Highly Efficient Neutralization of VOCs in Wastewater from CO_2 Capture Systems

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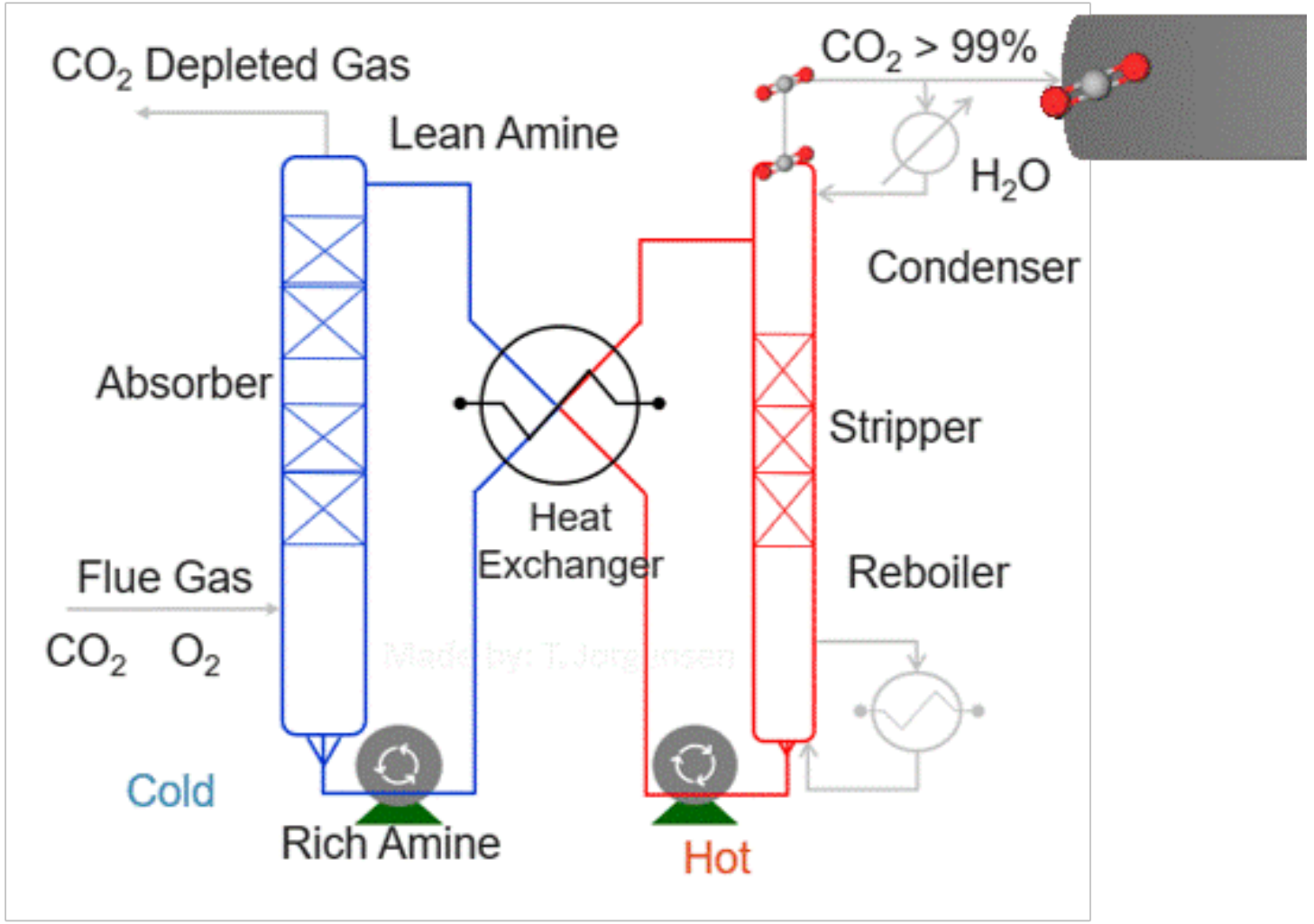
PCCC-8

IEAGHG 8th Post Combustion Capture Conference
16th to 18th September 2025 Marseille, France

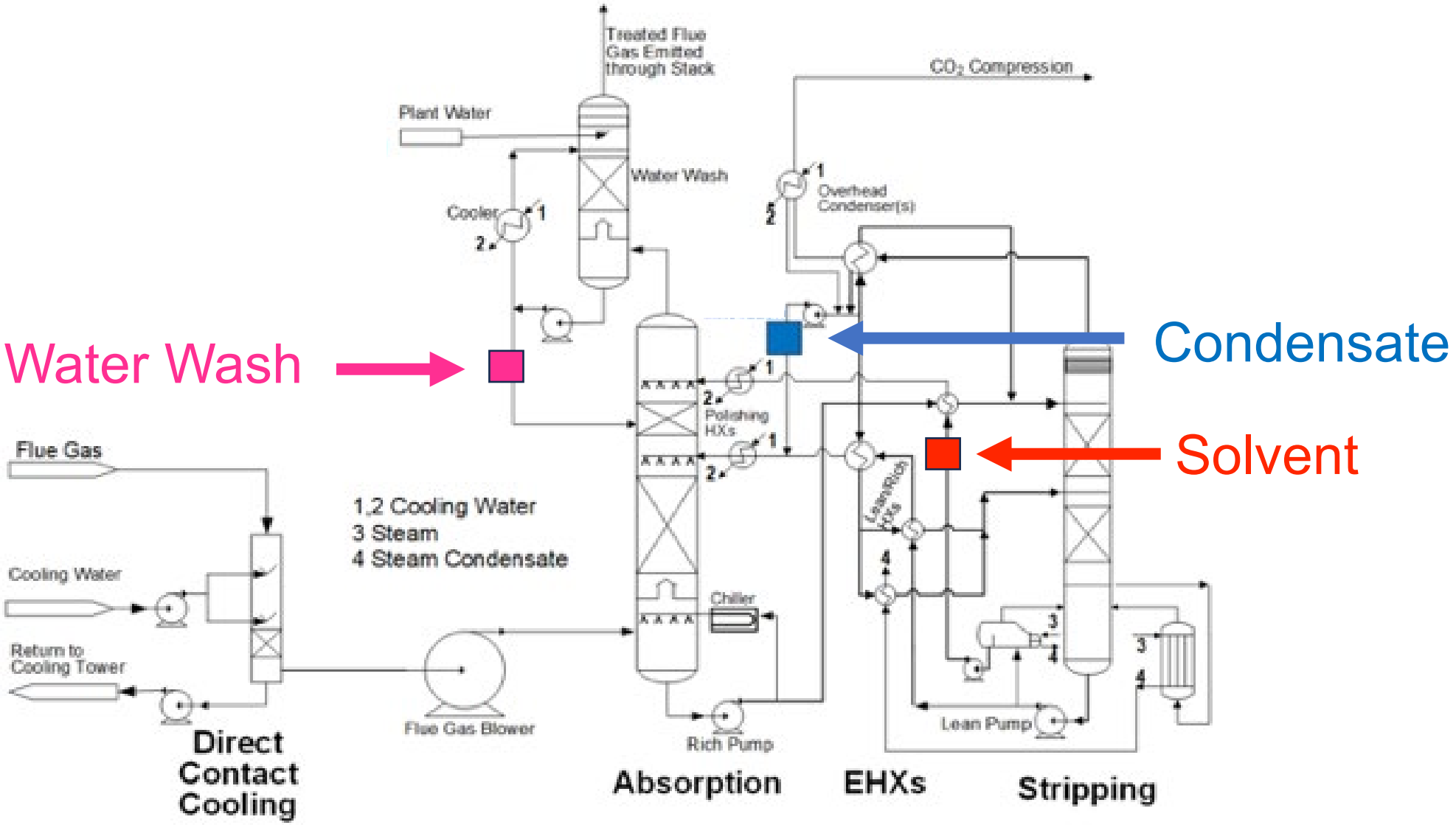
Motivation

Verify/Prevent any harmful compounds from coming out of the CO_2 capture plant that are worse for the environment than the CO_2 we are trying to capture

