



[www.cranfield.ac.uk](http://www.cranfield.ac.uk)

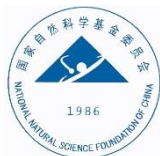
# Membrane Technologies for Decentralised Sanitation, Energy Recovery and Anaerobic digestion.

**Christopher Davey**

**17<sup>th</sup> October 2018**



英国文化教育协会  
英国大使馆文化教育处



RESEARCH  
LINKS





## Outline

- About Cranfield Water Science Institute
- Membranes at Cranfield
- Our Facilities
- Specific project examples
  - 1.) Nanomembrane toilet
  - 2.) Reverse Electrodialysis
  - 3.) Membrane Contactors for Ammonia Recovery





# Cranfield Water Science Institute



Sewage works of the future



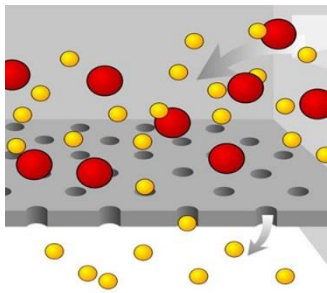
Water for food



Water governance and asset management



Water and sanitation in low income countries



Membrane processes



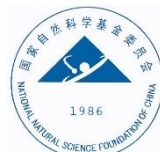
Catchment management



Drinking water treatment



Bioprocessing and environmental technology





# Membranes at Cranfield

Permanent  
members  
of staff



Marc  
Pidou



Bruce  
Jefferson



Ewan  
McAdam



Simon  
Judd

PDRA



Chris  
Davey



Mehrez  
Hermassi



Luca  
Alibardi

*>10 PhD students: Sam Houlker; Salvatore Bavarella; Edwina Mercer; Kanming Wang; Farhad Kamranvand; Dan Golea; Anna Hulme; Kostas Vasilakos*



## Materials characterisation



Permeability assessment  
-Crossflow  
-Dead-end



Surface free energy for cylindrical and flat-sheet materials



Gas-mixing manifold for determining gas phase flux of material

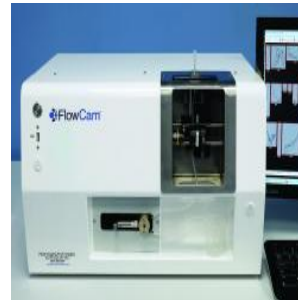
## Process diagnostics



Chemical gradient potential



Optical coherence tomography



Real-time particle tracking

## Scaled testing



Pilot-hall. More representative scale of economic feasibility on real wastewater



Import of alternative feed-water for testing new applications



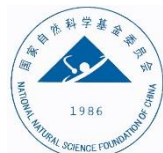
On-site demonstration (applicability to real environment)



## National water and wastewater experimental facility



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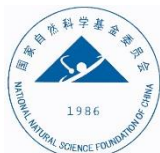
# Membranes at Cranfield

**1** Compliance

**2** Energy

**3** Resource recovery

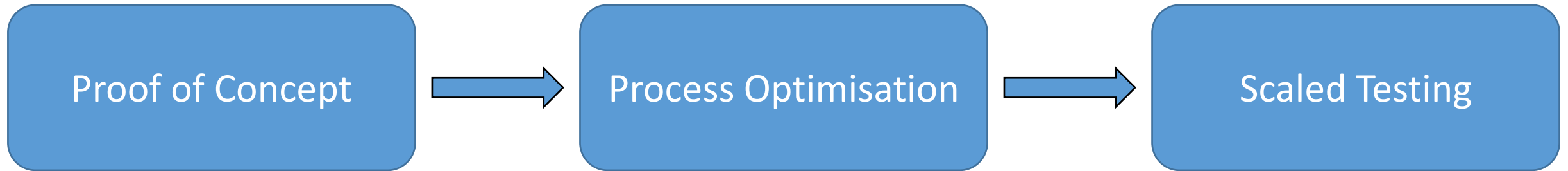
**4** Water recycling







# Membranes at Cranfield







# 1.) Nanomembrane toilet



'to achieve in-house piped water supply and sewerage connection with partial treatment of sewage would require investment of US\$136.5 billion per year'

