

Resource recovery from wastewater based on photo-bio-electrochemical and membrane processes with minimal chemical addition

ReWAdd

PROGRAMA
IBEROAMERICANO
CYTED
CIENCIA Y TECNOLOGÍA PARA EL DESARROLLO
RECIRCULA

From Brazilian wastewater to added-value streams: ED/NF/RO nutrient recovery and electrochemical destruction of CECs

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UFRGS · Brazil



Co-funded by
the European Union



Nutrient recovery turns a pollution load into a strategic agricultural input

Why recover nutrients?

Phosphorus is mined from finite deposits, while nitrogen fertilizer depends on energy-intensive ammonia production. Once discharged, N and P drive eutrophication and become far more difficult to recover after dilution.



Strategic and critical material

Phosphate is strategic for Brazil and critical for the EU and the US

≈85%

of Brazil's fertilizer demand was imported in 2022

34.6 Mt

of fertilizers were imported in 2022, exposing agriculture to global prices and supply disruptions

Recovering N and P supports fertilizer security while reducing nutrient discharges to rivers and reservoirs.

Sources: INPI (2023), citing ANDA and the National Fertilizer Plan 2050. Photo: Futura Sciences.

Water reuse turns treated wastewater into a climate-resilient local supply

Why reuse water?

Climate change is making water availability less predictable. Fit-for-purpose reuse converts treated wastewater into a reliable local source for irrigation, industry, urban services and environmental support—preserving higher-quality water for uses that need it.



Direct potable reuse

are increasing around the world

>10 M

people in Brazil were affected by droughts in 2024

50.3%

of Brazil's water withdrawals in 2024 were for irrigation—an immediate fit-for-purpose reuse opportunity

Reuse reduces freshwater withdrawals and discharge loads while strengthening drought resilience.

Sources: ANA, Conjuntura 2025; Regulation (EU) 2020/741; WHO potable-reuse guidance (2017). Photo: Su ve Çevre.

CEC destruction prevents contaminants from circulating through water reuse and products recovery

Why destroy CECs?

CECs include pharmaceuticals, pesticides, PFAS, microplastics and antimicrobial-resistance determinants. Many can pass through conventional treatment and continue circulating through receiving waters, reuse systems or recovered products.



Separate and concentrate

Phosphate is strategic for Brazil and critical for the EU and the US

EU 2024/3019

introduces quaternary treatment for micropollutants at large urban WWTPs

BRAZIL

CONAMA 430/2011 sets conventional effluent limits, but no nationwide routine limits for most CECs

CECs control is a prerequisite for safe reuse and uncontaminated recovered products.

Sources: CONAMA 430/2011; Directive (EU) 2024/3019; ReWAdd WP2 evidence. Photo: University at Buffalo.

Nutrient supply, Water quality and Emerging contaminants are three pressures with a single point of intervention: the wastewater treatment plant

What plants do today

- Nitrogen is removed biologically and lost to the atmosphere as N_2 , N_2O and NO_x .
- Phosphorus is precipitated with Al^{3+} , Fe^{3+} or $\text{Ca}(\text{OH})_2$, which raises sludge volume by up to 40%.
- CECs removal is implemented in very few plants; ozonation and activated carbon are the state of the art.
- Treated wastewater is disposal in surface water bodies.

What the new rules demand

- The revised Urban Wastewater Treatment Directive sets nutrient and micropollutant targets for 2033–2045, alongside energy neutrality.
- Recovery — not removal — is what turns a compliance cost into a product.
- Brazil is the world's largest fertiliser importer and the 4th largest consumer, so the same technology answers a supply-security question.

Wastewater has been treated as a waste to be cleaned, rather than a resource to be mined.

Concentration, extraction, destruction and conversion

SO1

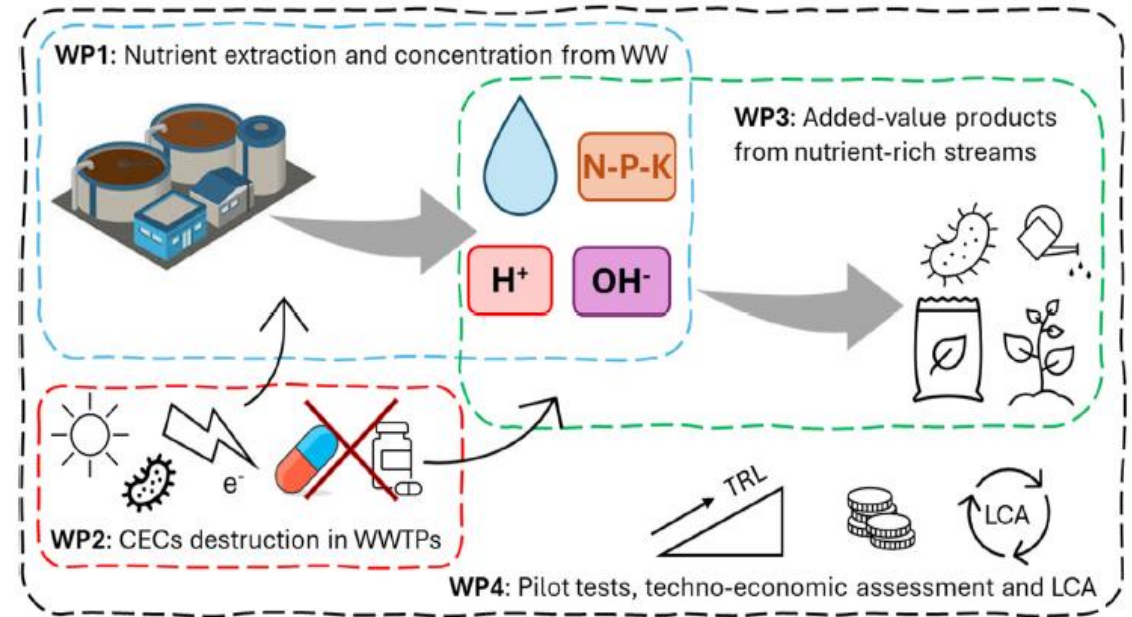
Couple processes that **extract nutrients**, **concentrate** them into feedstocks, and convert them into **marketable products**.

