Technology Development for Brackish Water Treatment

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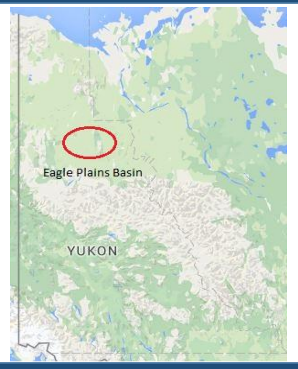

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Context

Need for suitable water treatment system in the North:

- Low maintenance (remote locations)
- Cost effective
- Energy efficient (remote location, energy restrictions)

Review of Potential Technologies

CDI:

Uses Voltage difference between parallel plates to draw cations and anions out of a brackish solution, and allows deionized water to flow through.

Qualities: Good ion removal efficiency, Cheap, Low energy requirements, No chemical additions, Low maintenance

RO:

Uses very fine filter membrane and high pressure pump to force water through the membrane while leaving the ions behind.

Qualities: Excellent ion removal efficiency, Costly, Intermediate energy requirements, Chemical addition required, Considerable maintenance

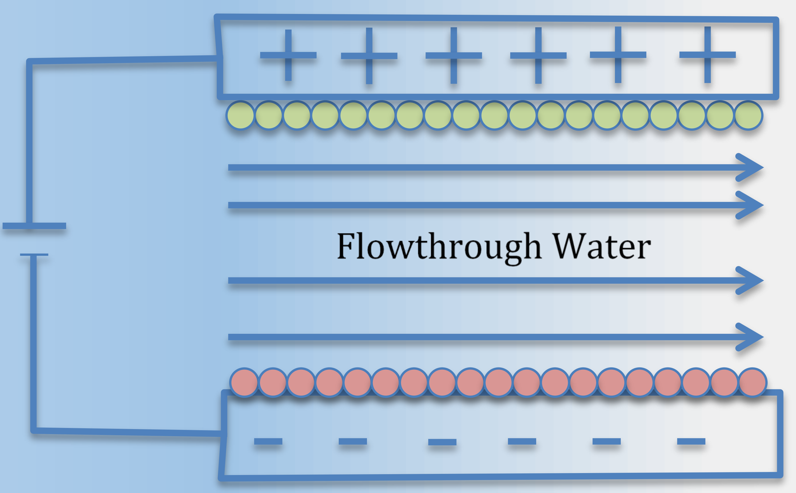
Electrodialysis:

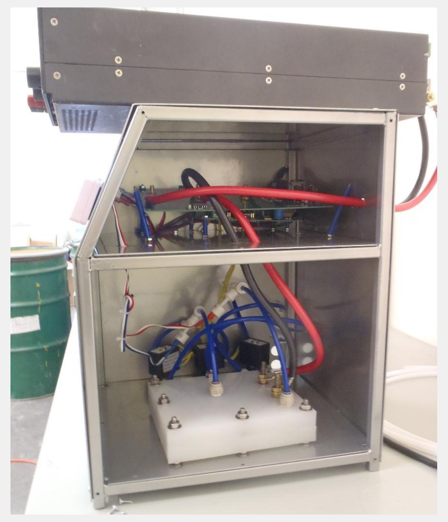
Works using parallel plates like CDI, but has ion-selective membranes in between the plates, causing a build up of high concentration brine in between some membranes, and purified water between others.

Qualities: Good ion removal efficiency, Cheap at low concentrations, Intermediate energy requirements, Chemical addition required, Considerable maintenance

Due to its low maintenance and energy use, zero need for chemical addition, and cheap operation, CDI was deemed as the most promising technology for use in a remote site in the North.

Selected Technology: Capacitive Deionization





Purification Stage: Voltage is induced between electrodes where the impure water stream runs. Cations from the solution migrate to the negative electrode, and anions migrate to the positive electrode. Purified water then exits the system

Recharge Stage: The CDI electrodes becomes saturated with ions, and ion removal drops to zero. The polarity of the electrodes is then reversed so that the ions release from the electrodes, and are flushed out of the system in a brine solution. This process then repeats.

