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Integration of anaerobic digestion and electrodialysis for methane yield promotion and ammonium in-situ recovery

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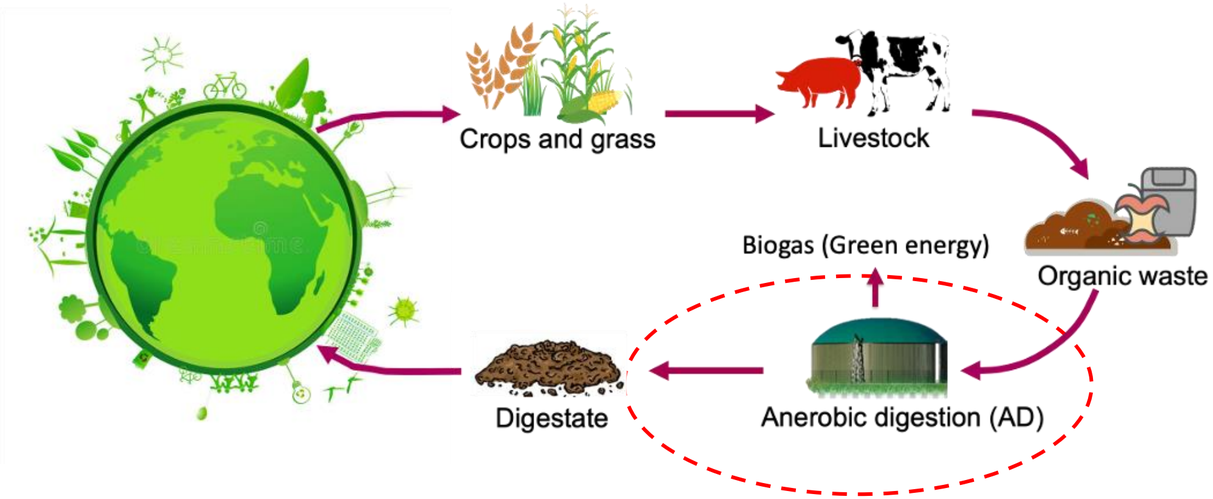
Background

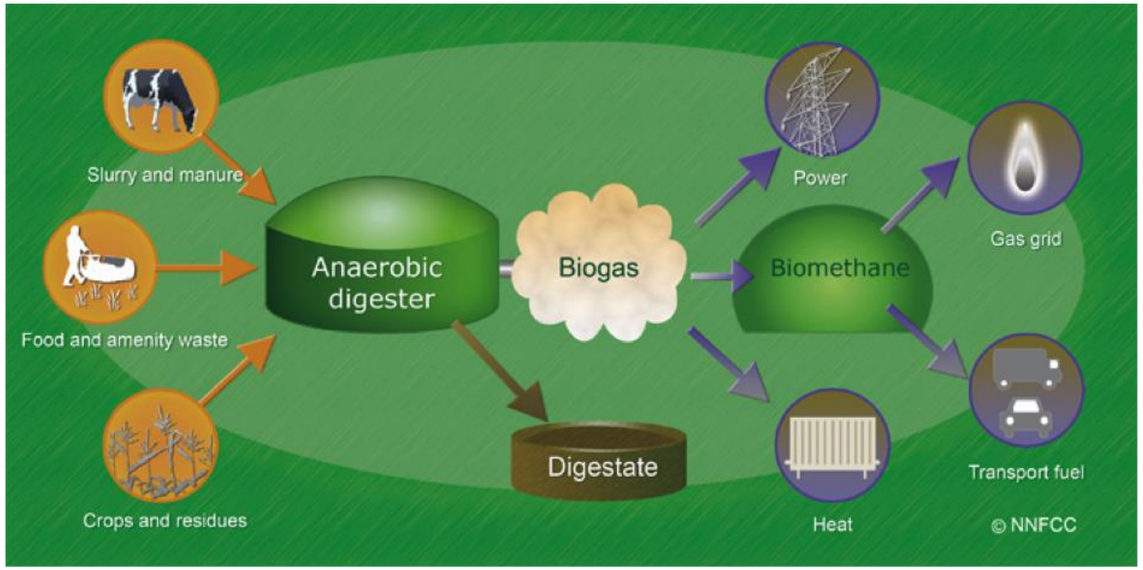
◆ Concept of Sustainable Development



Agriculture is an important sector for achieving carbon neutrality.

Anaerobic digestion (AD) plays a role in farm waste management.

