Lithium in flowback and produced waters from Duvernay shale and Montney tight reservoirs in Western Canada Sedimentary Basin: Resource evaluation and extraction

Chunqing Jiang[1], Andrew Kingston[1], Adam Leece[2], Xiaomeng Wang[3], Travis Hobbs[4]

[1]Geological Survey of Canada; [2]Integrated Sustainability Consultants Ltd.; [3]CanmetENERGY; [4]Ovintiv Inc.

Introduction

As an essential material for rechargeable batteries used in electric vehicles and renewable energy storage systems, lithium's occurrence in and production from various sources have attracted immense interest and attention from academia, industry, government and the general public. Most of the world's lithium is currently produced from two sources: hard rock deposits including pegmatite spodumene in Australia, and continental brines in South America and northwest China. Compared to other countries, Canada has limited lithium reserves that are primarily lithium-bearing spodumene deposits, and almost no production at all. More recently, lithium resources in geological formation waters associated with oil and gas production, termed oilfield brines, have received increased attention. These oilfield brines are characterized by high salinity with potentially elevated concentrations of critical minerals such as lithium. As such, they represent an unconventional source of lithium that has the potential to become an important solution to the lithium supply shortage in Canada. One type of oilfield brine is flowback and produced water (FPW) from the hydraulic fracturing operations of unconventional shale and tight hydrocarbon reservoirs in the Western Canada Sedimentary Basin (WCSB). Among the most active unconventional gas extraction operations in the WCSB are the developments of the Duvernay shale reservoirs in Fox Creek area of west-central Alberta (AB) and the Montney tight sandstone reservoirs in northeastern British Columbia (BC), focused around the Dawson Creek area.

Although solar evaporation and chemical precipitation techniques are widely used for lithium recovery from salar brines in South America and salt lake brines in China, recent research indicates that direct lithium extraction (DLE) technologies such as ion-exchange sorbents are likely the most viable technique for the extraction of lithium from oilfield brines including FPW. This is fundamentally due to their lower concentrations of lithium than the salar brines and salt lake brines, and the suitability of the environmental conditions at the operations (e.g., lack of solar heating and evaporation).

Samples and Methods

FPW samples were collected from hydraulic fracturing operations of the Duvernay shale reservoirs in Fox Creek, AB and the Montney tight sandstone reservoirs in Dawson Creek area of northeastern BC. The brine samples were submitted to qualified labs for the measurements of their physical and chemical properties including pH, conductivity, alkalinity, contents of major and minor cations (including lithium and other selected trace metals as determined using ICP-OES/MS), and major anions (as determined by ion chromatography). The water chemistry results were used for statistical characterization of the Duvernay FPW from Fox Creek of Alberta and Montney FPW from Dawson Creek of northeastern BC. The average lithium contents were used as inputs for economic assessment of the critical mineral's recovery from the Duvernay and Montney FPWs using ion-exchange-sorbent-based lithium extraction technology. A Discounted Cash Flow (DCF) analysis was conducted on scenarios of direct lithium extraction from Fox Creek Duvernay FPW and Dawson Creek Montney FPW, respectively with the jurisdiction specific economic factors such as discount rate, effective tax and royalty rates, and electricity costs as inputs for the economic model development.

Results and Conclusions

Water chemical analyses on over 100 FPW samples from the Duvernay of Fox Creek area indicate a high content of total dissolved solids/salts (TDS) ranging between 80 and 345 g/L, with an average of 191 g/L (Figure 1). While the TDS of the Duvernay FPW is dominated by sodium and chloride, the content of lithium in the analyzed Fox Creek Duvernay FPW ranges from 19 to 79 mg/L, with an average of 45.1 mg/L. In comparison, water chemical analyses on over 200 FPW samples from the Dawson Creek Montney operations display a TDS content between 125–300 g/L, averaging at 223 g/L. Also dominated by sodium and chloride, the Montney FPW samples from Dawson Creek area have lithium contents ranging between 10 and 80 mg/L, with an average of 57.7 mg/L (Figure 1).