Treatment at very low concentrations is difficult
– Need a targeted approach

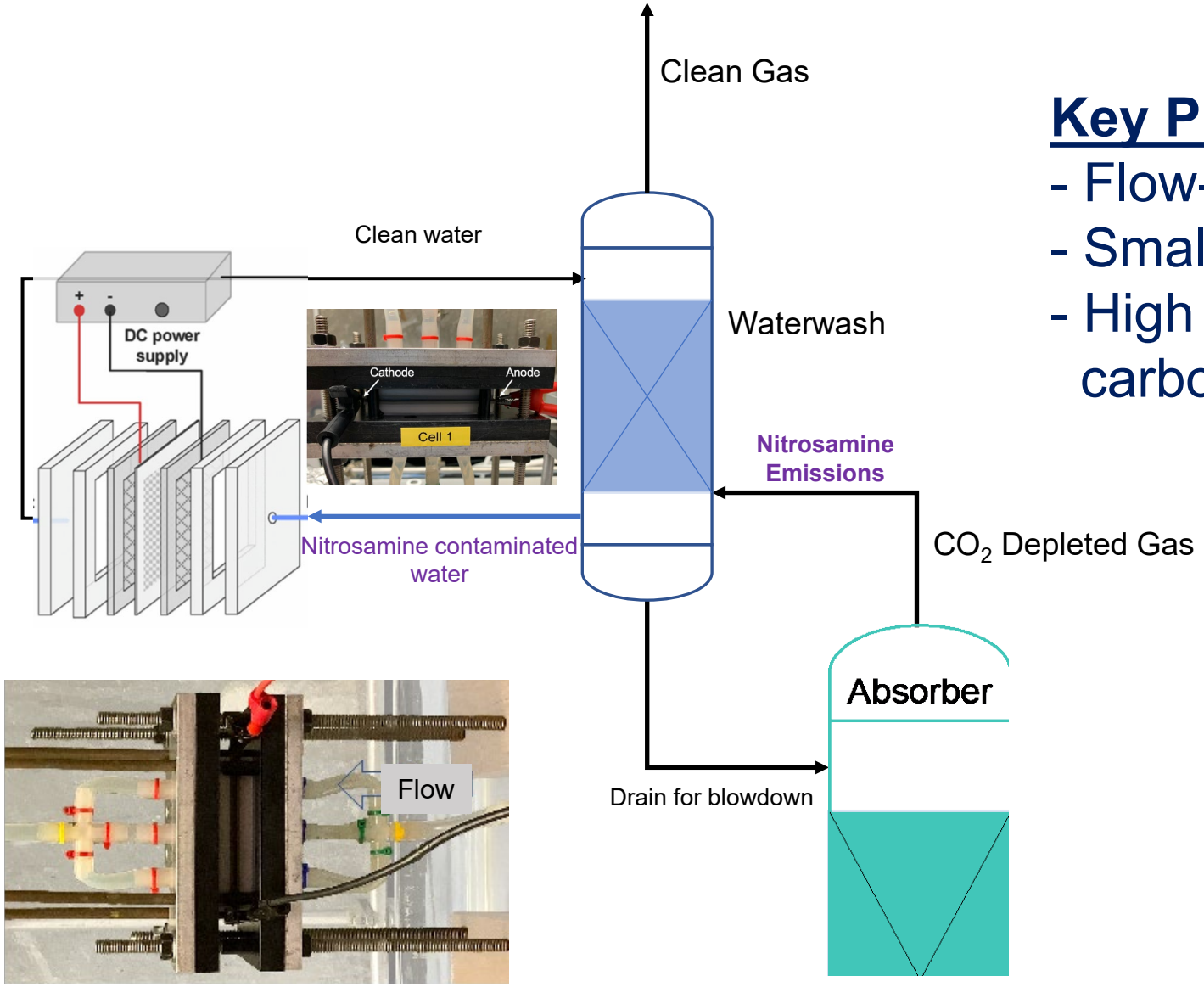


Locations within CO_2 Capture Plant



Nitrosamine Treatment

Flow-Through Electrochemical Cell

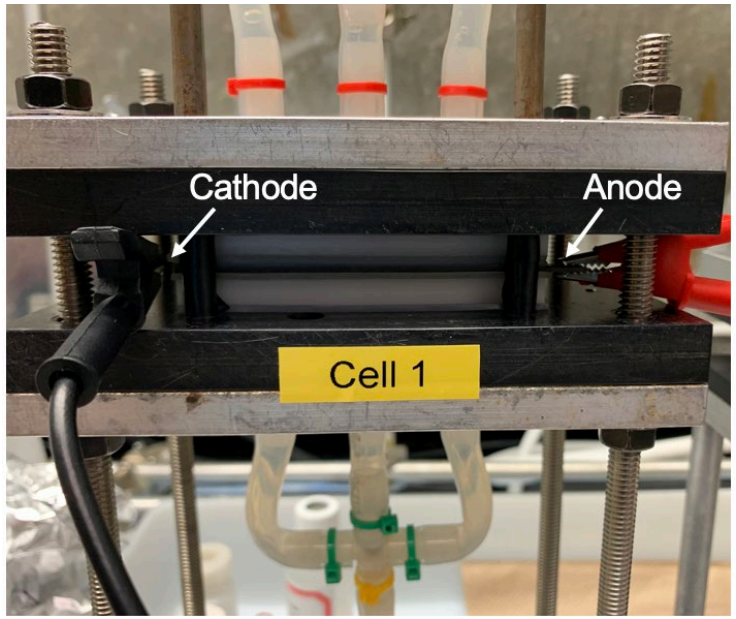


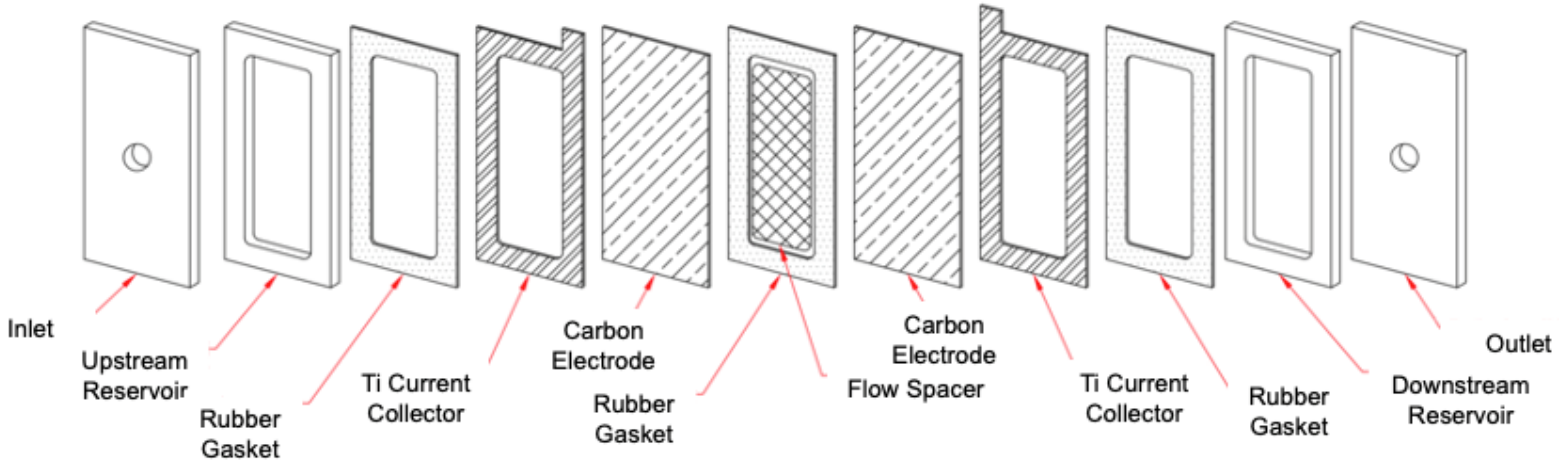
Key Properties:

- Flow-through design
- Small footprint
- High surface area carbon electrodes

Toma, et al. *Chemosphere*, **2023**.

Electrochemical Reduction

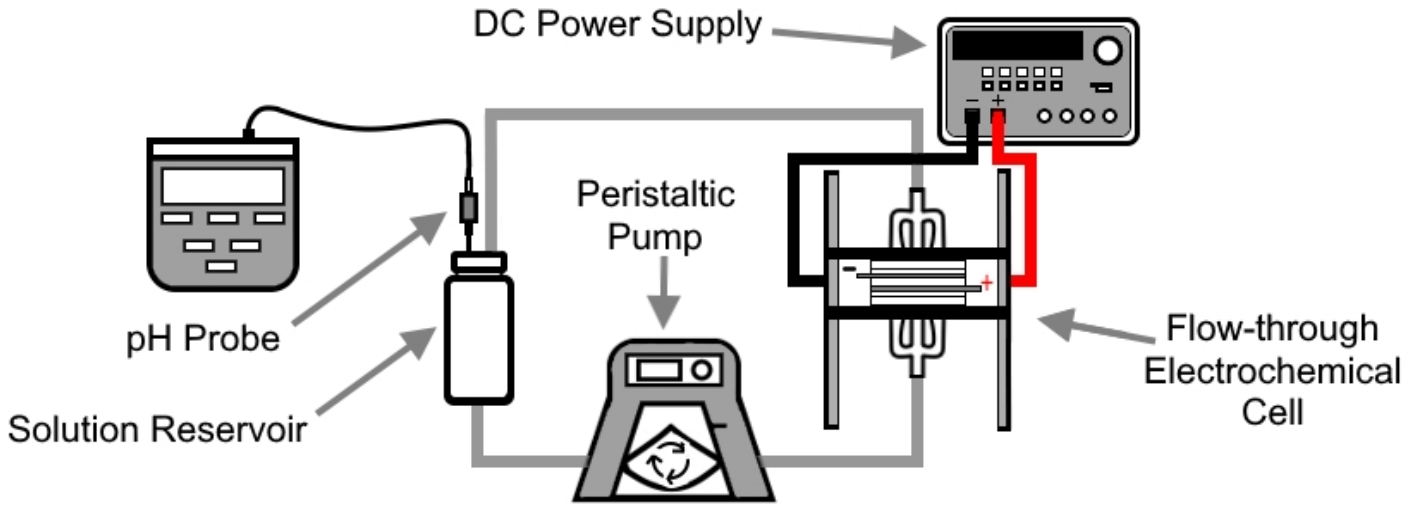


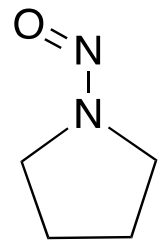


Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

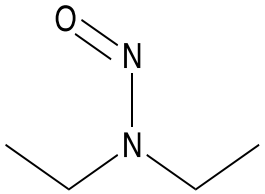
Electrochemical Reduction

- Simulated waterwash/condensate solution containing amines and spiked with N-nitrosamines
- Solution were pumped through the cell to ensure equilibrium
- Start electrolysis operation using DC power supply and constant current mode
- *Evaluated commercially available carbon materials as electrodes*

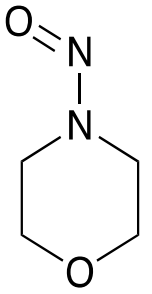




N-Nitrosopyrrolidine (NPY)
log K_{ow} - 0.19



N-Nitrosodiethylamine (NDEA)
log K_{ow} 0.48



N-Nitrosomorpholine (NMOR)
log K_{ow} - 0.44

Decomposition Efficiency

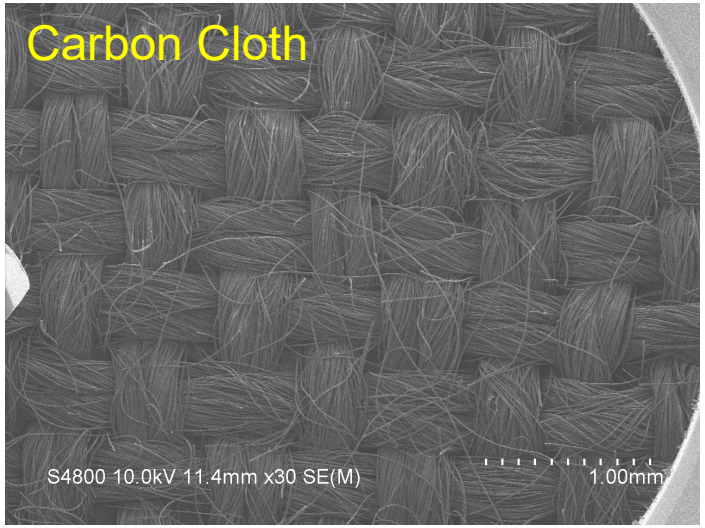
$$E = \frac{C_i \times V_f - C_f \times V_f}{C_i \times V_f} \times 100\%$$

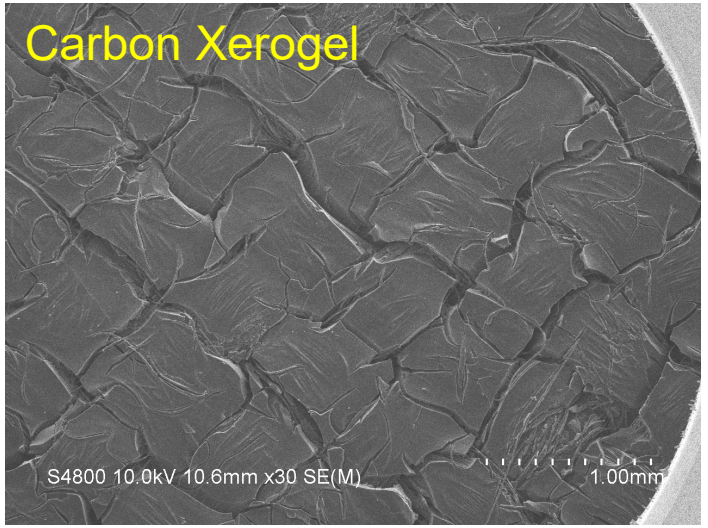
Decomposition Rate (mg m^{-2} h^{-1})