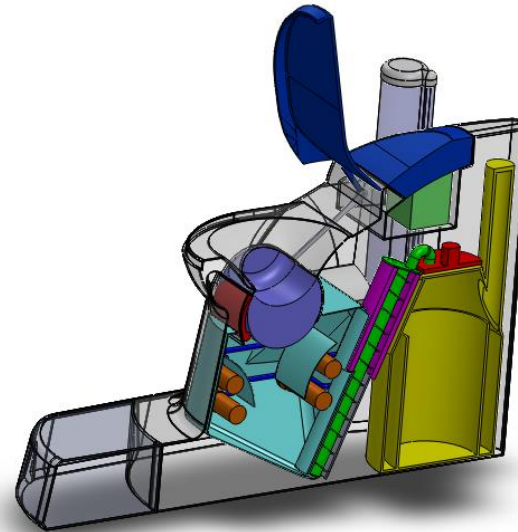
- World Health Organisation, 2004



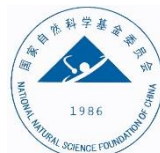
<http://www.iwa-network.org/press/18-winners-at-the-12th-iwa-project-innovation-awards/>



<http://www.nanomembranetoilet.org/meettheteam.php>



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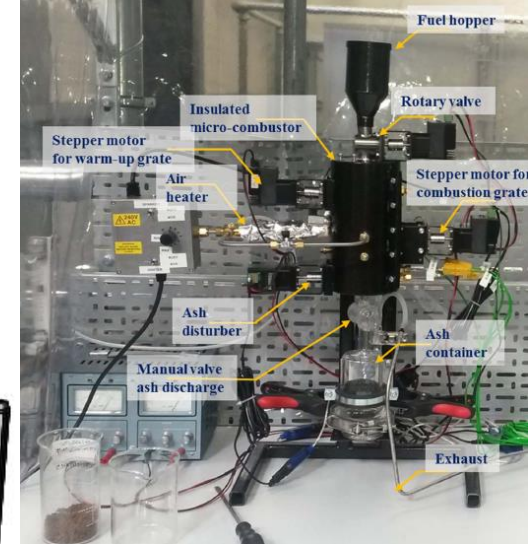
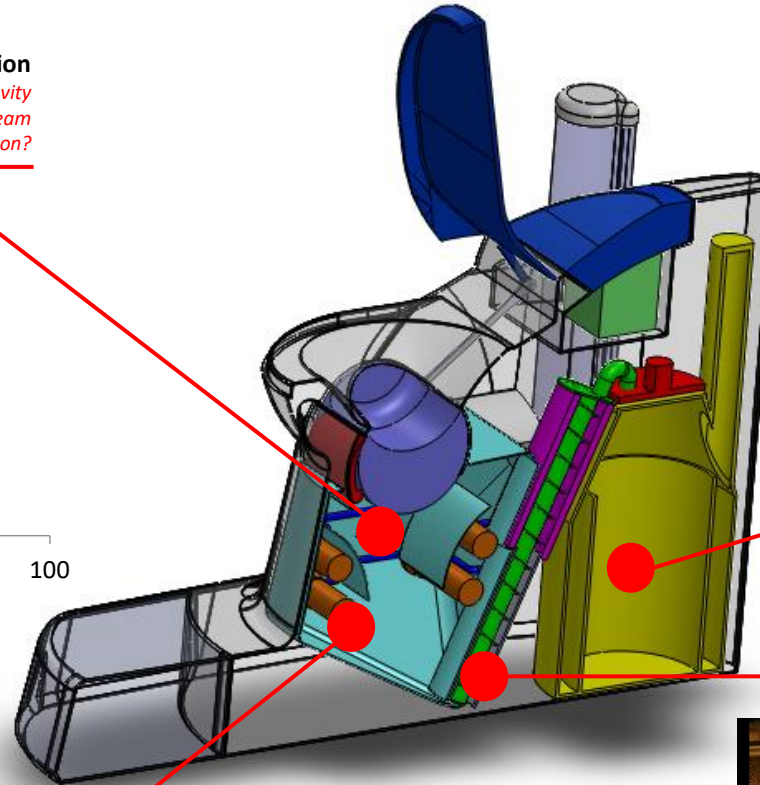
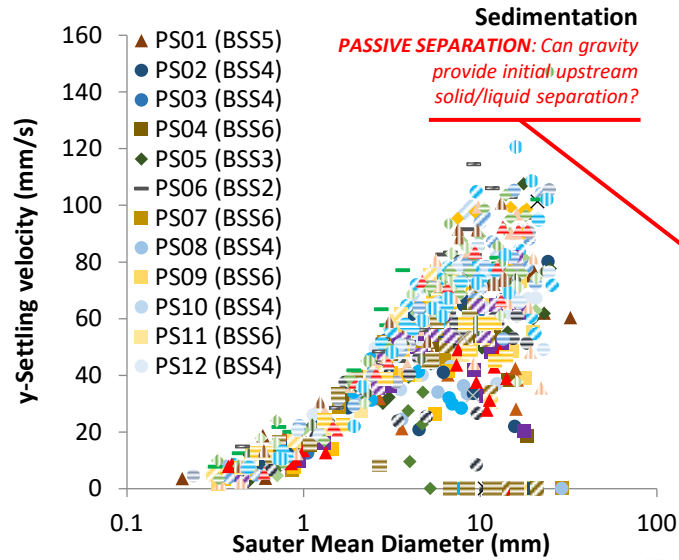


