ASSESSMENT OF SMALL SCALE DESALINATION BY CAPACITIVE DEIONIZATION (CDI) FOR THE TREATMENT OF NAP WATERS

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General Aim

To assess and determine technical options and economic potential of CDI for desalination of waters available on the Northern Adelaide Plains for use in horticultural production.

- Bolivar (St Kilda DAFF) recycled water ~2 mths
- Brackish ground water ~2 mths

Objectives

- **Improved understanding of the practical feasibility and commercial application of CDI in the NAP region**
- **Gain knowledge that supports development of future governance/regulatory needs related to desalination and brine disposal – liaison with SA EPA, horticulture industry**
- **Improved understanding of CDI technology development and application for fit-for-purpose use (more globally)**

What is Capacitive Deionisation (CDI)…….

- Electrochemically controlled process to remove salts from salty water (suitable for TDS < 5000ppm)
- Operates at low voltage (1–2V) –less/low energy
- Can be operated using solar energy via photovoltaic cells
- Removes a wide range of ions with high recovery rates
- Simple and inexpensive regeneration of electrodes
- Low pressure process – No large pumps
- Limited chemical cleaning waste
- Relatively free from fouling
- Operation with minimum technical expertise

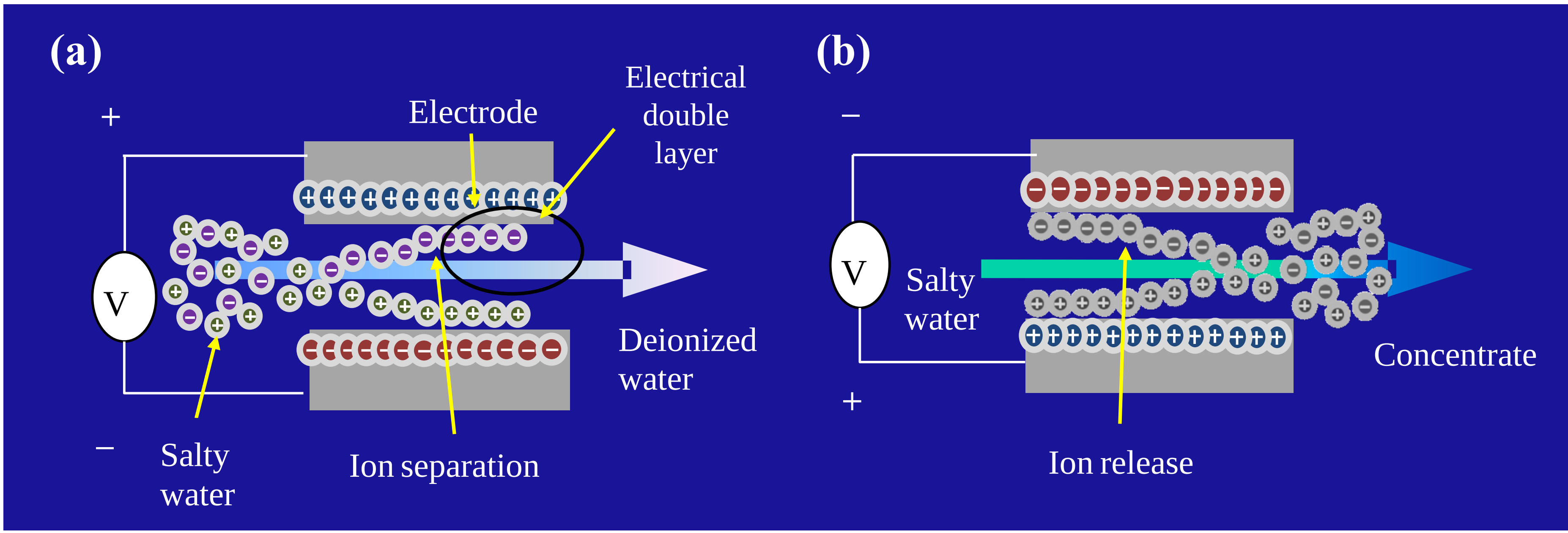
Some commercial CDI manufacturers

- **Voltea - Netherlands**
- **Aqua EWP- USA**
- **Atlantis - USA**
- **Idropan - Italy**
- **Enpar – Canada**

Enpar's Electrostatic deionisation (ESD) pilot plant designed for leach water treatment (12.5 m^3/day) in greenhouses in Ontario

http://www.enpar-tech.com/electro-static-deionization

How CDI Works….