SO2

Destroy CECs along every route, so they never reach the product streams or accumulate in the environment.

SO3

Add minimal or no chemicals and generate **minimal secondary waste**, raising the **circularity of the plant**.



Targets the consortium committed to

< 2 mg N/L · < 0.5 mg P/L
discharge quality

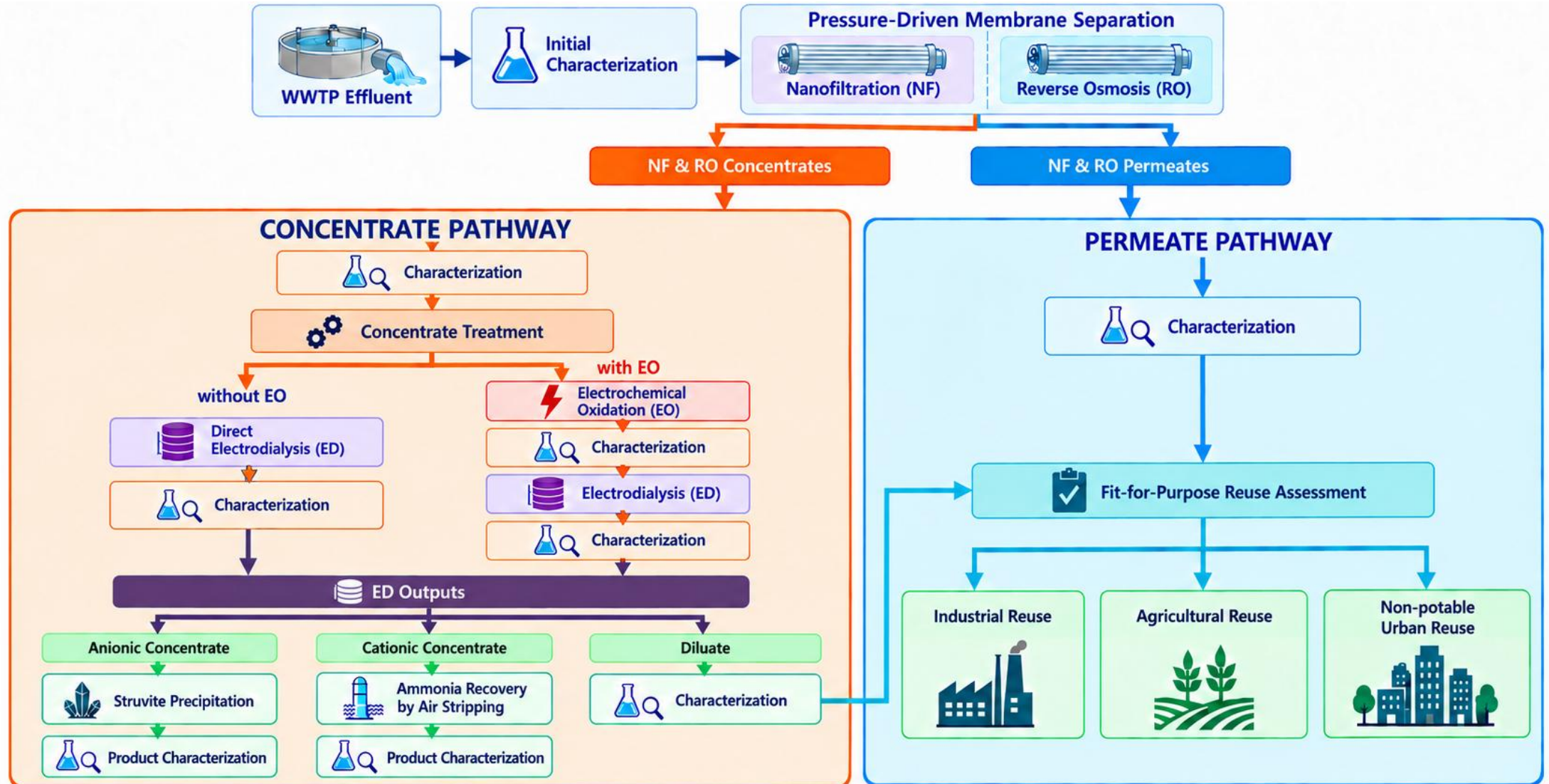
up to -40 %
sludge production

> 85 %
CEC removal

15 g + 12.5 g
struvite + protein per m³

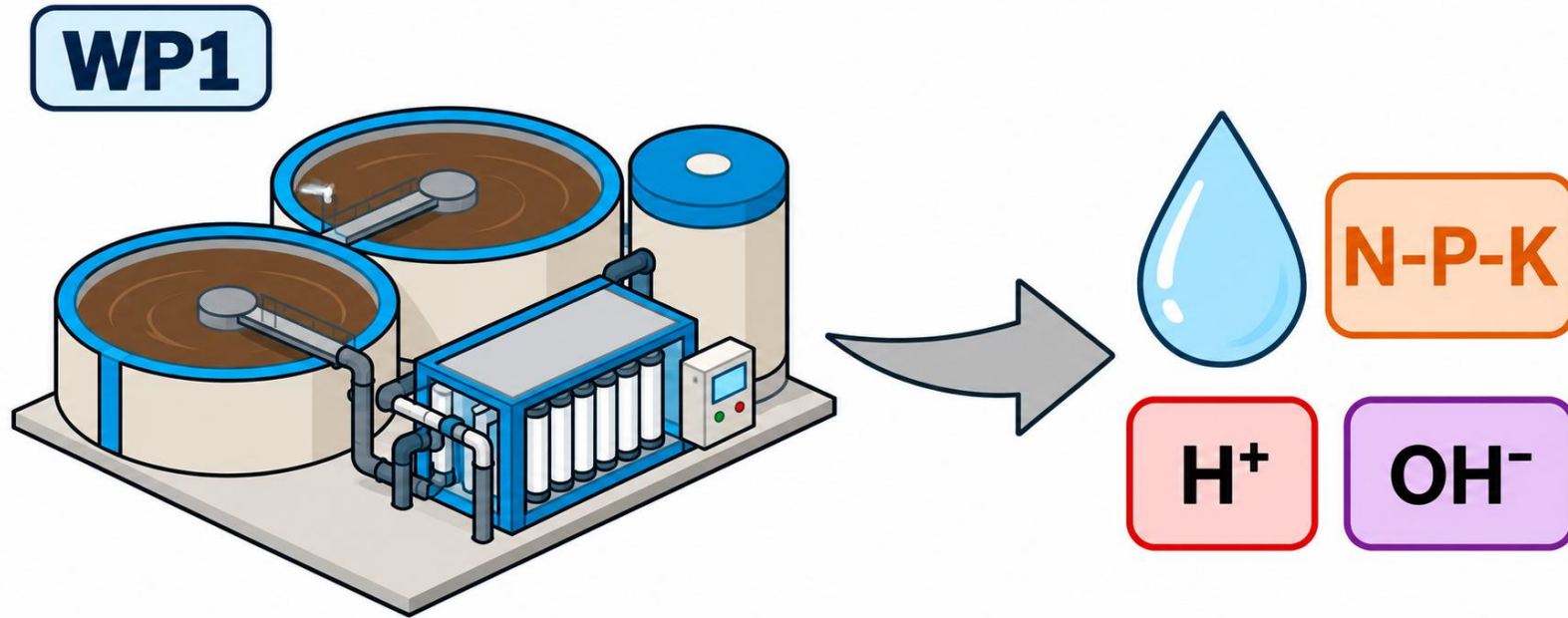
TRL 3 to 5
by month 36

Links pressure-driven membranes to EO, ED - recovery and reuse assessment

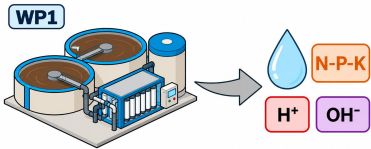


Characterization: physicochemical • microbiological • structural and morphological

WP1: nutrient extraction and concentration from wastewater



Regional data set

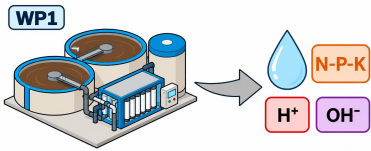


Six wastewater treatment plants in the Porto Alegre metropolitan region covered four treatment configurations.

