IOCC 2026 Conference
The 5th International Online Conference on Crystals
15–17 June 2026 | Online
MDPI

CFD Design of a NETmix Crystalliser for Struvite Precipitation from Sidestream Digestate

Laura J.R. Cullen[1*], Isabel S. Fernandes[1], Madalena M. Dias[1], José Carlos B. Lopes[1], Vítor J.P. Vilar[1], Ricardo J. Santos[1]

[1]LSRE-LCM, ALiCE, Faculty of Engineering, University of Porto, Rua Dr. Roberto Frias, 4200-465 Porto, Portugal
*Corresponding author: up201806139@edu.fe.up.pt

INTRODUCTION & AIM

Wastewater treatment plants

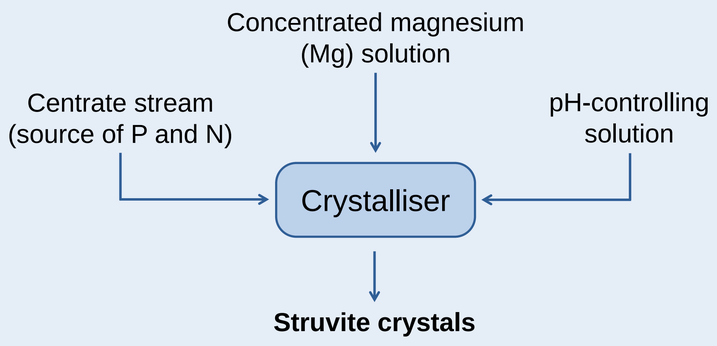
Dewatering process of digested sludge generates a liquid stream called the **centrate**[1,2]

Source of phosphorus (P) and nitrogen (N)[1,2]

Recovery of P and N in solid form through the **struvite precipitation** process[1,2]

Struvite crystals are subsequently used as slow-release environmentally-friendly fertilisers[1,2]

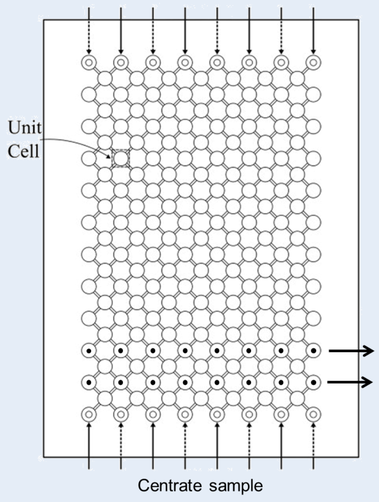
Struvite precipitation process[3]



Main objective

Assess the effect of injection chamber position on the micromixing performance of the NETmix reactor through the Computational Fluid Dynamics (CFD) simulation of passive tracer mixing

Struvite precipitation in NETmix



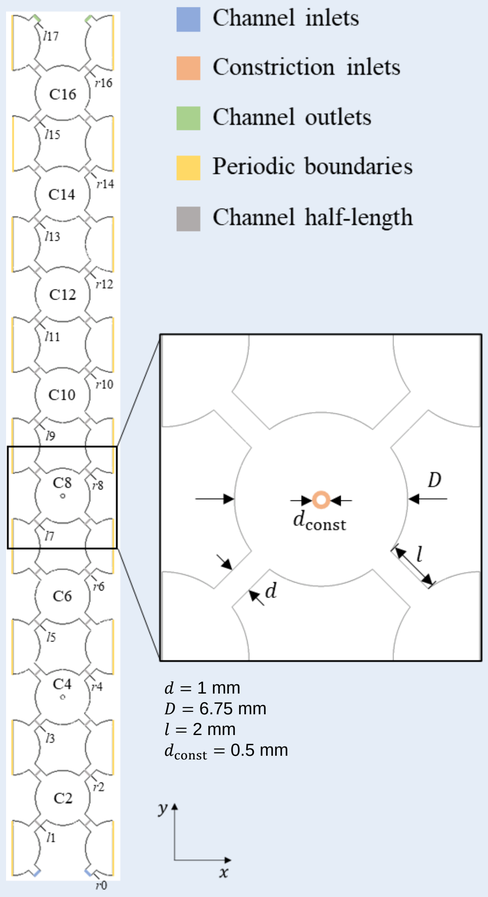
NETmix must ensure **efficient mixing** between the pH and Mg solutions with the centrate stream

How?

