# Novel Zero-Liquid-Discharge Pilot Project for Produced Water Management, Northeastern British Columbia

**J. Zoshi,** Saltworks Technologies Inc., Richmond, British Columbia, joshua.zoshi@saltworkstech.com

**B. Sparrow,** Saltworks Technologies Inc., Richmond, British Columbia

**H. Tsin,** Saltworks Technologies Inc., Richmond, British Columbia

Zoshi, J., Sparrow, B. and Tsin, H. (2022): Novel zero-liquid-discharge pilot project for produced water management, northeastern British Columbia; *in* Geoscience BC Summary of Activities 2021: Energy and Water, Geoscience BC, Report 2022-02, p. 9–12.

## Introduction

Canada's Montney play is one of the richest shale gas plays in North America. On its British Columbian (BC) side, however, tight geology limits disposal zones for produced water. Operators reuse produced water where possible but when in excess they often resort to deep disposal underground. As shale gas extraction increases, reuse opportunities diminish and the disposal capability of northeastern BC's geology is forecasted to become more stressed. Saltworks Technologies Inc. (Saltworks) is presently advancing a project to pilot test a novel zero-liquid-discharge (ZLD) technology aimed at providing BC's oil and gas sector with an economic and sustainable alternative for produced water disposal.

## BC Produced Water Disposal Management

On the BC side of the Montney play, tight geology closer to the Rocky Mountains results in limited access and reliability of Class II disposal wells for produced water. The cost to permit and install new disposal wells is substantial and, where possible, operators are reusing and sharing flowback and produced waters in order to reduce operating costs. However, where that is not possible, produced water must be disposed of, either by ponding or trucking to neighbouring disposal wells (Kniewasser and Riehl, 2018). Ponds present containment failure risk and a potential hazard to waterfowl, whereas trucking, the primary disposal method, is greenhouse-gas (GHG) intensive and involves land disturbance and the risk of spills. Conventional evaporators for concentrating produced water to reduce volume prior to trucked disposal have been trialed in shale plays other than the Montney play. However, they have not been widely adopted due to a typical feed water salinity limit of 20% salt by mass (below that of many produced waters), corrosion and resulting reliability challenges, and hazardous air emissions of volatile organic compounds (VOCs), such as benzene, common in produced waters. Another challenge with concentrating produced water is the increased risk of causing scaling in disposal wells. As BC's oil and gas sector continues to grow, disposal well capacity is likely to become more constrained and concentrated produced waters are less likely to find disposal outlets in a supply constrained market (Petrel Robertson Consulting Ltd., 2021).

## Salt Reuse Opportunity

On average, 5 million tonnes of road salt are used each year in Canada (Environment and Climate Change Canada, 2018). In BC, sodium chloride is used for road salting, bleach production in the pulp and paper industry and chlor-alkali chemical production, but BC is not a producer of sodium chloride and must import it (WaterSMART Solutions Ltd., 2012). Salt transportation contributes to GHG emissions. Analysis of BC Montney play water samples performed by Saltworks (Richmond, BC) showed $10–30 of recoverable salt per cubic metre of produced water, a relatively small mass of contaminants requiring removal to enable reuse, and dissolved components comprising approximately 95% sodium chloride and calcium chloride, the primary constituents of road salt (Transportation Association of Canada, 2013).

## The Case for Zero Liquid Discharge

A safe, economic and reliable ZLD solution could be an effective means of preserving BC's disposal well capacity while reducing the environmental impacts associated with existing produced water handling methods. The ZLD treatment of produced water provides the following benefits: it significantly reduces GHG-intensive truck hauling by transporting a much smaller relative volume of solid salt for reuse or landfill; it avoids potential scaling of disposal wells by concentrated fluids; and it debottlenecks production constrained by disposal and pond concentration limits. In addition, reusing residual salt for local consumption can further offset costs of treatment and disposal, enabling a circular economy. The ZLD technology is equally applicable to mining and manufacturing industries, enabling further economic and environmental benefits.

