columbia. Her main areas of research include mineral policy, environmental policy, public consultation and decision-making, and local community development in rural and remote regions.

MINING HERITAGE & CLOSURE MINES

Carvajal, D.J.; González, A.
Hydrogeology and Environment Group
High Polytechnic School. The Rabida Campus - University of Huelva
21819–Palos de la Frontera. Huelva. Spain
djcarvaj@uhu.es arsenio@uhu.es

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ABSTRACT

The deep and continuous changes that come affecting to technologies used in the mining industry have left a great heritage that a modern average multidisciplinary -and from all the corners of the planet- it is overturned in that constitutes a rich base with that to put heading for a more promising future. A town that is not able to lean on and to defend its past, difficulty will be able to face the future with clear perspectives of progress and obtaining of a better quality of life. The mining heritage is the history of the towns that successively have come using the matters minerals, and therefore it is part of the humanity's history, being for it very necessary today in day that the importance is valued that the extractive activities have possessed and they possess in our to happen daily, and that it is protected to the maximum as generating source of wealth and important alternative to the future development of many depressed mining areas.

INTRODUCTION

A high level of concern exists to international scale to be able to preserve for the future generations all those useful -machines, tools, tackle, etc. - and materials related with the production in the traditional industries that have left outside of use a series of direct testimonies after their closing, as the railways, power-house, industrial facilities of the steel, textile or coal that they are part of our more recent history and that the new technologies, the use of new materials –as plastics, for example- and modern activities have left in disuse and, in many cases, forgotten.

This phenomenon, known by Industrial Archaeology, has its beginnings in the XIX century, but it is not up to 1960 when its diffusion begins and already in the decade of the 70 when it takes doctrine body and it ends up consolidating trying to investigate, to analyse, to register and to preserve the remains of any industrial activity, being begun from then to put in value the materials abandoned by the industry, and to try society takes conscience of its patrimonial value and of the necessity of its conservation for use and enjoyment of the future generations.

The mining heritage tries to preserve, to conserve and to disclose all those elements characteristic of the extractive activity that have had a great protagonist, ending up being denominated mining-metallurgist heritage more openly to be able to include to the final result of the extraction that is the obtaining of the metal.

The mines represent an important heritage, because they are an example that conjugates the geological and mining aspects that we need to protect and preserve for to be able to transmit it and to disclose it and that this way it is known better.

The figure of the natural heritage has always made shade to other considerations –like geological and mining -, being today the figure of cultural park or ecomuseum one that is uniting all the patrimonial aspects. Nowadays there are already many the natural parks that include the protection of the mining heritage inside their enclosures, toward a work of conjunction of values and betting for a new model.

THE MINING-METALLURGIST HERITAGE IN WORLD

Today in day there are many associations and organisations that exist all over the world in behalf of Industrial Archaeology and recently they have arisen a great number of them with the thematic one it specifies and it sums up of the mining activity, aided under the term of mining-metallurgist heritage and that they have been divided of the industrial archaeology constituting for if alone one of the thematic but important association. A clear example of international level is The International Committee for the Conservation of Industrial Heritage (TICCIH) that completed its 25 anniversary in the 2000 that it has a section dedicated to the mining heritage and that it summons a next scientific meeting in June of 2001 in Butte, Montana, U.S.A.

In November of 1998 the European associations (Belgium, Finland, France, Germany, Greece, Ireland, Holland, Portugal, Spain, Great Britain, Slovenia, Czech Republic...), related with the industrial heritage, gathered in Barcelona (Spain) -a petition of the Belgian association agreed - that the 2002 were proposed for the European Industrial and Technical Heritage Year. In November of 1999 it is founded European Federation of Associations of Industrials and Technical Heritage (E-FAITH).

Next we pass to expose shortly which are the most excellent facts that have been happened in some countries with regard to this phenomenon of the Industrial Archaeology and the mining heritage.

In Ireland the organism that takes the responsibility of its conservation is the Geological Survey of Ireland through the Heritage Service created in 1845 and present at this year 2001 will open its doors the National Mining Heritage Centre in the mines of Shalle. In 1996 the Mining Heritage Society is created and already in 1998 they started: the Mining Museum of Arigna, the Glengow Silver and Lead Mines and the Quarries of Liscannor, already existing other projects in march like: the Allihiies Museum, Avoca Mines Heritage it Mines Park, The Bunmahon Cooper Coast -all of them old copper mines - and Castlecomer –on coal mining-, and on the other hand a mine of the age of the Brass in the centre of the Killarney National Park (Puche, 1999).

In United Kingdom, it is in 1959 when the British Archaeology Council founded the National Survey Industrial of Monuments dedicated to the inventory and conservation of monuments. In 1968 the Foundation of the Museum of the Valley of the Iron Bridge is created and nowadays the Ironbridge Gorge Museum, with a surface of 15,5Km^2 and with 300.000 visitors a year, they bills about 10.800 million pesetas lives (about 50 millions $USA); also, there are other important museums like the National Coal Mining Museum and the Peak District Mining Museum, or with smaller entity like the Florence Heritage Mines Centres, in Egremont, West Cumbria. In 1968 he/she took place the First International Congress of Industrial Archaeology. It is also the National Association of Mining History Organisations, NAMHO, from 1979 with 70 entities removed in 40 mine-museums, 20 societies and 10 institutional members, besides some 2000 people, of those that single three societies integrate practically half of these people, that are: Peak District Mines Historical Society Ltd., Northern Mines Research Society and Shoropshire Caving & Mining Club. Other communities are the Association for Industrial Archaeology and Trevithick Society. Also in United Kingdom is the Historical Metallurgy Society.

In Portugal the Geological and Mining Institute has inventoried all the points with interest in mining heritage and it collaborates in several projects in the Pyrite Belt: Mining Park de Cova dos Mouros, Lousal Mines (Grândola), Mine of Aljustrel and Sacred Domingo. The mine of Neves Corvo has already before its closing a musealisation project. It exists enough interest in constituting an Iberian Society for the Defence of Geological and Mining Heritage. From 1980 the Portuguese Association of Industrial Archaeology is developing an important of protection work and divulgation of mining and industrial heritage. Already in 1998 it organised a titled seminar The Archaeology and Mining Museology, in Lousal-Lisbon.

In United States there are many mine-museum of gold, uranium, copper, etc. Some examples can be the Western Museum of Mining and Industry in Colorado Springs, the Black Hills Mining Museum in Lead, South Dakota, Sterling Hill mine in Ogdensburg, in New Jersey underground -mine of zinc -, World Museum of Mining in Butte, Montana, and the National Mining Hall of Fame in Leadville, Colorado, the Crystal Gold Mines, Idaho, the Minnesota Museum of Mining in Chisholm, and the Bisbee Mining & Historical Museum, Arizona. Among the existent organisations are the Society of Mining Law Antiquarians, the Society for Industrial Archaeology and the Mining History Association.

In Canada several mine-museum projects already exist, such as British Columbia Museum of Mining, in Britannia Beach, on copper mining, Bell Island Mines, in Newfoundland, Cape Breton Miner´s Museum, in Glace Bay, Nova Scotia, Atlas Coal Mine Historical Society, in Drumheller, on coal mining, and it is also in Alberta the Association Québécoise pour le Patrimoine Industriel.

In Japan it is of highlighting the Ashio Mining Museum that has received 500.000 visits in one year (Mining Journal, 1999), and other like the Yunooku Gold Mining History Museum.

In Australia the Australian Mining History Association exists from 1995 with more than 130 collective members and singular (Mining Journal, op. cit.). The State Mines Heritage Park & Railway is a good Australian example of the setting in value of the mining heritage.

In Germany it is founded in 1906 the Deutches Museum von Meisterwerken der Naturwiessen chaft a Technik of Munich, by the hand of Arthur Miller who is the precursor of the Industrial Archaeology. As for mining museums, the Deutsches Bergland Musseum in Bochum, inaugurated in 1930, and that today it receives 400.000 visits a year (Mining Journal, op. cit.) and it is located in full carboniferous mining basin of the Ruhr. In 1934 the Musée of Houillére Mine (Saraland Mines - Museum) is founded at Bexbach in the carboniferous basin of the Sarre. Also in Germany is the Society for Mining Archaeology.

In Austria they opens up to the public in 1930 the underground Hinterbrúll gypsum mine, located in Modling that had been in activity during the period 1848-1912.

In Sweden has a good example of ecomuseum with its the Bergslagen Ekomuseum that embraces a mining region constituted by seven municipalities where they can visit mines, foundries, forges, energy power stations, the miners' housings and the bosses' palace-residence and so on. In Switzerland exists the Société Suise d'Historie des Mines.

In France in 1791 it was built museum of the Technique of the World, the Conservatoire des Arts et Métiers in Paris, but it is not until the years 60 is when the Industrial Archaeology is born. In 1960, to initiative of Raymond Aubet, becomes to the Mine Temoin d'Alés a Centre Historical Miner, and in 1966 it founded the Museum of

Nancy's Iron. In 1976 the ecomuseum concept is born in the context of a colloquy in Le Creusot titled Industrial Heritage and Contemporary Society. Exists in France The Association pour L'Étude des Mines et de la Metallurgie under the direction of Le Centre de Culture Scientifique, Technique et Industrielle, and the Equipe Interdisciplinaire d'Étude et de Recherches Arqueologiques -ERMINA- sur les Mines Anciennes et le Patrimoine Industrel. In the last 10 years a mining-tourist centre opens up half yearly, proliferating many mine-museum, historical-mining museums, ecomuseum, museums of the territory, geomining parks, etc., such as the Mine Blue, in Noyant-la-Gravoyère, or the Centre Historique Minier of Lewarde, that overcome the 100.000 visitors a year (Puche, 1996). Other examples are Ecomuseum Le Creusot-Montceau-les-Mines in Borgoña metallurgic-mining region, and Le Musée de la Mine de Cap Garonne.

Also, and with the help of the Spanish Society (SEDPGYM), in Latin America recently several similar American Societies have been created –with objective of the defence of geological and mining heritage-, such as the Oriental Cuban Society (Moa, Holguin), the Nica (Managua, Nicaragua), the Salvadoran (Republic of El Salvador), and the Boyacense (Sogamoso, Boyacá, Colombia). In July 1997 it took place in Quito (Ecuador), in the frame of the 49 International Congress of Americanist, a Industrial Archaeology and Conservation of Mining-Metallurgist Heritage Symposium in Hispanic world. In September of 2001 it will take place in Santiago de Chile that will be Third Latin American Colloquy on it Rescues and Preservation of the Industrial Heritage, as continuation to those carried out in Mexico and Cuba.

THE HERITAGE MINER-METALLURGIST IN SPAIN

By the middle of 1994 an idea arises in Spain –after the International Congress of Mining and Metallurgy in León- and in 1995 fifty people's April -among those that the Spanish joint author of this report was- they take place in Madrid the Assembly foundational of the Spanish Society for Defence of Geological and Mining Heritage (SEDPGYM) being legalised in October 9th of that same year. Today it possesses near 400 partners and carries out a nurtured number of activities that they go from the impression from their Bulletin to the organisation of five Scientific Sessions –the last in the mining district of Linares, Spain November 2000-, being convocated in these moments the sixth –a to take place in Beja, mining district of Baixo Alentejo, Portugal in October 2001-, and that in turn it will be the II International Congress about this topic. Also, this Society carries out other activities along the such year as field trip, exhibitions, cycles of conferences, seminars, collaboration in the foundation of geological-mining museums, etc.

As examples of experiences in those that has put on in value their Mining Heritage, some with more consolidation degree and others with the setting in work of so alone the first phases of wide projects, they can make an appointment the following ones:

Mining museum of Cerain (Guipúzcoa) next to Legazpi, museum project, facilities metallurgical, train mining etc.

Museographical Complex of Mining, in Barruelo of Santullán (Palencia), consistent in a visitable mine, a cultural centre and an interpretation centre with more than 600 m^2 on topics geological-miners.

Museum of the Mining of Castilla-León in Sabero (León) located in the restored building of the old Ironworks San Blas.

Mining Historical museum Francisco Pablo, from 1988, in Almadén (Ciudad Real) -mercury mining.

Museum of Puertollano (Ciudad Real) –coal mining-.

Museum of Gavá (Barcelona), you mine prehistoric of Gavà, (Llobregat) –variscite, sílex, turquoise and oligist -.

Geologic-mining museum of Peñarroya-Pueblonuevo (Córdoba) –coal mining-.

Mine Museum of Cardona salt mountain (Cardener), in Catalonia, the humanity's declared heritage for the UNESCO.

Mining Historical museum D. Felipe of Borbón and Greece, in Madrid.

Mining and Industry Museum –MUMI– El Entrego, Asturias, with 75.000 visit –coal mining-.

Geomining Museum of Spain, in the Geologic and Mining Institute, in Madrid.

Museum Historical Miner of the Union (Murcia).

Mine Museum of Cercs (Bergueda), in Cataluña –coal mining-.

Mining park of Riotinto, with more 2000 m^2 expositives in operation, 22 km of mining railroad in operation, roman necropolis, rail museum, 90 km^2 of visitables areas mining, visitors' housing, ethnographic museum and approved project of mine underground-museum, and that at the moment it receives 40.000 visits a year.

Projects of geological-mining Park of Mazarrón and Archaeoindustrial Park of The Union (Murcia).

Pre-project of Geologic-mining and Industrial Park of Tharsis (Huelva), there has been formed a work commission recently with the mayors of the affected municipalities, unions and people of the mining company and other persons of area.

PERFORMANCE ON THE MINING-METALLURGIST HERITAGE IN PYRITE BELT OF HUELVA (SPAIN)

It is a new way of revitalizing this important legacy of the past conserving the signs of identity of the mining communities and of people that made it possible. In these mining places it has been the print of the different technological advances, the stamp of the nationality of the operating mining companies and some aspects of the life that it was developed in each time.

In the historical pyrite belt of Huelva (Spain) they goes existing certain degree of social understanding on these topics, thanks to the important work that they come carrying out organizations like the Association of Friends of the Railway "Riotinto Mining Area" for some years, all the mines had its mining railway since of which they have been a great quantity of elements that they integrate the important historical mining heritage of the pyrite belt.

On the other hand, since in 1987 the Rio Tinto Foundation was created for the Study of the Mining and Metallurgy, this has impelled in a constant way the preservation of all material that can constitute an important database for investigating futures and it has developed a great project of Mining Park of the mining District of Riotinto, carried out with the support of continuous convocations of School-shop with twice as much objective of to conserve the mining-metallurgist heritage and to form professionals in this and other topics of among the youths of the district.

Something conservation and restoration projects they are that steam machine –that they puts into operation the first days of every month-, railway materials, wooden and metallic mining shafts, and construction of a complete space of Roman gallery is also culminating.

Another important activity is that of the Centre of Historical-mining Investigation of the Foundation, constituted at the moment by the historical archives a lot of mines, cartoteque, library and a great phototeque.

Nowadays great interest exists for the conservation, defence, divulgation and exploitation of this important heritage from diverse organisms and public institutions, such as city councils, Delegation of Huelva and University of Huelva that are summing up for example in restoration of locomotives, archives cataloguing, preparation of projects, realization of defence meetings of mining-metallurgist heritage, industrial archaeology, etc., in different towns and mining centres of the county.

THE MINING HERITAGE AS USE ALTERNATIVE

The essential philosophy of the use of the mining heritage as alternative of development of the mining regions consists on studying the possibilities of recovery of the area from all the points of view, not exclusively from the environmental means or landscape. Any project that it tried to return some areas with big exploitations to their initial natural state not alone would be impossible or inviable but rather it would not be keeping in mind the future socio-economic of communities of environment.

The idea that should prevail is "environmental recovery yes, but without destroying the heritage", since this can be considered as an exploitable resource -after finish mining activity- of such an important value or more than as benefits generated to the mining company and the society by the properly this exploitation.

Also, they must have very in mean necessities so much current as future of communities with purpose of being able to prioritise among possible use alternatives: recreational usage (wetlands and artificial lagoons, schools of risk sports, escalade, rockdromes, amphitheatres), environmental uses, diversion areas, dumping-places, residential areas, agricultural or forest uses, industrial facilities, etc. Also, and in a simultaneous way, it would be necessary to study their patrimonial value, in such a way that if this it was of great interest could optionally to carry out a project of type Museum or geo-mining Park.

What it is necessary to have very clear to undertake this type actions, it is that any project type that it is tried to approach it should conjugate aspects -such multidisciplinary as anthropological, archaeological and historical studies- that try of giving explanation to the changes that have left taking place in the work industrial productive -processes, relate social, technology, etc.-, in ways of life inside the exploitation and in the communities, allowing us everything it the understanding of the missing mining culture and the knowledge of the socio-labor conditions in those that lived.

This type of projects converges toward the denominated ecomuseums, open museums or cultural parks where they gives way the idea of static museums and it is focused toward a more dynamic model and with an important load of human aspects, where the elements are in situ and even in operation, and where you can usually appreciate, also, the manual and artisan work.

MUSEALISATION AND THEMATIC PARKS

The tourism, source of very important revenues for many countries, is an activity that is in constant evolution being continually to adapt to the demands of the market that every day is much more demanding and it requests something more than sun and beach, opting for an interior tourism, a tourism more in consonance with the environment and the country space –rural tourism- and with some strong connotations of cultural type. This joint must be taken advantage of by the organizations defenders of the heritage and to get the enough institutional support to undertake actions guided toward the setting in value of this rich historical-cultural legacy.

In this sense during these last years have increased considerably -so much on the part of the private initiative as public- interest for this type of tourism, what has been translated in the proliferation of great number of museums –musealisation- that have had great importance like source of revenues of depressed areas because of the end of a certain predominant economic activity. This tendency for the mining culture has international character, but it has been developed mainly in the most advanced countries as Japan, USA, the European Union, Canada, etc. In Europe three Mine-museum, Lewarde (France), Wieliczka (Poland) and Kerkrade (Holland), they possess more than 100.000 visits a year (Puche and Mazadiego, 1997).

As example of this new tendency the Ironbridge Gorge -with a surface of 15,5 km^2- is one of the first museums that pursues the objective of the recovery of the industrial heritage. It is located in one of the English valleys of the Serven river in which during the XVIII century that it was a region with a tremendous activity thanks to the exploitations of coal and to the trade of the iron, being the bigger centre producing of iron of Great Britain. Today in day it receives more 300.000 visitors year, with a cash of 10.800 million pesetas, about 50 millions $USA (Puche, 1996).

The Cultural Parks integrate multiple aspects at regional level. As model of this type of parks it can comment Aragon Government (Spain) interest that promulgated a law of creation of cultural parks. As example of this politics it is necessary to mention the Cultural Park of the River Martin, in Ariño, that includes many thematic –rupestrine arts, geology and speleology, fauna, flora, Iberian culture, palaeontology and popular arts- besides creation a Congresses centre in an miners old school of mining company SAMCA. What is pretend with it is it that people become aware of the rich heritage that possesses in the area that values it and mainly that participates in her conservation.

The modern idea that is also pursued today in day is that the Museums be able to interpretation centres, investigation and formation.

CONCLUSIONS

From it has been exposed in this article can be extracted the following conclusions:

1) it exists great concern and international sensitization to preserve the history of the mining and, in consequence, a culture that it needs to be diffused through museum experiences, cultural parks, etc.

2) it is necessary to undertake diffusion actions and development about the necessary protection and defence of great value that it represents the mining heritage, as the humanity's heritage, through the development of projects and publications as well as to generate several activities as courses, shops, conferences, divulgatives meeting from primary school, etc.

3) we have the obligation of preserving for the future this heritage, as historical inheritance that our ancestors have bequeathed us.

4) this task must be multidisciplinary and in her it must involved to communities.

REFERENCES

Mining Journal (1999). **Mining history matters.** March 19. London.

PUCHE, O. (1996). **The conservation of the mining heritage in Great Britain.** Bull. SEDPGYM, 5, 2. Madrid.

PUCHE, O. (1996). **France and the mining and archaeological heritage.** Bull. SEDPGYM, 4, 1. Madrid.

PUCHE, O. (1999). **The conservation Ireland´s mining heritage.** Bull. SEDPGYM, 14, 7. Madrid.

PUCHE, O. AND MAZADIEGO, L.F. (1997). **Conservation of the mining metallurgist heritage Spanish: recent performances and proposals.** Tecnoambiente, 69, 39-43. TIASA. Madrid.

SEDPGYM (1996-1999). **News and comments on the geological and mining heritage.** Bulletins 7, 8, 13, 14. Madrid.

Module IV

Technology and Mine Closure

MINE CLOSURE – A GEOMECHANICS VIEW

Prof. Dr. *Lineu Azuaga Ayres da Silva*
Prof. Titular, Departamento de Engenharia de Minas da
Escola Politécnica da Universidade de São Paulo

SUMMARY

To say that the closure of a mine should be planned at the beginning of the mine planning stage may seem an overstatement. However, when the mining operation is examined under the environmental perspective, it is difficult to avoid this. The problem becomes even more complex as it is considered that the final mine configuration will depend upon the mining method selected for the operation.

It is possible, therefore, to establish the following dependency sequence: (1) the mining method depends on the grade distribution of the metal or ore mineral being mined, conditioned by the geometry of the orebody and the geomechanical characteristics of the orebody and the surrounding rocks. All these conditions have to be considered when the cost-revenue analysis of the mining operation is carried out at the feasibility stage. The parameters related to the minimization of the environmental impact of the operation are also considered at this stage.

Under this general view, this paper contains a discussion of the relevance of the determinant factors on the behavior of mine excavations. The study of this behavior may be carried out using Rock Mechanics tools, which are progressively supporting decisions on mining methods, which, at the mine closure stage, ensure the minimization of the environmental impact of a mining operation.

1. INTRODUCTION

Most mines both open pit and underground, are developed in solid rock formations. The inevitable implication is that all determining factors of the final outcome of a mining operation are associated with the structural characteristics that delineate the mechanical behavior of the rock formation.

In a more direct approach, a mine will be the more economically feasible the simpler the solutions for the extraction of the waste associated to the orebody. And the amount of waste to be removed is directly related to the mining method selected. Therefore, in an open pit mine, the relation between the volume of waste to be removed and the volume of ore obtained will be the smaller the better the mechanical strength quality of the orebody; the steeper the slope angles, the smaller the blasting costs, the smaller the transport costs and the waste dumps.

Because of the relationship between the geomechanical quality of the rock formation and the volumes to be removed, it is certain that the environmental impact related to vibrations from blasting operations and transport will be smaller. The amount of investment for mine reclamation will also be smaller.

In underground mines, there will also be a similar relationship between the geomechanical quality of the rock formation and the mining costs, reclamation costs and the eventual re-use of mine openings.

2.MINE PLANNING

Planning means knowing the problem. All planning efforts will be the better the deeper the knowledge and information about the parameters relevant to the problem. However, knowledge means investigation and investigation demands costs which are proportional to the complexity of the object of the study. On the other hand, we know that financial risk control requires that costs be incurred as long as there is a safe and progressive expectation for their return. Therefore, planning of economical activities is usually established with increasing levels of certainty, as long term, medium term and short term planning.

This occurs also in mining. However, the parameters that are taken into account in mine planning are those whose importance is clearer. This will mainly be those where measurement and control techniques in the mine are known.

Even if currently well known, geomechanical parameters, mainly those strictly related to Rock Mechanics, are usually considered expensive in their evaluation and measurement methods. The degree of control that can be applied to these parameters is somehow limited dispersing with the current level of technical knowledge.

3.THE GEOMECHANICAL PARAMETERS

The geomechanical parameters mentioned above are those used for quantifying or assigning some measure to the specific properties of rock formations. These are listed below to ensure that the ideas transmitted here are conceptually supported:

Properties related to the physical nature of rocks:

Rock density.

Rock porosity.

Rock hardness

Rock texture.

Properties related to the mechanical strength of rocks and rock masses:

Compressive strength.

Shear strength

Poisson ratio

Modulus of deformation.

Cohesion.

Angle of internal friction.

Shear resistance of the rock joints

Parameters related to geology:

Stress state in the rock mass.

Lithological features of the rock mass

Particular Parameters associated with the structure of the rock formations:

There are ten parameters associated with the discontinuities as illustrated by the figure below, (after J. Hudson)

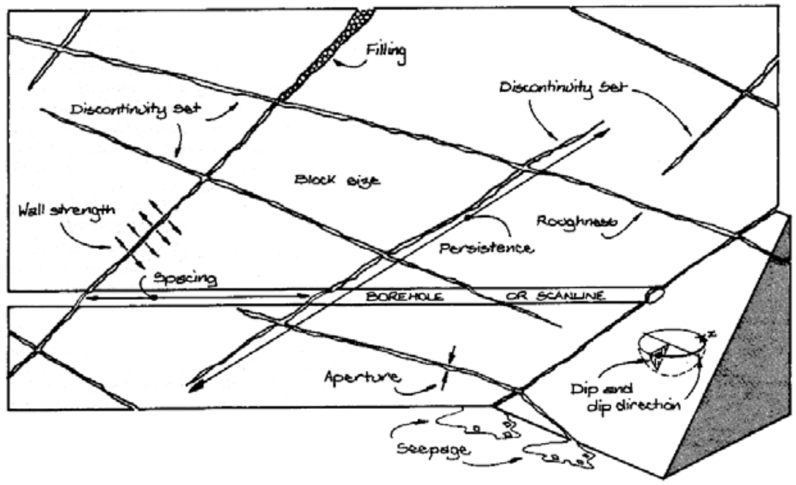


Figure 1. Illustrative diagram of rock mass descontinuity properties and water seepage (After John Hudson, 1989)

If on the one hand many mining operations do not consider and investigate geomechanical factors in an appropriate manner, on the other hand, modern companies, more technologically advanced, clearly recognize their importance. The main reason for this is related to the potential problems in the mining operations if geomechanical factors are not properly considered; when these are not considered, not only potential problems during mining may occur, but also during the closure of the mine.

3.1.The investigation

Whenever possible, the progressive planning of expenditures in a mining operation is a desirable alternative. Once the financial feasibility of a mining enterprise is confirmed, the most appropriate practice to avoid problems is the investigation of geomechanical factors in the orebody, during the pre-mining phase of the operation.

The author of this paper has been focusing, mainly in his recent research, in the economic, safe and low-risk benefits of activities such as exploratory drillholes, instrumented stopes, and stability systems testing. These activities may be carried out at the same time as the grade sampling and investigations for reserve estimation during the exploration phase before mining. The simultaneous execution of these investigations would certainly be cost efficient: if investigations for grade and reserve estimation are routinely carried out at this phase, geomechanical investigations have an equal degree of importance in the determination of the mining method and in the structural planning of the underground openings required in the mine.

However, in most cases, geomechanical investigations are completely ignored or relegated to future phases of the operation; in such cases, they are only taken into account with the occurrence of structural stability problems, with the false idea that they would be implicit in a mining operation.

A number of research groups, in various parts of the world, have been concentrating on the development of new techniques to determine better definition of underground structures by using 2D, 3D and 4D seismic. Among them are the DELPHI project at Delft University and the Geological Research Center of Edinburgh University, in Scotland, the latter with long experience from reservoir projects in the North Sea.

Figure 2 below shows sub- surface rock quality variations obtained by the Norwegian Geothechnical Institute (Barton, 1996).

The " cross-hole velocity tomography " technique was used in the investigations associated with construction of the 62m span GjØvic cavern for winter Olympic sports held in Norway in 1994. A strong link between seismic velocity, rock quality and rock support needs was established.

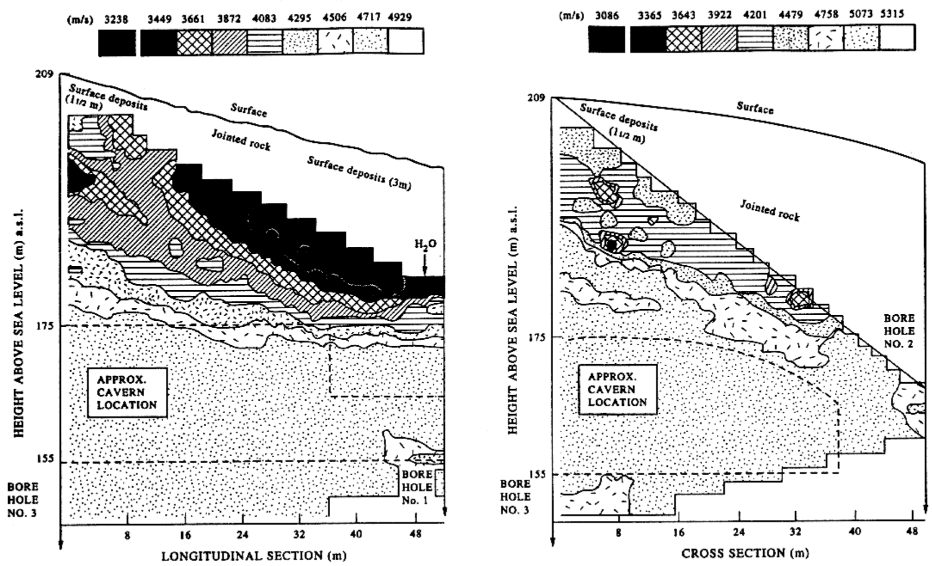


Figura 2. Seismic tomography (" cross - hole "), in the location of the olympic cavern at GjØvic (after Barton, 1996).

3.2. The economic implications

It is interesting to observe that the argument on the necessity of geotechnical and structural implications during mine closure brings up the fact that we are still discussing the need to start up the investigations during the mining operation itself. This may be justified by the fact that only recently Rock Mechanics has developed sufficiently to give the technical-economical decision-makers a clear vision of the technical advantages and the cost and risk reductions related to using the specific tools of this area.

For example:

- In an orebody where it is known:
- the grade distribution of mineable reserves,
- the volume to be produced in a particular time horizon,
- the strength and stress status in the rock formation, with the magnitude and direction of their components,
- the structural mechanical characteristics of the formation (presence and characterization of discontinuities, folds, fractures and their spatial position),

- the mechanical strength characteristics of the rock formation (orebody and surroundings);
- it will be possible to establish a geomechanical model that will allow the better definition of the directions of underground drives and stopes with improved stability. This will mean lower costs with roof support systems and will avoid costs with recovery of damages that could eventually occur with unpredictable risks.

The construction of a geomechanical model will also allow the selection of a mining method with lower operating costs and may avoid mining methods that would become impractical for those particular conditions.

This approach has been followed in a few technically equipped and well capitalized mines, where the mechanical behavior of the mining excavations have been well monitored and predicted. This has allowed the prevention of problems in the mine operation, using global solutions such as mining methods compatible with the mechanical nature of the orebody, with forecasts of structural difficulties at the end of the mine life.

4. The mine closure

As discussed above, it is clear how geomechanical models can contribute in the mine closure analysis.

In open pit mines, it is easy to realize that the mining method and the slope angles will not only depend on the orebody grade distribution and geoestatistical configuration, but also on the structural characteristics and mechanical behavior of the rock formation (orebody and surroundings). This will provide the total volume of the excavation and its spatial distribution. Further studies will allow the decision on the need for waste dumps, their configuration and procedures for slope stability perhaps through re-vegetation of the waste dump slopes? This phase of the study will certainly be associated with future land uses: recreation areas, perhaps with lakes and the setting up residential areas with progressive landscaping of slopes and waste dumps; land reclamation and re-vegetation.

Here we are not addressing the issue of water contamination, which is discussed later.

4.1.Underground mines

The appropriate use of Rock Mechanics allow the construction of analytical, physical and numerical models that are then used in decisions of the correct mining method in technical and economical terms. During mine closure, the same approach will allow the verification of the mining method chosen and the stability of resulting excavations. Each particular method considered here may be applied to the mine overall or individually by region, because the same orebody may have different regions exploited with different mining methods. In the present analysis it is considered that each example is associated with a specific mining method. Even the selection of a mining method requires methodologies and care related to its technical definition under given geomechanical aspects. What is being proposed is that such solutions are extended to the final phase of mine closure, with a verification of the actual compatibility of the selected mining method with an acceptable level of disturbance to the environment.

If eventual damages from the selection of a particular mining method cannot be minimized to an acceptable level, it will be necessary to investigate the adoption of an alternative method, where the resulting environmental impact is the lowest possible. A curious fact is that the final solution, with the lowest environmental impact, will certainly be the one with the lowest global cost, which includes all required reclamation costs. Recently, this has become compulsory in all activities dealing with nature, by law.

a. Analysis of a case study

A mining company started a mining operation in the thickest layer of a particular manganese deposit, where the orebody is divided into 3 layers outcropping in the side of a hill, with average thickness of 4m, 1m and 0.4m. The overburden was 150m at the highest point. Mining started in the 1970s. The mining method selected, based on previous experience from the 1920s, was room and pillar.

The average cross-section of the pillars was 4m by 3m, with span of approximately 4m in the room. Mined ore came from the thickest layer, with ore left in the pillars, which were not mined. The method was properly developed and supervised at that time, with the classical approach of leaving flag-pillars to indicate isolated areas. Mining continued for several years without problems and with a low waste extraction rate, because all the ore being mined was processed in the plant to produce alloys.

The main environmental impact came from the steel plant, through the emission of particulate material and ashes. This was reduced to trace levels after the introduction of appropriate filters.

At a certain stage during the 1980s, with the objective of obtaining a higher recovery, but without using Rock Mechanics information already available, the technical staff responsible for the mining operation decided to change the mining method. They started to reduce the cross-section of the pillars, and to transform flag-pillars into regular pillars, even though they still had a considerable ore reserve available. The objective was to maximize the profit of the operation with the decrease in mine development costs.

With the increase in the span, the result was the development of higher tension and shear forces in the roof with the progressive damage to the pillars – from the borders to the inside of the mine – which has caused the rotation of a large area in the slope. The resulting strain rupture patterns, later visible at the surface topography of the hill, were allowing the penetration of rain water, which made them wider. The pillars were then shortened, with a gradient increasing from the inside to the outside, and the overburden area of a larger portion of the mined out region has rotated as a large single block, thereby closing down the mine entry. The progressive crushing of the pillars, with the compressive strain leaning in its axis, has resulted in a large slide of the slope.

The reclamation costs are being considered impractical. Currently, the mine is under water and closed down. Later studies have allowed a better understanding of the process. If these studies were carried out at earlier stages, they could have prevented the problems and could have oriented a better refinement of the mining method. A brief explanation is presented below:

- Simple compression tests over the manganese ore have shown that the compressive strength of the orebody, considering a scale factor, is approximately 51 MPa.
- In the most critical region, the average strength on the pillars was approximately 4 MPa.
- 4m x 3m pillars with 4m gaps, according the tributary area theory, are submitted to a compressive charge of 23.130 tnf. The pillars could resist to a nominal charge of 61.918 tnf. This relates to a Safety Factor of 2.68, which is appropriate for this rock type, considering the scale factor for the compressive strength. With the increase in the spans (which means to decrease the cross-section of the pillars by 1m), the Safety Factor comes down dangerously to 1.7.

-The orebody layer has discontinuities forming 3 different families, in addition to random planes, with the most critical ones being close to 45º in dip.

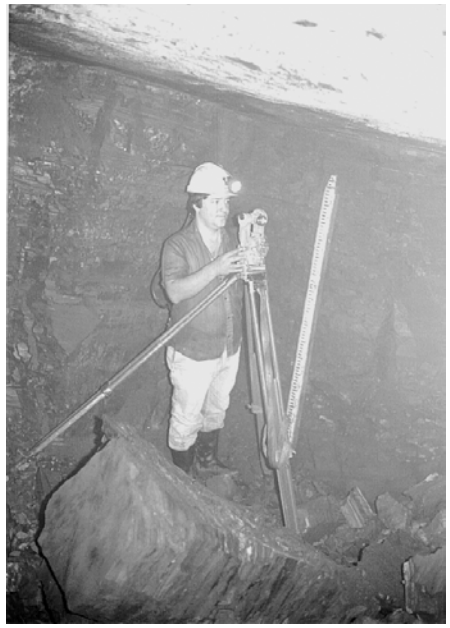


Figura 3 - Illustrative picture of the sampling of blocks to determine the rock mass strength parameters (surveyor gives scale)
(after Ayres da Silva,1992)

- The surrounding rock formation is an arcose (roof and floor), with an average thickness of 20 to 40 cm, significantly altered, over which there is a jaspelite with families of discontinuities with horizontal, sub-vertical and inclined planes, spaced by approximately 40 to 50 cm.

The increase of the spans has induced the increase in strain ruptures in the roof. These events were followed by a differential damage to the pillars, described in more detail by Ayres da Silva, et al. 1995.

The description above were extracted from the conclusions of research work carried out by the author with the use of experimental and lab-based tools, including the software UDEC **(Universal Distinct Elements Code)** for the numerical modeling of the rock structures.

5. Concluding Remarks

The ideas presented here hopefully support the principle that mine planning should provide the selection of a mining method that allows the economical extraction of the ore and requires a minimum volume of resources to mitigate eventual environmental impact, with an increasing degree of precision in the horizons where it is applied.

This will be possible if the company carries out the appropriate effort to investigate the relevant geomechanical parameters, in order to build a geomechanical model of the orebody.

It is also important to note that some of the alternatives being considered in this discussion, including methods that provide the refill of open stopes, or further utilization of mining openings for other uses, are being compiled by the author into a classification system to support the decision on which method should be applied.

6. References

Ayres da Silva, Lineu Azuaga. Proposta de metodologia para a determinacao da resistencia a compressão de maciços rochosos, a partir de ensaios de laboratório. São Paulo,1992. 225p.Tese (Livre Docência) - PMI.

Ayres da Silva, Lineu Azuaga. Comportamento mecânico das escavações subterrâneas. São Paulo: EPUSP / PMI,1998. 52 p.

Ayres da Silva, L A; Hennies, W T; Sansone, E C; Rusilo, L C. Dynamic aspects in the development of the pressure arch. In: International Congress on Rock Mechanics, 8, ISRM - Rotterdam: Balkema, 1995.Rotterdam: Balkema,v.2 p.467-70.

Ayres da Silva, L A; Hennies, W T. Methodology for rock mass compressive strength characterization from laboratory tests. In: International Workshop on Scale Effects in Rock Masses, 2, Rotterdam: Balkema, 1993.Rotterdam

Balkema, p.217-24.

Ayres da Silva, L A; Stellin Junior, A; Born, H. Some considerations on the present situation of underground waste disposal in brazil and its perspectives. In: International Conference on Environmental Issues and Management of Waste in Energy and Mineral Production, 2, Rotterdam: Balkema, 1992.Rotterdam: Balkema,v.1 p.659-63.

Barton, Nick. Influência das propriedades das fraturas na modelação dos maciços rochosos. 27p.: Comitê Brasileiro de Mecânica das Rochas, 1996.

Costa E Silva, V; Ayres da Silva, L A. Practical ways to reduce environmental rock blasting problems. In: International Conference on Environmental Issues and Waste Management in Energy and Mineral Production, 4, Cagliari: Digita-Universita di Cagliari, 1996. Cagliari:, Digita-Universita di Cagliari,v.1 p.291-7.

Hudson, J. A. Rock mechanics principles in engineering practice. London: Butterworths, 1989. (CIRIA Ground Engineering Report).

Sanchez, L E. In: Efeitos e impacto ambientais associados a projetos de mineração. São Paulo:, Cetesb, 1994, v.2.

Sanchez, Luis Enrique. A legislação ambiental brasileira e a mineração; dificuldades a enfrentar /Debate/. In: Encontro de Mineração no Município de São Paulo, 2, São Paulo: Prefeitura do Município de São Paulo, 997.São Paulo, Prefeitura do Município de São Paulo, p. 139-140.

Sanchez, Luis Enrique. Industry response to the challenge of sustainability: the case of the canadian nonferrous mining sector. Environmental Management, New York, p.521-531., 1998.

Sansone, E C; Ayres da Silva, Lineu Azuaga. Numerical modelling of the pressure arch in underground mines. In: Numerical modelling of the pressure arch in underground mines. International Journal of Rock Mechanics and Mining Sciences, p.436, 1998.

Sansone, Eduardo Cesar; Ayres da Silva, Lineu Azuaga. Estudo de aspectos geomecânicos aplicados ao projeto de minas subterrâneas. São Paulo, 1997. 207p.Dissertação (Mestrado) - PMI.

Silva, Jose Margarida da; Silva, Lineu Azuaga Ayres da. Contribuição a determinação da rugosidade da superfície de descontinuidades rochosas. São Paulo, 1998. 134 p.Dissertação (Mestrado) - PMI.

Silva, J M; Ayres da Silva, Lineu Azuaga. Determination of secondary roughness of rock discontinuities surface by scanning devices. In: South American Conference in Rock Mechanics, 5/Brazilian Conference in Rock Mechanics, 2, São Paulo: EPUSP, 1998. São Paulo: EPUSP, p.29-34..

Silva, Valdir Costa e; Ayres da Silva, Lineu Azuaga. Variáveis que interferem nos problemas ambientais gerados durante os desmontes de rochas. São Paulo,1998. 136 p.Tese (Doutorado) - PMI.

Souza, V P; Sanchez, L E. Drenagens ácidas do esteril piritoso da mina de urânio de Pocos de Caldas: interpretação e implicações ambientais. São Paulo, Epusp, 1996.

Vega, Hugo Antonio Merconchini; Ayres da Silva, Lineu Azuaga. Problemas relacionados a tensões naturais na lavra de rochas ornamentais. São Paulo,1999. 212 p. (Mestrado) - PMI.

DECREASE OF POLLUTION BY MERCURY IN GOLD MINING IN LATINAMERICA

Freddy Pantoja T.
Corponariño-Colciencias, A.A. 1476. Pasto, Colombia.
Ramon Alvarez R.
School T. S. Mining Engineers, c/Rios Rosas 21, 28003 Madrid, Spain.

ABSTRACT

It is known that mercury has a high pollution level and it is used widely in small gold mining in Latinamerica. Mercury has been used many times without needed precautions causing a big contaminant effect both in water, land and in workers than manage mercury.

On the other hand, this practice is the only possible to benefit those minerals since it requires less technology and investment, which means it could continue in use during a lot of time. Although some handicraft devices that decrease contamination, such as distillation retorts for amalgam, in the amalgamation process, keep still producing huge mercury losses.

It has been proved how it is possible to decrease mercury losses, washing mineral with detergent or alkaline agents, and using electrolytically activated mercury. This was compared with another usual methods and at the same time, it was proved that it is possible to get an increase in recovering gold that will be the main purpose of miners to use this technique.

In addition, it has been proved that it is precise to determine the proportion of mercury/mineral to use in an optimal amalgamation time to get less contamination as possible, which can be done with simple calculations.

Mercury losses (if retorts are used in distillation of amalgam) in amalgamation process are concentrated mainly in solid residues since in water used for the process contains normally from a hundredth to a thousandth or less part of what is found in solid residues. That is why solid residues are the main source of contamination above all looking to the future. Therefore it is offered as a palliative way of this problem the possible previous gravimetric concentration and the later amalgamation of concentrates, decreasing the volume of residues and making easy its safe removal or is treatment.

All these actions require neither expensive equipment nor a lot of knowledge and they improve gold recovery; therefore, they can greatly accepted by miners and they can be really effective in decreasing pollution caused by these activities.

Key words: Gold, mercury, amalgamation, pollution, preconcentration.

INTRODUCTION

The amalgamation technique is still widely used to extract gold by small miners, mainly in the tropical zones developing countries of the world. This technique is used because of it is very simple and it is efficacious, and above all, because it requires a small investment of money. We are referring in this article to this small art of mining since the big mining normally takes the need cautions and it controls its processes.

In the amalgamation process, gold is trapped by mercury in a watery pulp hole to form a highly viscous substance bright white colour, named amalgam. The final recovery of the precious metal is made through a strong heating of the alloy (mercury evaporation) or using nitric acid (mercury dissolution).

To get that gold is amalgamated it has to be in touch with mercury. Therefore gold included in another substances (for example sulphurs or quartz), cannot be extracted until getting a milling in such a way that all metallic particles are liberated or gold can have contact with mercury. Gold is amalgamated the same that some minerals of itself that are alloys of gold with another metals like electrum, propecite (gold and palladium), gold amalgam, (Au and Hg in natural occurrence), but another minerals of gold are not amalgamated, mainly in composed of tellurium like sylvanite and calaverite.

The inadequate use of mercury in these explorations lead to high loses, both in form of elemental mercury during the mineral benefit and in form of vapour and inorganic composed during the work of separation gold–mercury. Another important part which is common for all small mining is the low level of recovery of the precious metal caused by the defective application of amalgam.

Risks about health and environment are not taken into account by miners. They ignore the damages that a bad handling of mercury. The exposure to this substance not only is limited to workers but also it is extended to their relatives, since miners and traders, in many cases, distil amalgam in their kitchens or in the backyard of their houses (1) (2).

Mercury once it is absorbed by man, goes to the sanguine torrent, easily cross over the cellular membranes and it is accumulated in the liver, the bowels, kidneys, nervous tissue, etc (3). Chronic exposure to mercury caused the famous professional illness known as “mercurialism” or “hidrargirism”.

