Hydrodynamics in a gas solid fluidised bed

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Solids waste management

Organic waste

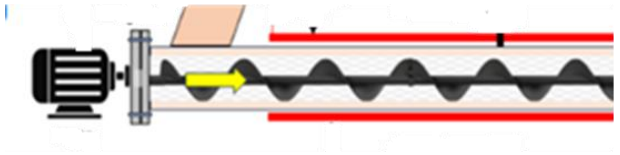
Biosolids

Agricultural

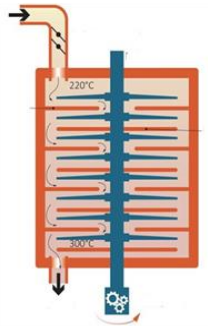
Forestry

Source

Thermal Treatment



Auger/Paddle



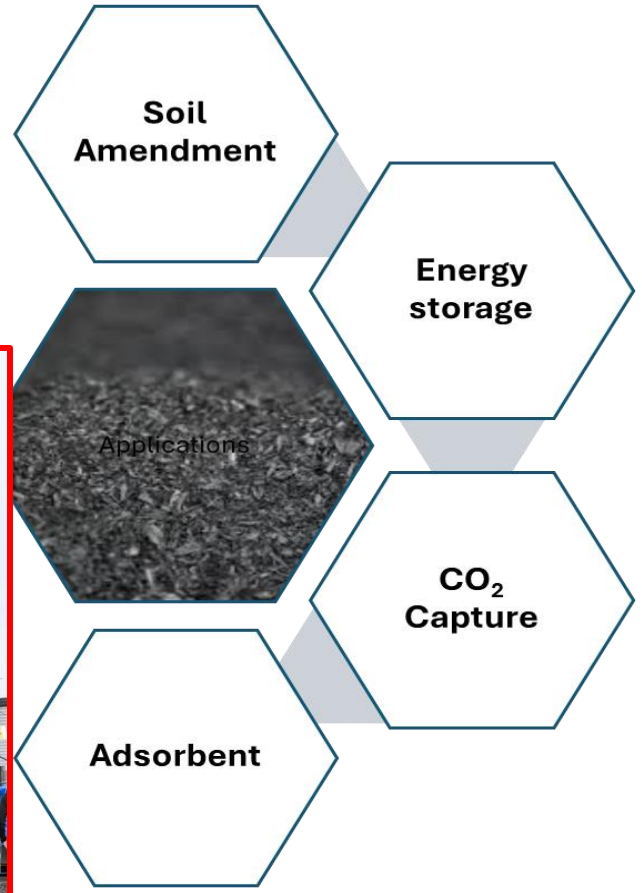
Multi-hearth

Fixed

F

Reactor Configurations

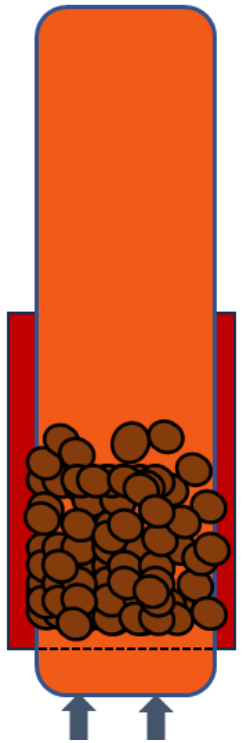
Value-added product



Biochar

Motivation for research

Conventional fluidised bed



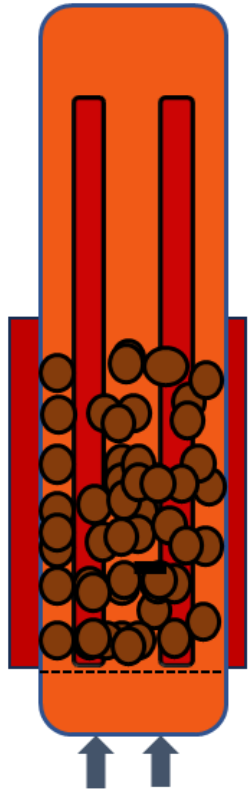
Benefits

