Conference or Workshop Item:
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School of Chemical and Process Engineering
FACULTY OF ENGINEERING AND PHYSICAL SCIENCES

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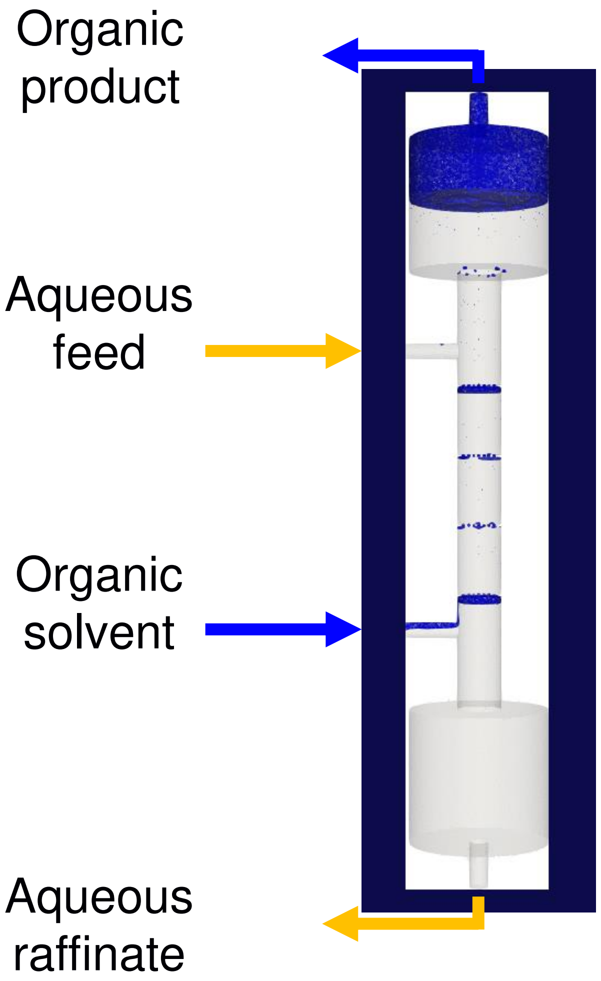
Characterising the dispersed phase hydrodynamics in Pulsed Sieve Plate Extraction Columns

Multiphase Transportation, Conversion & Utilization of Energy Conference
July 27th to 31st 2022
Alex Fells, F.L. Muller and B.C. Hanson, University of Leeds, UK

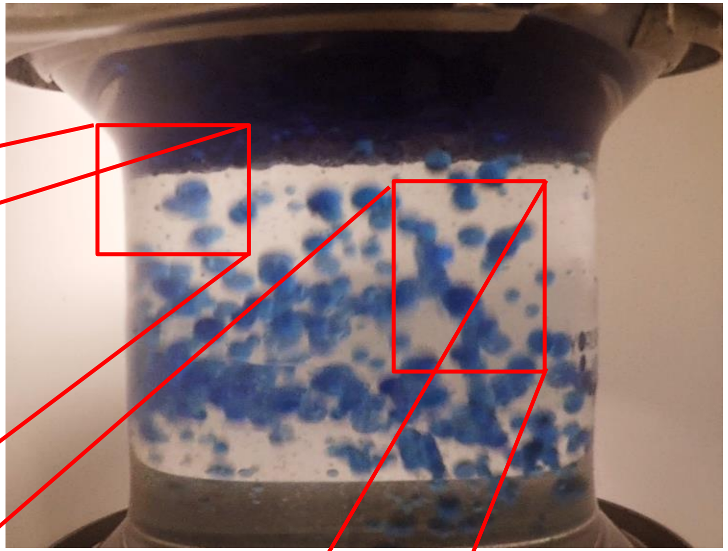
PULSED SIEVE-PLATE EXTRACTION COLUMNS

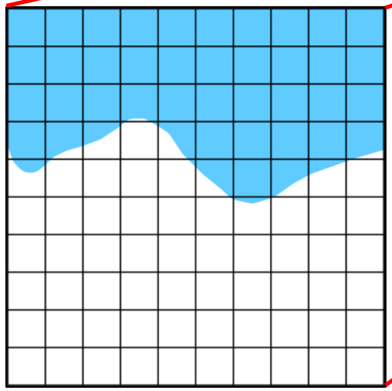
- Counter-current liquid-liquid extraction unit operation.
- The good:
  - No moving parts
  - Can operate with solids
- The bad:
  - Empirical correlations are poor and not general.
  - Pilot plants and expensive.
- Can we develop a generalised approach to design?
- Need experimental data for validation.



