GROUNDWATER AND ENVIRONMENT ON PERUVIAN MINING

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ABSTRACT

In order to satisfy water demands, the mining activity usually divert surface water resources from rivers and lakes, however, just in arid zones like south of Perú, they use groundwater. Oppositely, due to the excess of groundwater, in some mines, in order to improve mining drainage and using pumping of gravity tunnels, they discharge high water flows without treatment to the surface.

In general, due to mining activity the impacts or changes in the local aquifers, are notorious. Due to dewatering, usually occurs changes in water level, water flow direction and water quality. Water level drawdown can cause decrease of wetlands extension, reduction of water flows at springs, rivers, and the consequent readiness of water for irrigation or community uses. The infiltration of surface waters coming from tailing dams, pyritic waste dumps, leaching pads, benefit areas and human wastes, they can cause serious damages in the regional groundwater quality.

The recently environmental norms, are contributing substantially to minimise the referred impacts by means of the implementation of Environmental Adaptation Programs (PAMA) and Environmental Impact Studies (EIA).

To avoid contamination and to restore groundwater quality, before outflows divertion to the surface, the water of mine drainage should be treated, the spills of toxic substances should be eradicated and the toxic materials storage areas, mineral stock piles, waste damps, tailing dams and sanitary deposits should be waterproofed.

INTRODUCTION

In mining operations, water is very important. Unless certain cases, there are not excessive water in the whole country, because it is already destined to agricultural, human, or industrial use. For a new mining product, groundwater is a good supply alternative, because it is always in or near the mine. There are aquifers in valleys, bedrock, or extensive sedimentary watersheds located throughout the country.

According to the type of operations, mining is classified into underground mining and open pit mining, and from the hydrogeological standpoint and location, mining is classified into above or under the water table. In this sense, groundwater study is more important for underground mines, but in some cases groundwater study is important for open pit mines, since drainage could result in a concern.

WATER FOR MINING-METALLURGICAL SUPPLY

Demands

There is no mining without water. In a mine, water plays a decisive role, meanly because is not very available and quality is more restricted.

The major demand of water occurs in metallurgical processes; flotation is the most-consuming operation, and leaching is the lesser consumer. Population in camps are the second consumers, since due to lack or bad quality of surface water, they use to use springs groundwater. For mining processes, groundwater use is not important, but generally represents an obstacle.

Operation Size	Mining (%)	Concentration (%)	Population (%) Relationship	Water/Mineral
Bulk mining	3	85	12	1.00
Medium mining	14	59	27	3.70
Small mining	8	72	20	3.00

Table 1. Water demands in flotation mining.

Supply sources

In order to satisfy the water requirements, mining activity use to employ surface water (lakes and rivers) as principal supply source. Groundwater is only used in isolated cases.

Condestable, Raúl, Calpa, and Caravelí mines are supplied with groundwater from alluvial aquifers, since these mines are small operations, in the order of 30 l/s of water consumption. Marcona mine is integrally supplied with groundwater, which comes from Capillune aquifer. Cuajone mine uses 600 l/s of water conveyed via a 60 km length pipeline, and Toquepala mine uses almost 200 l/s of water conveyed via an approximately 100 km length pipeline.

Currently, in the arid southern zone of Peru, intense explorations are carried out in order to extract groundwater for Cerro Verde, Chapi and Quellaveco mines, and other small operations.

GROUNDWATER DRAINAGE AND MANAGEMENT

Depending on the geographical zone, mines can drain very varied streams of groundwater. Groundwater can be located in a shallow surface, interacting with surface water, or can be very deep inside, without any relationship with the surface. Deep underground mines have the strongest streams, which are associated with young volcanic rocks and located in rainy zones, with adits. Commonly, groundwater is obtained by pumping, although in some cases tunnels have been constructed in the top, in order to get water by gravity. In the last case, in spite of the initial investment is very costly, in the long-term the low costs of operations and maintenance result more economic than pumping.

Due to the shape and the extension of open pits, they use to catch groundwater, but they could have very variable quantity of water, depending on the permeability capacity of the rock, and the local rain rate. Probably, the open pit having stronger stream is Mc. Cune open pit, in Cerro de Pasco, and the open pit having less strong stream is Toquepala. In Cerro de Pasco, drainage (acidic water) is discharged directly into Río San Juan-Mantaro watershed, and indirectly through Yanamate lake, into Río Huallaga watershed. In Toquepala, the low stream is recirculated and evaporated by irrigating mine's roads.

Some new open pit mining projects such as San Gregorio and Conga Mines, whose water table is high, should include in their schedules an exhaustive drainage program, by installing tubular wells in the perimeter.

At the same time, underground mines drainage is done in order to avoid flooding, using pumping or gravity traditional methods. Many mines, such as Animón and Arcata have problems with excessive water that they pump, because these mines are located in highly permeable volcanic rocks. Mines such as Casapalca and Julcani have solved the problems using drainage tunnels (Gratón and Ganolini tunnels), but other mines having abundant pyrite have the problem of generating acidic waters. Mines located near magmatic or volcanic focus use to have problems with emanation of thermal waters, which substantially increase temperature in some mining labors, such as mine Huachocolpa. This mine had to be closed due to the insupportable heat in lower levels.