■ Anaerobic digestion



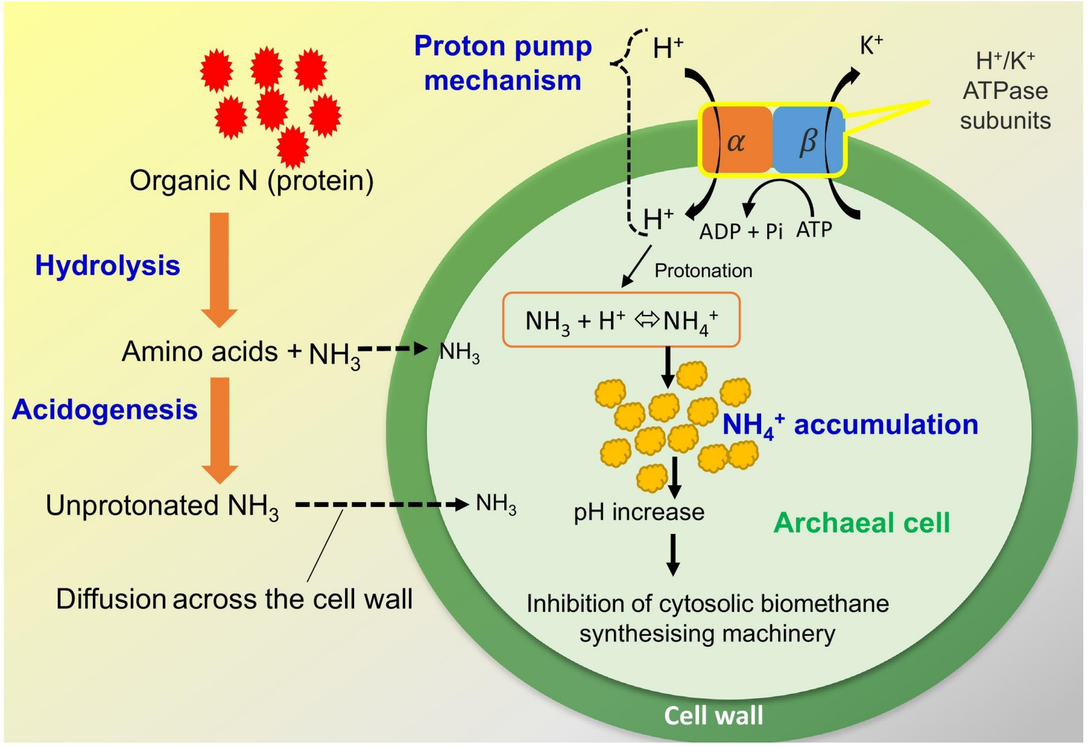
Producing renewable Biogas, nutrient-rich digestate

Reducing greenhouse gas emissions

Background

◆ AD Challenge: methanogenesis inhibition by high ammonia concentration

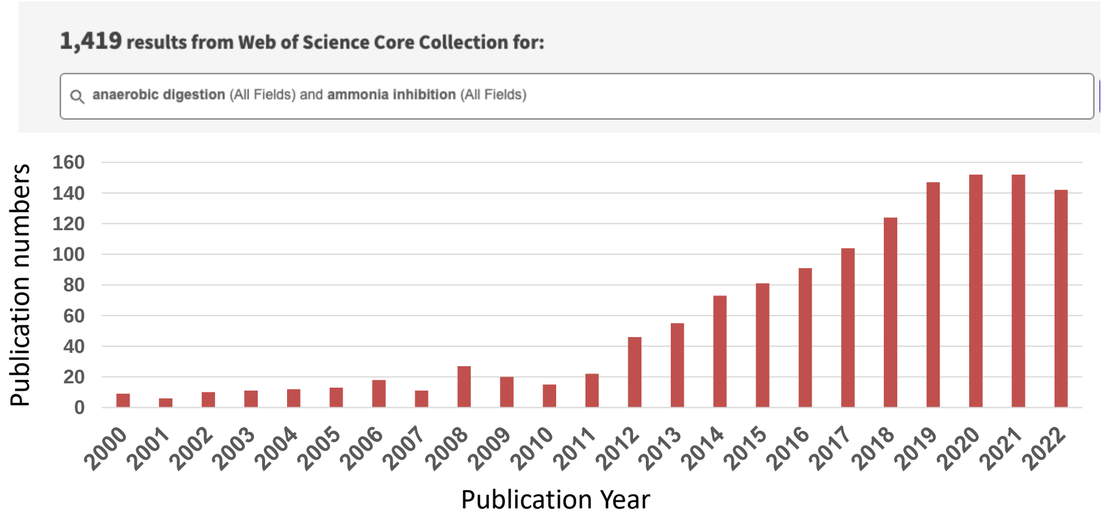
- Ammonia (NH_4^+) toxicity of AD process