In the environment mercury is accumulated mainly in form of metallic mercury (Hg^o) and composed of Hg^{++} and Hg^{+} like it happens with nitrate of mercury produced in the chemical separation of amalgam, in sediments of rivers and soils, where through bacterial action and under some conditions it can become organic mercury, especially metilmercury (4). This form of mercury which is highly toxic for human beings can be accumulated in water organisms and pass to man, for instance, by eating polluted fish.

However, the most urgent worry is related with health of miners and their families, because they are exposed permanently to mercury. In this sense, the following are the situations of high danger that have been recorded in all exploitations of the zone, and in which mercury can easily penetrate in people:

Exposure to mercury vapours during amalgam processing to open fire (“burn of amalgam”) in order to separate mercury of gold.

Handling of metallic mercury without any protection during the different stages of the process.

The following are some data that reflect the problem in Latinoamerica:

- In mining of south of Colombia are emitted from 3 kg to 10 kg of mercury per 1 kg of produced gold. As a middle value it can be taken 5 kg of Hg per 1 kg of produced Au (5).
- The primary mines in Brazil and Bolivia that use mercury directly in mills to achieve the simultaneous amalgamation lose from 5 kg to 10 kg of mercury (in extreme cases until 25 kg) to recover just 1 kg of gold (2).
- In alluvial mining, the loses are very similar to the above ones, when mercury is added directly to the auriferous gravel in situ, or in a mixer bowl placed before the small channel

or directly in the channel. Some of the countries that use this method are Venezuela, Colombia and Brazil (2).

- The average loses of mercury in informal miners of Brazil ("garimpeiros") has been estimated in 2 kg/kg of produced gold (6).
- The emitted mercury in the Amazonian complex are calculated in 300 t per year and until the present the accumulated quantities are from 1000 t to 2000 t in this important ecosystem (7) (8).

The annual quantity of lost mercury per about 100.000 miners in Equator is estimated in 50t.

In spite of the above data, amalgamation in a near future will carry on being the preferred method and will be still applied to small gold mining. Therefore it is important to improve technique conditions of the process through using simple technologies and easy handling equipment, lower costs of local manufacture. At the same time, it is necessary to consider the increase of recovery of gold and the lost of mercury, because its decreasing shouldn't produce the lower production of gold and this fact is very significative in order to miners participate in a project which will help to decrease the lost of mercury taking into account that if they find this project as a way to diminish their entrances they will not participate in it (they think that pollution effect are not important because theses effects are not immediate).

Technologies and equipment that have begun to be accepted are amalgamation in "closed circuit" in barrel of concentrates, distillation of amalgam in retort which make possible the recovery of mercury from amalgam and avoid its emission to the atmosphere, and activation of mercury through electrolysis. All of these require to be integrated to a mine–metallurgic coherent process. A description of a type of these retorts can be found in (10).

EXPERIMENTAL SECTION

In order to do the experimental study about recovery of gold and reduction of lost of mercury samples of mineral have been used which come from "La Bruja" and "La Gruesa" veins from the gold mine "Nueva Esparta" in the South West of Colombia, which is a bed of mineral of the lodge kind.

In table 1 the main characteristics of both samples are shown, being the sample from "La Bruja" a good example of mineral of high riches, while the sample from "La Gruesa" can be an example of mineral much more abundant in South America than in another places of the world.

Table 1. Samples Characteristics

CHARACTERISTIC	ORE	
	"La Bruja"	"La Gruesa"
Au (g/t)	317,40	44,40
Ag (g/t)	180,10	62,20
SiO_2 (%)	83,35	88,35
TiO_2 (%)	0,23	0,18
$Al_2 O_3$ (%)	3,79	2,57
$Fe_2 O_3$ (%)	3,30	2,31
MnO (%)	0,03	0,03
CaO (%)	2,11	1,56
MgO (%)	1,34	0,89
$K_2 O$ (%)	0,88	0,59
$Na_2 0$ (%)	-	-
$P_2 O_5$	0,02	0,01
S (%)	1,35	1
Pb (%)	0,19	0,13
Zn	0,17	0,13
Loss on ignition (%)	4,64	3,50

All the analysis of gold of solid samples (ores, tailings, concentrates) have been done through fire assay and cupellation, which determines the content of gold in the precious metal button, by attack with nitric acid (after inquartation if it's necessary) or by microanalysis in electronic microprobe.

It is important to stand out that native gold which the samples content has silver in a proportion that could make the mineral to show "electrum" (natural alloy with approximately 20 % silver) and not gold as such element. These analysis of gold and silver content in gold that samples have and made through electronic microprobe are shown in Table 2 as a measure of the got results in several grain of both kind of mineral.

Table 2. Mean Analysis Of Several Grains Of Native Gold

ELEMENT (g/t)	ORE	
	"La Bruja"	"La Gruesa"
Au	75,70	80,40
Ag	24,30	19,60

It is also important the presence of sulphurs such as pyrite, arsenopyrite, galena, etc.

Amalgamations have been done on natural minerals, after an adequate milling in less than 2 mm, and also on concentrates of the same minerals got by gravimetric concentration (Wilfley shaking table) or by froth flotation, with the purpose of studying the influence of these processes.

All devices, products and equipment to treat the mineral until to get gold have been chosen taking into account that they are easy manufacturer of lower costs and good use by small miners in order to get results comparable to real mining.

Amalgamation has been done through barrel amalgamation in which mercury and mineral are content into a closed rotator recipient without leaks of pulp and without direct intervention of operator. The main variable operations that have been taking into account are: amalgamation time, quantity of mercury, quality of mercury (normal or activated through electrolysis) and after the mineral have been washed.

One of the measures that must be taken in order to control production of mercury "flour" (very small droplets of mercury that non coalesce) that give rise to important lost of mercury through dragging with tailings or water is not to do milling and amalgamation simultaneously in the barrel (10). The samples were milled separately in less than 2 mm.

Rests of amalgam and mercury are picked up through decanting and dragging of sterile with water. Amalgam is separated through pressure hand filtered with a weaving (a piece of weaving where the mix mercury–amalgam must be twisted) using latex gloves and finally separation of gold from mercury made by distillation in a small manufactured "retort", screw and nut closed, which are being introduced to miners because they allow to recover mercury from amalgam and help to avoid distillation in opened recipients.

For the essays with activated mercury, the mercury that comes from recovery is submitted to electrolyses in a small manufactured cell, as those ones that miners are beginning to know, which are made from a small plastic recipient that in the bottom has a graphite electrode (cathode) which is connected to the negative pole of a battery of 9 or 12 volts (car battery). Upon this electrode a layer of mercury is put and upon it a solution to 10 % of NaCl is poured (kitchen salt) and into this solution another graphite electrode is put (anode) connected to the positive pole of the battery and the electricity has to pass for about 5 minutes. In this way, something of amalgam of sodium is produced in the mercury which also reacts with water to produce hydroxide of sodium and in conjunct they clean the mercury mainly from oxides that it has in its surface. The active mercury has a strong metallic bright and tend to form almost perfect spheres when it is divided in drops that coalesce quickly among them.

For the trials with washed mineral, the mineral is submitted to the action of a lot of water in a rotary drum with lime or soda and/or detergent, decanting the water from the washing before passing to the amalgamation. This process cleans and eliminated certain covers from the grains, and it makes possible to work with alkaline pH which decrease formation of mercury flour, since it is favoured (11) by the presence of sulphurs that reach with the small drops of mercury produced by mechanic action, covering them of a layer of HgS that makes that the electrostatic repulsion of the sulphide surface layers means that the droplets repel each other and cannot become reunited. In the alkaline medium (12) the complex HgS^{2-} is formed and it avoids the covering and repulsion of the small drops.

For the essays with previous concentration of mineral a Wilfley shaking table has been used. This is a device known by miners and in many cases allow to have manufactured constructions that are cheap. Its handle is very simple, although it can require of a motor that can be electric or by explosion to be used in remote places, or even it can be moved with a manufactured wheel for drawing water.

For the essays of flotation a cell Denver Sub A has been used. This is scale model of a very big equipment adequate more for median mining than for small mining because it requires much more knowledge and reactive.

RESULTS AND DISCUSSION

Through the research it has been shown that the best results are got using activated mercury and making a previous washed of mineral with alkalis or detergents which eliminate clays and very small particles, cleans the surface of small grains and remove grease as well as decrease the influence of minerals benumbed of amalgamation as the sulphurs are. In these optimal conditions and for the mineral from "La Bruja", the Figure 1 show the influence of the quantity of mercury used, expressed in kg of mercury per ton of mineral, with relation to the recovery of gold expressed in % also related to the total lost of mercury (the sum of the lost in decanting water and washed of the amalgamation process and lost of solid rests) expressed as grams of mercury per 100 g of produced or recovered gold.

It looks clearly the influence of mercury quantity both in the recovery of gold as in the lost of mercury mainly. The optimum quantity is 3 kg of mercury per ton of mineral, which gives a recovery of 94,.20 % of gold and a lost of 2,4 g of mercury per 100 g of recovery gold. With less quantity of mercury the quantity of gold is less by the time of given treatment and at the same time the amalgam is too consistent and coalesce badly making easy the lost in small drops that furthermore drag the gold.

When quantity of mercury is higher a similar effect is also produced due to the amalgam turn more liquid and there are more chances of lost of small drops. It has been deduced that in each mine is necessary a study in order to determine the optimum quantity of mercury to be used since this not just decrease the pollution diminishing lost of mercury to a minimum, but also it produces an increase in recovery of gold which is translated into a greater economical benefit for the miner.Another important aspect is the relation between lost of mercury in the water of the process and in the solid rests of amalgamation. In Table 3 these data are shown for the samples of the Figure 1.

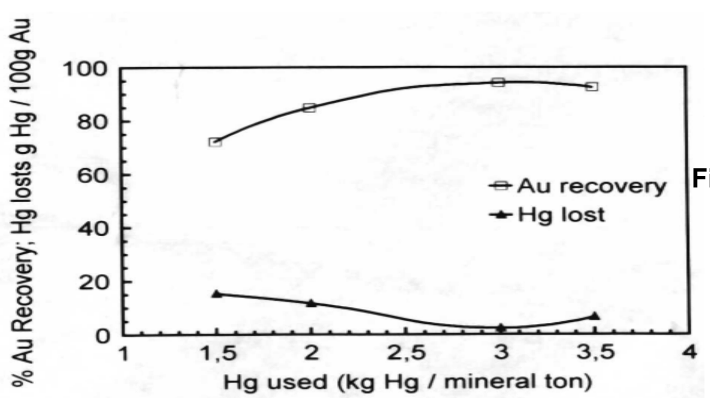


Figure 1

From Table 3 and another data from another essays, that coincide with theses, it is deducted that lost of water are from 100 to 1000 times minor that in solid, (and sometimes even minor); therefore the storage or deposition of these solid is very important as a mean to control pollution and there is where preconcentration techniques fall into because decreasing the quantity of mineral to amalgamate also the quantity of polluted solid rests to be deposited or treated decrease.

Table 3. "La Bruja": Mercury Losses In Almalgamation Of Previously Washed Mineral With Activated Mercury During 2 H.

MERCURY USED (Kg Hg/t)	MERCURY LOST (g Hg/100 g Au PRODUCED)	
	IN WATER	IN SOLIDS
3,5	0,06	6,50
3,0	0,008	2,40
2,0	0,0005	11,60
1,5	0,16	15,30

Operator conditions, mainly in what concern to the previous washed of mineral and the use or not use of mercury previously activated, have a decisive importance in reference to pollution caused by mercury and also in the recovery of gold. In Figure 2 results of using 3 kg of mercury per ton of mineral are shown. 3 kg is the optimum proportion according to Figure 1 with an amalgamation time of 2 hours and in the operator conditions above mentioned.

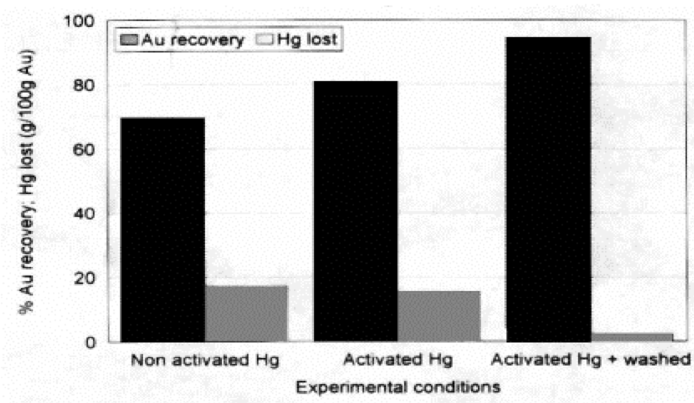


Figure 2

It is possible to observe how the recovery of gold growth significantly by using activated mercury and then by using this mercury upon previously washed mineral, but above all, all what decrease is the contaminant effect which is reduced to a eight part compared with using non activated mercury.

This beneficial effect of the activated mercury and of the previous wash is kept even if the optimum time or the quantities of mercury are not taken into account. It could be said that its effect is even higher in these cases. Thus in Figure 3 the results for a quantity of 3,5 kg of mercury per ton of mineral are shown. The excessive time of 4 hours makes easy lost due to the shred of mercury and amalgam (formation of mercury flour).

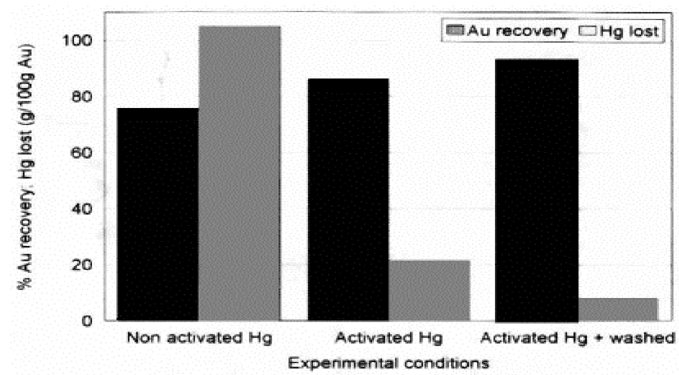


Figure 3

In this case there is an improvement in the recovery of gold, but the lost of mercury are reduced to the thirteenth part. In any case lost are higher that in the case of Figure 2 (2 hours and 3 kg of mercury per ton) and recovery of gold is lower, which show the importance of time of treatment, especially in formation of mercury flour.

Results of essays with activated mercury, at the same level than another conditions, have given better results always, referring to relative lost of mercury that in normal assays with normal non activated mercury. The microscopic exam of the sterile samples of the treatment with activated mercury, previous to a strong shaking to concentrate heavy minerals, showed less fine grains of lost gold than when the assays are done with non activated mercury. Spheres of activated mercury and gold amalgam are joined quicker and efficiently than in the case of non activated mercury, avoiding lost of gold and it requires less mercury for its collection. The amalgam filters better and its appearance is more solid, brighter and united in a mass than later will make it easy the formation of a sponge of gold more compact and easy of extract during distillation in the retort.

The most important aspect of this study is to have determine the function that the previous wash has. In this sense, the assays done during equal time and with the same quantity of mercury, activated or non activated, produced much better recovery of gold and relatively less lost of mercury when the mineral was submitted to a previous stage of washing. This simple operation eliminates grease substances from the pulp, removes the cover or patina that gold grains could have and minimises the action of another "amalgamation benumbed substances" (arsenic sulphurs, antimony, bismuth, lead, iron, copper, etc.) that contaminate mercury and appear in almost all beds of primary minerals of gold lodge type, as in the case of the mineral of the veins "La Bruja" and "La Gruesa".

Another conclusion from the experiments done with previous washing is that it is possible to decrease dosification of reactive and time of treatment to get the same recovery of gold, which implies less costs of production and higher entrances of resources represented by recovery gold and mercury, and at the same time less pollution is produced. Recovery of silver is always minor than those for gold, and the content of silver of the recovery gold is always just something higher than the content of silver of the native alloy gold–silver, which show that silver alloyed with gold is only amalgamated and almost nothing of this metal content in sulphurs.

The mineral from "La Bruja" is too rich in gold to be taken as a general case, although it is very illustrative of the efficacy of different used amalgamation processes. The mineral from "La Gruesa" represents in a better way most of minerals of lodge type from South America.With it, it is possible to see the same tendency, but because it has less content in gold, recovery are lower and lost of mercury per kg of recovery gold are higher. But working in the optimum conditions (using 3 kg of gold per ton of mineral, activated mercury and previous washing of mineral in 2 hours time of amalgamation) it is possible to get recovery of 92 % in gold and lost of mercury of about 8,6 % per each 100 g of produced gold. These are from 20 to 100 times less than common lost dated in done studies about this topic.

To see the influence of the used technique the Figure 4 shows the case of using optimum conditions referring to mercury quantity and amalgamation time (3 kg/t, 2h). It is possible to see how recovery increases until 92 % and it remains to 2 points under of "La Bruja" case, and also how the lost of mercury are decreased as well, although they are higher, mainly with non activated mercury, than in the case of "La Bruja", in such a way that it has been necessary to amplify the vertical scale of the graphic.

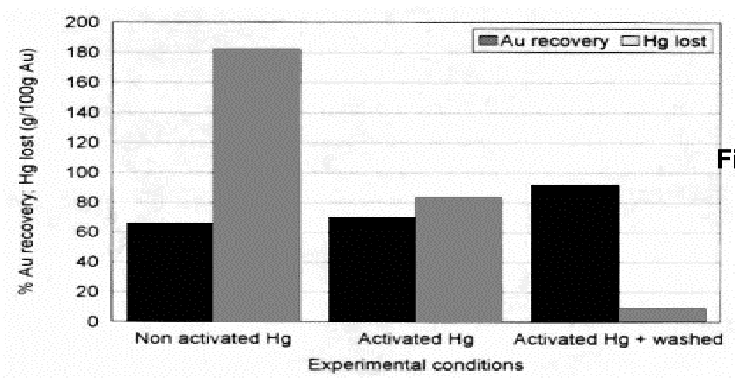


Figure 4

It non optimum conditions are used, as for example an excessive time of 4 hours (for the same quantity of mercury 3 kg/t), recovery of gold decreases and lost of mercury increases, as the Figure 5 shows. The scale of lost has been expressed in g per each 10 g of produced gold in order to get an adequate height of the bars. In this case, for activated mercury and previous washing of mineral, lost of mercury is 31 g per each 100 g of produced gold, that is, it has been multiplied by 3,6 times comparing with optimum time. Also the recovery of gold has been lower passing from 92 % to 86 %, approximately.

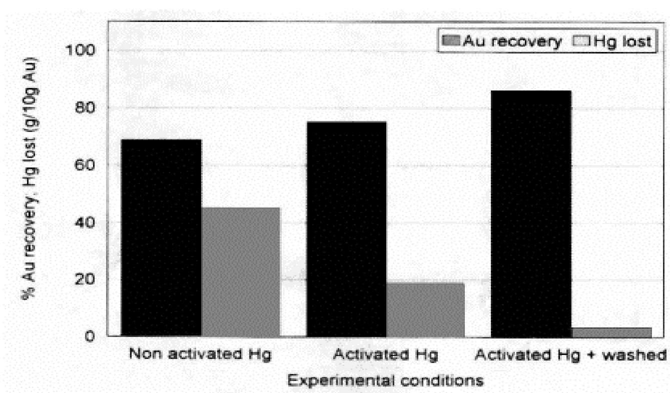


Figure 5

In the same way, the use of inappropriate quantities of mercury leads to worst results. Thus, if just 2 kg/t are used in the optimum time of 2 hours, results are shown in Figure 6, where it can be see a fall of recovery of gold, while lost of mercury are high (minor than with 4 hours, Figure 5, but higher than optimum conditions, Figure 4). Therefore, with previous washing of mineral and activated mercury, mercury lost are of 29 g per each 100 g of produced gold.

The most of the lost of mercury is produced with solid rests; they are the main potential source of pollution by mercury for future and they will demand an adequate deposition or a treatment, in many cases impossible to be done by the small miners. To investigate the possibility of reducing this contaminant fact, preconcentration of gold has been tested in a Wilfley Table, known and reliable equipment that can works with electric or hydraulic energy, because it requires a lower power.

In essays done with milled minerals in less than 0,25 mm the simplified results shown in Table 4 have been got. They have used a stage of hewing and another of trimming which produce a concentrate of lower weight and a very high sterling that could be benefited by direct fusion and a second concentrate which is that one treated by amalgamation.

Table 4. Wifley Shaking Table Preconcentracion

FRACTION	"LA BRUJA"				
	WEIGHT (%)	ASSAY (g/t)		RECOVERY (%)	
		Au	Ag	Au	Ag
1° CONCENTRATE	0,11	88,885	25,877	32,21	14,45
2° CONCENTRATE	28,22	623,20	368	63,54	52,74
TAILINGS	71,67	17,96	90,12	4,25	32,81
TOTAL	100	303	197	100	100
FRACTION	"LA GRUESA"				
	WEIGHT (%)	ASSAY (g/t)		RECOVERY (%)	
		Au	Ag	Au	Ag
1° CONCENTRATE	0,04	22,594	8,256	20,75	2,55
2° CONCENTRATE	16,69	164	306	62,86	39,46
TAILINGS	83,27	8,57	90,10	16,39	57,99
TOTAL	100	43,50	130	100	100

It has seen how the rendition and the recovery of gold in preconcentrates is high, mainly in "La Bruja" case, due to its higher initial riches and it is possible to see how the quality of solids have been reduced considerably.

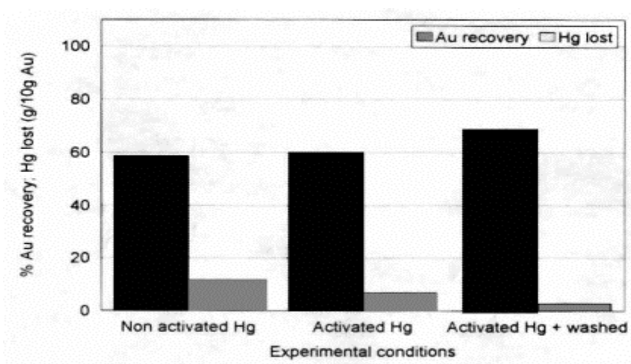


Figure 6

In "La Bruja" case the sum of the two concentrates reaches a 95,75 % of recovery. In "La Gruesa" case it reaches a 83,61 %. In the first case recovery is higher than in direct amalgamation but in the second it is lower. The second concentrates of both minerals have been amalgamated using the three variants of normal mercury without activating, activated mercury and previous washing of mineral and activated mercury. The results are given in Figures 7 and 8 for "La Bruja" and "La Gruesa" respectively, being recoveries in optimum conditions of 97,82 % and 97,42 % respectively, that means very good recoveries in this phase of amalgamation. Taking into account the global process concentration–amalgamation recoveries lay in 94,37 % and 82 % respectively, being similar the recovery to the direct amalgamation for mineral from "La Bruja" and lower for mineral from "La Gruesa", and therefore in this last case the preconcentration would not be well accepted by miners.

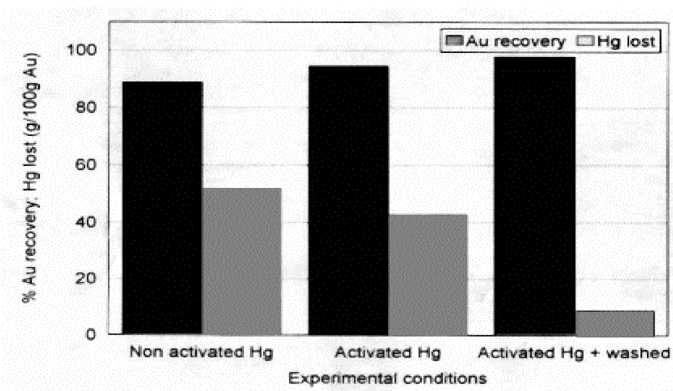


Figure 7

The mercury lost, in optimum conditions, are from 8,5 g and 15 g of mercury per each 100 g of produced gold in amalgamation, and if we have into the account the recovery gold in the first concentrates the results would be of 5,6 g and 11,3 g of mercury respectively, for each 100 g of produced gold because they are of the same order approximately than in direct amalgamation, but they are content in a lower volume of solids, that would be a 28 % of initial in "La Bruja" case and a 17 % in "La Gruesa" case, which would make easy its control.

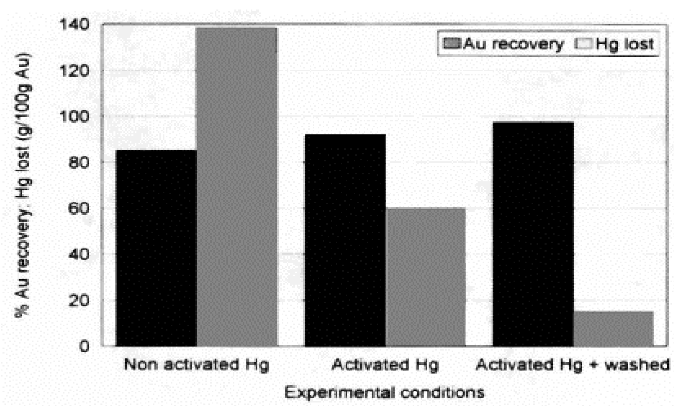


Figure 8

In the same way, by doing a balance of the advantages of concentrates amalgamation coming from gravimetry it must be considered that investments and expenses of production are lower than the whole mineral is processed due to the reduction of mass to be treated. Versatility and simplicity of combination of gravimetric concentration methods in a table for shaking, barrel amalgamation and direct fusion, added to its lower cost and great efficacy make that this system can be taken into account at the moment of planning an exploitation, especially because of the reduction of volume of polluted material and that it must be essayed in order to determine results that can be waited and its profit or convenience.

Flotation as a possible preconcentrator process has been researched, although it could be a technique which implies greater investment and greater knowledge. In the case of direct flotation over original minerals after milling at 0,125 mm, recoveries in both cases are of 91 %, lower than direct amalgamation, although the mass of concentrates is reduced to 8 %–9 % of the initial mass, which is an indubitable ecological advantage.

Flotation of tailings of the concentration table, after milling at less than 0,125 mm gets a concentrate that it could produce an increasing of recovery of gold of 2,5 points in “La Bruja” case and of 11,49 points in “La Gruesa” case, which makes of the gravimetric concentration and flotation improves recoveries of concentration on an isolated table and allows an important reduction of volume of polluted solids, due to the volume of the flotation concentrate is very small compared to the table one.

CONCLUSIONS

In amalgamation process mercury electrolitically treated through using a simple equipment named “mercury activator” produces best results than normal mercury increasing the recovery of gold and decreasing lost gold and therefore, decreasing pollution.

The fulfilment of a simple operation of “previous washing” of mineral with detergent and alkalis, before the amalgamation stage reduces ostensibly lost of mercury and increases notably recovery of gold.

An optimum dose of mercury and an optimum time of treatment, easily deducted by experimentation, lead to decreasing of lost of mercury and gold.

A gravimetric concentration previous to amalgamation process reduces the quantity of material to be processed and therefor e the quantity of polluted by mercury rests, whose treatment and deposition are much more easy and of lower cost than the handling of sterile things result of amalgamation of neat mineral. In each case it must be study its viability and convenience.

Amalgamation of table concentrates in barrel with activated mercury and previous washing, combined with and adequate dose of reactive (Hg) and an optimum time of treatment, produces a recovery of gold almost whole, that must be corrected by recovery got en gravimetric concentration, which turns is the controller of the global process.

Concentration on table followed by flotation of rests and amalgamation lead to good results but is a technical complicated system that demands greater investments and higher costs of operation. Therefore its possible application is doubtful in small mining.

BIBLIOGRAPHY

(1) Pantoja Timarán F. Doctoral Thesis. Universidad Autónoma de Madrid–E.T.S.I. de Minas de Madrid, Spain. 1999.

(2) Wotruba, H., Hruschka, F., Hentshel, T. y Priester, M. Manejo Ambiental en la Pequeña Minería. MEDMIN-COSUDE. La Paz, Bolivia. 1998.

(3) Minas de Almadén y Arrayanes, S. A. Actuaciones preventivas en el Campo de la Salud Laboral. Revista QUÍMICA E INDUSTRIA. Madrid, España. 1994.

(4) World Health Organization. Methilmercurio. WHO. Geneva, Switerland. 1990.

(5) Corporación Autónoma Regional de Nariño-CORPONARIÑO. Aplicación de un Plan para Minimizar la Contaminación con Mercurio. Pasto, Colombia. 1994.

(6) Neisser, W. Estudio del Efecto Ambiental Producido por el Empleo de Mercurio en la Pequeña Minería del Oro. Proyecto de Fin de Carrera. Pontificia Universidad Católica del Perú. Lima, Perú. 1995.

(7) Lacerda, L. and Salomons, W. Mercury in the Amazon: ¿ A Chemical Time Bomb? Nitoroi, Brasil. 1991.

(8) Malm, O., Pfeiffer, W., Souza, C. and Reuther, R. Mercury Pollution Due to Gold Mining in The Madeira River Basin , Brasil. AMBIO. Udderalla, Sweden.

(9) Hruscha, F. Utilización del mercurio en la Minería Aurífera y las Experiencias en la Implementación de Alternativas para el Mejoramiento y Sustitución de la Amalgamación. Loja, Ecuador. 1994.

(10) Cuadra, A., García Carcedo, F., Hernández Fernández, A. Ayala Montes, N., García Ventosa, E. Proceedings. Internacional Mining and Evironment Congress. 1999.

(11) Jackson, N.H. Memorias. I Congreso Internacional del Mercurio. Barcelona, España. 1974.

(12) Fernández-Tallante, M., Cuadra, A. y Limpo, J.L. Rev. Metal. 1969.

IMPORTANCE OF THE CLOSING OF MINES IN THE EXPLOTATIONS OF VEIN GOLD IN COLOMBIA - GREEN GOLD FOR THE SUSTAINABLE DEVELOPMENT

Maria Esperanza Lopez Gomez
Ing. M. Sc. Mines and Metallurgy, Professor and Investigator. Depto of Metalurgic and Materials ing., Group Gipimme - ANTIOQUIA UNIVERSITY; Medellín - Antioquia – Colombia; A.A.1226 Tel: +57-4-2105542 Fax: +57-4-2638282; Email: melopez@udea.edu.co

1. Introduction

Colombia has an important tradition in the gold production, that goes back to pre-Columbian times. The conquest in this country on the part of the Spaniards, was impelled to a large extent by the myth of " Gilded ", who listened to speak mainly of the treasure in the diverse regions and in Guatavita, although this myth we also found it related to other regions of the country where the main indigenous cultures were located.

The development of the mining in indigenoys epoch was on small scale, the natives used gold for its jewels and also it was importantin their religious rituals, the impact to the environment caused by the extraction of gold in that period was very slight. The environmental impacts of the indigenous cultures, though very serious that were, did not happen to represent local or regional effects around their own civilizations.

The society evolved and is as well as the establishment of another scale of values causes that this precious metal is a symbol of wealth, there are discovered important properties such as that it is a good conductor of electricity and heat, its malleability and ductility. All this did that the mining of gold, will be developed on a great scale and without considering the environmental impact that was generated by the mining explotations.

The studies made by organizations of the Colombian State as the INGEOMINAS maintains that Colombia has a high geologic-mining potential all over its territory and it is due to which good part of the economic history of the country, has depended in greater or smaller proportion of the mineral operation, specially of gold.

The resources are exhausted, the environment is contaminated; the modern development is threatening the total order of the life and is then when there is to raise the sustainable development in the activities that the man executes, a change process in which the use of the resources, the direction of the investments, the direction of the technological development and the management of the institutions must objectively take care of the human necessities of the present and the future. With the sustainable development it is tried to give a turn to the development concept, trying to conciliate the economic growth with the quality of life of the towns, with the social welfare and the preservation of the environment.

The gold is a resource, whose sustainable operation it can generate social wealth with environmental responsibility, becoming this way the auriferous potential of the country a source of development for the communities that live in regions where this metal abounds.

The sustainable operation of the mining must contain as a last fundamental step an adapted *closing of mines*, later to make of course, the previous steps in a project of mining exploration as there are those of prospection and exploration, planning and assembly, explotation, processing and metallurgical extraction of gold.

In this work important elements are contributed that they can be taken to the practice and thus to be able to operate in a rational way this gift that has offered nature to us and to have the pride to say that *green gold* for the development of our society is being extracted.

2. The Gold In Colombia

In Colombia which calculates that in the present century approximately 850 ton of gold have been extracted, it does represent more than 50% of the total production in the country through history; production that has responded to the national and international price directly. The macroeconomic importance of gold in Colombia is appraised specially in its participation within the exports and the amount of the international reserves in which they are represented.

Until the Sixties, the extraction of the metal in Colombia was made fundamentally by great companies, within which they excelled those of foreign property. This panorama has changed radically, inasmuch as the small and medium producers come registering a participation flood.

At the present time, Colombia is including between the ten main producers in the world-wide scope, and is the second of Latin America after Brazil. The main exploitation system is the alluvial one, that in 1991 contributed 78 % of the production, measured by the purchases of the Bank of the Republic; the rest was originated in the vein mines.

2.1 Deposits Of Vein Gold

In Table 1 the main auriferous regions of vein mining appear, that is worth to stand out is operated in its majority by methods of underground mining.

Table 1. Gold mining districts of vein gold in Colombia

Regions	Districts
Easterm zone of Antioquia	Zaragoza-Segovia – Remedios Puerto Berrío
Central zone of Antioquia	Murindó Tiribibí Acandí (Chocó)
Western zone mountain	Batolito de Mandé Desert of Frontino Plateado Torrá – Tamaná Cumbitara - Piedrancha
Zone Ibagué - Sonsón	Ibagué Sonsón The Hatillo – Florencia Cajamarca-Salento-The Salitre
Zone Cauca - Romeral	Buga - The Retiro (Valle) Almaguer Marmato- Caramanta (Caldas)
Zone of the South of Bolívar (Mountainous area of San Lucas y Montecristo)	Río Viejo San Martín of Loba Barranco of Loba Montecristo Santa Rosa of the South Morales
Zone Desert of Santander	Vetas - California

2.2 Vein Gold Explotations In Colombia

In Colombia explotations of informal type made by the barequeros are made, they are groups of miners who work tunnels of little dimension or which they extract material of vein of tunnels already left by other companies. Also the formal mining made by the companies of small and medium mining of gold is made. The operation method that is carried out in these companies can define as a variation of the traditional method of rooms and pillars.

The metallurgical extraction of gold is made in spaces located near the zone of operation, or in the municipal heads; generally involves some of the following operations:

- Classification
- Crushing
- Milling
- Concentration
- Amalgamation
- Leaching with cyanide
- Smelting and purification

3. The Originated Environmental Problem In The Vein Gold Mines

The auriferous mining affects the natural resources like the water, grounds, the fauna and the flora. The main environmental problems of the mining of gold are related to the situation of unmannerliness of the explotation, and the inadequate handling and environmental planning of the same ones.

In Colombia, including in the active life of a mine, diverse problems are being generated to the environment such as the collapse of the tunnels (subsidence), generation of the acid rock mine drainage, insuitable waste disposal, change in the run-off and underground waters, in the others. The dimension of this problems is greater when the owners decide to abandon the enterprise for a motives diferent to the deposits finished, it´s very commun in the small mining for lacking of a mine planing and a capital for to invest.

The pouring of the acid drainage of the heavy metal mine, rich, and the solid remainders which they are in waste areas of the mine, which they are remainders with effluents of the process of cyaniding and amalgamation and of the sterile ones of the mine, become activities that alter the water obstacles, because they are drainages that arrive at the water obstacles without before neutralizing them.

Physical-chemistries and biótics of the water change to the characteristics, the result is then, cloudy waters nonapt for human consumption or animal, in addition to the alteration of the ecosystem due to the diminution of present oxygen in the water, to the obstruction of the rivers and bogs, and to the difficulties in the development of the aquatic fauna. A negative impact is generated therefore on the productivity of the aquatic ecosystems, directly affecting the base of subsistence of the communities of fishermen.

4. Importance Of The Closing Of Mines

The explotations that are made in the mining of vein gold, in their majority are carried out by empirical methods, without no quantification of gold reserves and only by means of superficial geologic recognitions. The explotations are effected without mining planning and with rudimentary techniques of extraction. Lack planning, suitable technical methods and the technology that is had is not the adapted one, the methods are still very manual. As a result it has a low productivity, the investments are low and limited, that is to say, it is expensive in economic and environmental terms.

Before this panorama it is necessary that besides to legislate itself a control in the environmental part of the mining by means of a system of environmental monitored with the participation of the local authorities exists, mining companies and local communities, so that therefore can be fulfilled what the Code of Mines of Colombia says that prohangs by the conservation of the environment by means of mechanisms such as:

- Exigency of the Environmental License.
- Monitoring and control of the form as it is made the use, conservation and restoration of the natural resources.
- Referring coordination with the environmental authority for the expedition of norms, instructions and orders to the environmental part of the mining.

The mining is a necessary activity for the development of any society, nevertheless the environmental deterioration that causes its controlled execution has not lead to that a social and legal exigency settles down to recover and to diminish the environmental impacts.

Environmental exigencies and fulfillments in all the passages of a mining project and in special must exist in the related thing to an adapted closing of a mine in such a way that the environmental damage can be recovered and be compensated that can have been generated.

In Figure 1, a model of operation of the mining cycle appears which must include a suitable closing of mine to avoid the aggression with the nature. After coming to extract the mineral resource, a later restoration is due to have and a series of environmental measures is due to execute, because otherwise these lands will be left in a situation of degradation without advantage possibilities.

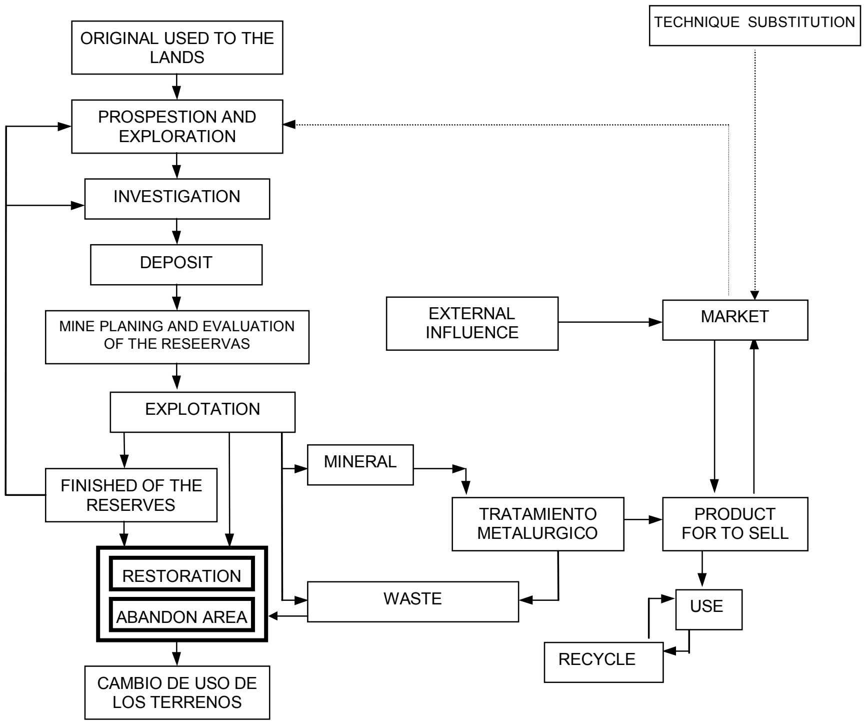


Figure 1 – Model of the operation to the mining cycle

A suitable plan of closing or abandonment of mining activities must contemplate the following aspects:

- Annexed supervision of the dismantling and activities
- Suitable evaluation and approval of works and activities of environmental restoration
- Final evaluation, identification of residual and alternative effects of solution
- Preparation and sustenance of all the information even the environmental design of the project and authorities

5. Aspects To Contemplate In A Closing Of Mines

5.1 Closing of Accesses

Once closed the mine it must be coming to its sealing by means of the construction of docks or bandage of closing of mine entrances and mouths diagonals or drums, with sufficient security and durability. The seal to place must prevent the oxygen entrance, of such form that prevents the formation of acid drainages of the mine. The seal must be of low permeability, like grounds of fine texture, the synthetic clays or slime, or materials.

5.2 Control of Effluents Liquids

It is made with the objective to avoid the pouring of residual waters of the mining to the environment without no previous processing and thus to prevent the superficial water contamination by residual and underground water pourings. One is due to carry out in the phase of dismantling of the mine.

With a good control of effluents the alteration of the physical and chemical quality of the water of the receiving bodies in the related a is avoided: pH, dissolved, mineral solids dissolved and solid suspended.

In the mining of vein gold, the gold is associated to sulphides and acid drainages of mine form, which are generated by the exhibition of sulfhides, mainly pyrite, to the air and the water; giving like result the production of acidity and high metal concentrations and sulfur. When the formation of acid drainage of the mine exists it is necessary to apply a neutralization technique, the used and more applicable technique is the lime addition, by its low cost and efficiency. This technique is made in five stages of processing: the homogenization, the mixture, the ventilation, the sedimentation and the final disposition of the remainder mud.

Also it is necessary to control the liquid effluents the solids in suspension that increase the turbidity of receiving waters, alternating the ecosystems. For the processing of solids in suspension of the mining drainage, sedimentations to gravity by means of the temporary storage of the water set out. These wells, tanks or lagoons of sedimentation must have a low speed of flow that allow the sedimentation of solids in suspension.

The processing of dissolved solids and the stabilization of pH, are managed by means of the ventilation of the mining drainage to favor the oxidation, this can be obtained making the water run through slopes by means of artificial cascades, with limestone rock beds of different sizes, for the stabilization of pH.

Another aspect to have is the fracture faults or on the rock induced by the mining that penetration sites allow that the underground or phreatic waters find footpaths, presenting towards the mine and becoming mechanisms of particle transport in suspension, of heavy metals, sulfur and of some metallic ions. It is very important then to characterize the deposit previously to be able to predict if the acid drainages of the mine will form.

The control of liquid effluents contain the processing and final pouring of mining remainders, it is due to disassemble and to close the mechanical systems of drainage and by gravity, except the constructed ones for the run-off water handling. The waste area of sterile must tell on a system of harvesting and processing of the run-off waters that have entered in contact with them, before being spilled to a water body or to infiltrate it in the ground.

He is recommendable which the waters that have journeyed on sterile materials and the originating ones of mining drainages are intercepted and lead to systems of processing by means of waterproofed channels.

All these workings of closing of mines must be in charge of the person in charge of the operation contract. The technical attendance and pursuit of the development of these activities must be in charge of the environmental authority.

5.3 Control of The Subsidence

The extraction of minerals and rocks of the terrestrial crust by underground workings potentially causes movements of the land and deformations of the surface, that is known with the subsidence name.

The operation method that is made in the gold explotations in Colombia is the one of rooms and pillars, with some modifications. This method indeed causes the phenomenon of the subsidence, more if it considers that the workings of the small mining are developed less than 50 m of depth and to this depth important implications in the stability of slopes are had. The underground excavations of the type of rooms and pillars collapse of unpredictable ways. Exceptionally works located to more than 150 m of depth can produce collapses, causing damages to the superficial structures. The main mechanisms of deterioration and collapse of these underground works are three:

- Swelling of the floor

- Crushing of pillars

- Collapse of the ceiling

From the environmental point of view, the importance of the mining collapses is bound to three main factors:

- The extension of the affected surface

- The present and future use of the land in the affected area

- Type of magnitude of the movement of the land

In the mining explotations the pack one is due to consider, to diminish the magnitude of the vertical displacement, also it is due to try to make partial or harmonic an extraction. In the sites where they are detected superficial cracks some technique of sealing or cap is due to use which it can use the material of the slime or clays, impermeable or geotextiles fabrics, gravel and the slime. For the collapses in chimney form, produced by the technique of cameras and pillars, closings in form of pyramid or inverted cone will be able to be used.

5.4 Waste Area Adjustment

It consists of the adjustment of slopes and slopes of the waste areas of and the solid effluents of metallurgical process of extraction making the reforestation workings and thus to integrate the waste area from sterile to the natural landscape of the area.

With the adjustment of the waste areas the permanence of this type of land in the landscape of the zone is avoided, causing a positive visual impact, also prevent the slidings and landslides of sterile material to leached adjacent lands and something very important are that the formation is prepared with, that in case of forming could transport contents of zone.

The slopes must have a suitable height, according to the type of material and must be contemplated to the rectification and reconstruction of channels of water harvesting rains.

All waste area of sterile must be located far from all source or water body, as minimum 30 m of the border of any type of channel, continuous or intermittent and consider hydrologic the conditions local. Its location must obtain that any observer sees the smaller amount of rubbish throughout slopes, avoiding preferably the vertical rubbish accumulation, must consider that exposes the smaller possible area to the predominant direction of the wind.

The capacity of the produced waste area must so be that the total of the sterile ones is handled, allowing the suitable drainage of run off waters and causing the smaller visual impact. The escombrera must guarantee the stability with suitable geometry, constructing around its crown and leg the harvesting channels, conduction of waters of run-offs.

