

Boron removal with layered double hydroxide thin-film nanocomposite desalination membrane

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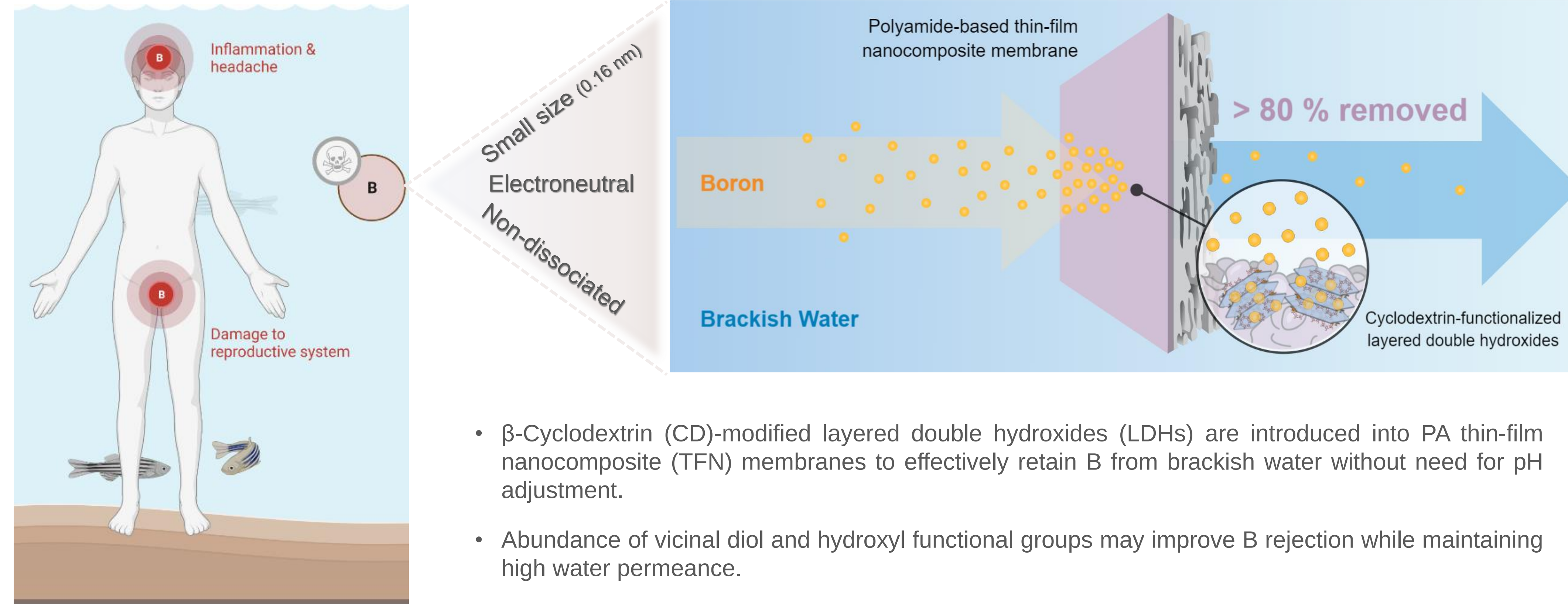
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Background

- Boric acid and borax popularly used in food preservatives and as flame-retardants.
- Boron (B) concentration: 10 mg L⁻¹ in seawater, 30 mg kg⁻¹ in soil, and ≥ 100 mg L⁻¹ in wastewater.
- WHO guideline for safe drinking water: ≤ 2.4 mg L⁻¹ B.



- β-Cyclodextrin (CD)-modified layered double hydroxides (LDHs) are introduced into PA thin-film nanocomposite (TFN) membranes to effectively retain B from brackish water without need for pH adjustment.
- Abundance of vicinal diol and hydroxyl functional groups may improve B rejection while maintaining high water permeance.

