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# Mine closure experiences — Bolivia, South America

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## Abstract

*Bolivia is a well-known mining country, mainly because of its rich tin, silver and gold deposits mined since the Jesuit and Spanish times; 17th to 18th centuries. There are three types of mining sectors: private, state and cooperatives.*

*Within the private sector four closures took place on the highlands: Kori Kollo (Golden Hill) and Kori Chaca (Golden Bridge) projects both located in Oruro, COMCO silver heap leaching Project located in Potosí; and Puquio Norte Gold Project located in the lowlands of Santa Cruz, agitation leaching operation.*

*Within the state sector, there were many mining operations with mine waste and tailings abandoned but not closed. However, in order to mitigate the pollution the Bolivian Government, together with some international donors such as the Danish International Development Agency, have prioritised and encapsulated some tailings deposits in the Potosí Prefecture.*

*The cooperative or artisanal mining sector lacks mine closures. Neither the government nor the communities have forced them to comply with the environmental mining regulations, which have been in force since 1997. Therefore, there are many environmental issues on the sites operated by artisanal miners.*

*This paper reviews the results of the closure efforts of the gold and silver heap leaching operations on the highlands of Oruro and Potosí, where pits, mine waste, evaporation ponds and tailings storage facilities were closed. The paper also addresses another gold agitation leaching operation, in the rainforest which was also closed. In all cases, closure plans and monitoring programmes were executed. Special focus was placed upon the physical and chemical stability of closed facilities so that no further effluents would be released and therefore no major threats would be expected to the environment and nearby communities.*

## 1 Introduction

Bolivia is well-known for its mining history. Ore and minerals have been extracted and processed for more than 500 years, although most of the time only on a small scale and via artisanal equipment. Few projects have been developed in the last three decades that have utilised high levels of technology, most of them sponsored by multinational firms such as Battle Mountain Gold Company, Newmont, Glencore, Pan American Silver and Coeur (Arce 2009).

Bolivia enacted its Environmental Law in 1992 whereas the specific Environmental Mining Regulations came in force in 1997. Since then, any mining operation should comply with pollution and prevention measures in order to take care of the environment and also comply with health and safety requirements to protect people working in the mining sector.

In the following sections the legal and institutional framework for the environmental management is presented. Then a brief explanation of the main characteristics of the private, governmental and cooperative sectors is summarised, emphasising its importance on the people's economy. Some case studies of mine closures for the private sector are reviewed, in order to rescue best practices to be applied in coming closures.

## 2 Legal framework

The legal environmental framework (Cardenas 2003) is composed of the following laws and regulations:

a. Environmental Law, Law 1333, 27 April 1992.

b. Environmental Regulations for the Environmental Law, Supreme Decree 24176, 8 December 1995. This has six general regulations:

- General Regulation for Environmental Management.
- Regulation for Pollution Prevention and Control.
- Regulation for Atmospheric Pollution.
- Regulation for Water Pollution.
- Regulation for Dangerous Substances.
- Regulation for Solid Waste Management.

c. Mining and Metallurgy Law, Law 535, 28 May 2014.

d. Environmental Regulations for Mining Activities, Supreme Decree 24782, 31 July 1997 (MMM 1997). Main regulations relate to:

- Environmental Management for Mining.
- Environmental Permitting Process.
- Environmental Base Line Audits.
- Water Management.
- Mining and Metallurgy Solid Waste Management.
- Dangerous Substances Management.
- Mine Closure (VMMH 2001).
  - Stipulates when an operator should close the mine.
  - Requires a closure and rehabilitation plan.
  - Advises requirements for a concurrent reclamation programme.
- Mining Exploration.
- Mining Activities with Minor Impacts.

e. Other regulations, such as Environmental Regulations for the hydrocarbons sector, roads, sanitation, landfill sites etc.

A wave of mine closures is expected to happen. Over the last decade, five medium scale mines in Bolivia were closed and for the next decade a similar number are scheduled for closure. How well these closures are handled has the potential to shape the national dialogue on the costs and benefits of the mining sector, especially for private mining.

# 3 Institutional framework

The institutional set up for environmental management in mining is ranked from the highest level to the lowest level, as follows:

- Ministry of Environment and Water is the National Environmental Competent Authority (NECA) and is in charge of the mining and hydrocarbon sectors.
    - The Ministry of Mines and Metallurgy is the Competent Sectorial Organisation (CSO) to assist the NECA, mainly develops norms, standards, manuals, guidelines etc. for the mining sector.
- The Governor is the Departmental Environmental Competent Authority (DECA) at the prefecture level and is in charge of all the sectors except the mining and hydrocarbon sectors.
    - The City Hall is the institution to assist the Governor. They follow up, supervise and monitor every activity, work or project. They review all the proposed projects, including environmental documents and, once approved, they will inform the Governor to enact the corresponding permits.

