INTERNATIONAL LITHIUM ASSOCIATION

Direct Lithium Extraction (DLE): An Introduction

A summary of the report exploring the various technologies used for direct lithium extraction (DLE)

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A very short introduction to

DIRECT LITHIUM EXTRACTION (DLE)

Exploring the technologies and potential for extracting lithium from brine without the use of evaporation ponds

The lithium industry is in a period of strong growth, driven by demand for rechargeable batteries for electric vehicles and supported by net-zero carbon policies. Albemarle, an industry leader, has forecast that the market could triple in size from 2023 to 2030 and as such it is important to consider all routes by which lithium might be produced.

Today the majority of lithium is industrially produced from two sources, hard-rock minerals such as spodumene or petalite, or extremely salty brines extracted from salars (salt lakes).

Traditionally, the way to produce lithium from brines has involved pumping the brine into large evaporation ponds and letting it evaporate until the desired concentration of lithium salts.

Although it is a relatively slow process, taking up to 18 months, it is well-understood and highly cost competitive.

Alternative methods of selectively removing lithium ions from the brine avoid the use of evaporation ponds and are collectively described as direct lithium extraction (DLE). These processes could allow for a radical reimagining of how lithium is produced and several governments, including in Bolivia, Chile and Argentina strongly support the use of DLE technology at new lithium projects.

A few industrial-scale DLE plants are already in operation and many others have been demonstrated at laboratory and pilot scale. Since 2020, over USD 980 million has been invested in DLE, with both government and private entities showing keen interest. DLE doesn't just offer possibilities for brines from salars though; several companies, including some ILiA members, are working on extracting lithium from geothermal brines and oil/gas-field brines too.

DLE has tantalising potential, but why is it not already widely used? The answer is complex and comes down to the fact that brines are very challenging liquids to work with and are often found in remote places. Every step of brine extraction, processing and reinjection carries technical challenges which must be overcome at scale.

Furthermore, every natural brine is different, with different levels of lithium content, total dissolved solids (TDS), location and more, which means that each brine requires a tailored approach and a DLE technology which works well in one salar may not work so well in another salar.

Salar de Uyuni in Bolivia is the largest salar and largest known lithium deposit in the world. The Bolivian government intends to extract lithium here using DLE.

The DLE process

Over the last 20 years, many DLE methods have been developed to separate lithium from other elements in brine. Several techniques use methods that were originally conceived for desalination and wastewater treatment purposes, rather than being specifically tailored for lithium extraction.

The DLE process begins with the collection of lithium-rich brine from underground reservoirs or salars, where it undergoes pre-treatment to remove impurities and create conditions for the subsequent extraction processes. DLE methods employ various techniques to selectively capture lithium ions from the brine while leaving other ions behind.

These extraction methods offer efficient and selective separation of lithium from the brine, paving the way for high-purity lithium production. Following extraction, the captured lithium ions undergo post-treatment to recover them in a useable form, such as lithium chloride (LiCl).

Additionally, post-treatment ensures proper management of the depleted brine, meeting environmental regulations before being reintroduced into the environment or reinjected into the underground reservoir or salar.

Key considerations which have an impact on the efficiency of DLE include the ratio of lithium to other salts dissolved in the brine (Li / total dissolved solids or TDS), of lithium to sodium (Li/Na), lithium to magnesium (Li/Mg), and lithium to sulphates (Li/SO_4) before and after DLE processing. Additionally, parameters such as the quantity of fresh water and energy requirement are critical to the success of a DLE project.

