Is Lithium Brine Water?

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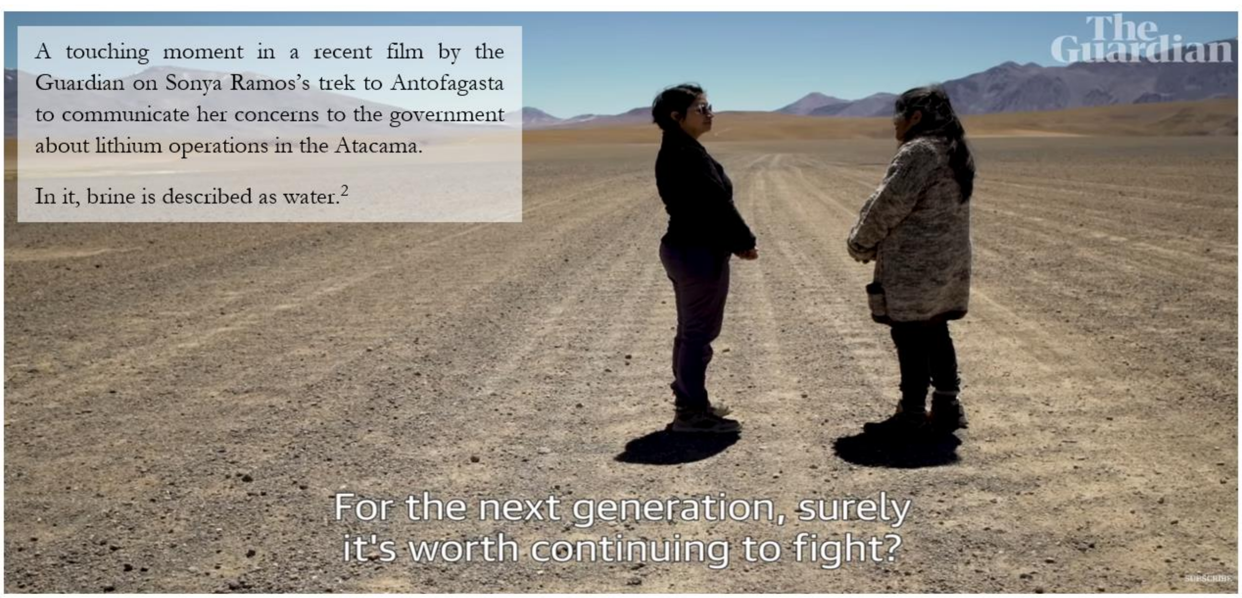
While the world needs increasingly large quantities of lithium chemicals to make batteries in electric vehicles to decarbonize transportation, one of the most important sites where it is extracted, the Salar de Atacama, has attracted attention for some problematic trends in aqueous resource behavior. The industry is grappling with what it means for the future of lithium extraction there and around the world. The situation includes (but is not limited to) the following components:

- The copper industry extracts large quantities of aqueous resources from the Atacama basin and they are now shifting sourcing to desalinated seawater, pumping it hundreds of kilometers to their operations instead of exploring for new aqueous resources in the area.
- The lithium industry extracts brine from the salar and returns minimal fluid to the aquifers (the water in the brine is lost in evaporative processing). This draw-down of the brine from salars without human impacted recharge causes a downward pressure gradient. This may cause other, less salty aqueous resources, to preferentially infiltrate into the salar due to this draw-down, affecting nearby lagoons that animals and humans depend on. This impact could equally be a result of aqueous resource extraction by the copper industry.
- Brines which contain economic lithium concentrations when processed using evaporation ponds contain around 25% salt by weight, while drinking water is defined by the World Health Organization as having < 0.2% salt by weight.[1]
- The local people of the Atacama are concerned about the impacts of mineral extraction on aqueous resources which they depend on, and are demanding that the government do more to monitor extractive industries. The lithium industry in particular has seen its social license to operate in the Salar de Atacama challenged. Given the fundamental human requirement for water, it is possible that wealth sharing alone is not a sufficient solution to the problem.



