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# Salts Removal as an Effective and Economical Method of Bakken Formation Treatment

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# Salts Removal as an Effective and Economical Method of Bakken Formation Treatment

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## Abstract

One of the main aims of managing and containing waste disposal in deep rock formations is to safeguard individuals, the surroundings, and the groundwater reserves. The elevated salt content of the water produced by the rock formation necessitated an analysis of its chemical composition, including its major ion content, in order to understand the characteristics of the rock. Additionally, the total dissolved solids (TDS) in the ND Bakken formation are greater than 300g/l, which is much higher than the concentration of salt in seawater; therefore, it is reasonable to propose a modified process to treat the salts found in this formation produced water. Produced water in the unconventional U.S. Bakken oilfield has become a significant concern since oil and gas production growth has been substantial, and operating costs are increasing. Reusing this considerable amount of produced water has become necessary since the treated water can be used for potable supplies, irrigation, deep well injection, maintenance, and fracking, which improves profits and mitigates groundwater pollution. Several metals (Mg, Ca, Mn, Sr, Li, and K) were extracted from the flow back water and water produced in the Bakken oilfield using lime, caustic soda, and soda ash at different dosages and pH values during this project. The separation treatment using selective precipitation can be invaluable as a pre-treatment process of desalination techniques. Extracted salts are effective coagulants for removing various contaminants from wastewater; therefore, the extracted Mg(OH)2 and CaCO3 were used for wastewater treatment and establish their efficiency in removing COD and the nutrients phosphorous and nitrogen from ND wastewater. The recovery of these elements from produced water may create additional financial benefits for oil-producing areas. More importantly, this sustainable disposal of produced water may encourage the recycling and reuse practice, ultimately reducing the use of freshwater for hydraulic fracturing.

## Objectives

The objectives of this study are as follows:

- Investigate the recovery of several elements from Bakken oilfield-produced water as financial benefits to oil-producing areas such as, (Mg, Ca, Mn, Sr, Li, and K) which can be an important domestic source.
- Investigate the feasibility and purity of chemical by-product recovery from the Bakken Formation's produced water.
- Investigate the applicability of salts (magnesium and calcium ) for wastewater treatment.
- To examine the Ca and Mg removal in reducing scaling and fouling on the nanofiltration and reverse osmosis membrane surfaces.

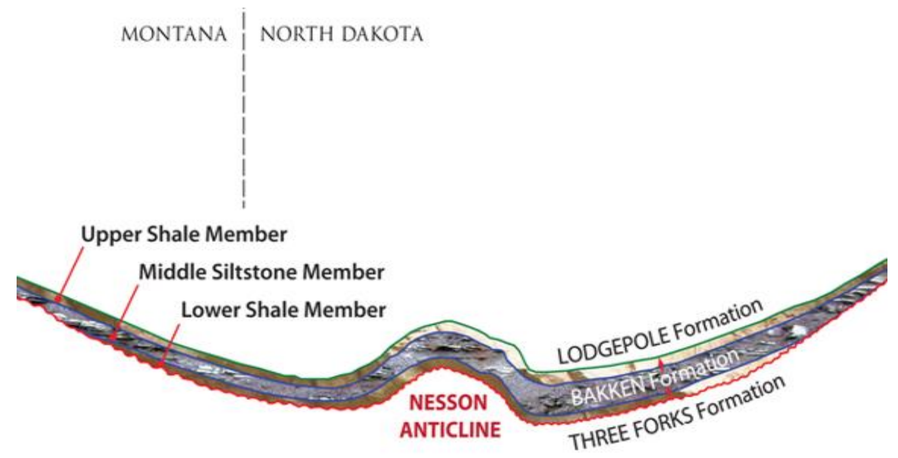
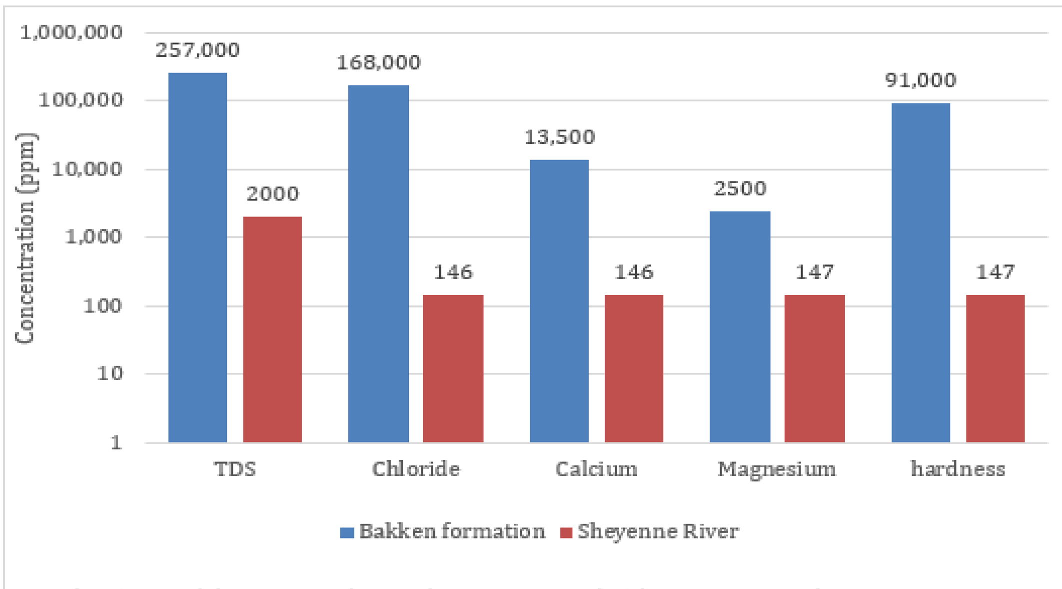