*This publication is also available, free of charge, as colour digital files in Adobe Acrobat® PDF format from the Geoscience BC website: http://geosciencebc.com/updates/summary-of-activities/.*

**Table 1.** Results of AirBreather pilot plant testing completed in the Marcellus shale basin, northern Pennsylvania. Abbreviation: n.d., no data.

| Pilot test | 1 | 2 |
|---|---|---|
| Uptime (%) | 97 | 96 |
| Feed water - total dissolved solids (TDS; mg/L average) | 210 667 | 326 333 |
| Feed water - benzene, toluene, ethylbenzene and xylene (BTEX; ug/L) | 823 | n.d. |
| Concentrated brine - TDS (mg/L average) | 391 333 | 384 333 |
| Treated water - TDS (mg/L average) | 367 | 90 |
| Treated water - BTEX (ug/L) | n.d. | n.d. |
| Volume reduction factor (average) | 1.93 | 1.18 |

## Novel ZLD Technology

Saltworks has developed a novel thermal evaporator-crystallizer technology, trade named 'AirBreather', designed to overcome the limitations of conventional evaporators. The novel technology is compatible with waters having over 20% salt mass, achieves 100% liquid volume reduction by crystallizing and extracting solids, uses waste heat to offset input thermal energy and employs corrosion-proof wetted components. Its key differentiator from commercially available evaporators is its novel air emissions management process, which mitigates the release of VOCs through zero contact of saline water with atmospheric air. Beneficially, and unlike conventional open-to-air evaporators, no vapour plume is produced.

Initial modelling by Saltworks estimates that a system sized to evaporate 100 $m^3$/day that reduces the concentration of salt in produced water from 20 to 40% by mass prior to disposal could offset 940 t $CO_2e$ per year, compared to hauling unconcentrated produced water by truck[2]. The authors estimate the novel technology operated as a ZLD solution will further reduce trucking by up to 75% (one truck equivalent moving solid salt for reuse or to a landfill instead of four trucks hauling concentrated produced water for disposal).

## Previous Work

The novel technology has been successfully tested at a prototype scale, producing solid salt from nonsynthetic wastewaters from industrial applications, including oil and gas and manufacturing. A containerized pilot plant with 0.3 $m^3$/day capacity was built (Figure 1) and two successful onsite tests were completed in the Marcellus shale basin, northern Pennsylvania (Figure 2), concentrating live produced water into a more concentrated brine (Table 1). The pilot plant generated treated water that met local surface discharge (Centralized Waste Treatment Effluent Guidelines [United States Environmental Protection Agency, 2020]) and air emissions criteria (National Emission Stan-

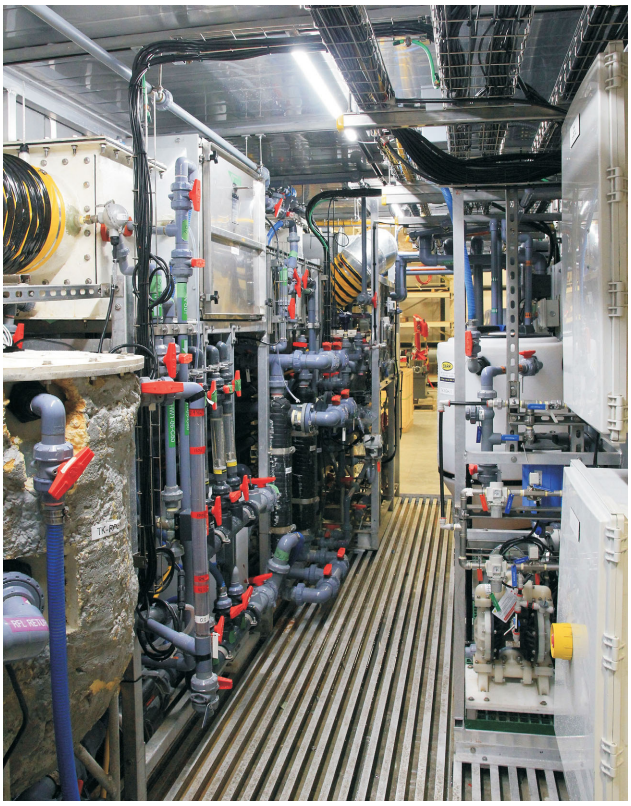

**Figure 1.** Interior of the main processing equipment container at AirBreather pilot plant, Marcellus shale basin, northern Pennsylvania.