Each institution has specific technicians or specialised people to help the projects' representatives to comply with the environmental regulations.

Mine closure is an increasingly complex process, and given the concerns of all stakeholders regarding environmental, social, and economic impacts, best practice has long gone beyond technical solutions. Nowadays, a trilateral process of consultation and problem-solving, involving mining companies, governments and communities, is required for a mine to be closed successfully. In fact, to be fully effective, the process of planning for mine closure should start as early as possible, i.e. at the mine design stage (WB & IFC 2002).

# 4 Mining sector

## 4.1 Private sector

Historically the private mining sector has been responsible for 64% of the total mineral production. During the last ten years, in terms of mining royalties, they have given to the State more than USD 200 million per year. However, nowadays only 10 out of 40 companies are still in operation, or under closure, and the benefits from mining have thus reduced dramatically. Table 1 provides details of the major private mining projects in Bolivia.

Most companies are medium scale mining operations i.e. processing mineral from 1,000 to 5,000 tonnes per day (tpd). The San Cristobal project is the only large scale open pit lead-zinc-silver operation (40,000 tpd).

## 4.2 Public sector

The public sector consists of the Corporacion Minera de Bolivia (COMIBOL). The current government has given them a lot of responsibility, especially in trying to move from a primary exporter into an industrialised organisation. However, historically COMIBOL has not shown to have the human resource capacity to adequately manage a mining project. As a result there are many exhausted operations abandoned without closure measures. Most of the current operations are uneconomic and are facing many social and environmental difficulties. Not one mine is scheduled for closure and, in the past, many mines have been left abandoned creating many environmental issues.

All the projects are small scale, ranging from a mineral processing capacity of 300 to 1,000 tpd. Among the significant projects are Huanuni (tin), Colquiri (lead, zinc and silver), and Corocoro (copper). The state mining sector contributes 6% of the total mineral production. They pay mining royalties of USD 10 million per year (Oporto 2012).

**Table 1 Summary of the major private mining projects in Bolivia, South America**

| Project | Enterprise/owner | Closure needs/location | Closure status |
|---|---|---|---|
| San Cristobal Project, open pit mine. Lead-zinc-silver flotation plant. 40,000 tpd | Minera San Cristóbal. Sumitomo, Japan | A large pit, waste dumps, and tailings storage facility (TSF). Potosí-Bolivia | In operation, not scheduled for closure |
| San Bartolomé Project, mine waste treatment project. Cyanide Agitation Leaching to recover silver. 2,000 tpd | Empresa Minera Manquiri. Coeur d´aleane Mine Corporation, USA | TSF and some parts of the Cerro Rico surface. Potosí-Bolivia | Concurrent reclamation of the soil where the mine waste were |
| San Vincent Project, underground mine. Lead-zinc-silver flotation plant. 2,000 tpd | Joint Venture COMIBOL, Pan American Silver, USA | Mine adits and TSF. Potosí-Bolivia | In operation |
| Porco Project, underground mine. Lead-zinc-silver flotation plant. 2,000 tpd | Compañía Minera del Sur (COMSUR), Glencore, Switzerland | Mine adits and TSF. Highland, Potosi-Bolivia | In operation |
| Bolivar Mine Project, underground mine. Lead-zinc-silver flotation plant. 2,000 tpd | COMSUR, Glencore, Switzerland | Mine adits and TSF. Highland, Oruro-Bolivia | In operation |
| Don Mario Project, open pit mine. Copper and gold flotation and leaching plant. 4,000 tpd | Empresa Minera Paititi. Orvana Minerals, USA | Open pit and TSF. Lowland Santa Cruz-Bolivia | In operation |
| Puquio Project, open pit mine. Gold agitation leaching plant. 1,000 tpd | COMSUR | Waste dump, open pit and TSF. Lowland Santa Cruz-Bolivia | Closed |
| Kori Kollo Project, open pit mine. Oxide gold and silver heap leaching plant (10,000 tpd), plus sulphide agitation leaching plant (20,000 tpd). Llallagua Project, is another open pit in the same area | Empresa Minera Inti Raymi S. A., Newmont, USA | Waste dumps, open pit, evaporation ponds, leaching pad and TSF closed. Highland, Oruro-Bolivia. Pit and waste dump | Under final closure (in progress for 10 years) |
| Kori Chaca Project, open pit mine. Oxide gold heap leaching plant. 10,000 tpd | Empresa Minera Inti Raymi S. A., Newmont, USA | Waste dumps, open pit, evaporation ponds and leaching pad. Highland, Oruro-Bolivia | Under final closure |
| COMCO Project, re-treatment of mine waste, Oxide heap leaching (2,000 tpd) and cementation | COMSUR | Heap leaching tailings and ponds | Abandoned |