WWTP	Treatment configuration	NH ₃ -N (mg/L)	Total P (mg/L)
Esteio-Sapucaia	Aerobic	15.61	1.50
Freeway	Anaerobic + facultative	8.43	2.73
Granja Esperança	Aerobic	18.17	1.85
Guaíba	Anaerobic + aerobic	1.46	<0.03
Mato Grande	Extended aeration	5.56	0.76
Parque dos Anjos	Anaerobic + facultative	9.97	8.03

The wide regional range supports a feed based on multiple plants rather than one local snapshot.

Reverse osmosis concentration run



Alfa Laval LabStak® M20-0.72-PSO

Membrane assembly

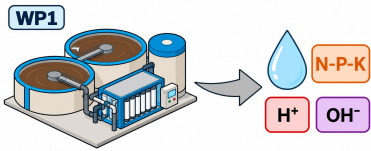
Membrane	BW30 flat-sheet RO
Assembly	5 membrane sandwiches
Area	0.036 m² each, 0.18 m² total

Concentration run

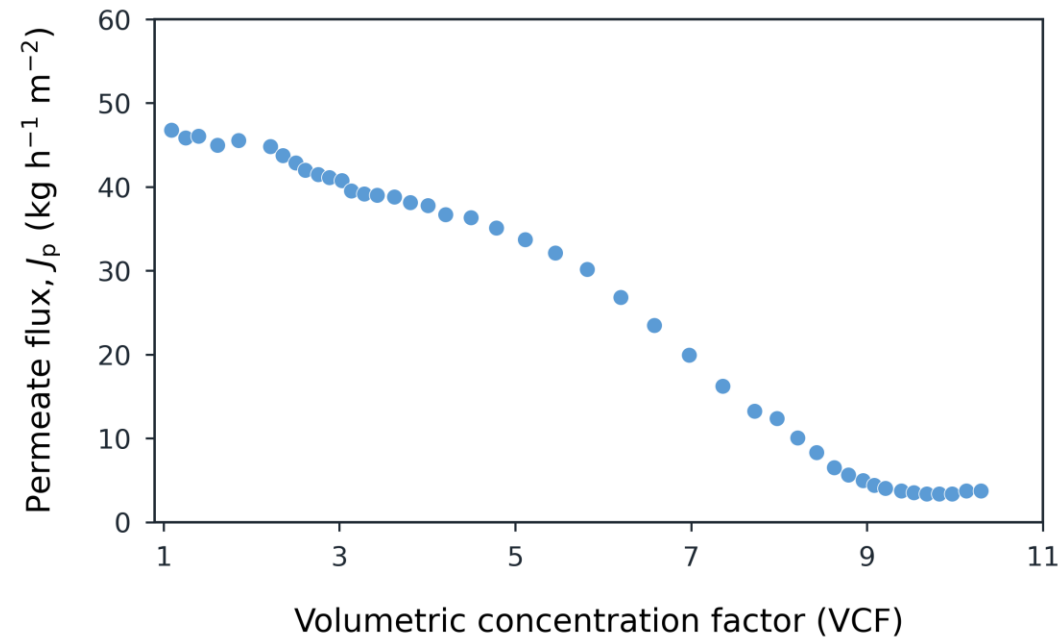
Feed	240 L secondary effluent
Pressure	25 bar
Temperature	25 °C
Recirculation	480 L h ⁻¹
Operation	39 h, intermittent daily operation
Sampling	Permeate flow and volume every 30 min