RESEARCHER LINKS



# 1.) Nanomembrane toilet

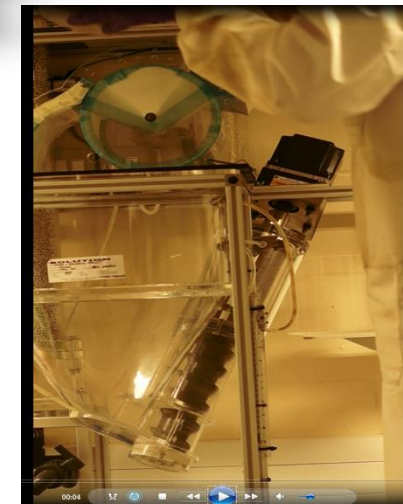
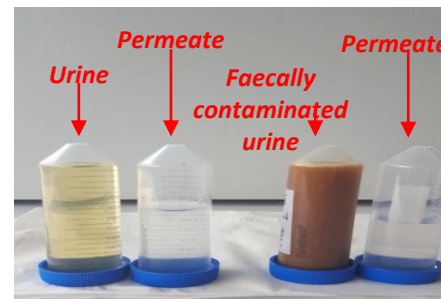
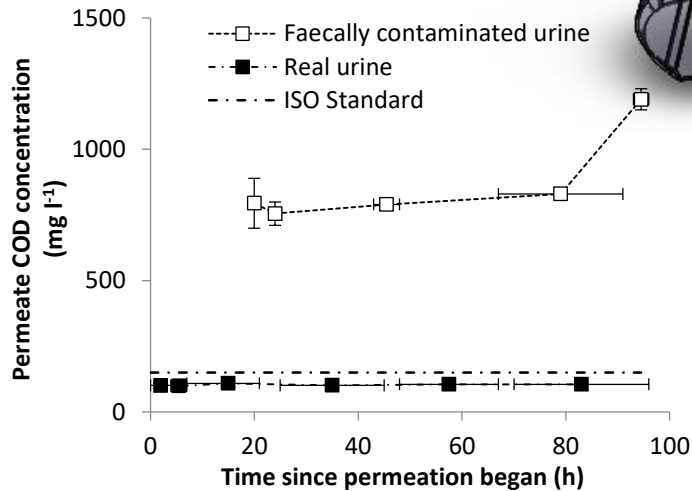
## True decentralisation of infrastructure