A touching moment in a recent film by the Guardian on Sonya Ramos's trek to Antofagasta to communicate her concerns to the government about lithium operations in the Atacama.

In it, brine is described as water.[2]

- In an environmental court case in 2019, data was presented showing algarrobo trees (a bellwether of water depletion) around the salar dying. Data was also presented which showed the moisture content of soil near lagoons surrounding the Atacama decreasing too.[3]
- Monitoring wells are employed to observe the hydrogeology of the salar but there is some concern that they are not sufficient to address the worries of Atacama residents, and lithium buyers who are demanding low CO_2 emission and low water intensity chemical products for battery manufacturing, increasingly important in Europe.[4]

The issues in aqueous resource behavior in the Atacama are nuanced and complex and this essay does not attempt to "solve" them. It also doesn't try to assign culpability for any or make any technical aqueous resource management recommendations, which specialized hydrogeology experts and the regulators of Chile are responsible for. Instead, it offers a framework for answering a fundamental question: **is lithium brine water?** Groups who feel strongly about this topic and are looking to discern whether this article supports "their side" are likely to find both positive and negative indicators, because this essay does not take "sides".

There has been a proliferation of the statement "brine is not water because you cannot drink it," but I am skeptical of this seemingly straightforward claim. I would say that you could technically drink it but it would kill you. Also, a 25% by weight lithium brine is technically 25% salt and 75% water, so the statement would be only 25% true, less than a majority if those molecules were voting on a mass-weighted basis. Aside from trivial technicalities, the statement that "brine is not water" deserves careful scrutiny because the implications of the answer are significant.

It is significant to lithium buyers who care about environmental impacts of the chemical products they buy. For example, when a life cycle assessment (LCA) is performed on a lithium chemical product, water intensity is a key component of the LCA along with CO_2 intensity, land footprint, and other impact factors. Obviously freshwater used in processing is included in the water intensity of the product, but is the water component of the brine included too? What about aqueous resources possibly destroyed by aquifer interactions?

It is significant to government agencies in jurisdictions which may look to better regulate their extractive industries. They should have unambiguous criteria for what water "is" and if brine is water or not in developing these regulations.

It is significant to future lithium project development in South America, since direct lithium extraction (DLE) technologies may be used to extract lithium from brines without evaporation of the water in the brine and possibly without causing aquifer interactions. This could impact how salars are managed for the next century of operation across the Lithium Triangle if DLE technologies are deployed there, and the majority of the brine is returned to the aquifer after lithium extraction.

The more I think about if brine is water or not, the more I realize that this is not exclusively a technical question. It is a philosophical question with technical components, and the framework used to answer the question should be structured that way. If it can be said that brine is water or not, then there should be some logical qualifier which makes a particular aqueous resource "water" or "not water" that demarcates the two. It could be a value of total dissolved solids (TDS, i.e. salt content) or something else. However, deconstructing the question makes it sound suspicious.

For example, it is not true that aqueous resources that humans cannot drink in their natural state cannot be drunk. Millions of people around the world live off of wells, and the water produced from those wells is often not drinkable without removing microbes which could cause illness. Most drinking water resources have TDS below 0.2%, but they still require processing before they can be ingested. If a requirement for water to be water is that it doesn't kill you or make you sick when you drink it, then almost all aqueous resources used for drinking water would not "be" water due to the presence of microbes and other contaminants, regardless of the TDS.

The City of Antofagasta produces a significant fraction of its drinking water via desalination of seawater. Is seawater water? When we go swimming in it, we say we are "going in the water", however seawater cannot be ingested directly for the same reason lithium brines cannot be ingested directly. Seawater has a TDS of 3%, around 8x less than most lithium brines, but is processed economically at large scale in Antofagasta using reverse osmosis (RO). RO would not be able to produce drinking water from lithium brines because the salt content is too high, though it is technically possible to use heat to evaporate the water out of a lithium brine, condense the water, cool it, and then drink it. So, any aqueous resource that contains water (e.g. a lithium brine which is 75% water), could be considered a source of drinking water before processing, with processing being required to produce all drinking water that does not kill or make sick the person who drinks it.