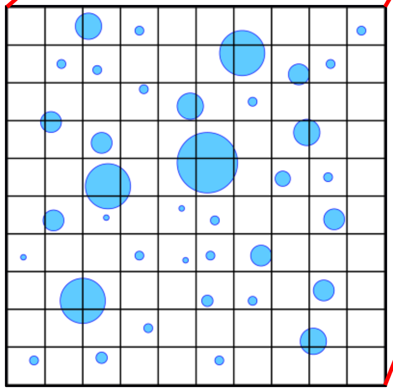
MODELLING MULTIPHASE FLOWS

- Two traditional approaches to multiphase flows modelling:
  - Interface-scale averaging
    - Multifluid (Eulerian) models
    - Generally used for dispersed flows.
    - Droplets are smaller than cells
  - Interface-scale resolving
    - Interface capturing models
    - Segregated flows
    - Mesh is smaller than interface scales
- PSEC exhibits both small and large interfaces, so hybrid method necessary.





Interface capturing



Multifluid

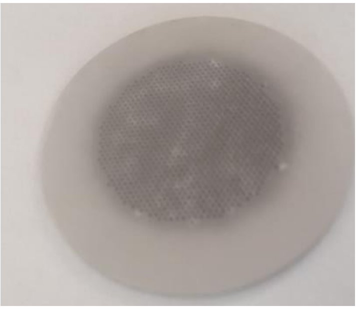
De Santis, A., Colombo, M., Hanson, B.C. and Fairweather, M., 2021. A generalized multiphase modelling approach for multiscale flows. *Journal of Computational Physics*, *436*, p.110321.

University of Leeds PSEC Pilot Plant

METHODOLOGY

- PSEC
  - 65 mm diameter, 3 stages, 4 plates (23% fractional free area)
  - 2:1 Solvent to aqueous flow ratio, 1 Hz pulse frequency
- Optical characterisation
  - 3 cameras, 30 fps, 1080p, 3 minutes.
  - Processing with Ilastic and OpenCV.

3 different plate designs used



d = 1 mm

d = 2 mm

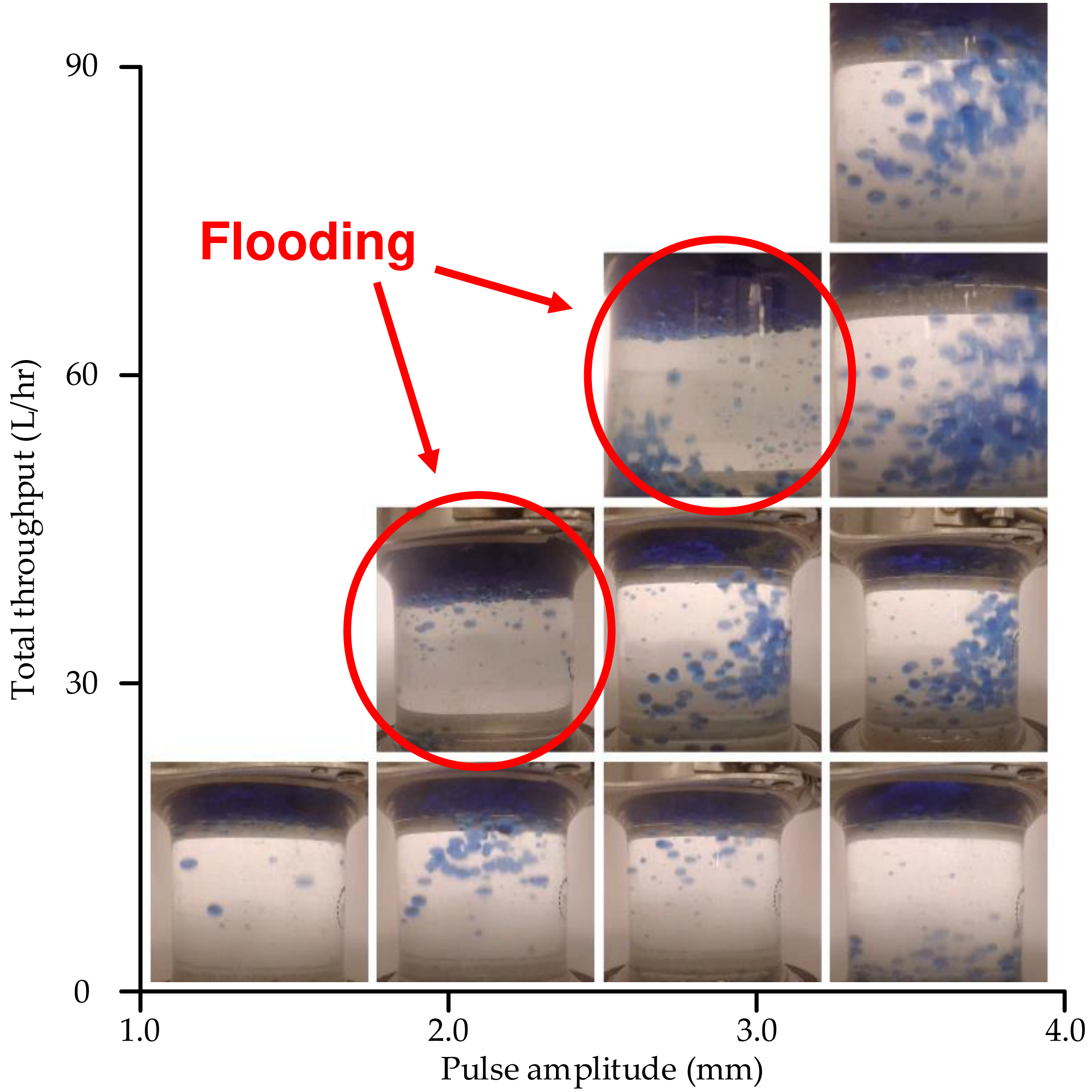
d = 4 mm

Table 1: Investigated experimental conditions

Parameter	Values
Total throughput *Q* (L/hr)	15, 30, 45, 60, 75, 90, 105, 120
Pulse amplitude *A* (mm)	1.48, 2.22, 2.96, 3.70
Plate hole diameter *d* (mm)	1, 2, 4