Salt adsorption

Electrode regeneration

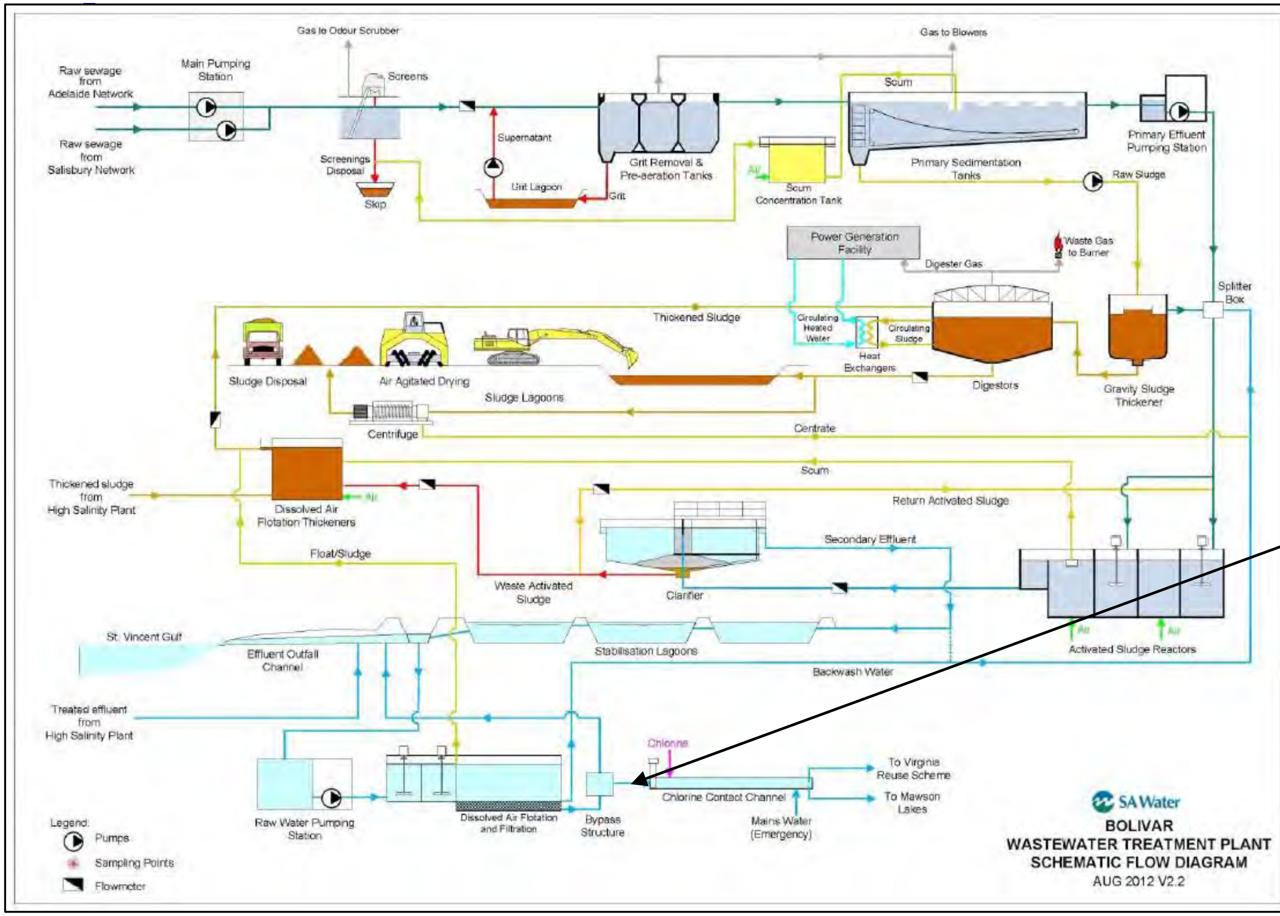
Preferred site selection

- A NAP location with ground water salinities preferably to 2500 EC (1650 ppm)
- A crop requirement for water with salinity lower than the above levels (such as to achieve improved yield or product quality)
- Irrigation pipework and infrastructure that would allow a small plot to be supplied with the trial desalination unit(s) treated water, up to around 12 kL/day. – {this a big risk}
- Power supply to test sites for the desalination unit
- Brine disposal (tank storage and transport to Bolivar WWTP or evaporation ponds on-site) { a big project cost risk, as well as logistical challenge}

UniSA CDI system specifications

Parameter	Value
Supply voltage	240 V, AC, 15 A single-phase
Individual electrode cell voltage	1.5 V DC, 100 pairs
Electrode material	Activated carbon, ~ 1.3 kg
Flow rates	1–9 L/min (1.2–10.8 kL/day)
Allowable source water TDS concentrations	500–3000 ppm
Design Input pressure	20-40 Psig
Operational temperatures	20–50 °C
Pre-filtration requirements	Cartridge filter rated for 10-25 microns

Reclaimed water - Bolivar WWTP & DAFF



CDI Trial: unit tested water post DAFF treatment, and before chlorination.