Figure 2 displays the sequence that is due to make when it is tried to remodel an already constructed waste area distributing its volume on a greater surface, will have to retire previously to the existing vegetal earth on the land to occupy, with the purpose of having a base of more resistant support and of the necessary material for the covering and reforestation.

5.5 Reforestation

The objective of this activity is to establish the vegetal cover in the waste areas of sterile.

The impacts that are avoided with this are the following ones:

- Drag solids by run-off waters
- Cracking and later slidings of sterile material
- Negative visual impact
- Alteration of the properties physical-chemistries of water bodies

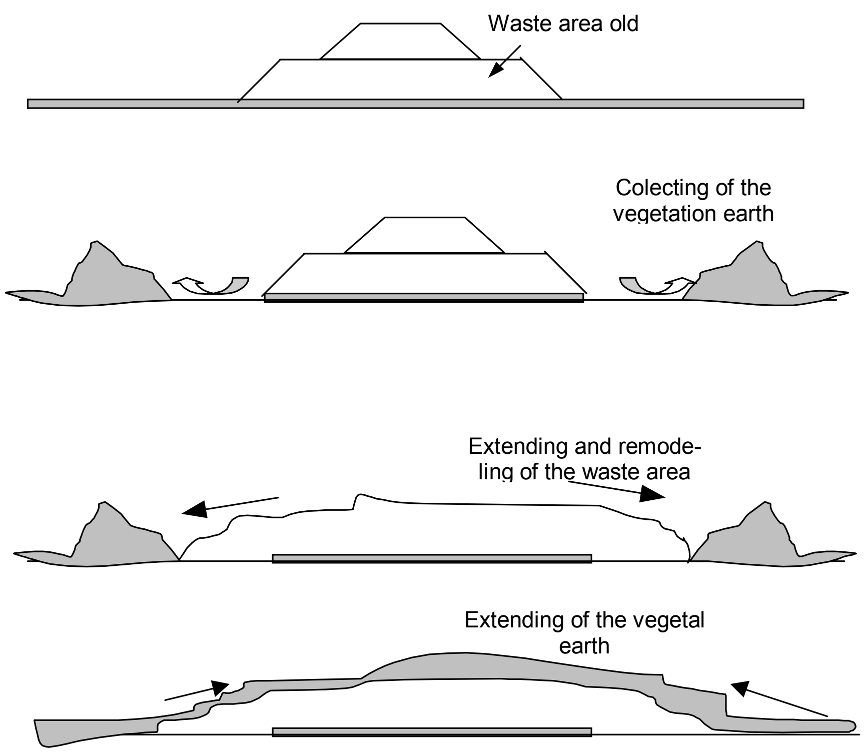


Figure 2 – Phases or the remodeling and the covering with the vegetal earth of the waste area old

The activities to develop in the closing of mine would be the adjustment of the land and relaxation of vegetal layer, sowing of seeds with native species of the region, fertilization and continuous irrigation, during the first three months of growth.

5.6 Protective Reforestation

It consists of seeding native arboreal species, for the long term establishment of protective forests of the hydric resource, and the habitat of the fauna.

It is tried to avoid the hydric erosion of grounds, the definitive loss of springs and water births and the definitive migration of some species of mammals and birds.

Native seeds of arbustivas species of the region are due to seed species, to prepare the land, to seed, with protective characteristics of channels of water and habitat of birds.

6. Conclusions

The explotations in Colombia are interrupted more by socioeconomic conditions not because the gold in the deposit finishes. Despite it is necessary to implement the program of closing of mines to avoid the environmental contamination.

The mining is an important line in the development of a country, by nature causes a negative impact to the environment, the intention is to implement environmental remediaciones to diminish the impact to ecosystems that the explotations surround by gold.

Sufficient investigations and works exist written in our country on closing of mines, is the moment for beginning to apply them and to remove them from the shelves of the libraries and the offices from the environmental authority, to avoid the future deterioration that could be reached.

The environmental costs must be assumed like a long term investment that will offer us in a future, one better quality of life, similar to the one of our Colombian indigenous ancestors.

It is necessary to develop to the mining of gold with techniques and suitable technology, in such a way that they are framed in the sustainable development and thus to be able to reach to produce so yearned

7. Bibliography

FLOREZ, M.T Y PARRA, L. N. Colombia y sus recursos. Medellín: Ed. Universidad de Antioquia., 1998. p.167-172.

INSTITUTO TECNOLOGICO GEOMINERO DE ESPAÑA. Manual de restauración de terrenos y evaluación de impactos ambientales en minería. Madrid: 1989. 321 p.

MINISTERIO DEL MEDIO AMBIENTE - SENA. Guía ambiental para la pequeña y mediana minería y del oro. Santafé de Bogotá: 1998.

MARTINEZ, M. T. Y GOMEZ, G .I. Metodología para desarrollar planes de manejo ambiental en minería subterránea del carbón. Medellín: 1996. 131 p Universidad Pontificia Bolivariana.

SAN GREGORIO PROJECT

Jorge De Los Santos
Montevideo - Uruguay

INTRODUCTION

"San Gregorio" project is an enterprising which has been taking place since the beginning of 1997 at República Oriental del Uruguay where gold deposit exploitation is carried out. It is located in the northeast of the country nearby "Minas de Corrales" city, Rivera. It dates from the first five years of the current decade when intending studies to make a fresh start were initiated to the exploitation of gold –bearing mineral in that area.

Gold detachment process from the rest of the minerals requires the employment of cyanide in the physical and chemical methods. The outcome from the processing gold plant which contains a high percentage of cyanide is stored in a damming named "Relaves Dam" (RD) .This outcome will remain there until the closing works are made once the project is finished. The project operations are bound to be taken at zero discharge to the environment because the liquid coming from the "Relaves Dam" is reinserted in the production circuit.

It is estimated a five- year period of deposit exploitation divided in three steps. Each of them is determined by a volume increase of the "RD" by means of elevating the dikes' crowning.

Cyanide storage in these confinement conditions represents a defilement risk for the underground. To prevent this situation, the recipient where the solution of cyanide is stored was covered with geo membranes increasing the precautions during its location, and at the same time to make sure the damming impermeability.

Nevertheless, a leakage of that dam may be registered which means that cyanide could get into the underground flow. Therefore, a constant revision of the leakage's quality is necessary to detect any presence of cyanide in the underground, evaluate whether the concentration of cyanide is within the average permitted as well as taking the correspondent measures in case the results obtained are not the ones expected.

At present, the revision is carried out through the analyses of water samples which are periodically done by control public organisim DINAMA (National Environmental Management which belongs to the "Ministerio de Vivienda , Ordenamiento Territorial y Medio Ambiente" and with the company that forwards this project by using kits and laboratory analyses.

Until now, only once the presence of cyanide has been detected in one of the wells which was quickly associated with a crack in the geo membrane that coated the RD.

Designing a revision network which adjust to the procedures needed to detect the minimum cyanide concentrations requires a wide range of studies (hydrologics, hydraulic, and hydrogeochemical) which allow us to describe the local underground flow.

Around August 1994 and May 1995, it was possible to create piezometric map using information from 28 existent wells. However, only five of them are currently preserved plus six new ones that were built in March, 2000. All of them are located around "RD" and "Fresh Water Dam". The latter damming is situated upstream from the former, both having a dike in common.

The underground flow was locally altered due to the above mentioned dams and this new dripping system is the matter in question.

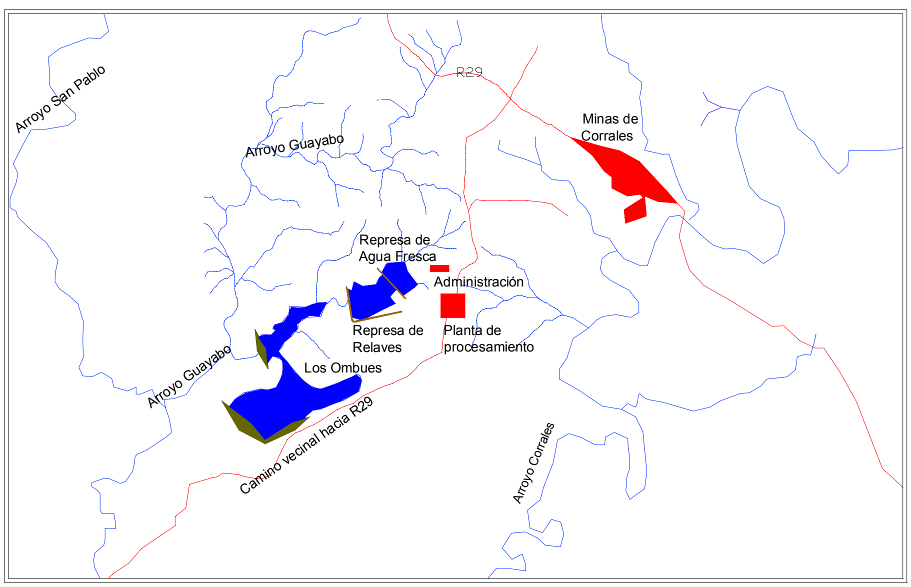
The local geology shows the presence of rocks which possibly suggest an underground flow through an interconnection fissure. According to the wells descriptions, there is a contact zone between the sedimentary source material and the main rock which is a greater aquiferous source than the fissured area.

The hydrologic model of the zone in question will allow us to establish the new wells location which will be incorporated to the network revision. In case any flow comes up, these new wells will assure the proper interception and sampling to detect a contaminant presence.

The study that is being carried out is an interesting matter to follow a preserving environmental policy . Nevertheless, the local characteristic of this study limits the resources available to complete all the tasks that need to be accomplished, but it also requires a precise measure when finished.

Project Description

The structure to exploit the gold-bearing mineral consists of an open air quarry, a processing plant for the removed material, and two dammings: one of them contains fresh water named Fresh Water Dam and, the other contains the discharge of the solid and liquid residues which is the result of the mineral treatment, and is denominated "Relaves Dam". The latter is located below and in a continual position from the former one. The location plant is found in the following plan:



LOCATION PLAN OF THE MINERAL ESTABLISHMENTS

The water for the industrial plant operation comes from the Fresh Water Dam. As the water and cyanide mixture is done during the minerals separation , the liquid with the processing material residues (1.36 density) is led to the Relaves Dam by means of tubes where solid residues deriving from the mineral treatment are discharged. The average poured was estimated as 2500 tons per day. The amount of solid to store 3.75 millons of cubic metres which agrees with 5.10 millons tons of rock to be treated at the industrial plant during the project.

Below the membrane that covers the Relaves Dam is placed a drainage that registers the flowing water and leads it to a not very deep ditch but with a great diameter called Revision Well. The level of this well is constantly maintained by pumping a certain flow of the gully. It is situated downstream of the Relaves Dam and it is also coated with a geo membrane. Water samples are taken from this well which are analyzed at the laboratory. As the above mentioned well is the drainage receptor below the Relaves Dam , it was taken into account as the best place for samples to detect cyanide, and with the five wells reserved, it becomes the network revision that is currently used.

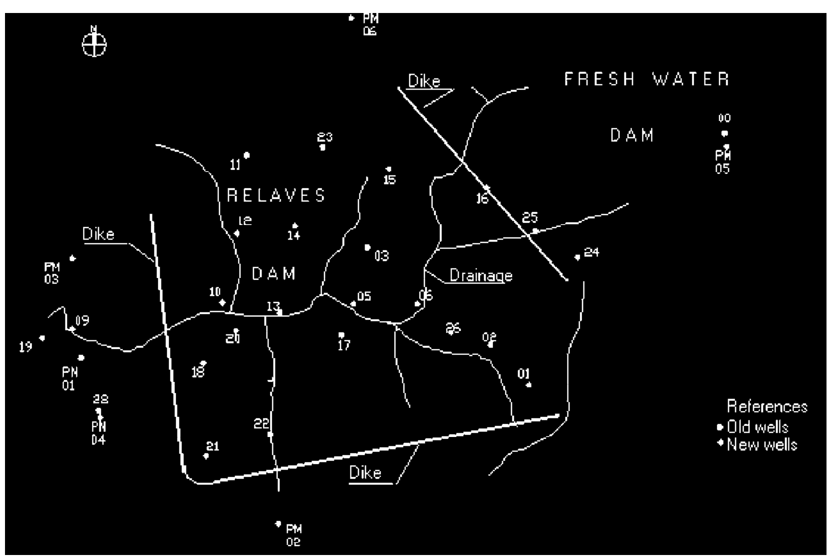
The Fresh Water Dam obstructs the watershed of 168 hás. It was foreseen a flood of 16 hás. The maximum deepness is of 7 metres and the maximum volume of water stored is 538.097 cubic metres.

The Relaves Dam occupies an area of 51 hás. The natural register watershed is of 238 hás from which 168 are obstructed by the Fresh Water Dam. According to the Engineering Project, besides the above mentioned measures, it must be added ,the necessary works to assure that the only contribution of water to the Relaves Dam (regardless the industrial process) comes from the direct pouring rain on the area intercepting another natural contribution by means of channels.

This dam contains a permanent water solution with cyanide with a concentration of 20mg/l , and the hydraulic charge varies according to the operation of it.

During all the damming operation, the dam would have a minimum of a sea room to retain a design storm that could give a water volume of 450.000 cubic metres (revenge 1.3metres)

The development of the project is carried out in three steps for the deposit exploitation which corresponds to the increasing capacity of the Relaves Dam. The elevation of this dam will reach its maximum height at the end of the third step. After each step is accomplished, the surface of the geo membrane is enlarged.



PLAN OF THE WELLS LOCATION.

Important aspects of the project

The underground area where this project is carried out is formed with sediments and splitting rock. The aquiferous is created where both sediments and splitting rock are touching each other.

Although the most important flow may take place in the porous area, it is necessary to identify the presence of a fissure system which could create ways of underground dripping of a logical magnitude

In terms of mineral establishments' construction, the location of the Fresh Water Dam up upstream which shares the same dike with the Relaves Dam, produces a dilution source when contaminant concentration is measures. This situation is increased in case samples are taken from the Revision Well.

Studies that have been carried out led mainly to determine the underground flow while identifying the respective proportion of the outcoming coming from the flirtation of Fresh Water Dam.

Within the preliminary studies, it was worked with monthly information of different parameters measured by the company as static level, pluviometry, temperature and water level in both dams. It has been intended to identify the connection between the wells and, indirectly, the fissures systems by means of the observation of the static level represented in the 28 wells and rains in the same period. The same goal was followed when Multi Varied Analyses Techniques were applied to the static level variations of the 28 wells. In that moment, it was concluded that two wells located in both extremes upstream and downstream from the ponds system had a similarity with the static levels. This might indicate an hydraulic connection between them, narrower than whichever other two wells that were nearer. The chemical analyses of the water samples carried out by the company gave the same results in terms of samples similarities ;except to the nitrates content which was different between one sample and another. This difference might be associated with some human activity nearby one of the wells that could imply this ion presence.

A calculation of the underground flow was done in the area of the studies starting from piezometric information of the 28 wells and estimations about the conductivity of the area. Such parameter will be adjusted through pumping rehearsals.

An hydrologic balance of the Fresh Water dam was put into practice to identify the flow received from the revision well. This flow is displayed in the balance within the loss flow from the Fresh Water Dam. It would get into the underground flow and it would modify it to such an extent that it will cause an important dilution in the water samples taken out to do the control of quality. The loss volume comes from the comparison between the monthly volume of that dam obtained by a hydrologic balance with the real volume that was in that month which was obtained by the measure of the water deepness in the damming and the height -volume curve of the recipient. Although is an estimated tool which may caused great errors for little gullies , it will be done a sensibility adjustment of each parameter. The calibration of this tool will be established by the comparison between the loss flow with the calculated flow by means of chemical substances between the Fresh Water Dam and the Revision Well

The feigning of splitting areas of the membrane are being carried out to assess the piezometric alteration of the area, and in consequence, the flow lines that were affected by the construction of both dams. This would round up the studies to determine the right location of the new wells to extract and analyses samples.

Once the new revision network is established , a new flow model with a contamination leakage will be applied to check out the selection of the sample.

This task of statistics information management and parameters valuation is constantly accompanied with works in the site which generate data by means of static level measurements and extraction of samples to further analyses.

A sounding line was used to outline the drills from which electricity conductivity measures were taken. As it was easy to obtain information as well as its consistency in accordance with chemical analyses results, we are bound to develop this method as our tool to analyze the stem of the underground water.

It was possible to observe the underground material and locate the altered rock layer where is situated the underground dripping by building six new drills. Five drills were incorporated to our daily quality water study from which one of them was bent 60º to obtain ground samples

At the same time, we are looking for a water tracer which comes from Relaves Dam and which can be of simple evaluation. (sodium in the first instance) deriving from the cyanide of sodium added to the process. In terms of usefulness, the first analyses were encouraging, because, even though sodium is an ion which is within the components of underground water, its concentration at Relaves Dam is approximately 20 times larger. For this reason , we expect to be able to estimate the ionic exchange with the area at different places until we can achieve a revision drill as well as assess its use as a tracer in the hydrogeochemical study of water.

DRAWBACKS

Our main drawback is the assignment of interconnected splits (under sediment and rock contact) and its three -dimensional continuity, which is a matter commonly seen when investigations with limited possibilities to perforate are made while taking out ground samples .

CONCLUSIONS

In case a tracer which allows us to decide whether any cyanide contamination (water coming from Relaves Dam) has began to take place, an important stage will have been taken in the hydrogeochemical studies to describe the local underground flow.

A pumping and salinity rehearsals of wells that will be carried out next month, will allow us to obtain an appraisal of the prevailing flow zones.

Our final purpose, and obviously this study contribution is meant to achieve the finding of contamination in elementary investigations circumstances. In case this goal is achieved, the methodology limitations will have been overtaken which implies the lack of adequate resources in the environment preservation

MODULE V

ECONOMY AND FINANCES

IMPROVING ENVIRONMENTAL COMPLIANCE IN MINE CLOSURE: THE CASE FOR A SYSTEM OF PERFORMANCE BONDS

Dina Franceschi
Department of Economics - Fairfield University
James R Kahn
Environmental Studies Program and Department of Economics - Washington and Lee University
Lexington, VA 24450

I) INTRODUCTION

The mining sector presents an interesting challenge in terms of reducing its environmental impacts. Environmental impacts include the emissions of pollutants during the period that mining takes place, transformation of the landscape and the creation of conditions that can lead to environmental problems in the future. Although mining has traditionally been regulated by specifying a set of restrictions on mining activity, this system has not been particularly successful in terms of maintaining environmental quality in areas where mining is currently taking place and in areas where mining activity has been concluded. Although there certainly are examples of mining activity which has been done in a careful, environmentally protective fashion, this is generally the exception. As a consequence, it is essential that we develop a set of new environmental policy tools with which to transform mining into an activity which yields a smaller ecological footprint.

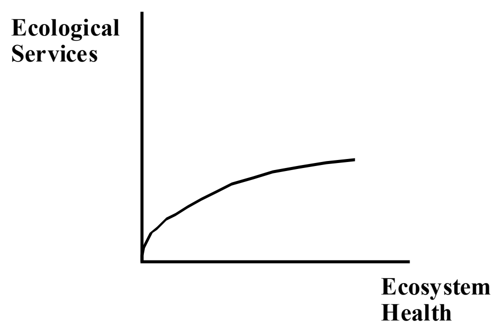
We suggest performance bonding as a policy tool that has the potential to contribute to the solution of the problem. A performance bond refers to a sum of money that is collected from the firm or individual before the potentially damaging activity begins. The money is typically held by the government or a third party (such as an NGO or in an escrow account at a commercial bank) and returned only if the activity concludes within the established restrictions. Although performance bonding has traditionally been used to ensure the restoration of surface mining areas in countries such as the United States and Canada, it has been a narrowly constructed environmental policy. First, it has only focused on the restoration of damages rather than the prevention of damages. Second, it has tends to focus on ensuring a minimum level of environmental quality rather than an optimal environmental policy. Third, it tends to be a discrete instrument, constructed as an “all or nothing” type of control. If the target or restrictions are only slightly violated, the entire bond is forfeited. In addition, there is no reward for exceeding the minimum level.

This paper develops a method which overcomes some of these limitations, transforming the performance bond into a continuous instrument that is capable of preventing damages. Section 2 discusses the structure of the proposed performance bonding system, highlighting its conceptual basis, its theoretical properties, and how it can be adapted to a broad set of environmental needs. Section 3 highlights environmental problems associated with mining in general, with a specific emphasis on mine closure. The section also shows the correspondence between these environmental issues associated with mining and mine closure and the performance bonding system outlined in Section 2. Section 4 provides a demarcation of the dimensionality of these problems both geographically and temporally. Difficulties engendered by temporal and geographical separation are solved by showing how an insurance system can be dovetailed with a performance bonding system. Section 5 details an example of the use of environmental bonding in a hypothetical mine closure example. Section 6 applies the performance bonding system to the artisanal and subsistence sectors of the economy, an area which has proved very difficult to handle with conventional environmental policies.

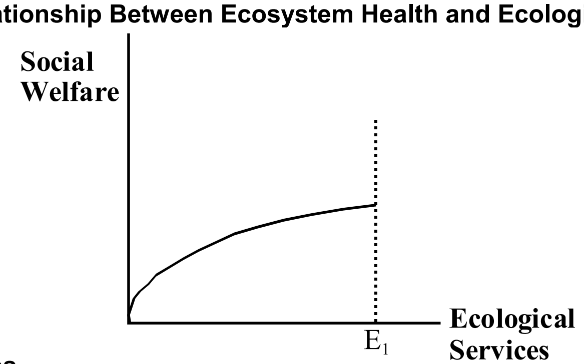
II) STRUCTURE OF A PERFORMANCE BONDING SYSTEM

The proper structure of a performance bonding system will be predicated on the relationship between social welfare and ecological services.[i] A reasonable interpretation of this relationship occurs in Figure 1, where social welfare increases at a decreasing rate as the level of ecological services are increasing. An important observation is that most of the social benefits of increasing the level of ecological services occurs before one reaches the level of services associated with a pristine ecosystem, which is E_1 in Figure 1.

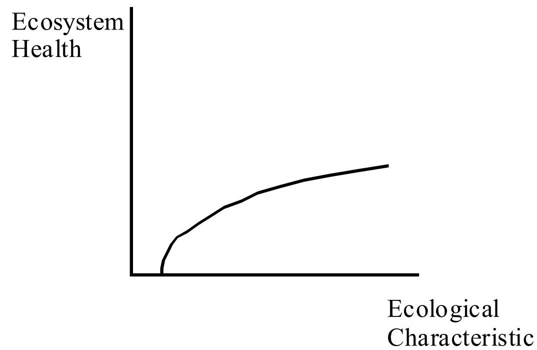
A similar relationship exists between ecosystem health and ecological services. This relationship is depicted in Figure 2. However, from a policy perspective one might want to focus on key ecological characteristics which contribute to ecological health, since ecosystem health is an outcome rather than a choice or control variable. The relationship between an ecological characteristic and ecosystem health is contained in Figure 3. Note that in this depiction, the ecosystem crashes as the level of the ecological characteristic approaches a low, but positive level[ii]. The three relationships in Figures 1-3 can be linked to derive a functional relationship between social welfare and a key ecological characteristic. This is done in Figure 4, forming the basis for structuring a performance bonding system. This relationship can be viewed as measuring the total social benefits (TB) of the ecological characteristic. TC represents the total costs of obtaining the ecological characteristic, and is presented in this graph as a linear function. The linearity of the cost function is chosen solely for ease of exposition, and does not represent a hypothesis concerning the shape of the function.



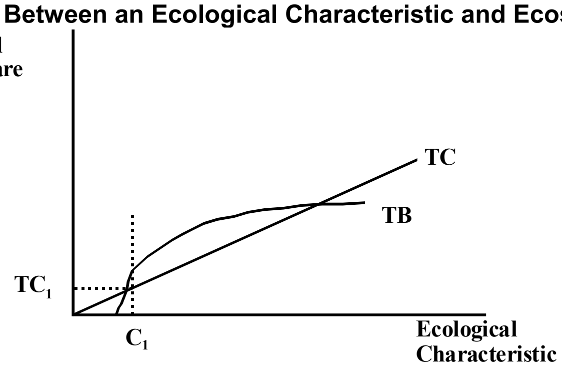
1 The Relationship Between Ecosystem Health and Ecological



Services
2 The Relationship Between Ecological Services and Social



Welfare
3 The Relationship Between an Ecological Characteristic and Ecosystem



Health
4 The Minimum Acceptable Level of the Ecological Characteristic

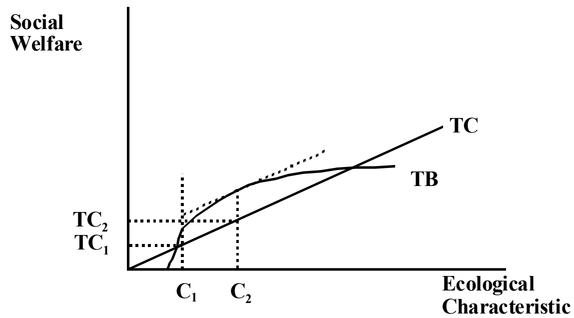
In the traditional performance bonding system, where one seeks to stay above a minimum acceptable level of environmental quality, C_1 would make a good candidate for the definition of the standard. The definition of a level such as C_1 allows one to remain above the collapse point, with an adequate margin of safety to guard against uncertainty associated with either measurement error or stochastic events.[iii]

To assure that the level of the ecological characteristic remains above C_1, the magnitude must exceed TC_1, the cost to the firm of maintaining the ecological characteristic at a level of C_1. The amount by which the performance bond should exceed TC_1 will be a function of the firm's perception of the probability of forfeiture from violating the standard (the expected value must exceed TC_1) and also will be related to the existence of random variables or measurement error in the total cost function.

However, as mentioned in the introduction, this system does not move society towards the optimal level of the characteristic. The optimal level of the ecological characteristic would be C_2 in Figure 5, where the marginal cost of obtaining the characteristic is equal to the marginal benefit of the characteristic. In this case, the magnitude of the performance bond must exceed TC_2 in order to generate the optimal level of the characteristic.

Returning the Performance Bond

If one is only interested in maintaining the minimum acceptable level of environmental quality the procedure for returning the performance bond is relatively straight forward. The bondis returned if the minimum acceptable level is exceeded, and forfeited if the minimum acceptable level is not attained.



5 The Optimal Level of the Ecological Characteristic

Unfortunately, a corresponding procedure will not work well if the optimal level of the characteristic is the policy target. The reason for this is that if the whole performance bond is forfeited for missing the optimal level of the characteristic, the firm will have no further incentive to maintain environmental quality, and will allow it to decline towards zero. When focusing on the optimal level of quality, there should be a small penalty for being slightly below the optimal level, and large penalties for being far below the optimal level. This structuring of penalties is very important given that the total benefit function is increasing at a decreasing rate, and is likely to be relatively flat in the vicinity of the optimal level of the ecological characteristic. If the total benefit function is known (or if an estimate of the total benefit function is available) then a continuous function of returning the performance bond can be developed as in Equation (1). This function specifies the fraction of the performance bond which is returned, where TB_2 is the level of total benefits associated with the optimal level of the ecological characteristic, TB_1 is the level of total benefits associated with the minimum acceptable level of the ecological characteristic, and TB_x is the actual level of the environmental characteristic at which the firm leaves the effected area.

$$P = \frac{TB_x - TB_1}{TB_2 - TB_1} \tag{1}$$

If $TB_x = TB_1$ (where TB_1 equals the total benefit associated with the minimum acceptable level of the ecological characteristic), then the numerator of Equation (1) will be equal to zero, and all of the performance bond will be forfeited. If $TB_x = TB_2$ (where TB_2 equals, the total benefit associated with the optimal level of the characteristic), the numerator of Equation (1) will equal the denominator, and all of the performance bond will be returned. As one moves from C_1 to C_2, the proportion of the performance bond which is returned increases at a decreasing rate, according to the slope of the benefit function, as illustrated in Equation (2).

$$\frac{dP}{dC} = \frac{dTB_x}{dC}\left(\frac{1}{TB_2 - TB_1}\right) \tag{2}$$

III) ENVIRONMENTAL PROBLEMS ASSOCIATED WITH MINE CLOSURE

Mine closure presents a whole host of potentially long term environmental effects that must be addressed preferably prior to the beginning of mine operation. Most mining firms committed to environmental compliance have found that if the issues are identified and addressed early in the process while recovery efforts are made throughout the life of the mine, environmental mitigation costs can be minimized. In this case, if environmental compliance is sought throughout, there is no reason to believe that the environmental bond should not be returned in its entirety.

Probably the most significant environmental concern with regard to mine closure is the land surface alteration and degradation that occurs due to mining operations. Reclamation efforts vary for every mine depending on such variables as soil type, contour slope, climate, predominant ecosystem, including preexisting vegetation and wildlife, as well as others. For most mining types, many of the issues associated with mining and land alteration are caused by the mining process itself. The clearing of property and then moving of massive amounts of overburden result in a substantially different topography than had originally occurred on site. Although often times, costs prohibit returning a mine site to the original landscape, efforts are usually required of the firm to integrate the site back into the primary, self-sustaining ecosystem that existed on site before operation began. A key component of mine site reclamation is the choice of proper vegetation and medium term care of the revegetation efforts. Vegetation selection will impact almost every aspect of site reclamation, especially the mitigation of erosion and the return of wildlife.

In addition to land use, both water and air quality are of concern during the post-mining phase. After pit and plant closure, the primary source of air pollution is a result of the increase in dust particles caused by soil erosion and transport. (During mine operation, dust, heavy metal particulates, toxins and other noxious pollutants can plague mining and beneficiation processes. These emission are reduced after production ceases when studies have shown ambient concentrations to diminish.) Proper dust suppression techniques, when employed through the production and closure phases of operation can minimize the extent to which post mine damage impacts the surrounding community. Here again, proper revegetation, as well as careful slope contour, can maximize air quality.

Water quality is often compromised during mine operation on site and downstream of production facilities. Issues can vary, depending on mine type. The major problems include acid mine drainage, sedimentation, groundwater disruption, ground or surface water movement and availability disruptions, and toxic leachates. Water control and treatment can occur both in-process and/or end-of-pipe. Technology to mitigate or recycle waters contaminated by effluent wastes, e.g., simple sediment or metals, from production processes is well developed. The minimization of water discharged from the system reduces impacts by limiting either sediments or toxins from entering a local water flow. Surface water runoff can be mitigated by erosion control techniques. The issue of tailing pond leakage or evaporation however, is a more difficult problem. Potentially hazardous effluent discharge, e.g., cyanide effluent, in the case of gold mining, requires careful monitoring and quick response. Any of these issues during mine operation can cause high concentration of effluents which complicate cleanup, closure and bond return.

One of the most common post production water quality concern is acid mine drainage. Water percolates through an abandoned mine site, carrying away any number of mining related contaminants. Careful long term monitoring of the mine site and water testing is necessary to prevent heavy loads of contaminants entering local water flows. Mine site pumping to keep water from collecting in mine sites and/or treatment of the flows is sometimes required. Finally, long term impacts on underground aquifers from subsidence or backfilling post-production, are also sometimes problematic. These occurrence can be unpredicted and also very difficult to reconcile. The environmental bonding system proposed can include a lagged return period, where the bond monies are returned over the course of several years, post production, to facilitate medium and long term monitoring.

Above all the most crucial and complicated component of environmental concern associated with the mining process is the characterization and evaluation of potential impacts before they occur, prior to mine operation. The EIS (environmental impact statement), required in most countries' environmental regulations, facilitates the inventory of existing environmental assets and estimates potential problems and conflicts between the mine operation and the surrounding ecosystem This process is key to the accurate assessment of the environmental bond. In the mine closure phase of production, the challenge is to meet the prescribed environmental quality standards set out by the EIS, while still remaining within production cost limitations. Of course, the bond is designed to ensure that funds are available for clean up in the event that the firm defaults on their promise.

IV) Demarcation of Issues

There are a set of related environmental issues associated with mining and mine closure. First, there are environmental problems associated with mining as the actual mining takes place. These include run-off of sediment, acidified waters and other types of emissions. Second, there are issues of alteration of the landscape and its impact on the ability of the impacted environmental systems to provide ecological services. Both of these types of problems can be adequately handled by performance bonds exclusively, or in combination with other environmental policies such as pollution taxes or direct controls. However, the same statement can not be made with respect to environmental problems associated with mine closure.

The reason that mine closure is more difficult to regulate is temporal in origin. The mine closure must leave the mine and the surrounding environment in a condition that minimizes present and future problems. However, this condition is not self-perpetuating and additional steps may be necessary to maintain this condition long after the mine has been closed. For example, tailing pond dams need maintenance, aquifers must be protected against leakages from waste disposal and contaminated areas, and formerly disturbed areas must be protected from invasion by exotic species.

The first step in the process is therefore to define the set of conditions at which the closed mine and the surrounding environment must be left. A performance bond can then be used to ensure that the closed mine and surrounding area are left at or near their optimal condition. However, the performance bond can not be used to assure the continued maintenance of these conditions over time, as the performance bond would have already been returned to the mining firm and could not provide any additional incentive. Since the conditions would have to be maintained in perpetuity, an additional performance bond could not work as there would be no logical termination point at which point to return the performance bond. Therefore, a second policy instrument must be developed to generate incentives for maintaining the site, protecting tailing pond dams, and rectifying any potential hazards or problems which develop over time.

There are several options which are available to provide this long term protection which are all designed to give either the mining firm or a contracted third party the incentives to provide the long-term protection. One potential policy would be just to establish liability for future environmental damages, where mining firms would be legally required to pay damages to society (through the government) and to individuals if and when future environmental damages occur. This is not likely to be a very good policy because firms may have planning horizons that are shorter than socially optimal, so they may not adequately include the possibility of future damages in today's decision to maintain the quality of the closed sight. Additionally, firms to not have infinite economic life, and if firms disappear there is no one to maintain the quality of the site. Note that this is a very different situation than that of establishing legal liability for oil spills. Since oil transportation is always a contemporaneous activity, the firms always have an incentive to maintain appropriate safety levels.

Another possibility would be for firms to be required to by a permanent insurance policy which would insure against environmental damages from the mine site. Insurance companies would then use part of the premium payments (or one time capital payment that they receive) to hire a third party to maintain the closed mine site. Note that this policy not only generates the maintenance after closure, but it also provides the mining company additional incentives to leave the mine in a good condition at closure. The reason for this is that the better the condition of the closed mine and its surrounding environment, the lower the payment that the insurance company would require.

A similar type of policy would be to require the firms to establish a fund which could then be used to pay a third party to maintain the site. This would not be as easy a process, because the government would have to estimate the potential hazards, maintenance require to minimize risk, and so on in order to determine the size of the fund. This would be a similar exercise to establishing the magnitude of the performance bond. Although this could certainly work, it might be better to rely on the market forces and the greater incentive that insurance companies would have to oversee the maintenance process in order to minimize their chances of having to pay an insurance claim from environmental failure of the closed mine.

V) An example from Mine Reclamation

In Amazonia, the concerns surrounding mining operations are much the same as in the United States. Land contour degradation, habitat destruction, water contamination and toxic soil seepage top the list. Much of Brazilian environmental policy related to mining is similar to U.S. policy. CONAMA (National Environmental Council) Resolution # 001/86 (amended 009/90 and 010/90) requires an Environmental Impact Assessment prior to commencing mining activity. Constitutional Decree # 99.274/90 authorizes state environmental agencies to obtain licenses from all mining firms regarding mine planning, environmental control planning during operation, and recovery of degraded areas. This decree also authorizes specialty agencies to license operators in highly sensitive environmental regions, e.g., IBAMA (Brazilian Institute for the Environment and Renewable Resources) has specific requirements for mining in the Legal Amazon. Finally, Decree # 97.632/89 requires all firms to submit a Plan for Recovery of Degraded Areas to be approved by the state environmental agency. Federal, state and municipal governments are charged with carrying out these regulations, however, monitoring in most cases is often difficult with agencies severely underfunded. Environmental bonds are sometimes, but infrequently used to ensure environmental compliance.

First, because of the nature of mining operations there is the potential for many more environmental damages to occur (heavy metal leachate, acid mine drainage, particulate emissions, etc.) during the period of operation than in other extractive industries. Second, because of the huge amount of land mass that is moved during a mining project, it is possible that the land area impacted can never be returned to its original ecological state or land use. Success of a reclaimed area then might be the return of as much of the land area to its initially determined baseline state before mining began, while providing some alternative ecological use with the land that cannot be completely restored.

In the rain forest, the issue of tree and vegetation clearing takes on a greater importance than in many other ecosystem types, as all of the nutrients in this type of ecosystem are stored in the living biomass. Virtually none of the nutrients are stored in the soil. Therefore, replacing the soil and haphazardly planting after mine closure is simply not enough. For a similar style of ecosystem to recover after mining activities are completed, care must be taken in both restoring the nutrient cycle and recreating a distribution of species similar to the original forest system. This is important because the correct habitat must exist to support the animals which in turn are essential to the dispersal of tree seeds that perpetuate the biodiversity of flora.

To ensure the return of environmental quality in this region, the bonding mechanism can be an extremely useful tool. First, we will assume that all of the land can be restored to forest after mining activities cease. If this is the case, a performance bond based on a specialized ecological ratio could enhance the success rate of reclamation activities. This ratio would be conceptually similar to the one defined for the forestry example, except the reclamation process would be dependent on replanting, rather than natural regeneration, because the process of mining would not leave long narrow strips of cleared area that would naturally regenerate.

Criteria used for measuring success of a revegetation project could include:

- the vegetative biomass
- the distribution of tree species
- soil quality (fertility and stability)
- general biodiversity (perhaps measured at a future monitoring date) (Leitch, 1992).
- number of days per year in which fruit can be found in the tract.[iv]

These characteristics could then be formulated into a recovery index (either weighted or unweighted) and then incorporated into a proportionality function in the fashion of Equation (1). Instead of a single ecological characteristic, the proportionality function would be based on the actual level of the recovery index (RI_x), the optimal level of the index (RI_2) , and the minimum acceptable level of the index (RI_1), as in Equation (3).

$$P = \frac{RI_x - RI_1}{RI_2 - RI_1} \qquad (3)$$

Although the above method would give a mining firm an incentive to restore the forest, in many cases, this is not technically and/or economically feasible. For example, if a large open mine pit were required to be back filled for reforestation purposes, the mine might in fact turn out to be economically infeasible. Backfilling effectively doubles the cost of a mining project. Instead, a restoration plan could construct an alternative land use for the portion of the mine land that is not recoverable to the baseline state.

Perhaps the largest pit in a project is slated to become a natural lake, allowing it to fill with seasonal rain water that over time will accumulate. With careful, periodic monitoring of the water quality in the lake, this source of water could provide a set of ecological services (albeit different from those provided by the rainforest) as well as economic services (tourism, commercial fishing, irrigation) and recreational services to area residents.

In the area that is not thought to be recoverable back to the forest baseline, a functionality index will weight the potential of this land's contribution to the forest ecosystem, based on possible ecological values of the area and/or anthropocentric use values. This functionality index would vary substantially based on potential alternative uses. In this example, functionality indicators could include

- water quality of the lake (dissolved oxygen, pH, absence of toxic metals and other contaminants)

- water quality downstream of the lake (dissolved oxygen, pH, absence of toxic metals and other contaminants)

- reproductive success of aquatic organisms

- growth rate of aquatic organisms

- biodiversity of flora and fauna in the area surrounding the lake

- aesthetic value and cohesiveness with original ecosystem of the surrounding area

-recreational quality of the area

The functionality index can be similarly incorporated into a proportionality function:

$$P = \frac{FI_x - FI_1}{FI_2 - FI_1} \quad (4)$$

Implementation of a Performance Bonding System in Mining

The first step in the process of implementation of a performance bonding system in a mining context is for the government to decide upon (or the government and the mining firm to agree upon) a restoration plan. This plan would determine which areas of the mining tract would be restored to its original state, and which areas would be restored to some other function.

For the area that is designated to be restored to forest, the first step would be to identify the components of the recovery index, and weights (if any) to be assigned to these components. Next, a performance bond would be established of a magnitude equal to the cost of obtaining the optimal level of the recovery index, RI_2. The performance bond would then be returned based on the proportionality function of Equation (3).

For the area that is designated to be an alternative land use, the first step would be to identify the components of the functionality index, and associated weights (if any). Similarly, a performance bond would be established equal to the cost of attaining the optimal functionality index, FI_2. As with the recovery performance bond, the functionality bond would be returned according to the proportionality function, in this case, Equation (4).

Monitoring

In the United States, the Surface Mining Control and Reclamation Act of 1977 establishes a system of enforcement and monitoring of environmental compliance both during mine operation and after mine closure. During the environmental inspections, all environmental damage mitigation techniques and environmental recovery indicators are inspected for quality. In the reclamation phase, the factors listed above included in the reclamation quality index can be easily tested as the reclamation process moves forward. Usually, a lag of five years or so is added to the end of mine closure in determining the date for full bond return. This allows environmental auditors to determine if the revegetation procedures have resulted in the beginnings of a healthy recovery of the surrounding forest and vegetation.

This type of hands-on monitoring, however effective, is understood to be a costly aspect of enforcement. These additional costs are the primary reason that environmental monitoring and compliance is so sporadic in many parts of the world. However, if the costs of monitoring are incorporated into the original license fee or into royalty payments, the system can work even in developing countries that typically have under-funded enforcement agencies.

VI) USE OF PERFORMANCE BONDS IN THE SUBSISTENCE AND ARTISANAL SECTOR

We define subsistence activities to include economic activities conducted by families primarily to provide goods for their own consumption. Although some of the production my be sold in markets, the market activity represents a small proportion of total production. In contrast, market sales are the primary focus of artisanal producers. Artisanal producers tend to be small scale operators, with low stocks of capital and unsophisticated technologies in comparison to the corporate sector. Entry and exit from the artisanal industries can be very rapid, for example, the number of artisanal gold miners in the Amazon region varies from 100,000 to 800,000, depending on the price of gold. Examples of artisanal activities include quarrying activities, production of gem stones, gold mining activities, small dairies and ranches, and fabrication of products from recycled materials.

Although subsistence activities and artisanal activities are quite different, they share some common characteristics which increase the difficulty of enforcing environmental policy. For example, both subsistence and artisanal activities often don't appear on the economic "radar screen" and thus are extremely difficult to monitor. In addition, this lack of visibility and extreme mobility in combination with an absence of, or small amount, of fixed assets makes enforcement of environmental fines quite difficult, as it is difficult to fine someone who has no money or visible assets to seize. In addition, there is the very difficult ethical issue of penalizing people who already suffer from poverty. These same characteristics also make the development of a performance bond (with the structure suggested above) very difficult.

However, rather than focusing on penalizing these small scale producers for improper environmental performance, the system we are proposing in this section of the paper would reward these producers for proper environmental performance. The proposed system, which we will call a performance bonus system, can be structured to reduce the problem of encouraging entry.

First, let's look at the case of an artisanal activity, such as the mining of ornamental stone for building facades[5] or wildcat (garimpo) mining of gold.[6] Quarrying activities can lead to environmental impacts such as water pollution associated with residues from stone cutting, dumping of waste rock, and noise pollution, while garimpo mining of gold can lead to mercury pollution, sedimentation of the water, and other pollution problem. Yet these artisanal firms are difficult to regulate because of the characteristics described above. A performance bonus can be established as follows. First, decide the periodicity and magnitude of the bonus. The bonus should exceed the cost of environmental compliance, and we will call this level, "Z." Instead of requiring the firm to post a bond equal to Z, the firm is required to post a bond equal to Z (where $0<Z<1$) and the government and/or NGOs contribute an amount equal to (1-)Z to an escrow account. This contribution is called the performance bonus.

Then, a proportionality function analogous to Equation (1) should be chosen based on the environmental risks associated with this mining activity. Performance will determine both the amount of the bond which is returned to the firm and the amount of the bonus which is awarded to the firm. For example, if environmental performance is below the minimum acceptable level of performance, the firm forfeits the Z it provided as a performance bond and also forfeits access to the (1-)Z that the government and/or NGOs have made available as a performance bonus. If the artisanal firm's environmental performance is at the optimal level, it receives all of the Z bond back, plus all of the (1-)Z that is available as a performance bonus. For levels of environmental performance between the minimum acceptable level and the optimal level, a proportionality function of the nature of Equation (1) can be used to determine the proportion of both Z and

(1-)Z that is awarded for the firm.

Additional discussion is needed of the proper determination of the magnitude of Z. Two factors can be identified which should be considered in the determination of this level. First, the greater the value of the firm's assets, the greater should be Z. Second, there is the need to discourage the entry of firms who enter the industry for the purpose of collecting the performance bonus. The greater the potential for the performance bonus system to encourage the entrance of firms, the greater should be to provide a corresponding disincentive.