Methods

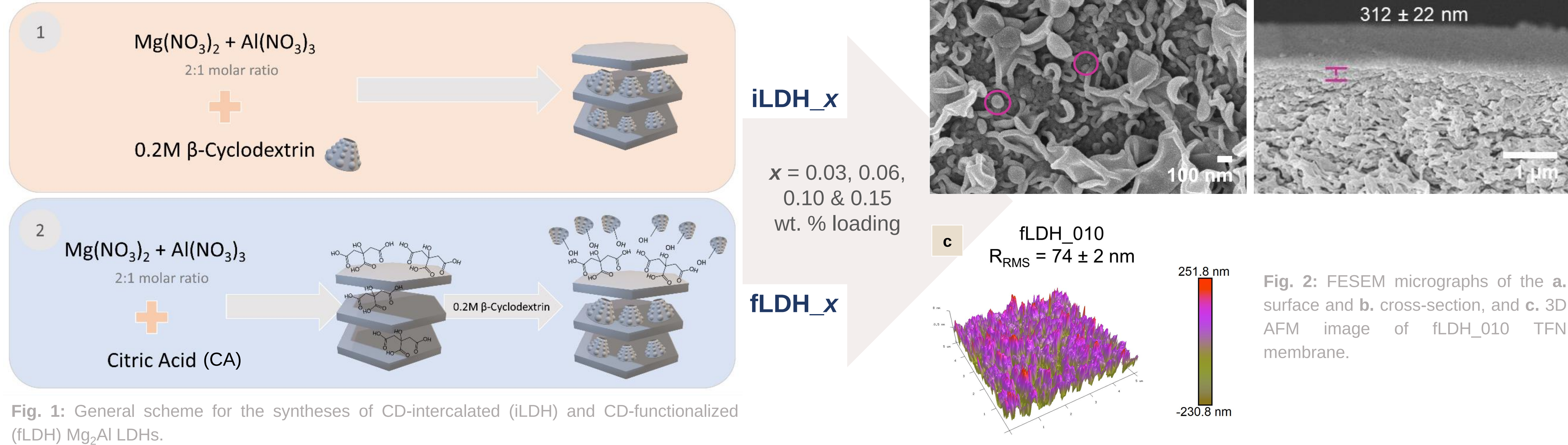
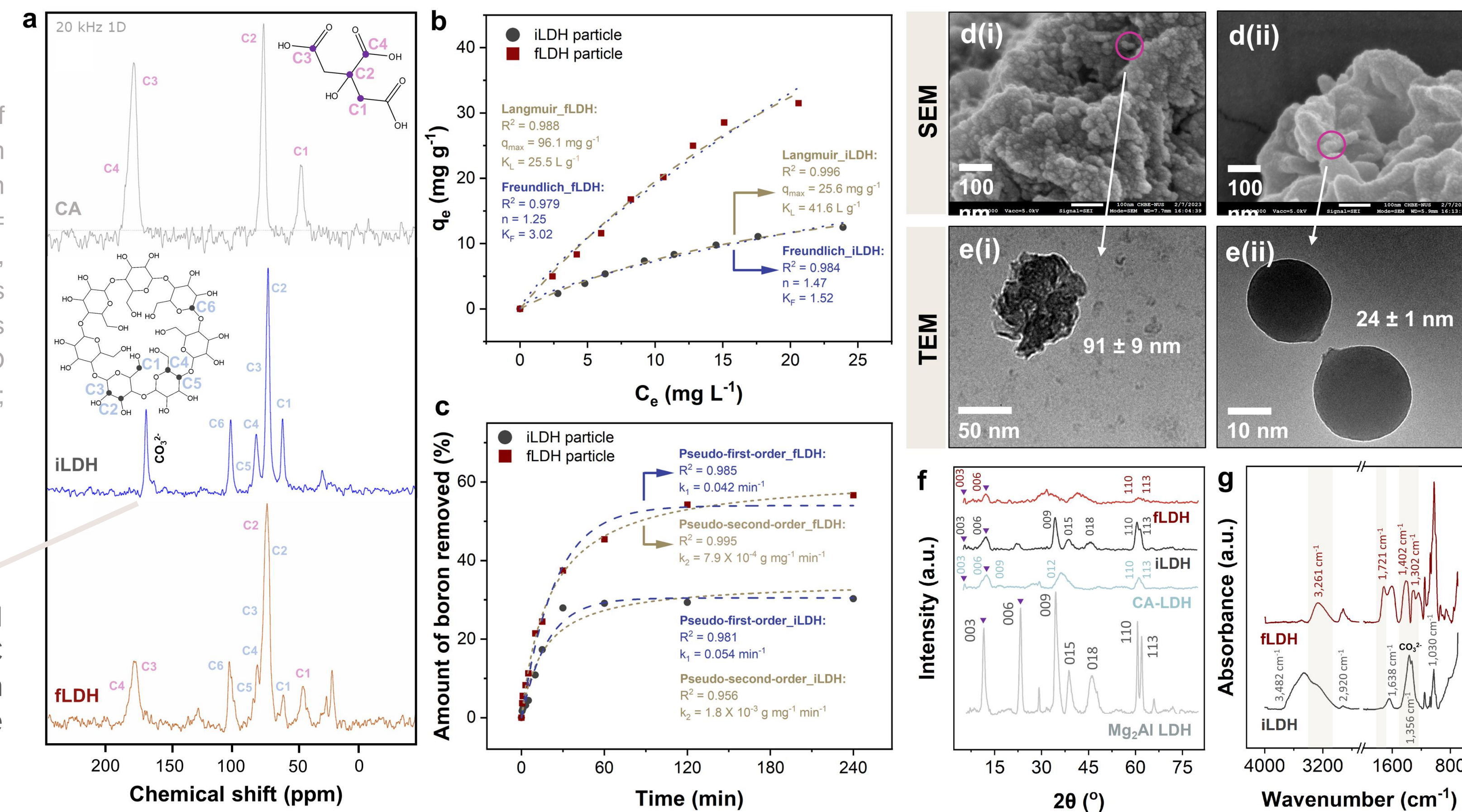


