Assessment of small-scale desalination by capacitive deionization for horticulture on the Northern Adelaide Plains

This research answers key questions regarding the potential of capacitive deionization (CDI) technology to improve the quality of marginal salinity groundwater and reclaimed water thereby providing opportunities to increase horticultural production in the Northern Adelaide Plains.

Leader: Professor John van Leeuwen, UniSA

Team: Yasodinee Wimalasiri, John Awad (UniSA)

Project partners:

University of South Australia

The requirement for water for horticultural irrigation to be of low-salinity limits the application of water resources that are marginally above the required salinity. This applies to marginal salinity groundwater in the Northern Adelaide Plains (NAP), as well as to the use of reclaimed water from the Bolivar recycling scheme to some horticultural crops that are particularly sensitive.

The availability of new desalination technology that has the benefits of low initial establishment costs and low ongoing energy requirements provides opportunities to unlock the marginal salinity water sources in the NAP for a range of horticultural purposes, if the new technology can be demonstrated to be practical, reliable and cost-effective for small to medium sized horticultural enterprises.

KEY FINDINGS

The project team used a capacitative deionization (CDI) unit provided by UniSA to investigate whether the technology could improve the quality of water resources that are available in the NAP. The CDI unit was operated over 24 hours at a flow rate of 1-2 L/min and produced an average salt removal efficiency of 30% for both recycled domestic wastewater from Bolivar Wastewater Treatment Plant (tertiary DAFF/chlorinated treated wastewater post activated sludge, ~1100 mg/L Total Dissolved Solids (TDS)) and groundwater (~800 mg/L TDS) used by one of the major greenhouse operators on the NAP.

CDI unit used in field testing

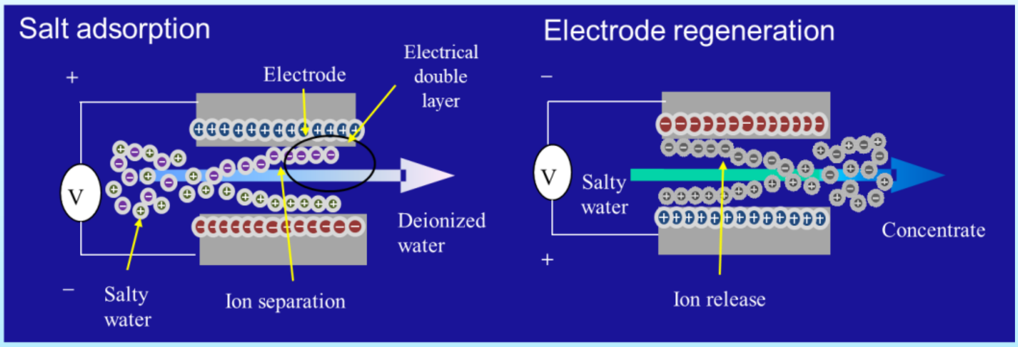
IMPACT

The reductions demonstrated by the small-scale CDI unit could improve water quality to tolerable levels for various crops in the Northern Adelaide Plains (NAP). Most horticultural production in South Australia occurs on the NAP. Production in the region makes it one of SA's economically important food bowls with approximately 204,000 tonnes of fresh produce grown each year valued at over $340 million. Increased horticultural production on the NAP could substantially improve SA's economic profitability by generating new and increased investment in horticulture infrastructure, production and jobs.

CAPACITIVE DEIONIZATION TO IMPROVE WATER QUALITY

In Australia, reverse osmosis (RO) is the most common desalination method, removing most organic and inorganic constituents including salts. Generally, RO involves high capital and operating costs, but these vary depending on source water quality and scale of desalination. CDI is an emerging, purported lower energy, electrochemical desalination technique that has several potential advantages over conventional technologies including: lower operating and capital costs; lower energy consumption; reduced brine volumes (2–4 times more concentrated compared to RO assuming a single CDI treatment pass); relatively easy maintenance; operation with minimum technical expertise; and the ability to be operated using renewable energy sources such as solar via photovoltaic cells.

Capacitive Deionisation (CDI) is an electro-chemically controlled process to remove salts from salty water. It is suitable for desalinating brackish water (TDS < 5000 ppm) and operates at low voltage (1–2 V)



What are the advantages of CDI?