Fig 1. The Bakken Petroleum System ( A laalam et al., 2022).




- Fig 2: Bakken produced water and Sheyenne River water composition besides total dissolved solids in ND.

## Methods

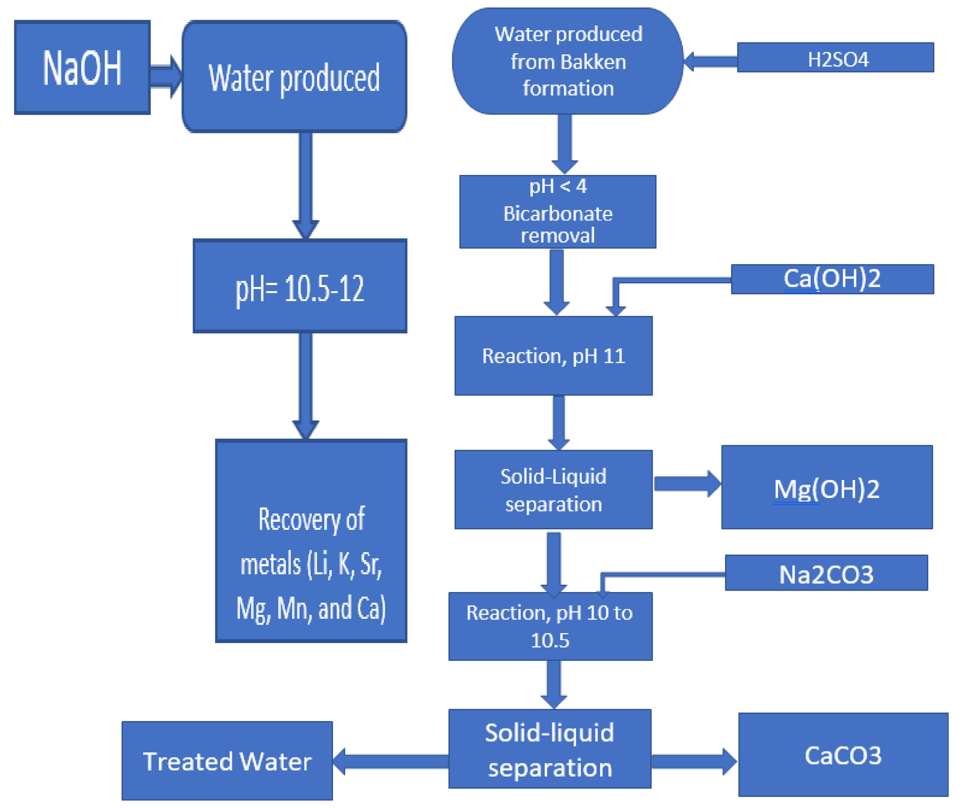



Fig 3. A schematic overview of the sequential recovery of salts.