- Uniform heat and mass transfer
- Better product quality

Drawbacks

- Scale-up difficult.
- Limited maximum surface area

Fluidised bed heat exchanger



Opportunities

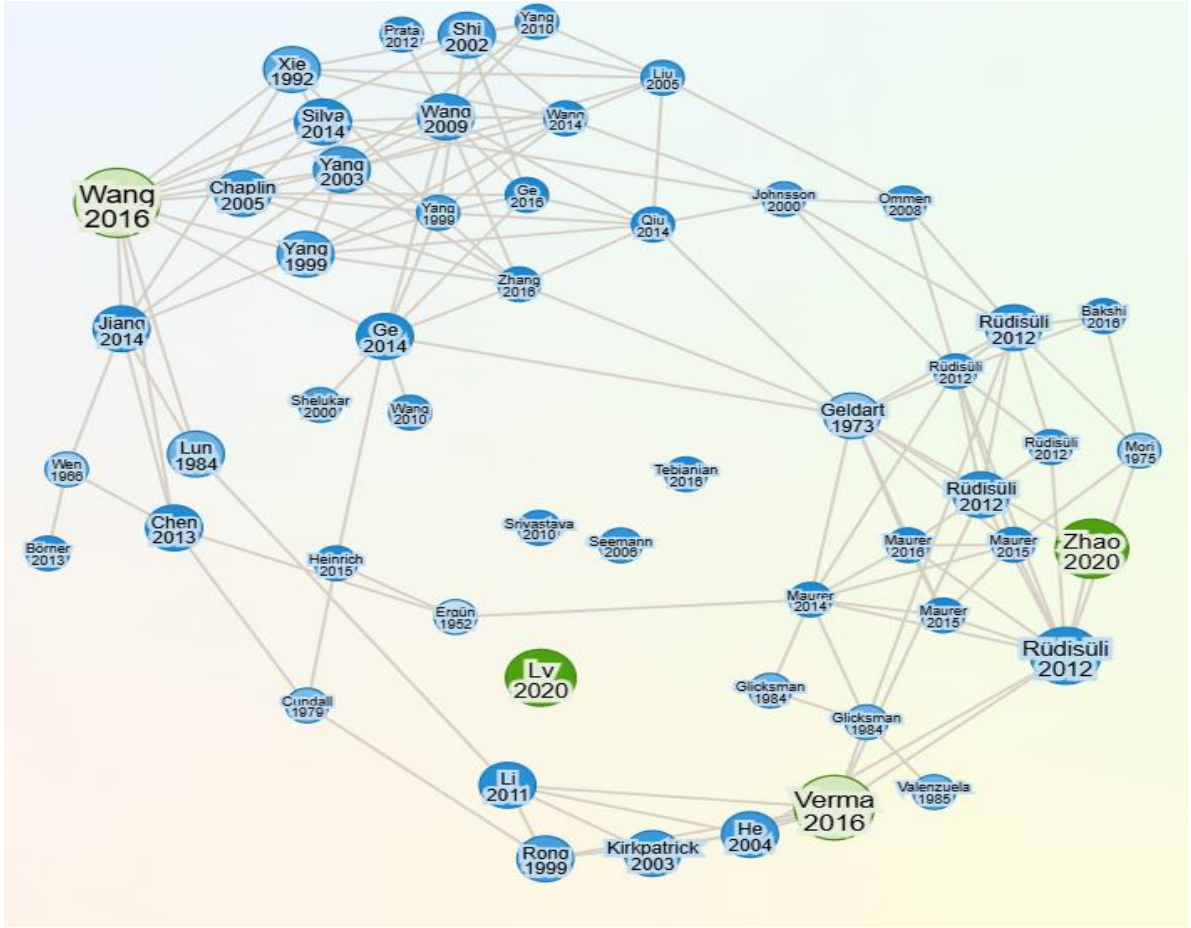
- Tube impact on hydrodynamics.
- Tube impact on heat transfer.

Benefits

- Higher heat and mass transfer
- Higher reactor life.

Knowledge Gaps

Addressing the heat transfer coefficient correlations at high temperature conditions



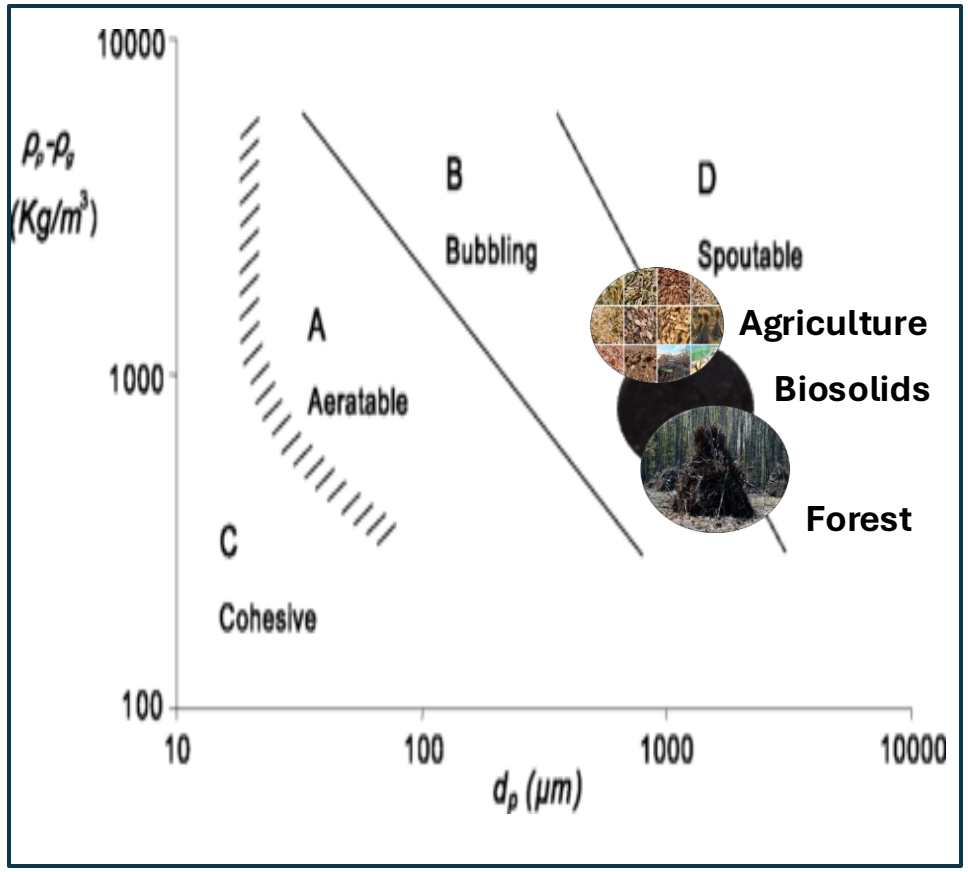
More than 40 different correlations available to determine the heat transfer coefficient