Injection chambers along the NETmix network

The Mg and pH-controlling solutions are separately injected at low flowrate ratios relative to the main feed flowrate (effluent) directly into selected chambers along the NETmix reactor

CFD MODEL



- Simulation of **passive tracer mixing** experiments
- No sub-grid scale modelling
- **Working fluids**: water (centrate stream), tracer 1 (Mg solution) and tracer 2 (pH solution) (ρ = 998.2 kg m^{-3} and μ = 1.003 mPa s)
- **Inlet conditions**:
  - Channel inlets: $\mathrm{Re_{ch}}$ = 300 (water)
  - Constriction inlets: $\mathrm{Re_{const}}$ = 45 (bottom: tracer 1 | top: tracer 2)
- **Topologies of injection studied**:
  - C2 and C4
  - C2 and C6
  - C2 and C8
  - C2 and C10
  - C4 and C6
  - C4 and C8
  - C4 and C10

d = 1 mm
D = 6.75 mm
l = 2 mm
d_{const} = 0.5 mm

$\mathrm{Re_{ch}}$ - Channel inlet Reynolds number
$\mathrm{Re_{inj}}$ - Constriction inlet Reynolds number
ρ - fluid density
μ - fluid viscosity

Figure 1. 2D NUB17 CFD model

RESULTS & DISCUSSION

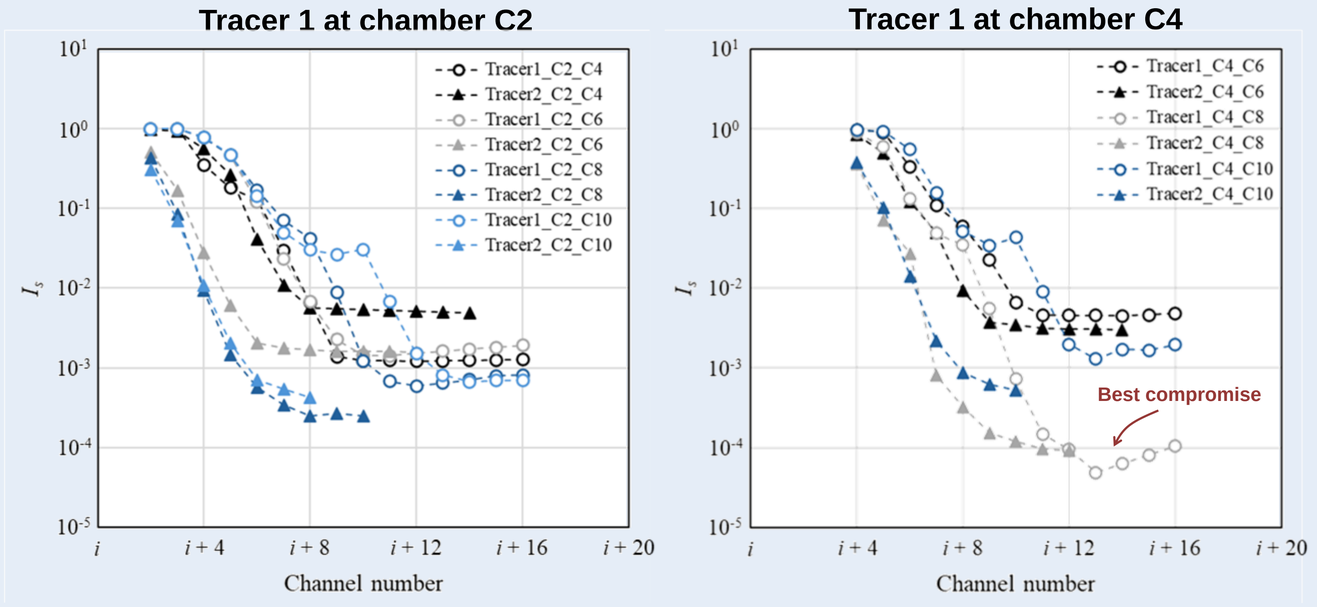


Figure 2. Intensity of segregation, $I_s = \frac{\sum_{n=1}^{N}(x_t - \bar{x}_t)^2}{\bar{x}_t(1-\bar{x}_t)N}$, along the NETmix channels when tracer 1 is injected in chamber C2 (on the left) and in chamber C4 (on the right) ($\bar{x}_t$ - average tracer mass fraction)