**Combustion**  
*SCALE DOWN: Can we reverse engineer combustion to match application scale?*

Jurado et. al., *Energy Convers. Manag.*, 2018, **163**, 9, 507–524

**Screw delivery**  
*SLUDGE TRANSPORT: Can we achieve solid/liquid separation, faecal sludge transport and dewatering in a single stage?*



Mercer et. al., *Environ. Sci.: Water Res. Technol.*, 2016, **2**, 953-964

Kamranvand et. al., *Sep. Sci. Technol.*, 2018, **53**, 9, 1372–1382



# 1.) Water Recovery - Membrane Distillation

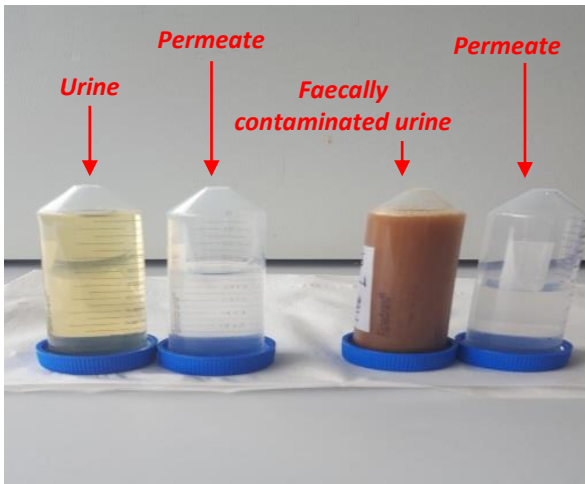
Proof of Concept



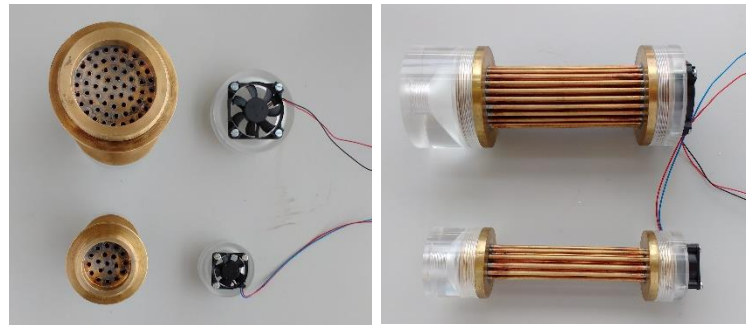
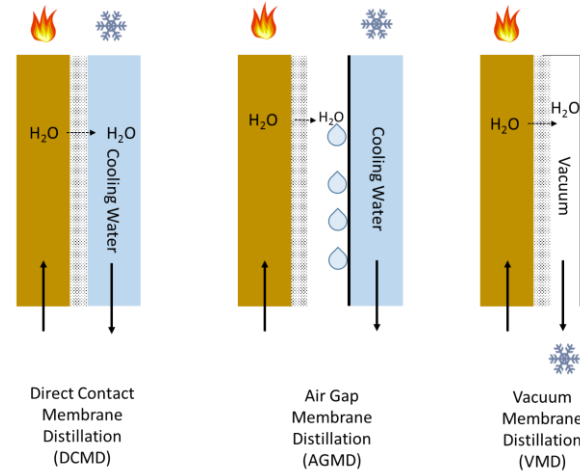
Process Optimisation



