First Screening for the Mitigation of Bolivian Historical Mining Wastes[1]

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ABSTRACT

The Environmental Department of the Bolivian State Mining Company - COMIBOL, has developed a system to evaluate and prioritize the mitigation of its historical mining wastes. The initial step of the system is a first screening. For this first screening general criteria have been used related to chemical, physical and socioeconomic aspects. Each criterion was given a relative score based on previous site mining documents knowledge. Data collection for the different aspects did not require field visits, which significantly reduced the costs of its implementation. The scores of the different aspects have been given a relative weight to calculate a relative site score. The result is a ranking of more than forty mining centers administrated by COMIBOL. After the first screening, detailed characterization follows starting in the ten mining centers with the highest ranking.

Additional Key Words: environment, prioritization, COMIBOL, characterization.

INTRODUCTION

In the early 1950's, the Bolivian Government nationalized privately owned mining companies. The operation and administration of these properties has since become the responsibility of the Corporación Minera de Bolivia (COMIBOL). The management of the mining wastes from the past at these COMIBOL mining sites is handled by the COMIBOL Environmental Office, (DIMA). The Bolivian mining industry was once very important for the world's supply of metals, especially silver and tin. Most of the properties are still being operated by small co-operatives and private companies that are extracting ores from these earlier mined deposits, from underground and from old mine waste material.

COMIBOL administrates approximately 40 mining centers. Although COMIBOL does operate only few of its mining centers, there is evidence that many of the new operations together with COMIBOL's old mining operations are contaminating soil and waters over a great distance. The World Bank performed a preliminary prioritization of these mine centers for mitigation work (Ayras et al., 1997). There is, however, little funding for mitigation work available and, therefore, a need for a reliable prioritization system. If for example we compare the budget for the cleanup of mining wastes of the United States with Bolivia we see a huge difference between both countries. Where the United Stated spent more than US$ 2,600 million (The Economist May 31st 2008) over the last 11 years, Bolivia only had a budget of US$ 5 million for the same period, which equals 0,2% of the United States Budget.

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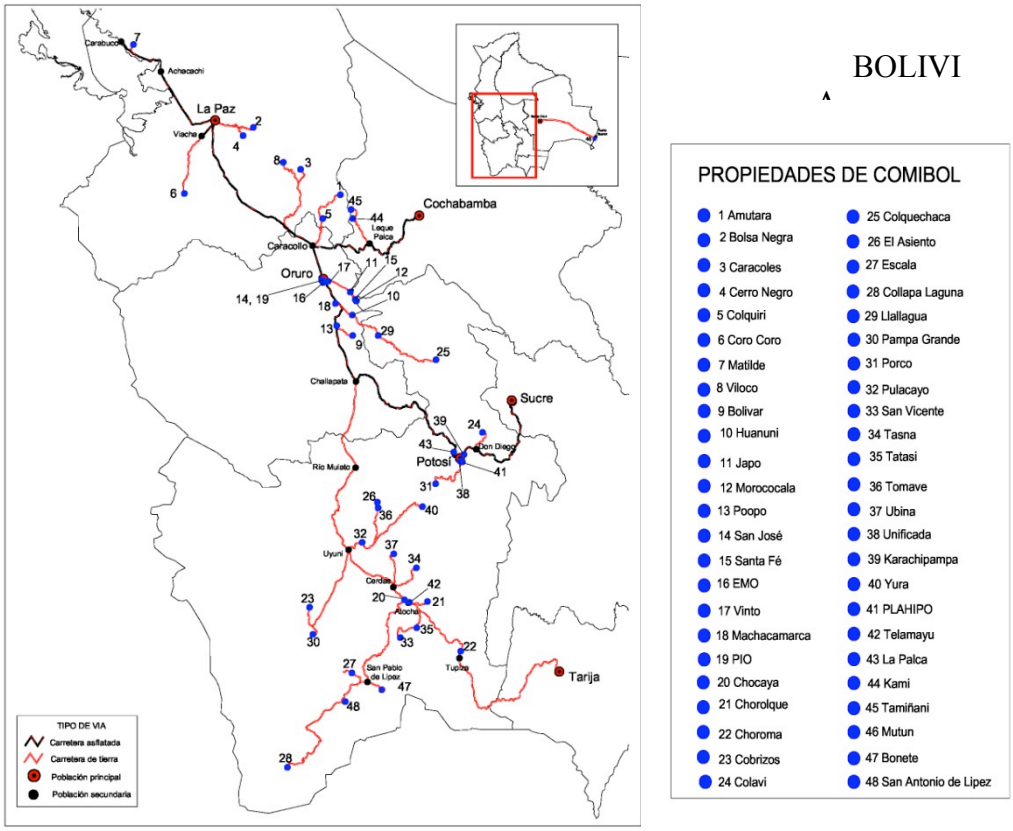

Figure 1. Overview of COMIBOL mining properties.