VII) Conclusion

Performance bonds can be very useful tools for achieving specific environmental quality standards if constructed properly. We have discussed a methodology that provides those using performance bonds more precision in the disincentives they give to those creating environmental damages. The approach taken here is directed at promoting environmental damage prevention activities since many damages are irreversible and since prevention of damages is often less costly than restoration. It also strives to achieve the optimal level of environmental quality, as opposed to the typical minimum acceptable level. This base minimum level is often the goal of restoration activities as it ensures complete return of the bond. However, there is no incentive (and in fact likely that additional costs would be incurred, a significant disincentive) in meeting any higher environmental standards with this system. Additionally, structuring this mechanism as a continuous tool so that action can be taken and compensation can be paid according to a variety of different levels of mitigating activity creates a clearer incentive system allowing for a balance between the marginal costs and benefits of environmental preservation (or restoration, where that is the goal).

Although traditionally performance bonds have been used most frequently and somewhat effectively in the mining industry, with a few adjustments bonds can be an effective regulatory tools in many other applications. By instituting a bonding system before disturbance activities begin, regulatory agencies can provide strong assurance that steps will be taken to either prevent damages or restore an area, depending on the policy goal.

The efficiency of the system of performance bonding described above increases with the more that is known about the relationship between social welfare and ecological indicators. While we have good knowledge of this for some ecosystems, more research must be done before the system can be widely employed in its most efficient form. The performance bonding system can still be employed without a knowledge of this functional relationship (based on Equation (1)) but it is less efficient in maximizing social welfare. Even with the current gap in scientific knowledge, integrating estimates of these more comprehensive characteristics of the relationship between social welfare and ecosystem health into performance bonding systems makes bonding a more effective and readily evolving regulatory tool.

References

Bishop, Richard, “Endangered Species and Uncertainty: The Economics of a Minimum Safe Standard”, *American Journal of Agricultural Economics*, 1978, 60:10-18.

Costanza, Robert and Charles Perrings, "A Flexible Assurance Bonding System for Improved Environmental Management", *Ecological Economics*, 1990, 2:57-75.

Kahn, James R., Frank McCormick and Vincente Nogueira, "Integrating Ecological Complexity into Economic Incentives for Sustainable Use of Amazonian Rainforests", forthcoming in the *Journal of Sustainable Forestry.*

Kahn, James R. and Robert O'Neill, "Ecological Interaction as a Source of Economic Irreversibility", forthcoming in the *Southern Economic Journal*.

McCormick, J.F., "Principles of Ecosystem Management and Sustainable Development", in Ecosystem Management for Sustainability, J.D. Peine, ed. St.. Lucie Press, 1998.

Miller, Silver and J.C. Emerick, "The Secondary Effects of Mineral Development", in Economics of the Mineral Industries, William A. Vogely, ed., 1985.

Leitch, Gary, "Rehabilitation of the Ballarat Goldfields", Rehabilitate Victoria: Advances in Mine Environmental Planning and Rehabilitation, Monash University, Nov. 14-15, 1992, conference paper, pp. 47-51.

Perrings, Charles, "Environmental Bonds and Environmental Research in Innovative Activities", *Ecological Economics*, 1989, 1:95-110.

Webber, Barbara S. and David J. Webber, "Promoting Economics Incentives for Environmental Protection in the Surface Mining Control and Reclamation Act of 1977: An Analysis of the Design and Implementation of Reclamation Performance Bonds", *Natural Resources Journal*, 1989, 25:389- 414.

World Resource Institute, World Resource: A Guide to the Global Environment 1998-99. Oxford University Press: New York, 1998.

Endnotes:

Ecological services are functions produced by ecosystems such as nutrient cycling, soil formation, carbon sequestration, maintenance of atmospheric chemistry, biodiversity, watershed protection, and so on.

See Kahn and O'Neill (1999) for a discussion of the policy relevance and ecological origins of this type of bifurcation or threshold.

See Bishop (1978) for a discussion of the concept of a minimum safe standard.

Presence of fruit during the whole year is necessary to provide sufficient habitat for large mammals such as monkeys and fruit bats. These large animals are essential to the dispersal of the large seeds (in large fruits) of many rainforest trees. If there is a protracted period without fruit, the mammals will migrate to another area, leaving the area without a seed dispersal mechanism.

See C. Peiter, R.C. Villas Boas and W. Shinya, "The Stone Forum: Implementing a Consensus Building Methodology to Address Impacts Associated with Small Mining and Quarry Operations, Natural Resources Forum 24, 2000, pp.1-9.

See Maria Laura Barreto, "Garimpo de Ouro no Brasil:Desafios da Legalizacao, PhD thesis, Escola Politecnica da Universidade de Sao Paulo, Sao Paulo, Brasil.

MINE CLOSURE: SELECTED HIGHLIGHTS

Eduardo Vale
Specialization in Mineral Economics
Post-graduating in Policy and Management of Mineral Resources, IG/UNICAMP
Director da Bamburra - Planejamento & Economia Mineral Ltda.
E-mail: bamburra@highway.com.br

I - MINING & ENVIRONMENT

Environmental Impacts

- Destruction of natural habitats & changes in landscape;
- Change in water courses & river regimes, clogged streams;
- Land degradation & instability;
- Abandoned equipment & buildings;
- Abandoned surface structures & opened underground access etc.

Pollution Impacts

- Air emission;
- Effluents from concentration & processing;
- Soil contamination;
- Acid Drainage, spills and leaching etc.

Health & Safety Conditions

The nature and the diversity of costs and disarray imposed on environment are exacerbated by means of the following aspects:

- Location Rigidity;
- Competition with other Natural Resources;
- Competition with other Uses;
- Mutually Exclusive Conditions;
- Economic & Social Community Relations;
- Opportunity Costs: *public & private;*
- Opportunity Costs: *present & future;*
- Cost / Benefits: *tangibles & intangibles;*
- Nature of Impacts: *irreversible & perpetual.*

In fact, the real level of sustainability commitment of the mining industry has been under increasing vigilance and questioning considering a series of accidents occurred in the last years (Figure 1).

A Chronology of Accidents

- **1992 - Summitville Gold Mine, Colorado**
- **1995 - Omai Gold Project, Guyana**
- **1996 - Marcopper Mine, Phillipines**
- **1998 - Zortman-Landusky, Montana**
- **1998 - Los Frailes, Spain**
- **2000 - Aural Gold Plant (Baia Mare), Romania**
- **2000 - Ok Tedi, Papua New Guinea**

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Figure 1 - A Chronology of Accidents

The majority of problems have been associated with:

- Errors in conception & design
- Poor operating conditions
- Spills of cyanide & heavy metals by means of breach & overflow
- Acid Rock Drainage

II - Mine Closure System

The challenge imposed by closure of mines can be approached like a system composed by five fundamental vectors:

EBS - Environmental Baseline Study

EIA - Environmental Impact Assessment

EMS - Environmental Management System

Conception & Feasibility Study

Mine Closure Planning

Figure 2 presents a profile of the relationship between the principal vectors of a Mine Closure System.

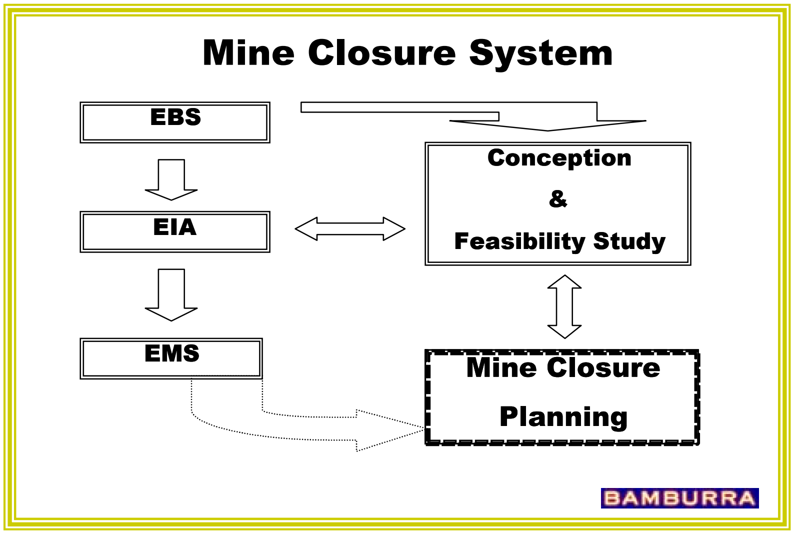

Figure 2 - Mine Closure System

Reclamation & Closure permeates the conception & feasibility interface at the level of its three fundamental dimensions (Figure 3):

- Geological Assurance;
- Engineering Conception; and
- Mineral Economics.

Conception & Feasibility Interface

Geological Assurance	**Engineering Conception**	**Mineral Economics**
Resources & Reserves	Tonnage / Grade Relations	Supply & Demand
Continuity of Mineralization	Stripping Ratio	Project's Market
Drilling & Sampling	Cut-Off Grade Policy	Price Behavior
Representativity of Sampling	Sequence of Mining	Oper.Costs & Investments
Assay Methods & Integrity	Open Pit Design	Leasing & Contracting
Margins of Errors	Minimum Minable Width	Mine Life
Confidence Intervals	Dilution & Specific Gravity	Economic Evaluation
Quality Assurance & Control	Mining & Processing Routes	Financial Engineering
Tonnage & Grade Estimates	Mining & Process. Recoveries	Taxation Planning
Reclamation & Closure	Oper. Costs & Investments	Competitive Analysis
	Reclamation & Closure	Risk Analysis
		Reclamation & Closure

Source: VALE, Eduardo. (1998)

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Figure 3 - Mine Project Interface

III - Mine Closure Planning

That depending of the region and the institutional regime mine closure planning activities embrace all the core segments of the mining industry and the closure and post-closure phases as well. Its basically focused on the rehabilitation and stability of the mine site and the protection of its area of influence. Figure 4 lists the principal areas of concern of a mine closure planning.

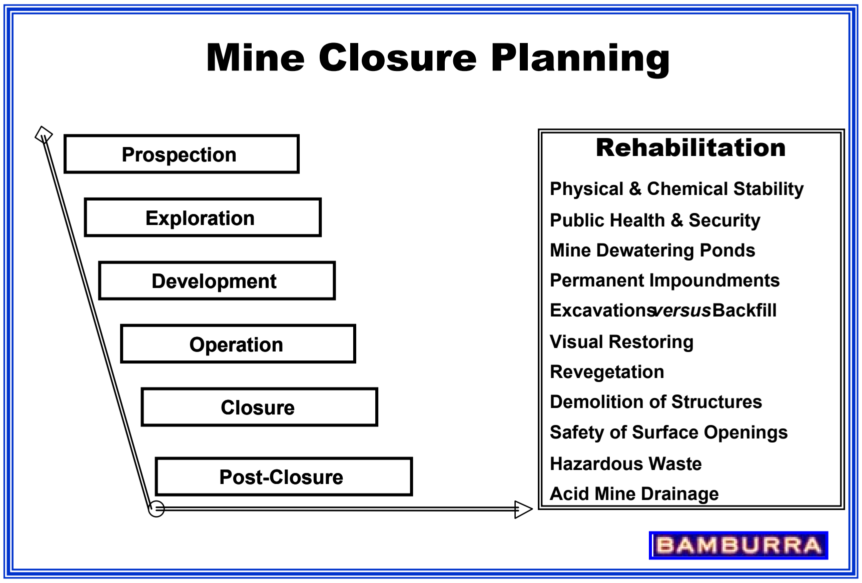

Figure 4 - Mine Closure Planning

In terms of mine closure budgeting the principal topics are:

- Demolition & Dismantle
- Remotion of Infrastructure & Superstructure
- Assets Recovery
- Landscape Reclaiming
- Acid Mine Drainage
- Close of Openings & Underground Access
- Maintenance & Monitoring
- Management
- Training & Realocation
- Socio-Economics Restoration & Redemption

By definition, closure budgeting should be included at the environmental impact assessment and feasibility study levels since it can influence the conception of the project and even degrade its attractiveness. Anticipation of impacts and available options, turns feasible the insertion of the following actions:

Prevention & Protection;

Control & Monitoring;

Descommissioning & Closure;

Remediation & Rehabilitation.

IV - CLOSURE BONDING

Bond Calculation - Closure budgeting

Life of Project Bond - A lump sum deposit

Phased Bonding - Gradual integralization of the financial garantee. Usually, during development and operation.

V - FINANCIAL ASSURANCE - OPTIONS

Cash

Surety ou Performance Bond

Irrevocable Letter of Credit

Dedicated Trust Fund

Properties & Assets

Certificates of Deposit

Savings Account

Self-Bonding

Surety by other Company

Government Bonds

Insurance

REFERENCES

VALE, Eduardo; Evaluation of Mineral Properties: Part I - Relevance of Establishing Standards - Mining Magazine - August, 1998 - London - pp. 80 - 84

SASSOON, Meredith. Closure or Abandonment? Mining Magazine. August, 1996. pp 96-100

MILLER, George C.. Use of Financial Surety for Environmental Purposes. ICME - International Council on Metals and the Environment Ottawa, Canadá.

THE ECONOMIC AND TAXATION ASPECTS OF MINE CLOSURE

Nelson Lara dos Reis
OAB RJ 19855
MBR, Brasil

ABSTRACT

This paper analyses the foundations for the creation of an economic policy based on taxation and accounting procedures, aiming at the lawful implementation of mine closure management (to be understood as environmental recuperation and protection management, following the cessation of the exploitation work due to the exhaustion of a mineral deposit).

There is no doubt that the activities related to the closing of a mine should be considered as one of the basic elements to integrate the mining project since its inception. Also, there is no question that the planning and scheduling of a mine closure should be considered as a determining factor for the sustainable development of the community and the country where the mine has been opened.

Doubts exist, however, about the feasibility of the procedures to be implemented for mine closure, specially regarding its economic basis by mine exhaustion.

A series of relevant aspects have been considered by the analysts of the matter, such as the technical and security questions that derive from the termination of the exploitation work, the environmental and administrative problems and the aspects of living quality, together with the decommissioning of the mining area.

Notwithstanding the multiple features of this subject, the economic solution for the mining project is the most complex part, among all other aspects, not only because it involves a series of interested parties, but also because the solutions are various and seldom can be previously ruled.

Under the economic point of view, the closure of a mining project depends upon a viable mechanism to implement it, after the exhaustion of the mineral deposit, taking into consideration that the mining operation has ceased and the economic interest has almost disappeared.

In order to make ends meet, such a mechanism has to be legally enforceable, must be clear in order to bring feasibility to the whole process and should involve consultation and active participation of all interested parties as the State, the Miners, and the Local Community representatives.

Undeniably the State has a particular role in the above mentioned process, not only as a ruler, but also as almost a partner, for the mining project involves interests of the whole society and the State has to manage public assets as a counterpart of its right to impose taxes.

The tax system is, accordingly, the natural political instrument to provide the funds for such a process, based on the national interest that aims at the macroeconomic growing and stabilization.

Summarizing, there are two mechanisms that assure the feasibility of a mining project closure: the official and adequate regulation of the matter and the system for funds allocation for such purposes, upon political support of the State.

One cannot assume, however, that the law alone is sufficient to impose to the miner the duty to create monetary reserves to be used after the ceasing of the mining operation, when there are no more revenues. Also, it is not possible to the Law to foresee all the details of the matter. Details like the amount of these monetary reserves should be carefully examined, due to the ever- mutating social and technical conditions of a mine closure process.

Further, the State cannot oblige the miner to provide such funds out of the limits of his economic capacity, endangering the profitability of the mining project. On the other hand, if such funds are not sufficient to backup the mine closure expenses, serious social consequences may arise notwithstanding political conflicts and possible environmental damages.

For the mentioned reasons, the State is responsible to create a taxation policy providing economic and social solutions for the mine closure process, balancing altogether the miner obligations and liabilities so that public welfare should result from such policy together with technical and operational solutions.

Regarding particularly the taxation aspects of the matter, one must take into consideration that the tax policy ruling the mining activity is considered by mining analysts as conceptually different from that applicable to any other activity.

The fact that the mining resources are not non-renewable already justify specific taxation rules as, for instance, the accelerated deductibility of costs and the future deduction of losses from past fiscal years.

The uncommon risks of mining bring indirect burden to the miners, which can be considered in fact as quasi-taxes. They derive mainly from the social demands, environmental obligations and other type of compensations involving local communities, expenses and administrative guarantees for the performance of mining work and what interests us most, the liabilities deriving from the mine closure.

In view of the above, it is fully justifiable that the burdening moment of mine closure be carefully observed and treated through a taxation policy in order to counterbalance the above mentioned requests and guarantee its full viability.

The idea about this taxation counterbalancing policy is to consider as deductible now for tax purposes the costs to be incurred in the future by mine closure, since in the future there shall be no more operational revenue to support the aforesaid deduction of such expenses.

It is worth mentioning that the modern taxation regimes provide three mechanisms for the compensation of these special risks inherent to the mining activity:

by anticipating the possibility of deducting the expenses incurred along the development of the mining project;

by allowing the deduction of the amount of the accrued costs estimated by the time of mining exploration to face the future mine closure expenses;

by reducing the tax to be levied during a certain time-span as a compensation for the costs to be incurred in the future by the end of exploitation work, when no revenue shall be available;

By enforcing such mechanisms, the State will be collecting less in the present, but shall not be liable to pay out of its reserves in the future, upon ceasing tax collection, guaranteeing altogether the implementation of a mine closure project which is its basic social and economic duty.

For the proper execution of such tax policy, the State should fix a timing for the aforesaid risks, reducing tax allowances based on the mine closure project duly approved by the authorities, aiming at both the public and the miner interests.

The three types of tax allowances above may be used together or separately but, whichever way used, they should bring to both the miner and the State confidence in the fulfillment of their objectives.

Criticism may exist, however, that the mining activity does not justify allowances since, according to scholars, mining is in no way different from the other industrial activities that may justify the granting of special favors.

Such allowances, however, represent no subsidy to the mining activity. The tax allowances above mentioned could be used to better implement all the steps of mining closure but they cannot be considered as subsidies. On the contrary, they establish a schedule for the collection of tax compatible with the absence of revenues at the time of mine exhaustion, based on the fact that the operational expenses are always deductible, since it reduces the miner's capital. Specifically at such cases, the tax allowance may authorize the earlier deduction of the costs to be incurred by mine closure, in order to adjust the effective tax payable along the time.

Taking into consideration that the mining activity makes use of the State assets, the scholars agree that no subsidies should be granted to it, establishing instead, a tax policy conceptually different as we have seen above, in order to provide peculiar conditions for implementation of a specific task.

By modifying the moment of tax assessment through a coherent tax policy the risk may be counterbalanced without menacing the objectives of taxation, specially regarding public assets.

The question arises, however, as how the results of such economic and tax policy shall be applied.

First of all, the economic means resulting from such tax allowances belong to the State, especially in this hypothesis where they effectively correspond to an anticipation or reduction of the tax due.

Also, the above conclusion results as a syllogism of the above referred statement, considering that such means generated by a tax allowance are subject to a special accounting procedure destined to assure the completion of a mine closure project.

Technically speaking, the product of such tax allowances should be kept aside in a special accounting provision to be used by the time of the execution of the mine closure project.

The Law, on the other hand, has to fix the conditions for the utilization of such means, otherwise they may be lost together with the conditions created for such important work. Eventually specific funds may be created to manage such means, but they have to be connected to the aforesaid objectives so that all such monetary means be sheltered in order to achieve its institutional objectives.

On account of the estimate of time when such means shall be considered necessary, this same tax policy shall have to provide the monetary correction of the amounts kept as well as its match with the cost of mine closure estimates, as duly approved by the government mining supervising authorities.

Like the various countries with identical or similar problems, the Brazilian government should create an organism to specifically supervise the mine closure projects.

Finally, there are two other issues that, according to scholars, are subject to careful attention: the question of the implementation of all steps of the mine closure project and the follow-up of such work during and after its execution.

Many hypotheses have been considered regarding the type of guarantees used for the implementation of the mine project. Personal grants as well as other guarantees provided by the Law may be used for this purpose, such as mortgages or a group of related obligations.

In fact, all possible guarantees to be created in this field are not always practical and may not always produce the expected results in such a wide spectrum, mainly when a series of factors may modify the reality during the closure phase of the mining project. On the other hand, if such guarantees are imposed as indispensable, they may turn the mine closure projects impracticable or reduce the interest of investors in the mining activity.

In this respect the most prudent action should be to provide a strict follow-up of the mine closure project by a governmental mining agency permanently helping and assisting the process, avoiding interruptions and coordinating interests, briefly, playing its role for the adequate administration of a public asset.

With regards to monitoring the steps for post-closure maintenance, this is a matter that needs further analysis and greater development.

Notwithstanding the above, it would not be considered an excess to request that the mine closure project includes considerations over the matter just mentioned. Three major questions then arise:

1. Which steps shall be implemented?

2. Who should participate in them?

3. Which are the economic bases for its implementation?

Actually, one cannot request from the miner to support the costs of a post-closure project, for it does not seem to be neither fair nor viable to create another burden in this respect.

If the owners of the mining project participate in another on-going mining project, a suggestion would be to allow the deduction of the costs of such post-closure monitoring process from the operational revenue of this other mining project or to reduce the above mentioned expenses from other Federal Taxes due.

Perhaps this problem may be also solved through granting a special subsidy to the neighborhood communities, thus providing a focused interest and a more efficient follow-up and execution of this work. Maybe the name "subsidy" would not fit the case since it does not refer to a productive activity. Nevertheless, the amount of such "soit-disant" subsidy may be contemplated in the State Budget under the title "public welfare", with great probabilities to be executed due to the cost reduction and political interest deriving from the direct public participation in its implementation.

How can such schemes be accomplished? How to unite people in order to attain such objectives? Certainly, as mentioned before, not only experience is needed, but also an effective State support to organize such interests and divide the onus, otherwise no prospective success shall exist.

Brazil has not officially regulated the matter in spite of its proved need. Moreover, economic-social factors linked to the reality of the country demand more than a regulation, on account of a special and mutating solution for every case and a constant and judicious follow-up as well.

Therefore, in view of the above arguments, one has to conclude by reinforcing the need for the regulation of the mine closure process, emphasizing the economic basis as a success condition.

BIBLIOGRAPHY

Instituto Brasileiro de Mineração - IBRAM-CONIM, *Minuta de Norma sobre Desativação de Mina*, Coordenação de Assuntos Legislativos, Brasil, Junho, 2000.

Colorado School of Mines, Global Mining Taxation – *Comparative Study*, Institute For Global Resources Policy & Management, United States of America, September, 1997

Garcia Guilhermo C., *Análisis de La Nueva Normativa sobre Cierre de Faenas Mineras*, Chile, 2000.

Diaz, Cartagena Patricio, *Marco Conceptual Sobre El Cierre Y Abandono de Faenas Mineras en Chile, Comision Chilena Del Cobre,* Chile, 2000;

Zamora Armando & Ericsson Magnus, *The Environment, Human Rights, Community, Participation, Small-Scale Mining*, Centre for Energy, Petroleum, Mineral Law and Policy, University of Dundee, Scotland, UK, 2000;

Lima,H.M & Wathern, P, *Mine Closure: A Conceptual Plan*, 1999.

Von Bismarck, Friederich, *Mine Rehabilitation: a Special Experience in Germany*, Centre for Energy, Petroleum, Mineral Law and Policy, University of Dundee, Scotland, UK, 2000.

Reis, Nelson Lara dos, *Mining and Environment: Two Apparently Controversial Subjects*, Centre for Energy, Petroleum, Mineral Law and Policy, University of Dundee, Scotland, UK, 2000.

Mcmahon, Gary, *Social Economic and Environmental Effects of Large Mines on the Community: Case Studies from Latin Amercia, Canada and Spain*, Centre for Energy, Petroleum, Mineral Law and Policy, University of Dundee, Scotland, UK, 2000.

De Castro, João Paulo Campello, *Planos de Fechamento de Minas Legislação Ambiental Incidente*, Advogado, Minas Gerais, Brasil, 2000.

FINANCIAL ASSURANCE FOR MINE RECLAMATION AND THE CLOSURE PLANS

Mauro Lobo de Rezende -
Forest Engineer MS in Forest Science
Manager of Environmental Development of the Rio Verde Mine

1. INTRODUCTION

Brazilian mining contributes significantly to the national economy, in the formation of GNP, generation of employment and exports. It represents 4.5% of the value of GNP, excluding petroleum and gas. It is particularly important due to the effects that it brings into the productive structure, including trade sectors and the transformation industry (metallurgy, cement production, chemical industry, ceramic and glass industries). The number of direct jobs - 230 thousand - generates the creation of 920 thousand other jobs in the trade sector and 1286 thousand in the transformation industry. The participation of the State of Minas Gerais in mineral production in Brazil is extremely significant, being responsible for the production of one third of the useful minerals.

In spite of its economic importance and its current technology, mining activity is still regarded as one which brings about environmental problems deserving special attention from environmental agencies and legislators. The adoption of closure plans, which were formerly limited to special cases, is now part of the environmental policy of several countries and it can soon be considered in licensing procedures.

The Brazilian Mineral Production Department (DNPM) have created a Work Group for the elaboration of the Mining Rules. The basic text resultant of this work is now available in the site “www.dnpm.gov.br” for analysis and suggestions from the community. This text proposes that, before the temporary or definitive break in the activities, the mining companies should submit to DNPM a Closure Plan, containing the measures related to environmental control, including those which refer to mine reclamation.

In this context, the mechanisms proposed to assure mine reclamation, which is part of the mine closure plans, have gained great importance in the definition of the governmental policies and in the strategy of the companies

2. SCENERY

The first instrument of mining permits in Brazil was instituted in the colonial period and it ratified the domain of the Portuguese Crown on the minerals, reserving to the royal treasury 20% of the country’s mineral wealth, free of any charges. In the subsequent periods, several alterations took place. With the Constitution of 1934, the regime of concession was adopted with the federal domain on the mineral resources (SOUZA, 1995).

The mining taxation system, which was influenced by historical and ideological subjects, has reached the complex picture of the current days, in which the Brazilian industry pays one of the highest taxes in the world. Despite the conclusion of some studies that place Brazil in an advantageous position in relation to mining taxation, after the Constitution of 1988 mining taxation presented a considerable rise, reaching approximately 53.4% of the net income (Table 1).

Table 1: Tax burden in the mining industry of Brazil - (COOPERS & LYBRAND, 1997)

ICMS (VAT)	17%
Financial compensation (government royalties) related to net invoicing, net of taxes, freight and insurance	2%
COFINS (sales levy – exempted when for exports)	2%
PIS (sales levy – exempted when for exports)	0.65%
CS – (income sales levy) – 8% of net income before CS (Social Contribution levy)	8%
Federal income tax – 25% of net income before income tax	25%
Effective tax burden	53.4%

The mining environmental guidelines elaborated by the Ministry of Environment (MMA/ABC/PNUD, 1997), considers that any proposal of control instrument that brings the introduction of new taxes will fail, unless it is based on the substitution of already existent rates or taxes.

The Federal Constitution of 1988 establishes that everybody is entitled to ecologically balanced environment and, along with the government, everybody is in charge of defending and preserving it for the present and future generations. Those who explore mineral resources take the responsibility of recovering the degraded environment, in agreement with the technical solution demanded by the concerning public organ.

The legislation of the states can be more restrictive than the federal legislation, and in this way the Constitution of the State of Minas Gerais is not restricted to the mining industry, extending the obligation to other activities when considering that "those who explore environmental resources are responsible for recovering the degraded environment".

Despite the importance the legislation gives to the environmental aspects of the mining activities, it also recognizes its characteristic of public interest. Act 3.365 of June/41, which is still effective, establishes the dispossession of lands for mining activities, considering them of public utility.

3. Environmental Instruments In Use

Act 6.938, of August /1981, that disposes on the National Environmental Policy, establishes in its Article 2nd that this policy "*aims at preservation, improvement and recovery of environmental quality favorable to life, in order to assure conditions for the socioeconomic development, for the interests of national safety and the protection of dignity of the human life considering, among other demands, the recovery of degraded areas in the Country".*

The main governmental instruments of control related directly to the need of mine reclamation are presented below.

3.1. Environmental Impact Assessment- EIA

EIA is the instrument of previous control of projects which can cause damage to the environment, aiming at avoiding pollution or, at least, minimizing it by means of mitigating or alternative measures (CONAMA Resolution no. 01 of 1986). The results of the EIA should be presented in the Environmental Impact Report (EIR), which evaluates alternatives for the project's technology and chosen site and includes aspects related to the construction and operation of the enterprise to be licensed.

Act 97.632 (April/89) establishes that during the EIA/EIR process, the mining entrepreneur should submit a mine reclamation plan to the approval of the environmental agency. It considers that the recovery should return the degraded land to its former condition in agreement with a preset plan for the use of the soil, in order to reach the stability of the environment.

The EIA/EIR usually include issues related to monitoring programs, the future land use and the physical and chemical stability of the rehabilitated areas, but a statutory requirement for a Closure Plan is not common.

3.2. Environmental licensing

Environmental licensing is the procedure by which the installation, amplification, modification and operation of enterprises that use natural resources or are potentially aggressive to the environment are licensed (Resolution CONAMA nº237/97).

In Minas Gerais, COPAM - State Council of Environmental Policy is responsible for environmental licensing. It operates through the specialized chambers, which are advised by the organs of the State Secretary of Environment - SEMAD. The operation license is granted by means of approval of an environmental control plan. For the mining projects this plan contemplates the several stages of the enterprise, and it also establishes the conditions, restrictions and measures of environmental control that should be obeyed. In the environmental licensing process, the decision about the need of elaboration of a closure plan is in charge of the technicians of SEMAD and of members of the Mining Activities Chamber.

The Forest Act of the State of Minas Gerais highlights the mining activities, considering that licensing for mining will depend on the approval of a technical project for flora rehabilitation with local or regional native essences in addition to the project for soil rehabilitation.

3.3. Financial compensation for mineral use

Financial compensation for the use of mineral resources was instituted by Act 7.990 (December/ 1989), and Act 8.001 (March/1990) in which the following percentile for the distribution of these values was defined:

- 23% for States and Federal District
- 65% for the Municipal districts
- 12% for the Brazilian Mineral Production Department that will assign 2% (two percent) for use in environmental projects in the mining areas through the Brazilian Institute for the Environment - IBAMA.

3.4. Compensation for environmental damages

Resolution of CONAMA-02/96 (April/1996) determines that the enterprises projects which can cause damage to the environment should implant any modality of Conservation Unit of public domain to compensate for the environmental damages caused by the destruction of forests and other ecosystems. This compensation can be turned into the costing of activities or acquisitions of goods for the already existent Conservation Unit or for the creation of a new one.

It also establishes that the amount of the resources to be used for these compensations cannot be lower than 0,5% (half percent) of the total costs for the implantation of the project.

The Forest Act of the State of Minas Gerais establishes the obligation of the implantation of forestry and reforestation projects to make up for the occupation of superficial areas for mining.

4. Assurances For The Rehabilitation Of Degraded Areas

There is an international trend to demand closure plans as part of the licensing process of new enterprises. In most cases, this Closure Plan contemplates programs of progressive rehabilitation, a long-term monitoring and a post-closure plan. The rehabilitation in on-going enterprises is usually in charge of the owner or current operator, but in some cases where the recovery is above the financial conditions of the company, the state might have to assume part or the whole cost of the rehabilitation. The greatest uncertainty is related to abandoned areas, where it is difficult to identify the responsible company. In this case the government might take the responsibility (SINGHAL, 1994).

Even if the Brazilian legislation does not define a statutory requirement for a Closure Plan, it establishes through the existent instruments the basis for its effective implementation. Meeting the requirements of all the stages of the permitting process and of all the compensations will assure an adequate behavior from the entrepreneurs, thus fully assisting one of the most polemic tasks which deals exactly with the rehabilitation of the mining areas.

The idea of a financial assurance system for the mining activity is related to the Closure Plan, more specifically to the need of mine reclamation. The mechanism for ensuring that appropriate procedures are followed is a reclamation bond or fund supplied by the companies themselves. The company would get the money back by performing the required work. In situations of abandonment of the mining project due to market conditions or any other reason, the government would have funds to assure the rehabilitation.

In 1997 in Minas Gerais an environmentalist NGO (ANDA) presented to the Mining Chamber of COPAM a proposition which demanded the confirmation of the investor's economic-financial reliability in mining projects, aiming at assuring the recovery of the degraded areas. Later on, this proposition was presented to the State Chamber, but it was not approved.

4.1. Economic aspects

One of the main advantages of the adoption of these instruments is considered to be the incentive to mining companies in planning and conducting the rehabilitation programs, consequently reducing the administrative costs of the agencies of environmental control. On the other hand, the uncertain effects on the balance and cash flow could put the company at risk. Furthermore, some issues lack more precise answers and should be evaluated carefully:

What are the models of deposit or assurance to be adopted and how would they be administrated?

Certainly, the requirement for up-front funding, particularly in the form of cash, will be a problem to many companies.

What should be the value of these deposits or assurances?

There must be a balance. Investments can not be discouraged and the government must have enough funds to accomplish the rehabilitation in case the company fails in its duties.

4.2. Technical aspects

Although the estimate of the costs of rehabilitation is relatively easy to be done, it varies from place to place depending on the technical solution suggested.

In some cases there is a tendency to demand restoration of the area to its original state. The legislation does not impose the physical recovery of the area exactly to it was before. It expects the area's adaptation to a situation of normality and stability. For the application of a system of financial assurance, this issue is of great importance and the cost/benefit of rehabilitation should be taken into account.

Thus, in agreement with the options of future use and of desired degree of environmental complexity, the following situations can be observed:

- Abandonment without specific rehabilitation
- Protection of the area for guarantee of safety
- Restoration of the area to its original state
- Conversion of the area into a new environmental balance
- Conversion of the site into a leisure area (golf course, lakes, parks)
- Conversion of the area for different commercial purposes (pasture, productive forest)

4.3. Legal responsibilities

The company can be considered responsible for the environmental impact associated to its activities even if this impact is caused after its closure. Sometimes this responsibility is defined in a very general way, causing a high degree of uncertainty according to the chosen approach of responsibility (CASTRO, 1996):

-· Strict Responsibility: responsibility for causing damages even if the activity of the company is considered legal and cautious.

-· Common Responsibility: a company can be made responsible for all environmental problems on its area of influence, even if this company is only partially responsible for the damage. This approach can discourage the retaking of the abandoned mines by other companies, even if this is the most acceptable way of achieving the rehabilitation of the area.

-· Retroactive Responsibility: responsibility for damages caused previously to the Act or any specific regulations. It usually implies high costs to define who should take the responsibility. It is estimated that 1/3 of the money collected by the Superfund in the United States has been spent in this activity.

In some cases this situation can lead companies to go beyond the commitments with the legislation, but usually these approaches are criticized for being unfair and for discouraging investments in mining activities.

The retroactive effect of the Canadian legislation demanding financial assurances for on-going mines took into consideration the need of a period of transition for the adaptation of the new demands. It is recognized that up-front funding, mainly in cash, would represent a strong limitation for new investments (REID, 1994).

The system of financial assurances should give the entrepreneur the possibility of the best choice regarding the technical solution for environmental recovery.

Therefore, the flexibility of this instrument should exist in the conception of the project, in the modality of financial assurance to be adopted and in the definition of responsibilities.

5. Conclusion

Although economic instruments are not the only solution for environmental management, they present great potential of application. Such instruments should be adapted to the specific conditions of the jurisdiction where they will be applied, considering the legal, economic and technological context.

The application of financial assurance as an instrument of environmental control in the mining projects seems to be an inevitable tendency, but still lacks studies to identify its incidence and effects on the sector. Possibly the companies that operate legally will be most affected, while the illegal ones, which are responsible for secret operations or abandoned areas, will be exempt of any financial obligation regarding the recovery of degraded areas.

Due to the increasing complexity of the environmental legislation and to the great number of effective control instruments in the country (including compensation for the use of the land), propositions that represent new obligations can be made unfeasible, unless they are based on the substitution of the already existent taxes or fees. Therefore, any attempt in this direction should take into account a wide revision of the existent instruments.

In case of application a system of financial assurance, the attributions and responsibilities of the several institutions involved in the licensing process and in fiscalization should be clearly defined in order to avoid differentiated approaches for mine reclamation.

The viability of a certain instrument is widely dependent on its flexibility. Thus, a system of financial assurance should consider the diversity of the technical projects, establish flexible approaches for the definition of responsibilities for the environmental damages and finally operate with a wide range of mechanisms of financial assurance.

Several countries have become stricter regarding their environmental demands thus rising significantly the costs for the mining companies. As a consequence, investments are expected to be directed to those countries where the balance between environmental protection and mining projects is more adequate.

6. References

CASTRO, João Paulo Campelo. Reabilitação de áreas degradadas – Aspectos legais, 1996 (9p)

EGGERT, Roderick G.. “Economic Perspectives on Mining and the Environment” in Curso internacional: Abordagem econômica da questão ambiental na mineração. (IBRAM – Belo Horizonte, 1995,Vol II)

SOUZA, Marcelo Gomes de. Direito minerário e meio ambiente – Belo Horizonte, 1995.

COOPERS & Lybrand. Investimento em mineração no Brasil – 3º edição – 1997

MMA/ABC/PNUD. Ministério do Meio Ambiente, dos recursos Hídricos e da Amazônia Legal – Agência Brasileira de Cooperação – Programa das Nações Unidas para o desenvolvimento, Diretrizes ambientais para o setor mineral – Formulação e implementação de políticas públicas compatíveis com os princípios do desenvolvimento sustentável – Projeto BRA/94/016. (1997)

REID, Patrick. Mine reclamation and financial assurance – Ontario Mining Association, Toronto (1994)

FEAM, Diretrizes para consolidação da política ambiental (sem data, texto fornecido durante o 1º Curso de Gestão Ambiental – FEAM/FUMEC)

SINGAL, Raj K. et al., Post conference Sumary – Enhancing the contribution of the mineral industry to sustainable development in Conference on Development Environment and Mining, Washington DC, 1994.

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i. Ecological services are functions produced by ecosystems such as nutrient cycling, soil formation, carbon sequestration, maintenance of atmospheric chemistry, biodiversity, watershed protection, and so on.

ii. See Kahn and O'Neill (1999) for a discussion of the policy relevance and ecological origins of this type of bifurcation or threshold.

iii. See Bishop (1978) for a discussion of the concept of a minimum safe standard.

MODULE VI

POLITICAL AND SOCIAL ASPECTS

MINING INTEGRATION - KEY ISSUES AND CHALLENGES

Ing. *Hugo Nielson*
General Manager
Scientific Research Commission, Province of Buenos Aires, Argentina

ARGENTINE ECONOMIC SCENARIO

Structural Economic Reforms
Legislation (1989-1991- 1993)

- Convertibility
- Privatization Process
- Markets Liberalization

CHILEAN ECONOMIC SCENARIO

Structural Economic Reforms

- Privatizations
- Trade Liberalization

DECREE LAW 600

FOREIGN EXCHANGE LAW

ARGENTINA - CHILE

FORMS OF GOVERNMENT

ARGENTINA	CHILE
FEDERAL	CENTRAL

MINING LEGAL SYSTEM

- CIVIL LAW
- CONSTITUTIONS CODES

ENFORCEMENT AUTHORITIES

ARGENTINA	CHILE
ADMINISTRATIVE OR JUDICIAL	JUDICIAL

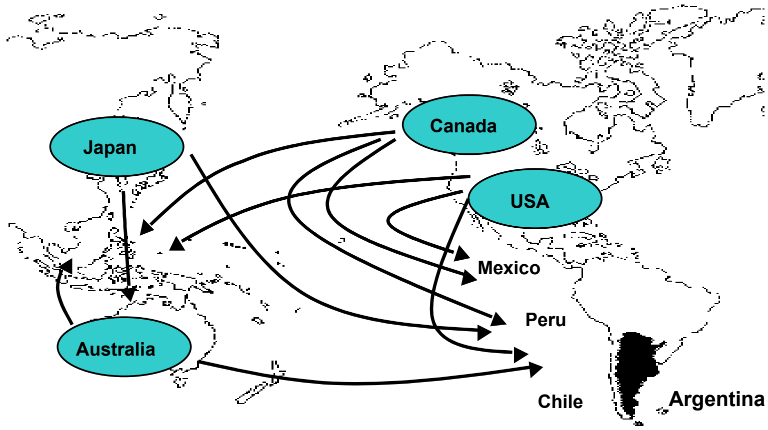
ARGENTINE MINING LEGAL FRAMEWORK

LEGAL FRAMEWORK FOR THE MINING ACTIVITY

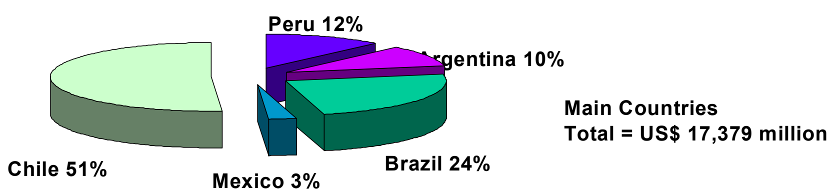
Mining Investments Law # 24,196 • Fiscal Stability For 30 Years • Maximum Royalties 3% Pithead Value • Income tax deductions • Exemption from import duties for capital goods, spare parts and supplies	**Vat Financing Law # 24,402** • Purchase or final import of capital goods • Investments made in infrastructure works • Advance repayment for new mining projects
Mining Rearragement Law # 22,224 • Systematic geological mapping • Federal mining council-advisory board • Geological chart advisory committee	**Mining Update Law # 24,498** • Removal of archaic institutions • Aerial research • Nuclear minerals become concessionable
Mining Federal Agreement Law # 24,228 • Investments promotion • Harmonization of mining procedures • Optimization of resources	**Environmental Protection Law # 24,585** • national legislation with provincial • enforcement authority • balance between mining production and environment • assistance to small scale mining companies

Complementary Laws
National Bank Of Geological Information. Law Nº 24,466: It centralises the Public Geological information of the Country at the Mining Secretariat
National Bank of Mining Information. Law Nº 24,695: Human Resources and equipment information bank at the Mining Secretariat
Bicameral Commission. Law Nº 24.227: Commission made up for 4 Senators and 4 Representatives

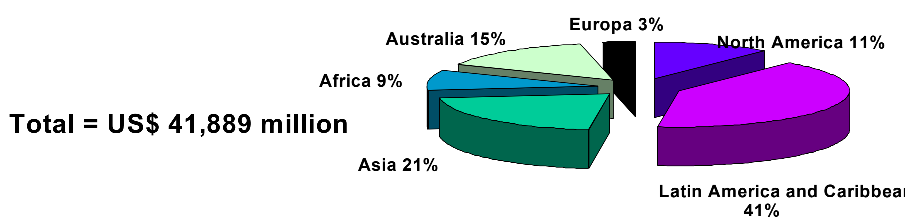
MINING INVESTMENT FLOW



MINING INVESTMENT IN LATIN AMERICA 1990 - 1997



WORLD INVESTMENT 1998 – 2007



Source: M.E. GROUP

MINING SCENARIO: ARGENTINA / CHILE

Top countries with potential geological mining resources

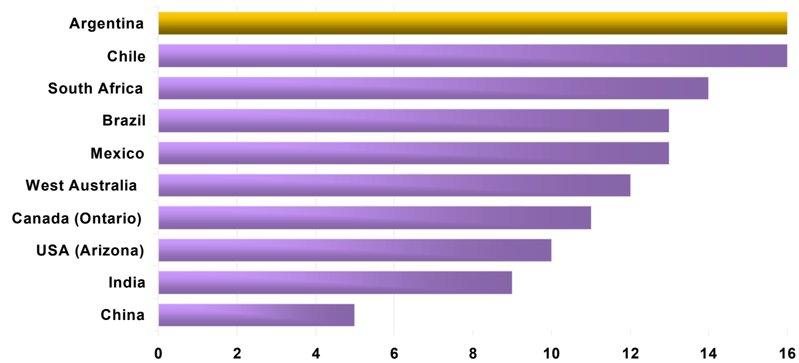
Fifth place	Chile
Sixth place	Argentina

Emerging country ranking 1999

Top of the list	Chile
Fourth place	Argentina

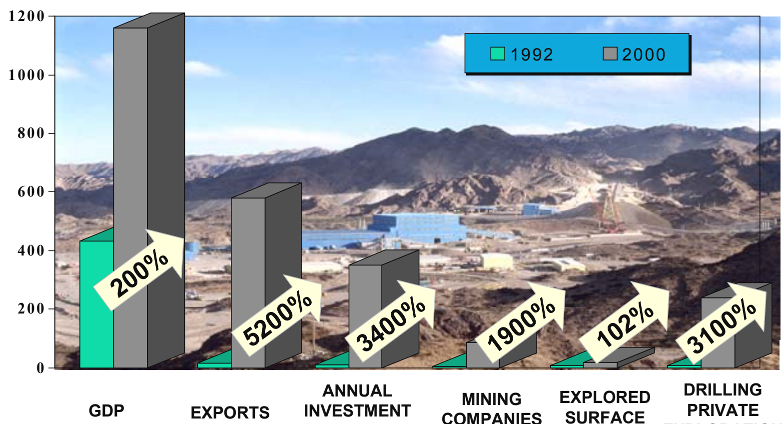
Source: Mining Journal

Copper Mine - Comparative Study



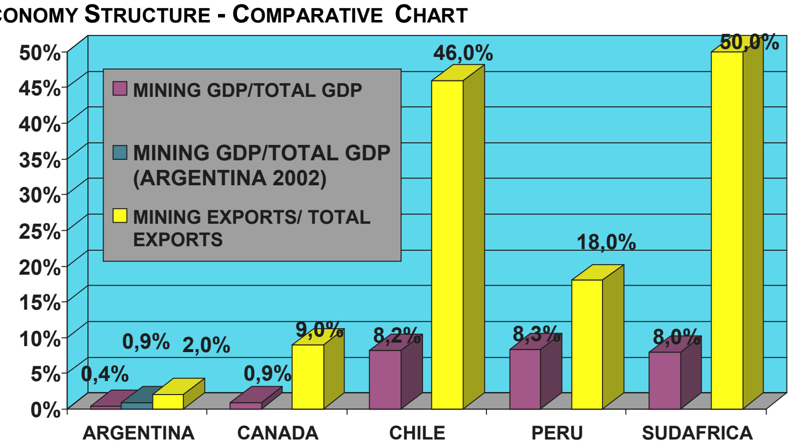
Source: Institute for Global Resources Policy and Management
Colorado School of Mines