References:

1. Duteau M., Janin A. and Mallet C. 2015. Treatment Options for Drinking Water Production from Brackish Well Water at Eagle Plain Base Camp, January 2015, 50 p.
2. Mossad M and Zou L. 2012. A study of the capacitive deionisation performance under various operational conditions. J Hazard Mater 213–214(0):491-7.
3. Solis-Correa H, Gomez-Lara J. 1987. Approximation of spherical polyatomic thermochemical radii of general formula MX_n^{z-}. J Chem Educ 64 (11): 942-943

Technology Bench Test

A test was completed comparing the capabilities of EWP P1+ benchtop CDI unit to purify:

- Simple synthetic NaCl solutions
- Water with complex chemistry from Eagle Plains (after filtration through 10&5µm cartridge filters)

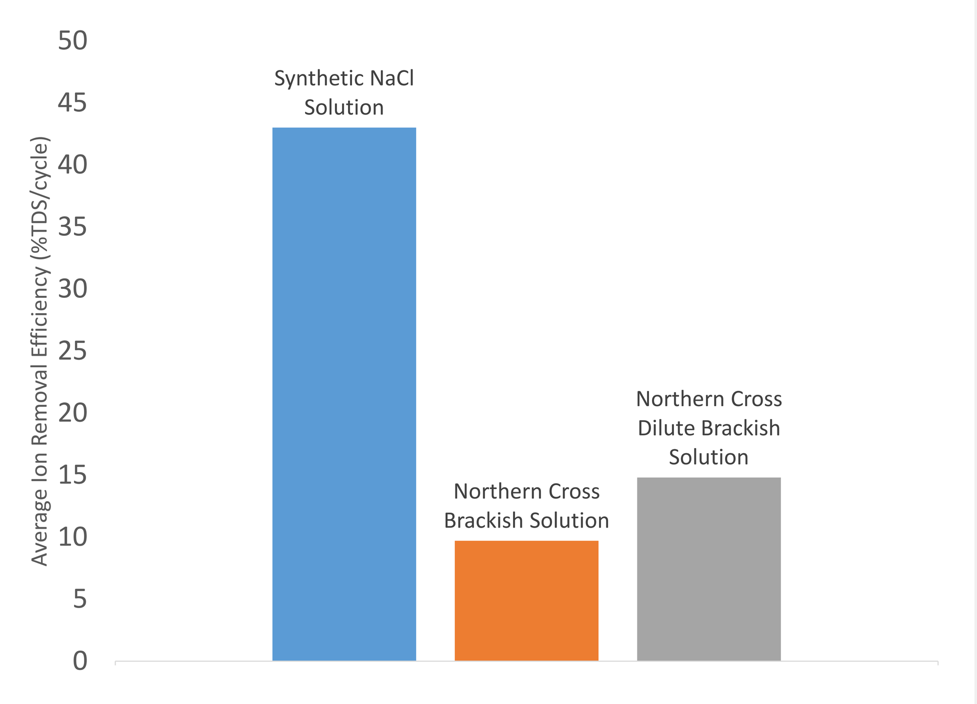
Results

Table 1. Northern Cross water quality before purification by cartridge filtration and CDI. Data taken from YRC Treatment Options for Drinking Water Production report[1]

Water Parameter	Units	Value
Conductivity	uS/cm	13 800
Hardness (as $CaCO_3$)	mg/L	3950
pH	pH	7.7
Total Dissolved Solids	mg/L	13 600
Alkalinity, Total (as $CaCO_3$)	mg/L	1 325
Chloride (Cl^-)	mg/L	12.5
Fluoride (F^-)	mg/L	0.5
Sulfate (SO_4^{2-})	meq/L	8 520
Calcium, total (Ca^{2+})	mg/L	314
Iron, total (Fe)	mg/L	5.6
Potassium, total (K+)	mg/L	13

Table 2. TDS of 3 different influents for the CDI unit following cartridge filtration of 10&5um.