The Bolivian prioritization and mitigation management consists of eight steps (see table 1). This paper discusses step 1, the first screening (Flores et al., 2006). An explanation will be given of the criteria and different scores used for the first screening. The results of the first screening will be presented in a list of mining sites starting with the highest priority.

Table 1.Eight steps for Bolivian mine site prioritization and mitigation management.

1. First Screening	5. Cost-Benefit Analysis
2. Characterization for Prioritization	6. Design Mitigation Option
3. Risk Assessment (add. characterization)	7. Mitigation Construction
4. Remediation Options (add. characterization)	8. Maintenance and Monitoring

FIRST SCREENING

For the prioritization of the mining waste mitigation a detailed characterization of all COMIBOL mining centers would be too costly and time consuming. In order to generate a first ranking of the different mining centers a first screening has been designed and carried out in 2006. Physical, chemical and socio-economic criteria have been selected and for each criterion a relative weight has been assigned. Each criterion has a score, of which most are from 1 to 5. The relative weight of physical criteria is 25%, chemical criteria 25% and for socio-economic is 50%. Criteria have been selected based on the availability of information and knowledge at the main office of COMIBOL. This to assure that all mining centers could be screened without detailed field work which has saved costs and time.

Physical criteria

For the physical impacts four criteria have been selected (see table 2):

- Volume of tailings, waste rock and slags
- Water erosion
- Risk of collapse
- Geomorphologic location

For the volume of tailings the Bolivia Mining Code for the Environment distinguishes waste volumes below 50,000 M^3 as minor volumes and waste volumes above 50,000 M^3 as large volume. The division of the other categories has been made on the knowledge of the COMIBOL mining centers, where only a few mining wastes are larger than 1,000,000 M^3. Scores for the other physical criteria have been based on the experience of Bolivian staff at the COMIBOL environmental office.

Table 2: Ranges and scores for physical criteria

Volume of tailings, waste rock and slags	Score
>1,000,000 M^3	5
>500,000 M^3 <1,000,000 M^3	4
>100,000 M^3 <5000,000 M^3	3
>50,000 M^3 < 100,000 M^3	2
<50,000 M^3	1
Water erosion	
Active in several areas	5
Active	4
Visible	3
Limited	2
Very limited	1
Collapse risk	
Deteriorated	3
In process of deterioration	2
Limited deterioration	1
Geomorphologic location	
Mountain or hills	2
Valley or mountain foot	1
Plain	0
Maximum score	15

Chemical criteria

For the chemical criteria a score has been assigned based on the mineralogy of the mining wastes. Wastes with high contents of sulfurs have received a higher score than

wastes with neutralizing minerals. Information on the mineralogy is available at the COMIBOL library and known to the senior COMIBOL geologists (see table 3).

Table 3: Ranges and scores for chemical criteria

Mineralogy	Score	Justification
High content of sulfur (more than 40%): pyrrhotite, arsenopyrite, pyrite, chalcopyrite, sphalerite, galena. Total absence of neutralizing minerals like: calcite, siderite, aragonite.	5	Very high acid generating potential
Significant content of sulfur (between 20% and 40%): pyrrhotite, arsenopyrite, pyrite, chalcopyrite, sphalerite, galena. Limited presence of neutralizing minerals like: calcite, siderite, aragonite.	4	Medium to high acid generating potential
Presence of sulfur: pyrrhotite, arsenopyrite, pyrite, chalcopyrite, sphalerite, galena. Presence of neutralizing minerals like: calcite, siderite, aragonite.	3	Low acid generating potential
Low presence of sulfur: pyrrhotite, arsenopyrite, pyrite, chalcopyrite, sphalerite, galena, Significant presence of neutralizing minerals like: calcite, siderite, aragonite, dolomite, siderite, magnesite.	2	No acid generating potential
Mayor presence of neutralizing minerals like: calcite, siderite, aragonite, dolomite, siderite, magnesite.	1	No acid generating potential

Social and economic criteria

For the social and economical evaluation of the mining sites three criteria have been used:

1. Poverty level
2. Population density
3. Land use

The poverty level is relevant as marginalized people are often more vulnerable to contamination, so the poorer the municipality the higher the score. In order to define the poverty level poverty maps from 2002 of the Bolivian National Statistical Agency have been used. They provide poverty levels for each municipality in Bolivia (see table 4).