Empirical in nature

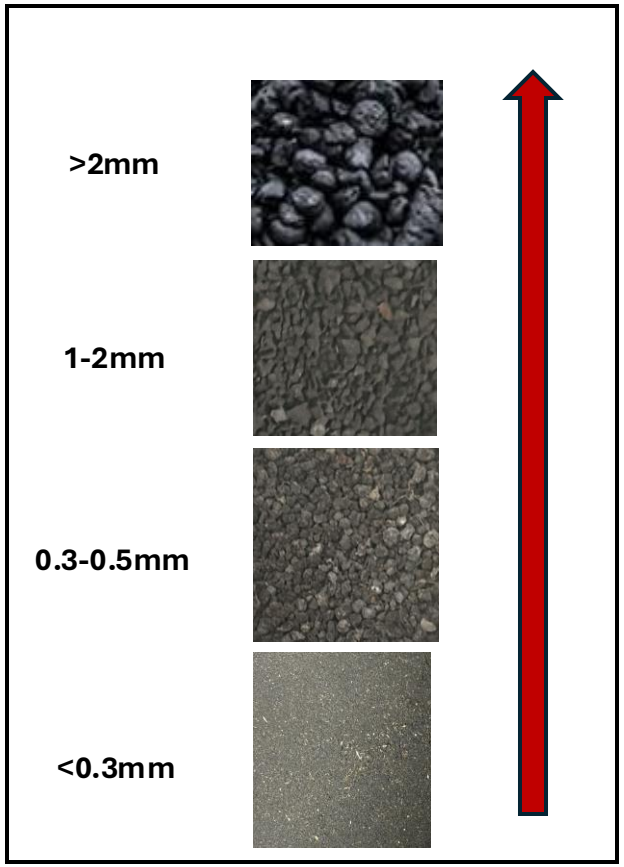
Strongly dependent on hydrodynamics or flow behaviour (Re,ϵ)

Current knowledge

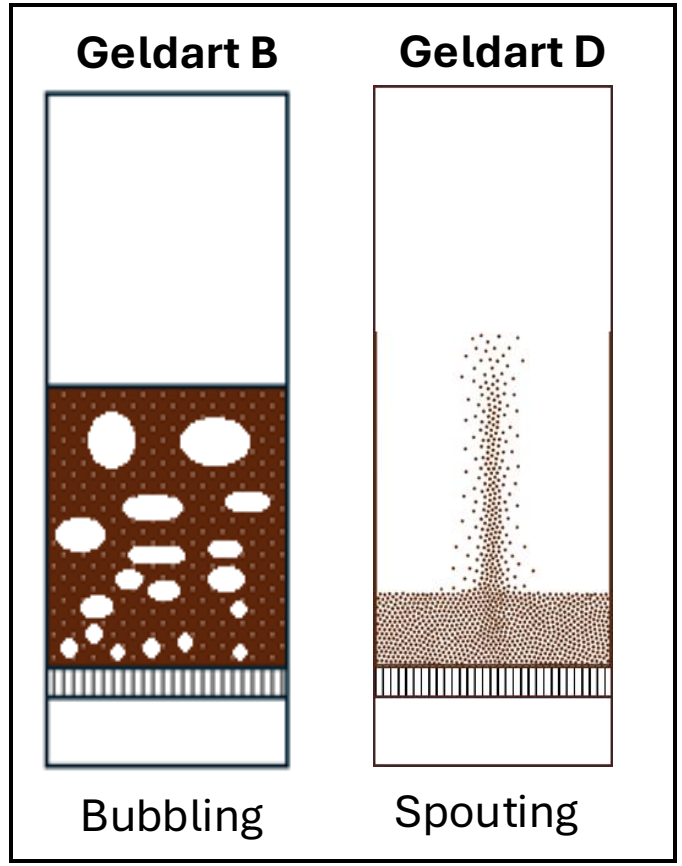
Geldart classification for waste



Biosolids size variation



Conventional fluidised bed



Hydrodynamics and bubbles impacting heat transfer

Pros

- Motors of fluidisation, as they contain 10-12% solid particles.
- Increases particle and gas mixing.
- Increases heat transfer between particles and the gas.
- Increases mass transfer between the gas and solid phase.