All elements were analyzed by ICP-MS in this study. The extracting of salts was performed by adding a known quantity of caustic soda (NaOH), lime ($Ca(OH)_2$), and Soda ash ($NaCO_3$) to the produced water samples at around room temperature (24°C). Then, the stirrer was set to 150 rpm for rapid mixing and continued for 1 minute before being lowered to 40 rpm for slow mixing. The precipitative softening process was simulated in a jar tester using six square jars, every 2 liters in volume ( N Ismail et al., 2022).

### Physical Properties of produced water samples collected from two wells of the Bakken oilfield (ND, USA).

Table 1: The cation concentrations present in the produced water from the Bakken oilfield.

| Ions | Well 1 (mg/l) | Well 2 (mg/l) |
|---|---|---|
| Na | 43,250 | 8652 |
| Ca | 16550 | 2852.4 |
| Mg | 1102.5 | 250.2 |
| Sr | 1317.5 | 249.6 |
| K | 9595 | 2374.2 |
| Li | 372.5 | 72.5 |
| Zn | 7.5 | 2.2 |
| Cu | 0 | 0 |
| Mn | 117.5 | 25 |
| Alkalinity CaCo₃ | 176 | 162 |
| Hardness as CaCo₃ | 52000 | 9870 |

## Facilities

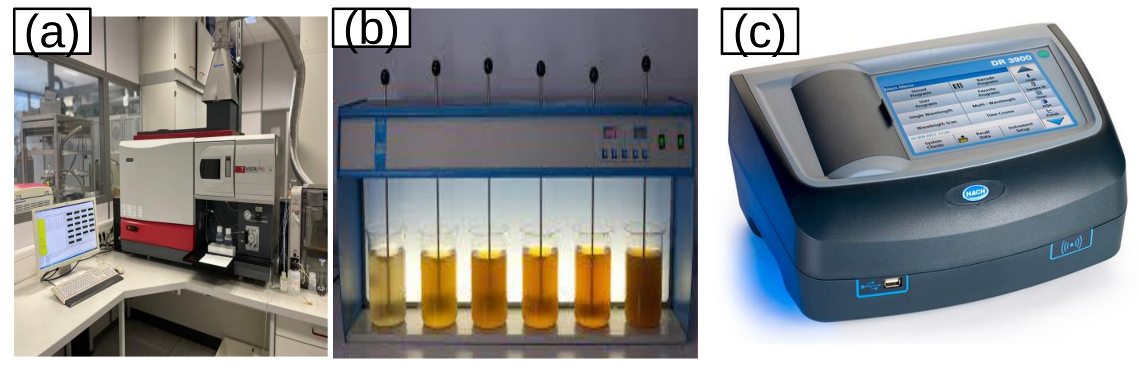



Fig4: (a) ICP/OES, (b) Jar Test, (c) Spectrophotometer

## Results

Table 2. Calcium and magnesium removal of produced water in two different wells in ND, USA.

| | pH | Lime | Soda (g/l) | Mg (mg/l) | Ca (mg/l) |
|---|---|---|---|---|---|
| **Well 1** | ? | - | | 1102.5 | 16550 |
| Step 1 | 10 | 194 | - | 469.37 | 17365.2 |
| | 11 | 243 | - | 36 | 18289 |
| | 12 | 350 | - | 20.08 | 18553.5 |
| Step 2 | 10.4 | - | 15 | 10.5 | 8650 |
| Removal % | | | | **98.17** | **41.08** |
| **Well 2** | | | | 250 | 2820 |
| | 11 | 103 | | 1.2 | 3420 |
| | 11.5 | 115 | | 0.3 | 3650 |
| | 10.1 | - | 15 | 0 | 494.7 |
| Removal % | | | | **99.88** | **82.45** |