Influent	TDS (ppm)
Synthetic NaCl solution	3 500
Northern Cross Brackish solution	7 500
Diluted Northern Cross Brackish solution	4 700



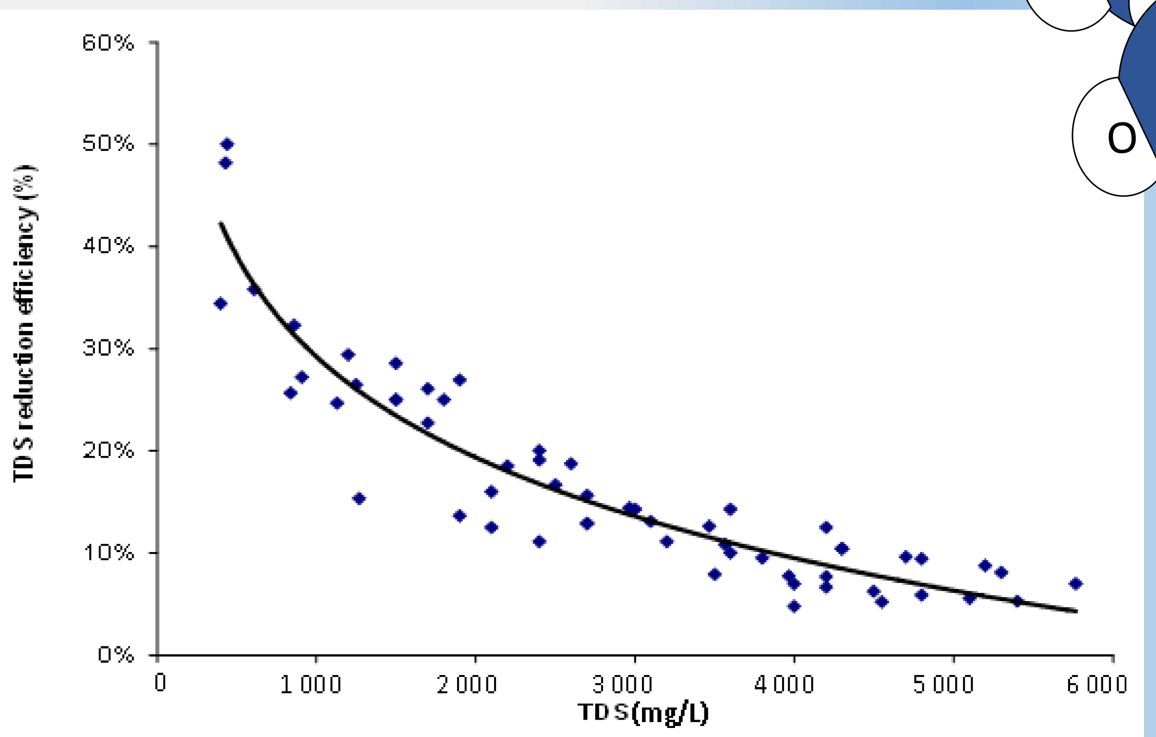


*Figure taken from YRC Treatment Options for Drinking Water Production report[1]

Observations

- Higher TDS concentrations caused lower removal efficiencies when treated with CDI
- The simple NaCl solution had much higher removal efficiency than the Northern Cross solution, even at the same TDS

Conclusion:

The literature suggests that Capacitive deionization removes ions preferentially in the order:

$SO_4^{2-} > Br^- > Cl^- > F^- > NO_3^-$ for anions & $Fe^{3+} > Ca^{2+} > Mg^{2+} > Na^+$ for cations[2]

Research should be done investigating the removal efficiencies of these various ions, such as SO_4^{2-} which was in high concentration in the Northern Cross solution. Comparing the thermochemical radius of Cl^- of ~181pm to that of SO_4^{2-} of ~214pm we suspect that the bulky nature of the SO_4^{2-} ion is one reason why the Northern Cross water had lower TDS reduction efficiency than the simple NaCl solution[3]. If the removal efficiency of SO_4^{2-} is lower than that of Cl^-, this would support our hypothesis. If, upon investigation the removal efficiency of the Northern Cross solution is still much lower than the removal efficiencies of any of the constitutive ions, then another explanation must be investigated. Possible mechanisms include organic material or chemical reactions in the Northern Cross water disrupting electrode adsorption, thus reducing TDS removal efficiency.