Argentine Mining Indicators - 1992-2000



Source: Secretariat of Industry, Trade and Mining

Mining Economy Structure - Comparative Chart

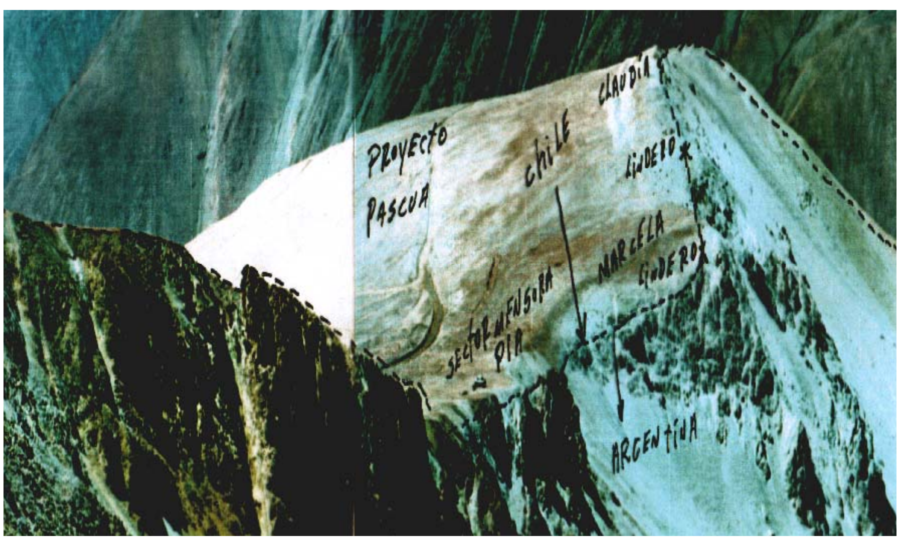


Source: Secretariat of Industry, Trade and Mining

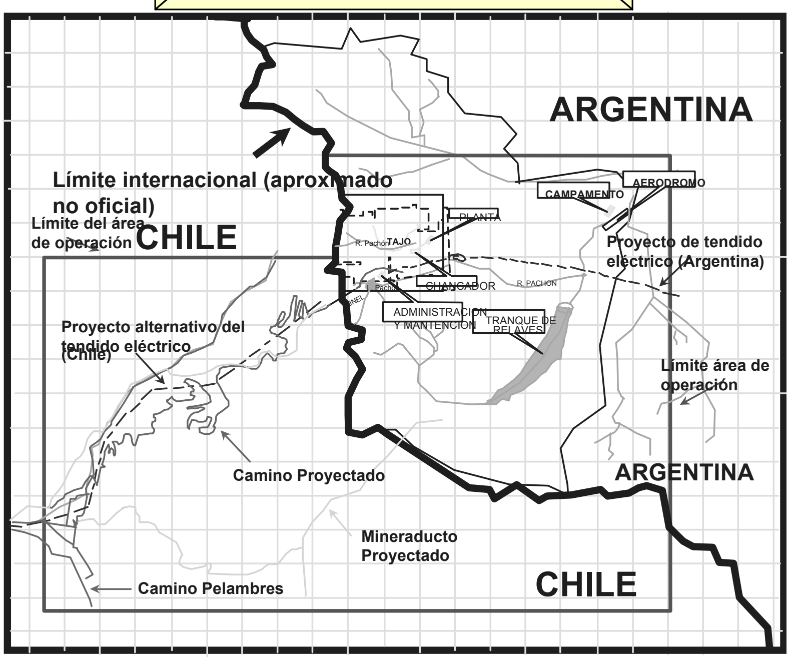
Mining Integration and Complementation Treaty Between the Republic of Argentina and the Republic of Chile

Santiago de Chile 08-01-1855	**FRIENDSHIP, TRADE AND NAVIGATION TREATY**
Vatican City 11 -29-1984	**PEACE AND FRIENDSHIP TREATY. Goals: Economic Cooperation and Physical Integration. Iniciative to explote natural resources.**
Buenos Aires 08- 02-1991	**ECONOMIC COMPLEMENTATION AGREEMENT Nº 16. Settlement of 23 border disputes between Chile and Argentina. Goal: To promote complementation and coordination to achieve mining development.**
Santiago deChile –B.A. 08-1991 – 01-1997	**BILATERAL NEGOTIATIONS. Goals: Mining Treaty and Specific Mining Protocols.**
Santiago de Chile 01-1997	**SIGNATURE OF THE PROTOCOLS PACHÓN and PASCUA-LAMA**
Chile – Argentina 12-1997	**SIGNED by the Presidents of Argentina and Chile. The respective Bills approving the Treaty were sent to both Parliaments.**
Santiago de Chile 12- 29-1997	**The Electrical interconnection and electric enrgy supply PROTOCOL was signed between Argentina and Chile.**
Buenos Aires 11- 24-1999	**The Argentine Senate PASSED the Bill approving the Mining Treaty.**
Santiago de Chile 01- 18- 2000	**The House of Representatives of the Republic of Chile PASSED the Bill approving the Mining Treaty.**
Santiago de Chile 01- 18- 2000	**Argentine enactment of the Mining Treaty by Law Nº25,243.**
Santiago de Chile 04-2000	**The Bill is presented to the Chilean Senate for enactment.**

Mining Protocols

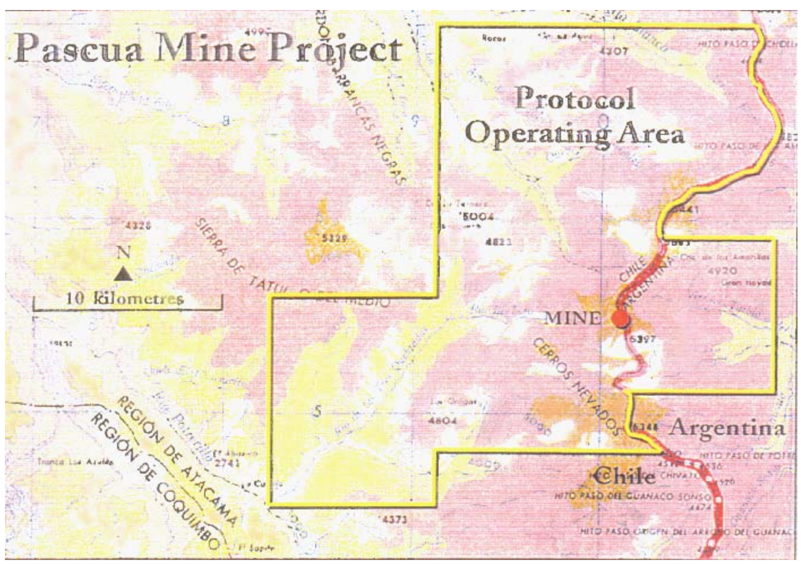


MINING PROTOCOL PASCUA- LAMA

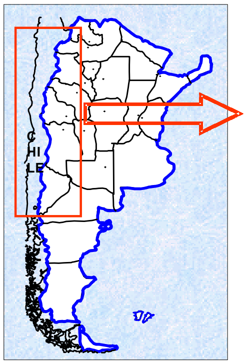


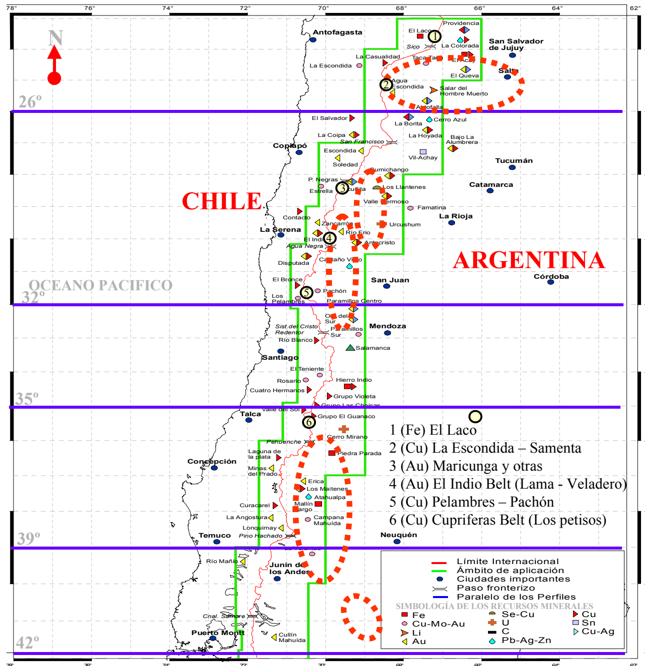
MINING PROTOCOL "EL PACHON"

PASCUA-LAMA PROJECT

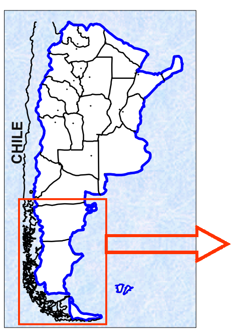


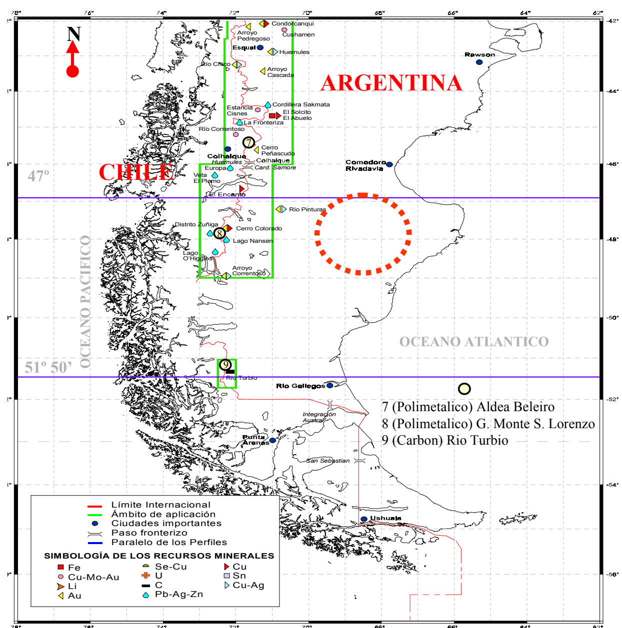
MINING TREATY - TERRITORIAL SCOPE





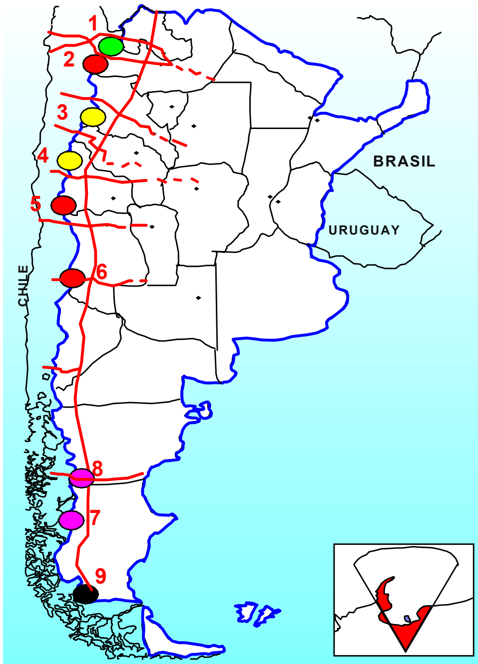
NORTH ZONE





SOUTH ZONE

ARGENTINE-CHILEAN MINING REGIONS



LEGEND

1- Fe: El Laco
2- Cu: La Escondida - Samenta
3- Au: Faja de Maricunga (Valle Ancho, F.La Vicuñita)
4- Au: Faja de El Indio (Lama, Veladero, Etc.)
5- Cu: Pelambres - Pachón
6- Cu: Faja Cuprífera (Los Petisos)
7- Pollimetalics: Grupo Monte S. Lorenzo
8- Pollimetalics: Aldea Beleiro
9- Coal: Río Turbio
Integration Paths

MAIN FEATURES

⇒ National treatment

⇒ Border facilitation

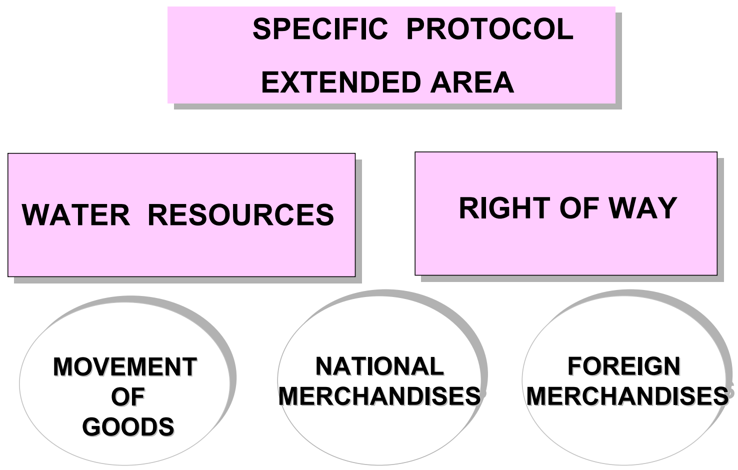
⇒ Specific additional protocols

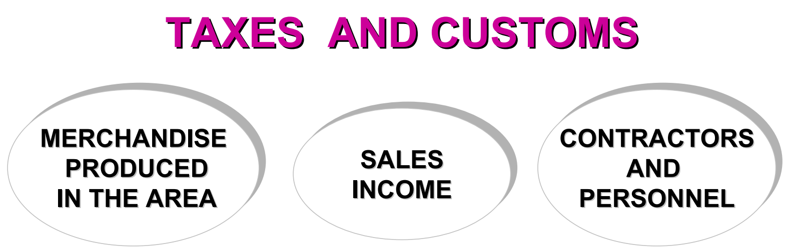
MINING INTEGRATION

Key Issues

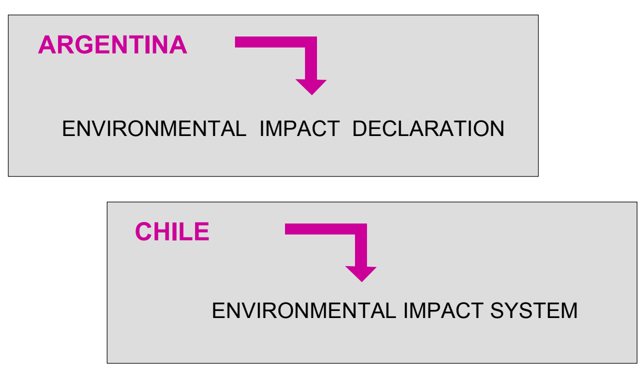
- Easements
- Taxation
- Environment
- Labour
- Disputes

Easements

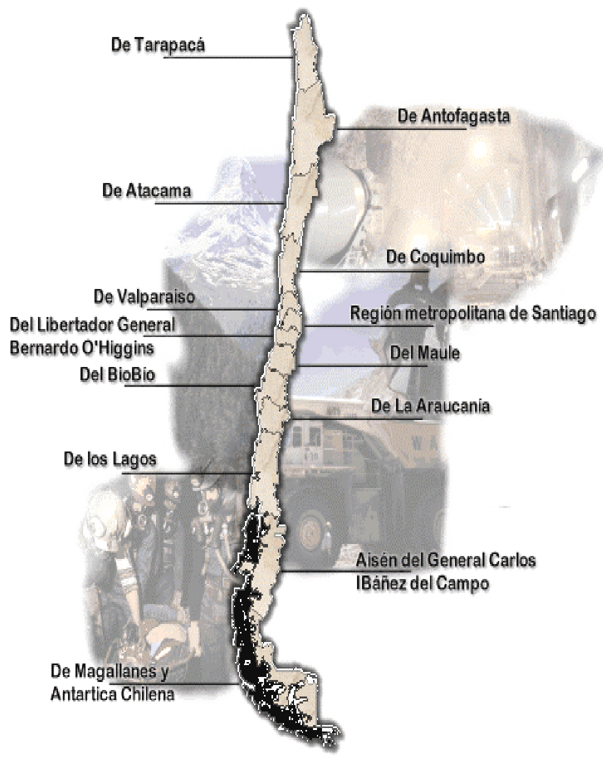




Environment



Chilean Environmental Law



General Environmental Law

DEGREE PRINCIPLE

LIABILITY

ARGENTINE ENVIRONMENTAL MINING LAW

LAW INCLUDED IN THE CODE

PREVENTIVE SYSTEM

ENVIRONMENAL IMPACT REPORT

ENVIRONMENTAL IMPACT DECLARATION

ENVIRONMENTAL QUALITY CERTIFICATE

LABOUR

GENERAL RULE

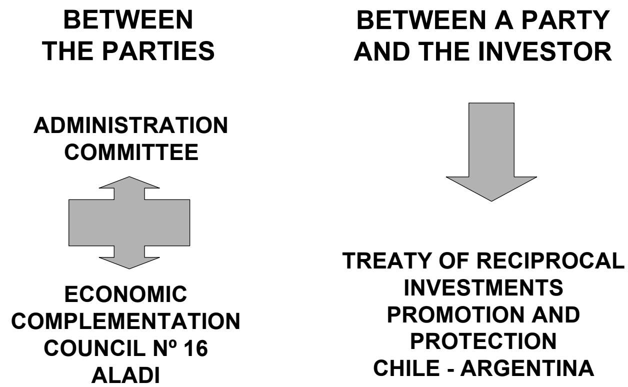
LAW OF THE PLACE WHERE THE SERVICES ARE RENDERED

AREA OF OPERATIONS

LAW OF THE PLACE WHERE THE CONTRACT WAS MADE

IN DUBIO PRO OPERARIO

DISPUTES

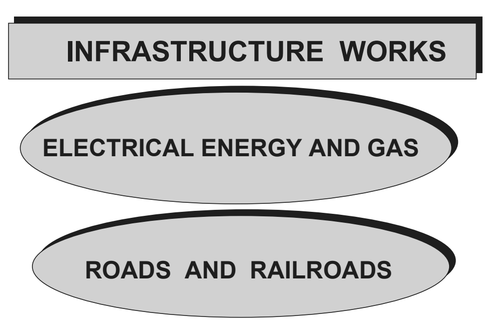


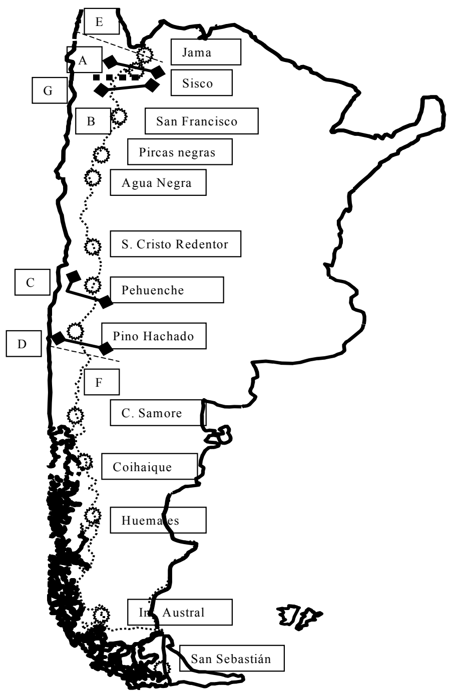
ADMINISTRATION COMMITTEE

COMPLEMENTARY PROTOCOL

- ➔ STATEMENT INCLUDING MEDIUM AND SMALL SCALE MINING COMPANIES
- ➔ STATEMENT ON WATER RESOURCES
- ➔ SPECIAL ADVISORY COMMITEE

INFRASTRUCTURE INTEGRATION





LEGEND

A ---- ATACAMA GAS PIPELINE
B ---- NORANDINO GAS PIPELINE
C ---- ANDES GAS PIPELINE
D ---- PACÍFICO GAS PIPELINE
E----- SALTA-ANTOFAGASTA ELECTRIC LINE
F----- NEUQUÉN CONCEPCIÓN ELECTRIC LINE

G ##### FFCC GRAL BELGRANO - BRANCH C14
ARGENTINA-CHILE: 13 BORDER PATHS

RESULTS

Pascua-Lama Mine Project

Projection

GOLD	1 MILLION OZ	
SIVER	36 MILLION OZ	
CASH COST	FIRST FIVE YEARS LIFE OF MINE	$60 per oz $ 100 per oz
CONSTRUCTION COST		$ 970 MILLION
PRODUCTION START - UP: 2003		

Labour Force

500 WORKERS

AT THE PROTOCOL AREA

END OF 2000

700 WORKERS

Regional Integration	→	Growing reserves Rising production Lowing costs

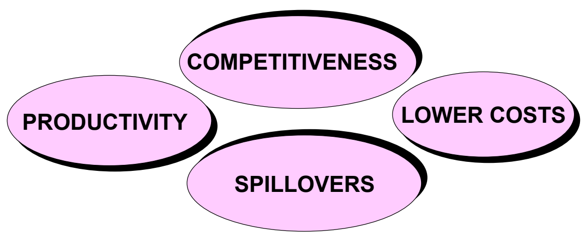
WITHOUT MINING INTEGRATION	MINING INTEGRATION
125 $/oz.	60 $/oz. 90-100 $/oz.

Mining Integration

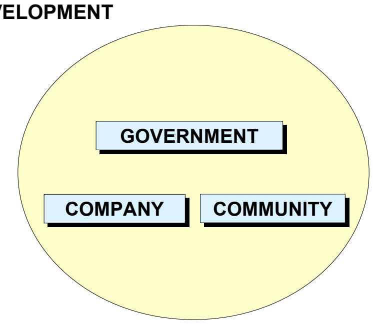
CHALLENGES

REGIONAL SUSTAINABLE DEVELOPMENT

REGIONAL SUSTAINABLE DEVELOPMENT



REGIONAL SUSTAINABLE DEVELOPMENT



MINING CLOSURE

The driving juridical reform mentioned, could not ignore the environmental effects that mining activity produces, bringing in a Clause in the Mining Code that controls the managing and environmental budgets on which mine operators should agree with the competent public authority by means of the presentation of a Report of Environmental Impact and the consecutive Statement of Environmental Impact.

In the first place it should be pointed out that the Article 249 of the Mining Code (t.o.) treats the mining closure as another activity, when it prescribes. "The activities which are included in this present section are: a) prospecting, exploration, working, development, preparation, extraction and storage of mineral substances included in this Mining Code, including all the activities assigned to mining closure; b)…"

Having the legislator's decision to grant the mining closure the character of "activity" it is important to define, if being an activity, it will be right to establish in the development of the mining project, the beginning of the mining closure as a step in the project, so as to fulfill law rules when it orders as a previous assumption at the beginning of the activity, the pronouncement of the Statement on Environmental Impact.

We believe that an expressed conclusion, may be too formal, regardless that a specific case should be solved on the basis of the above mentioned doctrine, meanwhile a harmonic and integrative interpretation of the law and its institutes leads us to a solution that conciliates with its essentially warning nature.

As a result the DIA updating (should be settled to the full extent of a biannual way) in those mining projects where exploitation is developed per decades, will allow the mine operator, as well as the application authority, to foresee step by step, the environmental consequences that were produced and the way in which they can be corrected so that when its exploitation finishes and facing the necessity of its probable closure, the future steps to formalize it will be expressed in a short way. This provision has to do with the planning, in the correct way and time, of a proper environmental managing.

If the deposit operator fully answers the environmental requirements, developing an environmental managing plan where the measures and preventing actions are introduced in organized stages together with the mitigation of possible impacts and the process to be used in the rehabilitation, restauration, and recomposition of the altered environment, also managing in this way his environmental managenmt in agreement with the fundamental law and its complementary rule, under control and checking of the authority of application, the mining closure will produce judicial effects with relevant economic repercussion planned on the activity and its residual consequences.

We shoul obviously highlight that if the proposer and the applied authority do not answer to the established environmental managing assumptions, the previous and posterior closure mining actions will then have accumulative effect actions of rehabilitation, recomposition, and restauration of the passive environmental.

When we cite the economic repercussion and its residual consequences, we referred to the patrimonial capacity of the company to answer after the mining closure. It should be specially taken into account the risk that may be produced by the insolvency and /or mistake of the company facing an eventual environmental damage that should be redressed by the company. In this hypothesis, the state, on legal guardianship of the judicial asset may be submitted to take mitigation, rehabilitation, recomposition measures among others with attribution to public funds.

We conclude that considering the incipient development on the mining activity in our country, it seems inopportune to state the subject we are on. Nevertheless, if we focus it from our point of view and if we take as a reference the warning nature of the environmental management that was carried out, we consider the mining closure as a task that should be performed from the beginning of the project and that is implicit in each of its different stages.

Module VII

Mine Closure: Case Studies

CLOSURE AND REMEDIATION OF THE POLIMETALLEC ORE DEPOSIT MINA ANGELA CHUBUT PROVINCE- ARGENTINA

Lic. *Guillermo E. Hughes*-
Dirección Gral. de Minas y Geología-Provinicia del Chubut-Argentina

INTRODUCTION

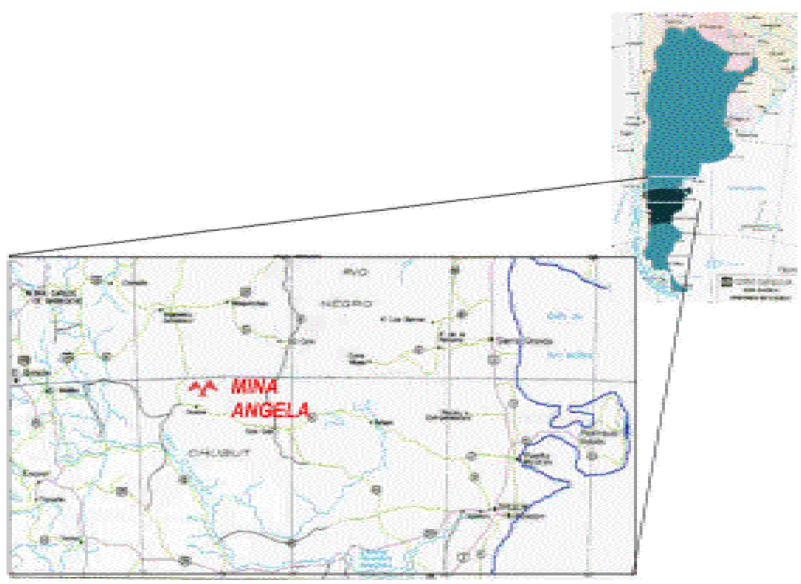
The present reports pretends to show the evolution and closure of Mina Angela, a Au-Ag–Cu–Pb-Zn mine, located in the Chubut Province (Argentina). The description will be done in chronological way, as there are several dates that are very important, especially from the legal point of view.

LOCATION

An Argentinian Company called Cerro Castillo S.A. (CCSA) owns the mine. Lonmin Plc (Lonmin) from Great Britain and by Garovaglio and Zorraquin S.A. (G y Z) from Argentina.owns CCSA

The Mina Angela mine is located at Latitude 42° S, and Longitude 69° W in the Gastre Department, close to the border with the Rio Negro Province. The Mine is at an elevation1400 mosl. A very low population density characterizes the district, and the main activity is the livestock farming.

Mina Angela is at 45 km North of Gastre (a small town of 400 inhabitant) by gravel roads, and at 116km south of Ing. Jacobacci (6500 inhabitant). The closest railway station is at Ing. Jacobacci, from where it possible to access to the port of San Antonio Oeste, and Port Madryn. The access by plane is through Bariloche.



ENVIRONMENT

Geology and Geomorphology

Mina Angela is located in the Somouncura Plateau. The geology comprises Jurassic breccias, tuffs and andesites (Taquetren formation). Comagmatic riodacite dikes intruded this volcanic complex.

Small mountains characterize the landscape. The land has been cut by an important drainage system from SW to NE. The highest mountains reach 1700 m. over sea level.

The structural characteristics, mineralization, and alteration indicate a low sulphidation ore deposit. There are very little indications of a high sulphidation deposit, and there are very little chances of a porphyry type mineralization.

Climate

Winds: Frequency, intensity.

The regional winds have SW-NE prevailing directions. We can say that they persist during the whole year, with an average speed of 40km/h, and a maximum speed of 120 km/h.

Rains, Humidity and temperatures

The annual average temperature is 9°C, with extreme temperatures between –30°C and 25°C during June and January.

The rainfalls are very rare, and vary from 125 mm and 300 mm per year. Snowfalls are very frequent in winter.

Hydrology a Hydrogeology:

General Features

The project is located close to where the drainage flows to the Maquinchao River, north of the property. The general features of the hydrogeology are controlled by geological structure and by the stratifigraphy.

The mine is located in the Clara Natividad cachtment and La Minas stream catchment (Fig. 2). The Clara Natividad catchment has an area of 8.6km^2. The Las Minas catchment has an area of 2km^2, and the streams finish in the Clara Natividad Stream, upstream of the tailing deposit. Downstream of the mine site and the tailing facilities, the Clara Natividad stream discharges into the Zarate stream, which discharges in the Caliente Grande River, and this one into the Maquinchao River.

The underground water is limited to the areas with a high density of secondary fractures. Regional water tables have not been identified.

Potential and actual uses:

Due to its remote location, and to the low population density, the water use is limited to the livestock farming.

It is important to say that only 21 persons live in a 50km range, downstream of the mine site.

Water Quality

The pH of the streams shows an average of 6,5. The quality of the waters is relatively good, and meets the Argentinean standard for drinking water.

Soils

Soils in the area tend to be generally thin and skeletal with a rocky and rubbly surface and poor developed profile. The soils are generally dry and only moderately eroded.

Vegetation

The area is located in one of the driest area of the Province, and small bushes characterize the vegetation.

MINE EVOLUTION

1920

Mina Angela mine was found by the son of a farmer in the 20's. A citizen of Trelew bought the rights of the mine. This person started to work with a small refinery and stopped at the beginning of World War Two.

1950-1955

The Compania Minera Patagónica S.R.L restarted the works with the technical support of the National Direction of Mining and Geology, and the financial help of the Industrial Bank of the Argentinien Republic. Due to the lack of positive results the work stopped.

1972

Norandex S.A., a subsidiary of Noranda Mines Ltd., acquired the mining right, and carried on the feasibility study, and showed that the project could be carried on as a 120t/d operation. Noranda decided to sell the project, as it was not big enough.

1975

By the end of 1975, a group of Argentinean showed interest in the Project. The Secretary of Mine carried on a program to increase in 800000tn the reserves of the mine. More works were carried on by the Rotatory Fund of the United Nation.

1978

The Mine went into production a rate of 120t/d.

The exploitation methods were cut and fill, and in a lesser extend open pit. At the end of the project they used jumbo drilling machines, and LHDs.

The plant facilities consisted in gravitational concentration, and differential flotation to obtain a concentrate of Pb, Au, Ag, and Cu, and another concentrate of Zn.

Due to the remote location of the mine, a camp was built for 400 people. The camp consisted in bedrooms for the workers, houses, offices, a school, a first aid installation, and general reparation facilities.

1979

The name of the Company changes to Cerro Castillo S.A. (CCSA).

1992

The mine stopped due to the low prices of the commodities, and to bad sailing obligations, and also to a lack of reserves. From that moment the mine started an exploration program.

1993

Due to financial problems the activities were stopped.

During the life of the mine more than one million tons of minerals were produced, which meant 105000 oz of Au, 1250000 oz of Ag, 3300 ton Cu, 18000 ton of Pb, and 38000 ton of Zn.

1996

Lonmin Plc. From Great Britain, with its subsidiary Lonarg (Pty) Ltd (Lonarg), reached an agreement with GyZ, and adquired 51% of the shares.

1997

An exploration program started in 1997 orientated to reopen the mine, and also to explore other properties of CCSA.

1998

By the end of 1998, because of the results of the exploration program, and because of the metals prices, the Company decided to stop the project.

PROCESS OF CLOUSURE AND REMEDIATION

Considerations

Once finished the exploration program, the decision to carry on a remediation plan, in order to minimize the impacts caused through nearly 80 years of activity was taken.

- At this point, there are some legal aspects, which gave the project some special features, should be taken in account.
- All the environmental legislation took place after the closure of the mine.
- There was not an environmental legislation before the actual mining law.
- Mina Angela had to be considered as an environmental passive.
- Environmental passive means that the remediation is a responsibility of the state.
- The annex III of the mining environmental legislation, just makes a small mention about the closure of the mine, and it does not set any procedure.
- In the Chubut Province, the Mining Authority is also the Authority of the Mining Environmental law.
- Mina Angela mine was designed, constructed, and operated, before any environmental legislation.

In this context, a team formed by different organisms from the Government, CCSA, and the consultant carried on the remediation plan.

Evolution of the Activities

February 1999

The first meeting took place, where CCSA showed the wish to carry on a remediation plan. In this meeting it was agreed that CCSA was going to prepared a first report in which all the impact where going to be established, and the most reasonably solution where to be proposed.

May 1999

The first report was presented, and professional from the Direction of Mine, and from the Direction of Environment visited the mine.

In this report there were several impacts identified:

- The mine facilities.
- The plant facilities.
- The Tailings damp.
- The camp.
- The drainage system.

The surface affected by the mining activities was 41 ha (Fig. 2), as it is showed in the following table:

Use of the land	Surface(ha)
Main roads	4,32
Secondary roads	8,61
Electric lines	9.169 m
Buildings	1,27
Mine Facilities	2,99
Debris	4,79
Tails	14,59
Water deposits	4,07
TOTAL	**40,64**

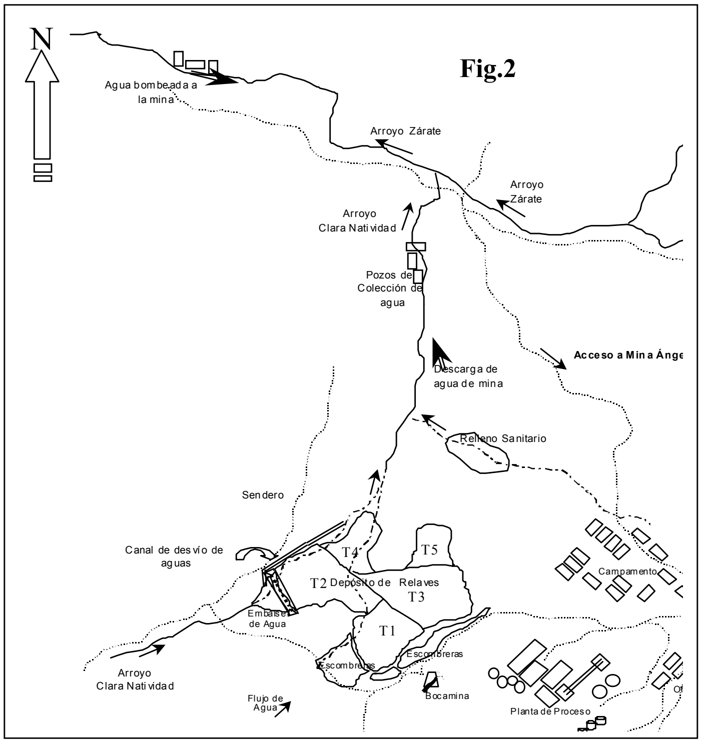


Fig.2

The design of the closure and remediation program was based on the following studies:

- Environmental audit.
- Remediation Strategies
- Soil and water sampling.
- Hydrologic studies of the Clara Natividad and Las Minas stream.
- Evaluation of the acid rock drainage.
- Cover of the tails.
- Closure of the main tunnel.
- Closure of the shafts and adits
- Hazardous waste management.

July 1999

A preliminary presentation held by Knight Piesold Ltd from Great Britain and Micon International Ltd from Canada took place in Rawson, Chubut. Professionals from the Direction of Mines, The Direction of Environment, an the Under-Secretary of Development took part in the presentation.

Several suggestions were made after this presentation, and from the following visits to the mine, which were accepted by CCSA.

September 1999

A final presentation of the remediation program took place in Rawson. The University from the Patagonia, Mining Authorities from Chubut, Santa Cruz, and Rio Negro, Congressmen, Mining companies, and journalists, were present.

From this presentation, new suggestions were proposed, and they were taken in account by CCSA.

October 1999

The Environment Impact Declaration was issued, in which the entire proposed program was approved.

November 1999

The remediation program started.

April 2000

The program is finished. During the period from November 1999 to April 2000, monthly inspections were held, together with authorities of Provincial Governments and National Government.

The works consisted in:

-The entrances of the mine were closed with concrete, ore with big rocks, or by blasting. The shafts were close with I beams and a mesh of steel, and then with rock, some of them were closed with concrete. The open pits were closed with the waste, and then with rocks. Signs were put close to the open pits.

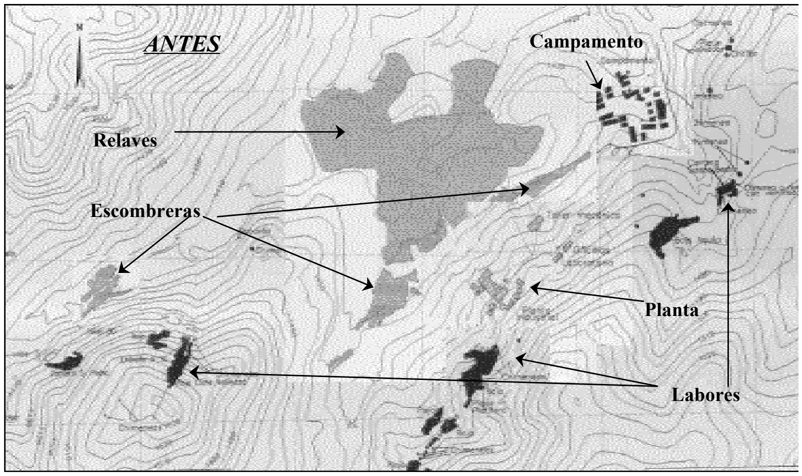
- The plant facilities were dismantled, and some of the equipment was sold. Special care was taken in handling the chemical substances, which were sold to a mining company. The parts of the plant that could not be sold were put in an open pit and then covered with rocks. The camp was also demolished and taken to an open pit. Once all this work was finished, the area was re-contoured.

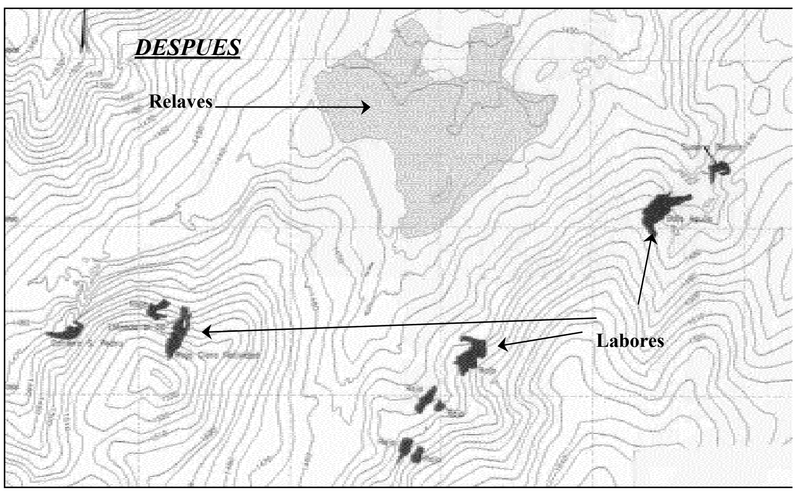
- The remediation of the tailing facilities included a cover with non-reactive rock. This cover was done after a re-contoured was accomplished. Channels around the tails to detour the water were built. On the cover two swales were constructed (wide shallow channels to detour the water in case of the centenary rainfall).

The quality of the water coming out of the mine is under the limits established for cattle. Anyhow water samples will be taken during two years, once the remediation is finished.

A study was carried to establish what would happened if the water from the mine comes out. Based on the information of the water flow from the mine, and the information of the water quality, an evaluation was done for the water quality on the Zarate Stream at the limit of the property. The study showed that the water quality would meet de Argentinean standards for cattle drinking water.

The company invested over 3000000US$ in the remediation plan.





Final Considerations

At this point, we'll try to show what Mina Angela mine meant to the Province during the operatin period, and during the process of closure.

Explotation Period

- During a period of 15 years, Mina Angela mine gave work directly to over 400 people, and indirectly to 1500 people.
- A great amount of these people came from the nearby area. These people were prepared for the mining work.
- Important investment was done in infrastructure.
- Mina Angela produced 1037358 ton of minerals, with 105000 oz of Au, 1.25 Moz of Ag, 3300 ton of Pb, and 38000 tn of Zn.

Closure Period

- Mina Angela is the first case of a mine closure in Argentina, taking in account the environment.
- A procedure between the private sector and the State was established for a mine closure.
- More than 50 persons worked during the closure of Mina Angela.
- An important amount of the infrastructure was given to the nearby town (Gastre and Ing. Jacobacci), as well as the laboratory equipment that was given to schools and Universities.
- This case showed the community in general the concern of the mining activities with the environment.

CONCLUSION

Every Project has a life, and this life is established by its reserves or by the changing of the market conditions. This is a fact that all the people engaged in mining know, but when the times comes, it is hard to accept. The Governments should be prepared for this fact, and should started thinking about a way of changing the local economy.

REFERENCES

BRION, ROSSO & ASOCIADOS, 2000. Informe final sobre Productos Químicos y Materiales en el Distrito Minero Mina Ángela; Mayo 2000.

CERRO CASTILLO S.A., 1998. Summary of 1997-1998 Exploration Activities, Mina Ángela Project, Chubut Province, Argentina; December 1998.

CERRO CASTILLO S.A., 1999b. Inventory of Assets for Sale, Mina Ángela, Los Manantiales District, Chubut Province, Argentina; July 1999.

CERRO CASTILLO S.A., 1999c. Annex III, Environmental Impact Report (English and Spanish versions); September 1999.

CONSTRUCCIONES PATAGÓNICAS S.R.L., 1999a. Obra: Mina Ángela, Proyecto de Cierre de Bocas de Chimeneas; Octubre 1999.

CONSTRUCCIONES PATAGÓNICAS S.R.L., 1999b. Legajo Técnico, Higiene y Seguridad en el Trabajo. Obra: Mina Ángela; Octubre 1999.

CONSTRUCCIONES PATAGÓNICAS S.R.L., 2000b. Obra: Cierre Mina Ángela, Procedimiento constructivo para el cierre del acceso de bocamina; Mayo 2000.

DIRECCIÓN GENERAL DE MINAS Y GEOLOGÍA DE LA PROVINCIA DEL CHUBUT, 1999. Declaración de Impacto Ambiental; Octubre 1999.

FUCHTER W., CHITI P., ACLAN M., 1999. The adjudication of bids and the selection of contractors for the closure and remediation of Mina Ángela; October 1999.

GARCÍA O., 1999a. Rainfall Data 1978-1999, Establecimiento El Molihue, Río Negro Province, Argentina; May 1999.

GARCÍA O., 1999b. Soil and Water Sampling Data, Mina Ángela, Chubut Province, Argentina; July 1999.

GARCÍA O., 1999c. Inhabitants along the River System Downstream, Chubut Province, Argentina; July 1999.

GARCÍA O., 1999d. Description of Transformers and their Contents, Mina Ángela, Chubut Province, Argentina; July 1999.

GOROSITO A., 1999. Marketing Campaign, November 1998-June 1999; July 1999.

KNIGHT PIÉSOLD LTD., 1998a. Environmental Audit and Preliminary Assessment of Mine Closure Requirements; October 1998.

KNIGHT PIÉSOLD LTD., 1998b. Soil and Water Sampling Programme; December 1998.

KNIGHT PIÉSOLD LTD., 1999b. Clara Natividad and Las Minas Diversion Channels, Design Report; May 1999.

KNIGHT PIÉSOLD LTD., 1999c. Hydrology Analysis of the Clara Natividad and Las Minas Catchments; June 1999.

KNIGHT PIÉSOLD LTD., 1999d. Mina Ángela, Tailings Facility Cover, Design Report; July 1999.

KNIGHT PIÉSOLD LTD., 1999e. Mina Ángela Tailings Facility, Acid Rock Drainage (ARD), Evaluation and Closure Implications; July 1999.

KNIGHT PIÉSOLD LTD., 2000b. Environmental Monitoring Programmes, Surface Water, River Sediments and Soils; February 2000.