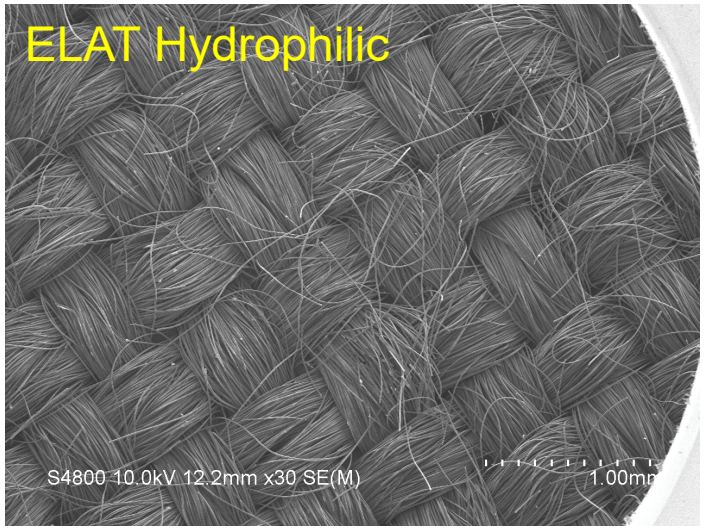
$$R = \frac{C_i \times V_f - C_f \times V_f}{A \times t} \times \frac{3600s}{h}$$

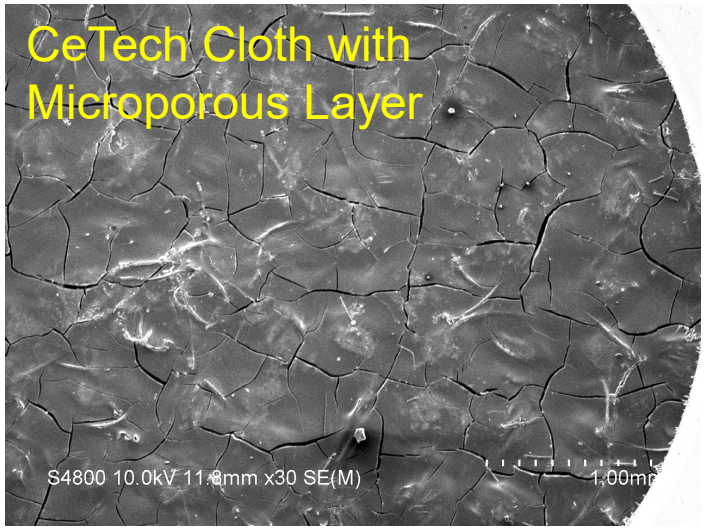
Abad et al., *Industrial & Engineering Chemistry Research* **2025**; B.Jurado-Sanchez et al. *Talanta*, **2009**

Carbon Electrodes









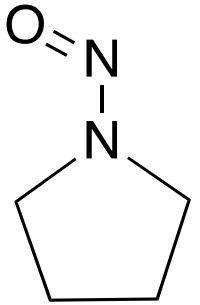
Experimental conditions:

- 25 mA constant current
- 20 mL/min flow rate
- simulated WW with 1 wt% MEA
- NPY, NDEA, and NMOR
- Anode and Cathode same material

Electrode	Conductivity (S/cm^2)
CC	0.40
CX	0.52
ELAT	0.40
CeTech	0.94

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Nitrosamine Reduction - NPY



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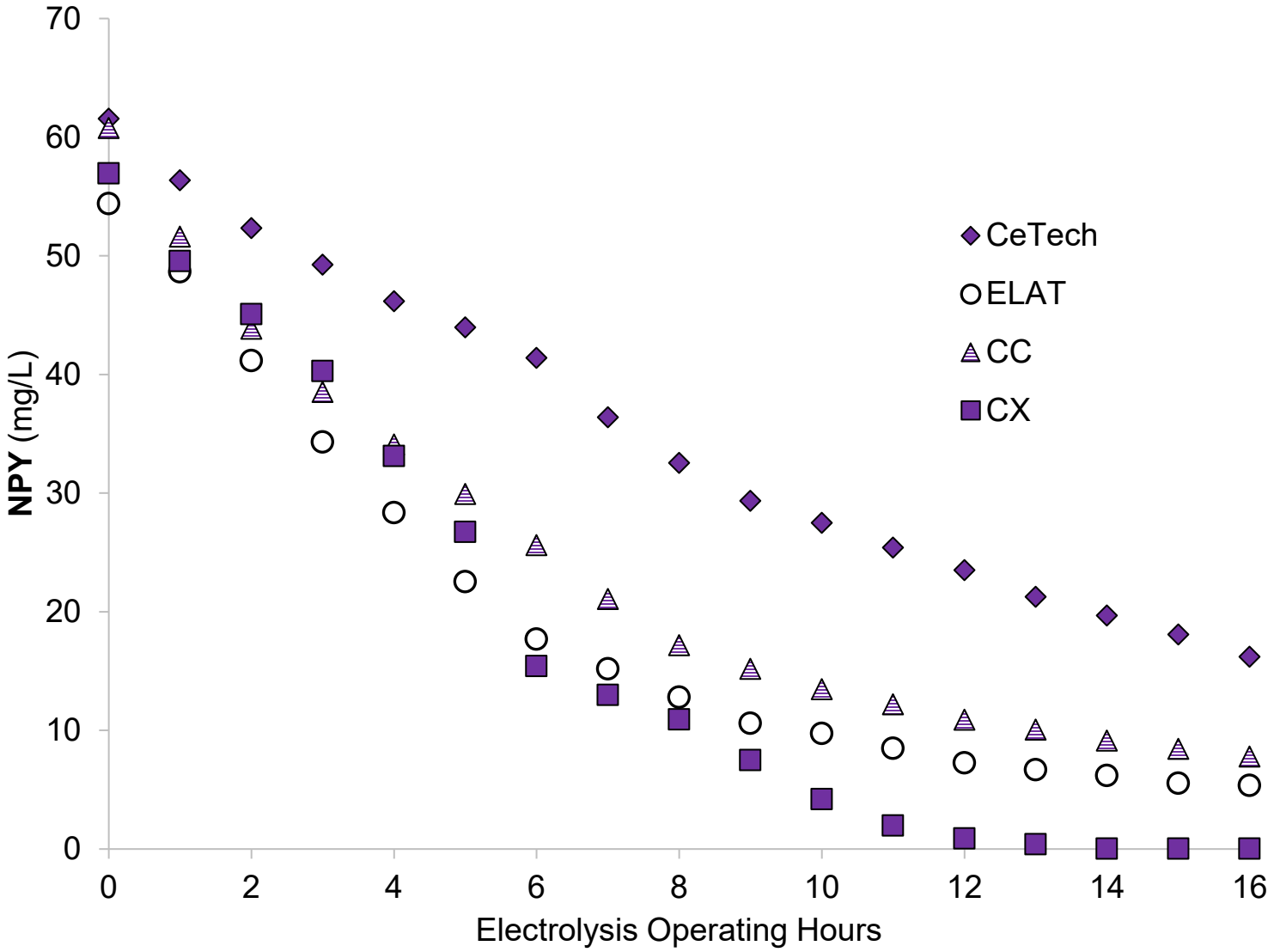
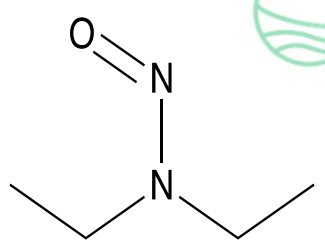


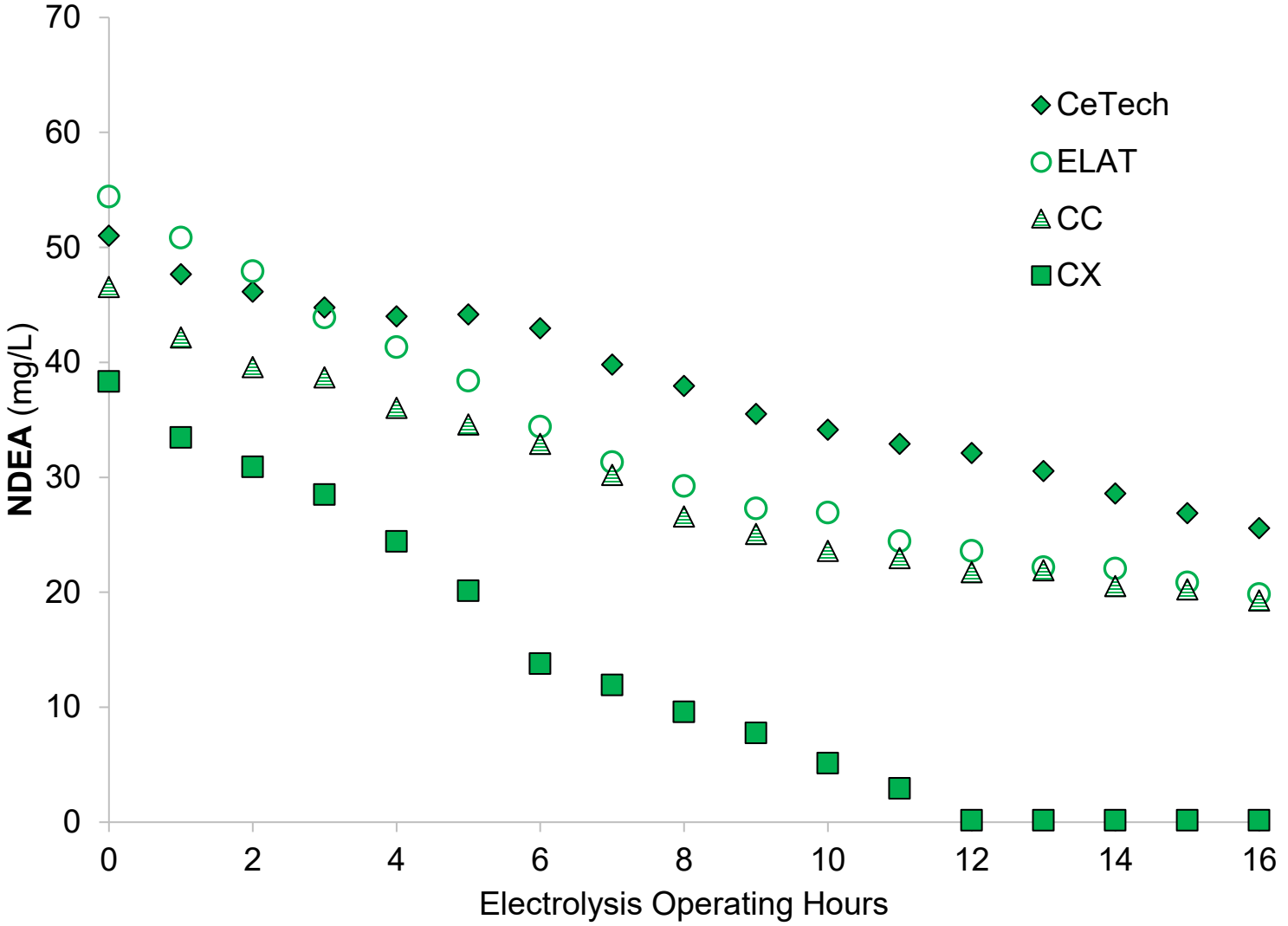
Electrode Material	Decomposition Efficiency h=16 (%)	Average Decomposition Rate h=16 (mg m^{-2} h^{-1})
CX	> 99	861.77
CC	87	802.33
ELAT	90	742.30
CeTech	74	686.97

The CX electrodes exhibited better NPY decomposition than the other electrodes, likely due to the previously observed adsorption of the N-nitrosamine onto the surface.