Lead to methane yield inhibition

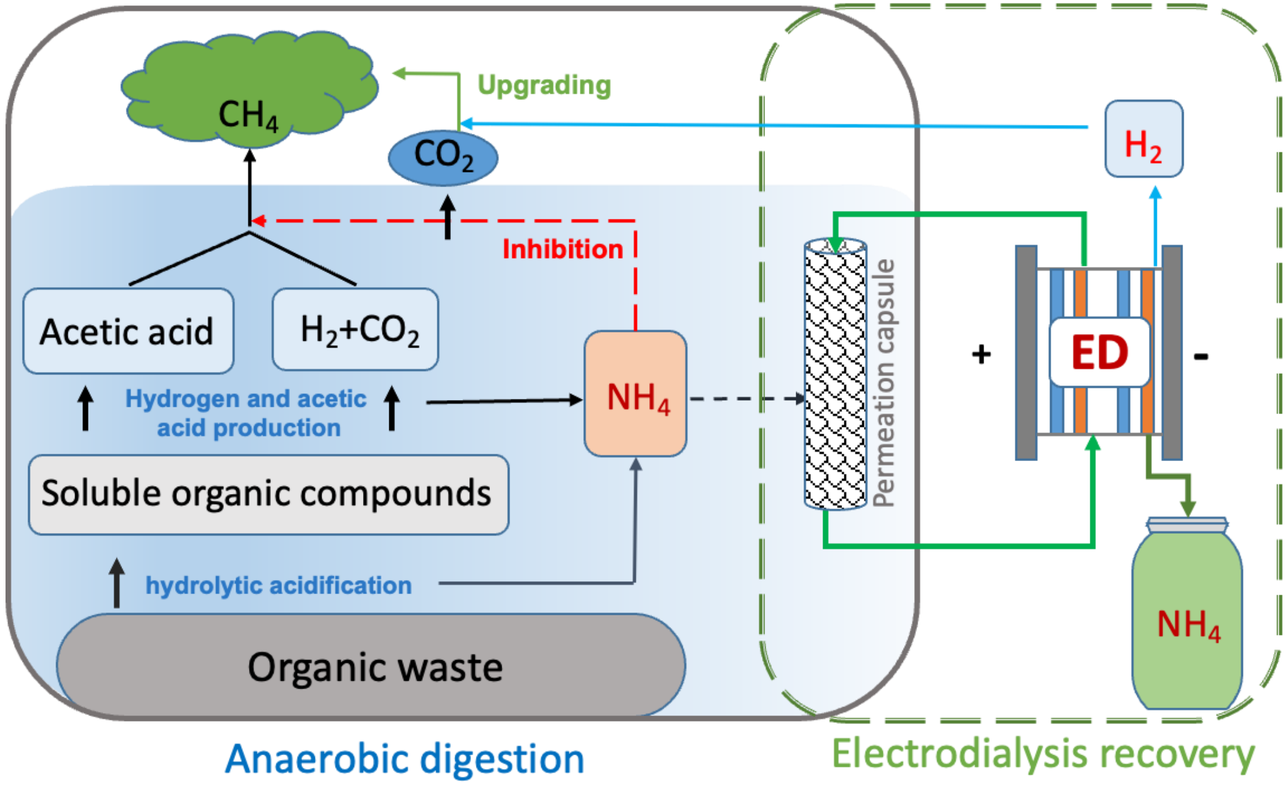
How to remove NH_4^+ from AD digester for releasing its toxicity?

- **Ammonia inhibition in AD is receiving increasing concern**



Research target

A novel AD process integrated with electrodialysis (ADED) for in-situ recovery of NH_4^+ from AD digester for relieving NH_4^+ inhibition.



The proposed novel integration provides a unique solution with the advantages as follows:

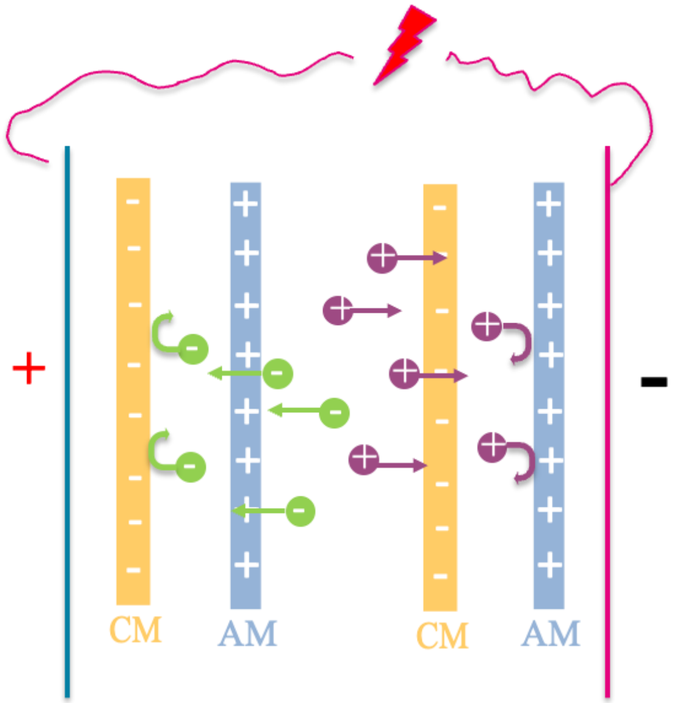
(1) Relieving NH_4^+ inhibition and improving the CH_4 yield

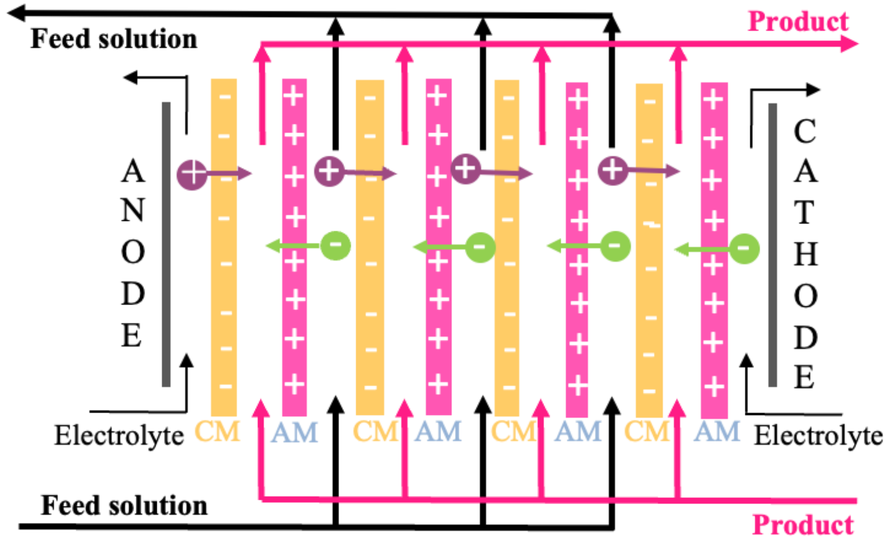
(2) Recovering NH_4^+ as nutrient

Electrodialysis

What is **Electrodialysis (ED)**?