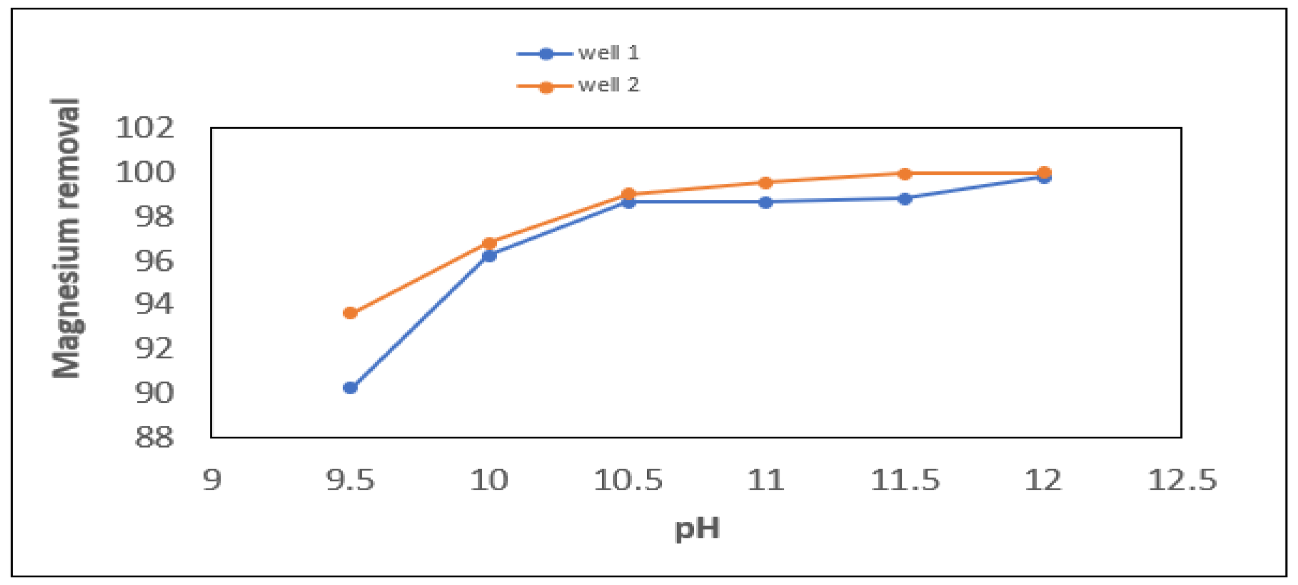



Fig.5. Effect of pH on magnesium removal in produced water.

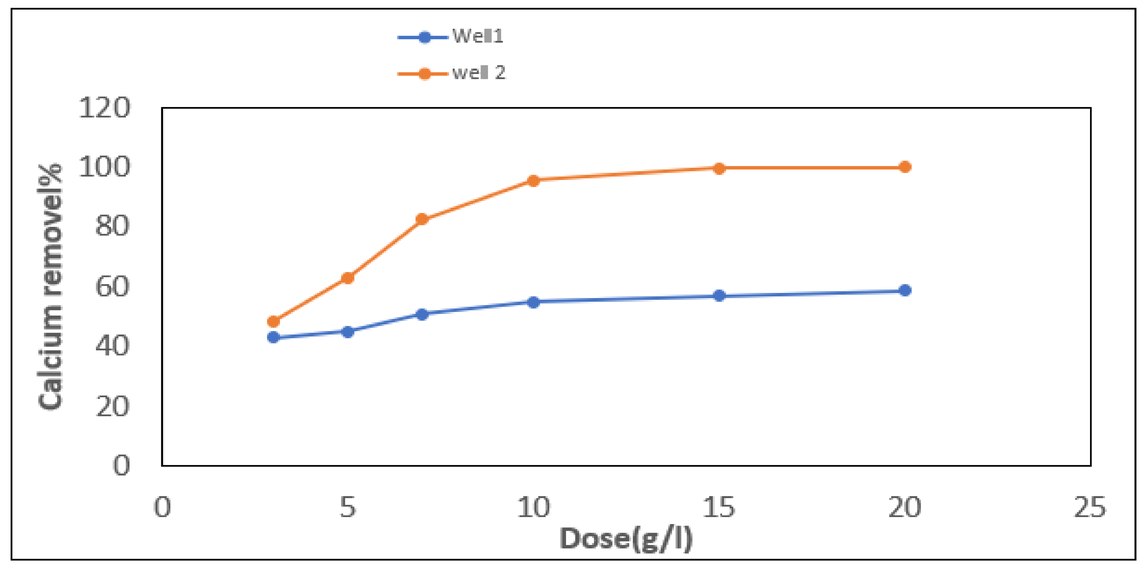



Fig.6. Effect of soda ash dosage on calcium removal in the produced water.