Source: SA Water

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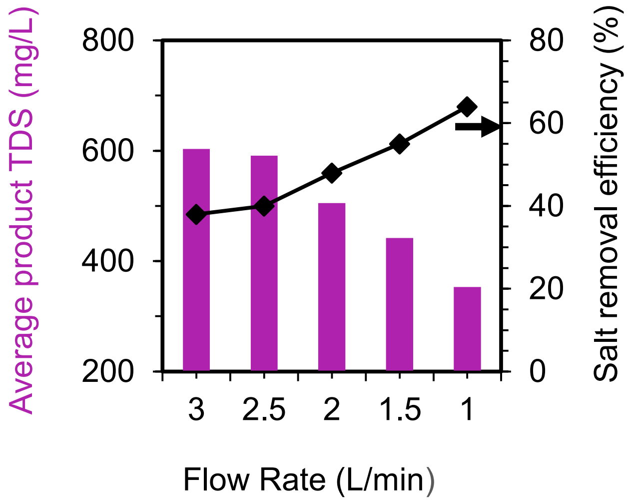
Desalination trial at Bolivar DAFF plant

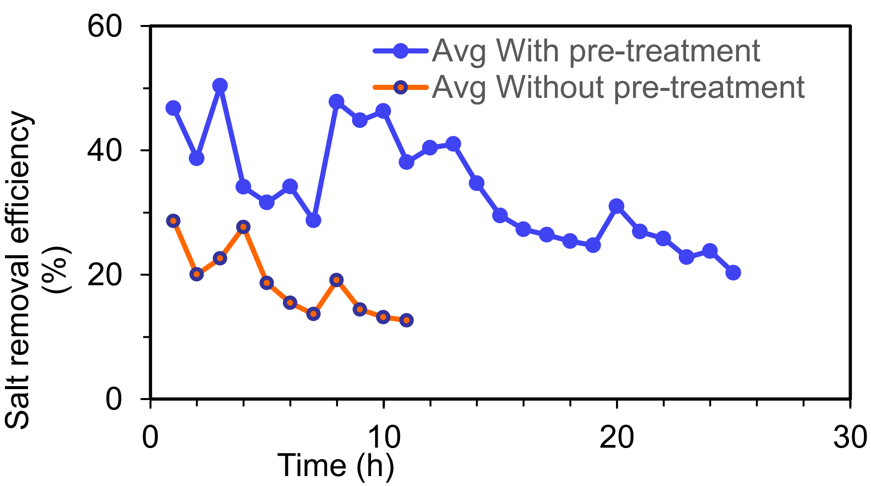
- CDI units (one only available- UniSA)
- Feed water before chlorination
- Salt removal efficiency under various flow rates and over time with/without pre-treatment
- CDI connected to main plant process without the need for pumps
- Operation as a continuous process
- Pre-treatment process (GAC) for Dissolved Organic Carbon (DOC) Removal
    - 1-2 mm size granules
    - Surface area of GAC ~ 900 m^2/g
    - Complete removal of Boron
    - Minor TDS removal
    - 20 min residence time

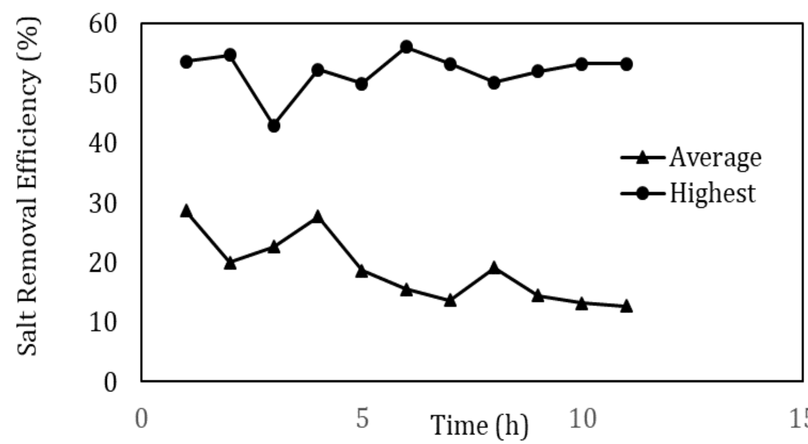
Parameter	Concentration (mg/L)
Total Dissolved Solids @180°C	1000
Total Alkalinity as CaCO3	105
Total Hardness as CaCO3	230
DOC	6.1
Calcium	36
Magnesium	34
Potassium	41
Sodium	268
Chloride	434
Nitrate	11
Sulfate	205
Fluoride	0.3
Total Phosphorus as P	0.04
Boron	0.27
Iron	<0.05