Scaled Testing

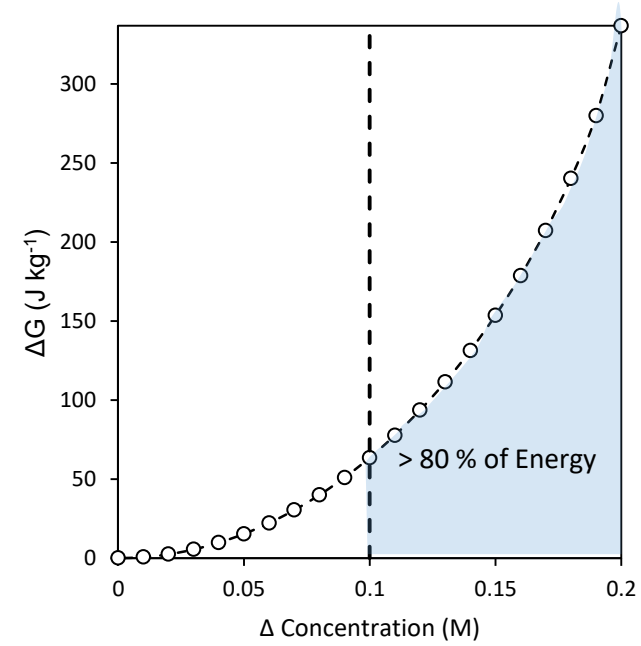
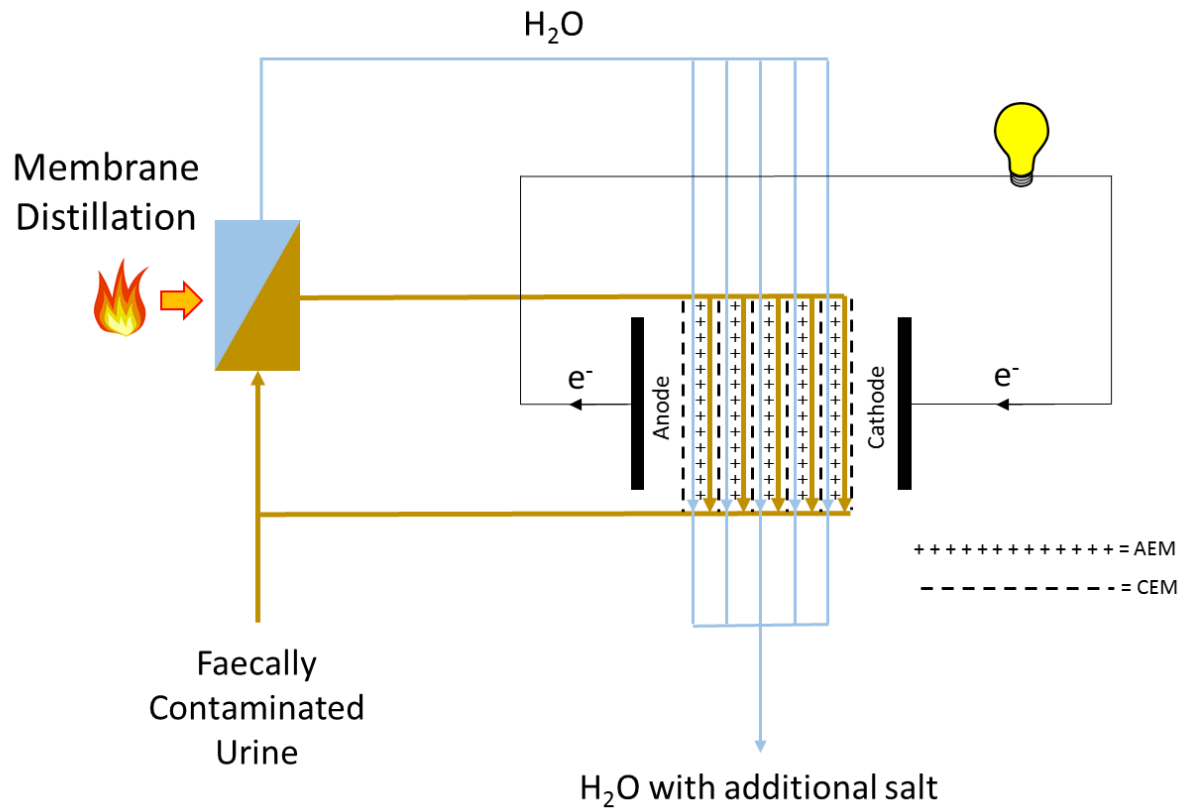


