geoconvention
Virtual Event
September 13 - 15
2021

Life Cycle Impacts of Direct Lithium Extraction from Canadian Brine Deposits

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Summary

The global demand for lithium is expected to increase up to 450% by 2050, driven by the increased production of lithium-ion batteries (LIBs) [1,4]. Consequently, the environmental impacts associated with the extraction and production of raw metals, like lithium, will increase. Upstream mining and refining processes are found to be the main source of emissions in LIB production [2]. With the recent developments in Direct Lithium Extraction (DLE) technology, the economic case for producing lithium from oilfield brines in western Canada is strengthened. This method of production can advantageously leverage the infrastructure and knowledge of the oil and gas industry in a transition to an environmentally sustainable economy. No studies have been conducted to quantify the life cycle impacts that these emerging processes will incur in the area of deployment. This research sources primary data from Prairie Lithium's DLE and purification process to quantify the impacts of lithium production from Canadian reservoir brine. The research problem is approached through Life Cycle Assessment (LCA) methodology, to accurately evaluate the environmental impacts of developing this nascent industry. The results will contribute to the western Canadian potential of supplying battery manufacturers with sustainable lithium chemical products.

Background

Lithium extraction is most commonly achieved through spodumene hard rock mining and evaporative salars from continental brines. Pegmatite deposits that are host to spodumene hard rock mining are currently dominated by Australia which is the largest lithium producer worldwide at an estimated 42,000 metric tonnes extracted in 2019 [9]. The extraction includes significant hydrometallurgical processes and the required crushing of ore and roasting of concentrate is both capital and energy intensive compared to evaporation processes [3]. Continental brines that utilize evaporation methods are concentrated in what is known as the *Lithium Triangle* of South America, the area includes northwest Argentina, southwest Bolivia, and northern Chile. The *Lithium Triangle* is estimated to host greater that 50% of worldwide lithium reserves and typical brine deposits are on average an order of magnitude larger than pegmatite deposits [7]. Evaporative extraction can take between 12-24 months due to its dependence on climate and weather conditions such as wind and rainfall [3]. Hydrogeologic factors are becoming increasingly important when producing deposits on the Salar de Atamaca, of which 30% of global lithium production is attributed and hold estimated reserves of 6.3 million tonnes [7]. Ramping up extraction and purification of currently producing lithium reserves could have significant environmental impacts.

Extraction of lithium from lower concentration brines has been studied as an alternative to evaporative mining. The concentration of lithium within enriched reservoir brine in the Williston Basin has been sampled from 75 mg/L to 112 mg/L [8]. This process involves the use of lithium selective ion exchange materials to preferentially pull the lithium from the brine while leaving the other metal ions in solution. Regeneration of the ion exchange material gives a purified and concentrated lithium salt that can be more easily refined into battery grade lithium carbonate or lithium hydroxide. Successful development of this method would allow for lithium mining from resources that have previously been considered marginal at best.

Theory / Method / Workflow

Life Cycle Assessment (LCA) is a tool that can provide a holistic view of environmental impacts across the life cycle of a product or process. An LCA for a specific product would typically cover the entire cradle-to-grave life cycle, which would include raw material extraction, manufacturing, distribution, use, and end of life recycling. However, a more narrowly defined cradle-to-gate assessment, looking at one or a few of the life-cycle stages, can also be valuable for comparative studies – such as this one. The International Standards Organization (ISO) has developed principles and guidelines for quantification and evaluation of environmental impacts for products using LCA in the ISO 14040 and 14044 documents [5,6]. As stated by ISO 14040 [5] there are four steps to be followed for completion of an LCA. Including the goal and scope definition, life-cycle inventory (LCI), life-cycle impact assessment (LCIA), and interpretation of the results. To date there are no LCA studies on direct lithium extraction and refining from Canadian brine deposits.