Desalination performance



	Duration	Feed Volume	Cleaning water Volume	Brine Volume	Product water	Water Recovery
	h	L	L	L	L	%
With GAC pre-treatment	24	1716	100	510	1206	64
Without GAC	11	743	100	203	540	59





The average and highest TDS variation without pre-treatment

- **Flow Rate 1.5 L/min**

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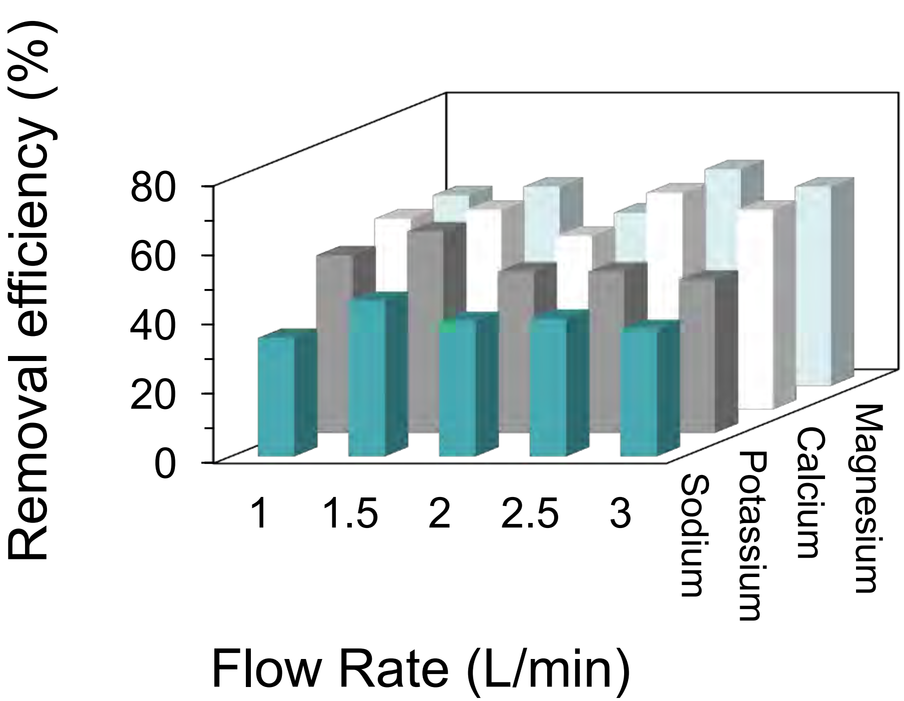
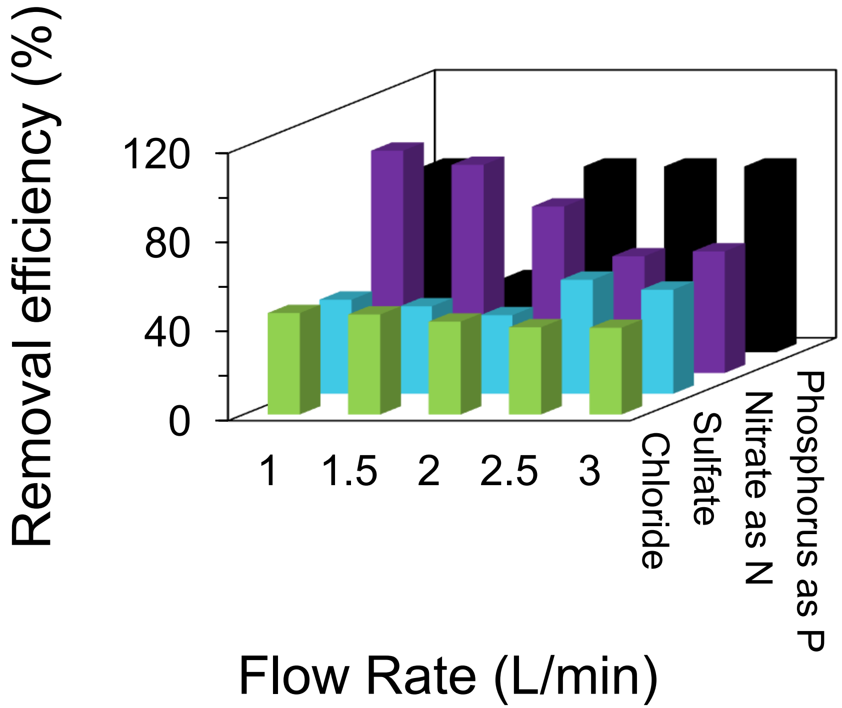
Efficiency of ion removal with flow rate