Batch concentration: retentate recirculated; permeate withdrawn continuously

RO turned a dilute wastewater into a precipitable P stream



Permeate flux declined as the volumetric concentration factor increased



RO produced a low-P permeate for reuse and a phosphorus-rich concentrate for WP3.

10.5
volumetric
concentration factor

90%
water recovered as
permeate (217.0 L)

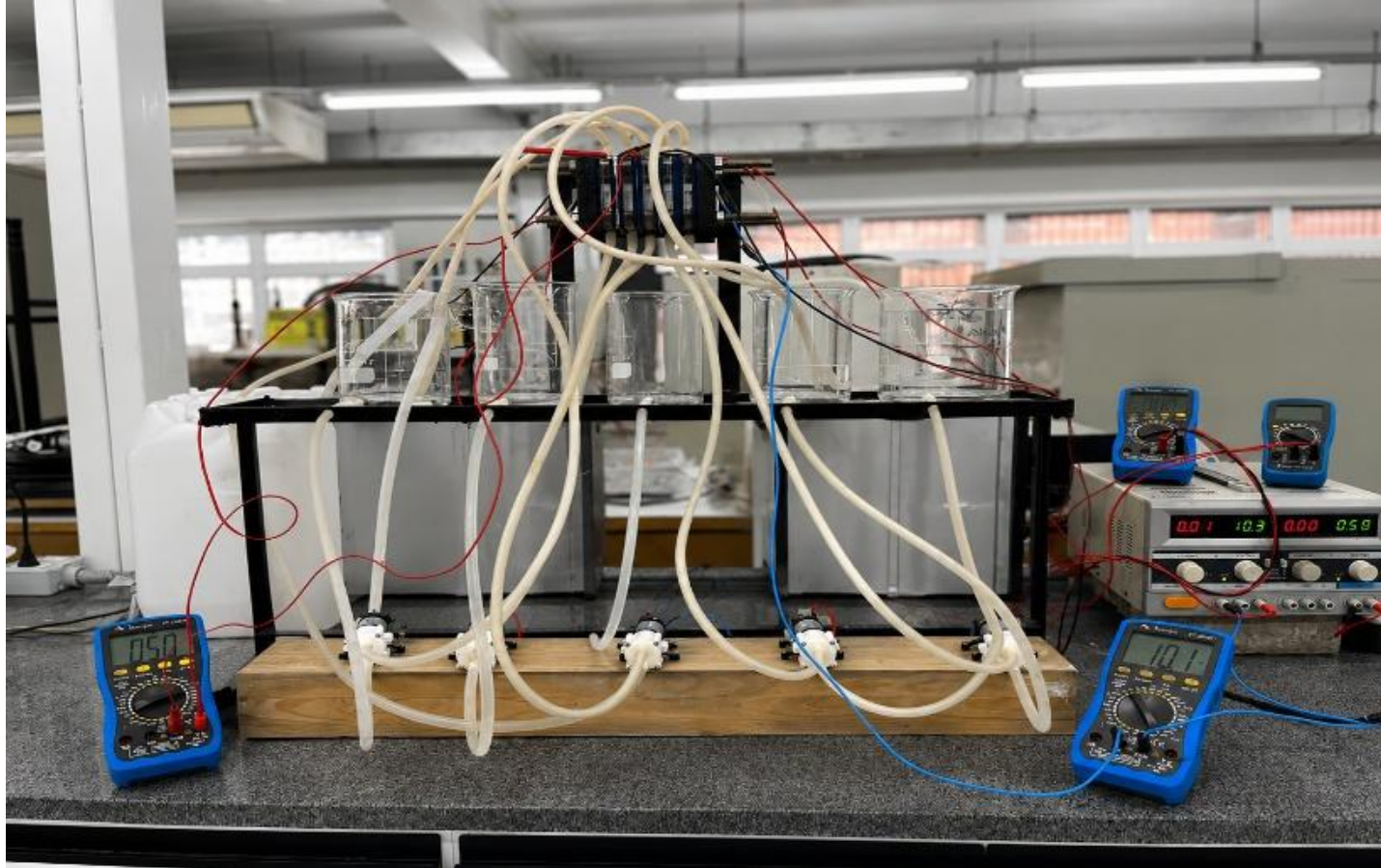
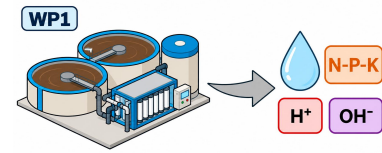
8 to 149 mg P/L