Electrodialysis is an electric-driven membrane-based technology, which can recover ions from solution.



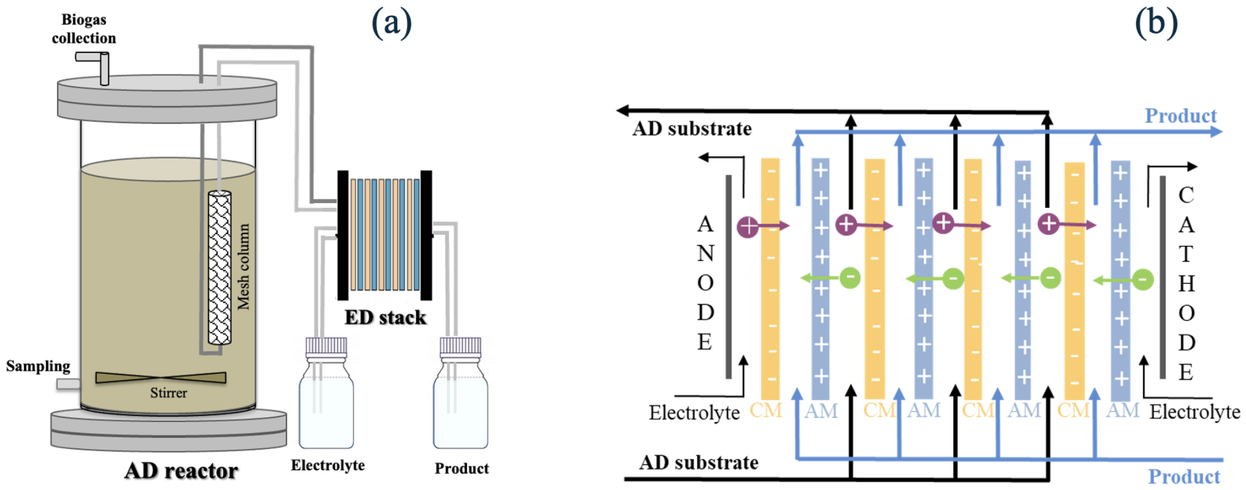


⊕ : Cations ⊖ : Anions CM : Cation exchange membrane AM : Anion exchange membrane

Advantages: high energy efficiency,
high tolerance with high suspended solid water,
higher concentration of nutrients can be produced.

- *J. Meng, et. al, Journal of Membrane Science, 642, 2022*
- *L. Shi , et. al, Journal of Membrane Science, 573, 2019*
- *L. Shi , et. al,, Chemical Engineering Journal, 334, 2018*

Experiments design



Schematic of ADED reactor (a) and ED stack utilized (b). AD: anaerobic digestion; ED: electrodialysis; CM: cation exchange membrane; AM: anion exchange membrane

ADED system build in lab

Experiment condition :

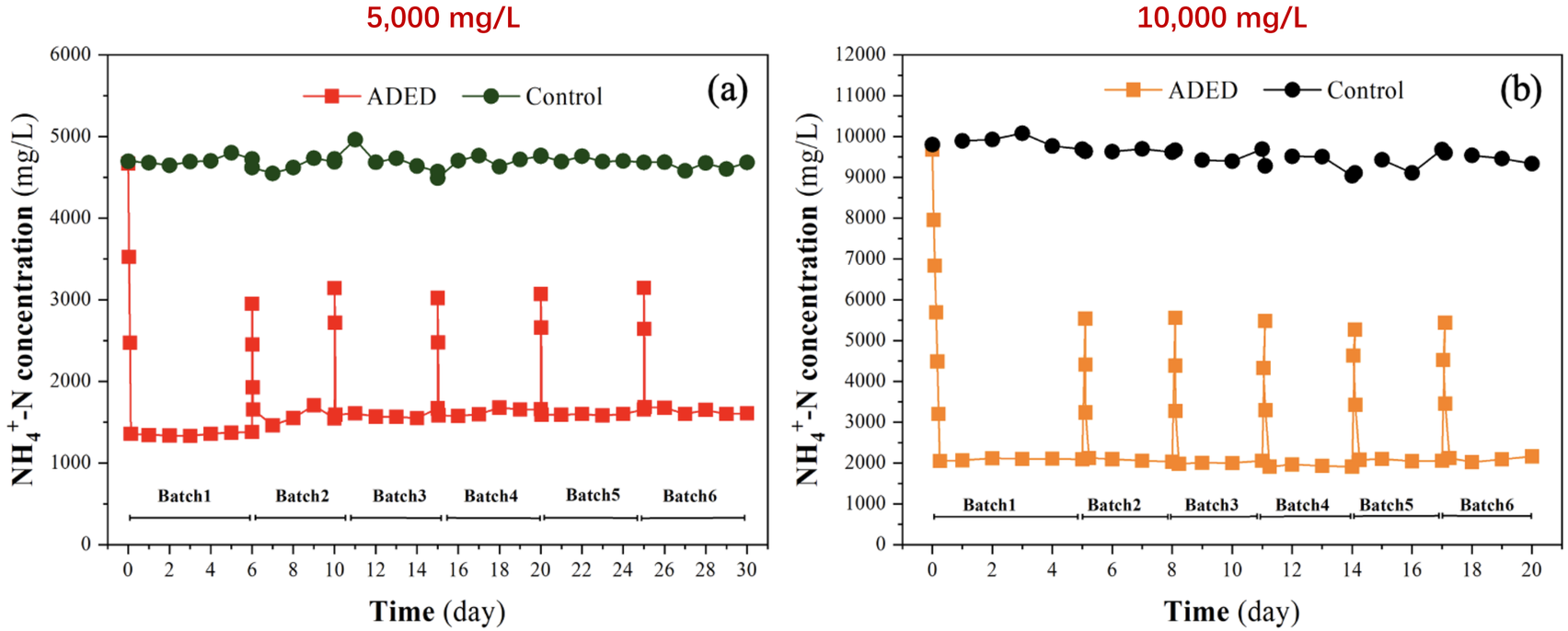
Two scenarios: influent with 5,000 mg/L NH_4^+-N and 10,000 mg/L NH_4^+-N