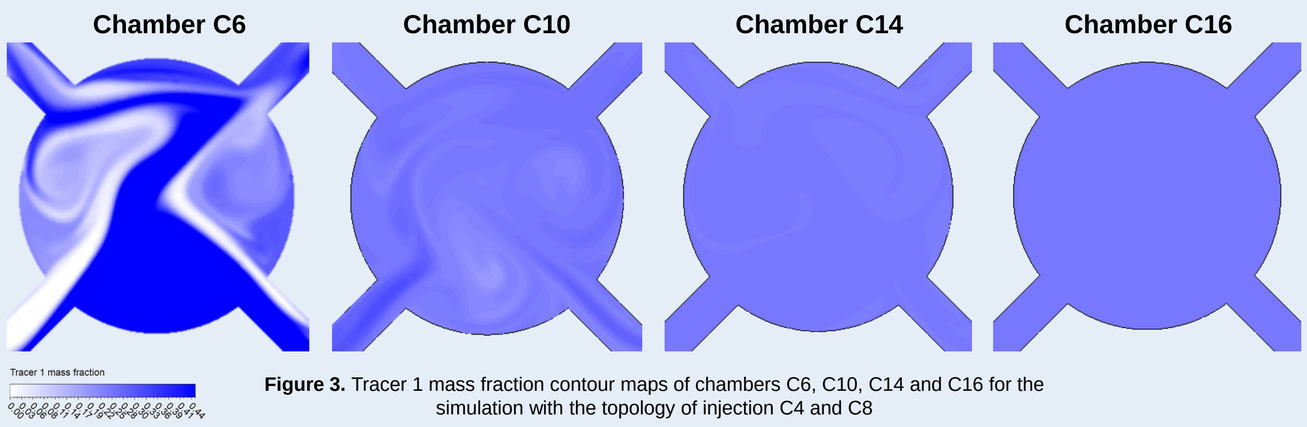


Figure 3. Tracer 1 mass fraction contour maps of chambers C6, C10, C14 and C16 for the simulation with the topology of injection C4 and C8

CONCLUSIONS

- Results showed that the topology of injection has a great impact on mixing;
- For all configurations studied, the intensity of segregation decreased along the NETmix network, indicating **progressive homogenisation of the streams**;
- The topology of injection that ensured **better mixing performance** (lower I_s values) was the one with the injection points at **chambers C4 and C8**;
- The optimised injection scheme reduced the intensity of segregation by 99.9 %;
- It also ensured **comparable mixing degrees for both tracers** (Mg and pH-controlling solutions) at the outlets;
- These results are highly relevant for crystalliser design, since mixing directly influences supersaturation, chemical reaction, nucleation and crystal growth during precipitation processes;
- A NETmix crystalliser prototype was constructed based on the CFD results of the present work and will be used for the production of struvite crystals from centrate streams.

REFERENCES

[1] Zhang, T., R. Jiang, and Y. Deng, Phosphorus Recovery by Struvite Crystallization from Livestock Wastewater and Reuse as Fertilizer: A Review, in Physico-Chemical Wastewater Treatment and Resource Recovery, R. Farooq and Z. Ahmad, Editors. 2017, IntechOpen: Rijeka.
[2] Desmidt, E., et al., Global Phosphorus Scarcity and Full-Scale P-Recovery Techniques: A Review. Critical Reviews in Environmental Science and Technology, 2015. 45(4): p. 336-384.
[3] Lu, H., et al., Crystallization techniques in wastewater treatment: An overview of applications. Chemosphere, 2017. 173: p. 474-484.

ACKNOWLEDGMENTS

This work was supported by projects: i) “RENURE – Integrated and circular process for the recovery of nutrients and removal of micropollutants from waste water”, with nr. 21336 and operation code at the Funds Platform (Balcão dos Fundos) COMPETE2030-FEDER-02218300, co-financed by COMPETE 2030, by Portugal 2030 and by the Europen Union, and ii) “WAVES - Seawater & Wastewater: Turning Challenges into Resources”, with operation code at the Funds Platform (Balcãodos Fundos), NORTE2030-FEDER-02716600, co-financed by the European Union through the NORTE 2030 Regional Program, of Portugal 2030. This research was also supported by Fundação para a Ciênciae a Tecnologia, I.P./MECI through national funds: LSRE-LCM, UID/50020/2025 (https://doi.org/10.54499/UID/50020/2025); and ALiCE, LA/P/0045/2020 (https://doi.org/10.54499/LA/P/0045/2020). L.J.R. Cullen acknowledges her FCT scholarship (2024.00685.BD).