The base case for this study will be a pure lithium mine located in SE Saskatchewan, and the only product of the system being >99.5% lithium carbonate (Figure 1). Additional cases will be assessed with adjusted life cycle inventories to reflect the difference in impacts for coproducing from an oil and gas waste stream, and coproducing from a geothermal waste stream. Canadian oil and gas producers generate significant volumes of brine wastewater and could add direct lithium extraction technology to their operations. Geothermal power production has recently gained interest in western Canada, which produces large volumes of brine and once depleted of its thermal resource is reinjected back into formation. A geothermal well could produce both the power requirements for a commercial lithium plant and supply a source of lithium rich brine. This could enhance economics and reduce emissions intensity by powering the commercial facility and supplying surplus baseload power to the grid. LCA results will be evaluated to determine impact hotspots and areas to improve environmental performance.

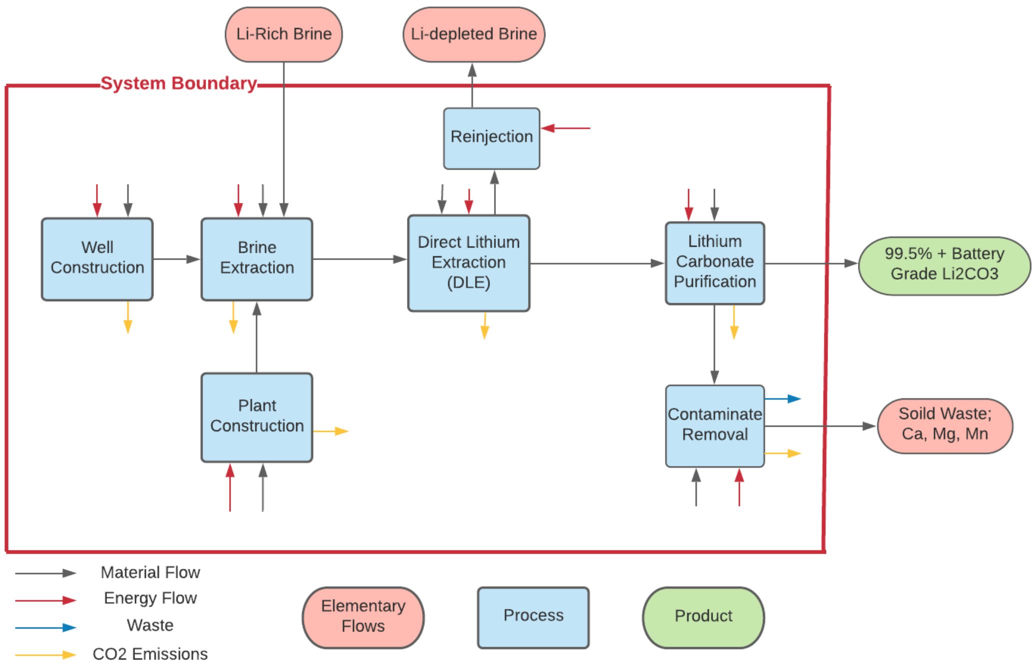

Figure 1: System boundaries for the base case lithium carbonate product

Results, Observations, Conclusions

The study is currently ongoing and results will be completed by the end of August 2021. The identified impact categories of interest are carbon intensity, freshwater depletion, particulate matter, ecotoxicity and land occupation. The research results will be used to conduct a comparative analysis to life cycle assessments on South American evaporative salar extraction and Australian spodumene mining.

Novel/Additive Information

This project contributes a greater understanding for the life cycle impacts of the lithium supply chain and the consequences of rising demand. Further contributing to the Canadian opportunity of becoming a sustainable supplier in the battery metals market. The research will give insights to where the lithium extraction process can be improved in order to reduce impacts. This research should be viewed as an important consideration when battery manufacturers procure the raw materials for lithium ion battery construction in the future. The successful development of this new industry can leverage the vast knowledge and expertise of the Canadian oil and gas sector to supply the lithium required for the energy transition. Presenting an opportunity to revitalize the economy while reducing the impacts across the lithium supply chain, but only if those impacts are accurately quantified.

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