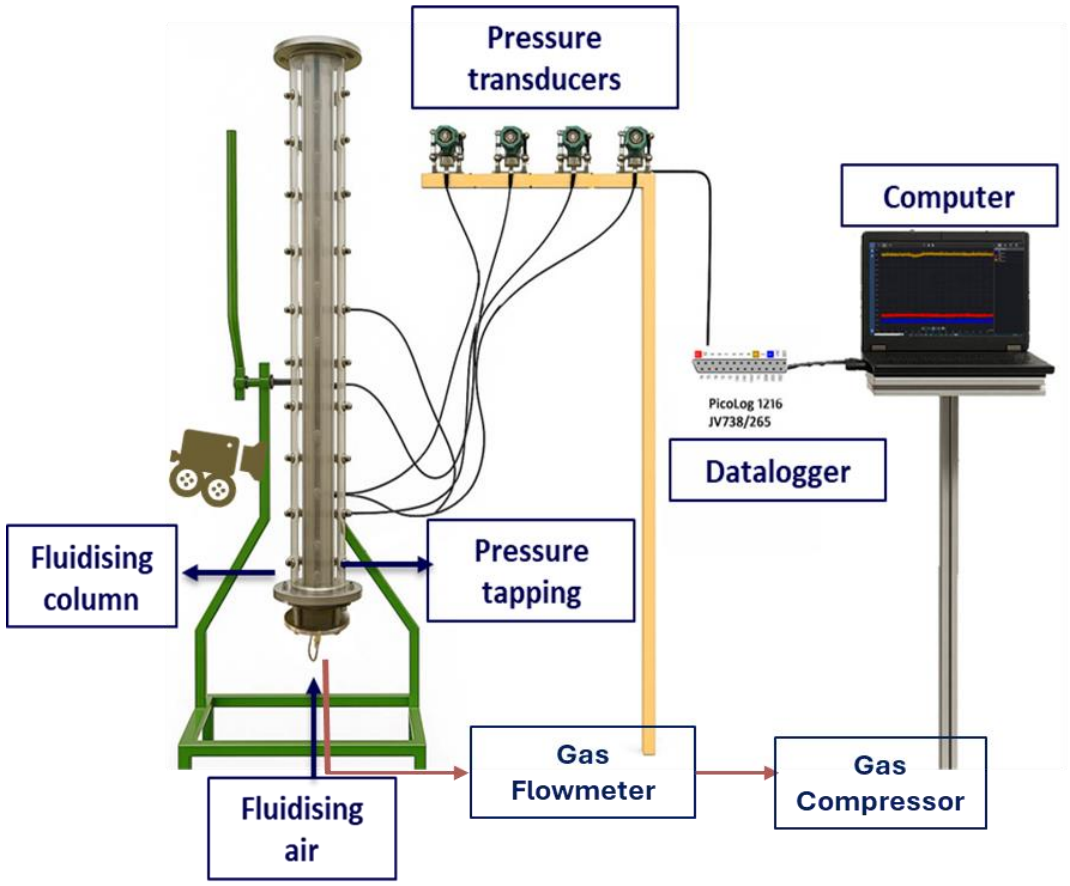
Cons

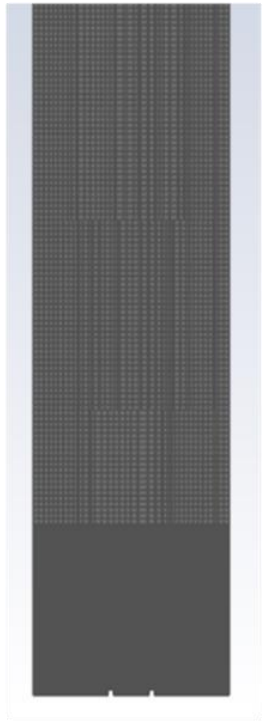
- As the bubble size grows, it may not pass through the bed without contacting the gas phase.
- Increasing bed expansion may lead to solid entrainment.
- Oversized bubbles may decrease the quality of fluidisation and, hence, mixing.

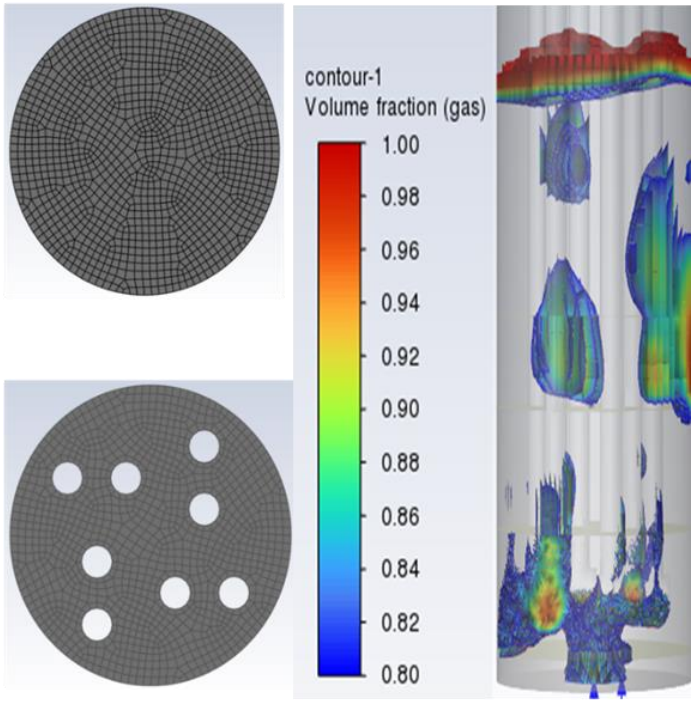
Will tubes enhance/reduce the fluidisation behaviour in the fluidised bed?

Strategy to address the gaps

Capture hydrodynamics reliably in the presence of tubes using a combination of experiments and numerical simulations