AD reactor volume: 2L, The AD reactors were operated as an anaerobic sequencing batch reactor (AnSBR) process for 6 cycles.

An ED stack consisting of 3 repeating units was used, with an ion exchange membrane size of 21cm × 9 cm. Applied current: 2A

Results and discussion

◆ NH_4^+ recovery by ED



Variation of NH_4^+-N concentration during AnSBR operation: (a) the feedstock had an NH_4^+ concentration of 5,000 mg/L, and (b) the feedstock had an NH_4^+ concentration of 10,000 mg/L

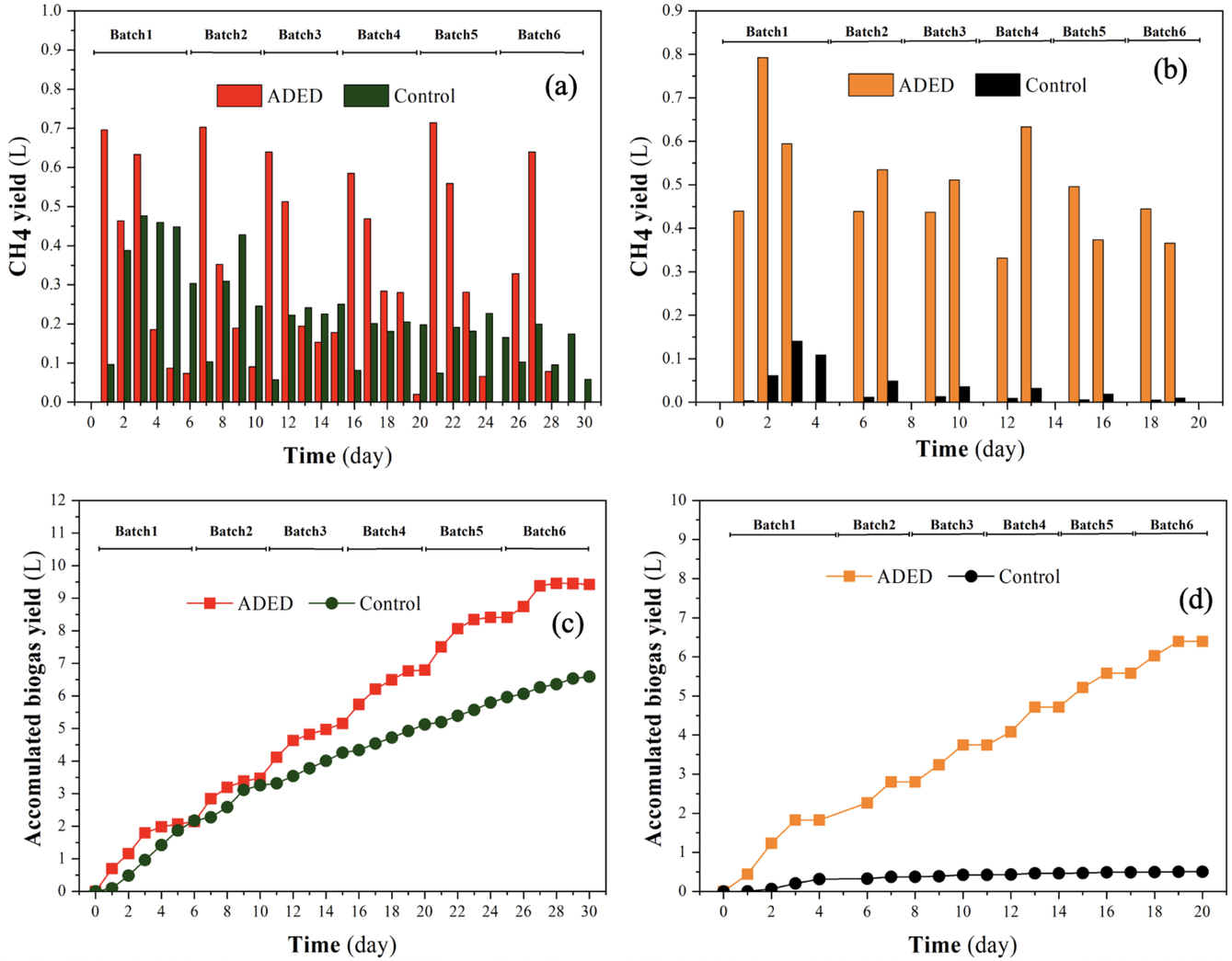
With the operation of ED, the NH_4^+ concentration in the ADED reactor was reduced to below 2,000 mg/L.