Table 4: Ranges and scores for poverty level

Poverty level	%	Score
Very high	98 – 100	5
High	95 – 97	4
Medium	85 – 94	3
Moderate	60 – 84	2
Low	17 – 59	1

Population density is an important social economic criterion. When the population density is higher more people can be affected by contamination and consequently, more people will benefit from mitigation measures carried out. Data have been taken from the municipal social demographic profiles of the Bolivian National Statistical Agency in 2002 (see table 5).

Table 5: Ranges and scores for population density

Population density	Inhabitants / km^2	Score
Very high	>15	5
High	>10 and < 15	4
Medium	>5 and <10	3
Low	>0 and >5	1

Mitigation in an area with high economic importance is expected to give better economic benefits than areas with low economic importance and is therefore included as a criterion. Urban areas and protected areas have been assigned the highest score. Lowest economic importance is land with limited use. Data and types of land use have been used from the geographic zoning project "ZONISIG" carried out in 2000 (see table 6).

Table 6: Description and scores for land use

Description	Score
Urban area and Protected areas	5
Intensive agricultural areas	4
Extensive agricultural areas	3
Forests	2
Protected land with limited use	1

Relative weight of each criterion

Each criterion has been given a relative weight. The three social economic criteria have a total relative weight of 50%, and the physical and chemical criteria have a relative weight of 25% each (see table 7). Social economic criteria have a large relative weight as it is expected that more benefits will achieved if mitigation works are carried out in areas

with higher poverty levels, population density or more intensive land use. Social demand for the mitigation works in the mining centers has also proven to be essential in order to gain support from COMIBOL management to invest in environmental projects. This coincides with the higher scores for the social and economic criteria.

Table 7: Relative weight for each criterion

Criterion	Relative Weight
Poverty level	10%
Population density	20%
Land use	20%
Physical impact	25%
Chemical impact	25%

RANKING FIRST SCREENING

Table 8 shows the final scores of the first screening of 43 COMIBOL mining centers. The mining center with the highest score has, based on this first screening the highest priority for mitigation. In Telamayu (see figure 2), Chocaya, and Tatasí mitigation works have been carried out, which reflect a lower score in the ranking, compared with the situation before the mitigation works. This should be mainly reflected in the physical criteria as socio economic criteria and the chemical criterion (mineralogy) do not change with the mitigation works. Water erosion and collapse risks are the physical criteria that have been be reduced after the mitigation works.

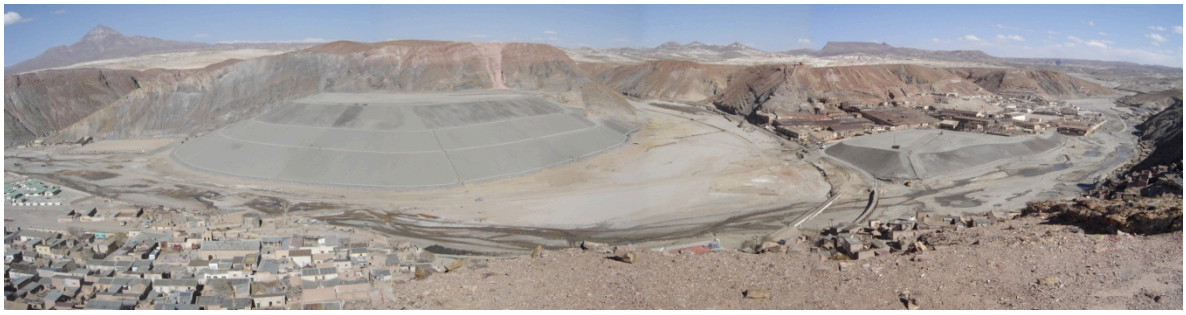

Figure 2. Panoramic view of the mitigation works carried out in Telamayu, 2004.

