



Capacitive Deionization as an Emerging Technology in Wastewater Treatment

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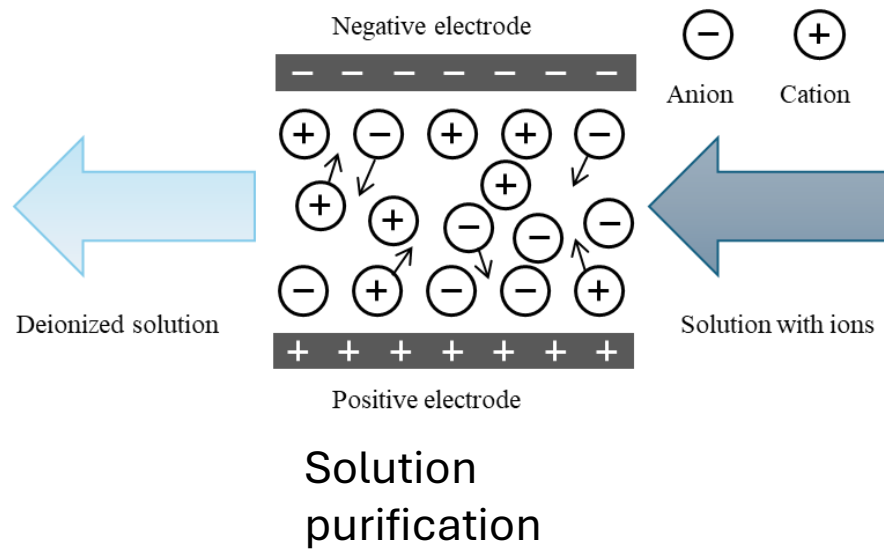
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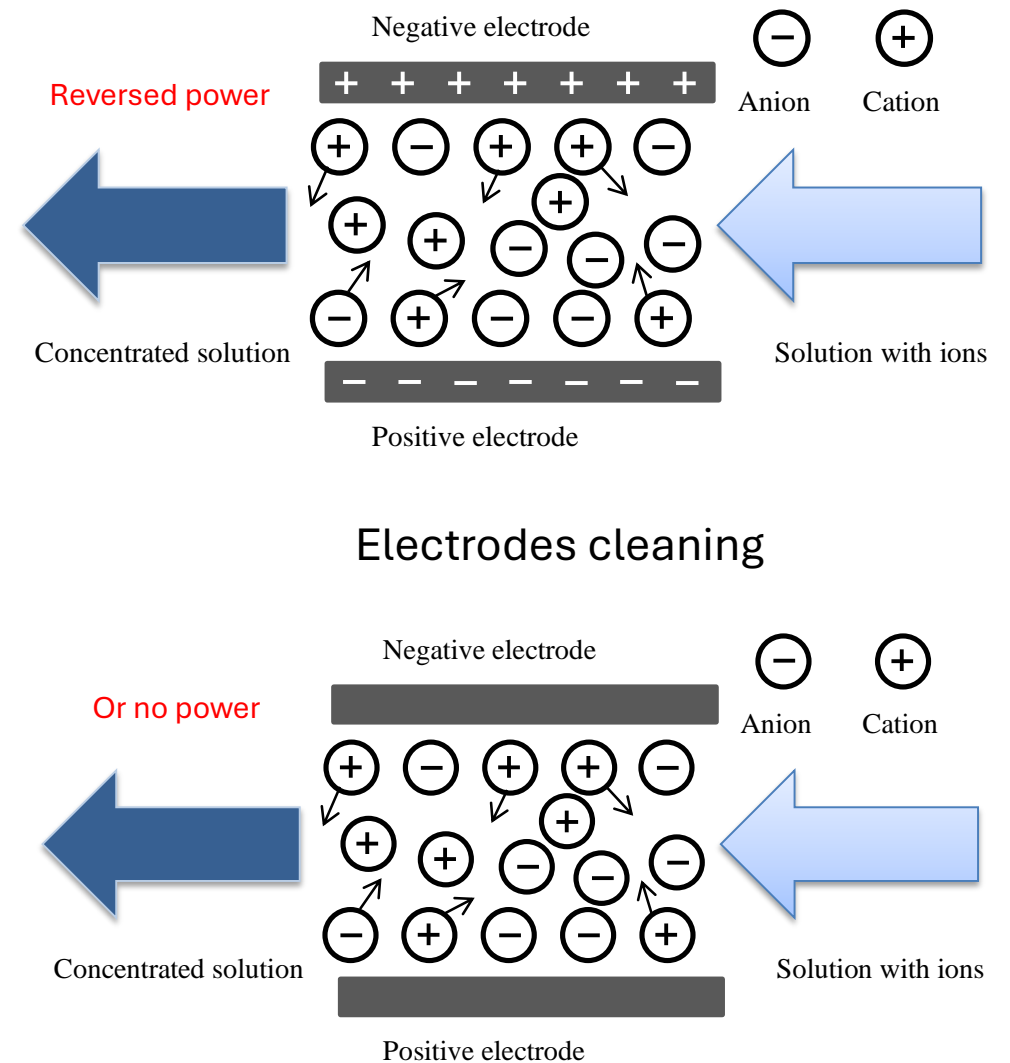
What is Capacitive Deionization (or CDI)?

