Low-power, ground water desalination system adaptable for Indian households

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54% of India Faces High to Extremely High Water Stress
Motivation of the Work

Reverse osmosis
Thermal process
Capacitive deionization

Expensive and energy intensive, non-portable
Not effective < 1000 ppm salt concentration

Can we develop a rapid, efficient route to desalinate water?
What have we achieved?

Electrosorption capacity, \( q_e = \frac{\text{Concentration decrease} \ast \text{Volume}}{\text{Weight of electrode}} \)

Average salt adsorption rate = Rate of \( q_e \)

High \( q_e \) and high ASAR for < 1000 ppm

3 times higher \( q_e \) and 1.5 times higher ASAR than any known material.
How did we achieve this? Carbon nanotubes

- Bio-compatible
- Forms supra-molecular gel-like assemblies
- Crucial for integrating onto clothing and fabrics.
- Easy to remove.

CNT conductive ink/paste stabilized by NaDoC is highly stable. No aggregation observed after 30 days.
Facile, scalable device assembly.
Miniaturized and portable.
Low energy consumption (0.15 mW)
What is important?

High SSA ~ 900 m²/g

- Sub-nanometer pores enhance electrical double layer for CDI.
- High SSA leads to increased deionization.
- Hydrophilicity is critical for fast deionization.

CNT-thread
\( t = 20 \text{ s} \)

CNTs
\( t = 80 \text{ s} \)
Performance evaluation

- Electric field > 2.5 V/cm leads to saturation in performance.
- $Q_e$ increases with salt concentration.
- Saturation of $q_e$ and EE relates to wetting of water by electrodes (hydrophilicity)
Electrochemical studies of the CNT-thread

- Electrical double layer without any faradic reactions.
- Symmetric nature of electrical double layer at both the electrodes.
- Signifies the similar rate of diffusion for both the cations and anions.
Reusability of device

Reverse bias/ Zero bias
Washed with water and EtOH

Electrosorption efficiency (%)
Number of cycle
Residence time of 27 sec
Residence time of 81 sec

• Initial decrease (< 10%) in activity is due to pore-blocking.
• Subsequent cycles exhibit stable performance to desalination.

Water flows through the active material
Inverting the concept: Prototype design

Winding of CNT-thread as electrodes for capacitive deionization

Assembling the portable CDI system for household desalination of water

Advantage of electrode flexibility and tenacity

To AA battery
Inverting the concept: Prototyping

Highly efficient desalination of water at low power-cost.
Extremely low wastage of water.
Way forward

Field trials
Nov, 2018
INR 0.50/liter
INR 0.10/liter

Thank you
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**Winding of CNT-thread as electrodes for capacitive deionization**

**Assembling the portable CDI system for household desalination of water**

<table>
<thead>
<tr>
<th></th>
<th>Na(^+), K(^+), Mg(^{2+}), Ca(^{2+})</th>
<th>Chlorides</th>
<th>Sulfates</th>
<th>Fluoride</th>
<th>Arsenic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Initial TDS</strong></td>
<td>2000 ppm</td>
<td>2000 ppm</td>
<td>200 ppm</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Removal efficiency</strong></td>
<td>&gt; 85%</td>
<td>&gt; 85%</td>
<td>&gt; 65%</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cyclability (5000 ml batches)</strong></td>
<td>&gt; 100</td>
<td>&gt; 100</td>
<td>Currently at 50</td>
<td>&lt; 10%</td>
<td></td>
</tr>
<tr>
<td><strong>Wastage</strong></td>
<td>&lt; 5%</td>
<td>&lt; 5%</td>
<td>&lt; 10%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Next work plan

• To have electrodes and sensing system to indicate the TDS of water (green/red) for end-user.

• To develop pilot plant for making the nanomaterial.