## 4.3 Cooperatives

A mining cooperative is a group of people that has been provided special treatment or incentives from the Government, such as low taxation on their mineral production. This sector has grown dramatically during the last 10 years which coincides with the current presidential period. In 2005 miners from the cooperative sector used to employ around 50,000 people; today they employ 200,000. Assuming five members per each cooperative, the total number would be around a million people. Therefore, this is a sector with powerful political influence in the decision-making process of the Government; especially in terms of advantages that they could receive from the President assisting their mining operations. Unfortunately today most cooperatives do not comply with environmental regulations and social responsibility. However, their contribution to the national mineral production is around 30% and, for mining royalties, they pay around USD 40 million per year.

# 5 Closed mines

## 5.1 Inti Raymi Mining Company

Inti Raymi had exploited Kori Kollo and Llallagua gold-silver deposits, located close to each other, in the La Joya-Chuquiña mining area. In addition, Inti Raymi discovered another small gold deposit named Kori Chaca, located 60 km to the south of Kori Kollo, 40 minutes by car from Oruro city.

### *5.1.1 Kori Kollo Mine*

This mine is located in the department of Oruro, on the Bolivian altiplano. Empresa Minera Inti Raymi operated Kori Kollo Gold Mine from 1983 to 1997, producing gold and silver from open pit mining and heap leaching operations of oxide and transitional ores. Once oxide ore was exhausted and sulphide ore appeared, an agitation leaching mill was built. The main differences between the new circuit and the former heap leaching process were the incorporation of a grinding circuit, agitation leaching tanks and a tailings storage facility (TSF). The new Carbon in Leach (CIL) process for the sulphide ore operated from 1997 to 2005, until the sulphide ore was depleted. Then the closure on the Kori Kollo pit, mine waste dump and TSF started.

In order to close the pit, a rapid filling with water technique was used. Water from the nearby Desaguadero River was diverted during 2003 and 2004. Stratified layers of water formed with good water quality on the upper layer (<2,000 total dissolved solids (TDS)); medium water quality on the intermediate layer (up to 40,000 TDS) and; poor water quality at the lower layer (>40,000 TDS).

The mine waste dumps were encapsulated using multilayers of low grade oxide material and topsoil, then all surfaces were revegetated using local seeds collected by the local community people.

Evaporation ponds were used to dewater the pit during production. At closure, once the total volume of water was evaporated, the salt was collected by mining equipment and encapsulated into the TSF. The area of the evaporation ponds was allowed to be rinsed with rainwater over several years until no salt residues were observed on the surface.

The TSF was also closed using the multilayer technique. The sulphides were covered by a layer of oxide material, compacted and then topsoil was placed on the surface. This topsoil was seeded by local plants (Schlumberger 2009a).

### *5.1.2 Llallagua Mine*

The Llallagua pit is located close to the Kori Kollo pit. During 2006 to 2014, the gold and silver prices were good so it was possible to process lower grades of oxide ores that had been considered uneconomic. During this time a permanent heap leaching pad was constructed and all the previous Kori Kollo heap leaching tailings, plus Llallagua lower grade oxides, were leached on the new pad. Later some waste dumps from

Kori Kollo were also reprocessed extending the life-of-the-mine for another eight years. Meanwhile, the closure of Kori Kollo was taking place concurrently.

The same techniques used for the Kori Kollo Mine were used at Llallagua Mine to close the waste dump and pit. The experience gained at Kori Kollo was useful to turn the Llallagua pit into a wonderful lake in less than three years. The two pits became lakes that are interconnected each other and with the river so they form part of the natural hydrological Desaguadero River basin. Most of the areas disturbed by mining activities are closed, rehabilitated and revegetated. However, the closure plan has not yet defined what to do with some auxiliary installations such as the mining camp, airport, electricity and gas lines. It is expected to be reviewed amongst interested parties (local government and communities).

From 2008 to 2013, the first environmental mining audit was conducted by the Bolivian government at Kori Kollo Mine in response to some complaints from nearby communities. However, the result of the audit was that no environmental impacts can be observed in the project area because all mine waste dumps and TSFs were encapsulated, the perturbed lands have been reclaimed and revegetated successfully. In addition all the monitoring results show that no major threats are expected against the environment and nearby communities.

### *5.1.3 Kori Chaca Mine*

Empresa Minera Inti Raymi operated Kori Chaca Gold Mine from 2007 to 2014, producing gold from open pit mining and heap leaching operations of oxide and transitional ores. This mine was located in the department of Oruro, on the Bolivian altiplano. This small mine was designed to operate for four years but because of the good metal prices it operated for around nine years. With the Kori Kollo closure experience, closure took place concurrently and with less effort (Schlumberger 2009b). For example, there was less re-handling of solid waste and less lime required covering sulphides in the bottom of the pit. Less time and money was needed to get very good quality water in the pit lake. Here the rapid filling technique was also used to create an artificial lake. This lake now has natural fish, birds, plants and other animals.