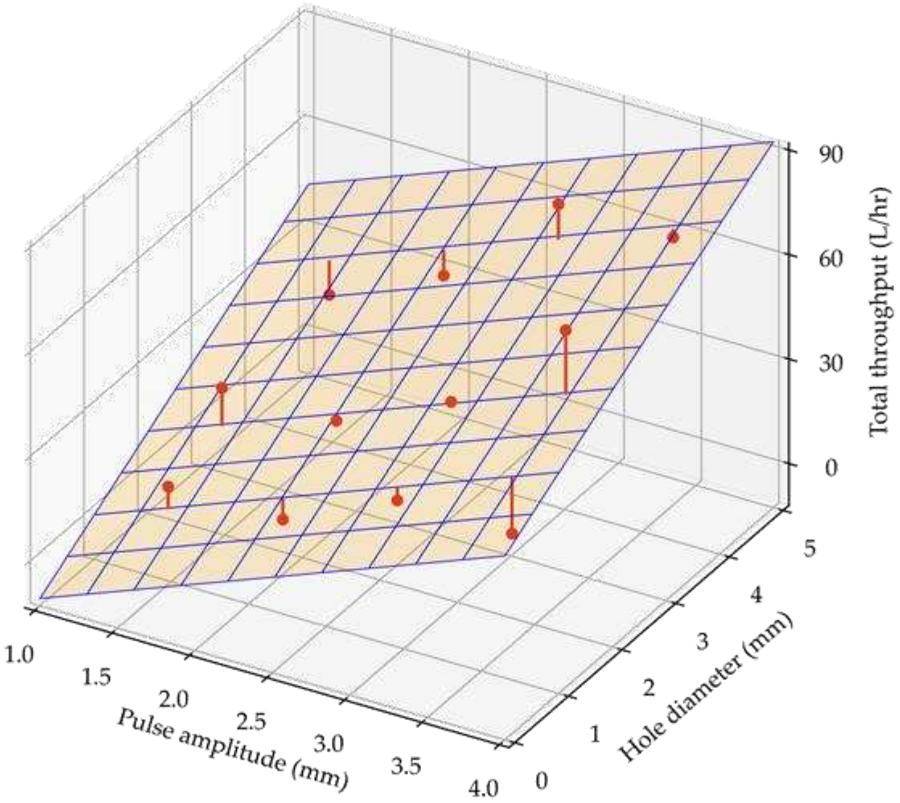
RESULTS

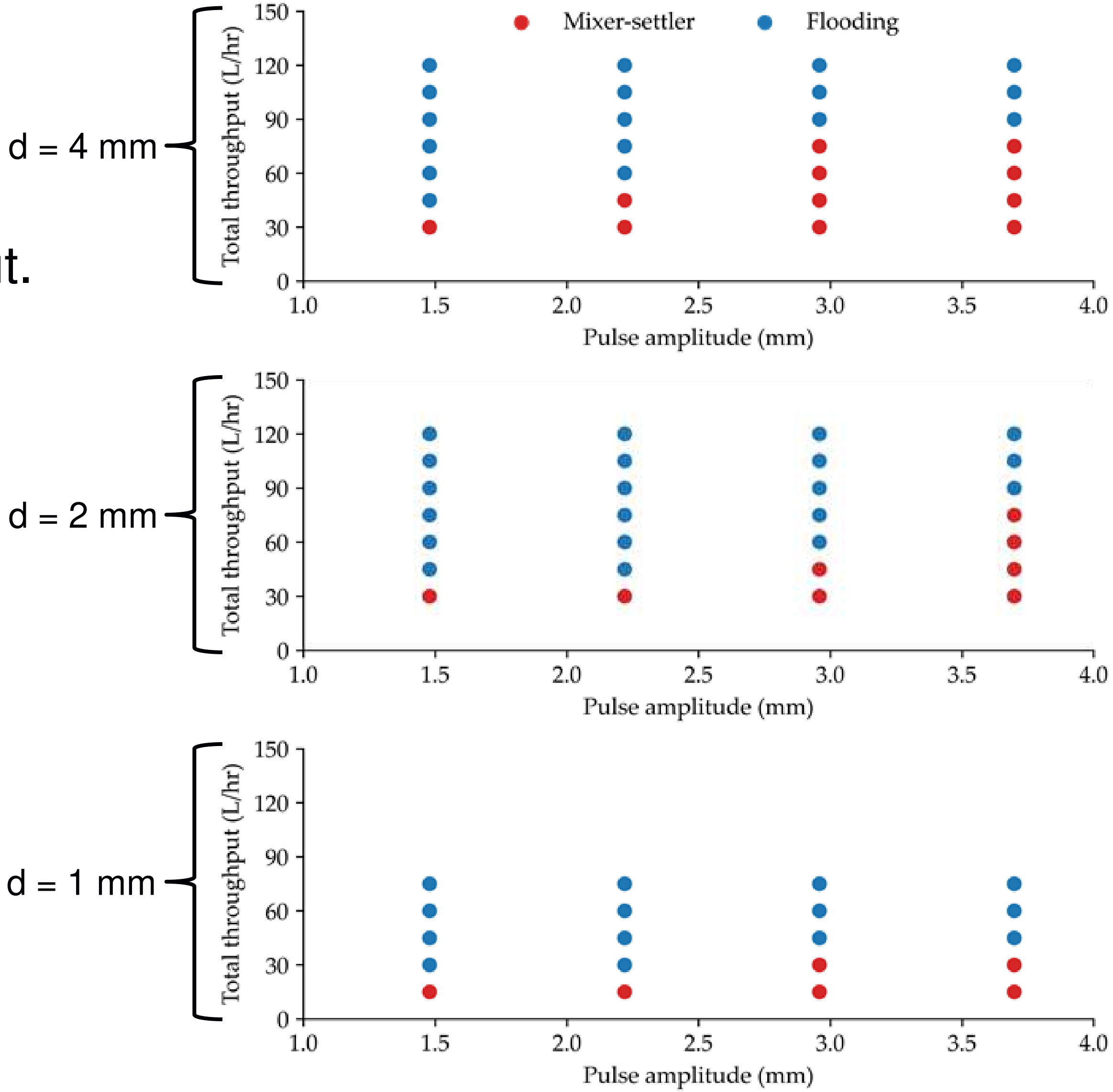
- 1.8M droplets measured, 78 Gb of footage.
- Column operates in pseudo-steady-state mixer-settler (MS) regime.
    - Droplets formed by jetting.
    - Droplets rise and coalesce at plate.
- Insufficient pulsation results in flooding.
    - Accumulation of organic below plate.
    - Interface moves downwards overtime.
- Excessive throughput results in flooding.
    - Droplet rise velocity insufficient to overcome down coming fluid.