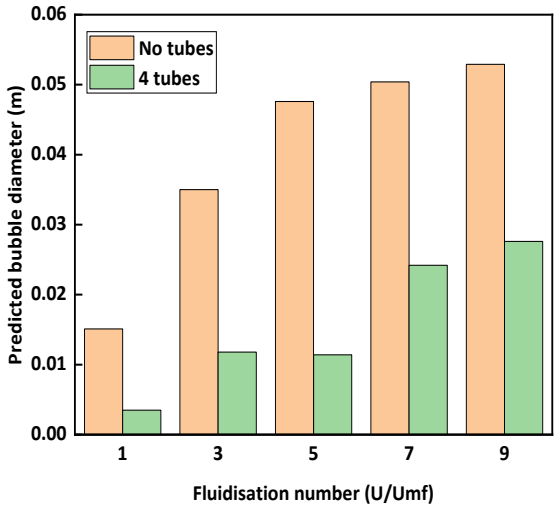


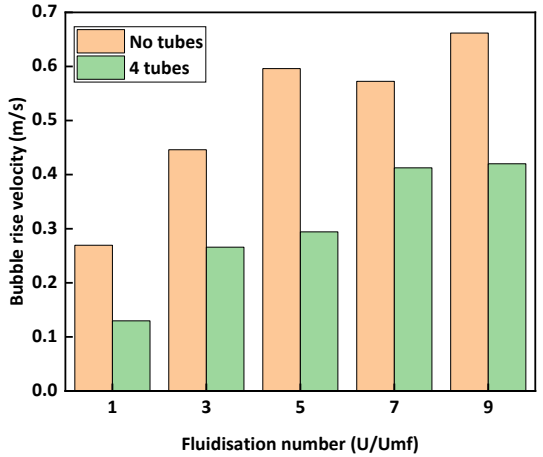




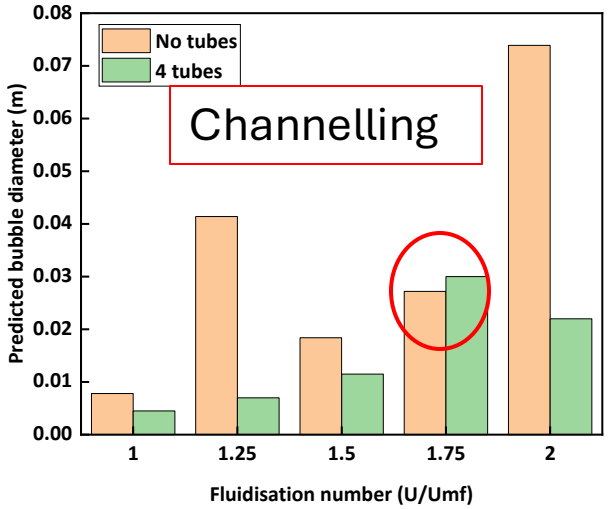
Impact of tubes on bubble behaviour in a fluidised bed

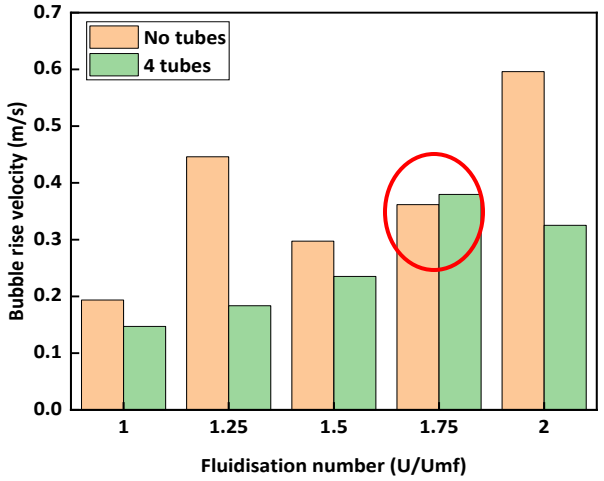
Geldart B particles





Geldart D particles



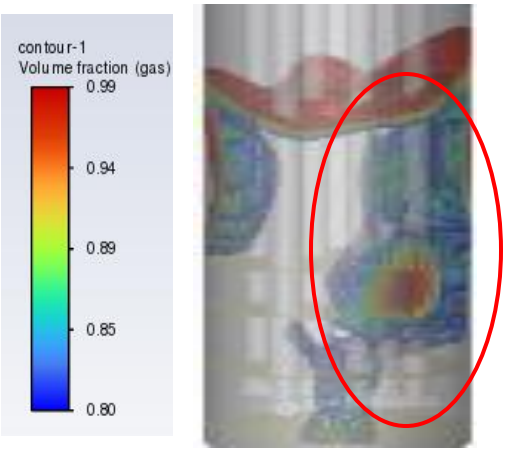


Findings

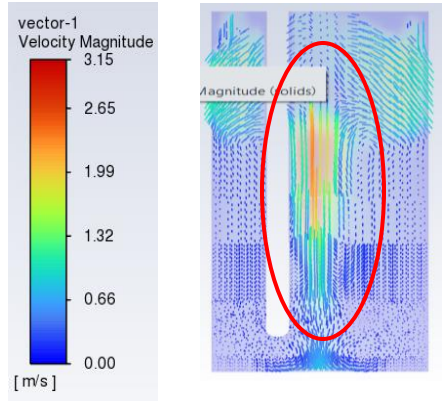
1. Reduction in bubble sizes into varied smaller sizes for Geldart B and D particles.
2. The sizes in Geldart D particles are non-uniform because of larger solid particles leading to channelling.
3. Reduction in bubble rise velocity due to the lower bubble size.
4. Due to varied bubble sizes, larger bubbles in larger particles could squeeze into the space between the tubes and travel in the column at a higher velocity.