- An electrosorption technique for the removal of ions from the given solution.
- Generally it can remove ions from any solution.
- Examples of ions: Na^+ , Cl^- , NO_3^- , PO_4^{3-} , $[\text{NH}_4]^+$, MEACOO^- , etc.

What is Capacitive Deionization (or CDI)? (...)



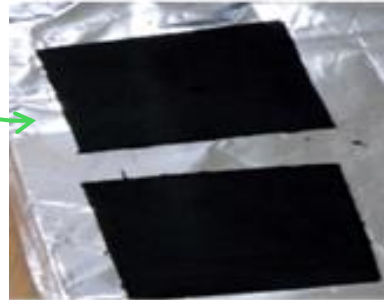
Please note that the definition of electrode polarity is done referring to the period during which charging/purification is done.



Key CDI Components

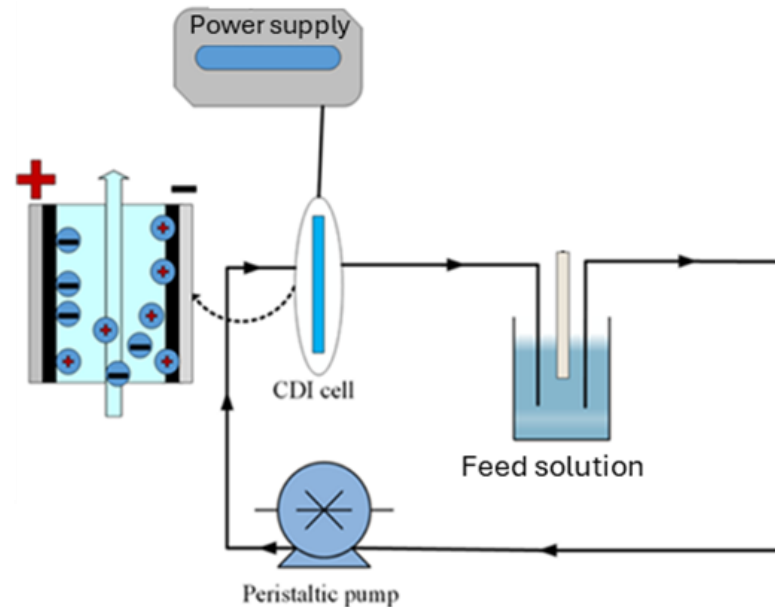
1. Electrodes

Mostly are porous carbon based with sufficient capacitance



2. Pump; flow rate has its influence on CDI performance

3. Power supply; generally relatively high power is preferred for better CDI performance.



Why CDI can be used for wastewater treatment?

- Waste water contains some ionic species apart from other substances
- Examples of ionic species, depending on the source, are:
 - ✓ NO_3^-
 - ✓ PO_4^{3-}
 - ✓ $[\text{NH}_4]^+$
 - ✓ Extracellular Antibiotic resistance genes (eARGs); DNA is highly negatively charged.
 - ✓ Heavy metals,
 - ✓ etc.