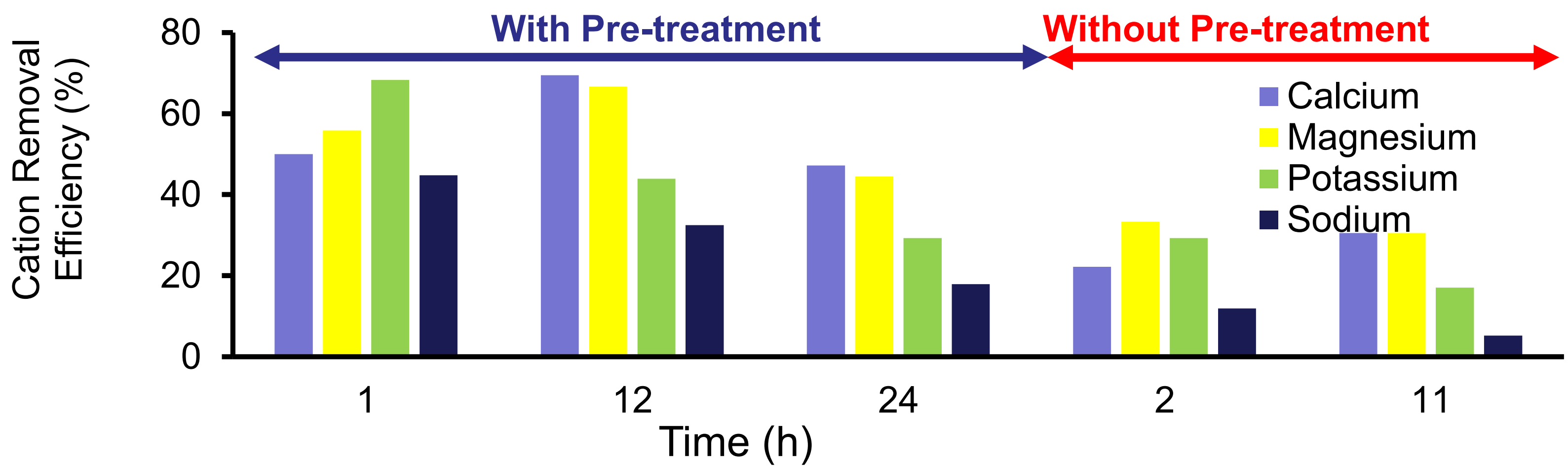
Major Cations

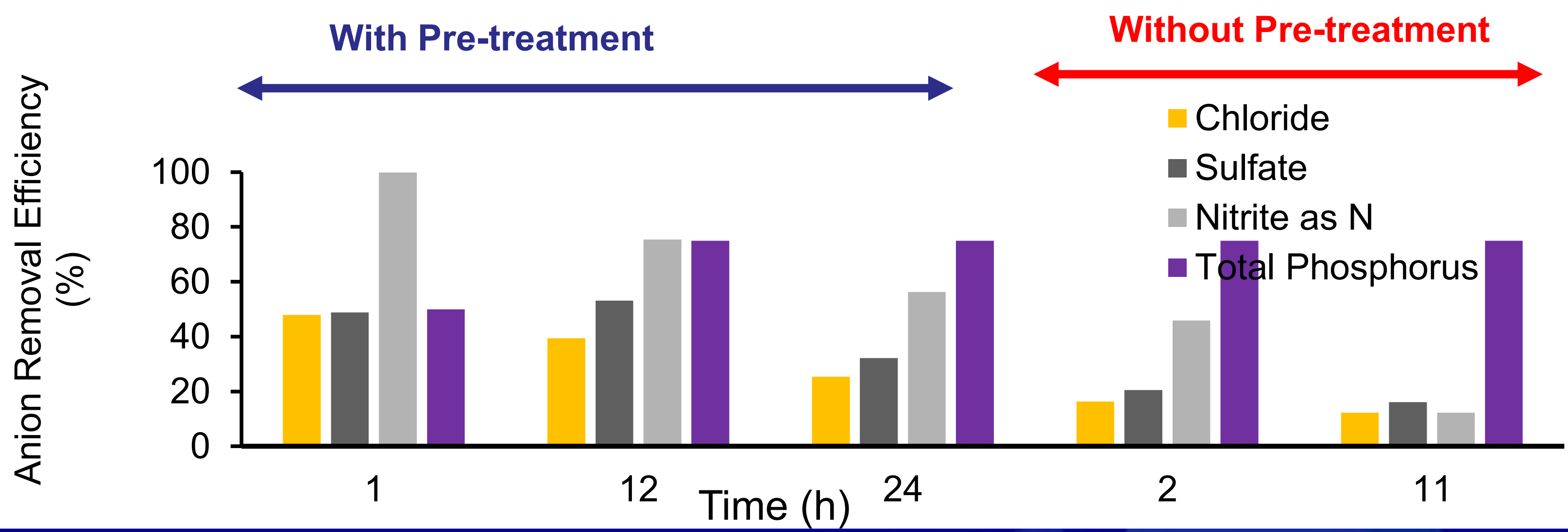


Major Anions



Removal of Major ions

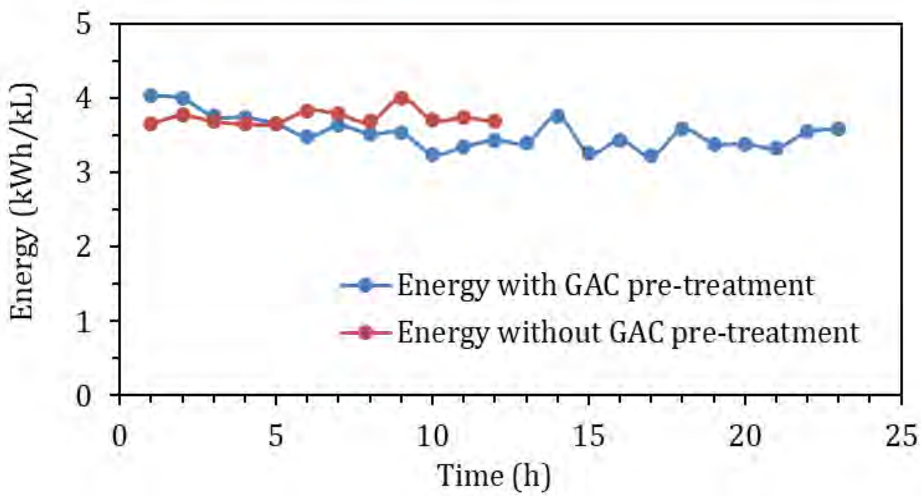




Energy consumption- Reclaimed water

- Operation of CDI unit (Average < 300W)
- Energy for circulation of cleaning solutions using a pump

240V, Davey Centrifugal XF 171 (Model No- 71101-1)



Average energy consumption at 1.5 L/min flow rate for reclaimed water desalination by CDI

Overall Bolivar Trial Findings

- ~ 50 % and ~30% salt removal from reclaimed water with and without DOC removal, respectively
- ~ 70% water recovery
- Brine TDS ~ 1300 -1800 ppm
- Organic fouling significantly affects the salt removal efficiency of CDI
- Components that were not removed by CDI
  - Fluoride, Boron.
- Regular cleaning of electrodes required

  Acid wash - 2 % Citric acid - Removed scaling

  Alkaline wash - 2 % NaOH – Removed organic fouling

  Potable water
- Lower energy consumption at high flow rates

Ground water – P'Petual Holdings, Buckland Park

6 ha of greenhouses,
expanding a further 20 ha,
Currently use bore water,
Will use Bolivar reclaimed water in the future