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Nitrosamine Reduction - NDEA



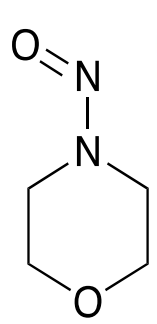


Electrode Material	Decomposition Efficiency h=16 (%)	Average Decomposition Rate h=16 (mg m^{-2} h^{-1})
CX	> 99	577.99
CC	59	412.84
ELAT	64	523.50
CeTech	50	385.33

Differences in the NDEA decomposition rate could be contributed to the polarity and structure of the NDEA resulting in decreased surface interaction leading to the lower decomposition rates in this system.

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Nitrosamine Reduction - NMOR



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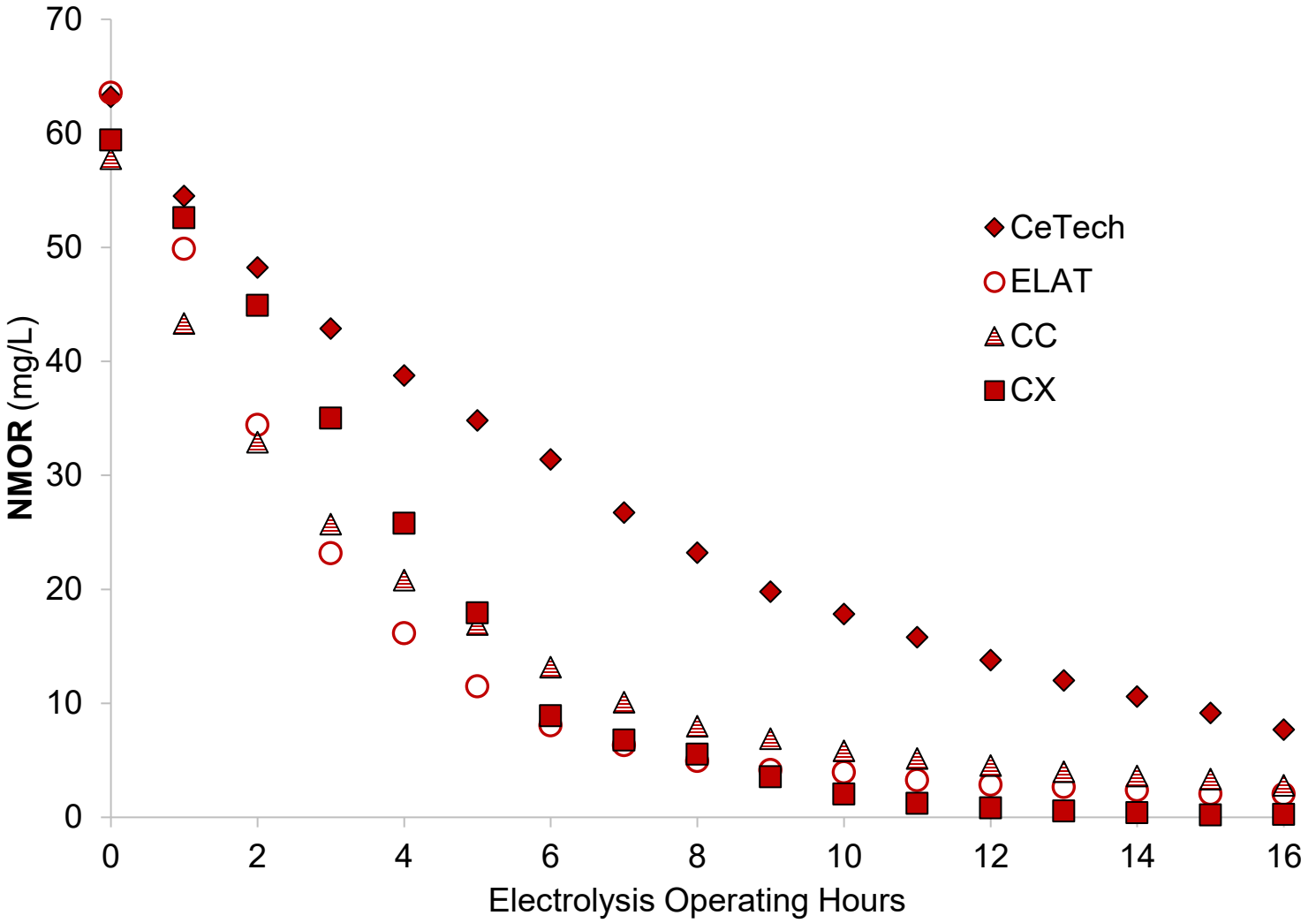

Electrode Material	Decomposition Efficiency h=16 (%)	Average Decomposition Rate h=16 (mg m^{-2} h^{-1})
CX	> 99	895.50
CC	95	832.34
ELAT	97	931.32
CeTech	88	840.73

This electrochemical approach was most efficient at decomposing NMOR using all four electrodes

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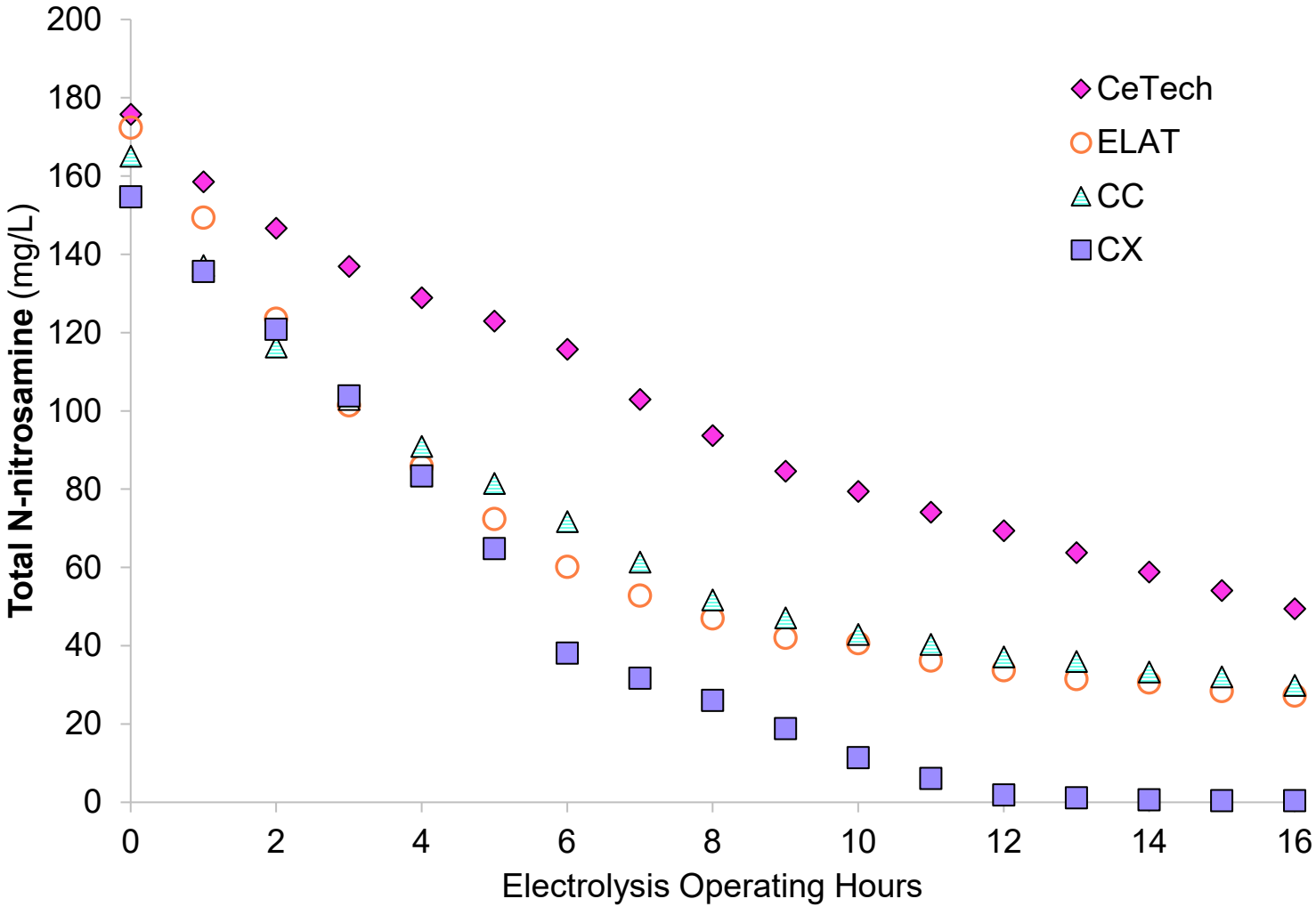
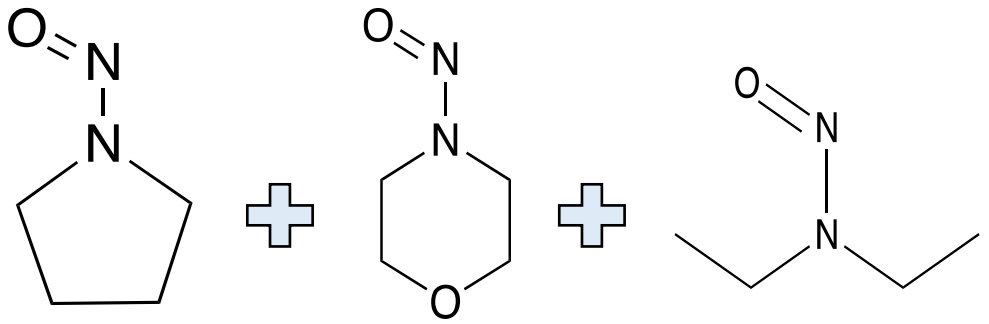
Nitrosamine Reduction - Combined

