Electrocoagulation & Boron Removal

As a means of produced water treatment

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Abstract

High boron levels in oil & gas produced waters prevent its beneficial reuse as irrigation water without additional selective treatment. Electrocoagulation (EC) has been shown as a promising technology for Boron removal, but removal from produced water requires further research. Synthetic solutions with Douglas County (DGC) produced water (TDS ~30,000 mg/L) is studied to understand mechanisms of EC and achieve optimal Boron removal.

Introduction

Billions of barrels of produced water are generated from oil & gas industry. In Kansas, one oil barrel generates 22 barrels of produced water. Standard disposal practices include subsurface re-injection for enhanced oil recovery or controlled injection wells. Increased seismic activity in regions with little prior history of such events has been correlated with deep well injection. The development of treatment technologies for produced water reuse could mitigate seismic risk and provide economic value. Boron, a vital micronutrient for plants, is detrimental when present over its low threshold toxicity (as low as 0.5 mg/L). Boron presents a particular challenge due to its poor rejection in Reverse Osmosis (RO) membrane process under normal pH conditions.

Background Work

Electrocoagulation involves generation of insoluble Aluminum Hydroxide solids on which adsorption of Boron takes place. For equivalent aluminum dosing, higher boron removal is achieved in EC than through chemical coagulation. Adsorption modeling carried out in samples in absence of divalent cations showed clear overprediction when used with real produced water. Determination of factors affecting such behavior is the focus of current work. 0.5A & pH 8 was determined as optimal values for this setup.

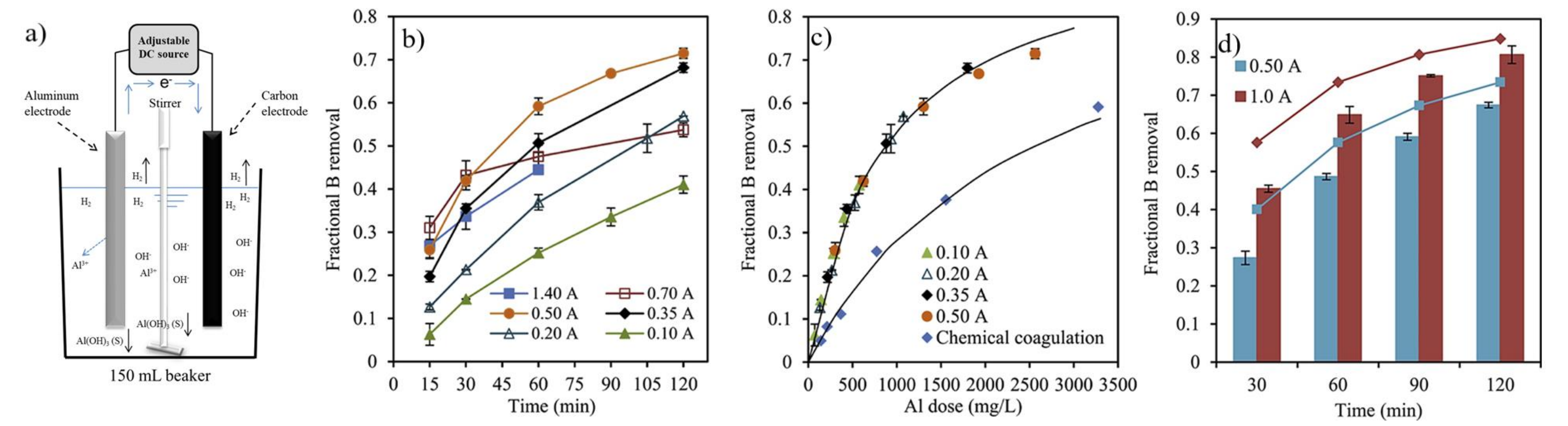

Fig. 1 a) EC reactor setup b) Boron removal with time at varying current loading c) Boron removal during chemical coagulation & EC d) Boron Removal from DGC produced waters (solid lines show modeled removals) (Chen, 2020)