- Trends observed across all plate designs



OPERATIONAL ENVELOPE

- Flooding caused by insufficient pulsation.
- Flooding caused by excessive column throughput.





SAUTER MEAN DROPLET DIAMETER ($d_{3,2}$)

- Highly correlated to plate hole size.
- Unaffected by throughput or pulse amplitude.
- Hole size defines diameter.

Q_{TOT} = 30 L/hr, A = 3.70 mm

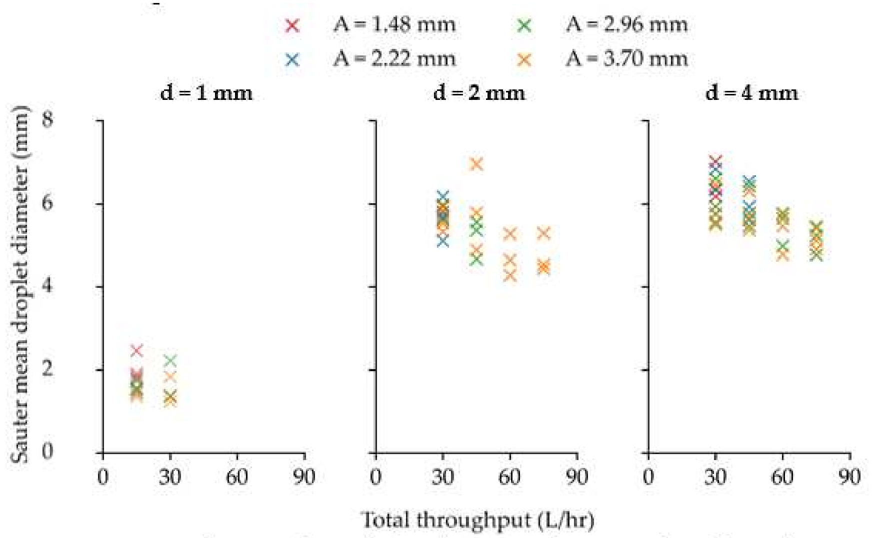


Figure X: Sauter mean diameter for each plate design as a function of total throughput (Q_{tot}), grouped by pulse.