- Can be operated using solar energy via photovoltaic cells
- Removes a wide range of ions with high recovery rates
- Involves simple and inexpensive regeneration of electrodes
- As a low pressure process, no large pumps are required
- Limited chemical cleaning waste
- Relatively free from fouling
- Can be operated with minimum technical expertise

RECLAIMED WATER DESALINATION

The highest salt removal efficiency of the CDI unit was around 50% for reclaimed water, with an average of 30%. The water recovery rate was 64% with pre-treatment and 59% without pre-treatment. Water recovery from the CDI operation was calculated as the percentage of product to the feed water.

Removal of dissolved organic carbon (DOC)

All DOC was removed with a contact time of 20 minutes and flow rate of 1.5 L/min. Salt removal efficiency declined at different flow rates, indicating that longer resident times within the CDI electrodes will be more efficient.

Water quality analysis

The CDI also removed a large quantity of calcium, magnesium, sulfates and carbonate cations to about 50%. Water hardness ions can cause faster electrode saturation and require more frequent chemical cleaning but in this experiment, CDI contributed to water softening as well as desalination.

Performance and chemical cleaning

Monitoring over a 24 hour period indicated that maximum salt removal efficiency could be achieved within 12 hours. Organic fouling of the CDI electrodes occurred when treating reclaimed water and this significantly reduced CDI efficiency. The unit required enhanced chemical cleaning, but cleaning with citric acid and sodium hydroxide restored desalination efficiency and removed inorganic scaling.

Energy consumption

Energy consumption declined with the increasing flow rate indicating that the higher the salt removal capacity (low flow rates), the higher the energy consumed. The average energy consumption was approximately 3.5 kWh/kL when the Granulated Activated Carbon (GAC) filter was used and increased to approximately 3.8 kWh/kL when the filter was not used.

GROUNDWATER DESALINATION

The highest salt removal efficiency recorded was 57% (no pre-treatment required) for groundwater with an average of 30%. Water recovery was at 72% for groundwater – higher than the recovery rate when reclaimed water was treated.

Performance and chemical cleaning

Over a 24hr test period, the highest salt removal efficiency remained at approximately 57% for eight hours and then declined to approximately 50%. The average salt removal efficiency dropped from 35% in the first hour to between 15–20% for the remaining period. The CDI unit's desalination capacity was lower for groundwater compared to reclaimed water. Cleaning with sodium hydroxide had a detrimental effect on the surface coating of the electrodes that inhibited co-ion adsorption.

Energy Consumption

Similar to results for reclaimed water, the energy consumption declined with increasing flow rate. This again indicated that the higher the salt removal capacity (low flow rates), the higher the energy consumption. The average energy consumption was approximately 3.5 kWh/kL when the GAC filter was used.

COULD CDI HELP GROWERS IN NAP?

A small-scale CDI unit could lower salinity levels of irrigation water (reclaimed or groundwater) by at least 30%. This could improve water quality to tolerable levels for various crops in the NAP, although CDI would not be suited for advanced hydroponics industries that use water with very low salinity levels. New generation, commercially-sourced CDI technologies may perform better than the test unit used in this project. A number of factors were identified that could influence the use of CDI and provide a challenge to the horticultural industry on the NAP. These include: the influence of temperature, pretreatment effects, availability of equipment to ensure water volume output and performance at higher salinity levels, energy fluctuations compared with manufacturers specifications, performance/cost and availability, and currently limited commercial establishment. The use of CDI technology is feasible but is not yet commercially available in South Australia.

Only the major hydroponics industries in the NAP require licensing of RO operations, based on their water processing volumes and on brine wastewater production. The impact of non-licensed RO operations of less than 200 kL/d process water and associated brine discharges should be investigated. Licensing of all RO operations should be considered to monitor brine waste production, but this should be based on low-cost licensing requirements to gain the support and cooperation of industry.

CAPITAL COSTS OF CDI VS CURRENT TECHNOLOGIES

DESALINATION/ PRETREATMENT	REVERSE OSMOSIS	MICRO-FILTRATION	ULTRA-FILTRATION	CAPACITATIVE
Small scale systems				
BW 5,000 L/day	$ 10–12 K[a]	$ 8 K[a] (RW)		$ 5 Kc (~6.6K AUD)
BW 10,000 L/day	$ 12–15 K[a]	$ 10 K[a] (RW)		$ 6–12 K[c] (~8-16 K AUD)
BW 20,000 L/day				$ 8–16 K[c] (~10.5-21K AUD)
Medium scale systems				
BW 100,000 L/day	$ 70 K[b]		$ 80 K[b]	
BW 120,000 L/day	$ 76 K[a]		$ 29 K[a]	$ 39 K[c] (~51K AUD)
BW 200,000 L/day	$ 110 K[b]		$ 150 K[b]	$ 50 K[c] (~66K AUD)
BW 240,000 L/day	$ 99 K[a]		$ 43 K[a]	$ 78 K[c] (~103 K AUD)
Large scale systems				
BW 400,000 L/day	$ 150 K[b]		$ 210 K[b]	

