AQUIFERS MANAGEMENT CONCERN AT SALARS IN NORTH ANDEAN OF ARGENTINA

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Geographical location and environmental description

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The Andean Northwestern in Argentina include Salta, Jujuy and Catamarca provinces, bordering by Bolivia and Chile. The Puna environmental is the more occidental part of the region. The altitudes is over 3000 masl y with mountains over 6000 masl.

There are several endorreic systems in Puna, with big salars like Pozuelos, Salinas Grandes, Olaroz, Hombre Muerto, Arizaro, Pocitos, Antofalla, Centenario, Ratones, Rio Grande, Cauchari........

The winters are cool with sporadic snow in August; summer is the wet season with many rainy days between December and February. The average precipitation are 100-300 mm/y, the evaporation 2000-3000 mm/y due to high solar radiation and winds, and 25 – 30 C of thermal amplitude.
The salars or brine salt lakes are natural deposits of different kind of salts and sediments form under extremely arid climate conditions. The main salars are closed system where the poor flow from underground and superficial water has finished. The Puna rivers are semi-permanents.

Source: Modelado del Reservorio de Salmuera, Salar del Hombre Muerto, Integral Consulting, Diciembre 2016
The salars have different extension and depth of filling sedimentary material with different concentration of salts and minerals. The sedimentary materials are halite, borates, gravel, sand, silt and clay.

A very low quantity of people live close to the salars, in general native small villages that use the ground and water for shepherds activities.
Currently the main interest is the lithium mineral, present in the majority of salars. The mining task in this case consists in pumping the brine from wells which reach the aquifer (50 to 600 m).

In general the brine is saturated in Na and the Li concentration is between 200 – 750 mgr/l.

Considering the world Li reserves, the 58% are in brine aquifers in China, Chile, Bolivia and Argentina (17% of the reserves).

In Argentina more than 50 Li projects are working in different steps; FMC and Orocobre announced duplication of their production capacities and at least 5 projects are planning to start the production in 3 years.

To produce lithium derivatives it is necessary to manage two connected aquifers: brine and fresh water aquifers. The lack of fresh water could limit the projects and it could be the main restriction.
Brine from wells

Lime

Lime slurry

Water

Mg/Ca Removal in Pond Systems

Li concentration in pond system

Brine concentrated to carbonate plant
LITHIUM CARBONATE PROCESS

Brine purified/concentrated → B, Ca/Mg removal

Soda ash (Na2CO3) → Soda ash solution

Chemical reaction: Na2CO3 + 2Li = 2Na + Li2CO3

Purification/Filtering

Dryer and packaging

Li2CO3

Mather liquor

Water
<table>
<thead>
<tr>
<th>CRITICAL VARIABLES</th>
<th>COMMENTS</th>
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<tbody>
<tr>
<td>Mine</td>
<td>The mine is essential, define the quality of brine and the volume. Need deep study. Models are necessary.</td>
</tr>
<tr>
<td></td>
<td>900 – 1000 m3/h of brine (15000 Tn/y of carbonate)</td>
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<tr>
<td></td>
<td>70 – 350 m3/h depending on the process (15000 Tn/y of carbonate).</td>
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<tr>
<td>Province</td>
<td>Permit. Inspections. Rules and law.</td>
</tr>
<tr>
<td>EPCM</td>
<td>Engineering and construction management is very important.</td>
</tr>
<tr>
<td>Customers</td>
<td>Main Asiatic.</td>
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</table>
GOVERNMENT OBJECTIVES AND ISSUES

OBJETIVES OF ARGENTINA FEDERAL AND PROVINCIAL GOVERNMENTS

- Looking at long term, necessity to give impetus to exploration and operation of lithium resources
- Development of mining operations from brine salt lake with sustainability.

MAIN ISSUES

- The information about environmental issues at salars are minimal
- The salt lakes have very complex, marvelous and fragile ecosystems
- The mining of liquid is novel and require legal adequations, develop of new instruments to evaluate environmental impacts, create new capacities in the regulatory and control departments of governments, coordination between communities and companies, etc.
- Several companies want to develop projects in the same salars
- The opportunity is TODAY and requires time and creativity!!!
In the early step of exploration on salars is extremely important to build exploration wells, in order to know the brine characteristics and the lithology and mineralogical of the sediment of the ground. It is very important to calculate the transmissivity and the storage coefficients, because define the pumping efficiencies.

Also it is important to know about the Li concentration variation on depth and in horizontal direction.

The last step of exploration on the brine is the proposal of a conceptual mathematical model that explains the behavior of the brine aquifers.

Several times the projects fail: poor base line in hydrogeology and hydrology, lack of data to know about the effect over ecosystems, concerns over the validity of the model.
WATER AQUIFERS: IMPORTANT ISSUES

Regarding to the fresh water it is important to understand its behavior to know about quantities and qualities. In the majority of cases the water has too much Ca, Mg, B, Si, Na; impurities that condition its applications and define the treatment process necessary to obtain water of different qualities for the process, human consumption, etc.

It is very important to understand the recharge of the water aquifer analyzing the precipitation, snowing, evaporation, infiltration; this data are normally insufficient.

The government obligation is responsible regulation of the water utilization, looking for the rational management of the aquifers.
GENERAL TECHNICAL RECOMMENDATIONS

When the mining operation starts the aquifers suffer several changes: Li concentration, density of brine, level of aquifers, growing of impurities in fresh water mainly. The mining operation will produce significant changes and may cause effects on the surface, groundwater behavior, landscape, soil moisture content, evapotranspiration and affect all ecosystems.

Then it is necessary to develop a hydrogeological balance to know the natural water inputs to the aquifer and the outputs due to mining activity. This balance is very complex in the Puna environment due to lack of measurement of different parameters of the balance and lack of statistical data of precipitation, evaporation rates, physical inspection on rainwater, infiltration mechanism, etc. The model will allow to lead the battery of wells construction, manage the pump rate, to know the influence of waste brine deposit, prediction of changes of aquifers and the changes of natural conditions.

Is very important to start the study of the water aquifers in parallel with the brine aquifers. Finally the studies and characterization of the aquifers, of brine and water, must continue during the whole life of mining operations, to calibrate them continuously when new data appears.
Another important issue is the localization of the liquid effluents from the process. The companies proposals are: areas close to the salar, over the salar or injection on depth; but we have not reliable idea of the effect or impact in the time.

The good and robust model will allow to evaluate the influence of the technical waste deposition decision.
PATH FORWARD IN IMPLEMENTATION

✓ Conform the Mesa del Litio between experts of the Salta, Jujuy and Catamarca Province and Federal Government to define the same focus analysis and similar rules to manage the aquifers resources. The main ideas are: evaluate the complete system, considering all actors in the salar, considering the brine and water aquifers in parallel way, evaluate the sum of impacts of all actors, validation of the model, calculate the reserves whit professional certification, obligation of agreement of a monitoring plan whit authorities, tide to produce others mineral present in the brine, tide to applicate non conventional energy and applies thinking of continue improvements.

✓ Sign an accord whit USGS to obtain cooperation regard energy topics and salt lake operational issues, modeling, limits inter-provincial conflict, etc.

✓ Provide training to Argentina experts to have professional certifications in aquifers and lithium business.

✓ Applying the Nuevo Acuerdo Federal Minero principles regarding the communities, social development, environmental plans, rules and laws.
Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.