Results and discussion

Methane (CH_4) yield

5,000 mg/L

10,000 mg/L

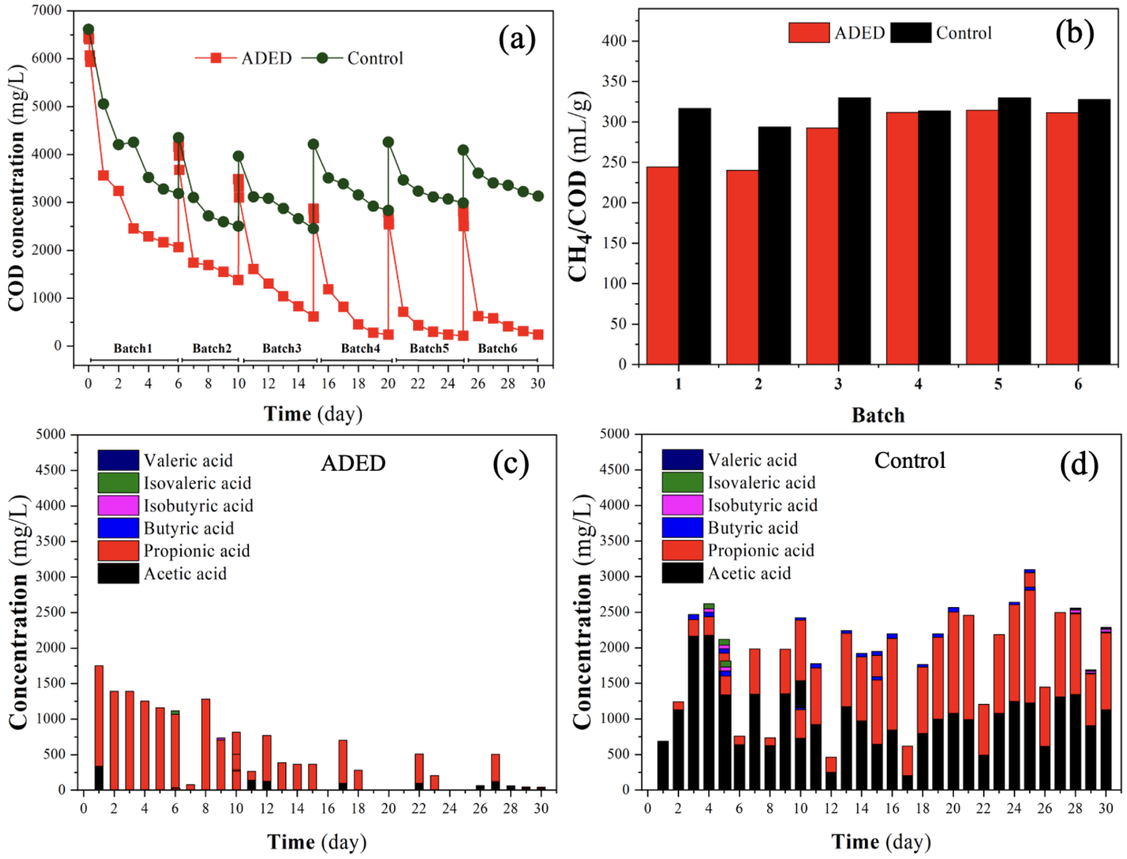


Daily CH_4 yield in the group of 5,000 mg/L influent NH_4^+-N (a) and 10,000 mg/L influent NH_4^+-N (b), and the accumulative CH_4 yield in the group of 5,000 mg/L influent NH_4^+-N (c) and 10,000 mg/L influent NH_4^+-N (d)