0.24 mg P/L
phosphorus in the
pooled permeate

97.5%
apparent P rejection

Sample	pH	Conductivity (µS/cm at 25 °C)
Synthetic secondary effluent (feed)	6.38	314.2
RO concentrate	7.73	4,700
Total BW30 permeate	7.39	35.36

Direct electrodialysis (ED) of secondary effluents



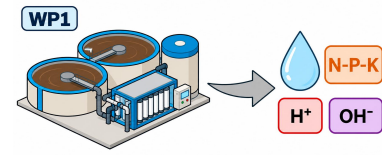
CELL CONFIGURATION

System	5 independent stacks
Membranes	4 total: 2 CEM + 2 AEM
Electrodes	Ti/70TiO ₂ ·30RuO ₂ , 16 cm ² each

OPERATING CONDITIONS

Diluate	15 L secondary effluent
Concentrate	0.5 L effluent in each
Electrode loop	0.5 L of 2.0 g L ⁻¹ Na ₂ SO ₄ in each
Flow rate	18 L h ⁻¹
Operation	64 h; 1.75 mA cm ⁻²

Electrodialysis (ED) to secondary effluents



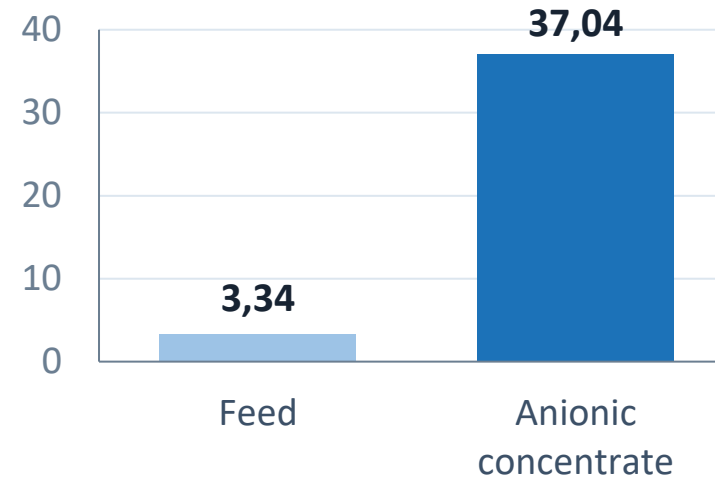
Visible change in the effluent



Before ED

After 64 h

Phosphorus concentration (mg P L⁻¹)



11.1×

P concentration factor

37%

feed P recovered

800 to 274

μS cm⁻¹ in the diluate

pH during the run

≈ 2

Anionic concentrate

7-11

Cationic concentrate

5-7

Diluate

Ion removal slowed after about 45-50 h as concentration polarization developed.

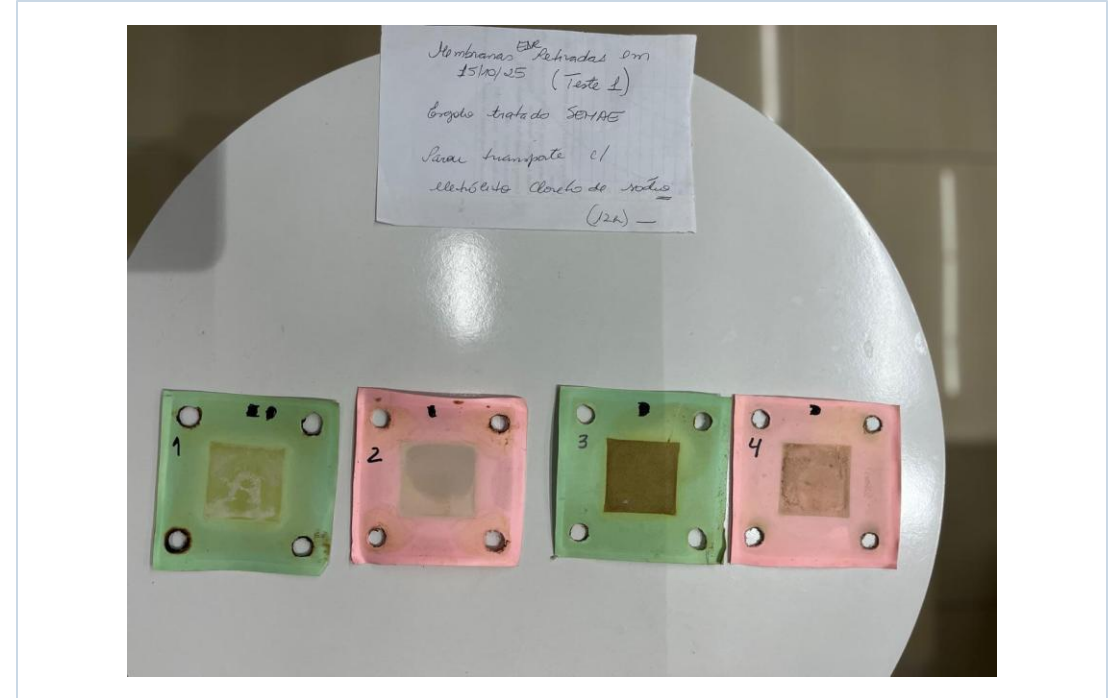
Membrane changed visibly during the ED experiment