Some Works on CDI for Wastewater Treatment

Ammonium removal from low-concentration wastewater¹

- Electrode materials used: reduced graphene oxide/ cerium dioxide (rGO/CeO₂)
- Electrosorption operation conditions:
 - ✓ 1.2 V applied voltage,
 - ✓ Operation mode: batch
 - ✓ 1.0 mmol L⁻¹ initial concentration,
 - ✓ 30 mL min⁻¹ flow rate, and
 - ✓ 20 °C temperature.
- With the integration of photocatalysts 88 % ammonium removal efficiency was achieved.

¹ B. Xu, K. Jiang, Y. Gan, K. Zhang, J. Zhang, J. Luo, H. Xu, Z. Chen, W. Yang, H. Li, X. Lu, An integrated capacitive deionization and photocatalysis system for efficient ammonium removal from low-concentration wastewater, *Journal of Water Process Engineering*, 58 (2024)

Extracellular antibiotic resistance genes removal (eARGs)²

- Electrode materials used: activated carbon
- Electrosorption operation conditions:
 - ✓ 1.2 V applied voltage,
 - ✓ Operation mode: single-pass
 - ✓ 1.0 mL/min flow rate, and
- It reached maximum removal efficiency of 3.3 log (more than 99 %).

²W. Wang, Q. Deng, X. Zhang, Q. Yuan, K. Zuo, Effective attenuation of extracellular antibiotic resistance gene risks in wastewater by capacitive deionization, *Journal of Environmental Chemical Engineering*, 12 (2024)

Copper ion (Cu^{2+}) removal³

- Electrode materials used: metal organic frameworks (MOFs), carbon-loaded cobalt metaphosphate ($\text{NC-Co}(\text{PO}_3)_2$)
- Electrosorption operation conditions:
 - ✓ 1 V applied voltage at 4.5 pH,
 - ✓ Operation mode: batch
 - ✓ 25 mL/min flow rate, and
- Removal efficiency 91.6 %.

³H. Wang, G. Wu, Y. Xiao, Z. Zhang, L. Huang, M. Li, H. You, Z. Chen, J. Yan, X. Liu, H. Zhang, Exploration of selective copper ion separation from wastewater via capacitive deionization with highly effective 3D carbon framework-anchored $\text{Co}(\text{PO}_3)_2$ electrode, Sep. Purif. Technol., 336 (2024)

Uranium (UO_2^{2+} ion) removal⁴

- Electrode materials used: chitosan/phytic acid complexes anchored on polypyrrole nanotubes (CS/PA-PPy)
- Electrosorption operation conditions:
 - ✓ 1.2 V applied voltage,
 - ✓ Operation mode: batch
- Removal efficiency is over 97 %.

⁴X. Zhao, D. Chen, M. Shi, R. Zhao, Anchoring chitosan/phytic acid complexes on polypyrrole nanotubes as capacitive deionization electrodes for uranium capture from wastewater, *Int. J. Biol. Macromol.*, (2024) 132491



⁵Large scale CDI desalination modules produced in China: (A) municipal wastewater reuse desalination plant with a capacity of $60000 \text{ m}^3 \text{ day}^{-1}$ and (B) coal mine wastewater remediation plant with a capacity of $5000 \text{ m}^3 \text{ day}^{-1}$

⁵M.E. Suss, S. Porada, X. Sun, P.M. Biesheuvel, J. Yoon, V. Presser, Water desalination via capacitive deionization: what is it and what can we expect from it?, *Energy Environ. Sci.*, 8 (2015) 2296-2319.

Some models for your CDI design

Two different JK models can possibly be used for CDI design:

- ⁶For the constant voltage operated CDI system and,
- ⁷For the constant current operated CDI system.
- Details of all these models can be found in the below references.

⁶Y.A.C. Jande, W.S. Kim, Predicting the lowest effluent concentration in capacitive deionization, Sep. Purif. Technol., 115 (2013) 224-23.

⁷Y.A.C. Jande, W.S. Kim, Desalination using capacitive deionization at constant current, Desalination, 329 (2013) 29-34.

Thank you

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