Fig. 1: General scheme for the syntheses of CD-intercalated (iLDH) and CD-functionalized (fLDH) Mg₂Al LDHs.

Results & Discussion

Fig. 3: **a.** ¹³C CP/MAS ssNMR spectra of CA, iLDH, and fLDH; **b.** Boron adsorption isotherm of iLDH and fLDH; **c.** Boron adsorption kinetics of iLDH and fLDH (C₀ = 15 mg L⁻¹ B in 2,000 mg L⁻¹ NaCl solution, 25 °C, pH 8, 240 min); FESEM micrographs of **d(i).** iLDH and **d(ii).** fLDH; FETEM images of **e(i).** iLDH and **e(ii).** fLDH; **f.** PXRD spectra of LDH, CA-LDH, iLDH, and fLDH; **g.** ATR-FTIR spectra of iLDH and fLDH.

- CO₃²⁻ contamination of iLDH observed at 169 ppm in ¹³C CP/MAS ssNMR and 1,356 cm⁻¹ in ATR-FTIR. CA and CD eliminate this contamination in fLDH.



- Langmuir adsorption isotherm predicts maximum B adsorption capacities of 25.6 mg g⁻¹ (iLDH) and 96.1 mg g⁻¹ (fLDH).
- Pseudo-second-order kinetic model fits fLDH's predominant chemisorption behaviour from vicinal diol chelation and host-guest complexation.
- Shift of (003) peak to lower 2θ → larger interlayer spacing distances of 1.61 nm (iLDH) and 1.67 nm (fLDH), compared to 0.77 nm in carbonate-intercalated LDH.
- Successful CD functionalization and envelop of LDH evidenced by diminished crystallinity and peak at 3,261 cm⁻¹ in ATR-FTIR of fLDH.