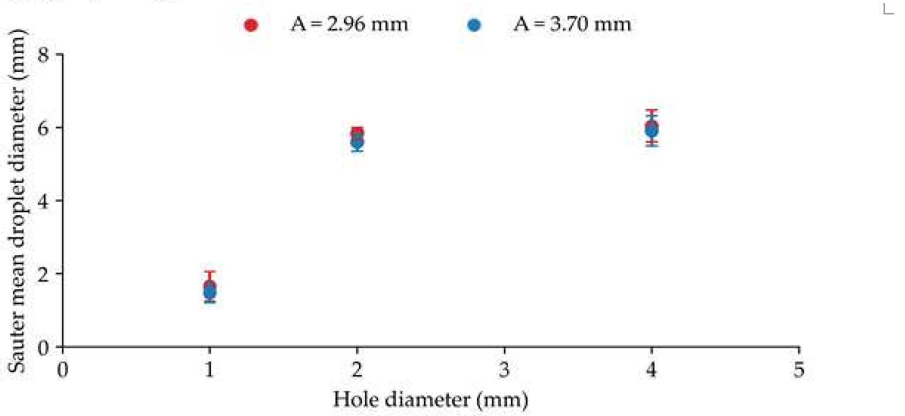


Figure X: Sauter mean droplet diameter for a total throughput (Q_{tot}) of 30 L/hr for pulse amplitudes (A) of 2.96 mm and 3.70 mm.

DROPLET SIZE DISTRIBUTION (DSD)

- Behaviour consistent with operation in MS.
- Expect DSD to tighten for greater pulsation.
- Further work should consider PSEC operation in dispersion mode of operation.

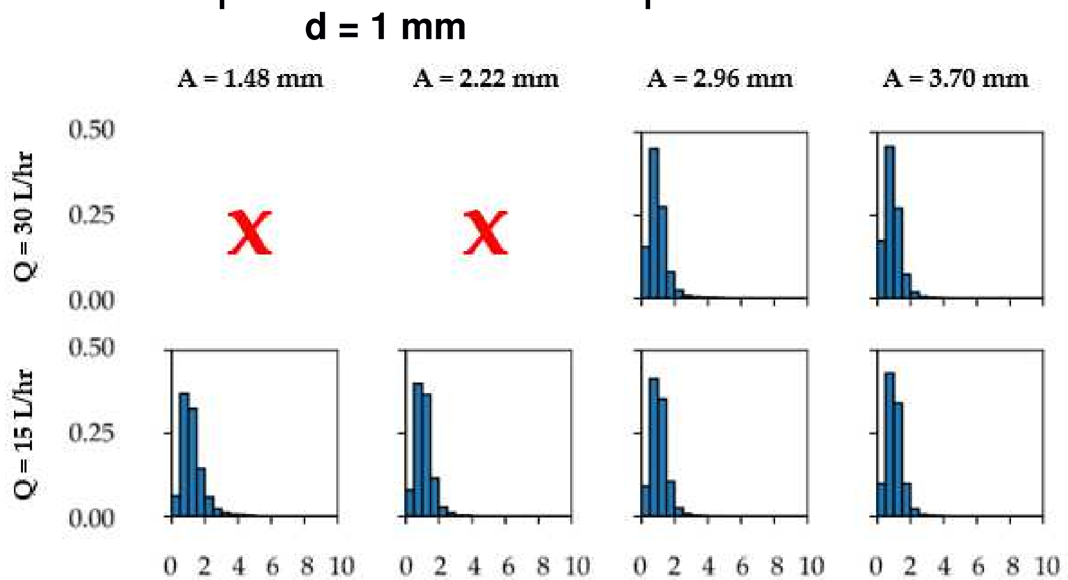


Figure X: Droplet size distribution as a function of total throughput (Q_{tot}) and pulse amplitude (A) for a plate hole diameter (d) of 1 mm. A red x donates column flooding at the particular operating conditions.