Before use and stack assembly



Clean sheets and assembled stack

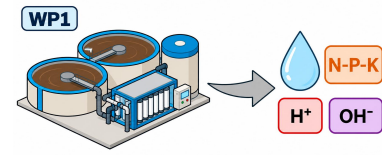
After the 64 h run



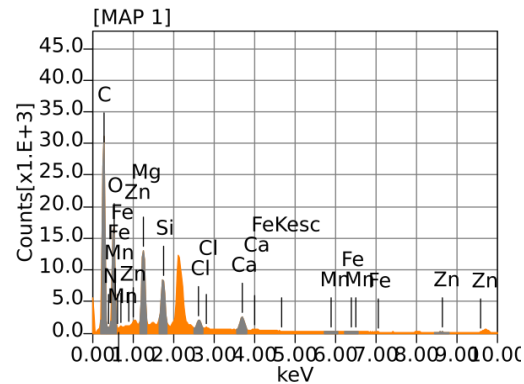
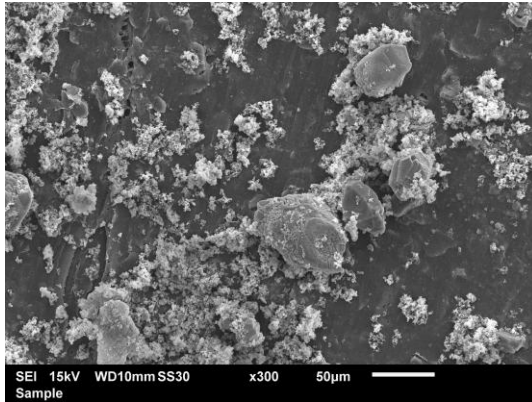
Discoloration and surface deposits

The visual changes may indicate fouling and scaling.

SEM-EDS confirms heterogeneous deposits

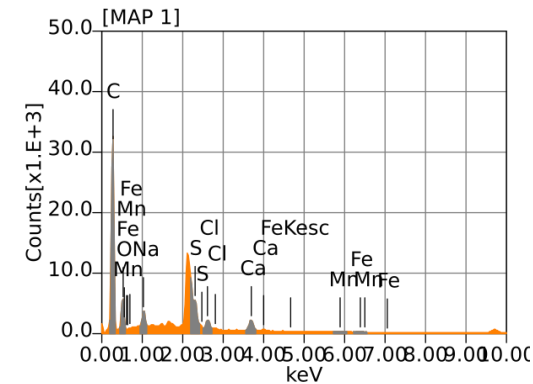
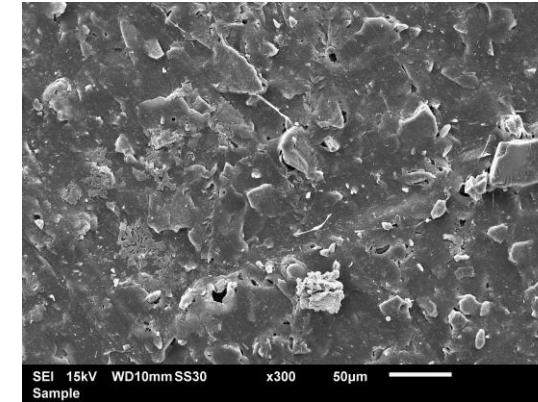


Anion-exchange membrane



C and O dominate; Ca, Cl, S, Fe and Zn were also detected.

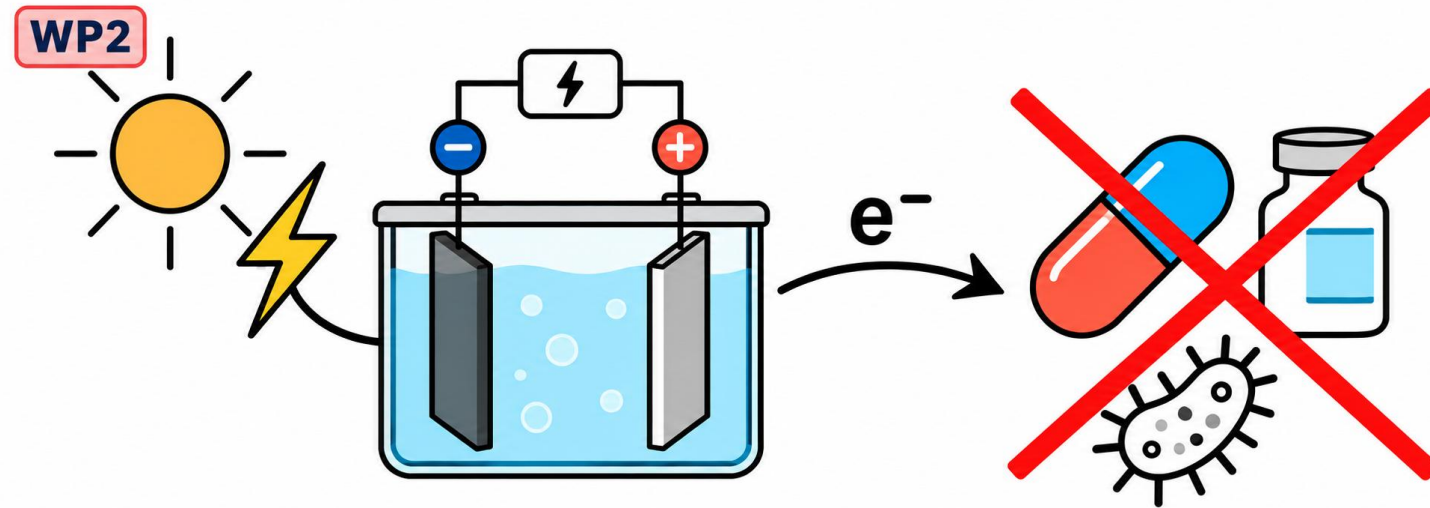
Cation-exchange membrane

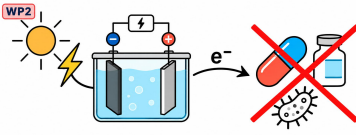


C and O dominate; Na, Mg, Si, S, Ca, Fe and Nb varied by analyzed area.