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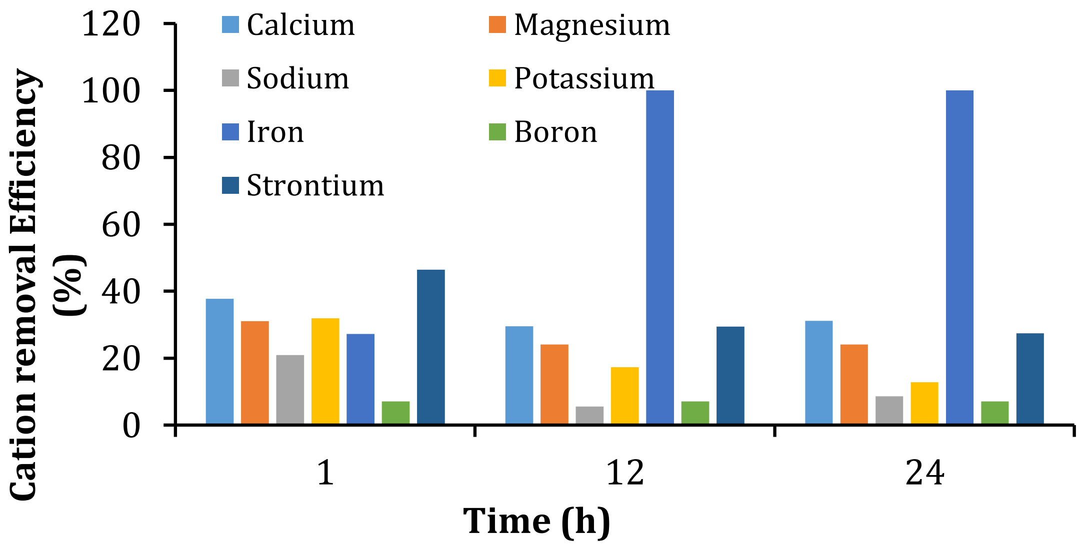
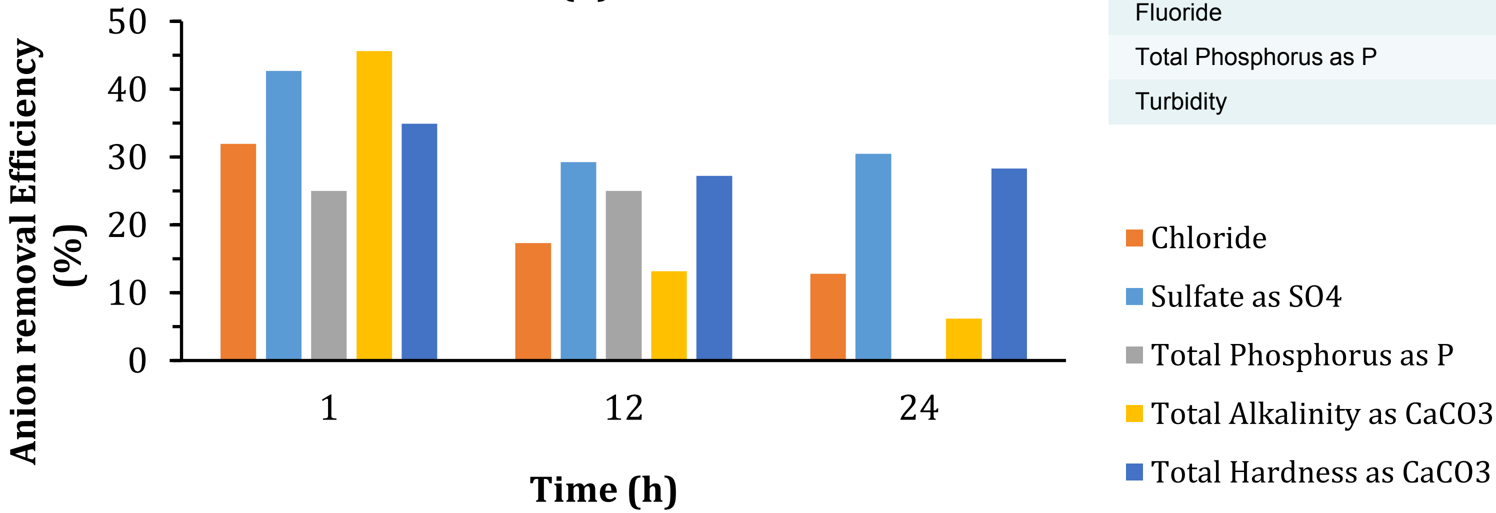
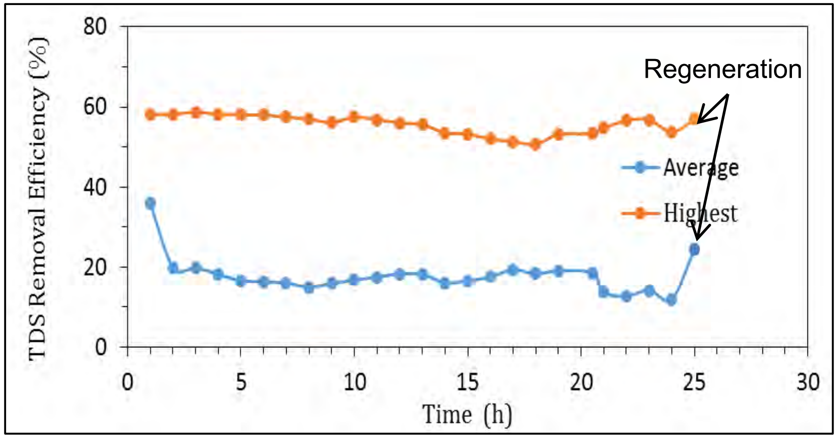
Bore water – Removal of major ions





Parameter	Concentration(mg/l)
Total Dissolved Solids @180°C	769
Total Hardness as $CaCO_3$	272
Total Alkalinity as $CaCO_3$	228
Calcium	61
Magnesium	29
Sodium	162
Potassium	9
Chloride	266
Sulphate as SO_4	82
Strontium	0.612
Boron	0.14
Iron	0.22
Fluoride	0.4
Total Phosphorus as P	0.03
Turbidity	1.9 NTU