BW- Brackish Water, RW- Reclaimed Water.
[a] Fresh water Systems AUD$, [b] Integra water systems AUD$, [c] AQUA EWP US$ (AUD$),

CDI TECHNOLOGY MANUFACTURERS

Idropan Australia markets small scale modules that can treat saline waters up to 1250 ppm TDS and each unit produces up to ~ 2000 L/day. Using several modules together could achieve higher production capacities. Currently available technology is purported to be able to treat and supply waters at industry/commercial scale flow rates. For instance, AQUA EWP markets a P8 model that is stated to treat water to 2.4 kL/hr, Voltea BV markets CDI CapDI© modules that are claimed to be able to treat to 20 kL/hr and Atlantis Technologies market their RDI© systems as able to treat water in single module to ~23kL/h [with more modules up to 1000 gpm (or ~230 kL/h)]. These levels of supply rates would meet the supply needs of the horticulture industries of the NAP, providing that treated water quality meets industry requirements.

MORE INFORMATION

The following technical report associated with the research program is located at www.goyderinstitute.org/publications/technical-reports/:

- Wimalasiri, Y., Awad, J. and van Leeuwen, J. (2018) Assessment of small scale desalination by capacitive deionization for horticulture on the Northern Adelaide Plains. Goyder Institute for Water Research Technical Report Series No. 18/01, Adelaide, South Australia.

GOYDER INSTITUTE FOR WATER RESEARCH

Contact:

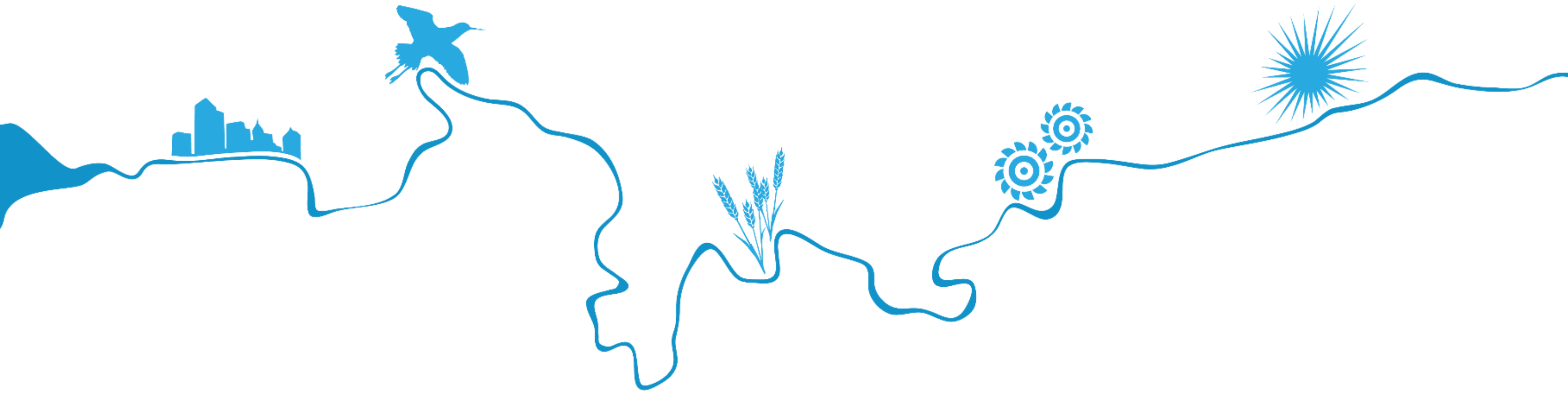
209A, Level 2, Darling Building, The University of Adelaide, North Terrace, Adelaide, SA 5005

+61 (08) 8313 5950

enquiries@goyderinstitute.org

@goyderinstitute

www.goyderinstitute.org



PARTNERS

Government of South Australia Department for Environment and Water

CSIRO

Flinders University Adelaide • Australia

The University of Adelaide

University of South Australia

ASSOCIATE PARTNERS

EPA South Australia

National Centre for Groundwater Research and Training

SARDI South Australian Research and Development Institute

SA Water