Channelling

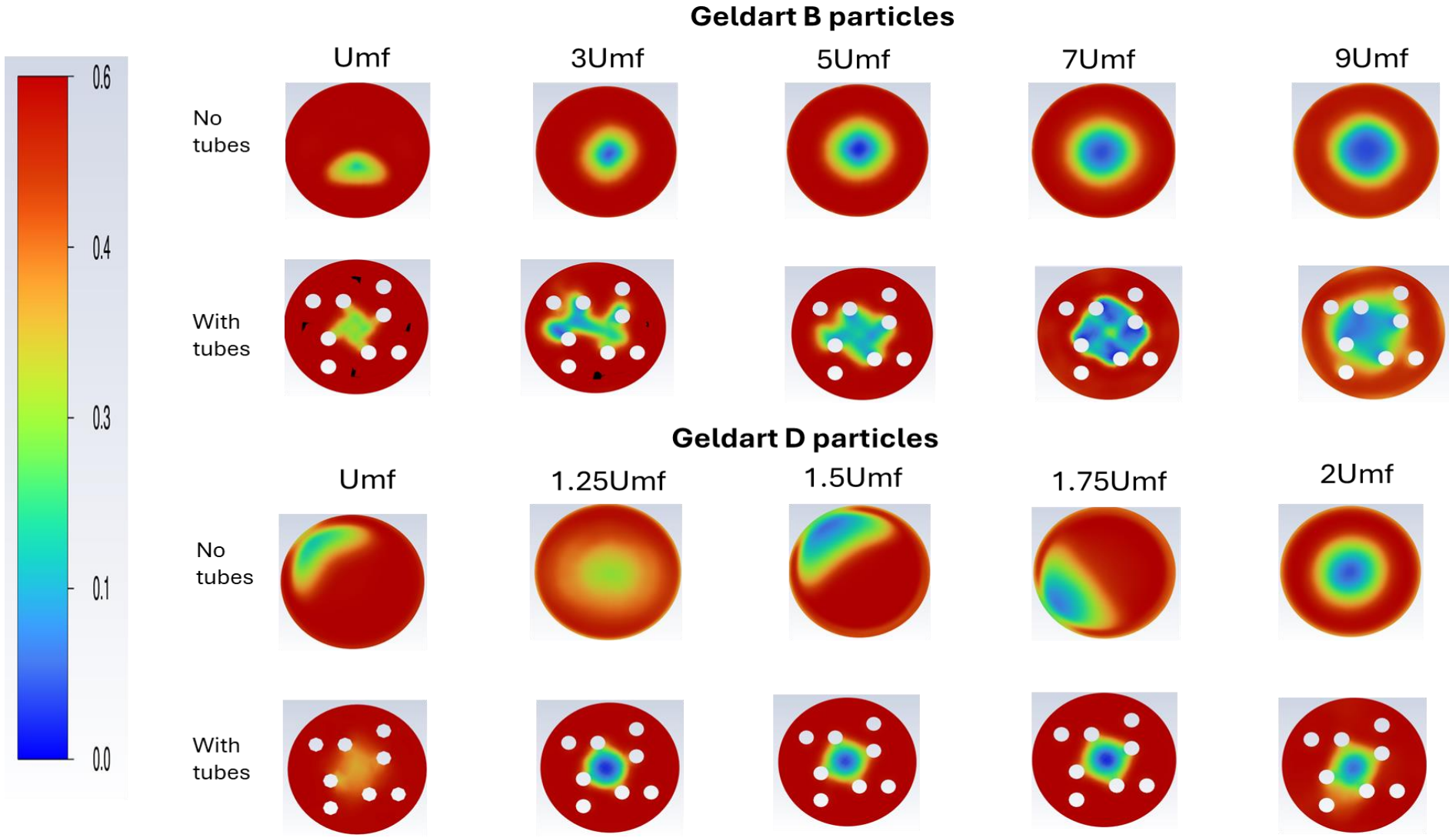
Bubble size



Bubble rise velocity



Impact of tubes on solids behaviour in a fluidised bed



Findings

The mixing of solids improves with the addition of tubes in Geldart B and D particles.

Learnings and path forward

- ✓ Tube improves the hydrodynamics of the fluidised bed for both Geldart B and D particles.
- ✓ Tubes help by splitting bubbles, improving the gas particle mixing.
- ✓ Tubes reduce the bubble rise velocity, increasing the residence time.
- ✓ Tubes improve solids distribution in the fluidised, complementing the findings in the literature.
- ✓ Larger particles end up in some larger bubbles as well, and cause channelling.
- ✓ Tube diameter and orientation could be a possible method to overcome issues such as channelling.