Results

- In single cation solutions, magnesium (Mg) ion was the only element to produce a pH drop during electrocoagulation, similar to the actual produced water sample. The mechanism causing this pH drop is still under study.
- This pH drop affect B removal, since pH ~8 produces the best interaction between borate ions (BO_4^-) and positively charged Aluminum precipitates. At lower pH, the boron is primarily uncharged $B(OH)_3$.
- Solution chemistry affects settling- individual cation solutions produced cloudy, fluffy non settling solids, but the DGC produced water had powdery quick settling solid mass under same conditions.
- Scaling of carbon cathode was also observed in the presence of divalents, indicating cation removal..

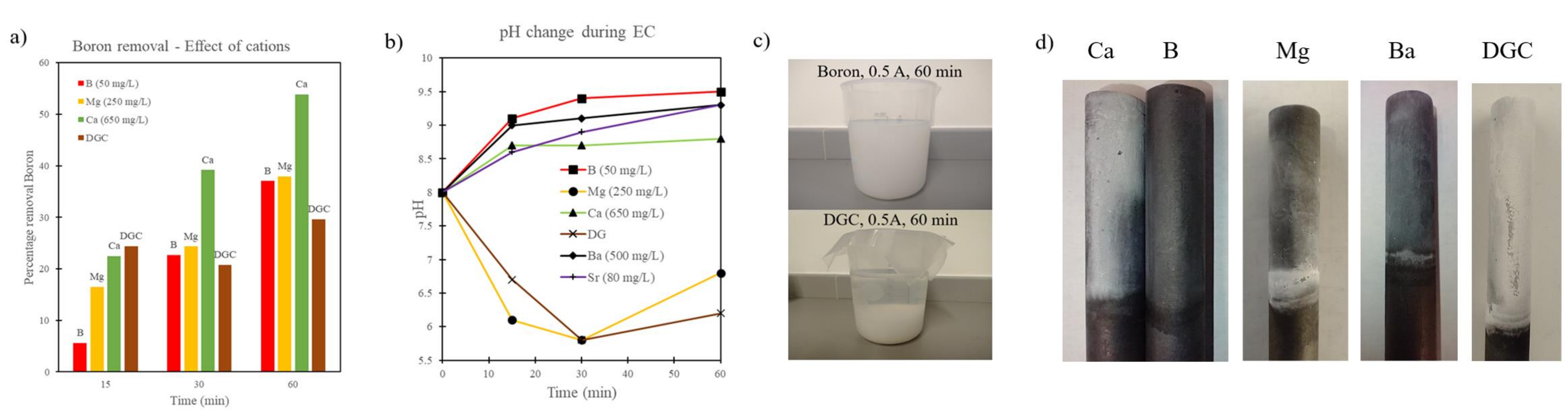

Fig. 2 a) Effect of cations on Boron removal vs. time b) pH change during EC process c) Solids formed during EC after letting it settle for 24 hrs. d) Scaling of Cathode

Conclusions

Experimental data indicates that Magnesium in produced water drives a reduction in Boron removal by depressing pH. This means that different produced waters would behave differently during EC depending on their chemical profile. This variability should be factored into models of PW treatment effectiveness and cost..

Discussion

Most produced waters necessitate membrane treatment due to presence of high salinity. If taken independently as a treatment step for Boron removal, EC would appear inefficient. However, integrating with conventional pretreatment methods, required for membrane treatment i.e., by replacing chemical coagulation to remove TSS, Boron removal by EC, would compliment membrane treatment thereby eliminating the need for a specific post-treatment step aimed only at Boron Removal.

Future Directions

While presence of Magnesium alters behavior during EC, it is one among many factors which control this process. Upcoming work focuses on developing a clear understanding of all factors involved in Boron removal, and to develop an approximate mechanism that can be applied over a wide range of produced water to estimate EC behavior.