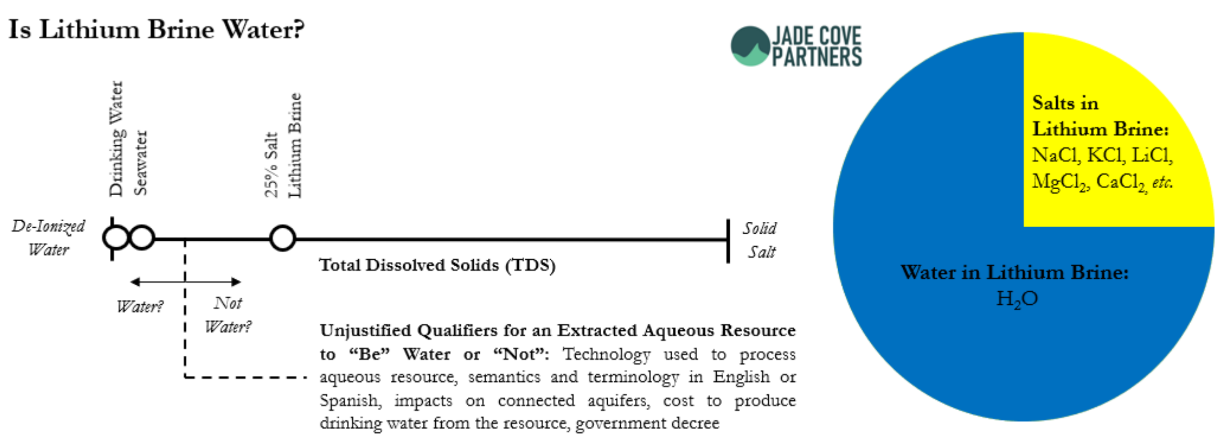
If seawater is water and drinking water under 0.2% TDS can be produced from seawater, then what is the maximum TDS for an aqueous resource before it no longer "is" water? 5%? 10%? Is there any justified TDS cut-off for demarcating between "water" and "not water"? Producing drinking water from an aqueous resource needs to be economic (e.g. to be competitive with other sources like trucking in drinking water) or else no one will ever actually do it. It is unlikely to be economically competitive to produce drinking water from Atacama lithium brines by burning natural gas, so it is unlikely that lithium brine will ever produce large quantities of drinking water for humans from that aqueous resource unless advanced technologies are deployed to extract the water. Economic viability for producing freshwater from an aqueous resource sounds like a good determinant for if a brine "is" water or not because it governs if water will ever actually be produced from it in a free market (e.g. unless the government mandates water production from brines by burning natural gas). But there might be other logical qualifiers for if brine "is" water we should also consider.

In the oil and gas industry, produced water is called water because it phase separates from hydrocarbons even though its TDS can be high, and though there are few economic technologies for producing drinking water from that aqueous resource. Is this aqueous resource "water" simply because it is a fluid that doesn't mix with oil? A flash steam geothermal system where steam is extracted from geothermal brine to produce power can produce almost pure water from that steam, or a low TDS aqueous resource that is more easily processed into drinking water than the original geothermal brine. This is compared to a binary cycle geothermal system in which the brine is not flashed, but remains at high pressure, and does not produce steam. If the former could produce freshwater and the latter could not, then "is" geothermal brine water when it is processed using flash steam systems but "isn't" water in binary cycle systems?