TYPICAL HYDROLOGICAL IMPACTS

Impacts or roads in local aquifers due to the direct mining activity are very notable. Due to pumping and mining dewatering, variations in water tables and changes in spring streams and flow direction are produced. Sulfide leaching results in alteration of water quality (acidic waters). Decreasing of water table could cause decrease of wetlands size, decrease of spring streams, decrease of base stream in some rivers, and the decrease of water available to irrigation.

Many wetlands located near underground mines have disappeared due to the decrease of the water table or due to they were dewatered in order to occupy the wetland surface as areas for infrastructure and services construction.

Water quality can be affected due to infiltration of toxic substances from surface. Color, taste, odor, and temperature could be affected too.

In many underground mines located in Cordillera Andina, there are dramatic changes in the aquifers, such as Hualgayoc, Pataz, Quiruvilca, Cerro de Pasco, Morococha, Huancavelica, and Mazca mining settlements.

Environmental regulations, recently approved by MEM, are contributing to minimize the mentioned impacts by implementing Environmental Adequation Programs (PAMA) and Environmental Impact Assessments (EIA).

WATER QUALITY

In order to preserve groundwater quality, several national and international agencies have established limits in the contaminant contents. Some of these agencies are General Directorate of Environmental Affairs from Ministry of Energy and Mines (MEM), Ministry of Agriculture by General Law of Waters, D.L. 17752 (LGA), and the Environmental Protection Agency (EPA), among others. As in the national framework, parameters are not already defined, the following standards should be taken in account, in order to protect groundwater quality.

CONTAMINANTS	MEM*	LGA**	EPA
Arsenic	1.0	0.1	0.05
Boron	—	—	0.75
Cadmium	—	0.001	0.01
Total cyanide	2.0	0.2	0.01
Chlorides	—	—	250
Coliforms	—	8.8	<1/1000 ml
Copper	2.0	1.0	1.0
Hexavalent chrome	—	0.05	0.05
Total hardness ($CaCO_3$)	—	—	300
Iron	5.0	0.3	0.3
Manganese	—	0.1	0.05
Mercury	—	0.002	0.002
Nitrates	—	0.01	45
pH	5.5 to 10.5	5 to 9	—
Silver	—	0.05	0.05
Lead	1.0	0.05	0.05
Dissolved solids	—	—	500
Suspended solids	100	0	—
Sulfates	—	—	250
Zinc	6.0	5.0	5.0

* For new mining-metallurgical units.
** For reception and domestic supply water bodies with simple disinfecting.

Table 2. Water quality maximum permissible limits (mg/l).

Water consumption exceeding permissible levels could produce a range of sickness, such as damage to liver and kidney, high risks to getting cancer, disorders in the nervous system, skin decoloration, and hypertension. Sulfate contents higher than 500 mg/l can produce laxative effects.

Cattle can tolerate levels higher than 300 mg/l of lime hardness, but dissolved solids with contents greater than 10,000 mg/l could create problems. Excessive content of suspended solids can affect fauna and flora.

The most evident effect of water hardness is manifested in the lack of foam in soap, and incrustation in kitchen utensils and pipelines.

AQUIFER CONTAMINATION

Acidic water discharge in lakes and rivers is not the only element producing impact in surface hydrological system. Damage of groundwater is caused by contaminated water percolation from surface, from metallurgical activity and benefit areas, and by discharging hydrocarbons and sewage without previous treatment.

Adits drainage in ore bodies with abundant content of sulfide and acidic rocks can generate acidic water with abundant sulfate and oxides contents, which, when produce decrease of pH in receptor water bodies, can make local flora and fauna disappear.

Surface water percolation from tailings deposits, pyritic dumps, leaching pads, benefit areas, and human wastes can cause serious damages to regional groundwater quality.

GROUNDWATER PRESERVATION AND REMEDIATION

In order to avoid contamination and remediate groundwater quality, toxic spills should be avoided and toxic materials storages, mineral piles, waste dumps, tailings deposits and sanitary fills should be impervioused, before discharging water to the environment.

Furthermore, care must be taken for avoiding reducing extension of wetlands, because they preserve fauna and represent natural elements for the passive treatment of contaminated waters.

To preserve groundwater quality, during operation waters from mining-metallurgical process should be used, in such a way that effluents disposal and discharge meet water quality standards established by national and international agencies.

As the modern mines of Yanacocha, Cerro Verde, Orcopampa, and Tintaya are proceeding, in order to avoid groundwater contamination, preventive actions should be implemented since the beginning of the operations, such as soil impermeabilization, construction of rain water diversion channels, encapsulation, and revegetation.

Mines closure

Historically, Peruvian mines have been abandoned in conditions similar to operation, that is, adits, open pits, waste dumps, and tailings deposits rested exposed to the environment, and, consequently, subjected to floodings, erosion, acidic water generation, and progressive destabilization of soils. To minimize impacts to the underground hydrological system, an efficient closure plan must include, at least, adits closure, and diversion of runoff in open pits, tailings dams and waste dumps. Acidic waters must be treated and thermal waters should be used for recreation purposes.

A good monitoring plan using piezometers will allow maintaining a permanent and opportune record of groundwater quality in the mining contour and even after closure.

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