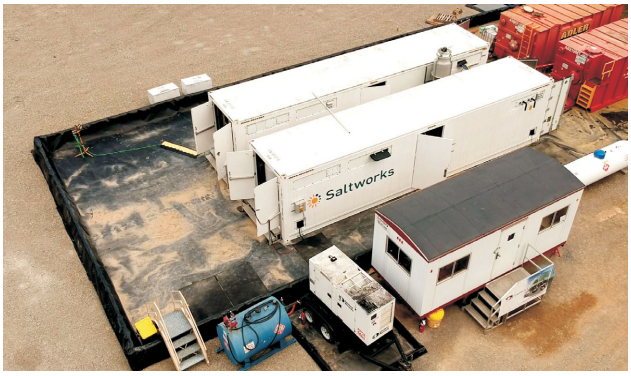


**Figure 2.** AirBreather pilot plant consisting of two 12.2 m (40 ft.), International Organization for Standardization (ISO), shipping container units, Marcellus shale basin, northern Pennsylvania.

[2] *AirBreather GHG offset calculations are based on a truck round trip distance of 150 km, 135.25 g $CO_2e$/tonne-km emission factor, produced water density of 1100 kg/$m^3$ and concentrated brine density of 1200 kg/$m^3$.*

dards for Hazardous Air Pollutants [United States Environmental Protection Agency, 2021]), making it the first process to receive a full-scale permit in a challenging jurisdiction where previous open-to-air evaporation systems failed to meet air emission requirements. In separate testing, Saltworks produced salt meeting BC road salt specifications from Montney play produced water, without trace deleterious elements (the firm has technology to remove naturally occurring radioactive materials [NORM]).

## Present Project

A project is presently underway to adapt the novel technology for ZLD treatment of produced water. The project's goals are to de-risk a full-scale implementation and enable a future alternative for produced water management in BC's oil and gas sector. The project is supported by Geoscience BC, the Natural Gas Innovation Fund, Sustainable Development Technology Canada and industry partners.

Project objectives include i) upgrading pilot plant systems to enable ZLD operation on produced water; ii) producing solid salt from live produced water supplied by industry partners while meeting water discharge and air emissions requirements; iii) producing industrially reusable salt; and iv) mapping the economics of the total process, including the salt reuse market potential.

Upgrades to the pilot project include adding an upstream NORM management subsystem, a downstream solids management system and modifications to mechanical, electrical and control systems. The project draws on lessons learned from past industrial water treatment technology development and solid salt production experience by Saltworks. Project activities are presently underway at Saltworks' Richmond, BC, facility.

### Completed Activities

The following activities have been completed:

- design of mechanical, electrical and control systems required for ZLD operation;
- installation and integration of ZLD-specific components into the pilot plant, including additional tanks, pump skids, electrical systems, and solids containment and handling equipment (Figure 3);
- checks and calibrations of transmitters and sensors, mechanical systems and safety systems;
- establishment of maintenance procedures, spare parts and wear component lists and kits; and
- commissioning with fresh water, including thermal start-up and testing of pretreatment, NORM and VOC subsystems.

### Current Activities

Six batches of Montney play produced water totalling 6000 L were received from industry partners (Figure 4) and are presently undergoing independent lab analysis. The upgraded pilot plant is now ready to produce, in successive stages: treated produced water without NORM; distilled water extracted from produced water; VOC-treated distilled water for evaporation and release; and solid salt for beneficial reuse. The pilot plant will also produce waste in trace amounts: solids from selective precipitation and separation of NORM (dependent on water chemistry) and sludge from removal of VOCs.

### Remaining Activities

Remaining project activities include developing pilot plant testing procedures and performing ZLD testing on each batch of water. In parallel to the testing, pilot plant process control tuning and additional component upgrades will be