Government regulation is usually cited as a logical qualifier for if brine is water or not. In Nevada, the Silver Peak lithium operation owns the water rights in Clayton Valley, which includes the brine from which they produce lithium. In this case, the government considers lithium brine to be water due to the way they regulate the aqueous resources there.[5] Meanwhile, geothermal brines are not regulated as a water resource in Nevada. In other places like Chile, governments regulate lithium brines and low TDS aqueous resources differently.

In the case of evaporative lithium operations like in the Atacama, the water in brine is lost to the atmosphere to concentrate salts with little or nothing returned to the salar, which may impact other aquifers through complex hydrogeological interactions. Social justice campaigners and DLE technology proponents often refer to this water loss as a serious concern. But what if DLE technologies can be used to extract lithium from the brine, then return the brine to the aquifer and potentially prevent infiltration of other aquifers into the salar which could deplete drinking water resources? In this case, would we say that brine "is" water when evaporative processes are used because they may impact aqueous resources which may be amenable to drinking water production, but when DLE technologies are used and these impacts are potentially mitigated, brine "is not" water?

These would all be totally absurd conclusions. There are two reasons why deconstructing the question "Is lithium brine water?" turns into a *reductio ad absurdum*. First, other living things may be able to use water from higher salt content aqueous resources than humans can (algarrobo trees, flamingos, lilac bushes), and the people of the Atacama value the healthy flourishing of these things. Flamingos may rely on the animals in high TDS aqueous resources to survive, even if humans might not be able to economically produce water from those resources, and these animals are important to tourism, which is important to humans. Salty aqueous resources might not produce drinking water for humans but might "be water enough" to sustain other life.[6] Second, water is a malleable word that is used differently in different circumstances. If Inuit communities have 50 words for "snow", then the lithium industry can probably have as many words for "water".[7]



No logical person would accept the conclusion that "lithium brine is not water because it cannot be economically processed to produce drinking water" or any other qualifier like some of the absurd ones described above. These qualifiers are arbitrary, while "lithium brine is not water" is an absolute logical equivalence that should be universally true or not true at all.

When philosophers reach absurd conclusions when trying to answer a question, it usually means that the starting question was not a good question. "Is Lithium Brine Water?" is a terrible question. The corollary to the question being a terrible question is that the statement "Lithium brine is not water" is a terrible statement. A better question is: "Do extractive operations impact the accessibility of water for things which we value?" The corollary statement to this question is that lithium extraction operations in the Salar de Atacama or in South America in general either do or do not impact the accessibility of water for things which we value.

To answer this question, we need to know the values of the people potentially impacted by lithium brine extraction operations and all other relevant stakeholders. The lithium brine industry must align its values and goals with these stakeholders. As the Business Roundtable recommended in 2019 to redefine the purpose of a corporation: companies must take into account the interests of all stakeholders, with shareholders being a subset of the list of total stakeholders.[8] Business leaders now understand that non-alignment with relevant stakeholders is a leading indicator for poor returns to shareholders in the long term. Some lithium extraction operators and developers are now working on resolving non-alignments due to the sway of social justice campaigners, but declaring that "brine is not water" is not a helpful foundation for this harmonization of values and goals. In the case of the Salar de Atacama, the people who live there claim to be impacted, and that the things they value are threatened. This cannot be ignored.

Being clear about the right questions is an important requisite for the future (or non-future) of development of lithium brine resources across the Lithium Triangle and any potential expansion plans in the Atacama. The voices of social and environmental justice campaigners should be heard, and importantly, these groups should work with extractive industries and the government to clearly identify the specific negative impacts of extractive operations so that solutions can be found. For example, if social and environmental justice campaigners are concerned that brine contains water and the water is lost in evaporative processes, I think it's important to formulate exactly what impacts that brine extraction has on the things that they value and to direct campaigning towards preventing real negative impacts on those things. If the water in brine is not used for anything and if brine extraction could be performed in a way that doesn't impact other aqueous resources which sustain life (life being one thing we value), then there may be no negative impact of the operation. To say otherwise is like saying a space rock is a paper holder. It theoretically could hold down paper, but it never will because it is in space, and no one is going to go to space to retrieve a space rock to hold down their envelopes. It would only make sense if we ran out of rocks on Earth, which would be a different situation.