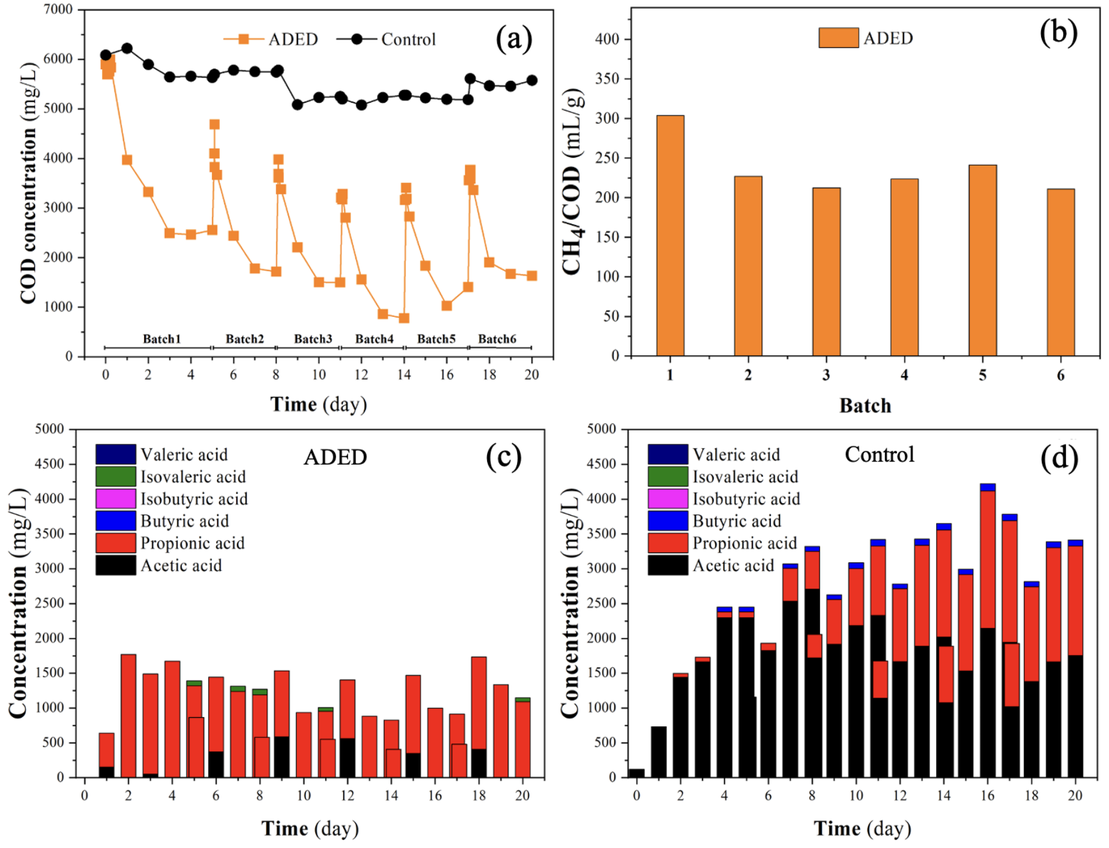
Results and discussion

◆ COD removal

5,000 mg/L



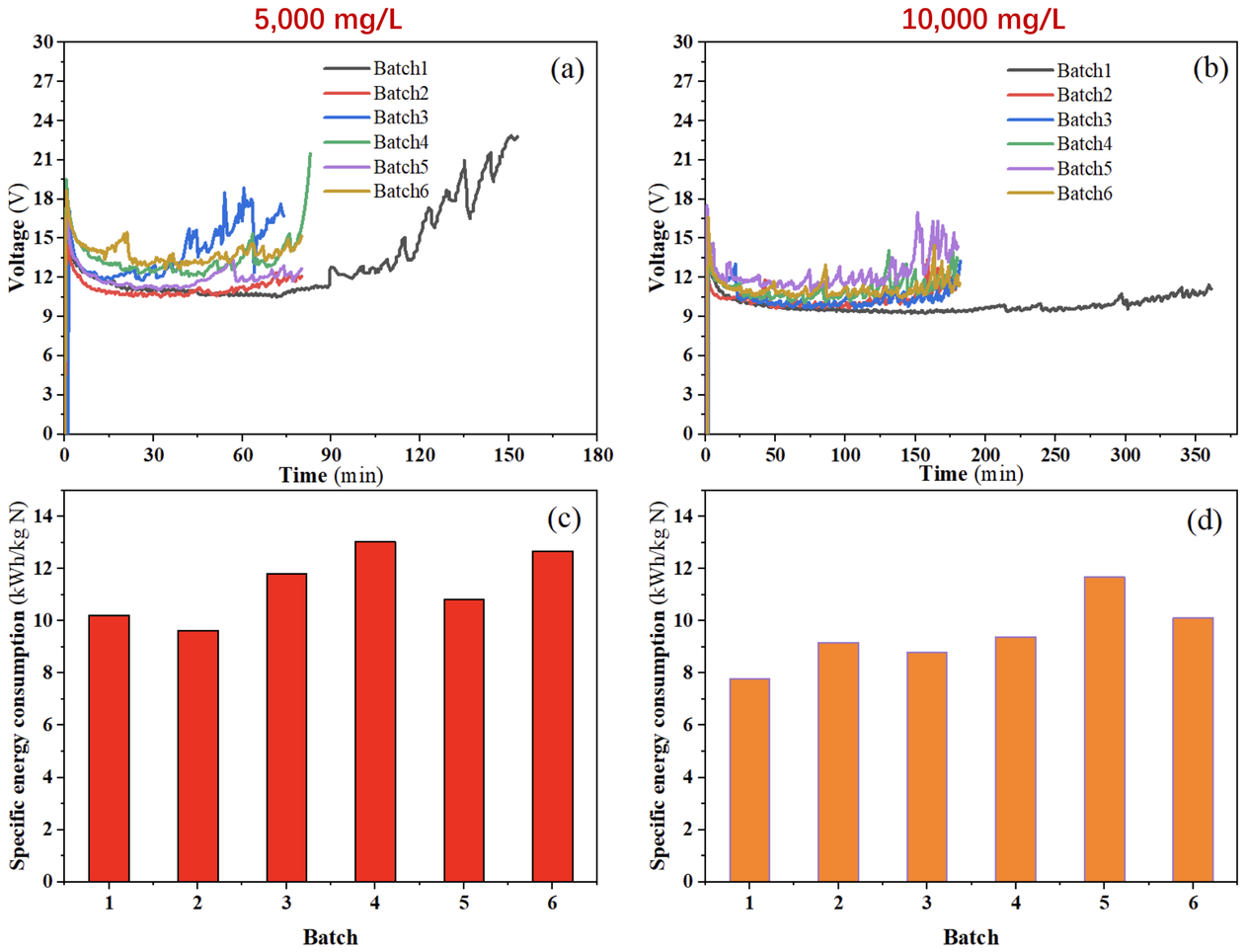
10,000 mg/L



Variation of soluble COD concentration (a), CH_4 yield per g removed COD (b), VFA concentrations in ADED reactor (c) and control reactor (d) in the condition of 5,000 mg/L (left) or 10,000 mg/L (right) influent NH_4^+-N.

Results and discussion

Energy consumption

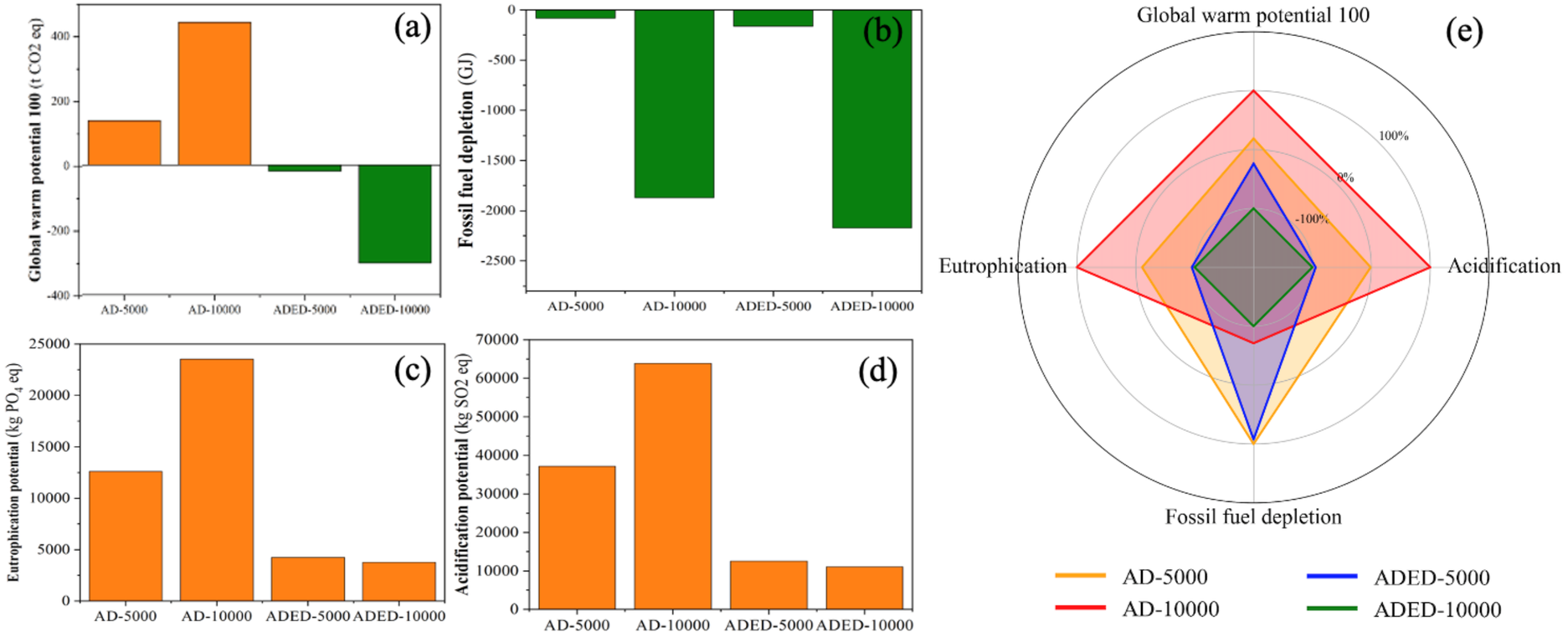


Voltage variation of ED stack during ED operation at 5,000 mg/L influent NH_4^+-N (a) and 10,000 mg/L influent NH_4^+-N (b), and the specific energy consumption for NH_4^+ recovery at 5,000 mg/L influent NH_4^+-N (c) and 10,000 mg/L influent NH_4^+-N (d)

10 kWh/kg N is comparable to the energy consumption for industrial ammonia synthesis of 9.1 kWh/kg N

Results and discussion

Environmental impacts assessment



The impacts of different scenarios, including AD-5000, AD-10000, ADED-5000, and ADED-10000, on life cycle midpoint indicators: (a) Global warming potential 100, (b) Fossil fuel depletion, (c) Acidification potential, (d) Eutrophication potential, and (e) Normalized comparison of midpoint indicators among different scenarios.

Conclusion

- ED integration can recover NH_4^+ from an AD digester and reduce its concentration to below 2000 mg/L.
- The NH_4^+ recovery prompted the AD methane yield.
- ADED application can reduce the environmental impacts significantly.

Thank You!

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