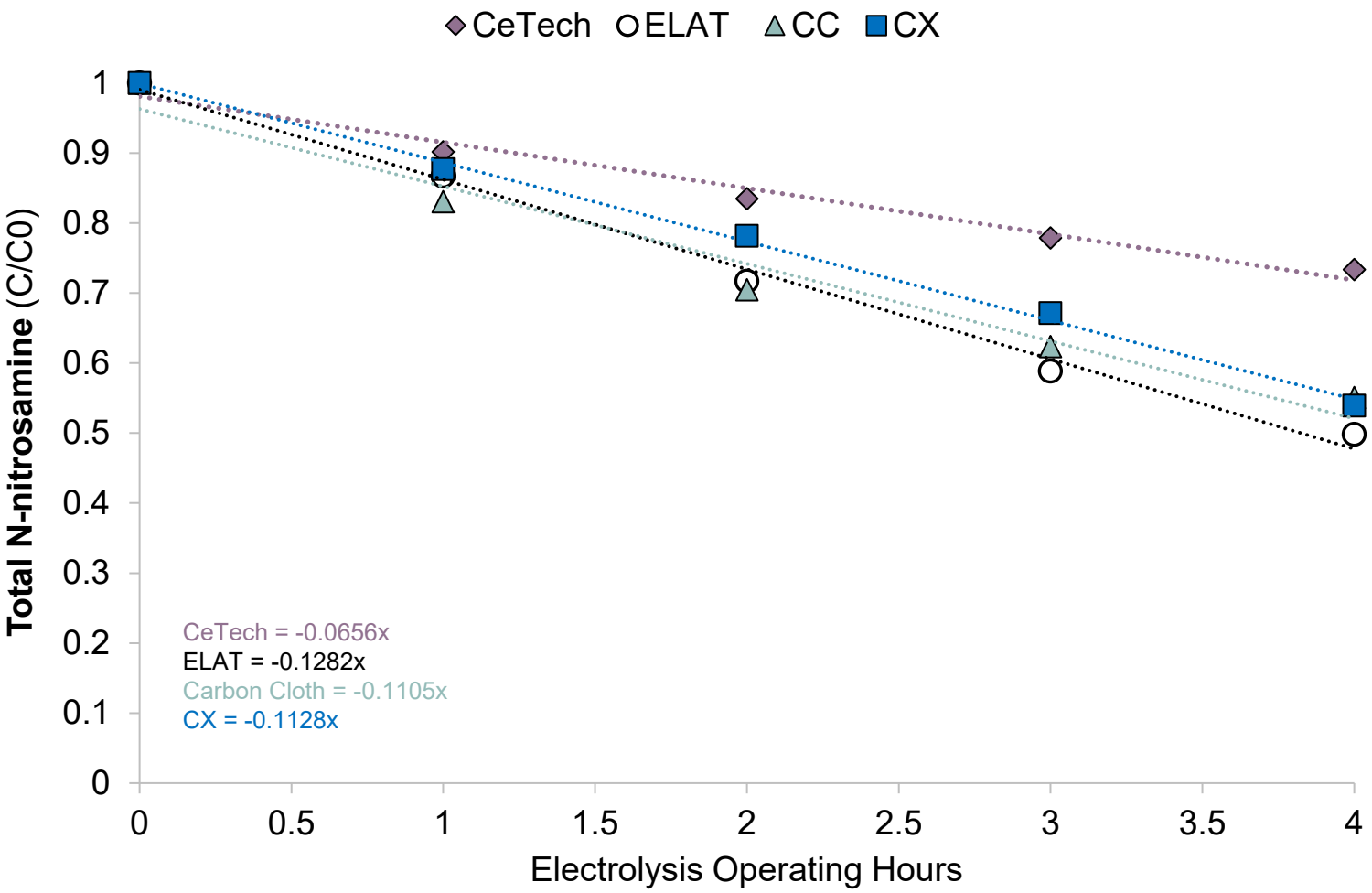




CX (99%) is the most efficient followed by ELAT (84%), CC (82%), and with CeTech (63%) being the least efficient overall

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Initial Reduction Kinetics



- The slope corresponds to the initial decomposition rate for each electrode, with a larger negative slope correlating to a fast initial decomposition rate
- Similar observed rates using CX, CC and ELAT.
- CeTech exhibiting a markedly slower N-nitrosamine decomposition rate.

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Faradaic Efficiency

$$F = \frac{n * F * z}{Q}$$

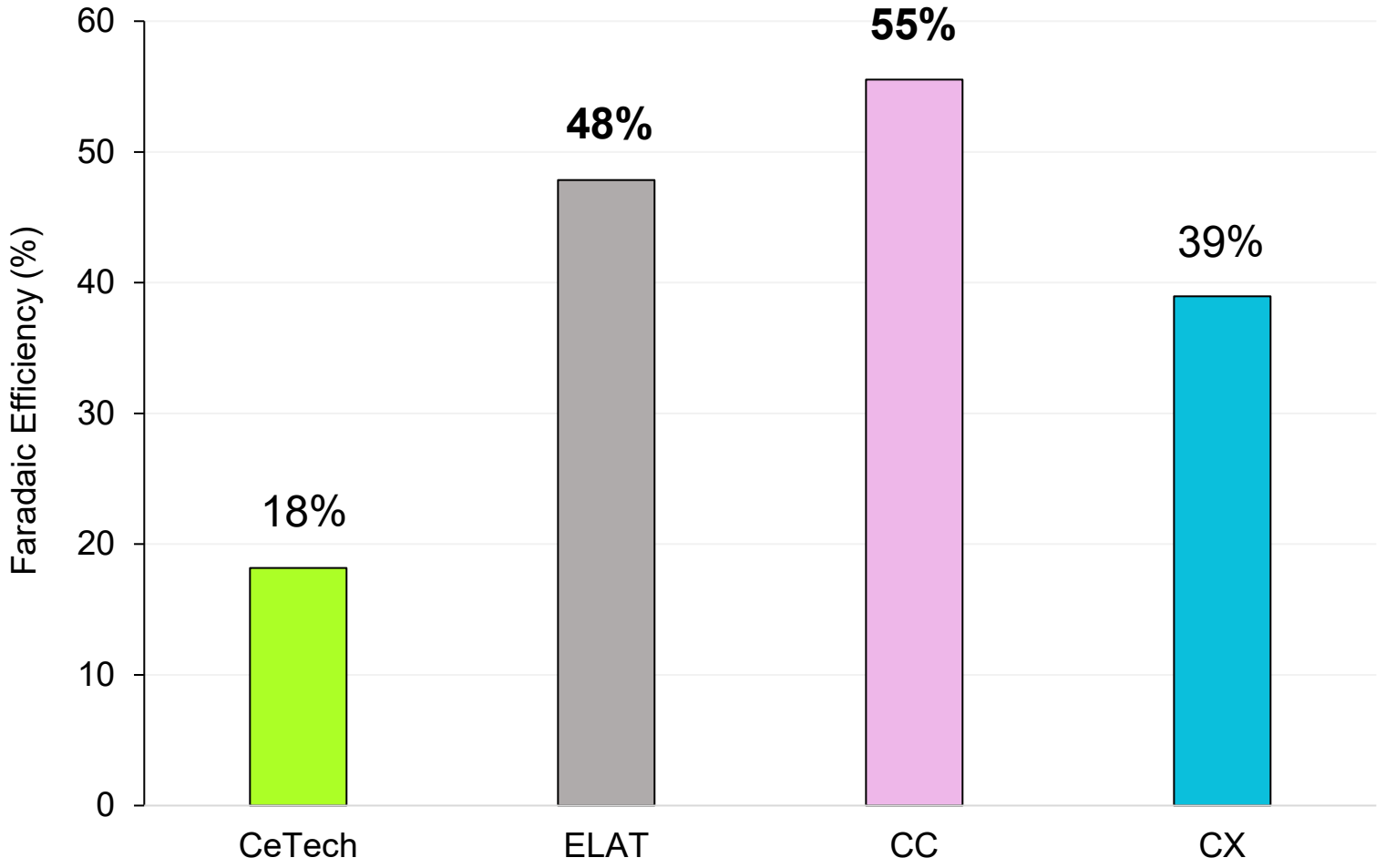
n = N-nitrosamines decomposed

F = Faraday's Constant

Q = total charge passed

z = electrons transfer in reaction ($2e^-$)

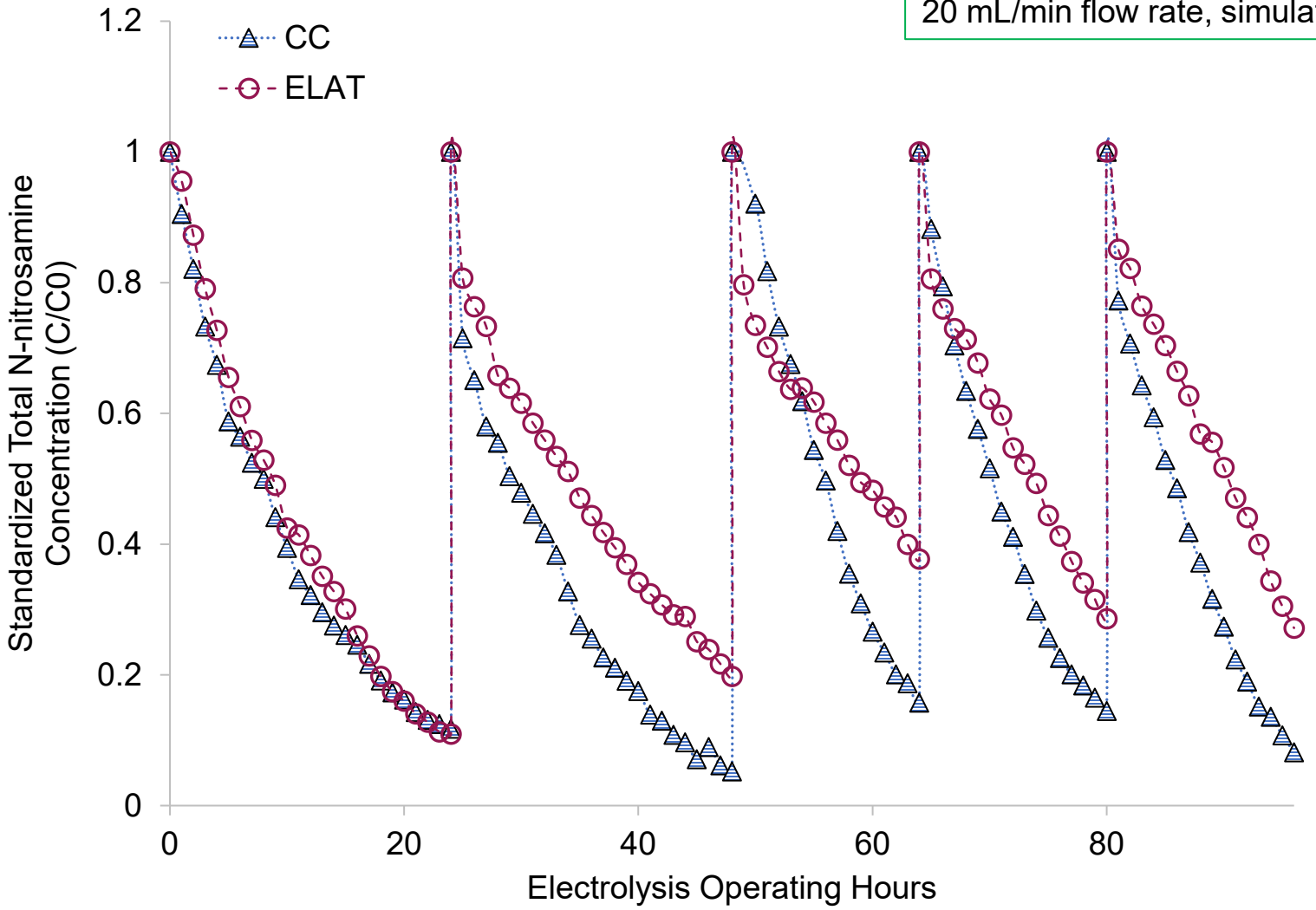
Peak Faraday Efficiency observed within the first two hours of operation



Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Electrode Stability

Operating conditions: 5 cycles for total of 96 hours, 25 mA constant current, 20 mL/min flow rate, simulated waterwash with 1 wt% MEA, NPY, and NDEA



N-Nitrosamine Decomposition Efficiency (%)		
Cycle	**CC**	ELAT
1 (24 hours)	88	89
2 (24 hours)	95	80
3 (16 hours)	84	62
4 (16 hours)	86	71
5 (16 hours)	92	73

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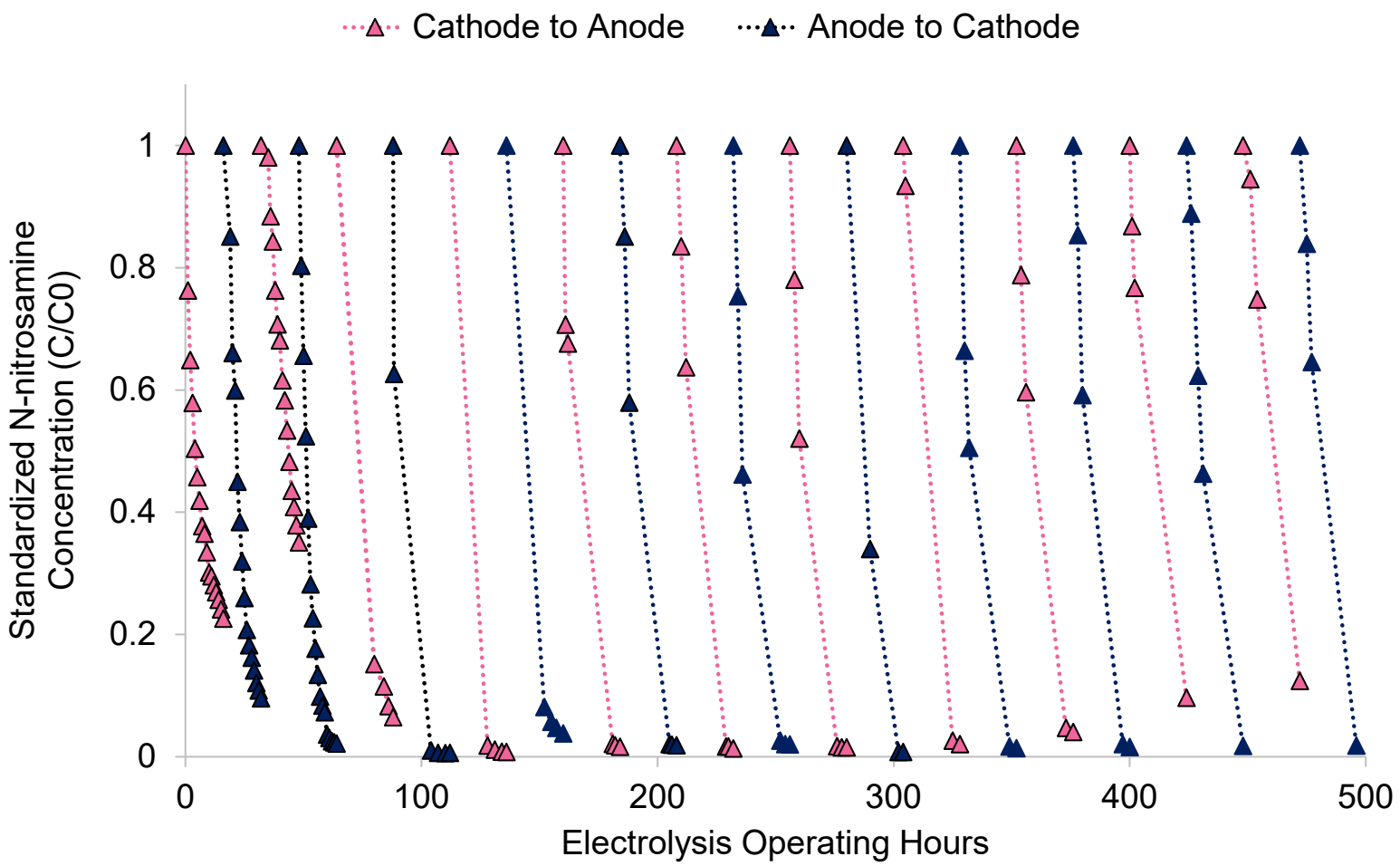
Long Term CC Electrode Stability



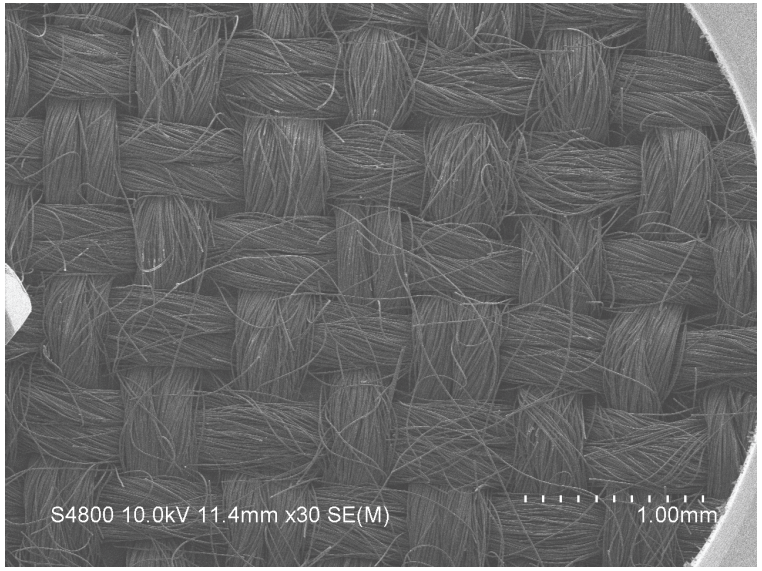
Operating conditions: 500 hours of cyclic operation, 25 mA constant current, 20 mL/min flow rate, simulated waterwash with 1 wt% MEA, NPY, NDEA, NMOR, and **CC electrodes**

Each cycle reached greater than 90% N-nitrosamine decomposition, indicating stable and consistent decomposition over 500 hours of operation

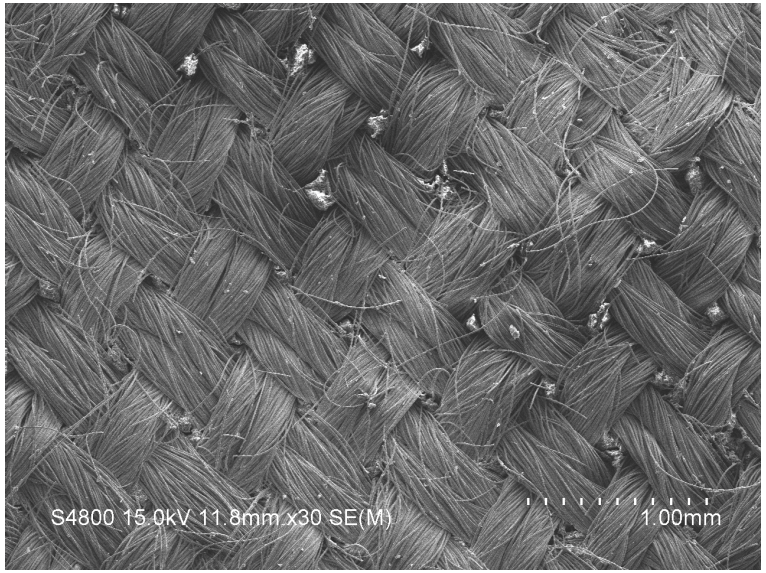
Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