KNIGHT PIÉSOLD LTD., 2000d. Mina Ángela Mine Closure Study, Predicted Water Quality Assessment; May 2000.

KNIGHT PIÉSOLD LTD., 2000e. Site Remediation, Adit Plug Design Report, May 2000.

MICON INTERNATIONAL LTD., 1999a. Assessment of the Mining Potential of Mina Ángela; February 1999.

MICON INTERNATIONAL LTD., 1999b. Preliminary Reclamation Strategy/Summary of Site Discussions, Mina Ángela, Argentina; June 1999.

MICON INTERNATIONAL LTD., 1999c. Excerpts of Relevant Canadian Water Quality Guidelines; June 1999.

MICON INTERNATIONAL LTD., 2000. Comments on Reclamation Activities, Industrial Area and Mine Openings; Mina Ángela, Argentina; May 2000.

NULLO F., 1999a. Reservas de Material de las Escombreras, Mina Ángela, Newphoenix S.R.L.; Agosto 1999.

NULLO F., 1999b. Inventario de piques, chimeneas y rajos en el Distrito Minero Mina Ángela, Newphoenix S.R.L.; Agosto 1999.

NULLO F., 2000. Evolución y cierre definitivo de chimeneas, piques y rajos en el Distrito Minero Mina Ángela, Provincia del Chubut, Newphoenix S.R.L.; Mayo 2000.

ONTARIO MINISTRY OF NORTHERN DEVELOPMENT AND MINES, 1995. Shaft Capping Standards; March 1995.

PACHECO M., 1999. Logistics Report on Additional GPS Survey Data, Mina Ángela, Los Manantiales District, Chubut Province, Argentina; June 1999.

PONTE H., 2000. Disposición final de bienes, Mina Ángela, Provincia de Chubut; Mayo 2000.

SÁNCHEZ M., 1999. Description of Housing Infrastructure, Mina Ángela, Los Manantiales District, Chubut Province, Argentina; June 1999.

ÁGUAS CLARAS MINE CLOSURE LIABILITY ASSESSMENT

Lima, H. M.[1,2]; Wathern, P.[2]; Franca, P. R.[3]
[1] School of Mines, Federal University of Ouro Preto, BRAZIL. Ph.D. student at University of Wales.
[2] EIA Unit, University of Wales – Aberystwyth, UK.
[3] Minerações Brasileiras Reunidas (MBR).

ABSTRACT

Closure programmes have extensive environmental and socio-economic implications and require the evaluation of liabilities from technical, environmental, social, financial and regulatory perspectives, if they are to be effective. When designing for closure, mining companies should estimate the main liabilities associated with the closure. A programme for assessing mine closure liability was conducted at Águas Claras Mine, Minas Gerais State, Brazil, in July 1999 as part of MBR planning for closure. The expected end of Águas Claras Mine production is scheduled for September 2001. This paper presents the implications and main long-term liabilities of Águas Claras Mine closure. In addition, it suggests the assessment of mine closure liability as a tool to assist regulatory agencies to evaluate proposed closure plans as well as mining companies design for mine closure.

1. INTRODUCTION

The challenges facing the mining industry today are many. Among them are the replacement of reserves, additional limitations on access and the possession of mining rights, ever more prescriptive environmental regulations and, potentially, associated compliance costs. Additionally, successful mine closure is becoming a focus of the industry as well as a measurement of performance by stakeholders (Russel, 1995).

In Brazil, the National Department of Mineral Production (DNPM) is responsible for granting mining title. In relation to mine closure, DNPM deals with cases of abandonment, surrender, cancellation, forfeiture or termination of a mining claim. Estate environmental agencies require an environmental impact assessment (EIA) for all mining projects during the licensing process. All environmental impact statements (EIS) have to include a plan for the rehabilitation of degraded areas (PRAD). However, this process does not ensure that the mine company's plan for closure will be implemented, nor guarantee satisfactory site rehabilitation at the end of the mine life cycle, especially when cash balances are frequently negative. In summary, no regulatory systems for mine closure exist in Brazil. However, at present, the Brazilian Department of Mineral Production, the Brazilian Institute of Mining and environmental agencies are working together on the development of a regulatory mine closure system. Águas Claras Mine closure process coincides with the closure debate.

A liability assessment was conducted at Águas Claras Mine in July 1999 as part of MBR closure planning. The expected end of Águas Claras Mine production is schedule for September 2001. A liability assessment is an estimate of the measures necessary to meet mine closure objectives. Typically, closure objectives should include the protection of public healthy and safety, minimising environmental, social and economic impacts of the closure and provision for future land use (Brodie, 1998).

2. MINE CLOSURE LIABILITY ASSESSMENT

The methodology applied in this assessment is similar to an environmental audit procedure, except that the scope is broadened to include all mine closure objectives. The similarities lie in the fact that much of mine closure liability focuses upon controlling environmental impacts, which are typically the most costly component of meeting closure objectives. An important difference between environmental audit and assessing mine closure liability is that the latter must consider changes that may occur at a site over the coming decades, or even centuries, and then provide rehabilitation measures to address these long-term concerns.

The liability assessment conducted at Águas Claras Mine consisted of two phases. In phase one, a questionnaire was submitted to company management to obtain preliminary information about the mine site and activities. This questionnaire allowed a better definition of the objectives and scope of the liability assessment programme. One essential step of the programme was the determination of assessment criteria. The established criteria based upon requirements and guidelines, such as the Ontario guidelines on planning for closure, adopted in countries where mine closure is a statutory requirement (Ontario, 1995). The criteria were agreed with MBR and communicated to Águas Claras Mine personnel before fieldwork began. Phase two involved two weeks of site visit to apply the liability assessment programme. All fieldwork was undertaken with two engineers from MBR, one from the geotechnical group and the other from the environmental group plus the site manager.

Much of the information was based upon documents related to the operation and environmental conditions of Águas Claras Mine supplied by MBR. These include technical reports elaborated by consultancy firms and internal reports. Additional information was obtained from the environmental agency and other federal and state agencies. The environmental management system, as well as other technical issues related to closure, were observed in the field and based upon technical reports and then interpreted and assessed to determine whether the programme criteria were met. (Lima and Wathem, 1999; Lima, 2000). The procedures followed were:

Review of MBR environmental policy and structure. In this context the environmental and socio-economic impacts at Águas Claras Mine, the Environmental Management System, the progressive rehabilitation programme, monitoring systems and permits were reviewed.

Meetings and interviews with members of different management areas at the mine and with regulatory agency personnel about the closure of the mine were held.

Review of the mining plan and specific mine closure measures. This included a review of geotechnical, geochemistry and monitoring reports.

Preparation of an assessment report which summarised current and ultimate site conditions, identified deficiencies and potential implications of closure and post-mine use of the site for each mine component. Finally, the current and anticipated long-term closure liabilities were summarised.

3. ÁGUAS CLARAS MINE HISTORY

Águas Claras Mine is one of the mining operations of the Minerações Brasileiras Reunidas S.A. (MBR). MBR is Brazil's second largest producer and exporter of iron ore. MBR is based upon mineral resources situated in the Iron Quadrangle, a geographical region rich in mineral resources that encompasses the central part of the Minas Gerais State. The Águas Claras Mine is an elliptical-shaped open pit operation located in the Curral Mountain in the municipality of Nova Lima 14 km from the centre of Belo Horizonte, the capital of the Minas Gerais State. In 1973, MBR commissioned the Águas Claras

Project. Since the beginning of its activities, Águas Claras Mine has produced about 259 million tons of iron ore. At the end of operations, by September 2001 the total production is expected to reach about 265 million tons iron ore. The iron ore deposit is composed of high-grade hematite, in both friable and compact forms.

4. Águas Claras Mine Components Addressed on the Liability Assessment

The final Águas Claras pit will have the following dimensions: 1,200 meters in length, 800 meters in width, 250 meters in depth. The maximum difference in level from the top of Curral Mountain to the bottom of the pit will be 500 meters. It is expected that about 350 millions tons of iron ore and about 170 millions tons of waste rock from the pit. Geotechnical studies have been conducted concerning both short- and long-term stability. Slope configurations (angle and height) and a safety factor (FS > 1.3) were designed and have been periodically checked with emphasis on slope stability. The objective has been to achieve lower level of slopes instability in order to avoid production breakout and accidents to personnel and equipment.

Waste Dumps

Águas Claras Mine has five waste dumps identified as Grotas –1, 0, 1, 2, and 3. These grotas correspond to valleys of the region. Their overall capacity is about 100 million cubic meters. Geotechnical studies concerning the engineering properties of soils and rocks were performed in dumps during project design and construction. An integral part of the project studies were stability analyses related to both the short and long term. As with the pit, appropriated slope configurations (angle and height) and safety factors (FS >1.2) were designed and checked. The dumps were constructed by disposing waste in layers 20 meters high. After complete construction, slopes were flattened to 1V: 2H. Internal drainage systems were constructed of blocks of hard rock, while surface drainage consists of peripheral channels along the berms.

Tailings Dams

Águas Claras Mine has two tailings dams; tailings dam #5 is already filled, while the Grota 3 PFF dam is operational. Tailings dam #5 storage capacity is about 11,300,000 cubic meters and the overall capacity of Grota 3 PFF dam is about 4,200,000 cubic meters. Tailings dam #5 was constructed by conventional methods using natural soil borrow as a dam, while the PFF dam from mine waste. Both have an internal drainage system. However, the tailings dam #5 overflow spillway is constructed in reinforced concrete while the PFF dam spillway is made of rocks.

Processing Plant

The Águas Claras iron ore processing plant, in general involves crushing, screening, washing and filtering of ore products based upon size and the metallurgical characteristics of the ore. The installed capacity on a dry-weight basis of the ore processing plant is 11 millions tons of product per year. The main products of Águas Claras Mine are lump ore (LO), pellet feed (PF) and pellet fine feed (PFF).

Others components of Águas Claras Mine include sedimentation ponds, the Patrimônio Peak, the Railway load out loop and buildings. The central office for MBR is located at the Águas Claras Mine. This includes support personnel for development, operation, human resources and finance. There are also management and technical teams providing support to all operational units. Administrative provision systems include offices, restaurant, healthcare, commissaries, changing rooms, telephone systems, truck scales and laboratories. Maintenance infrastructure includes repair shops for heavy equipment, light vehicles, truck washing, fuelling stations and lubricant bays.

5. Environmental Management System (EMS)

MBR's Environmental Management System (EMS) is based upon established company policy, Brazilian environmental regulations and international protocols. To establish environmental policies, MBR has developed an environmental management team that is accountable to the Director of Development. Currently, the environmental management team has 26 employees on two supervisory boards. The team's responsibilities include supervision of rural areas and supervision of the rehabilitation process. Simultaneously, the environmental management team coordinates the environmental follow-up group (Portuguese Acronym GAMA). The principal objective of GAMA is monitoring the performance of the environmental programmes of each operational unit. GAMA cares for environmental compliance through regular inspections, internal auditing and suggestions for improving existing environmental programmes.

Closure of a mine is a complex procedure involving and drawing upon a variety of different disciplines. Experience from closed mines emphasise the necessity of a closure team to design and conduct the closure activities. A closure team should comprise members of the mining operations, environment, legal and social departments. This closure team should work in close co-operation with the mine superintendent and his administrative staff, in addition to providing them with a pool of skills that can be utilised to co-ordinate and monitor the closure activities. Experiences from the GAMA group will be very helpful in the establishment of the closure team.

6. Águas Claras Mine Closure Plan

The closure plan for any mine is site specific. In general, the closure plan consists of ensuring that the physical structures that remain after mine closure do not impose a long-term hazard to public health and safety or to the environment.

The final mine closure plan is a hybrid, ideally formulated from continuous development of the initial and interim plans. The final closure plan forms the detailed working document for the implementation of mine closure. When the liability assessment programme was conducted, a general closure plan for Águas Claras Mine did not exit. However, many mine components already have closure plans prepared in order to achieve the best environmental conditions and final use for the area. The projects already conducted relate to a sustainable land use (Águas Claras Village), lake water quality analysis and pit slope stability upon lake filling. Other projects to be conducted concern compliance with governmental requirements, rehabilitation actions and custodial transfer. Although MBR has identified a final project use for the Águas Claras Mine, called Águas Claras Village, this is not the final decision and other alternatives are being studied.

The Águas Claras Village project was conceived in the late 1980s in a joint venture developed by MBR and Design Workshop, Inc. from Denver, Colorado, USA. The main idea of the project was to create an urban settlement so that minimal disturbance and maximum integration with the surrounding environment is achieved. The principal feature of the village will be the Águas Claras Lake to be created in the pit.

7. Results and Discussions

7.1. Implications of Closure and Future Use of the Site for each Different Mine Component

The definitive final use of the Águas Claras Mine area has not yet been determined. The first proposed post-mining use for the area was the creation of Águas Claras Village; other proposals for the area include an extension of the Mangabeiras Park, an extension of the Jambreiro Forest Preserve and a conference centre development. The development of a conference centre in the mine area is a new idea that has been studied. Because Águas Claras Mine is located in an area of high demand for urban development, many other future uses for the site are envisaged. However, independent of the future use of the site, each different mine component has its own characteristics and limitations that have to be considered before custodial transfer.

Table 1 summarises the expected closure characteristics for each mine component that will have to be accommodated within any final use of the area. These features relate to physical issues such as demolition, re-profiling and revegetation, stability of slopes and dams, effective drainage system and control; chemical factors including water quality, oil and grease clearance as well as a major biological topic namely the revegetation success that must be achieved by a closure plan.

Table 1 – Águas Claras Mine Components and Expected Closure Characteristics.

Components	Expected closure characteristics
Open pit / Curral Mountain	No deformation or erosion of slopes and benches; water management system functioning effectively; security arrangements functioning properly.
Process plant	Demolished; re-profiling and revegetation successful.
Waste rock & overburden piles	No deformation or erosion of slopes; drainage water quality and quantity acceptable; adjacent groundwater quality acceptable; revegetation successful.
Tailings management facilities	No deformation or erosion of dams; dam drainage effective; tailings geochemistry acceptable; surface water management system remains effective; surface and groundwater quality acceptable; security arrangements functioning properly.
Water management facilities	Rehabilitation and revegetation successful; effective surface drainage of the site.
Landfill and disposal facilities	No deterioration in groundwater quality; cover secure; revegetation successful.
Buildings and equipment	Demolished, re-profiling and revegetation successful.
Infrastructure	Dismantling, re-profiling and revegetation successful.
Exploration areas	Reinstatement of drill and access roads successful.

7.1.1. Pit

The Águas Claras Mine pit is the main feature of the area. The most appropriate after use of the pit seems to be to fill the void with water by stopping the dewatering system, directing surface drainage to the pit and pumping external water to accelerate the pit filling process. The proposed lake will have a depth of approximately 239 meters from an altitude of 866 meters to 1105 meters above sea level respectively.

Studies on Águas Claras pit show that the time required to fill the cavity will be about 20 years. However, pumping of external water can reduce this to 8 years. In addition, the lake is expected to improve overall slope stability (França, 1998). The principal problem related to the lake is the long-term responsibility for maintenance concerning stability of the walls during the filling process that will be required and for monitoring the water quality of the lake.

Another important matter to be considered during the Águas Claras Mine decommissioning phase is the security of the site. The mine is located in a very populated area, close to the neighbourhoods of Belo Horizonte City and Nova Lima town and surrounded by many states. The north and northeast faces of the pit are easily accessible through Mangabeiras Municipal Park at Belo Horizonte and by many trails. Bench heights in these faces are 26 meters. The maximum altitude between the top of Patrimônio Peak and the bottom of the pit will be approximately 500 meters. Therefore, the risk of people falling in these areas is high, considering the easy access to the locale and its attraction for sports such as mountain biking and walking. Consequently, signposts will be necessary together with an education campaign about the risk of accident in the area. In addition, ditches and berms or fences must be installed to restrict access to the pit area.

7.1.2. Waste Dumps

There are five waste dumps at Águas Claras Mine, called Grota –1, 0, 1, 2 and 3, with an overall capacity of about 100 Mm^3. Waste dumps Grota –1, 0 and 3 have already been closed and rehabilitated. The others have only the lower slopes rehabilitated at present, because the upper slopes are still in construction or are being flattened to receive vegetation. Most of these wastes dumps have been created as platforms on the sloped terrain. In general terms, these waste dump platforms, given the construction method and their waste and rock geotechnical character, would be appropriate for buildings, for example in association with the proposal village. However, any buildings for residential or economic proposals will have to be designed and constructed with due consideration to the physical characteristics of the dump. This will be necessary in order to minimise impacts on the dumps themselves during and after construction. The most probable impact on the dumps caused by the construction of buildings will be slope instability by erosion and overtopping of drainage systems by sediments and debris.

The security of the mine area should be a priority during and after closure. Security will also present problems, particularly with respect to the sedimentation ponds from the waste dumps. People from nearby communities are frequently seen at the sedimentation ponds. They use the area especially for camping, swimming and fishing in the lake. These people put the security of the area at risk, as they constantly use fire. The sedimentation ponds will remain as lakes when the mine is closed. The consequence of closure for these components is that they will be subject to degradation by human activities. These problems have been minimised by the intense security of the site while the industrial activities have been in operation. In future, a security plan for the mine area as a whole will have to be designed to avoid long-term liability.

7.1.3. Tailings Dams

A closure plan for the tailings dams requires a comprehensive re-assessment of both the facility and dam stability under closure conditions. All aspects of the facility and dam stability should be reviewed. In particular, the actual performance of the dams in service, including deformation, seepage, foundations and sidewalls, should be checked against design projections as well as against projected post-closure conditions. Designed loads might be different after decommissioning and closure.

Structural monitoring and inspection should be continued for all facilities and the dam until they are decommissioned and, thereafter, as appropriate. It will be necessary to identify and delineate any requirements for continuing inspection and monitoring of structures remaining after closure. A closure plan for the tailings dams should also involve an action plan to deal with shortcomings in closure characteristics and difficulties in complying with closure specifications. In addition, it should also examine the consequences of closure of the facilities on emergency plan procedures and update these as appropriate. Furthermore, it is essential to ensure the continued availability of design, construction and operating records after closure for structures remaining in place.

The objectives that need to be considered when planning the closure of the Águas Claras tailings storage area should include surface drainage and erosion protection to prevent surface water transporting tailings to the storage area. A stabilised surface cover (revegetation of settled tailings) will prevent surface water and wind erosion, while a good design of the closure will minimise post-closure maintenance.

At Águas Claras Mine the most appropriate scenario expected for the tailings impoundment #5 is the incorporation of part of the site into the Jambreiro Forest through revegetation with native species. To achieve this, the first step would be the establishment of appropriate drainage to avoid erosion of the settlement tailings. The revegetation process does not appear a difficult task, given MBR's experience in revegetation and the presence of the forest, which will facilitate the invasion of native plants, surrounding the pond. The remaining portion of the site, close to the pump station, will continue as a lake.

The PFF pond will be completely drained after the end of the operations. The settled tailings are expected to behave in a stable manner after drainage. However, as a security measure, especially given the risk posed by water pore pressure development, any kind of building should be avoided in the area. This procedure would avoid future adverse consequences after closure of this facility.

The Jambreiro Forest Preserve borders tailings dam # 5. Therefore, particular attention should be taken in terms of forest fires. Forest fires should be expected to occur relatively frequently, especially when close to an inhabited area. Of themselves, they do not pose a significant threat to the stability of rehabilitated mine components. However, loss of vegetation cover may lead to accelerated erosion by wind and water, or development of oxygen or water pathways along root holes through soil covers. Such fires are relatively frequent because of the invasion of the area by people for walking, camping, fishing and hunting.

7.1.4. Processing Plant

The MBR processing plant is old and, therefore, after equipment transfer or sale for recycling scrap, the entire structure will be dismantled. In this way, the foundations will be removed or buried and the site re-graded and prepared for the post use

7.1.5. Railway Load Out Loop

The railway load out loop, unless incorporated into the post-mine use of the site, will be dismantled. The Design Workshop Report (1991) suggests that the railway could serve as a road access to the area. With respect to the railway load out loop area the final use should pay due regard to the unstable slope that exist. Therefore, construction near it should be avoided.

7.2. Long-term Liability

After closure, some of the Águas Claras Mine components will remain as a residual effect of mining. The open pit and the lake that will be created, the waste dumps and the tailings barrages, for example, will remain as permanent features of the landscape and are, therefore, a long-term source of liability. The liability associated with them depends upon the potential for environmental impact should, for example, the slopes or structures that contain the wastes or tailings fail. In addition, the liability depends upon the hazard to public health and safety that such components might represent.

At Águas Claras Mine no chemical instability is expected due to the mineralogical characteristics of the iron ore, waste rock, tailings and ore treatment process that has been utilized. Most of the expected instabilities are physical. They are mainly related to pit slopes, waste dumps slopes and tailings dam slopes and rehabilitation process. Legislative instability, however, should be considered, because of incipient Brazilian legislation and requirements related to mine closure. The long-term liability of Águas Claras Mine is, therefore, critically dependent on the long-term stability of its principal components. Additionally, the hazard to public health and safety that such components represent, being located close to a populated area, must also be considered.

The principal liabilities with respect to the Águas Claras Mine components are summarised in Table 2. Table 3 lists the measures to be implemented during the decommissioning phase. For each mine component measures that should be taken in order to avoid physical instability and hazard to public health and safety were considered. Some of these measures are already being implemented according to the rehabilitation plan in progress.

Table 2 –Liability Summary for Águas Claras Mine Components

Mine Components	Liability
Open pit	Slope failure, especially during lake filling, and quality of the lake water.
Patrimônio Peak	Slope failure, rock fall.
Waste rock dumps	Slope failure, water erosion, drainage systems failure.
Sedimentation ponds	Water erosion, over topping of structures.
Tailings dam # 5 facilities	Water erosion, over topping of structures, failure of spillways.
PFF dike	Slope failure, water erosion.
Infrastructure (roads, railway load out loop, etc)	Water erosion and slope failure

Table 3 – Decommissioning Measures to Achieve Physical Stability and Public Security.

Mine Components	Physical Stability	Public Security
Open pit and Patrimônio Peak	Prevent deep-seated failure especially during lake filling. Revegetate or place riprap on slopes. Install steel net to avoid rock displacement on Patrimônio slope. Provide adequate surface water drainage.	Emergency access to lake Restrict access with ditch, berm or fence and signpost.
Waste rock dumps	Doze crest or construct toe berm to flatten overall slope	Restrict access to slopes with fence and signpost.
Sedimentation ponds	Increase freeboard to prevent erosion by overtopping. Ditch, berm or fences to prevent erosion by motorized vehicles.	Restrict access to pond with ditch, berm or fence and signpost.
Tailings dam # 5	Increase freeboard and/or upgrade spillway to prevent erosion by overtopping. Ditch, berm or fences to prevent erosion by motorized vehicles. Re-concrete the spillway for long-term stability. Define and provide for long-term monitoring and maintenance, avoid ongoing operation where possible.	Restrict access to lake, slopes and spillway with ditch, berm or fence and signpost.
PFF dike	Drain and contour the entire area.	
Infrastructure (roads, load out loop, power lines)	Remove culverts, barricades, approaches and stabilize. Rip compact surfaces and establish vegetation. Restore drainage patterns.	Follow specifications for maintenance and prevent inadvertent use. Discharge and lock open all non-essential power lines.
Buildings	Decontaminate if necessary, disassemble and remove all equipment and buildings. Backfill excavations, Remove buried tanks, Restore natural drainage	

8. Conclusions

The responsibility for closure of the Águas Claras Mine is a high priority for MBR. The results of the Águas Claras Mine closure and post-mining use of the site will be a benchmark for mine closure programmes and regulations in Brazil. The reasons for this arise from two facts. First, Águas Claras Mine closure coincides with the debate over mine closure regulations in Brazil. Second, the Águas Claras Mine is located in a very populated and environmentally sensitive area. The mine site is located in an area of high demand for urban development as well as industrial development.

From the mining industry point of view, the closure of Águas Claras Mine has become an important issue where the outcome is awaited with great anticipation. A well-planned closure of Águas Claras Mine certainly will contribute to the longevity of MBR mining operations as well as of the mining industry itself. To assure this contribution, MBR should address the needs of all stakeholders in the closure of the Águas Claras Mine.

The assessment of mine closure liability is a valuable instrument for regulatory agencies evaluating mine closure plan. This is particularly true in systems where no closure plan is required by the licensing process. From the mining industry perspective, liability assessment is a useful tool to assist mining companies design for closure. The quality of the available mine information, however, is essential for the accuracy of the assessment. The lack of this information requires site investigations that can impose additional cost and may postpone the mine closure process.

9. Acknowledges

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10. References

Brandt, 1999. Minerações Brasileiras Reunidas (MBR) - Long-term Development Plan. Belo Horizonte, Brandt Meio Ambiente.

Brodie, M. J., 1998, “Aquisitions and Mine Closure Liability.” Canadian Mining Journal **119**(4): 21-24.

Franca, P., 1998, “Post-mining Pit Lakes and Slope Stability - The Águas Claras Mine Example”.Mine Planning and Equipment Selection 1998, Calgary, Balkema, 135-140.

Lima, H. M., 2000. Águas Claras Mine Closure Liability Assessment Report. Aberystwyth, University of Wales.

Lima, H. M. and P. Wathern, 1999, “Mine closure: A conceptual review.” Mining engineering **51**(11): 41- 45.

Ontario, 1995, Rehabilitation of Mines: Guidelines for Proponents, Ministry of Northern Development and Mines.

Russel, L. J., 1995, “Mine Closure: Renewing a Corporate Strategy”.Mine Closure: Creating Productive Public and Private Assets, Nevada, 71-81.

REHABILITATION OF DEGRADED AREAS IN URBAN MINING: THE CASE OF THE METROPOLITAN REGION OF SÃO PAULO, BRAZIL

*Omar Yazbek Bitar**
*Institute of Technological Researches of the State of São Paulo - IPT

ABSTRACT

This paper summarizes resulting observations of researches accomplished by the Institute of Technological Researches of the State of São Paulo- IPT in the last years, concerning the post-mining process and rehabilitation of degraded areas by mining of aggregates in urban contexts, based on the case of the Metropolitan Region of São Paulo- RMSP, Brazil.

It especially deals with the rehabilitation procedures put into practice in active mines, besides the rehabilitation process and post-mining land uses verified in sites of ancient mining.

1. INTRODUCTION

The Metropolitan Region of São Paulo- RMSP (Figure 1) represents the largest concentration of population in South America, sheltering about 50% of the population of the State of São Paulo and 10% of the one of Brazil. It is today the second or the third larger metropolis of the world, with almost 18 million inhabitants in 8.051 km^2 and 39 municipal districts, whose growth is directly related to the accelerated industrialization and urbanization processes that started in the 1940's, especially after the end of the Second World War.

SOUTH AMERICA AND BRAZIL

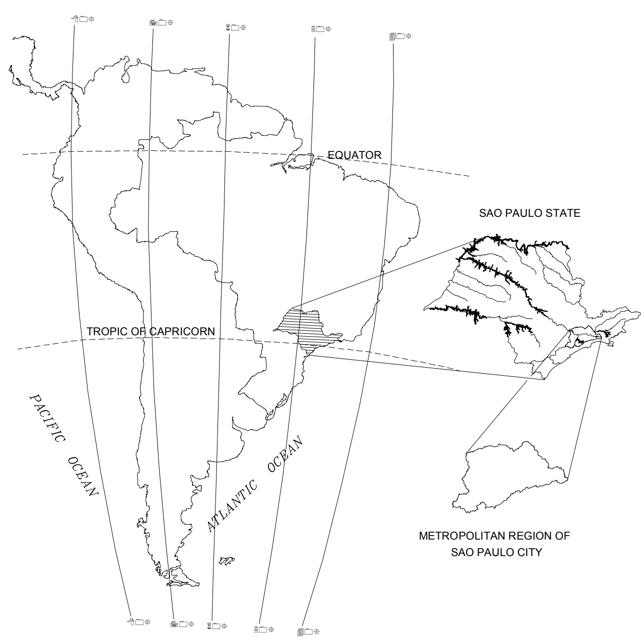

Figure 1- Localization of Metropolitan Region of São Paulo- RMSP

Among the main factors of this process, one can stand out the suitability of mineral resources for civil construction, as crushed stone, sand, clay, and carbonatic rocks for cement. The relative abundance of these inputs, given by the geological characteristics of the area, has allowed to build, at low costs, a huge amount of constructions, infrastructure works and industrial facilities in the metropolis.

However, due to the continuous relationships that have settled down between mining and the dynamics of growth of the metropolis in the last decades (Photo 1), several negative environmental effects have emerged (environmental impacts, risks, conflicts of land use, economical depreciation of the neigbourhood land, disturbances by the heavy traffic and others). One can stand out the progressive and non-planned occupation of degraded areas, whose rehabilitation constitutes the indispensable demand for the environmental sustainability of the metropolitan region.

In this context, the considerations here presented, mainly based on the works of IPT (1985, 1988, 1991, 1993, 1994 and 1995) and Bitar (1997) about 107 areas of mining in the RMSP, point out aspects related to the historical process of occupation and rehabilitation of degraded areas by mining in Brazil, emphasizing their relationships with the expectations of sustainability of the big cities.

Photo 1- Sand mining (pit: red; stocking: yellow; tailing dams : blue) in Itaquaquecetuba city, RMSP.

2. Aspects Of The Mining Activity

According to estimates of the National Department of the Mineral Production - DNPM, in the 1990's, the economical value of the mineral production in RMSP pointed the following distribution: 75% corresponding to *in natura* resources (55% of rocks for crushed stone and 20% of sand for building construction), 22% of industrial minerals (9,5% of kaolin, 6% of plastic and fire clays, 4,2% of quartzites and 2,3% of other mineral goods) and 3% of mineral waters. One can point out the expressive economical meaning of *in natura* resources, that is to say, mineral products used as aggregates and of direct employment in the civil construction, especially crushed stone and sand, responsible for

75% of the total. It should be observed that distribution has been maintaining relatively constant in the last years.

The production methods have been varying according to the type of the mineral resource and of the context of each occurrence. In RMSP, the stages of the mining productive process usually includes traditional practices: stripping, excavation, ore dressing, waste disposal, stocking, transport of products and auxiliary operations.

The monthly average production, declared by the miners, is quite variable. For sand, for example, it varies between 600 and 12.000 m^3/month; for crushed stone, between 15.000 and 90.000 m^3/month (the most frequent number is 30.000 m^3/month); for clay, between 15 and 500 ton/month; for limestone and feldspar, about 500 ton/month; for kaolin, with up to 120.000 ton/month; for quartzite, between 1.500 and 2.000 ton/month and for dimension stone, with about 50 m^3/month of blocks.

Concerning the involved human resources, the crushed stone mines do their work with a relatively larger number of employees, between 15 and 150 people, which is variable according to each enterprise. For the other types of mines (sand, clay or kaolin), the variation is smaller, between 15 and 30 employees.

The demand of sand in RMSP depends not only on its own production, but also of the increasing complementary contribution of the neighbouring areas. In fact, this demand leads to a sectorized contribution, which is geographically well positioned: in general, the production of the Paraíba Valley (located at NE, out of the RMSP) goes to the north region of the metropolis; the production of the S-SE portion of the RMSP serves the east zone; the production of the S-SW portion of the RMSP goes to the south portion; and the production of the W-NW portion goes to the west zone.

3. The Environmental Context

The mining activities in RMSP develop on a diversified and complex environmental context. Concerning to the geological scenary, it can be distinguished the precambrian crystalline rocks (granites, gneiss, migmatites, schists, quartzites, among others), which prevails the relief of hills and little hills and give support to sand, crushed stone and kaolin explotation; the tertiary-quaternary sediments, which frequently occurs in the hills relief and give support to sand production; and recent alluvial sediments, which are distributed in plains and wetlands associated to the main water courses of the area, as in the Tiete river, the largest of the metropolis, where prevails the production of sand and clay.

These characteristics allow to distinguish the main geotechnical units and their respective susceptibilities to the processes of superficial dynamics induced by human activities, among which mining is included. The correlation of those units with the main geological and geomorphological domains keeps in evidence problems such as: erosion and landslides associated to the production of sand, crushed stone and kaolin in hills and little hills; erosion associated to the production of sand in hills; and stream sedimentation and flooding associated to the production of sand and clay in alluvial plains. The understanding of them is the most fundamental aspect to take into consideration in the rehabilitation projects.

The residual soils (saprolitic soil or pedologic C horizon) from those crystalline rocks, when exposed to the action of rain are, comparatively, about six times more erodibles than the corresponding levels in the tertiary. Therefore, they potencially increase the production of sediments, leading to higher risks of stream sedimentation and, as a consequence, of floodings, with strong consequences in the rehabilitation perspectives of these sites.

The types of land use of these areas ordinary include: residential, industrial concentration, industrial predominance, commercial concentration, mixed use, institutional use, recreation, small farms and leisure, parks and state protection areas, among others.

There are several kinds of units of environmental conservation in RMSP, embracing remaining spaces of the primitive ecosystem (Atlantic Forest); although they are protected by law, mining activities frequently take place. There are those areas protected by their historical and/or artistical and/or architectural and/or touristic importance. There are also state parks, forestry/biological/indigenous reserves, ecological stations, environmental protection areas- APAs, areas under special regulation and spring protection areas, among others.

4. Applicable Concepts

Brief comparative analysis among different *reclamation* approaches and their applications to the mining degraded areas allows to identify an evolution of this concept along the last decades. In general, one can realize a transition between the idea of trying to return the site to its original condition, thoroughly spread in the 1970's, and the search of situations in which the environmental stability and its sustainability be guaranteed, according the concepts spread around the world in this transition of century.

Looking for an appropriate understanding to the metropolitan context, the *reclamation* concept should still contemplate a harmonious approach with the development of the mining works, taking into account the risks of accelerated urban degradation that the abandoned mined-out sites may be submitted. Such risks are especially owed to the intensity and speed of land uses and occupation process observed in the average and big cities.

Thus, the rehabilitation of mining degraded urban areas, like those located in RMSP, may be seen as part of a process that should embrace the procedures and the necessary measures to the fast environmental stabilization and the progressive development of a planned land use (rehabilitation).

The primordial task may be the stability or balance of the sites in relation to their neighbourhood. So, the proposed post-mining land use should be in accordance with the environmental and cultural patterns of the neigbourhood and also be productive, manageable and potentially sustainable. The urban or metropolitan stabilization is implicitly established as a short-term objective, while the foreseen of after land use or occupation implies medium and long-term results.

5. Practices In Active Mines

The procedures of rehabilitation of degraded areas in active mines in RMSP generally involve the surveillance of the implemented measures stawhile the exploitation is taking place (vegetal barrier, remoldement of mined areas, removal and use of organic soil, and others), in order to avoid or mitigate each detectable degradation process. The main objectives of these measures are attenuation of the visual impact, geotechnical stabilization, revegetation, reduction of the waste, geotechnical stabilization and chemical stabilization. Generally, the performance of these measures is regular.

However, they are few cases in which those procedures have been put into practice in conformity with the after land use originally planned and approved by the environmental agencies (Table 1).

Table 1- Active mines, according to their conformity to the original after land use plan.

Conformity to the original after-use plan	Active mines (%)
Yes	14
No	86
Total	**100**

6. Post-Mining Land Uses

In formerly mining sites in RMSP, one can distinguished two basic situations: occupied and non-occupied areas.

The non-occupied areas embrace those in which there is not defined use or even evidences that the exploitation could be retaken. They sometimes shelter temporary land uses, as warehouses or football fields. There is an intense and accelerated degradation in formerly sand or kaolin exploitation located in residual soil areas (Photo 2); there is a relative stability in remaining areas of old mined-out quarries located in hills; in formerly sand or clay exploitation sites, located in alluvial plain areas, the remaining digs left by the dredging works are in general flooded and frequently submitted to illegal dumping.

Photo 2- Degraded area by mining of sand in São Paulo city, RMSP.

On the other hand, the occupied areas embrace those contexts in which the occupation has disorderly happened (24%), besides the cases in which some planned after-use project was implemented (76%), even if inadequately.

Disordered occupation of degraded areas

In the disordered land occupation, whose pattern is given by evidences that the occupation has been accomplished without previous project, one can realize that the posssible manageability and sustainability are extremely uncertain (Table 2).

Table 2- Disorderded occupation, according to the current land use

Current land use		**Total (%)**	
Low income houses in hillsides slopes and alluvial plains		41	41
Different kinds of waste deposits (domestic, industrial, from hospitals)	At open sky	35	59
	In lake	24	

Concerning to houses located in hills, there are evident risks to the residents due to the high susceptibility of processes as erosion, landslides and unstable rock fall blocks (Photo 3). In plain areas, the residents ordinarily stand floodings; garbage and sewer *in natura* are frequently disposed without previous treatment, not only in the proper sites but in downstream areas as well, where remaing digs left by dredgind works are used by this purpose.

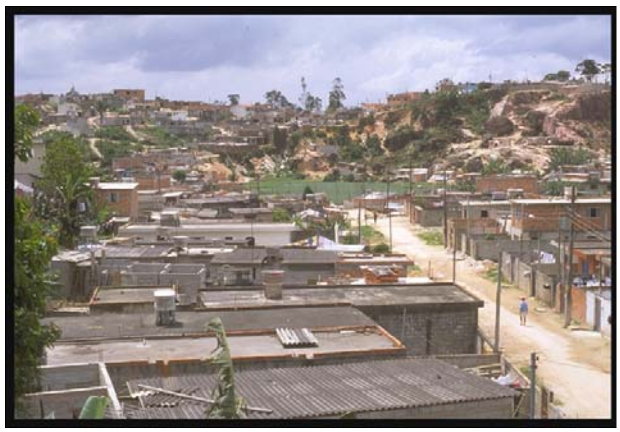

Photo 3- Disordered ocuppation by housing, in São Paulo city, RMSP

Planned land use

On the other hand, the rehabilitation based on a planned project generally leads to a productive and useful mined-out land use (Table 3).

Table 3- Areas in rehabilitation process, according to the current land use

Current land use	**Total (%)**
Waste disposal	24
Industrial and commercial uses	24
Leisure, recreation and community sports	21
Housing, division into lots	15
Traffic facilities	05
Education	05
Private recreational club	02
Hostelry	02
Fish farming, fishing	02
Total	100

In spite of the rehabilitation perspective given by the executed projects, the implementation of the planned land uses in RMSP has not always meant the solution of problems related to the environmental stability. Some areas have demanded permanent management and continuous achievement of severe measures of control and stabilization, depending on the type of land use adopted, according to their particularities.

Several implemented rehabilitation projects still live with instability problems. Some has been executed without a previous investigation of the environmental impacts and without a prospective analysis about the possible evolution of the degradation processes that could persist after the installation of the new land use. Also, they did not take into consideration the likely influence of those processes on the operation of the own project.

Among the situations related to stability, one can enhance those quarries planned for sanitary landfill. This kind of land use has been requesting continuous and expensive works concerning the drainage of gases and liquids, in order to assure the geotechnical stability of the embankment. This type of work has also aimed to avoid the occurrence of failures, like those happened in the sanitary embankments of Mauá and Bandeirantes, built respectively in formerly sand and crushed stone mining sites. Another aspect to be considered is the attractiveness of the sorrounding areas of the sanitary embankments to low income housing occupation, due to the depreciation of the adjacent lands. There are several episodes of current conflicts related to these two types of land use.

Besides the waste disposal, the plane areas of formerly quarries have also been used for the installation of big commercial facilities as supermarkets and deposits of construction materials, in relatively stabler situations. However, some places still face problems related to rock masses instability, mainly induced by the infiltration/seepage of rain/served waters, but more frequently linked to the presence of flakes and unstable blocks and the inherent risks and hazards associated to eventual falls.

In formerly sand alluvial extraction areas, whose land occupation by huge projects was become feasible after the backfilling works of the remaining digs, drainage problems can still persist. The main aspects are owed to the flooding, due to the alluvial context and to the low steepness of the built lands. Unstable slopes in remaining sand or kaolin extraction sites are also common, although with relatively smaller risks.

On the other hand, most of the post-mining uses related to leisure, recreation, community sports and housing live together with restricted stability problems. Also, they show quite favorable use modalities, considering not only their manageability but also their sustainability and that have been well successful in the relationships with the neighbourhood (Photo 4). These cases tend to serve as reference for more complex situations The uncertainties are owed to the situations in which the implementation of the post-mining project was preceded by waste disposal of several origins, including polluted sediments came from dredging works in local rivers.

Photo 4- Rehabilitation of mined area for leisure, recreation and community sports in São Paulo city, RMSP.

The promoter of the rehabilitation

The dimension of the rehabilitation projects executed in former degraded mining areas in RMSP suggests that the financial costs have been quite significant in most of the cases. The available data do not allow the obtaining of reliable values, but just the identification of the type of sponsor agent or promoter of the rehabilitation, in other words, the company or institution that financed the project and the implementation of the new land use.(Table 4).

Table 4- Rehabilitated areas, according to the promoter agent.

Promoter agent		**Total (%)**	
Public power	**Local government**	37	49
	State (regional) government	10	
	Federal government	02	
Private companies	**Mining**	05	51
	Other economical sector	46	
Total		100	

One can notice the balance between the cases promoted by public power and private companies. In the public sector, it is notable the prevalence of local governments, with about 2/3 of the rehabilitation projects implemented with public funds, followed by state and federal governments. There are cases in which the project has been executed in partnership, including international one. It can be pointed out that the mining companies have been having a very small participation in relation to the total of rehabilitation projects put into practice in RMSP.

The participation of public power has been happening mainly in leisure projects, recreation and community sports, besides waste disposal (sanitary landfill embankments); private companies have been dealing especially with industrial and commercial projects and also with real estate businesses, usually through big enterprises (Table 5).

Table 5- Rehabilitation projects, according to the land use and the promoter's nature.

Type of land use	Promoter's nature (%)	
	Public Power	Private Company
Waste disposal	20	04
Industry and commercial uses	-	24
Leisure, recreation and community sports	21	-
Housing	02	14
Traffic facilities	04	-
Education	02	03
Private recreational club	-	02
Hostelry	-	02
Fish farming	-	02
Total	49	51
	100	

7 Final Considerations

The results of this observations allow to point some of the main challenges related to the activities for rehabilitation of mined areas, concerning their potential contribution to the environmental sustainability of the big cities, among which one can enhance:

a) to hinder the disordered land use and occupation of degraded areas; and

b) to support the implementation of post-mining modalities of land uses that, besides productive, tend to be more feasible, not only in terms of manageability but environmental sustainability as well.

c) to estimulate the implementation of the rehabilitation projects by mining companies.

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References

BITAR, O.Y. Evaluation of the rehabilitation of mining degraded sites in the Metropolitan Region of São Paulo. São Paulo. 1997. 184 p. Thesis - Polytechnic School of the University of São Paulo. (in portuguese).

INSTITUTE OF TECHNOLOGICAL RESEARCHES OF THE STATE OF SÃO PAULO- IPT. Contribution to the urban land use planning applied to the rehabilitation of subnormal housing and degraded areas in the Metropolitan Area of São Paulo. Geotechnical map of the Metropolitan Area of São Paulo; scale 1:50.000. São Paulo. 1985. (IPT. Report, 19.817). (in portuguese).

__________. Study of sand mining methods and rehabilitation process in mined areas - RMSP - 2nd phase. São Paulo. 1988. 2 v. (IPT. Report, 26.943). (in portuguese).

__________. Evaluation of the potential of alteration of the groundwater quality in the Mineração Horii's area, Mogi das Cruzes, SP. São Paulo. 1991. 29 p. (IPT. Report, 29.253). (in portuguese).

__________. Industrial and technological updating program - PATI. Sectorial studies - Mining. São Paulo. 1993. 280 p. (IPT. Report, 30.503). (in portuguese).

__________. Slopes geological-geotechnical conditions of the of the abandoned mining "Giosa", in the municipal district of Embu, SP, with preliminary estimate of stabilization costs and indication of rehabilitation alternatives. São Paulo. 1994. (IPT. Report, 32.478). (in portuguese).

__________. Considerations on the stability and efficiency of tailing dams associated to sand mining in the Mineral District of Araçariguama, SP. São Paulo. 1995. 12 p. (IPT. Report, 33.160). (in portuguese).

THE CLOSURE OF SMALL MINES OF DIMENSION STONES IN LAGOA SANTA EPA

Adilson Curi
UFOP

ABSTRACT

The Environmental Protection Area - EPA - of Lagoa Santa was created by the Brazilian Federal Government on January 25, 1990, through the statute 98.881, published in the Act 6.902 of April 27, 1981 and Act 6.938 of August 31, 1981 and in the CONAMA (Conselho Nacional do Meio Ambiente) Resolution number 10 of December 14, 1988.

Lagoa Santa EPA is located in the metropolitan area of Belo Horizonte in the State of Minas Gerais, in the eastern margin of the Das Velhas river.

The mining of Lagoa Santa dimension stone for use as construction material is concentrated, mainly, inside of the limits Protection Zone of the Cultural Patrimony–PZCP, constituting one of the conflicts of use of this zone.