EDS identifies elements in the deposits, not crystalline phases.

WP2: CECs destruction in WWTPs





EO has not yet been applied to this RO and ED concentrate

Four studies support the WP2 concentrate-treatment design



RO LANDFILL LEACHATE

Electrochemical oxidation and membrane distillation for RO-concentrated landfill leachate

Illi et al., Sep. Purif. Technol. 370 (2025) 133229

[10.1016/j.seppur.2025.133229](https://doi.org/10.1016/j.seppur.2025.133229)



RO HOSPITAL WASTEWATER

RO and electrochemical oxidation for pharmaceuticals and AMR bacteria in hospital wastewater

Rizzana et al., J. Environ. Chem. Eng. 14 (2026) 124883

[10.1016/j.jece.2026.124883](https://doi.org/10.1016/j.jece.2026.124883)



NF REAL SURFACE WATER

NF-assisted electro-Fenton for pharmaceuticals in real surface water

Giacobbo et al., Desalination (2026) 120626

[10.1016/j.desal.2026.120626](https://doi.org/10.1016/j.desal.2026.120626)

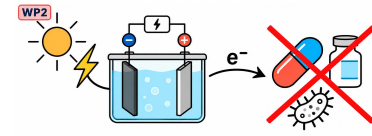


NF PLUS ELECTRO-FENTON

Nanofiltration and electro-Fenton for pharmaceutical degradation

Albornoz et al., Sep. Purif. Technol. 373 (2025) 133639

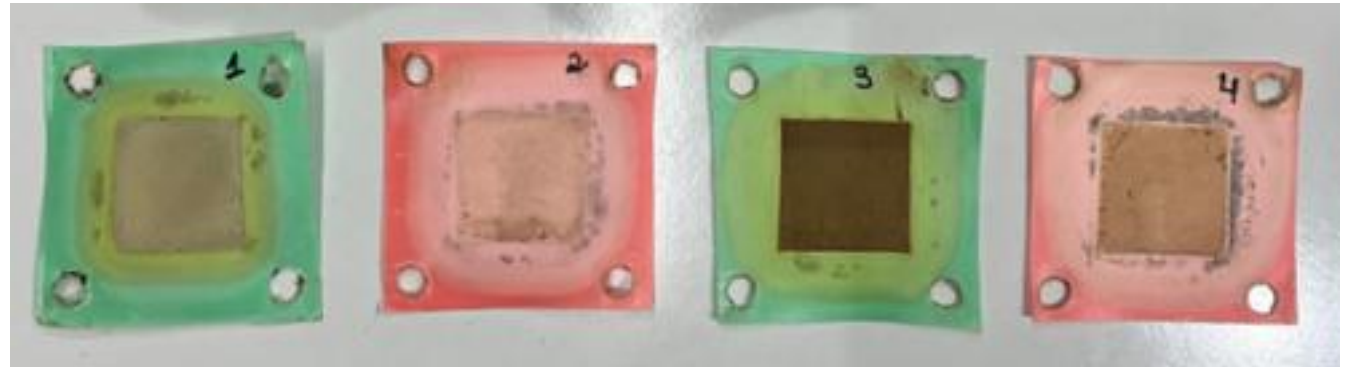
[10.1016/j.seppur.2025.133639](https://doi.org/10.1016/j.seppur.2025.133639)



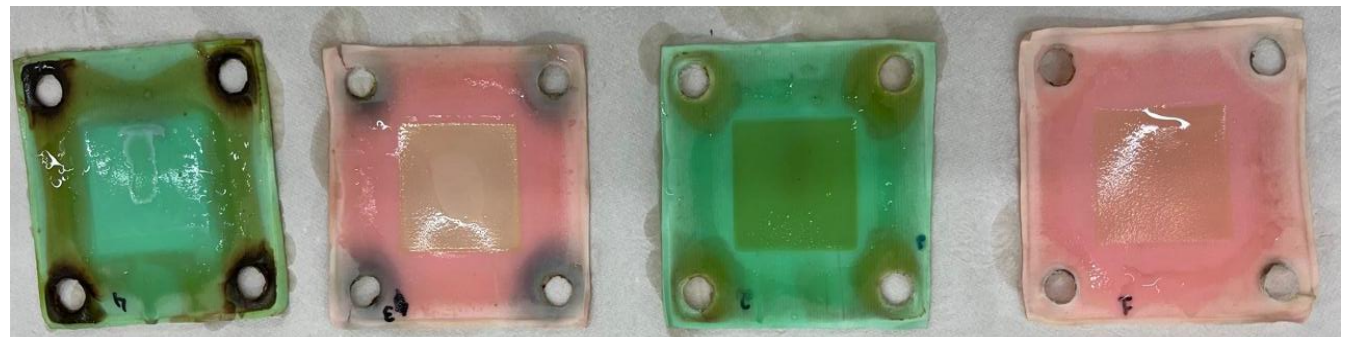
Small preview of EO applied to NF concentrate before selective ED nutrient separation