Electrode Stability

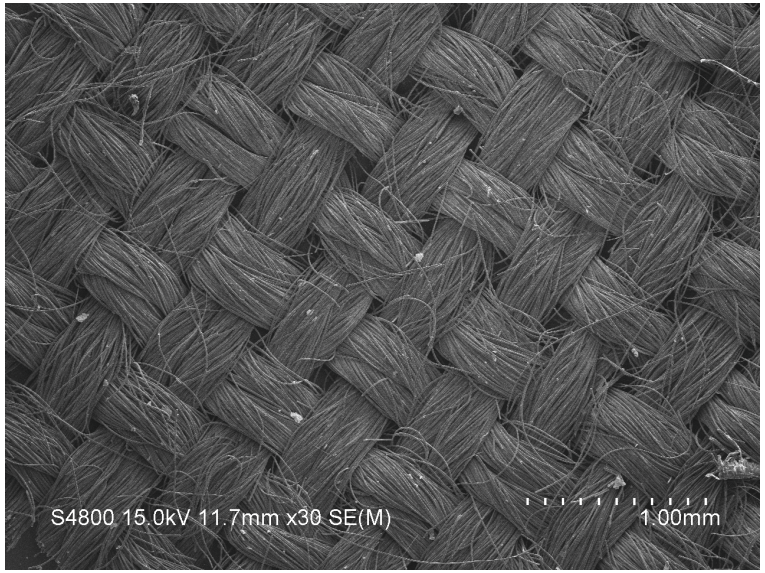
Before



Top electrode



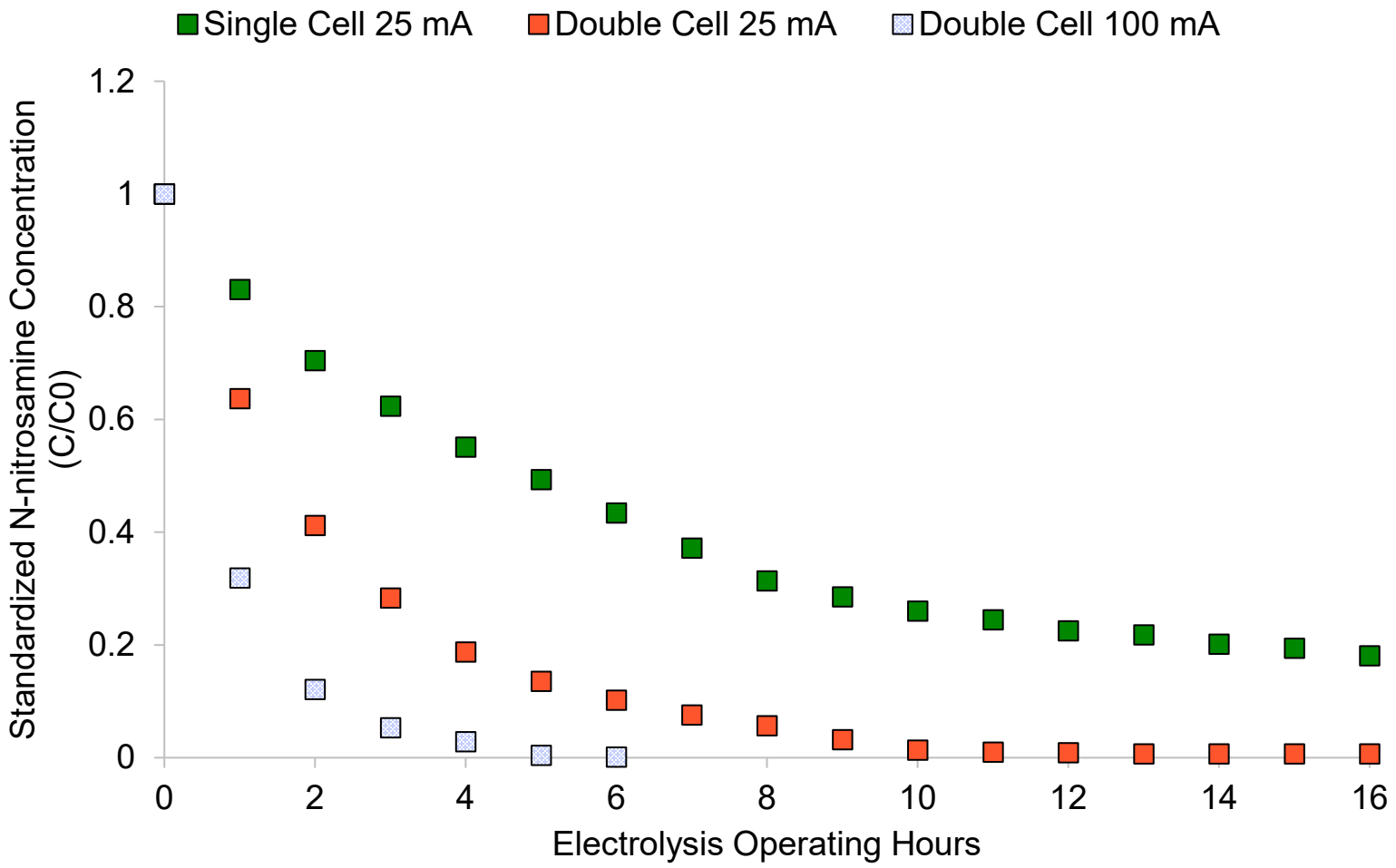
Bottom electrode



Carbon Cloth Electrodes After 500 hours of Electrolysis

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

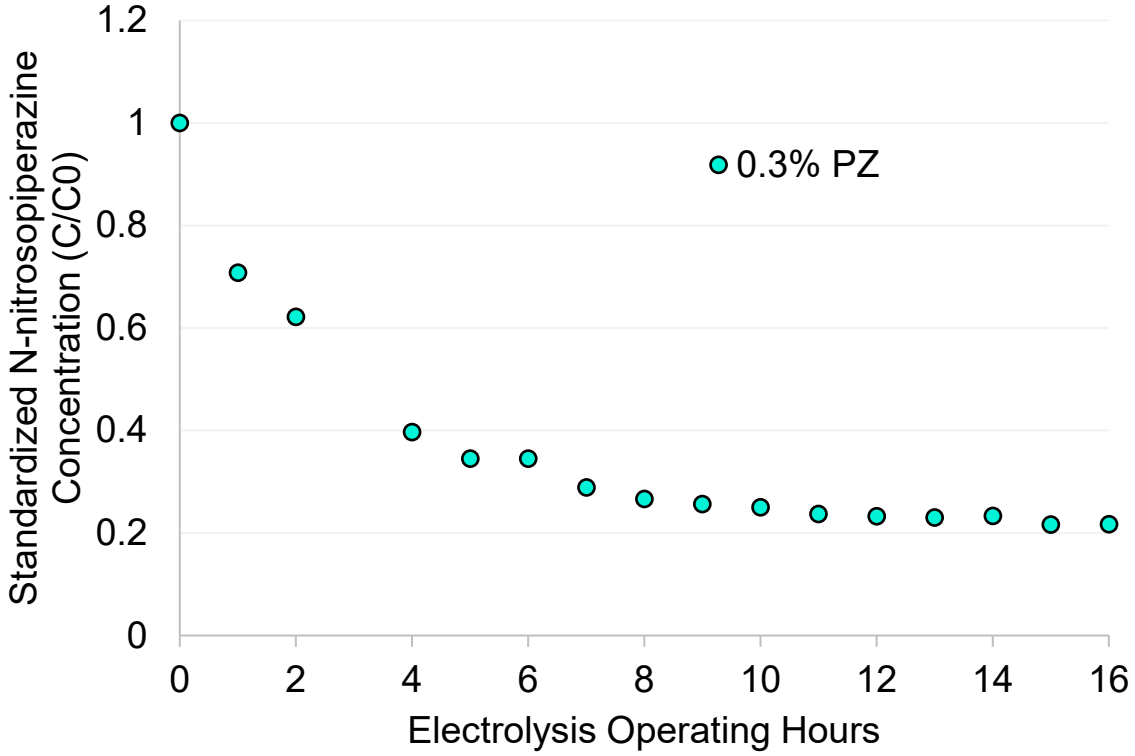
Next Step - Scaleup



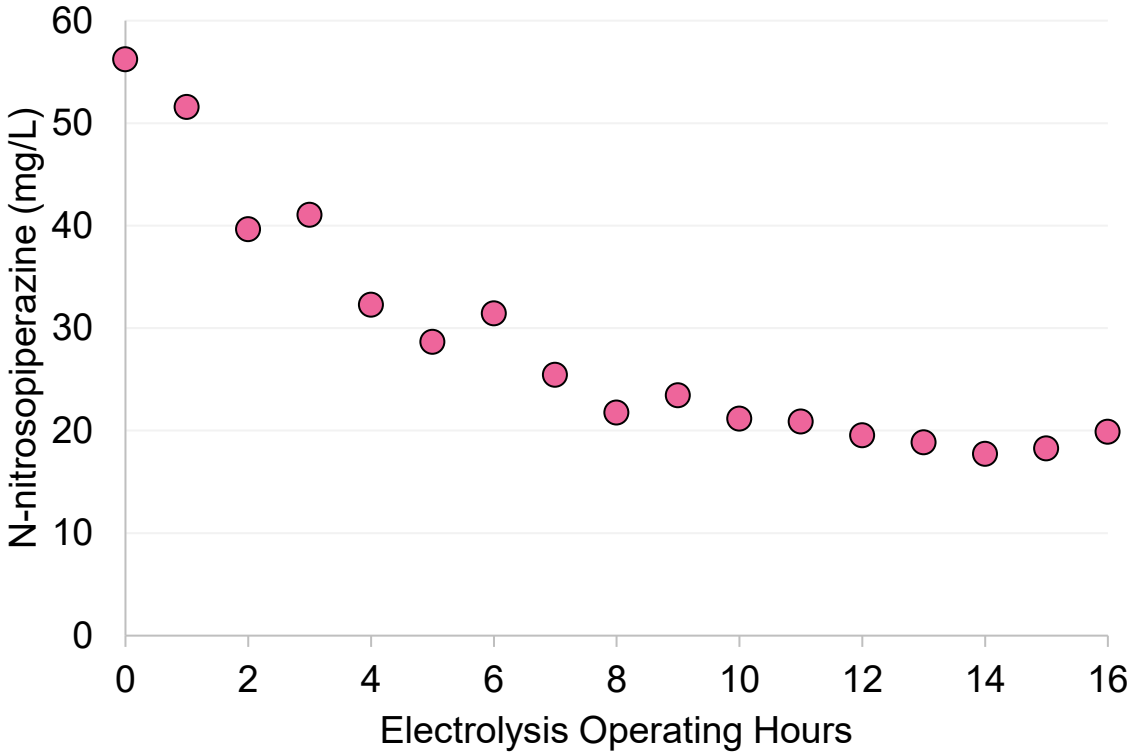
- Total N-nitrosamine decomposition efficiency at > 99% with two cells in series
- Operation at 100 mA led to > 99% N-nitrosamine decomposition within 6 hours of operation
- More electrode surface area = more decomposition and faster

Abad et al., *Industrial & Engineering Chemistry Research* **2025**.