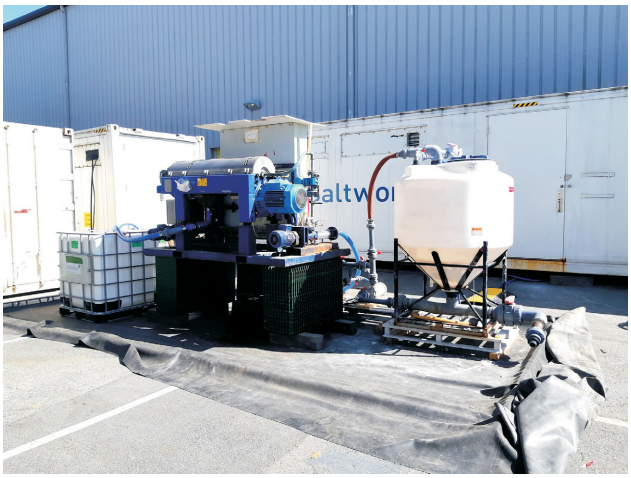

**Figure 3.** AirBreather pilot solids management subsystem showing centrifuge (left) and process tank (right).

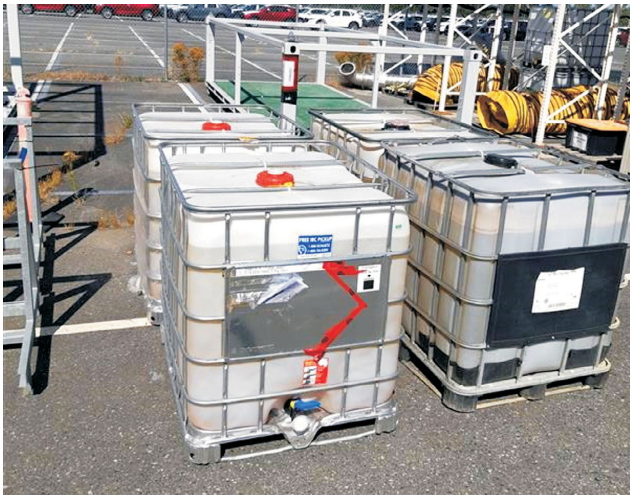

**Figure 4.** British Columbia Montney play produced water received from industry partners.

performed as necessary and following learnings from the testing procedures. Final activities include results analysis and reporting, analysis of solid salt produced and updating the economic model for full-scale implementation and salt reuse.

## Summary

As British Columbia's natural gas sector grows and produced water disposal becomes more challenging, an economic and green alternative for produced water management could be made available to the sector. As a zero-liquid-discharge solution, novel AirBreather evaporator-crystallizer technology has the potential to preserve disposal well capacity, while reducing costs and greenhouse gas emissions associated with trucked wastewater hauling, and enabling a circular economy through industrial salt reuse.

## Acknowledgments

Funding for this project was provided by Geoscience BC, the Natural Gas Innovation Fund and Sustainable Development Technology Canada. The authors would like to thank the industrial project partners for providing representative waters, technical advice and guidance for the project. The authors also thank M. Man for his review of this submission.

## References

Environment and Climate Change Canada (2018): Code of practice: road salts environmental management; Environment and Climate Change Canada, URL <https://www.canada.ca/en/environment-climate-change/services/pollutants/road-salts/code-practice-environmental-management.html> [October 2018].

Kniewasser, M. and Riehl, B. (2018): Risks to water and public health from unconventional gas in B.C.: a review of new research on hydraulic fracturing impacts; The Pembina Institute, 19 p., URL <https://www.pembina.org/reports/unconventional-natural-gas-water-risks-2018.pdf> [May 2018].

Petrel Robertson Consulting Ltd. (2021): Wastewater disposal in the maturing Montney play fairway of northeastern British Columbia; Geoscience BC, Report 2021-14, 237 p., URL <http://www.geosciencebc.com/i/project_data/GBCReport2021-14/GBCR%202021-14%20Wastewater%20Disposal%20in%20the%20Maturing%20Montney%20Play%20Fairway%20of%20NEBC.pdf> [November 2021].

Transportation Association of Canada (2013): Syntheses of best practices - road salt management; Transportation Association of Canada, 6 p., URL <https://www.tac-atc.ca/sites/tac-atc.ca/files/site/doc/resources/roadsalt-1.pdf> [April 2013].

United States Environmental Protection Agency (2020): Centralized Waste Treatment Effluent Guidelines; United States Environmental Agency, URL <https://www.epa.gov/eg/centralized-waste-treatment-effluent-guidelines> [April 2021].

United States Environmental Protection Agency (2021): National Emission Standards for Hazardous Air Pollutants; United States Environmental Protection Agency, URL <https://www.epa.gov/stationary-sources-air-pollution/national-emission-standards-hazardous-air-pollutants-neshap-9> [April 2021].

WaterSMART Solutions Ltd. (2012): Sodium chloride market: an overview of the sodium chloride (salt) market in western Canada (v.02); Oil Sands Leadership Initiative, 20 p., URL <https://content.energy.alberta.ca/xdata/IETP/IETP%202012/06-098%20Water%20Mgmt.%20Through%20Water%20Treatment%20Technologies/Appendices/APPENDIX%20H_OWM-MD-Salt%20Market%20Study-v02%20(2012-12-21)%20(2).pdf> [December 2012].