In 2008 mitigation started in Tasna, Colquechaca, and Matilde. In Tasna mitigation has been prioritized because of an immediate risk of collapse due to the deterioration of the tunnel beneath the tailing. Colquechaca and Matilde have been chosen as a result of social pressure and environmental deterioration, which seems justified as the first screening shows a high score for both mining centers. Figure 3 shows the mining wastes in Colquechaca before mitigation started.

The first screening gives Colquechaca the highest score. Characterization studies carried out afterwards showed very high levels of contamination, for example lead passed 7,000 times the Bolivian water quality standard for drinking water. Cerro Rico in Potosi has the second highest score, which reflects the high levels of contamination very close to the urban areas of Potosi. COMIBOL senior geologists validated the ranking of the first screening, based on their knowledge of the situation in each mining center.

Since 2007 detailed characterization work, step 2 of the Bolivian mine site prioritization and mitigation management, is carried out for the first 14 mining centers

listed in the first screening. The characterization work uses a similar approach as the first screening but with more criteria and requires extensive field work (Walder et al., 2008). With the result of the characterization and additional risk assessment studies decisions can be taken in which mining centers mitigation works should be carried out first. The current annual budget of COMIBOL allows starting mitigations works in one mining center per year till 2011, which will be more effective if the mining waste with the highest impact are managed first. After 2011 funding for the mitigation works is not assured.

Table 8: Final ranking first screening of COMIBOL mining centers

Nr.	Mining center	Poverty level max 10	Population density max 20	Land use max 20	Physical impact max 25	Chemical impact max 25	Final score max 100
1	Colquechaca	8	16	20	20	25	89
2	Cerro Rico de Potosi	2	20	20	20	25	87
3	Colavi	10	20	16	15	25	86
4	Matilde	10	20	20	20	15	85
5	San José	2	20	20	15	25	82
6	Santa Fé	4	20	16	15	20	75
7	Bolsa Negra	10	16	12	10	25	73
8	Kami	6	20	16	15	15	72
9	Morococala	4	20	4	20	20	68
10	Huanuni	4	20	4	15	25	68
11	Viloco	10	16	12	15	15	68
12	Siglo XX	2	20	16	10	20	68
13	Colquiri	6	8	16	20	15	65
14	Japo	4	20	4	15	20	63
15	Poopó	4	12	12	15	20	63
16	La Palca	4	16	16	5	20	61
17	Tatasi	4	12	4	25	15	60
18	Caracoles	4	8	16	20	10	58
19	Tasna	6	8	4	25	15	58
20	EMO	4	20	20	5	10	59
21	Choroma	4	12	12	15	10	53
22	Cerro Negro	10	8	4	10	20	52
23	Oruro (PIO)	2	20	20	5	5	52
24	Bolivar	4	12	4	15	15	50
25	Machacamarca	4	8	8	10	20	50
26	Plahipo	2	8	4	15	20	49
27	Porco	4	8	4	15	15	46
28	Telamayu	2	12	20	5	5	44
29	Chorolque	2	8	4	15	15	44
30	Pulacayo	2	8	4	10	20	44
31	San Vicente	2	12	4	10	15	43
32	Portugalete	4	12	4	5	15	40
33	Coro Coro	6	16	8	10	0	40
34	VINTO	2	20	8	5	5	40
35	Amutara	8	8	4	5	15	40
36	Ubina	6	8	4	5	15	38
37	Cobrizos	6	8	4	5	15	38
38	Mutún	2	8	12	5	10	37
39	Karachipampa	2	20	4	5	5	36
40	Vetillas	4	12	4	10	5	35
41	Tamiñani	8	8	4	5	5	30
42	Chocaya	2	12	4	5	5	28
43	Pampa Grande	6	8	4	5	5	28

Figure 3: Mining wastes in Colquechaca.

CONCLUSIONS

Social pressure and environmental legislation in Bolivia force COMIBOL to resolve environmental issues of its mining centers. The very large amount of mining wastes generated in the past and limited annual budget forces COMIBOL to establish clear prioritization criteria. The first screening designed by the COMIBOL environmental office is a low cost method based on available information at the central office, which justifies costly and time consuming characterization work in the mining centers with the highest scores. The first screening also facilitates transparency in the selection of the mining centers towards the external funding sources for the implementation of the mitigation works. The first screening is easy to be applied in other countries with mining wastes from the past.

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