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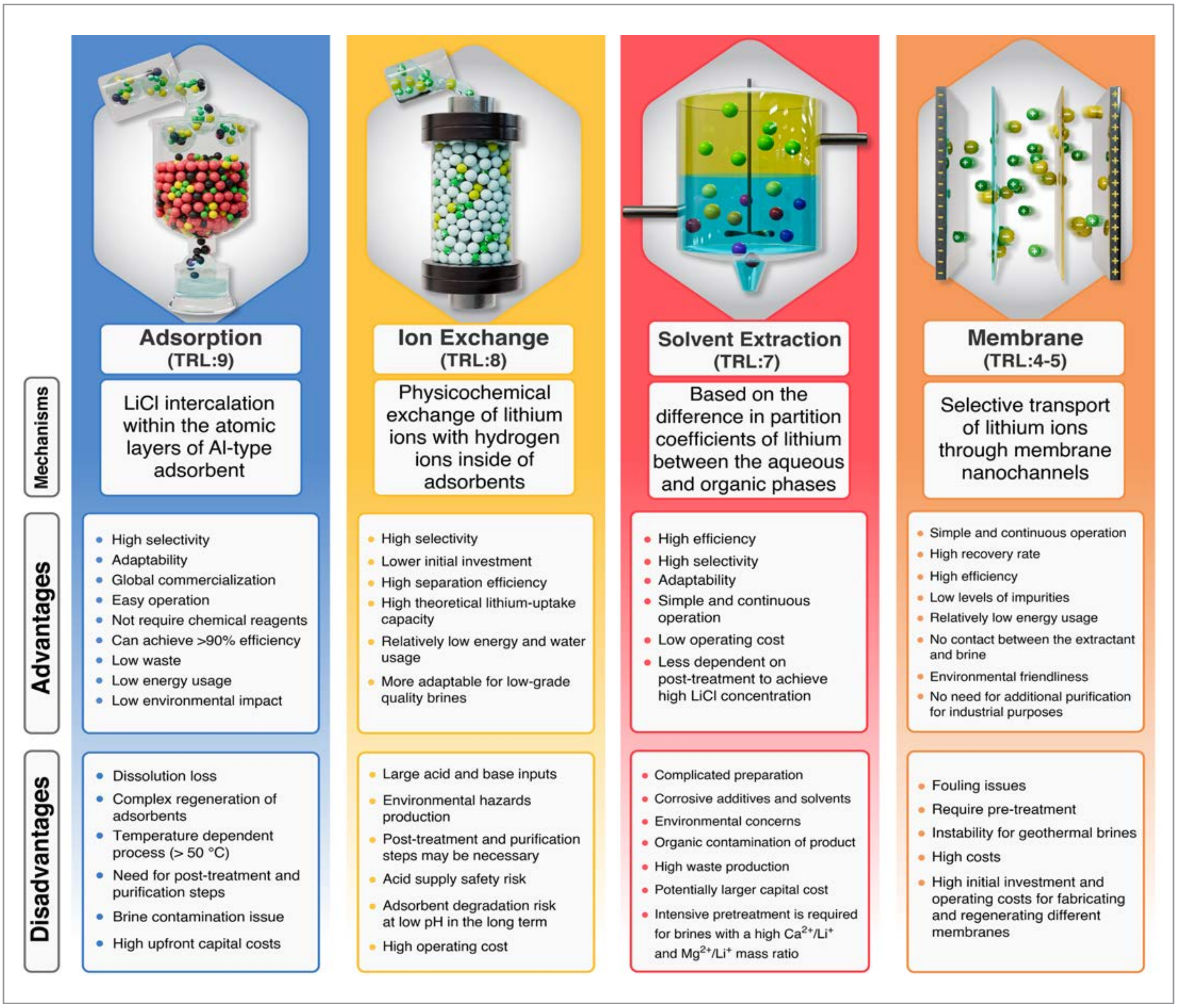

Figure 1 provides an overview of these selected DLE techniques, showcasing their mechanisms, advantages, and disadvantages. TRL refers to the technology readiness level, a method of assessing the readiness of a technology from 1 (low) to 9 (high) that was first devised by NASA. (Source: Dr A Razmjou).

DLE is already producing lithium at industrial scale at a handful of sites. This plant in China, owned by EVE Energy Co. Ltd, extracts up to 10,000 tpa LCE (battery grade) from brines using DLE technology provided by Sunresin New Materials Co. Ltd. The lithium concentration in the brine which is treated at this plant is 100-120 mg/L (Photo: Sunresin New Materials Co. Ltd).

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Key DLE technologies

DLE technologies can be categorised into four groups *(see Figure 1)*:

- Adsorption
- Ion exchange
- Solvent extraction, and
- Membranes

In adsorption based DLE, lithium ions intercalate into the surface of solid particles, typically aluminium-based sorbents. In the industry, aluminium-based sorbents are sometimes referred to as generation one DLE, while manganese and titanium-based ion exchange sorbents are referred to as generation two DLE.

Meanwhile, ion exchange based DLE involves swapping lithium ions in a liquid phase with ions of the positive charge but different chemical properties e.g. H+ on a solid ion exchanger, mainly manganese and titanium-based sorbents.

Solvent extraction DLE for lithium recovery relies on exploiting the different solubilities of compounds in aqueous and organic phases. This method involves several steps: combining the organic phase that has a lithium selective extractant with brine to form lithium complexes, subjecting the complexes to a stripping step to extract lithium, and recycling the organic phase.

Lithium extraction makes use of a range of organic solvents, including kerosene (the most common one), m-xylene, p-xylene, chlorobenzene, benzene, dodecane, chloroform, cyclohexane, ketone, methyl-tertbutyl ether, and acetic ether.

Membrane technology plays a crucial role in the advancement of DLE methods. Here a membrane acts to filter lithium ions out of the host liquid. Within membrane-based DLE, it is important to recognize two main types of membrane processes: pressure-assisted membrane processes; and reverse osmosis and potential-assisted membrane processes.

This list is far from exhaustive and several other types of DLE technology are reported to be in development.

The road ahead

From a technical perspective, the outlook for DLE appears promising, with advancements in technology leading to improved efficiency and effectiveness in lithium recovery.

From a sustainability standpoint, DLE offers several potential advantages concerning environmental footprint. They require less land area, have relatively low water usage (assuming they recycle water and reinject spent brine), and could even have lower greenhouse gas emissions when renewable energy sources are utilized to power the extraction process.

The main challenge for DLE is the unique composition of each brine found across the world, while the risks and benefits of reinjection of spent brine needs further investigation too.

While no 'magic answer', this is a technology with considerable potential to contribute much-needed lithium units to the market in the years ahead.

Watch this space!

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