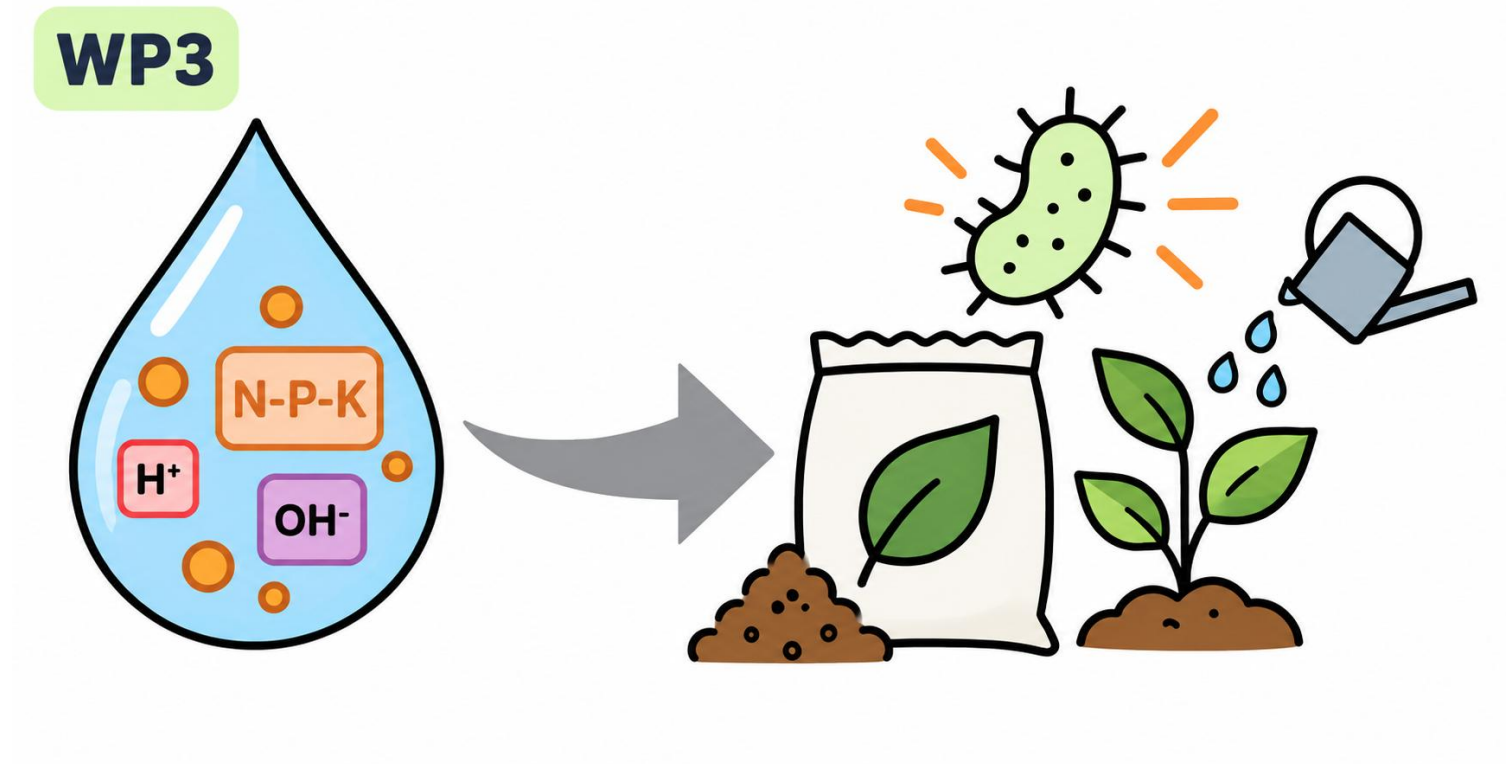
ED applied to NF concentrate



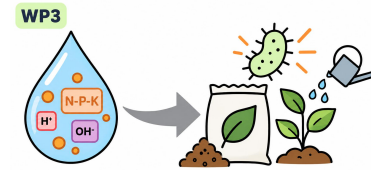
ED applied to NF concentrate after EO



WP3: Added-value products from nutrient-rich streams



RO concentrate yielded a struvite-rich crystalline solid



91%

P removed from the treated aliquot

1.25 g

dry solid from the 1 L aliquot treated with $\text{Mg}(\text{OH})_2$

+127%

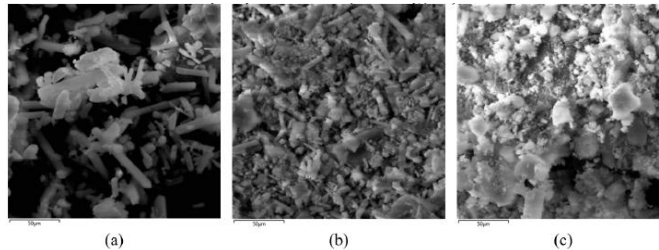
more dry mass than natural settling

72-76%

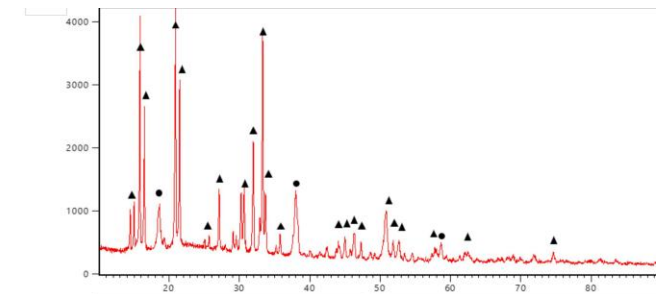
struvite by XRD, ~8% K-struvite and ~20% brucite



Dry solids after settling, filtration and drying at 40 °C



SEM at 1000×: reference struvite, $\text{Mg}(\text{OH})_2$ treatment and natural settling



XRD identified struvite, K-struvite and brucite

$\text{Mg}(\text{OH})_2$ increased solid recovery and produced a struvite-rich mineral mixture.

Thank you — and to the Brazilian team



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