Kamranvand et. al., *Sep. Sci. Technol.*, 2018, **53**, 9, 1372–1382



# 2.) Reverse Electrodialysis

## Concentrate Management and Energy Recovery



MD Permeate ~ 0.5 mS cm<sup>-1</sup>  
 Drinking Water ~ 5 – 50 mS cm<sup>-1</sup>



## 2.) Reverse Electrodialysis

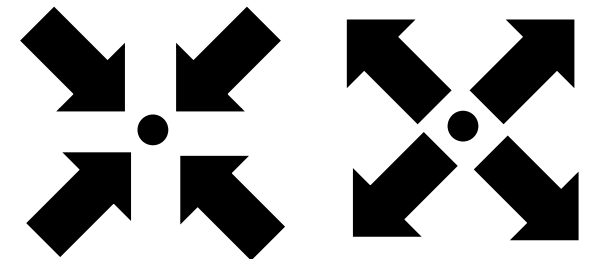
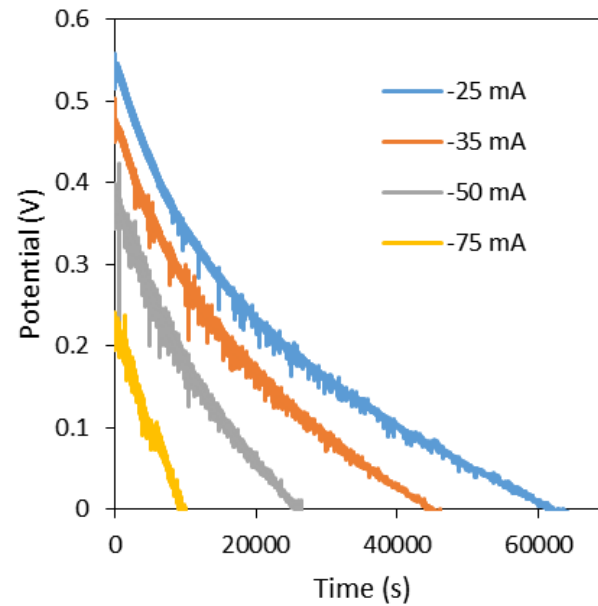
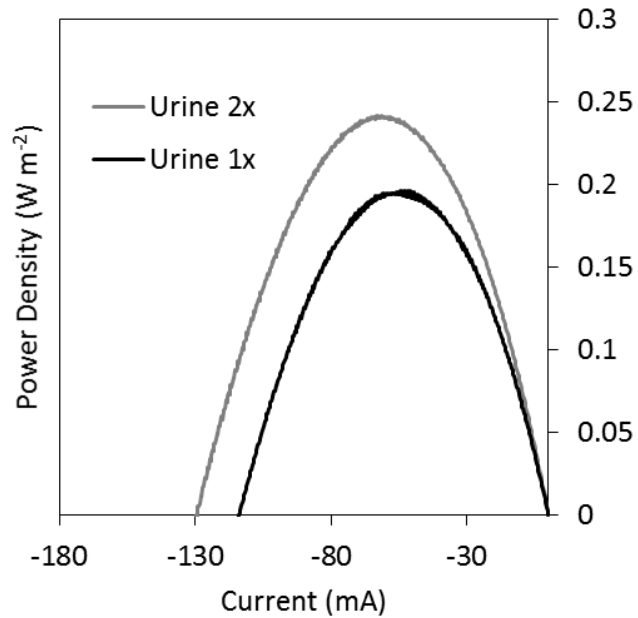
Proof of Concept