In the assessment of Duvernay FPW processed at a selected centralized facility that has an annual throughput of about half million cubic meters and an average lithium content of 45.1 mg/L, it is estimated that 92.5 metric tons of Lithium Carbonate Equivalent (LCE) could be produced per annum. Through a discounted cash flow (DCF) analysis, the after-tax and royalty Internal Rate of Return (IRR) is expected to exceed 20% in the production of lithium carbonate, and greater than 35% in the production of lithium hydroxide monohydrate. Comparatively, in the assessment of Montney FPW processed at a theoretical centralized facility with a 57.7 mg/L lithium content, 117.6 tons of LCE could be produced per annum. Similarly, through a DCF analysis, the after-tax and royalty IRR is expected to exceed 25% in the production of lithium carbonate, and greater than 45% in the production of lithium hydroxide monohydrate.

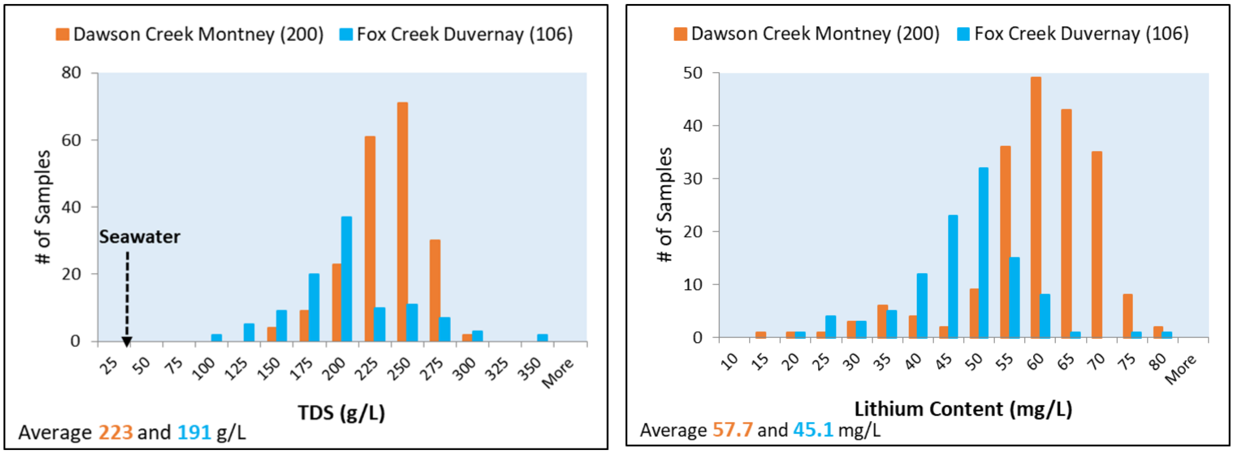

Figure 1. Histograms showing the contents of total dissolved solids (TDS; left) and lithium (right) in the analyzed flowback and produced water samples from Duvernay shale developments in Fox Creek, AB (blue) and Montney tight sandstone reservoir operations in Dawson Creek area of northeastern BC (orange).

Novel Information

The results indicate that lithium extraction and refining into battery-grade products from a novel feedstock source are potentially economically feasible at forecasted commodity prices. Further investigation into field pilot testing DLE technology, potential of integrating geothermal energy carried by the production fluids with the extraction process, and the minimum scale of lithium extraction and refining development is recommended.

Acknowledgements

This study was supported by NRCan's Geoscience for New Energy Supply (GNES) program at the Geological Survey of Canada and B21 Critical Minerals program at CanmetMINING. Funding from NRCan Office of Energy Research and Development (OERD) is acknowledged.

References

Jiang, C., Andrew, K., Wang, X., Hobbs, T., 2023. Chemical composition of flowback and produced water from the unconventional Duvernay shale and Montney tight reservoir developments in Western Canada: Potential for lithium resources from wastewater. Geological Survey of Canada, Open File (in prep).

Leece, A.S., Jiang, C., 2023. A preliminary techno-economic assessment of lithium extraction from flowback and produced water from unconventional shale and tight hydrocarbon operations in Western Canada; Geological Survey of Canada, Open File (in prep).