PZ and CESAR1



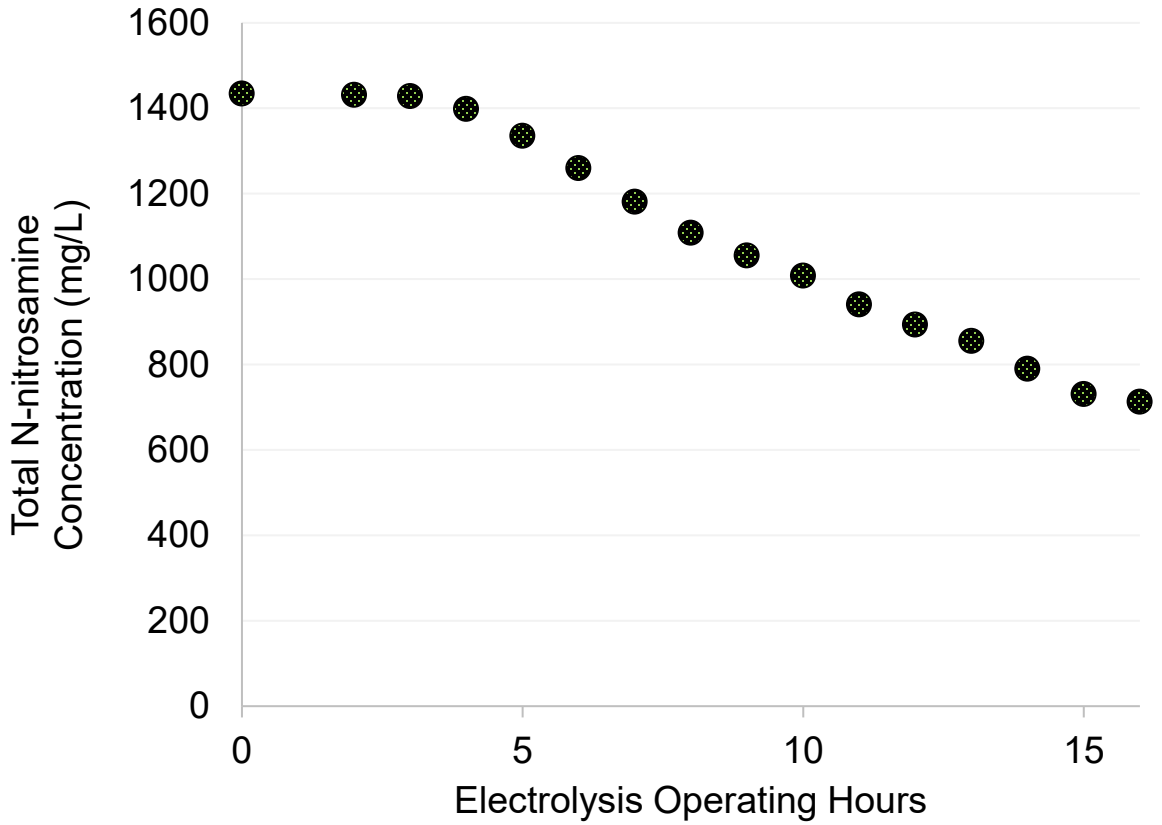
NDEA, NPY, NMOR and NPZ in a PZ waterwash



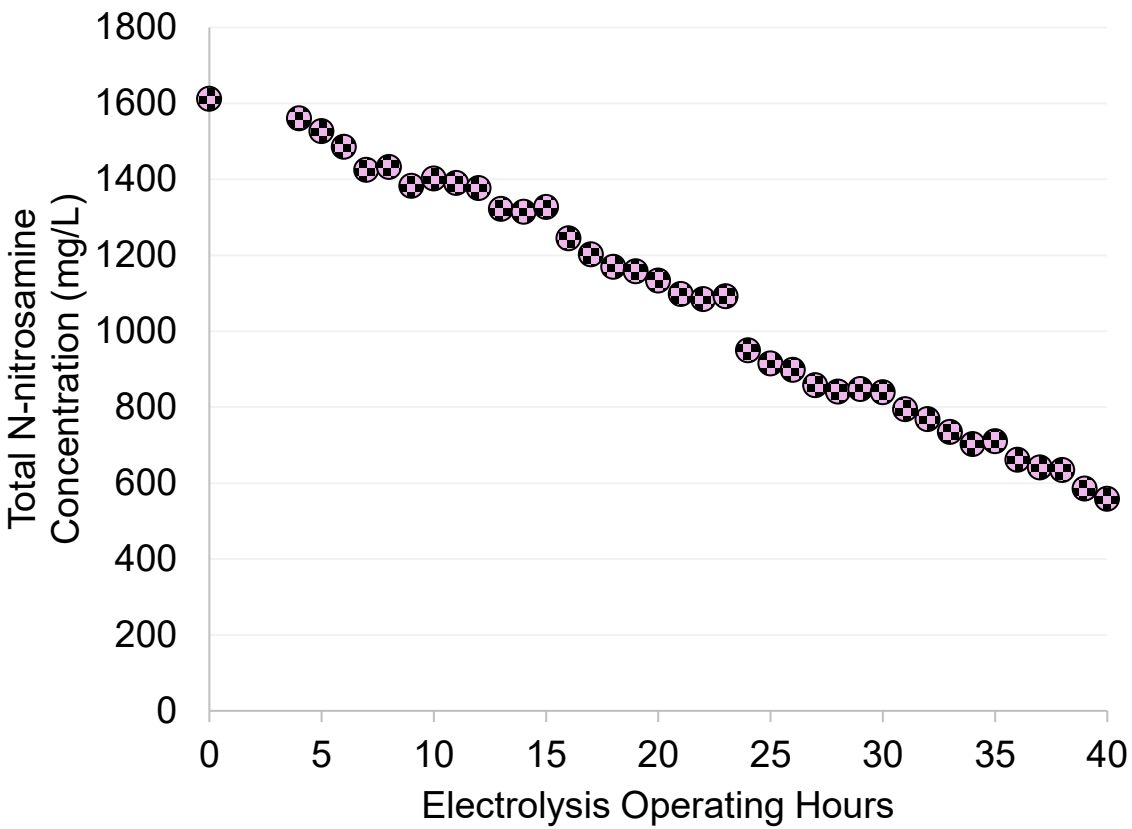
NPZ in CESAR1 waterwash (1%)

Abad et al., *SSRN* **2024.** http://dx.doi.org/10.2139/ssrn.5049344

Direct Solvent Treatment



NPY, NDEA and NMOR
in MEA solvent



NPY, NDEA, NMOR and NPZ
in CESAR1 solvent

Abad et al., *SSRN* **2024.** http://dx.doi.org/10.2139/ssrn.5049344

Toolbox for Environmental Mitigation

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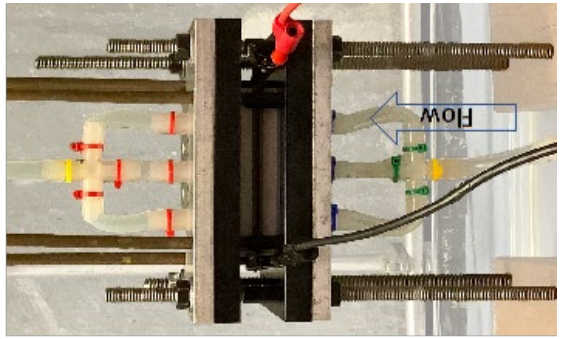
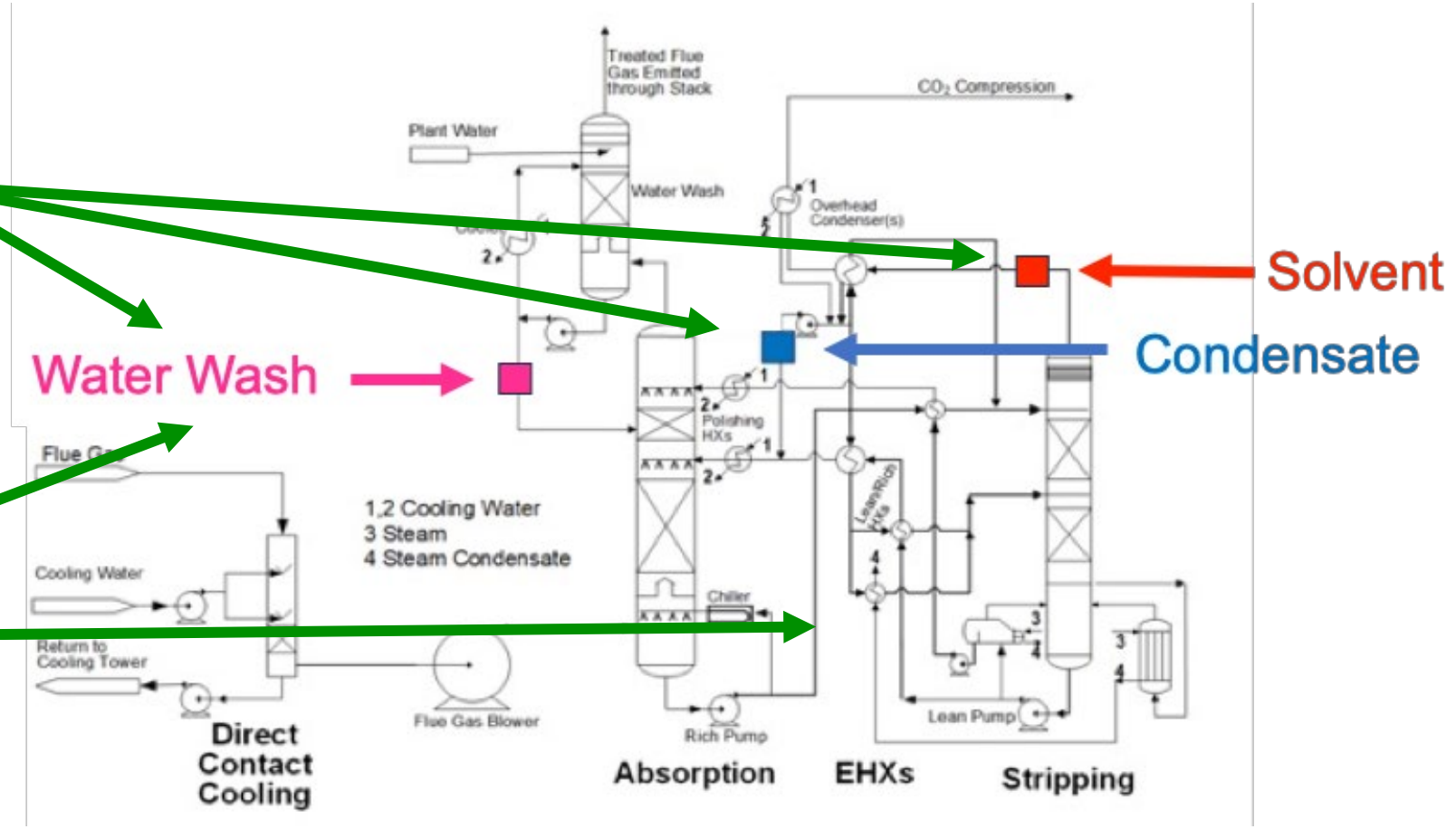
Targeting removal or destruction of VOCs within the CO_2 capture plant before they can be emitted as a strategy for proactive engineering controls and risk reduction

Electrochemical Cell





References

Toma, et al. *Chemosphere*, **2023.**
Available at: https://doi.org/10.1016/j.chemosphere.2023.138915

Abad, et al., *Industrial & Engineering Chemistry Research* **2025**.
Available at: https://doi.org/10.1021/acs.iecr.4c04270

Thompson, et al., Proceedings of the 2025 Biocatalyst Interactions With Gases (BIG), *SSRN* **2024.**
Available at SSRN: http://dx.doi.org/10.2139/ssrn.5049344

Abad, et al., Proceedings of GHGT-17. SSRN **2024**.
Available at SSRN: http://dx.doi.org/10.2139/ssrn.5049344

B.Jurado-Sanchez et al. *Talanta*, **2009.**

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