Although the dimension stone mining is only a temporary occupier of the land surface, it causes serious environmental impact associated with overburden, hauling roads, unvegetated surfaces, coarse rejects, fine-grained tailings, topsoil and stockpiles. The quality of the air, water and land is affected. Dust adversely affects air quality. The physical quality and quantity of surface water and groundwater can be affected if reclamation is not practiced. Water courses may be disturbed and flow rates altered. Erosion may be excessive, and the surface and ground water may become mineralised. The topography, drainage, vegetation, appearance, and surface texture of the mine site may all be seriously impacted. The gradients of sidecasts spoil may make the topography unsuitable for the planned post-mining land use (Williams, D.J. et al, 1997). The impacts of mining also include the destruction of the landscape, degradation of the visual environment, destruction of agricultural and forest lands and degradation of recreational lands.

The mining of Lagoa Santa's dimension stone is developed out of the technical, environmental parameters and in disagreement with the legislation. For the economic use of that ore considering the sustained development, are necessary changes in the productive process.

In this article are commented measures to improve the environmental quality in this area of environmental protection through the use of methodologies adapted to the closure of small mines.

The closure of small mines of dimension stones in Lagoa Santa EPA

1. INTRODUCTION

The Environmental Protection Area - EPA - of Lagoa Santa was created by the Brazilian Federal Government on January 25, 1990, through the statute 98.881, published in the Act 6.902 of April 27, 1981 and Act 6.938 of August 31, 1981 and in the CONAMA (Conselho Nacional do Meio Ambiente) Resolution number 10 of December 14, 1988.

EPA can be implanted in lands of public domain or of private domain, previously inhabited. These areas of environmental protection are destined to maintain the well-being of the urban populations and to conserve or to improve the local ecological conditions. In those areas, of private or public domain, the government organizations will establish norms, limiting or prohibiting some activities with objectives of protecting local interest for its specific environmental characteristics (Act 6.902/81). The CONAMA Resolution number 10

(1988) establishes the economic and ecological exploration norms, not allowing activities of earth movement, mining and excavations that cause damages to the environment and represent danger to people or to the biosphere, making restrictions to the those activities in areas close to caves, waterfalls and natural monuments. All those activities will depend on special licensing.

The mining is considered an activity that degrades the environment, in agreement with the CONAMA Resolution number 1 of January 23, 1986, what implies certain restrictions, and even prohibition, for its exercise in certain areas defined as untouchable as, for example, conservation areas and indigenous areas, where it can only be exercised with authorization of the National Congress. This characteristic of degradation of the mineral activity doesn't imply that its exercise is prohibited in certain Units of Conservation. However, the previous authorization of the responsible government environmental organizations is demanded by the administration of the Unit of Conservation (Act 7805/89).

The environmental fragility of that EPA, for being a limestones area, is enough reason to call the attention of everybody involved directly or indirectly, in the sense of trying to divide responsibility of its rational use, being still considered the inherent important aspects to its biological, cultural nature, landscape, as well as its social and economic characteristics (Barreto, M. L. & Sirotheu, G. J.).

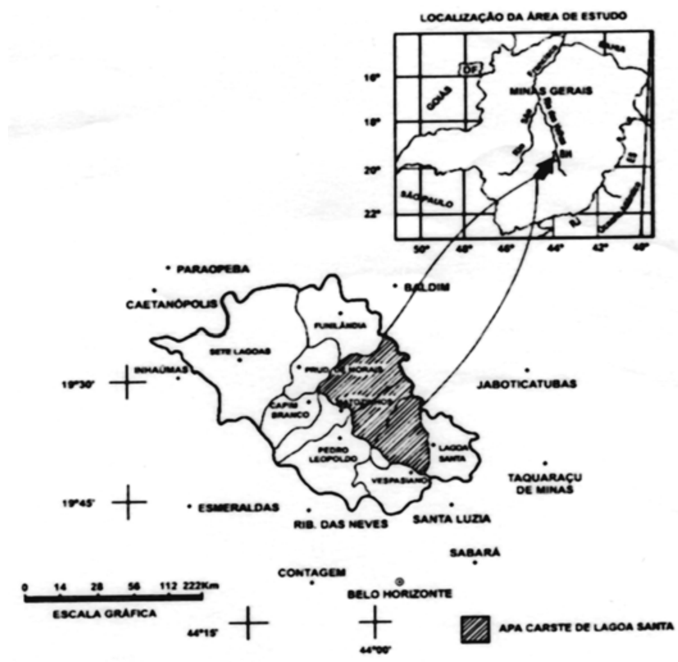
In this context, is inserted, as conflict of use of the area, the mining and the treatment of Lagoa Santa dimension stone for industrial use. These mining activities of small size should receive mechanisms of environmental control on its disordered expansion and technical and operational attendance with relationship to its handling which is the main objective of that work.

2. The Area of Environmental Protection of Lagoa Santa and the Mining of Lagoa Santa Dimension Stone

2.1. Location of Lagoa Santa EPA

Lagoa Santa EPA is located in the metropolitan area of Belo Horizonte of the State of Minas Gerais, in the eastern margin of the Das Velhas river (Fig. 1). It could be reached by the highway MG-424, in the direction Belo Horizonte–Pedro Leopoldo–, or by the highway MG-010, in the direction Belo Horizonte– Confins International Airport.

This EPA, with an area of 35.600 hectares incorporates the municipal districts of Lagoa Santa, Pedro Leopoldo, Matozinhos, Funilândia and Confins (Cabral, J.A et al, 1998).



(Source: CPRM - IBAMA)

Fig 1: Location Map and zoning of Lagoa Santa EPA

The mining of Lagoa Santa dimension stone for use as construction material is concentrated, mainly, inside of the limits of the Cultural Patrimony Protection Zone – CPPZ-, constituting one zonal use conflicts.

2.2. The main characteristics and objectives of the CPPZ is:

<u>Functions:</u>

- To protect and to promote the landscape and the regional culture, represented by the Sumidouro arqueo-paleontological environmental System patrimony, for the Lapinha archaeological patrimony and Fidalgo historical patrimony;
- To protect the humid ecosystem and the remaining species in the environment, especially the fauna associated to the Sumidouro lake.

<u>Elements to analyze</u>

- Sumidouro lake, especially the features of the calcareous landscapes;
- Rosário chapel;
- Sumidouro lake, an important humid system of great relevance for the survival and the maintenance of the diversity of the regional fauna, including species that are threatened of extinction;
- Lapinha cave group , of great tourist, cultural, archaeological, paleontological and speleologic importance;
- Fernão Dias House: A historical and cultural reference, where the EPA reference center is located;

- Fidalgo and Quintas of Sumidouro Urban environmental context;
- Group of native vegetation (denominated " cerrados ") that is located to the north of EPA and in all the proximities of the Sumidouro lake ;
- The Jenipapo water course, a calcareous area with mountainous, and low resistance lands subject to the erosion processes and mass sliding;
- Non calcareous areas more vulnerable to the erosion processes;
- Expressive species diversity the humid EPA environment, represented, especially, for the Sumidouro lake, in the interface with the "cerrado'' nuclei.

Conflicts of Use

- Activities of sands extraction in the Das Velhas river, causing significant impacts to the fluvial system and the surrounding vegetation;
- Inadequate disposition of urban solid residues and of the residues of the mining;
- Extraction of Lagoa Santa dimension stone, with impacts on areas of great environmental fragility;
- Impact to the speleologic patrimony, to the archaeological and cultural patrimony and to the landscape, due to the activities of production of the Lagoa Santa dimension stone;
- Blockage and pollution of the water sources;
- Guidelines of Environmental Protection

Incentives

- To reactivate the mechanisms for the creation of the Sumidouro Park, with the objective to protect the patrimony and to integrate local communities in its maintenance and operation;
- To establish a managing plan for execution of support structures for visitation and to increase the value of the patrimony;
- To establish technical and financial conditions to elaborate and to implant the managing plan for the urban nuclei of Fidalgo and Lapinha, seeking to adapt them with the new functions foreseen for the area;
- To establish technical and financial conditions for the small producing cooperative organization of the Lagoa Santa dimension stones, seeking to concentrate the production areas in mining districts, to guide the extraction technology and treatment, to reduce the losses and the environmental impacts of the stone's cutting machines residues.

Main Restrictions

- To discipline the use of the soil, controlling its expansion in the direction of the most vulnerable areas;
- To restrict the use of the soil for urban constructions;
- To establish occupation patterns that guarantee the maintenance of low population densities;
- To control the agricultural activities that cause pollution in the Sumidouro lake;
- To control the mining activities, especially the Lagoa Santa dimension stone extraction and the calcareous exploitation.

Norms and Guidelines of Use

- Allowed uses

- Reforestation with native species, seeking to the recovery of the vegetation and the renewal of the fauna, mainly in the proximities of the areas of natural vegetation;

- Scientific research;

- Agricultural, wild activities or activities of the creation of animals in areas with a decline less than 45% that use handling techniques that are compatible with the natural processes of the ecosystems;

- Ecological tourism, that uses techniques with low impact on the environment to be preserved;

- Subsistence fishing;

- Recreational ranches, with minimum fraction of 5.000 m2, being 20% of the area destined to the vegetation with species of the native flora;

- Urban equipment and visitation infrastructure destined to organize the tourist and cultural activities of the area.

Tolerated uses

- Extraction and irregular treatment of the Lagoa Santa dimension stone, conditioned to its regulation and the participation of the producers in a program of environmental extension, destined to the reduction of the impacts of the activity, technological improvement and residues reduction;

- Agricultural and wild activities and creation of animals already existent and conditioned to the reduction of disconformities such as: use of areas with decline of more than 45% and with handling practices that cause the degradation and pollution of the soil and the underground waters, hindered the expansion of the cultivations already existent.

- Activities of mineral extraction already existent and regularly approved by the Organizations of Environmental Control, with appropriate treatment systems and disposition of liquid residues and of solid waste, which promote the environmental recovery of the degraded areas, hindered the expansion of the mines already existent.

- Urban establishments already installed in inadequate areas, since endowed with systems of garbage collection, disposition and treatment of sanitary residues, adapted to the demands of the calcareous environment;

- Industries already existent, since licensed by the competent organizations of environmental control and with appropriate treatment systems and disposition of liquid efluents and solid waste, hindered the expansion of the industrial areas.

Forbidden uses

- Activities of mineral extraction that cause any risks to the environmental, archaeological, paleontological and speleologic patrimony;

- Intensive creation of animals;

- Agriculture with intensive handling and with use of herbicides and fertilizers;

- Division of the soil in small lots, with urban purpose or for recreational small farms;

- To install and to operate new industries;
- Use of areas for disposition and treatment of sanitary efluents, domestic or industrial solid residues, under any conditions;
- Disposition of chemical efluents, including fertilizers.

3. THE AREA OF FIDALGO

The district of Fidalgo represents most of Pedro Leopoldo municipal territory and has the prevalence of activities destined for the creation of animals. However, the activity that characterizes the district is the presence of small industries for production of the Lagoa Santa dimension stones , in the margins of the Lake of Sumidouro, linked to the irregular extractions, that absorb practically more than 90% of the local population. Fidalgo is located about 16 km from Pedro Leopoldo. The mines are located approximately 3 km from the town of Fidalgo.

The current population of Fidalgo which is the area of direct influence of the mines is approximately 4.000 inhabitants. As spoken before, about 90% of the active population works in the production of dimension stones for civil construction. The remaining population works in the creation of animals, mainly cattle. This percentage of the local population that works in the production of dimension stones includes children starting from 12 years of age. The average workers' salary is US$ 150,00 a month.

The area is considered rural, being largely destined to recreation and tourism. Thus, are common in the Sumidouro district the ranches and small farms in the lake margins. The cultivation of agricultural products is only made for subsistence, because, according to previous citation, the labor used in Fidalgo is, in its majority, working in the main economic activity of the area, the small mining.

4. THE WASTE DISPOSAL

Mine site waste disposal and rehabilitation operations comprise the actions of disposing of the waste products, preparing mined land for future land uses after the ore has been removed, and returning the disturbed land to a future use. They also include those actions that stabilise mined land and improve the land environment. The purpose of waste disposal and rehabilitation operations are to reduce the environmental impacts of mining and to meet the satisfatory requirementes (Williams, D.J. et al, 1997).

A disposition project of waste in a pile should be elaborated for each small mine in activity. The Brazilian norms NBR 13029 of ABNT (Associação Brasileira de Normas Técnicas) should be followed, seeking to assist safety conditions, hygiene, operation, economy, abandonment and mitigation of the impacts to the environment, according to the legal patterns (Brandi,I.V.,1994).

The waste piles should be disposed, if possible, inside of the mine pit exploited, or close to the areas already degraded. It should be avoided to dispose the material in valleys, mainly, with larger inclination than 18 degrees; natural surfaces drainages, water courses; areas of permanent preservation; unstable areas, flooded lands; areas with exuberant native vegetation; areas with fertile soils. As the external and internal geometry of the pile, the following limits and cares should be observed: maximum height of banks of 10 meters; minimum width of berms of 6 meters; maximum height of the pile of 200 meters; existence of maintenance accesses; to reduce the angle among banks, for values less than the natural angle of rest of the waste ; berms with longitudinal and traverse minimum gradient of 1% and 5%, respectively; drainage in the pile. Other parameters in the conception of the project are: size classification of the materials to be disposed of to take advantage of the maximum resistance and drainage characterisrtics of each material; adaptation of the formation and classification of the pile with the stages of waste removal; execution of the pile in an ascending way; protection of the slopes with vegetation; removal and deposit of the organic soil of the pile for future use; interns, superficial and outlying drainage system; system of retention of sediments originating from erosion; maintenance system and control.

5. Rehabilitation of the Degraded Areas

A project of rehabilitation of degraded areas should be elaborated by the mining, following the norms NBR 13030 of ABNT, therefore, should be made the adaptation of the landscape to ensure the harmonization of the mined areas with its proximities, with the purpose to minimize the visual impact and to do the topographical adaptation objectifying the future use of the area.

Fig. 2: Impacts on the soil due to mining in Lagoa Santa EPA

It is necessary to make the rehabilitation (group of procedures through which is returned of the productive function and the natural processes of the area, seeking adaptation of future use) or the recovery (group of procedures through which is made the recovery of the area degraded for the establishment of the original function of the ecosystem) or the restoration (group of procedures through which is made the replacement of the exact ecological conditions of the area degraded by the mining, in agreement with the established planning) to define a future use (use foreseen for a certain area, considering its aptitudes, intentional use and fragility of the physical and biological environment).

5.1. Vegetation

The establishment and the growth of the plants should be observed with the purpose of return of the native fauna. The fertility of the soil, the pH and the salinity should be controlled.

5.2. Dimension stone production reject

Dimension stone production reject is a great problem, that can be solved, for example, with its use in a cement industry, in the construction of houses or roads, in general. The best option should be verified for its use.

In any case it doesn't have an economic use this material should be transported and arranged in piles controlled with a contention system of fine (Dike).

Fig. 3: Dimension stone production reject in Lagoa Santa EPA

6. CONCLUSIONS

Although the dimension stone mining is only a temporary occupier of the land surface, it causes dramatic and serious environmental impacts associated with overburden, haul roads, unvegetated surfaces, coarse rejects, fine-grained tailings, topsoil and stockpiles. The quality of the air, water and land is affected. Dust adversaly affects air quality. The physical quality and quantity of surface water and groundwater can be aggected if reclamation is not practiced. Water courses may be disturbed and flow rates altered. Erosion may be excessive, and the surface and ground water may become mineralised. The topography, drainage, vegetation, appearance, and surface texture of the mine site may all be seriously impacted. The gradients of sidecasts spoil may make the topography unsuitable for the planned post-mining land use (Williams, D.J. et al, 1997). The impacts of mining also include the destruction of the landscape, degradation of the visual environment, destruction of agricultural and forest lands and degradation of recreational lands.

The mining of Lagoa Santa's dimension stone is developed out of the technical, environmental parameters and in disagreement with the legislation. For the economic use of that ore, inside of the approaches of sustained development, are necessary changes in the productive process, as:

- Qualified professional technical support (mining engineers and geologists), seeking a better planning of the mining operations are necessary. This technical support can be made possible by the Small Producing Cooperative organization of the Lagoa Santa dimension stones, assisting the needs of all the associated quarries;

- To assure measures to mitigate the impact caused to the environment and for the controlled disposition of the sterile generated by the production of the dimension stone;
- Study of economic use of the reject of the production. This study can be developed in partnership with Institutions of superior level of the mining area, objectifying to find use for it;
- Technical study with the purpose of decreasing the loss of the dimension stone of Lagoa Santa during the production process;
- Use of research methods, such as, seismic refraction to identify the fractures in the mines reducing the material loss during the mining exploitation.

7. References

Barreto, M. L. & Sirotheu, G. J. Mineração em Áreas Ambientalmente Sensíveis – Um Estudo Comparativo. Conselho Nacional de Desenvolvimento Científico e Tecnológico. 1992. 18 p.

Brandi,I.V, Estudo da efetividade dos planos de recuperação de área degradas de atividades de explotação de minérios de ferro na região do quadrilátero ferrífero –MG – Dissertação de Mestrado. USP-EESC. 1994.114p.

Cabral, J.A et al., Zoneamento Ambiental da APA Carste de Lagoa Santa. IBAMA, CPRM, Brasília, 1998.

Williams, D.J; Wu,Y; Morris, P.H systems analysis of engineered mine site rehabilitation, Proceedings of The Fouth Intern. Conf. on Tailings and Mine Waste, Fort Collins, Colorado, 1997, Rotterdam: A.A. Balkema.

Norma NBR 13029 da ABNT (Associação Brasileira de Normas Técnicas), Coletânea de Normas de Mineração e Meio Ambiente , Companhia Vale do Rio Doce, Rio de Janeiro, 1993.

Norma NBR 13030 da ABNT(Associação Brasileira de Normas Técnicas), Coletânea de Normas de Mineração e Meio Ambiente , Companhia Vale do Rio Doce, Rio de Janeiro, 1993.

RECLAMATION OF CLOSED OPEN PIT MINES IN METROPOLITAN AREAS: BRAZILIAN CASES

Eduardo C. Damasceno(*)
geólogo, Dr., Professor Titular, Departamento de Engenharia de Minas, Escola Politécnica da USP, Diretor Acadêmico da Área de Exatas e Tecnologia da UNIBAN - Universidade Bandeirante de São Paulo, São Paulo, SP. , Brazil, Rua Cordeiro Galvão, 36, 05450-020, São Paulo, SP.5, edamasceno@uniban.br
Paulo Fernando de T. Damasceno(**)(**)
engenheiro de minas, Votorantim Cimentos, Cimento de Sergipe – CIMESA, Rua Sonia Alves Lopes, 2691, 49035 - 740, Aracajú, SE, pftd@uol.com.br

ABSTRACT

In this paper is presented a roughly description of two cases of reclamation of open pit decomissioned mines. The first one, is an old site of sand production transformed in a place for regatta races and, the second an old quarry, now used as a park and a theatre. These two cases, both located in the large cities of São Paulo and Curitiba, Brazil, are good examples for the new uses and reclamation of closed open pit mines.

INTRODUCTION

Aggregates like sand and crushed stone due his low unit value affected by the transportation costs must be produced near the cities in were are being used. Quarries for crushed stones and mine of sand in several cases are located into the urban areas of the cities and as a paradox, must move to new far places pulled out by the growth of the city. Some years later new moving of the mines is needed pushed off by the urbanization, in general a very fast process in the metropolis. The planning of aggregate production could prevent possible disagreements concerned to the expansion of the cities.

In the moving of the mines closed open pit remain in the side of hills, in the case of quarries, or along the river valleys from where sand was exploited. The owners of the mines and metropolitan authorities must find and plan solutions for new uses of the closed mines as places for rest and recreation, tourism attractions, houses and industrial buildings, rubbish dumps, industrial garbage deposits and other uses.

In this paper are described two cases of interesting uses closed open pit mines: the first one an alluvial sand mine located at Cidade Universitária, São Paulo City, and the second, a quarry in a hill side, at Curitiba, both in Brazil.

In the first example the mine was reclaimed for a regatta rece place ("raia olimpica") and, the second a theatre ("Ópera de Arame") constructed in a tubular structure linked to a park ("Parque da Pedreira").

These two cases are very impressive and unnusual reclamation examples of uses for open pit closed mines. In both cases the aggregate exploitation was planned in view to the future use of the site after the mine closing.

THE CLOSED SAND MINE AND THE "RAIA OLÍMPICA DA CIDADE UNIVERSITÁRIA"

The City of São Paulo, capital of the State of São Paulo, Southeast Brazil, it is one of the largest cities of the world. In the Great São Paulo which is the most important industrial centre in Brazil lives about 16 millions inhabitantes. The growth of the City of São Paulo occurred after the II War due to the economic change toward an industrial pattern from the agricultural set production. This explosive expansion have required a big infrastructure and the construction of factories, houses and buildings which required large amounts of sand. The present demand of sand in the City of São Paulo is estimated as more than 2 millions cubic meters per year. But this production amount was larger in the past years.

Sand is very common in the alluvial deposits along the Tietê and Pinheiros rivers, this last one the most important river located in the West region of the City of São Paulo. Before the urbanization of this region that ocurred in the end of 60" and begning of 70' a lot of sand mines were in operation along the Pinheiros river and among them the site "porto de areia da Cidade Universitária". This mine with 3000 meters length, 50 meters wide and about 10 meters depth was developed in the parallel side of the Pinheiros river. The total amount of sand produced is estimated as 1,5 million cubic meters. This mine was closed in de end of 60" and his sides urbanized to the present rectangular shape design.

Today is a part of the sport facilities of Universidade de São Paulo -USP now used for regatta races. It is also a very pleasant place in the big concrete city.

THE "PARQUE DAS PEDREIRAS PAULO LEMINSKI" AND THE "TEATRO ÓPERA DE ARAME"

These beside places are located at Curitiba, the capital of the State of Paraná, South of Brazil. Curitiba is one of the best planned cities in Brazil and presents the largest green area per inhabitants, about 55 square meters. In 1990 Curitiba the UNEP - United Nations Environment Program prize was granted to the city of Curitiba due the system to collect and recycle the urban rubbish. Curitiba presents also a modern and efficient system of surface public transportation. Curitiba presented in the last years a large urban growth and today is one of the most important Brazilian automobile industries center. The conservation of natural forests and green areas and the construction of public gardens are impotant goals of the public policy at Curitiba and among them are the "Parque das Pedreiras" (Quarries' Park) and the" Teatro Ópera de Arame" (String Opera Theater).

The "Parque das Pedreiras" e a "Ópera de Arame" are both located in the place of a quarry for crushed stone, closed in the 80'. The production of crushed stone is estimated as more than 500,000 cubic meters.

The "Parque das Pedreiras" was developed in the end of 80" It is a very pleasant place with lakes, falls and native vegetation. Into the park sthere are the Paulo Leminski Cultural Centre for meetings , a library for childrens and an open-air theatre with a capacity for 10000 siting or 50000 up people.

The " Ópera de Arame" is a another theatre beside with a capacity foor 2,400 people. It is located in the bottom of the closed open pit. Was stablished em 1992 and it is a very interesting tubular construction with a transparent roof. It it is one of the most impressive tourist attraction in Curitiba.

CONCLUDING REMARKS

These reclamation examples of closed open pit mines located in metropolitan areas describe in this paper shows the great improvements that we could have for tourism, culture and sports purposes. The two cases are good examples of well planned mining for future use of the site not only in metropolitan areas, that could be used also in several other regions.

REFERENCES

Luz, A.B. & Damasceno, E.C., 1996, Desativação de minas, CETEM/CNPq, Série Tecnologia Ambiental, 14, 18p, Rio de Janeiro

http://www.viaje.curitiba.pr.gov.br/pontos turísticos/operadearame.html

EVALUATION OF ENVIRONMENTAL RISKS ASSOCIATED TO MINING IN PORTUGAL. GUIDELINES FOR A STUDY PROGRAMME AND RESULTS

J.M. Santos Oliveira[1], M.R. Machado Leite[1], M.J. Canto Machado[1], M.Y. Pedrosa[1], L.M. Quental[2], J.M. Matos[3], C.J. Rosa[3], P. Ávila[1], L.P. Martins[2], F.S. Daniel[4]
1)Instituto Geológico e Mineiro, Rua da Amieira, 4465 S. Mamede de Infesta, Portugal
2)Instituto Geológico e Mineiro, Estrada da Portela, Zambujal, 2720 Alfragide, Portugal
3)Instituto Geológico e Mineiro, Rua Frei Amador Arrais, 7802 Beja, Portugal
4)Instituto Geológico e Mineiro, Rua Almirante Barroso, 1049 Lisboa, Portugal
E-mails: santos.oliveira@igm.pt; machado.leite@igm.pt; lidia.quental@igm.pt; igmbeja@ip.pt; lmar@igm.pt; paula.avila@igm.pt; fernando.daniel@igm.pt

Key words: Environment; Abandoned mines; Geochemistry; Hydrochemistry; Hydrogeology; Mine safety; Earth Observation Techniques.

ABSTRACT

The Instituto Geológico e Mineiro (IGM), the Portuguese Geological Survey, actually develops a wide plan of environmental studies focused on the main abandoned mine sites that occur dispersed over the country. With this project it is aimed:

a) to characterise chemically those mine sites and their surrounding areas;

b) to undertake detailed geochemical and hydrochemical R&D studies, as well as to study the hydrogeological models for the most important case studies;

c) to make a risk assessment particularly oriented to contribute for the study and proposal of measures of mitigation and rehabilitation of the mines themselves and their affected areas.

Results achieved so far indicate the existence of some situations of concern from an environmental point of view. In particular, a number of heavy metals and other trace elements which are released continuously from erosion and leaching of the mine tailings, shafts and open pits are being responsible for chemical contamination of waters, soils and sediments. For some of the cases, the study of rehabilitation proposals is already in course.

A first diagnosis (mainly supported in chemical and safety parameters) of all the main mine sites (about 80 old mines) is also being carried out. The results to be obtained will furnish very shortly a significant amount of data which will certainly be conclusive for the mine's hierarchization in terms of hazard regarding the environment and their surrounding living ecosystems.

Geochemical, hydrochemical and hydrogeological methodologies are being widely used in the study of the most important mine case studies. Beyond of this, another approach to assess and monitor the environmental impact of mining sites is being performed by IGM, as a member of MINEO project, which is based on advanced (hyperspectral) Earth Observation techniques.

1. INTRODUCTION

With regard to the mining sector, and more specifically, the consequences of its activity, it is understood today that inactive or abandoned mines are characterised as sensitive areas with respect to environmental issues as these can constitute sources of chemical, physical and landscape eyesores in surrounding areas. Soil, water and ecosystems in areas surrounding these mines can be seriously affected (Marcus, 1997; Alloway, 1993; Thornton, 1983; appelo and Postma, 1994; Forstner and Wittmann, 1983;

Ross, 1996; Moldan and Cerny, 1994). In Portugal a few situations of this type are known which constitute potential public health hazards as exemplified by recently published literature.

The Instituto Geológico e Mineiro (IGM) in Portugal aware and concerned with these facts produced, in 1993, a first document pondering about this subject. In it, it warned of the need to launch environmental research into the areas adjacent mining centres influenced by abandoned mines throughout the country since these were considered to be under the auspices of the state. Based on this document, a study programme was formulated. This programme seeks to determine the impact that mining has had in adjacent areas with respect to contamination of waters, soils, sediments and vegetation as a result of the accumulation of toxic elements. Meanwhile the celebration of a co-operation protocol between the Direcção Geral do Ambiente (DGA – *National Environmental Protection Agency*) and the IGM acted as a catalyst for the latter organisation to initiate a set of environmental studies on three case studies considered typical with respect to abandoned mines. Although the term "abandoned" is generally applied to mines to whom no responsibilities can be directly attributed to its concessionary because of bankruptcy or simple abandonment, the possibility of including case studies whose properties are still held by the private sector, was not overlooked. Growing environmental and legislative pressures to which environmental accidents such as Aznalcóllar (Spain) and Baia Mare (Romania) are not immune, have been felt at a European mining and industry scale although their contribution to the GNP of the EU is only 7%. It is then necessary to create innovative methods and tools that allow evaluation and monitorization of the mining activity such that it contributes towards its sustainable economic development. In this context the IGM is integrated in the MINEO Project - *Assessing and Monitoring the Environmental Impact of Mining Activities in Europe Using Advanced Earth Observations Techniques*, whose strategic objectives are to develop tools for possible future decisions, in environmental planning, dissemination of knowledge and conscientious evaluation of the role of data obtained by hyperspectral earth observation (EO). Already promising studies (Antón-Pacheco et al, 1999) show the importance of hyperspectral EO data with regards environmental impact in the mining industry.

2. Strategies And Methodology Results

The present study programme at the IGM, related with the identification and evaluation of possible environmental impacts in areas adjacent abandoned or inactive mining centres within the country (Fig. 1), comprises a group of technical and scientific investigation tasks. The programme also takes into account aspects related with security of both people and their assets. During the development of these studies we have acknowledged the wealth of geo-mining information that the IGM has gathered through decades of investigation as well as the enormous database of geological, geochemical and geophysical data on archive at the IGM. In generic terms, the studies develop simultaneously in the following areas of influence given the different level of technical-scientific demand:

Investigation of <u>pilot areas</u> referred to as case study areas.

<u>Diagnostic</u> of the current situation of abandoned mines in the country.

<u>Detailed R&D studies</u> on specific and selected cases.

<u>Evaluation of the mitigating circumstances</u> with the launch of rehabilitation studies.

Besides these main activities, the IGM has also participated in tasks with institutional co-operation (e.g. DGA, Direcção Geral de Saúde – "national health authorities", universities) and also in partnerships with exploration companies who currently hold exploration licences within the country. Of these partnerships, the projects on the management of mining waste under the auspices of the DGXI and another project that investigates the application of EO techniques (airborne and satellite) determining the severity of environmental impact by mining (e.g. São Domingos Mine in Portugal) deserve highlighting. The IGM has also established contracts; within a programme for support to industry (Pedip II), with the aim of characterisation and remediation of a few abandoned mines. The whole group of activities make up the study programme which is defined as being of R&D in nature, multidisciplinary, multinstitutional and multidepartmental (Fig. 2).

2.1. Investigation in pilot areas

The following mines were selected for investigation (Fig. 1):

Jales, in the Vila Pouca de Aguiar County; old gold and silver producer whose paragenesis contains appreciable quantities of sulphides. Executing entity: IGM, Faculty of engineering of the University of Porto, COBA.

Cunha Baixa, in the Mangualde County (explored till recently for uranium). Executing entity: IGM, with support from state-owned company ENU.

Pejão, in the Castelo de Paiva County (mine where coal was produced till recently). Executing entity: IGM, with support from state-owned company ECD.

Vale das Gatas, in the Sabrosa County (producer of tin and tungsten). Executing entity: IGM, with support from the University of Aveiro.

Lousal e Caveira, in the Grândola County (exploited for polymetallic massive sulphides). Executing entity: University of Aveiro.

S. Domingos, in the Mértola County (exploited for copper and polymetallic massive sulphides). Executing entity: COBA. The IGM is studying the environmental impact of this old mine through the MINEO Project which has targeted this location a s a test site.

Some results

A certain degree of pioneering work must be attributed to the study programme due to its conception since the levels of knowledge, of such and related problems, in the country were virtually non-existent. The methodology using various synergies has favoured a maximised usage of resources.

As a first conclusion we acknowledge the fact that certain **chemical signatures** because of the presence of elevated quantities of heavy metals associated with the mining activity can be directly responsible for the contamination of soils, sediments and waters in the areas surrounding the mining centres. The level of knowledge acquired till now demonstrates that secondary geologic material and waters, both subaerial and subterranean, can be chemically contaminated in both small and large extensions. Different element associations are highlighted in each studied case. These element associations are correlatable, particularly in soils, with the original mineral paragenesis. However, it has been noted that the products used in the ore treatment process also appear in samples and contribute towards pollution (e.g. leaching of uranium ore in the Cunha Baixa Mine). Impacts in the environment will tend to worsen considerably with time in mines that enter into advanced stages of abandonment and occupy extensive geographic regions if there is not a timely undertaking of corrective measures. The frequent use of dump material as a source of raw materials for building landfills and road repairs causes dissemination of the polluting elements over a much larger area. The solutions that have to be adopted to minimise these effects will vary and have to be determined on a case by case basis.

Of the first four above mentioned cases (the ones studied thus far) we can concluded that mines with radioactive minerals will be the ones that cause the greatest harm given the natural properties of these elements as well as their highly mobile nature. This is particularly critical for uranium, radium and other elements capable of elevated biological and radiological activity. However, the mines where sulphides were extracted, or mines where these made up a large percentage of the gangue, acquire dangerous environmental status. Examples of these are present the Iberian Pyrite Belt (S Portugal); Aljustrel, S. Domingos, Lousal and Caveira. In these types of mines we see acid water drainage into the adjacent hydrological network as result of leaching of extensive dumps and the extraction of copper by the cementation process.

Globally, the diverse situations that were investigated correspond to a scenario that characterises the majority of abandoned mines in the country. The group of coal mines probably represents the least worrying situation in terms of environmental risk since the coals are deficient in metallic minerals and few coal mines ever attained significant levels of activity with the possible exception of Pejão and S. Pedro da Cova. However, although these mines represent minimal environmental hazard we have to be aware of the by-products of power stations, the likes of which may contain appreciable quantities of heavy metals.

In general terms, taking into account the sites already investigated, we can draw up the following contaminating geochemical associations in **sediments and soils**:

Jales

As, Cd, Pb, Zn, (Cu), (Mn), (Ag)

Cunha Baixa

U, (226Ra), (Mn), (Zn)

Pejão

Fe, (Cu), (Ni), (Co), (Zn), (Mn)

Vale das Gatas

As, Pb, Cu, Zn, Cd, (Bi), (Ag) associados a Sn e W (main elements of the mineral paragenesis)

Caveira

Cu, Pb, Zn (Ag, Sb)

Lousal

Cu, Pb, Zn (Ag, Sb)

S. Domingos

Cu, Pb, As, Sb, Fe (Zn, Ag, Cd, Mn, Co)

Differences delimited in the types of geochemical dispersion are conditioned by type of lithology and paragenetic sequence of ores, be these the original ones in the deposit or the result of processes that occur at the interfaces of oxidation/reduction and hydrolysis/precipitation or co-precipitation. In any case, the decrease in geochemical pollutants away from the loci are greater in sediments, extending for dozens of kilometres, than in superficial waters (Compare Fig. 3 to Fig. 4).

Without invalidating the above statement, it is expected that the chemical mechanisms may also become more relevant in soil, aluvium and sediment with the passage of time, particularly when the water-soil-rock interfaces become progressively more vulnerable to variations in physico-chemical conditions of the substrate (surface alteration of more friable minerals, changes in pH and Eh and alteration of the ratios of mineralogical to organic phases).

Relative to **waters**, these occur more or less contaminated because of the intervention of the “mining” variable, which determines alteration of the hydrochemical facies. These alterations are reflected by the water composition in two distinct modes: 1- by the introduction of certain macro elements that produce alterations that are more or less pronounced in the ionic structure of aqueous systems and, 2- by the appearance of anomalous metallic loads that can turn the water improper for certain uses.

The influence of mining is evidenced in the main watercourses by the elevated quantities of sulphate ions (SO42-). This species is relatively innocuous, exhibiting a conservative chemical behaviour by not participating in secondary chemical reactions and its diminished concentration in aqueous systems occurs by dilution. However, the presence of sulphate does not always have the same origin. In the case of the sulphides and coal (Jales and Pejão) it originates from the mineral paragenesis. In a uranium mine (Cunha Baixa) its presence is related to the chemical process by which the ore was extracted. The chemical facies of the circulating waters, characteristically with sodium chloride or bicarbonate of soda change to calcic-sulphate or calcic-magnesium in the vicinity of mining centres. Samples further away from the polluting sites show enhancement of gradational changes, be it in terms (delete o que está a vermelho) of cationic or anionic composition. This situation is easily identifiable by the equation *R=SO42-/Cl-*, which has revealed itself to be a very sensitive parameter for masking this type of contamination.

Besides sulphate, certain metallic components act as indicators, in water, for the presence of contamination from a mining source. Manganese, always present in the dissolved fraction is an indicator metal for mining-derived pollution. Manganese occurs many times in higher quantities (above legal limits). Its presence is related directly to its due mobility in solution and because it is a common element in oxide, carbonate and silicate species. Aluminium and zinc are equally common in both areas adjacent mine water flow and in water flow from its dumps. Cd, As, Cu, Ni, Co, Sr, Be, Y and U were also noted in significant concentrations. We note that the group of anomalous elements in waters is not exactly equal to the group present in soils and sediments which means that there is some contribution from the leaching of host rocks and accessory minerals in mineralised structures (e.g. Ni, Co, Sr, Be and Y). In subaerial waters the “decay” of dissolved metals is generally rapid (see example Fig. 4).

The scenario observed in ground water is substantially different. These have frequently accentuated toxic metallic components, frequently in high concentrations and with a large range of elements, which leads us to conclude that the contamination is more significant than in surface waters. Therefore the usage of these waters, in areas adjacent mining centres, should be viewed with caution and that the drilling of water–supplying boreholes should be accompanied by hydrological studies.

Mining pollution invades aquifers by a process of remobilization of metals retained in the soil or by the infiltration of residual waters that lower levels of pollution than prior to infiltration. In all cases studied, subsurface water circulation was carried out through fractures thereby making the structural and geological characteristics of the terrain determining factors for the dispersion of contaminating ions in water. The usage of mine shafts as rubbish dumps contributes towards accelerated contamination of respective acquifers.

2.2. Diagnostic of the principal abandoned mines

Through studies such as these we intend to characterise the more severe situations, in mining centres, with respect to abandoned mines. During a first phase of work we proceed with a preliminary diagnostic of each situation in order to construct an hierarchy of potentially dangerous situations. The results will then determine the elaboration of more comprehensive studies with the conclusive diagnostic of the more severe cases. This study will only really be definitive when a risk assessment component is drawn up and will consider identification and characterisation of the principal pollutants, measurement of the evolution of contaminants in the ecosystem, evaluation of the toxicity indices and characterisation and risk determination. When necessary a rehabilitation programme will be implemented and it will entail two phases: *project phase* (to define and quantify the solution needed to mitigate and/or eliminate the identified problem) and the *execution phase* (to carry out the rehabilitation work). Realisation that the vocation and capacities of the IGM do not encompass all the specialities demanded in a programme of this magnitude, it will be necessary to recruit the assistance of other state-run organisations (DGA, DRA´s, DGS, DRE´s) and industry (both state-owned and private) in co-operation or in a consulting capacity. If on any of the mines should there be interested or responsible parties, these should also be integrated in the project. At present, the IGM, is undertaking preliminary diagnostic studies in 80 mining sites scattered throughout the country that were previous targets of mineral exploitation. This task involves the co-operation of several departments of the IGM (Laboratory, Metallic Minerals Exploration Dept. and the Mines and Quarries Division). Shortly, the results, in the form of individual cards with the necessary information to class each situation, will be made available.

2.3. New tasks of R&D

The investigation carried out under the auspices of this project shows that the case studies that were selected, given the objectives and priorities set out by the DGA, were correct and revealed themselves typical of the majority of mines abandoned in the country. From the preliminary studies we have seen that the mining sites, as well as some of the mines still in operation, fit into generalised large groups:

Sulphide producing mines with/out precious metals (e.g. Jales Mine)

Tin/tungsten mines (e.g. Vale das Gatas Mine)

Radioactive ore producing mines (e.g. Cunha baixa Mine)

Coal Mines (e.g. Pejão Mine)

Mines producing Zn/Pb oxides/carbonates (e.g. Preguiça and Vila Ruiva Mines)

Magnetite mines (e.g. Orada, Azenhas and Alvito Mines)

“Vein-type” copper producing mines (e.g. Aparis, Botefa, Mostardeira, Miguel Vacas and Mociços Mines)

Manganese and iron mines [Rosalgar (e.g. Cercal), Ferragudo and Balança Mines]

Mines of complex massive/disseminated sulphideswith polymetallic characteristics (e.g. Lousal, Caveira e S. Domingos, Chança and Montinho Mines).

All the cases referred to above are sufficiently characterised with the exception of the latter group. The study of larger massive sulphide mines in the Iberian Pyrite Belt, Lousal, Caveira and S. Domingos, have been adjudicated to third parties (with financial support from Pedip II) although S. Domingos is also targeted by the MINEO Project financed through the EC's V Programme-Framework. With respect the EO techniques, hyperspectral aerial images were acquired. Their processing and treatment will permit the evaluation of the environmental impact the S. Domingos mine has had on this specific location. These images will be validated with ground, geochemical (rock, sediment, soil, water) and spectroradiometric data. The latter have already been collected in selected subareas taking into account different geological, biological and environmental patterns.

Some of the situations arising from the preliminary diagnostic will require further in-depth study that will take into account an understanding of the main dispersive mechanisms, mitigation and reconcentration of metals in the various material substrates (mineralogical, water, live beings). In this context, the IGM will continue with its core mission and develop tasks with the necessary priority as more results come to light. The fundamental objective consists in the consolidation of a knowledge base and methodologies that will allow the drawing up of a conceptual table of the environmental problems in the areas adjacent the mining projects. Those research topics will be varied and centre around equally varied scientific domains.

3. Summary and Conclusions

The groups of studies carried out thus far have encompassed the following topics:

Chemical characterisation of the sites investigated,

Evaluation, although preliminary, of the state of the consequences of the mining activity,

Rock mechanic evaluation of the stability of dumps,

Identification of situations of risk with respect to security of people, animals and assets, highlighting the existing protection of shafts, addits and pits;

It is now possible to determine situations of chemical pollution that affect waters in particular (subaerial and subterranean), soils and sediments in the vicinity of a few mining centres. Many of the values exceed concentrations for drinking water and baselines and limits established for contaminated areas in the case of soils and sediments. The mechanisms of geochemical and hydrological dispersion have been investigated. The symptoms detected in a few of the situations indicates that live organisms (fish and cattle) could be affected although in the S. Domingos area we note that these have adapted and thrive in extreme geochemical conditions. With regards the Jales mine, it has been possible to advance with mitigating proposals and measures and launch a public tender, under the Pedip II Programme, for the rehabilitation of the area and the reconstruction of the existing dump through a engineering project.

Considering that the IGM:

Actually develops diverse studies and research and has adjudicated studies that aim to obtain a definitive diagnostic of three mines in the Alentejo region;

It is in an advanced phase with the preliminary diagnostic of the most important past mining sites (approximately 80 in total);

Is already in possession of a significant amount of technical and scientific know-how about the materials under study.

We are confident that briefly, a vast and useful synthesis of data, will be made available together with methodologies capable of contributing, in a scientifically sustained way, to the global hierarchization and study of the problem of abandoned mines in the country

REFERENCES

Alloway, B.J. (1993). Heavy Metals in Soils. B.J. Alloway (Ed.). Blackie USA and Canada: Halsted Press, 339 pp.

Appelo, C.A.J. and Postma, D. (1994). Geochemistry, Groundwater and Pollution. A.A. Balkema, Rotterdam, 536 pp.

Antón-Pacheco, C., Gumiel, J.C., de Miguel, E., López, E., Gómez, J.A., Giménez, M., Rejas, J.G., Barettino and D., Ortíz, G., (1999). Cartografía del vertido de lodos de la mina de Aznalcóllar mediante imágenes Daedalus ATM. Revista de Teledetección , vol. 12, pp.13-19.

Ávila P.H., Santos Oliveira. J.M. and Cardoso Fonseca, E. (1999). Um caso de impacte ambiental relacionado com a actividade mineira no país: exemplo da Mina do Vale das Gatas. Actas da 6ª Conferência Nacional do Ambiente, Lisboa, vol. 1, pp. 639-648.

Canteiro, M. (1995). Mina de S. Domingos: um caso de estudo de contaminação histórica. Tese. Dep. Zoologia Fac. Ciências e Tecnologia de Coimbra, 178pp.

Canto Machado, M.J. and Alves Ferreira, M.A. (1997). Números ou resultados. Estudos, notas e Trabalhos do IGM, tomo 39, pp. 115-122.

Canto Machado, M.J. (1998). Comportamento dos metais dissolvidos nas águas da Cunha Baixa e Quinta do Bispo. IGM and DGA archives, 15 pp.

Canto Machado, M.J. (1999). Hidroquímica dos metais pesados na Mina do Pejão. IGM and DGA archives, 9 pp.

Forstner, U. and Wittmann, G.T.W. (1983). Metal Pollution in the Aquatic environment. Springer-Verlag, 486 pp.

Henriques, F. and Fernandes, J. (1991). Metal uptake and distribution in rush (*Juncus conglomeratus*) plants growing in pyrites mine tailings at Lousal, Portugal. The Science of the Total Environments, vol.102, pp.253-260. Elsevier Sc. Ed., Amsterdam.

Marcus, J.J. (1997). Mining Environmental Handbook. Jerrold Marcus (Ed.). Imperial college Press, 785 pp.