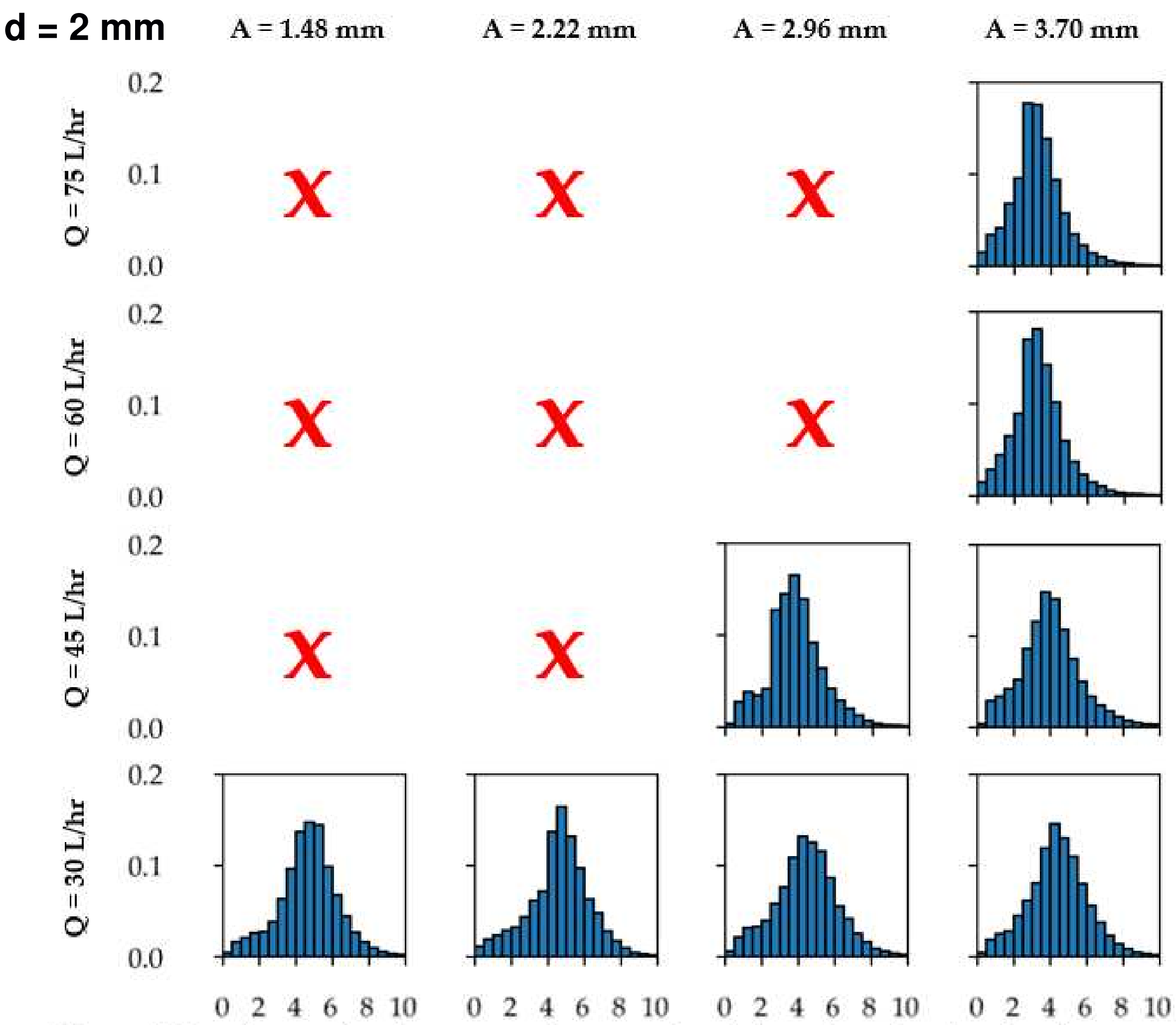


Figure X: Droplet size distribution as a function of total throughput (Q_{tot}) and pulse amplitude (A) for a plate hole diameter (d) of 2 mm. A red x donates column flooding at the particular operating conditions.