Acknowledgments

RMIT UNIVERSITY

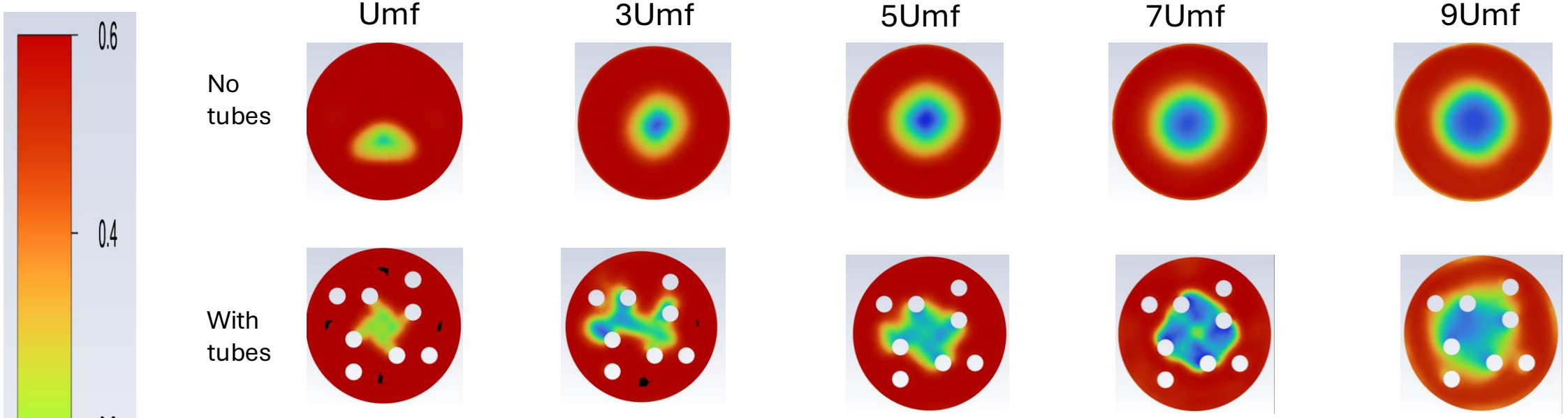
Water Research AUSTRALIA

South East Water

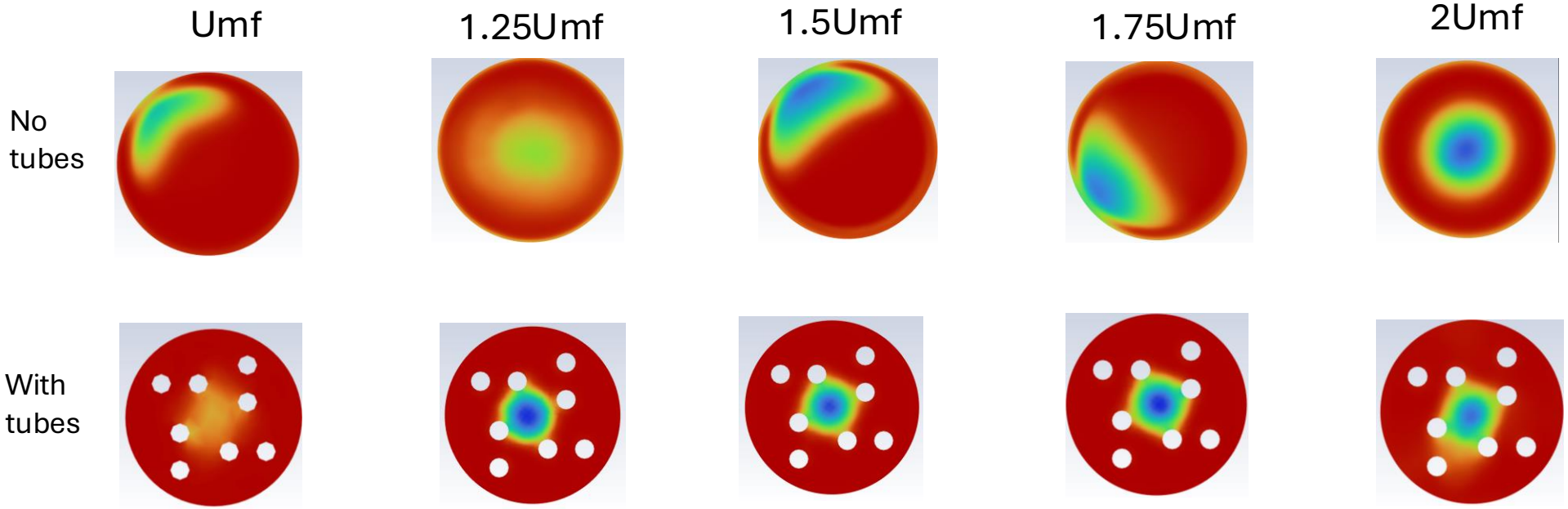
Transforming Biosolids

ARC Training Centre for the Transformation of Australia's Biosolids Resource

Geldart B particles



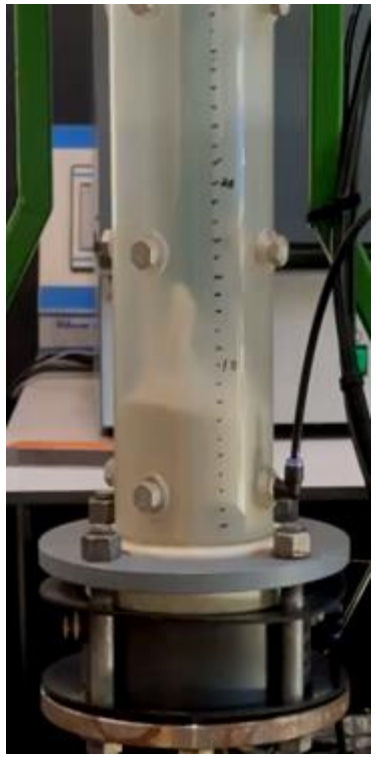
Geldart D particles



Fluidisation behaviour of different materials

Fluidisation behaviour is similar for a given Geldart classification

Geldart B particles



Glass beads
(212-300mic)

Biochar
(212-300mic)

Geldart D particles

Glass beads
(710-1180mic)

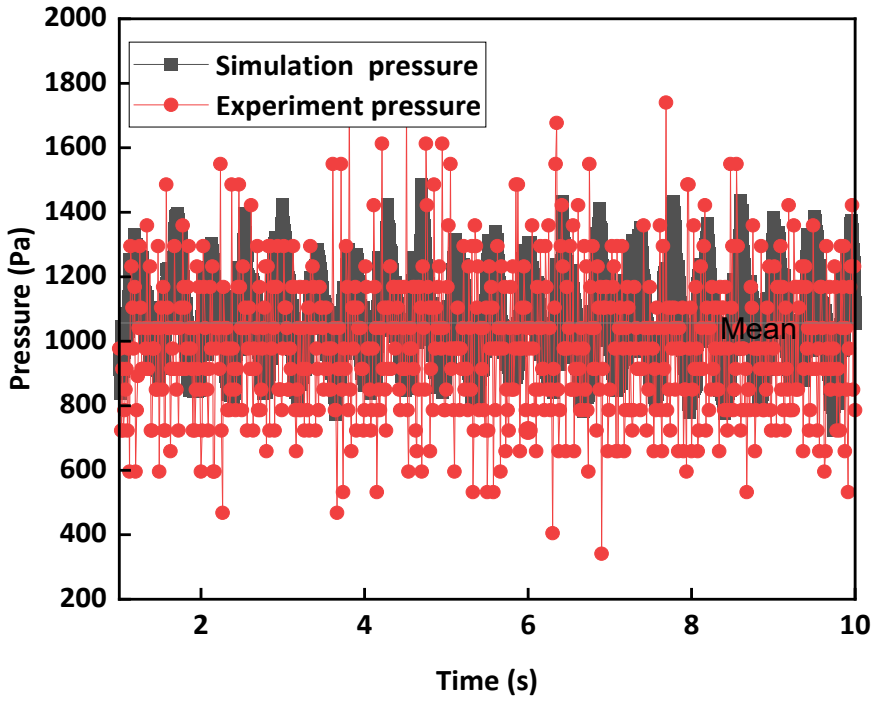
Mustard seeds
(1000-2000mic)