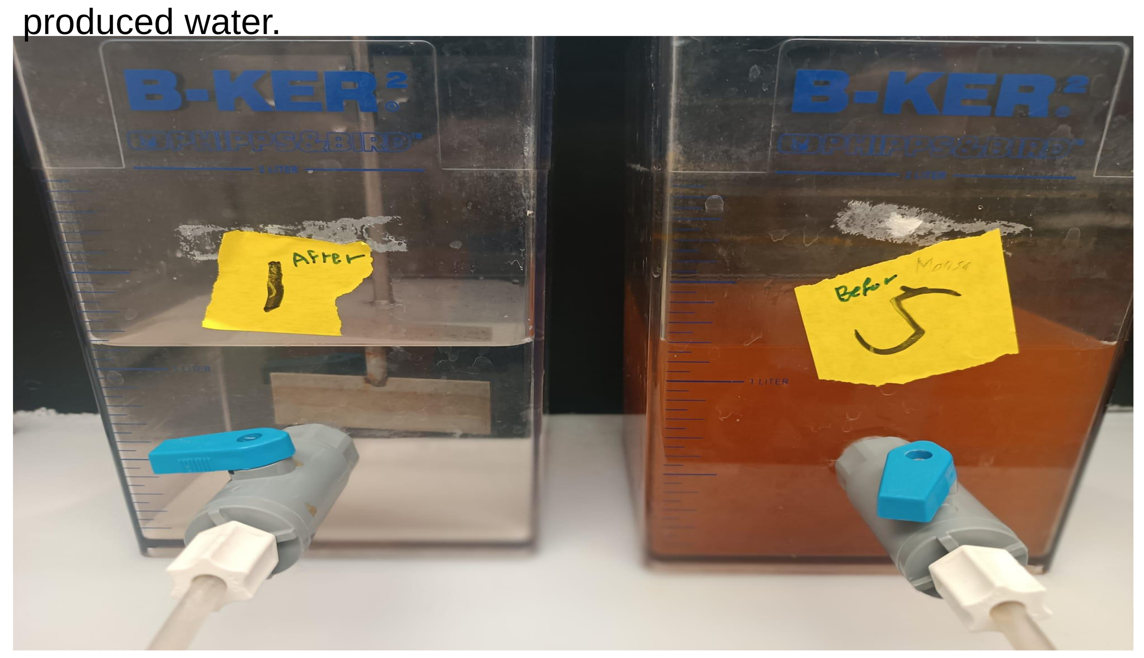


Fig.7. Effect of pH on magnesium removal in produced water.

## Conclusions

- This study showed that the produced water can be effectively softened by increasing the pH to ~11.5 with caustic soda, limestone, and soda ash.
- The main benefit of using pre-acidification in conjunction with lime-soda softening to eliminate carbonate is the creation of calcite that may have economic value.
- This sustainable disposal of produced water may encourage the recycling and reuse practice, ultimately reducing the amount of freshwater for hydraulic fracturing.
- Selective precipitation can be a pre-treatment of desalination tech; thereafter, reduce the deep-well injection route of produced water.

## References

- Ifrene, G. E., Irofti, D., Khetib, Y., & Rasouli, V. (2022, June). Shear Waves Anisotropy and Image Logs Integration for Improved Fracture Characterization. In 56th US Rock Mechanics/Geomechanics Symposium. OnePetro. https://doi.org/10.56952/ARMA-2022-0319
- Laalam, A., Ouadi, H., Merzoug, A., Chemmakh, A., Boualam, A., Djezzar, S., ... & Djoudi, M. (2022, June). Statistical analysis of the petrophysical properties of the Bakken Petroleum System. In *SPE/AAPG/SEG Unconventional Resources Technology Conference*. OnePetro. https://doi.org/10.15530/urtec-2022-3725863
- Ismail, N., Alshami, A. S., & Hussein, I. A. (2022). Synthesis and evaluation of a novel polyacrylamide functionalized nano-silica as a calcium carbonate inhibitor in upstream applications. Journal of Petroleum Science and Engineering, 209, 109864.

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