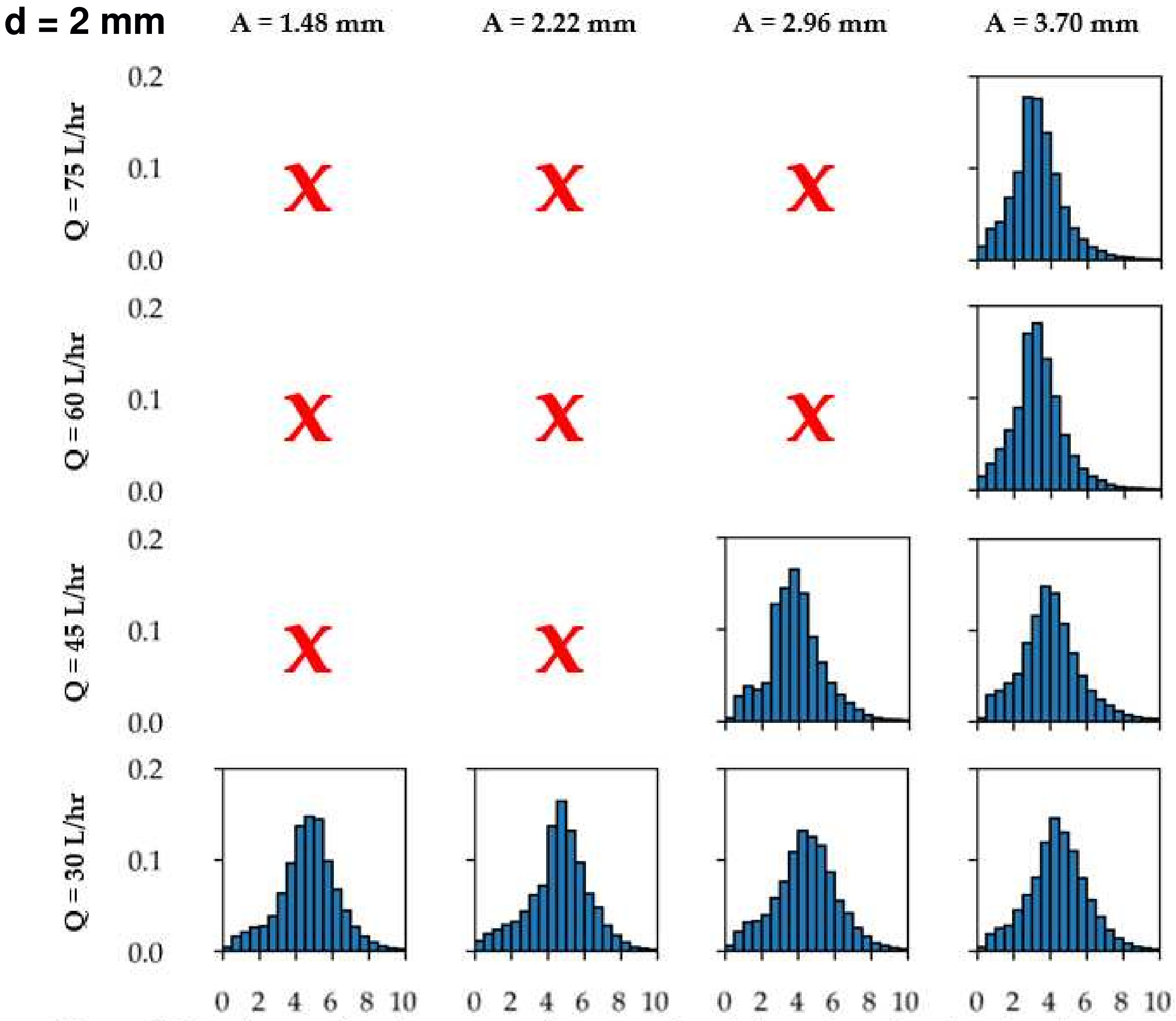


Figure X: Droplet size distribution as a function of total throughput (Q_{tot}) and pulse amplitude (A) for a plate hole diameter (d) of 2 mm. A red x donates column flooding at the particular operating conditions.

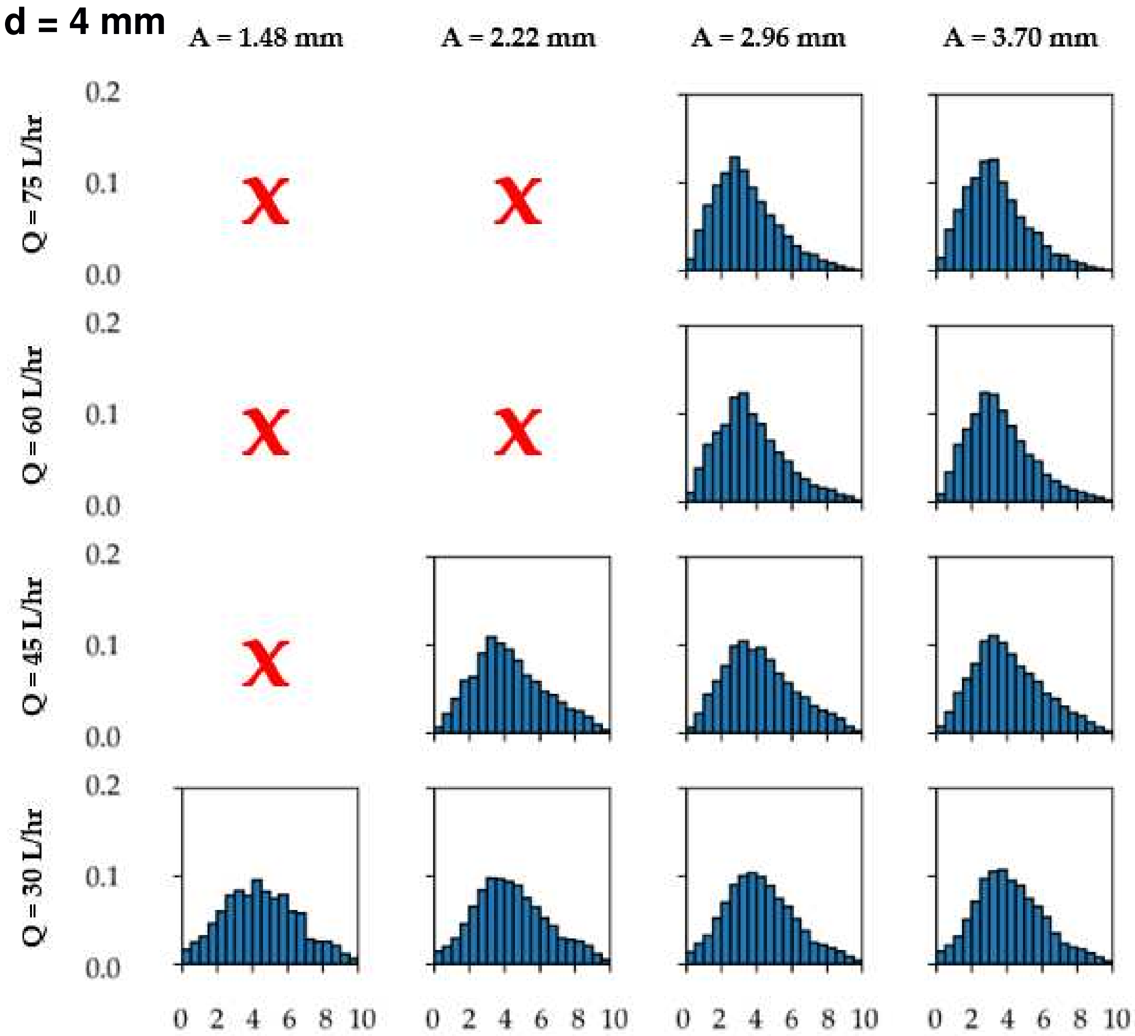
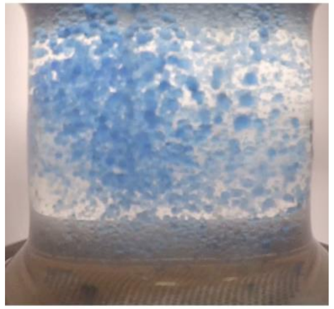
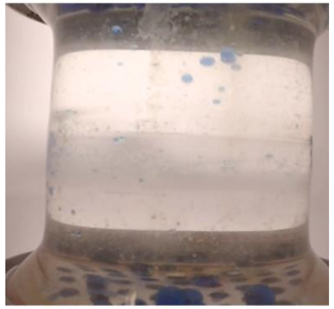