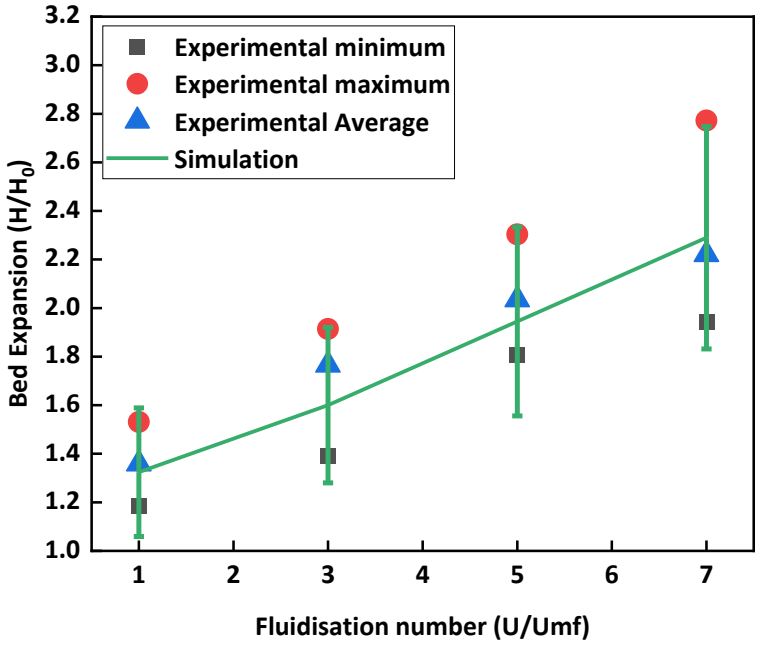
Model Validation Criteria

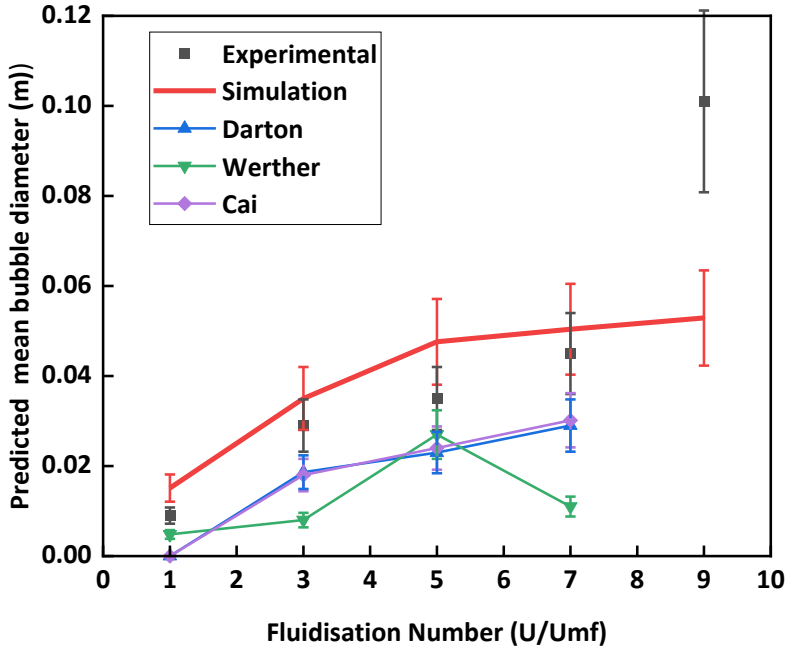
Raw Pressure Signal Comparison

Bed Expansion Comparison

Mean Bubble diameter measurement







Organic waste

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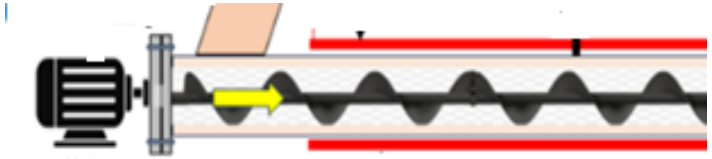
Thermal Treatment



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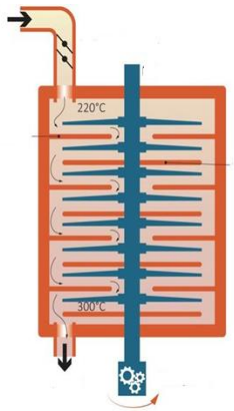
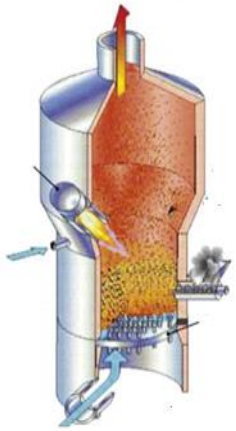


Multi-hearth

Fixed



Fluidised

Reactor Configurations

Value-added product

Soil Amendment

Energy storage

CO_2 Capture

Adsorbent

Biochar