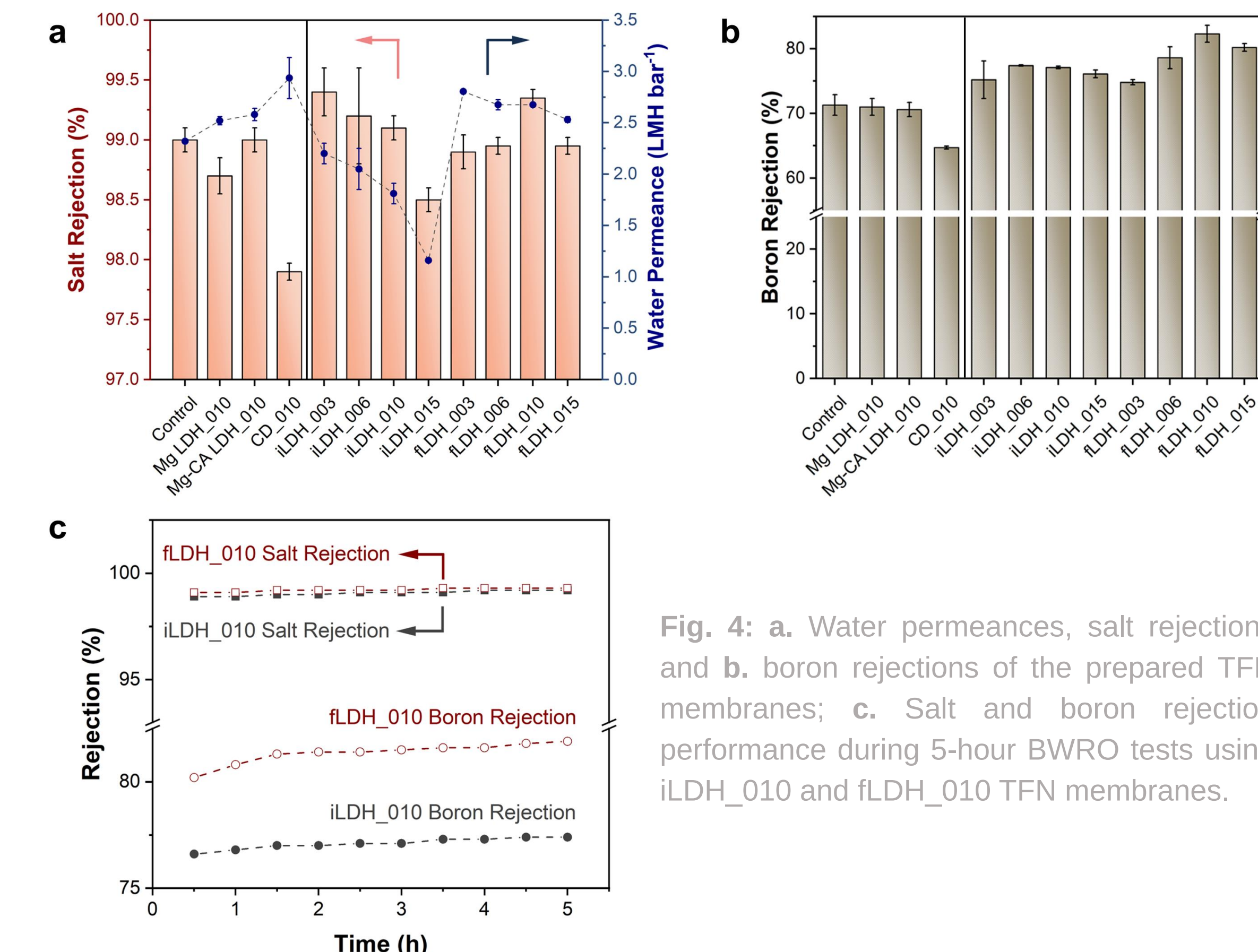


Fig. 4: **a.** Water permeances, salt rejections and **b.** boron rejections of the prepared TFN membranes; **c.** Salt and boron rejection performance during 5-hour BWRO tests using iLDH_010 and fLDH_010 TFN membranes.

- fLDH_010 TFN membrane achieves impressive salt rejection of 99.4 ± 0.1 % and water permeance of 2.68 ± 0.02 LMH bar⁻¹ against brackish water.
- CD acts as an effective ion sieve (~0.60 nm cavity) for Na⁺ and Cl⁻.
- fLDH_010 TFN membrane attains highest B rejection of 82.3 ± 1.3 % at natural pH of brackish water.
- Stable desalination performance of both iLDH_010 and fLDH_010 TFN membranes, with slight improvement in B rejection, over 5-h continuous operation.

Conclusion

Through meticulous molecular design and optimization, PA TFN membrane with a loading of 0.10 wt. % fLDH displays a high salt rejection and water permeance of 99.4 % and 2.68 LMH bar⁻¹ for brackish water. This can be attributed to the increased interlayer spacing and thinner selective layer. The innovative TFN membrane also achieves a high boron rejection of 82.3 % at natural pH of brackish water, providing safe drinkable water upon treatment.

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