Figure X: Droplet size distribution as a function of total throughput (Q_{tot}) and pulse amplitude (A) for a plate hole diameter (d) of 4 mm. A red x donates column flooding at the particular operating conditions.

DROPLET RISE VELOCITY

- Highly correlated to plate hole size.
- Unaffected by throughput or pulse amplitude.
- Hole size defines diameter.
- Larger droplets result in a greater buoyancy force, resulting in increased rise velocity.





Q_{TOT} = 30 L/hr, A = 3.70 mm

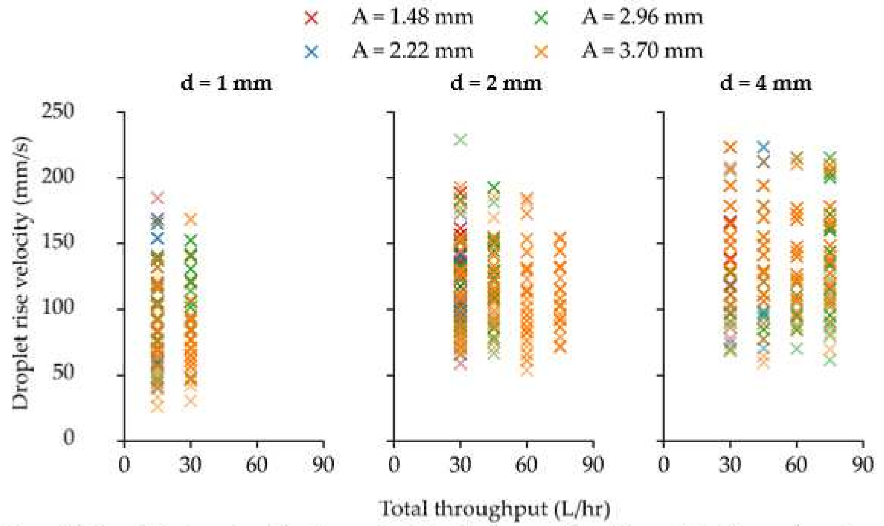


Figure X: Droplet rise velocities for each plate design as a function of total throughput (Q_{tot}), grouped by pulse.

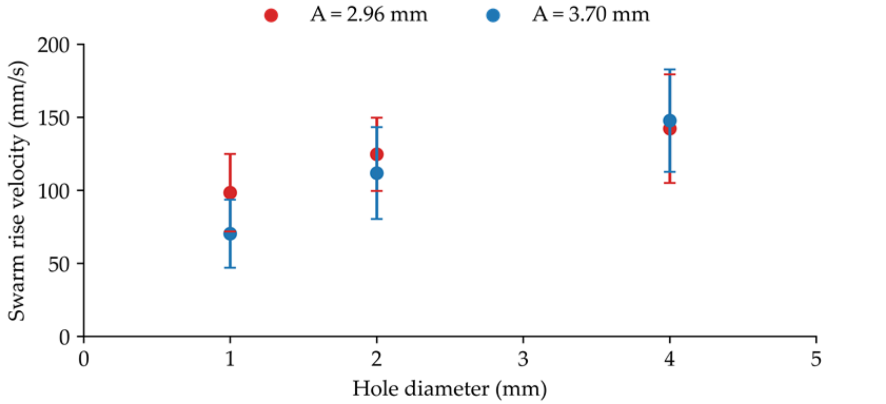


Figure X: Droplet swarm averaged rise velocities for a total throughput (Q_{tot}) of 30 L/hr for pulse amplitudes (A) of 2.96 mm and 3.70 mm.

ACKNOWLAGEMENTS

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CONTACT DETAILS

- pm11af@leeds.ac.uk

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EPSRC
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Department for Business, Energy & Industrial Strategy

AFCP
Advanced Fuel Cycle Programme

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