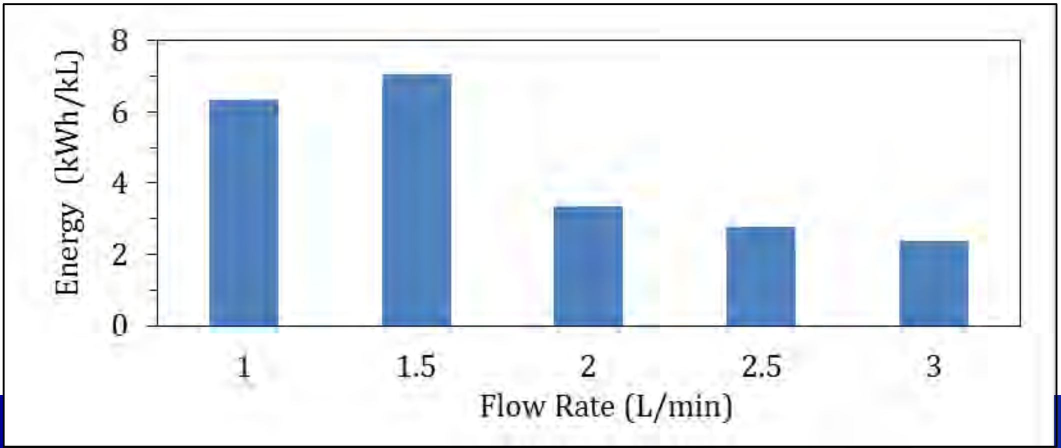
Bore water – CDI treatment



Salt removal efficiency over a 24 h period for the bore water tested

Water recovery from CDI desalination of bore water						
Water type	**Duration**	**Feed Volume**	**Cleaning water Volume**	**Brine Volume**	**Product water Volume**	**Water Recovery**
Unit	h	L	L	L	L	%
Bore water without pre-treatment	24	2152	95	517	1635	72

Water recovery from the desalination of bore water



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Energy consumption at different flow rates for bore water desalination

Table 8: Comparison of capital costs of CDI with current conventional desalination and pre-treatment technologies applied in the NAP

Desalination/ Pre-treatment	**RO**	**MF**	**UF**	**CDI**
Small scale systems, 5000 mg/L				
BW 5,000 L/day	$ 10–12 K[a]	$ 8 K[a] (RW)		$ 5 K[c] (~6.6 K AUD$)
BW 10,000 L/day	$ 12–15 K[a]	$ 10 K[a] (RW)		$ 6–12 K[c] (~7.9-15.8 K AUD$)
BW 20,000 L/day				$ 8–16 K[c] (~10.5 - 21.1 K AUD$)
Medium scale systems, 1500–2000 mg/L, 5000 mg/L				
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] (~51 K AUD$)
BW 120,000 L/day				€37 K EUR[d,1] (~59 K AUD$)
BW 200,000 L/day	$ 110 K[b]		$ 150 K[b]	$ 50 K[c] (~66 K 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]	

[a] Fresh Water Systems AUD$, [b] Integra Water Systems AUD$, [c] AQUA EWP US$, [d] Voltea BV, BW- Brackish Water, RW- Reclaimed Water, [1]EURO exchange rate 1 AUD = 0.63 euro, on 08/05/2018, 0.76US$ 12/6/18

Governance and Regulation (SA EPA ACT 1999; EPP 2015; Env. Prot. Reg. (2009)

- **Processing water volumes >200 kL/day, and brine wastewater >2ML/annum- a EPA licence is required**
- **For inland brine wastewater management - evaporation lagoon/pond with HDPE lining preferred**
- **Smaller systems come under local government authority**

Study recommendations- for governance and management

- **Development of EPA guidelines specific for various size categories of desalination plants and for brine handling, all licenced (but minimal licence fees)**
- **Assess feasibility of common evaporation lagoons for clustered smaller scale (<200kL/d) desalination plants.**
- **Alternative brine management options such as by ultra-high TDS concentration as offered by Atlantis Technologies through their RDI©, is recommended for consideration and evaluation; potential for aquifers for brine disposal be assessed**

Summary of key findings

- **Comparative trial data acquired; the CDI unit available was a research and development unit not a commercial unit.**
- **Dissolved organics impact significantly on the performance of the CDI unit. Longer term CDI use for reclaimed waters needs to be determined.**
- **CDI may be suitable for some BW and RW of the NAP. Pilot testing needed.**
- **Hydroponics industry requires low TDS waters (<100 mg/L) from RO treated reclaimed and bore source waters. Questionable if CDI can meet this TDS level in a single treatment pass.**
- **Need desalination technologies that can be applied for soil based horticulture- low cost/low energy requirements**
- **Licencing of desalination operations is for large scale only, further governance development is suggested for broad based brine management.**

Challenges in CDI and future Research/Work

Challenges

- Limited number of manufacturers & suppliers of CDI systems
- Capital, operational and maintenance costs untested in NAP
- Only one case found of purported CDI use in horticulture globally – Voltea BV
- Appears an emerging technology. May have future energy benefits

Future directions

- Management, minimization/hyper concentration of brine
- Energy efficiency enhancement through solar PV cells
- CDI potential for soil based horticulture- would be of high value and for targeted agricultural practices
- Desalination essential for horticulture expansion of the NAP and northern corridor where ground waters are brackish

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Thank You

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