Molden, B. and Cerny, J. (1994). Biogeochemistry of Small Catchments. B. Moldan and J. Cerny (Eds.). John Wiley & Sons, 419 pp.

Pedrosa, M.Y., Canto Machado, M.J. and Pereira, A.P. (1998). Hidroquímica da Mina de Jales. V Congresso Nacional de Geologia. Comunicações do IGM, tomo 84, fasc. 2, pp. E66-E69.

Pedrosa, M.Y and Lima Martins, H. (1999). Hidrogeologia da Mina da Cunha Baixa. IGM and DGA archives, 48 pp.

Pedrosa, M.Y. (2000). Hidrogeologia do Couto Mineiro do Pejão. IGM and DGA archives, 28 pp.

Pereira, E., Moura, I., Costa, J.; Mahony, J. and Thomann, R. (1995). The S. Domingos Mine: A study of heavy metal contamination in the water column and sediments of the Chança River Basin by discharge from an ancient cupriferous pyrite mine (Portugal). Marine Freshwater Res., vol. 46. pp.145-151.

Pereira, E., Moura, F., Moura, I., Costa, J. and Mahony, J. (1993). Mina de S. Domingos: Contaminação por Metais Pesados na Albufeira do Chança pela descarga de uma antiga Mina de Pirites de Ferro Cupríferas. Gaia nº 7, pp. 18-27.

Rocha Silva, J. (1996). Geotecnia da escombreira de Jales. IGM and DGA archives, 11 pp.

Ross, S.M. (1996). Toxic Metals in Soil-Plant Systems. Sheila M. Ross (Ed.). John Wiley & Sons, 469 pp.

Santos Oliveira, J.M. and Ávila, P.H. (1995). Avaliação do impacto ambiental provocado por uma exploração mineira. Um caso de estudo no país. Estudos, Notas e Trabalhos do IGM, tomo 37, pp. 25-50.

Santos Oliveira, J.M. and Ávila, P. (1996). Geochemical characterization of an abandoned mining site in Portugal. Distribution of some heavy metals in stream sediments, alluvium and soils with basis on a multielement strategy. Symposium Proceedings of the Third International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe, Warsaw, pp. 909-912.

Santos Oliveira, J.M. (1997). Algumas reflexões com enfoque na problemática dos riscos ambientais associados à actividade mineira. Estudos, Notas e Trabalhos do IGM, tomo 39, pp.3-25.

Santos Oliveira, J.M., Pedrosa, M.Y., Canto Machado, M.J. and Rocha Silva, J. (1998). Impacte ambiental provocado pela actividade mineira junto da Mina de Jales, avaliação dos riscos e medidas de reabilitação. Comunicações do IGM, tomo 84, fasc. 2, pp. E74-E77.

Santos Oliveira, J.M. and Ávila, P.H. (1998). Geochemical signatures of selected heavy metals in contaminated soils, stream sediments and alluvium associated to one case study of mining exploitation in Portugal. Proceedings Contaminated Soil´98, Edinburgh, vol. II, pp. 937-938.

Santos Oliveira, J.M. and Ávila, P. (1999). Estudo geoquímico na área da Mina do Pejão numa perspectiva ambiental. IGM and DGA archives, 15 pp.

Santos Oliveira, J.M., Canto Machado, M.J., Neves, O. and Matias, M.J. (1999). Estudos de impacte químico associado a uma mina de urânio no centro de Portugal. Anais do V Congresso de Geoquímica dos Países de Língua Portuguesa, Porto Seguro (Brasil), Tema 1, pp. 170-173.

Santos Oliveira, J.M., Machado Leite, M.R., Daniel, F.S., Dinis, P., Ávila, P.H. and Martins, L. (1999). As minas abandonadas e o ambiente. Programa de diagnóstico das situações e contribuição para a sua remediação. Jornadas de Informação Geográfica e Geológica de Base Regional, Beja, pp.3.20-3.32.

Thornton, I. (1983). Applied Environmental Geochemistry. Iain Thornton (Ed.), Academic Press, 501 pp.

EXPERIENCES AT THE CLOSURE OF THE CANDELARIA MINE

Alberto Pool
Parcoy, La Libertad, Peru

The Parcoy mine, currently operated by Consorcio Minero Horizonte, is located at the Pataz Batholith in the department of La Libertad, 500 km. north of Lima, the capital city of Peru, east of the Maranon river between 2,600 and 3,000 meters above sea level approximately.

The main units that constitute this operation are Parcoy, Bernabe, Patacas and Candelaria. The mineralization is of fracture filling type and is hosted in an intrusive granodiorite, from the Upper Carboniferous.

The Incas and the Spaniards worked the veins of this deposit at a small scale in a sporadic way. Although the latter achieved greater progress than the first ones due to the use of gunpowder, they were not able to go deep into the aquifer and they had to abandon ore work sources due to floods.

In the middle of the XIX century, the exploitation of veins decreased significantly, no doubt due to the wearing out of the free gold ore, which caused low recoveries. When the cyanidation process was discovered (1887) the situation changed and many works were reactivated.

In 1934, the "Sindicato Minero de Parcoy" (SIMPAR) was founded. Its operations were based on the consolidation of properties that used to belong to small miners or to companies that had previously closed. This company worked for 25 years and closed its activities in 1960 when the profitable ore wore out, as a consequence of having stopped its explorations and developments. The main cause for such a decision was the stable price of gold (US$35/ounce) against the increase in operating costs, that is, workers payroll, prices of fuel, machinery, spare parts, freights, along with a chronic indifference shown by the governments in that time.

During the 25 years, a large amount of veins were worked in the surrounding areas of Retamas and Parcoy, southeast of the former and in the Cerro Gigante (under MARSA's operation currently) in the southeast. In addition to the inherent work of the company whose graphic records (plans and sections) were inherited by Consorcio Horizonte, the local people and the contractors of SIMPAR, exploited other veins. There never was any information available about them, neither in writing or graphic.

The work carried out by the Sindicato Minero de Parcoy was of technical nature. The few reports available on that operation reflect the professionalism and competence of the technical and management personnel in charge of this company. If they did not exploit the deposit further it was simply because they lacked time, specially due to the gold price, stable over many years, as it is well known.

When the mine closed its operations the workers and most of the inhabitants in those areas, migrated to Trujillo, Chimbote or Lima. Out of a population over 3,000 people, less than 200 remained there. Some of them extracted gold in a rustic way, processing it in "quimbaletas" or sieves, rustic devices activated by the feet that finely grind the ore which then is recovered with mercury. This practice, still available at present, is the most contaminating factor for the water of the Parcoy River and little has been done in order to eradicate it, due to the social implications.

In Parcoy and Retamas there were over 60 of these devices operated by their owners or leased to thirds.

In 1978 Consorcio Minero Horizonte S.A. was incorporated, which after exploring Retamas and its surroundings, started the gold production in 1985, at a rate of 10 tpd, based on veins that SIMPAR had not found.

It was only at the beginning of 1990 that the company grew with the findings of new zones and its production increased to 30 tpd, thus increasing its complexity and efficiency. In 1994 they extracted 400 tpd, rate that remained stable during several years. Currently they are working with a little over 600 tpd.

The renascence of the Parcoy mine caused the opening of new work places and the closing of others.

We can differentiate three types of works closing in Parcoy:

- To prevent ore thefts
- To ensure the isolation of abandoned works
- To avoid connections with former works
- Ore thefts.

This cause, unthinkable in common metals mining, is severe in gold mining, due to reasons easy to understand.

The daring boldness and ease in front of the danger shown by people dedicated to the illicit extraction of ore, made necessary to be alert as to identify possible entrance and exit ways for these people, in order to close them or to neutralize them through special surveillance. They usually used the surface chimneys or those used to introduce material towards the work points. The intruders used the ropes to go down and then they used them to pull the bags with the gold material, if the chimney's diameter was big enough. They also went down holding on the salient if the size of the opening slope allowed doing so.

Another common practice was to stay at the mine on Saturday until Monday, when they left the area among the other workers. Sometimes they pulverized the ore inside the mine and left carrying small amounts of selected portions, easy to hide, leaving less material in the hiding places.

This was possible because the mineralization in Parcoy is rather simple and ductile to the metallurgic treatment. It consists of quartz with pyrite, occasionally accompanied with sphalerite in a very punctual way, chalcopyrite and galena. The arsenopyrite is still less frequent. Gold is associated to pyrite, being more abundant in the massive pyrite and in the fine grain. Free gold is also found in small grains, both in quartz and in the wall rock which is a kaolinized diorite grain.

In order to prevent the entrance of intruders, a circular or rectangular frame of reinforced cement was built, in some cases a door was installed with construction rods or with flat metal plates welded among each other and which opened with hinges and was closed with a lock. Then the entire frame was welded and another chimney was implemented to send the material down. However, the grille had to remain there in order to allow airflow from the inside, which had to be above 15 m per minute.

The plundering product went to the small mills whose activity increased when an important finding happened in the mine and it decreased when a vein disappeared temporarily.

Those small mills provided for the family economy of the local people, and for those who had survived through this activity since 1960 and who had their underground "parcels", we were the intruders.

Theft claims to the police authorities had to be handled very carefully, because they could cause revenges. In some occasions they appeared as terrorist attacks, with no apparent connection to the affected family.

By the end of 1991, weapons and explosives were found in an abandoned site somehow far from the operations center, certainly hidden by a terrorist group. The fact was reported to the police that confiscated the material sealing the site. As a result of this situation, other remote sites, which were disconnected of the operations from Consorcio Horizonte, were also sealed in order to prevent they could become a hiding place for terrorists or a place to keep their belongings. Fortunately, this measure did not provoke any reprisals from those affected. All these sites were above the phreatic level and it was not necessary to make further studies in order to close them.

ISOLATION OF ABANDONED SITES

When the ore in a zone wore out and it was determined that the personnel should not return there in order to avoid injuries due to asphyxia (lack of oxygen), or due to the presence of noxious gases, a wooden fence was built with horizontal planks and the sign of "abandoned zone" was placed. In those places, the air velocity decreased and the temperature increased.

When it was discovered that some of those areas were used to hide stolen material, they were closed with cement and stone, leaving small windows in the upper part thus allowing ventilation, in the event that they could be reopened. A small opening was left on the ground to drain the area through the chute.

These condemnations frequently altered the airflow forcing to redesign the ventilation circuit through new chimneys or dogholes, in order to maintain the duly proper air circulation. The security department personnel were very efficient in these tasks.

Given that these measures increased the operating cost, they had to be carefully managed.

CONNECTIONS WITH FORMER SITES

The biggest challenges were the former sites, whether from the Spaniards time or from more modern times, which did not appear in the plans that Consorcio Horizonte found when they started their operations. It was necessary to avoid them in order not to generate problems with water strokes or gas emanation.

This situation happened twice, at the sites in an area called Candelaria, located approximately 1 km south from the treatment plant which long time ago had had an intense exploitation activity due to the richness of its ore. A secondary enhancement process motivated that the grade of gold increase to 40gm/ton and a little more in some places. Although the sites were located in both cases above the phreatic level in the 90's, they had been below that level in the past.

Connecting those places caused serious problems in several facilities, specially at the mine entrance whose platform, built with the rock material extracted in the x-cuts was eroded in the worst of the two cases, by a torrent that lasted more than ten hours, fortunately without human losses.

It was feared that there would be other places with similar characteristics and, given the lack of information about the work carried out prior to the activities of the Sindicato Minero of Parcoy, the risk of lacking the random protection was latent.

(A similar problem happened at 500 m. south of Candelaria, at the neighbor mine MARSA, whose level “La Espanola” reached the bottom part of a former flooded site. The water stroke had the characteristics of an alluvium and although there were no victims, it lasted for two days and destroyed crops in the town of Llacuabamba, considerably damaging the main road from Trujillo to Tayabamba).

Due to reasons which are not mentioned herein, Consorcio Horizonte decided to close the Candelaria mine, which until then contributed with about 30% of the production, whose lower level was located at the elevation 2820. During the opening and subsequent development of Candelaria, the drainage of the works was by gravity and forced ventilation was only used at one exploration site, because the other work places had chimneys linked to higher levels or connected to the surface. For the forced ventilation an electric fan was used with tubes of 18 and 12 inches. Ventilation funnels (Venturis) were installed at some places.

The following steps were taken for the closure:

- Airflows were measured
- Ventilation plans were tuned
- Air samples were taken
- Water flows were measured
- Water samples were taken

An environmental plan was prepared with this information which, after compared with the scheme to be met, was used to approach the points susceptible to generate or promote contamination. Thus, a clean model was obtained with which present and future damage to the environment would be attenuated considerably until almost eliminating it.

As previously explained, the chimneys that reached the surface were locked and in addition, a security fence was built around each one of them to prevent accidents with people or domestic animals owned by the people in Retamas or La Soledad. Such a fence was made of cement and barbed wire because the wood was quickly used by the community as firewood. Air samples taken always showed levels below those that could damage human health.

In order to take air samples Drager detection tubes were used, and their results showed contents of C02, CO and SO2 far below the harmful limits.

A fence made with discarded bore holes welded among each other was installed at the main mine entrance, proving very strong. A metallic door was installed in the middle with three locks.

The drainage was deviated through two chimneys at level 2750, which has its main extraction level at the mine entrance (1,600 m north), at 250 m from the coarse hopper.

A very little amount of water that was not deviated towards level 2750, run by the mine entrance of Candelaria through a chute and ended up in the sterile platform. The analysis of such effluent constantly showed a ph between 5 and 6, free of bacteria, without harmful elements to the environment and with very low or non-existent turbidity.

Flow meters, ph meters and other required instruments were used in order to determine the water volume and its characteristics. The results of the water samples analysis showed levels below the permissible limits, with slight oscillations that never reached amounts to be concerned about.

The Candelaria site is located at the left bank of the Llacuabamba river, which in the town of Retamas joins the Parcoy river; this empties its waters at the Piaz lake, about 10 km downstream. During its stretch it goes down about 900 m along a ravine with a very steep V profile, which only allows crops in terraces and in places where an affluent (most likely in the left margin) has formed extensions suitable for crops. It is worth mentioning that the terraces and the small valleys originated by the mentioned affluent, have always been watered with water from the side creeks and not from the Parcoy river. The banks of this river are rather rocky thus no crops are possible.

The main products collected nearby the Parcoy river are fruits: bananas, cherimoya, apples and avocados. In the terrace there are crops of gramineous and vegetables, and in the higher sections, potatoes and rye. In the area the population is spread among villages that as a whole amount around 1000 inhabitants, with very low health conditions. The highest economic and social activities take place in Parcoy and Retamas, where there are about 3,000 inhabitants, most of them working for Consorcio Horizonte.

At the right margin of the Parcoy river where there are neither villages nor population, the affluents provide potable water. One of the most important is the Castilla ravine that supplies Retamas; another important one is Yuracyacu, approximately 8 km. downstream.

One kilometer before arriving to the Piaz Lagoon, 4,000 m long by 1,000 m wide, the Parcoy river stream decreases its gradient, the water flows at a lower speed emptying part of its load, except during rainy seasons, where coarse fragments reach the lagoon. It is there where a wide sandbank was formed allowing to build an airstrip of 1,200 m long, which was operative during the Sindicato Minero de Parcoy operation and is currently gone.

There is no crops or wild vegetation in that rocky area.

The Piaz lagoon hosts a moderate population of carps; the efforts to grow trout have failed. In the Piaz town there are small trout breeding farms more for entertainment or sports than for human consumption. They are located in Diaz, Ariabamba and at the MARSA mine site.

The Environmental Protection Law, enacted in 1992, caused a change as to how to approach and solve the problems originated by the mining activity on the environment.This law, subsequently implemented has strengthened the measures aimed at preserving the environment.

PERUVIAN POINT OF VIEW ON THE CLOSURE OF MINES

Eng. *Maria Chappuis*
Geotec, Peru

THE IMPORTANCE OF MINING FOR PERU

Mining is an important sector for the growth and development of Peruvian economy due not only to the magnitude of the capital invested, but also to its permanence, duration and geographical location. The mining sector is a leader for other economic sectors, within an economy that relies on exploitable natural resources and enjoys reasonable relative competitive advantages. The mining sector has also maintained its position as leading investor during recent years. Although currently there is a broad and unexplored potential, mining is the most important source of foreign revenue; its contribution fluctuates between 42-48%.

Peru's extensive mining potential is primarily made up of copper, gold and polymetallic (zinc, lead and silver) deposits located in the Andes which cross the country from North to South.

Peru is currently one of the world's leading producers of silver (2), tin (3), zinc (4), copper (6) and gold (8).

Chart N° 1 below shows Peru's rank in mining worldwide:

Chart N° 1

Position of Peru in World Mining

Metal	Peruvian production (in K TM) 1999	Peruvian position in World Mining 1999	Participaiton in World Production (%) 1997
Zinc	900	4	12
Copper	536	6	5
Lead	271	4	8
Tin	30	3	18
Silver (millon oz)	71	2	13
Gold	128	8	3

2. ENVIRONMENTAL LEGISLATION APPLICABLE TO PERUVIAN MINING

Until 1990, mining activity in Peru was subject to diverse legislation regulating both procedures as well as environmental standards, but in practice proved to be ineffective. In September 1990 the Code for the Environment and Natural Resources (Decree Law 613) was introduced. This was the first serious attempt to establish a clear and ordered legal framework which would permit the development of the diverse economic activities in a reasonably environmentally friendly fashion.

This law established the sector's competence in environmental matters for all economic activities, and this is how the Ministry for Energy and Mines (MEM) was charged with the responsibility of ensuring that the environmental regulations applicable to the mining sector were fulfilled.

In September 1993 MEM issued a regulation specifically for mining activities which in general terms, obliged mining concerns to carry out Environmental Impact Assessments (EIA: *Estudios de Impacto Ambiental*) prior to commencing any activity whatsoever, in addition to executing an Environmental Management Program (PAMA: *Programa de Adecuación y Manejo Ambiental*), which in the time period between five (for mines) to ten years (for smelters) would permit companies in operation to invest and take the necessary action to comply with the environmental regulations.

This norm also regulated the environmental audits through private firms selected by the MEM for this purpose in addition to regulating the imposition of fines in the case of pollution or non-compliance of this law.

Chart N° 2
Environmental Legal Framework
Peruvian Mining Sector

General regulations
Political Constitution of Peru
Code for the Environment and Natural Resources, Decree Law 613
Penal Code, Title XIII "Crimes Against the Ecology", Decree Law 635

Sectorial regulations
General Mining Act, Title XV
Environmental Protection Regulation and its amendments
Regulation on Public Hearings
Resolution on Maximum Permissible Limits
Environmental Guidelines
Resolution for the Registry of Companies authorized to carry out Environmental Impact Assessments
Resolution on Administrative-Environmental Stability Contracts for the execution of the Environmental Management Programs (PAMA)
Regulation for the Control of Mining-Energy Activities carried out by Third Parties

Related regulations
Law for the Creation of the National Environmental Council (CONAM: *Consejo Nacional del Ambiente)*
Legal Framework for the Growth of Private Investment
Law for Protected Nature Areas
General Water Resources Law
General Health Law
Law on the Procedure for Denouncing Violation of the Environmental Legislation
Organic Law for the Exploitation of Natural Resources
Law on the Conservation and the Sustainable Exploitation of Biological Diversity
Law for Environmental Impact Assessments of Works and Activities
Law for the Environmental National Fund FONAM (*Fondo Nacional del Ambiente*)

For the last eight years the Ministry for Energy and Mines has focused on monitoring and regulating active mining operations to ensure that they are taking the necessary measures to adjust to the established environmental regulations, eliminating environmental liabilities and authorizing only those new operations seen as environmentally friendly activities.

Through the execution of the PAMAS it is sought to obtain recovery rates of 90 % of gas emissions and particles, and 95 % of metal content in effluents.

It is expected that the PAMAS which are being prepared for the mines currently in operation shall be completed towards the end of the year 2001 and those corresponding to smelters by the year 2007. These assessment programs are estimated to require an investment of no less than US$1,000 million.

In order to eliminate the environmental liabilities (mines abandoned before the promulgation of the new laws) the authorities have ordered a series of environmental assessments to be carried out over certain basins (EVATs) and other areas with the aim of prioritizing restoration projects and evaluating their financing.

The task of ensuring that Peruvian mining operations are constructed in compliance with the established environmental regulations has required the preparation of reliable assessments and their presentation in public hearings, the publishing of the environmental guidelines and the accreditation of laboratories.

However, the completion of a number of EVATs, the implementation of the monitoring and environmental data system, and the restoration of the environmental historical liabilities, are all still pending.

3. Environmental legislation for mining in relation to mine closure

The draft for the Law for the Closure of Operations Program applicable to Mining Activity presents the following characteristics:

- It is a rule which regulates definitive closure as part of the Environmental Impact Assessments.
- The objective of the rule is to achieve the reappraisal of the used or disturbed area after its closure.
- Three clear stages for the procedure are established: "Commercial Operation," "Final Closure" and "Post-Closure".
- The "Commercial Operation" stage begins during the construction of the mine.
- The "Final Closure" stage commences two years before terminating mining operations and concludes with the attainment of the Final Closure Certificate.
- During the "Post-Closure" stage a process of control and monitoring is carried out.
- This stage concludes with the attainment of the Definitive Closure Certificate.
- According to this rule any Closure Program must include the following elements: method and work program of the physical and chemical stability works, control and verification methods, calculation of the economic resources and financial guarantees for the different periods.
- During the life of the mine, the Closure Program must be updated every 5 years as a minimum.
- In the case that mine operations are interrupted for over than a 3-year period, a Definitive Closure Program must be initiated.
- Securities shall only be lifted once the Final Closure Certificate and the Definitive Closure Certificate are issued and delivered.
- Fines range between 0.5 to 500 UIT (1 UIT is approximately US$ 800).

4. Mine Closure Programs

4.1. Assessment of closure works to eliminate zinc leach waste and copper and lead slag.

Centromin Peru S.A. (CMP) exploited various mines in the central region of the Peruvian Andes. Concentrates proceeding from these mines were treated in the Metallurgical Center of La Oroya (CMLO) which also pertained to Centromin Peru S.A. up until 1997 when it was transferred to Doe Run Peru. The sales contract contained a purchase option clause for the Huanchán waste deposit. CMP ordered closure studies to be carried out but Doe Run expressed its interest in utilizing the deposit and exercise its option in mid-1998.

CMLO's waste material is deposited in three nearby areas: Huanchán, Vado and Malpaso. The Huanchán deposit (currently in operation) receives leached zinc residues (ferrites) and copper and lead slag.

The Huanchán site is located at a mean altitude of 3,750 meters above sea level in the Department of Junín. The Mantaro river runs adjacent to the deposit and flows towards the city of Huancayo and on to the Mantaro hydroelectric plant, the largest of its kind in Peru.

Although the Mantaro river water flowing right by these deposits is acceptable for irrigation, evidence shows that it contains high concentrations of zinc, manganese and sulfates. The concentration levels remain constant during the course of the river, except for the zinc content which shows an increase of 3.0 to 4.7 mg/l. This increase is probably due to the discharge from the ferrite ponds.

The ferrite zinc deposits are 40 years old and hold 1.27 million tons in 11.4 hectares. 120 - 130 tons of ferrite is produced daily of which 35 % is treated, and the remnant is pumped in the form of pulp to five ponds, three of which are located adjacent to the Mantaro river.

In general, the closure studies recommended:

- Technical covering of ponds 3 and 4, using a membrane and ground cover, and the installation of an evacuation drain, composed by two pipes and a draining area.
- Reinforcement of the perimetric dykes using containment dams (gabions) particularly those dykes adjacent to the Central Highway, at ponds 3 and 4.
- Reinforcement of the Mantaro riverbank through the construction of rain defense works at ponds 1 and 2, in order to stabilize the ponds and make them more secure in the event of landslides. However, due to the high cost and complexity of this work, it was recommended to remove ponds 1 and 2 and deposit the content of these two into ponds 3 and 4.

Treatment of effluents

Approximately 10 million cubic meters of copper and lead slag has been deposited in Huanchán covering an area of 25 - 13 hectares and against the mountains surrounding the Mantaro river's left bank. The subsoil is made up of limestone and silt. At the moment, 450 tons of copper slag and 320 tons of lead slag are disposed of daily. The oldest deposits are over 70 years old. The slag is accumulated in cone shaped piles reaching up to 110m high and show sufficiently stable slopes.

The fresh slag is a glassy, black, highly permeable course grained sand. Because of its high permeability the water it receives is filtered immediately and there is no evidence of surface runoff nor effects of water erosion. Likewise, its minimum fine content impedes aeolian erosion.

Average annual filtration is estimated to be $440m^3$ /day, while the river carries a volume of flow of 5000 l/s resulting in a 1:1000 dilution ratio. The waters flowing down the adjacent mountains are not considered critical as the carbonaceous nature of the hills render these waters basic. In view of this, the construction of deviation works was not considered justifiable except only to avoid water erosion.

The oldest deposits show a cemented and oxidized coffee-color surface. It is possible that this cementing process may have been generated by the emission of SO2 from the smelter. The sulfuric anhydride is most likely deposited on the damp surface in the form of gas turning into sulfuric acid which is then carried by the rainfall. These oxidized layers vary in thickness up to one meter thick. The pH in these layers is between 3.9 and 4.8. The fresh slag shows pH levels in excess of 6.3.

Chart N° 3
Chemical composition of slag

	Copper slag (g/kg)	Lead slag (g/kg)
Copper	6.5	2.8
Lead	11.7	19.7
Zinc	25.9	107
FeO	434	354
Sulfur	11.0	10.7
Arsenic	4.6	1.7
SiO_2	327	210

The biochemical studies which we are carried out for the closure of this deposit, concluded as follows:

The deposited slag contains approximately 140,000 tons of lead and 490,000 tons of zinc. As the slag is not easily soluble, the water that comes into contact with it evidences high but not critical concentrations, representing a potential source of pollution of the Mantaro river which flows nearby.

The criteria for determining whether the slag deposits constitute a real environmental risk was based in the speed of the meteorization and oxidation processes of the deposited materials which define the rate of discharging lead and zinc into the receiving waters.

The analyses carried out demonstrated that the metals contained in the deposits are scarcely soluble. Leaching assays confirmed that no special protection of the water table was required.

The assays carried out to determine any potential generation of acid by oxidation demonstrated that the slag contained only traces of oxidazible sulfides counteracted by a great neutralizing potential. That is to say, that the slag does not only not generate acid, but rather shows to be a great neutralizing agent which permits the neutralization of the acid deposited by the atmosphere.

Because rain falling on the piles percolates through the slag it was recommended to install three monitoring ponds to detect any possible leakage of contaminating solutions.

In view of the chemical and physical-static stability it was not considered necessary to protect the slag piles with a cover, nevertheless it could be done for aesthetic landscape purposes as it would facilitate an overlying growth of vegetation This measure would consist in covering the area with a 15 cm thick layer of colluvial matter, covered in turn by organic material to encourage the growth of vegetation over the affected area.

Despite this, slag used as an underlying base for bio-remediation - either natural or artificial - is not the optimal solution, although it is thought that the affecting factor is not so much its toxic metal content but rather its course grading and the absolute absence of organic material which makes water retention practically impossible.

Assessment to abandon the Rosaura Open Pit

In 1998 Centromin Peru ordered a basic study for proceeding with the closure of this mine located in the district of Casapalca, in the central Peruvian Andes.

The analysis focused on the study of the geotechnical faults in the entire area and the potential surface effect particularly in relation to the stability of the slopes, in addition to the design of a works program to divert the runoff waters.

Moreover, different geochemical analyses based on historical data and measurement of samples of liquid effluents were carried out on site.

Finally, the study included evaluating the best alternatives for replanting the site considering the altitude of the area (4,200 meters above sea level). It was decided to select native forest species known to grow well at that altitude such as the "molle" and the "quinual," to cover some of the benches with topsoil in order to prevent the accumulation of rainwater, and to carry out a detailed zoning of the area in order to locate the species in their most favorable environments.

The main conclusions of the closure study where:

- The Rosaura open pit slopes show sufficient geotechnical stability so as not to require modifying their geometry prior to abandonment.
- The geochemical analysis carried out on the different soils of the area determined that these do not generate of acid water in the short term. Nevertheless it was recommended that the owner orders the carrying out of humid cell type kinetic assays in order to totally discard an eventual generation of acid by the waste material, in the long term.
- The pH levels of the effluent liquids are neutral, and the levels of heavy metals are low and totally acceptable in all of the samples.
- In order to comply with the regulations established by the environmental protection law, closure of the old mine entrances and the installation of a perimetric fence were recommended.

5. Final Commentaries

So far, mine closure programs in Peruvian mines have been carried out according to the rules set forth by the " Regulation for the Protection of the Environment Applicable to the Mining and Metallurgical Industry" which orders the execution of measures which guarantee land stability (physical and chemical), maintain water bodies unpolluted and encourage revegetation of the area (if its is technically and economically feasible.) This regulation however, does not clearly establish the time period (50, 100 or 500 years) for which the construction of the civil works in general must be designed (mine entrance plugs, deviation canals, dams, etc).

Mine closures as described above, are being executed by solvent mining companies like Centromin or Buenaventura, which are companies which do not rely exclusively on one mine but also obtain income proceeding from other operative mines. In addition to mine closure programs, Buenaventura for instance, has also invested in creating job reconversion programs for its workers so that these may be skilled to work in other types of jobs once the mine is definitely closed.

This is a very important issue to consider in any mine closure program as generally mines are located in isolated areas and become the most economically attractive area in the region.

The biggest problem comes from mines which have begun to evidence depletion of their mineral resources and whose owners have not initiated a systematic mine closure program and worse still, don't have the financial resources to do it. The result of this combination of factors typically translates into an outlook of bankruptcy and total abandonment of works, creating a situation of high risk of pollution. As far as Peru is concerned, unsupervised informal gold mining has caused serious environmental damage to vast areas in the jungle area, contaminating soils and rivers which flow towards Brazil and Bolivia.

The promulgation of this new mine closure regulation - it is currently undergoing revision - which obliges miners to work in an environmentally friendly manner, backed by bank bonds which guarantee the execution of mine closure works at the end of the life on the mine, is one of the Ministry for Energy and Mines' environmental policy's priorities, as is the reclamation of the so called "environmental liabilities" which are mining areas which were once extensively exploited and then abandoned before any environmental regulation existed, but which are to all effects a source of pollution, particularly affecting the water currents. This is the case of old tailings dams or waste dumps draining acid, or old gold alluvial placer sites, where the use of mercury was common practice.

So far, there is no financial way out of this problem and thus the solution is constantly being postponed. The creation of a "Super Fund" destined to clean up environmental liabilities tends to loose priority in a country where the state still cannot meet most of the population's basic health, education and infrastructure needs.

Many aspects of this problem is also common to other countries, which only goes to confirm that it is vitally important to encourage close coordination between the different environmental organizations in order to exchange experiences and access innovative technology and efficient ruling.

6. References

Centromin Perú S.A., Agosto 1998, Ingeniería de Detalle para Obras de Abandono de los Depósitos de Residuos Lixiviados de Zinc y Residuos Sólidos de Escorias de Cobre y Plomo, Lima, Perú.

Centromin Peru S.A., Mayo 1998, Estudio de Abandono del Tajo Abierto Rosaura- Informe Final, Lima, Perú.

Cía. de Minas Buenaventura S.A., Agosto 2000, Programa de Reconversión Laboral Mina Julcani, Lima, Perú.

Ministerio de Energía y Minas, Enero 2000, Proyecto Completo Plan de Cierre de Operaciones para la Actividad Minera, Lima, Perú.

Ministerio de Energía y Minas, Dirección General de Asuntos Ambientales, Octubre 1999, Política Minera y Protección Ambiental en el Perú, Lima, Perú.

Sociedad Nacional de Minería, Petróleo y Energía, 1998, "Reglamento para la Protección Ambiental en la Actividad Minero-Metalúrgica", Manual de Normas Mineras, Lima, Perú.

MINING AND ENVIRONMETN – PREMISES FOR THE TEMPORARY MINE CLOSURE

Dr. *José Castellanos Suarez*; Lic. *Esteban Alfonso Olmo*; Ing.*Aurora Picayo Flores*, CIPIMM
Dr. *Javier E. Rodríguez Rubio* CESIGMA SA
Ing.*Edilia García,* EOC
Participantes:Ing. *Pilar Pacheco*; Ing. *Antonio Vera*; Ing. *Mailene Duménigo*; Ing. *Mercedes Hernández*

In June 1994, GeoMinera Pinar Enterprise puts into operation the first gold plant in Cuba, with a capacity of 350 000 tpa and a production of 300 kg of gold per year.

This operation is outstanding because of:

- It is the first gold plant that is put into operation in Cuba, with Cuban technology, Cuban technicians and state financing.
- The deposit is constituted by an oxidized ore that contains raw fine gold, and the mineral covers a deposit of Zn and Pb sulfides ores.
- The oxidized ore deposit and the leaching plant is located near St. Lucia and Mina de Matahambre villages and also near the sea shore.
- Some brooks flow near the plant and join Palma brook, which discharges at sea.
- During mining works of the oxidize ores we could extract also sulfide ores (pyrite, Co sulfide, etc) that could produce a potential acid drainage.
- Overburden must be controlled and checked periodically to determine the possible acid drainage.
- Industrial water will be accumulated in a lagoon and potable water will be taken from two springs in the mine. Due to deposit polymetallic characteristics, water contamination by heavy metals could occur.
- A sulfuric acid plant located 4 km away from the mine with possible emission of SO2 to the atmosphere can produce acid rain according to the wind direction that could get the leaching plant.
- Though the ore is clayed and contains a great quantity of fines, mineral agglomeration has been optimized, so are heap leaching and leaching with a gold recovery between 75 and 85%.
- According to the pregnant liquor composition, we decided to use Merrill Crowe process (acquired in Canada) that after being modified and optimized, has permited us to achieve a high efficiency in gold recovery.
- Smelting process was adjusted and optimized.
- Further studies on the ore quality of both sectors that are being exploited, Farallones and Susana, on agglomeration and heap formation, leaching and precipitation with zinc dust, together with the crushing plant expansion have permited to increase gold production from 300 kg to over 500 kg per year with a sustained increase in total gold recovery, keeping gold grade between 1.5-1.6 g/t.

LOCATION , HISTORY AND GEOLOGY

Oro Castellanos Deposit is located 4 km to the South of St. Lucia village and 6.5 km from Mina de Matahambre village by the Western part of the country, in Pinar del Rio province.

The polymetalic ore Castellanos was discovered in 1963 as a result of geological works 1:50 000, where Castellanos Sector was given as a perspective sector for sulfurous zin mineral, Pb, pyrite and barita.

The form where the ore is located is of a very developed geomorphology with a level over 130 m. The deposit has two different kinds of ores: an oxidized ore cap containing gold and in a lower level primary sulfurous ores, polymetalic ores.

The oxidized ores- interesting and currently under exploitation- are on the surface, on the sulfurous cuerpo and is larger than the sulfurous ore deposit, going farther the limits, either on the yacente side or the colgante side. It is 800 m long and 50-150m wide. Its potencia is 3 - 60m.

Oxidized ores are formed in carboniferous slate-clay, sandstone, cuarcitas and in primary sulfurous cuerpos as a result of leaching-oxidation processes.

Oxidized ores are mainly formed by quartz, iron oxides and hydroxides, barita, plumbojarosita and clay. We also find small quantities of jarosita and other phases of sulfates minerals, their mixtures, phosphates and Pb arseniato. Pb, Zn, Cu and Fe sulfides in primary ores of the deposit are totally oxidized and can be observed only as spread grains. The very fine gold is spread in the mineral mass.

Studies began in 1987 to exploit both ores in cooperation with the former USSR.

In 1989 and 1990, detailled studies were carried out in Research Centre for Mining and Metallurgy, CIPIMM, to put into exploitation the whole deposit. The Feasibility Study did not give acceptable indexes.

In 1992 - 93 we decided to put into exploitation only gold. To achieve this goal, based on an investment and low operation costs, we started studying heap leaching at bench and pilot plant scales.

That way, with Cuban specialists technology, design and construction, and with governmental financing, we put into operation Oro Castellanos in June 1994.

EXPLOITATION

Quarry limits were determined taking into account the maximum utilization of the reserves, leaving a step (10 m) for protection of the sulfurous ores and the slopes inclination angles in their limit position.

Mining is open pite type, extracting only the 30% of the ore mass by drilling and blasting when lithologies are represented by cuarcites, cuarzosas sandstone and for some types of limonita, and the rest is extracted by bulldozers. Mineral is carried in trucks (~ 1 km) to the processing plant.

Plant was designed to process 1000-1200 tpd and can prepare now a days 2000-2600 tpd.

Mineral is crushed to -20 mm and agglomerated in a drum. Cement and lime are added to the drum through a transportation band.

Agglomerated mineral with ~13% moisture is taken to the heaps (currently 6) with a capacity of 28000-30000 t each, through a system of 5 transportation bands.

Plant has 2 reservoirs- one for rich liquor and the other for the steril liquor and a third reservoir for emergency cases.

All water streams, treated solution etc poured to the sorroundings during rainy days and waters from colera, go to a water recycling dam.

Solution treatment to destroy cyanide is done with hydrogen peroxide.

Gold rich solution is pumped to Merrill Crowe plant where after being clarified (less than 5 ppm of solids in suspension)it is dearated. Oxygen free liquor is added zinc powder and then filtered in three press-filters.

Precipitate is extracted from the filter every 8-10 days and melted in a Rodwel oven.

Final product is dore metal with a gold content of 20 - 50% of gold and 5-10% of silver. Pb and Cu among other impurities can be observed accompanying precious metals.

Now a days production is a bit over half tone of gold, 1.8 times higher than the design capacity of the plant.

TECHNOLOGICAL INNOVATION

During the first 2-3 years of exploitation, leaching and plant efficiency was relatively low (50-60% gold) due to the few knowledge of ore characteristics, limited technological studies and low expertise of the process.

Since 1995 CIPIMM has been intensively carrying out technological studies in cooperation with plant specialists and management. This gave as a result an immediate improvement in the industry because once a technological or engineering improvement was defined, it was immediately included in the technological process.

A multidiscipline team work permited to shorten interphase I D and technological innovation with a short term benefit.

The most important technological improvements were:

- Study of rock fine size to be fed to the agglomerator. As a result we obtained a rock size of -12 to -20 mm. A new ore preparation line was installed.
- Optimum conditions for clayed ore agglomeration-leaching were stablished, also for their mixtures with oxidized minerals, lime consumption, cement and cyanide solution.
- Heap formation was optimized, so were irrigation system and type, leaching time, recycling of steril and washing liquor, etc.
- Checking and re-design of the gold precipitation plant (Merrill Crowe, Canadian method) that resulted in a jam due to its capacity and efficiency.
- Heap taking out, batch capacity and heap forming time.
- Improvement of gold precipitation process, clarification, zinc adding, reation time and filtering area, etc.
- Optimization of smelting process for gold precipitate and slag re-treatment.

- Optimization and daily control of the technological parameters, efficiency by process sectors and operation costs.
- Implementation of methodological and environment standards control.

The most outstanding results achieved by the Enterprise are:

- Increase of the total metalurgical efficiency to 73-75% of gold, by processing an ore with a gold content of 1.5-1.6 g/t.
- Reduce the operation costs under 200 USD/oz of gold.
- High plant profitability and an increase in gold production of 1.8 times related to the design capacity.
- Use of a new colera, designed by CESIGMA S.A. according to the environmental law with a minimum investment and using an impermeabilization system with local industrial materials.
- Use of a Sampling monitoring Program for Environment and the restoration of the areas affected during the first years of exploitation.

ENVIRONMENTAL ASPECTS

Oro Castellanos Enterprise contracted CESIGMA S.A, an specialized firm in Environment Checking from Mining Industry, which carried out in 1998-99 a detailled multidiscipline study of the impact mining has on the environment.

That environmental checking included a study on flora and fauna, ground, mine, technological process, water sources and hydrology of the zone, etc.

The main studies carried out were:

- A study of the old colera and cyanide behavior.
- An engineering study of the area to locate the new colera.
- Design and supervision of the new colera that fulfils the environmental laws, with capacity enough to operate till the ore is exhausted.
- Study of solid/liquid management.
- Treatment and movement of the leached tailings.
- Treatment of the solutions or steril liquors before they are thrown.
- Study of the underground waters, streams, superficial waters and brooks.
- Study on the movement of the country rocks in the oxidized zone, the overburden and the leached tailings.
- Study of the acid drainage of the rocks in mine sectors.

Study of the working conditions in smelting area, such as gases, dust and temperature.

As results of those studies was concluded that:

- Decomposing process of cyanide contented in leached tailings is slow under the tropical conditions of the zone.
- Monitoring and environment control system must be planned taking into account that:

- Presence of heavy materials in industrial waters and in streams higher than the average stablished by the standards, provoqued by the cations movement phenomenom country rocks and overburden present.
- Irregular presence of sulfurous minerals (pyrite and Pb sulfosalts) in overburden and the transition zone (between oxidized ores and poymetalic ores) are potential generators of acids, and that accelerates the movement of mineral components that go to the waters and can contaminate the streams and the sea in the sorrounding areas.
- High Pb content in the smelting area which constitutes a potential source of health affection for workers, so they recommended to improve ventilation systems and gas extraction.
- Feasibility of locating the plant under no contamination conditions with relatively low costs.
- Enterprise management and its will was predominant to turn the process in a friendly one for the environment with a high efficiency and profitability.
- Recommended program allowed the Enterprise to stablish a General Program to check and control environment parallel to mining, warrantying the care of environment.

TEMPORARY MINE CLOSURE SCOPE

Oro Castellanos closure is planned to be carried out when Fe gossan is exhausted taking into account that a 10m step of oxidized ores must be left above the sulfurous polymetalic ores to avoid their contact with water and oxygen, which could produce acid and so the emission of acid leached materials to environment, warrantying useful water resources are not contaminated.

It is planned to:

- Carry out an environment checking before the ore temporary closure to stablish the necessary measures and a plan to mitigate the effects mining has had on environment.
- Keep the control of the overburden, current ore drainage and control drainage in the surrounding area, overburden and the water recycling impounding.
- Use of other ores processing .
- Possible re location of the plant establishing the measurements needed for caring and or for treating the reservoirs of rich, sterile and emergency liquors.
- Take all measures to eliminate erosion with settlings discharge to receptive waters and leaching of reject metals to superficial and underground waters.
- Restore and revegetate the coleras of leached tailings keeping a periodical control of the possible drainage of residual cyanide because of the rains.
- Neutralize and treat waters and liquors accumulated, solid wastes, storage areas, etc to avoid any contaminating effect due to weather conditions.
- Environmental audit when temporary closure is performed to evaluate the final impact on environment and its approval by authorized institutions.

SOME PAGES WEB OF INTEREST FOR THE THEME CLOSING OF MINES

Glória Janaina de Castro Sirotheau
gcastro@cetem.gov.br
Research IMAAC/UNIDO , Brasil

Http://www.bhp.com.au/press/bhp_press/data/19990604a.htm - Site da Broken Hill Proprietary Company Limited – BHP

Http://www.pnl.gov/china/coalclose.htm

Http://165.83.32.34/pubs/yr_rvw96/chapter8/npfaward.htm – Site do *National Park Service*

Http://www.conama.cl/chile-canada - Site da *Comisión Nacional del Medio Ambiente – CONAMA* - Chile

Http://www.crandonmine.com/mmsecac.html

Http://www.expressindia.com/fe/daily/19990518/fma18019p.html – Site of The Financial Express

Http://web.kwic.com/barrett/preserving.html - Site of Toby Barrett

Http://instrm.org/pmatrix/BonneTerre.htm

Http://www.emlf.org/books/Vol14/ch11v14.htm

Http://www.uswa.ca/STEELABE/backis3/heathsteel.html

Http://www.interchg.ubc.ca/plan/thesis/britton/ch3b.htm

Http://www.cookeng.com/mining/mining.htm

Http://www.dep.state.mt.us - Site do *Department of Environmental Quality*, Montana (EUA)

Http://www.infomine.com/index/suppliers/GD_Resources_Inc.htm

Http://www.admin.uq.edu.au/community/ingmines.htm – Site of *UQ Faculty of Engineering, Department of Civil Engineering*, Austrália

Http://www.infomine.com/rgroup/rgc/vangrum.html

Http://www.juneau.lib.ak.us/cdd/Kensington/reclamat.htm

Http://www.desarrollo.gov.bo/mde/leyes/mineria/reglamento ambiental.html

Http://www.emlf.org/books/vol15/ch3.htm

Http://www.coaleducation.org/abstract/SME/99-038.htm

Http://www.dme.gov.za/minerals/mine_closure.htm

Http://www.sonami.cl/boletin

Http://www.cochilco.cl/ambiente/ambiente.html

Http://www.mem.gob.pe/wmem/legisla/aa/cierreabandono.pdf

Http://www.idrc.ca/mpri/docments/cierreminas,html - Site of *International Development Research Centre - IDRC*, Canadá

Http://es.epa.gov/oeca/sector/sectornorte/pdf/metminsn.pdf – Site of Environmental Protection Agency, EUA