This decision making depends on the quantity and quality of information collected on aquifer behavior, and we should take conservative approaches to development and expansion plans until adequate information is assembled by independent hydrogeologists, engineers, and regulators. Feasibility studies (PFSs, DFSs,) are the best place to start in analyzing impacts on aqueous resources, and should incorporate more professional hydrogeological studies to rule out potential impacts.

As mentioned above, there may be hydrogeological opportunities of DLE technology deployment, notably the possibility of preventing aquifer interactions like infiltration as described in this research article. DLE projects can take advantage of water recycling to drastically reduce net water consumption of lithium production. It should be noted that if brine "is not" water, then DLE is not more "sustainable" and does not reduce water impact.

To the contrary, DLE could end up impacting freshwater availability more significantly to make lithium concentrates than evaporative processes do unless water is recycled properly. Though they have made significant progress to reduce net water consumption in the last decade as new technologies like RO have matured, at the time of writing, an operating commercial DLE operation in Argentina is being protested because of concerns by local communities about expansion plans. They use a DLE technology and do not evaporate all of the water in their lithium brine in evaporation ponds. We clearly need a better way of discussing water impacts.

Below is a proposed consensus framework for modeling water impacts in an LCA. Water intensity in lithium brine extraction should be broken down into three distinct impacts which vary between aquifers, resources, and types of technology chosen for extracting lithium from the brine. This is a simplified lithium brine adaptation of the approach taken by Boulay *et al.* to categorize different kinds of water impacts when the quality of aqueous resources varies (they propose 17 categories...!).[9]

The three distinct water impact categories of lithium brine extraction are:

1. Water in lithium brine (it is 75% H_2O by mass).
2. Water in aqueous resources which may be lost to aquifer interactions (infiltration).
3. Water for processing brines and chemicals (lime slurries, DLE lithium concentrates).

Properly categorized, the recipient of the LCA can decide how to judge water impacts themselves. Data used to evaluate these impacts should be obtained via third party, independent modeling and empirical data collection of aquifer behavior when possible. The difficulty of calculating the different impacts are not homogeneous, and it may be much more challenging to predict or measure hydrogeological phenomena like aquifer infiltration. Unfortunately, this type of water impact could be the most relevant for existing evaporative systems, which may partially explain why there is so much disagreement on this topic in the Salar de Atacama. Informed regulators will adjudicate.

I believe in a future where South American brine extraction operations play an important role in decarbonization and climate change mitigation without major impacts on water availability in the Atacama or other basins, but it will require more transparency, accurate environmental impact assessment, cooperation, advanced technology, and new ideas to materialize.

Category of Aqueous Resource in Lithium Brine Extraction Context	Likelihood of Impacting Accessibility of Water for Things Which We Value	Difficulty to Model Impacts on the Aqueous Resource	Possible Evaporative Processing Impact	Possible DLE Processing Impact
Water in Brine: Water in high TDS lithium brine	**Low** (Water in brine is likely not useful to any life or for any other purpose)	**Low** (Easily calculated)	**High** (Water lost in evaporation)	**Low** (Brine returned to aquifer with less lithium)
Water for Process: Water in low TDS aquifers consumed in processing	**High** (Other aquifers sustain flamingos, algarrobo trees, humans)	**Low** (Easily calculated)	**Medium** (Depends on process)	**Medium** (Depends on process)
Aquifer Interactions: Water in low TDS aquifers depleted by infiltration due to brine aquifer extraction	**High** (Other aquifers sustain flamingos, algarrobo trees, humans)	**High** (Requires advanced hydrogeological studies)	**Medium** (Depends on hydrogeology)	**Low** (If brine re-injected strategically)

Framework for Evaluating Risk of a Water Impact

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