Special focus was put on the physical and chemical stability of the waste dump and heap closure so that no further effluents could leach and release metals. In this way, no major threats are expected against the environment and nearby communities. The pit is now a well-established lake with fish and many birds that have started the development of biodiversity. Therefore, this mine site is another example of successful closure and rehabilitation.

## 5.2 Compañía Minera del Sur

Compañía Minera del Sur (COMSUR) used to belong to the former Bolivian President Gonzalo Sanchez de Lozada. President Gonzalo Sanchez de Lozada left the country for political reasons (Evo Morales became President in 2005). COMSUR, in order to keep its mining concessions and to protect its mining operations, changed its name from COMSUR to Sinchi Wayra (Strong Wind), and is now a subsidiary of the Glencore Mining Company.

### *5.2.1 Compañía Minera Concepcion*

Compañía Minera Concepcion (COMCO) used to be a 2,000 tpd cyanide silver heap leaching plant that operated from 1988 to 2008. Through a cementation process followed by fusion, silver ingot was produced. Compañía Minera Concepcion left in place approximately two million tonnes of heap leaching tailings. No contouring, capping or revegetation of the heap slopes was conducted. Until now even the leaching ponds remain open. This is not a good example of responsible mine closure and is not in compliance with the minimum standards of the national environmental regulations (Figure 1).

**Figure 1 Cyanide silver heap leaching facilities at Compañía Minera Concepcion, Potosí, Bolivia**

### *5.2.2 Puquio Norte Mine*

Puquio Norte Mine operated from 1995 to 2001 at 1,500 tpd. It was located in the tropical area of Bolivia, in the San Ramón Gold District, Santa Cruz. The waste dump and the TSF are physically and chemically stable and therefore have been acceptably closed, but this is not the case for the pit. The pit walls are steep and because of the quality of the material, the slopes are eroding and falling into the lake (Figure 2). Moreover, the pH of the water in the pit has turned acidic (pH 2). Apparently there is a non-controlled source of acid rock drainage (ARD) in the vicinity of the pit. This was confirmed during a site visit to the mine in 2014 by students from the Universidad Mayor de San Andrés (UMSA), Metallurgy Career (Yujra 2014).

**Figure 2 Open pit left by COMSUR at Puquio Norte Mine. The oxidised gold ore was treated by cyanide agitation leaching, followed by the cementation and fusion process, Santa Cruz, Bolivia**

## 5.3 Coming closures

Conditions for private investors are not ideal because of high Government taxes and there are no incentives for the companies who are working in compliance with the laws and regulations. Therefore, it is anticipated that many more private companies will continue to close their mines. The three saints, as they are known; San Cristobal, San Bartolome and San Vincent (all of them in the highlands of Potosí), are going to close

very soon. The gold open pit at Don Mario in the Precambrian is also nearing its end. Huge pits, mine waste dumps and TSFs are going to be the major challenges, together will all the potential social difficulties they may face.

Because of the importance of groundwater for consumption it will also be important to know if groundwater has been impacted by mining activities. Social mitigation will also be an important factor to be reviewed.

In the public sector, COMIBOL has some very well-known mines such as the famous Cerro Rico de Potosí, Huanuni, Colquiri, Corocoro or Telamayu mines which will also be closed in the coming decades. Therefore, all the experience and best practices from case studies around the world should be used to conduct responsible mine closure in compliance with mining and environmental regulations.

# 6 Conclusion

Bolivia has specific environmental regulations for mining activities, together with an appropriate legal and institutional framework. However, there are still problems regarding the follow up of mining closure activities (private, state and cooperatives) to ensure they comply with the laws and regulations and, thus, prevent and control environmental and social impacts. Best practices around the world should be implemented.

Bolivia has gained good experience in terms of responsible mining closure with reputable international operators. It has been demonstrated that it is possible to do productive mining but also be environmentally and socially responsible. Because environmental management has been a priority for private companies during the life of the mine operation, environmental management at closure was effective and less costly. It was demonstrated that investing in environmental management is a win-win situation for all the mine stakeholders.

Some other private mines were not closed in a responsible fashion and the effects of that can be seen now after many years of abandonment. These are lessons learned that should be reviewed among the different mining stakeholders to avoid future problems and liabilities.

COMIBOL has, in the past, abandoned many mines without proper closure but today has the responsibility to do things in a different manner. Most of the mining cooperatives neither practise environmental management nor plan closure measures. The government has to make all necessary efforts to ensure that mining operators comply with the laws and regulations.

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