Process Optimisation



Scaled Testing



# 3.) Membrane Contactors for Ammonia Recovery

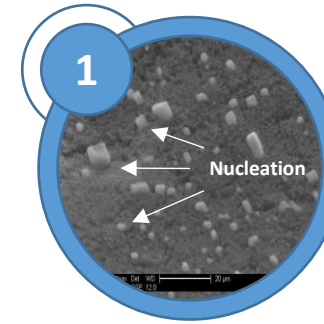
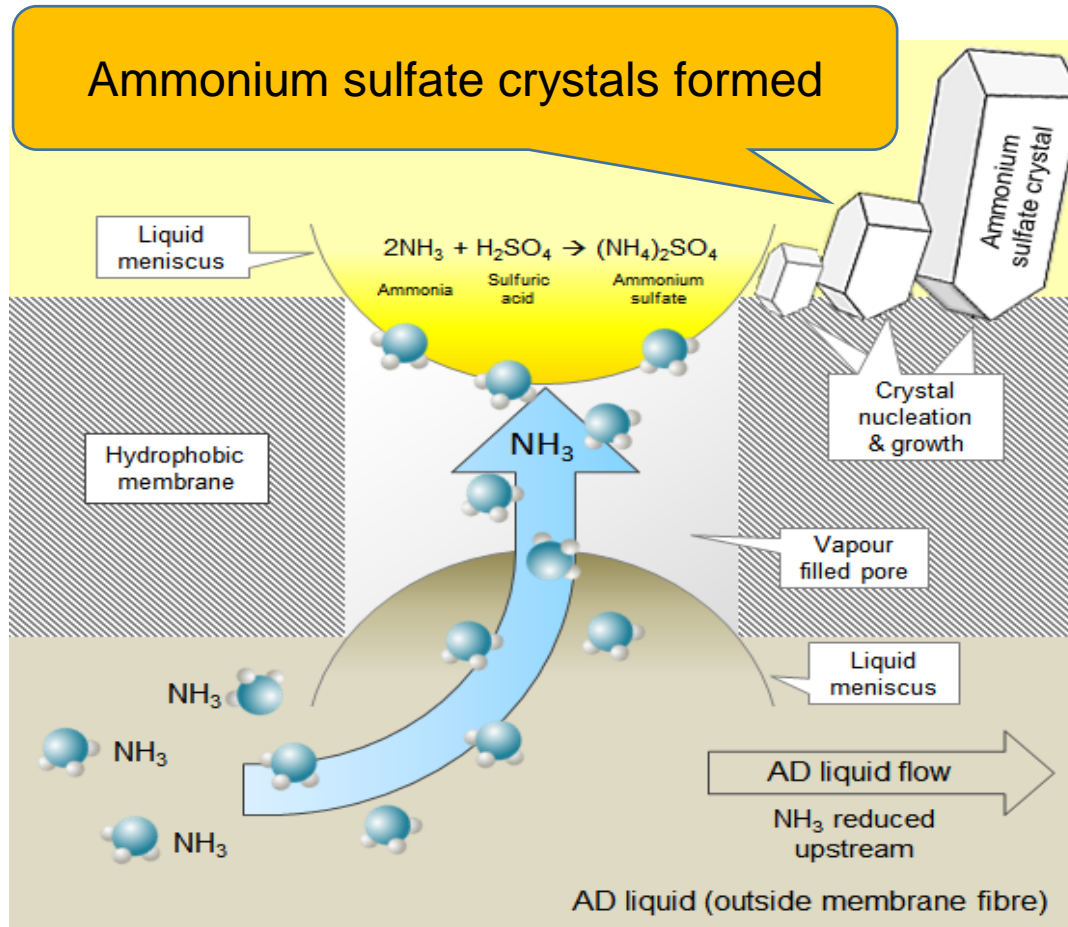
## Anaerobic Digestion – Ammonia Problematic



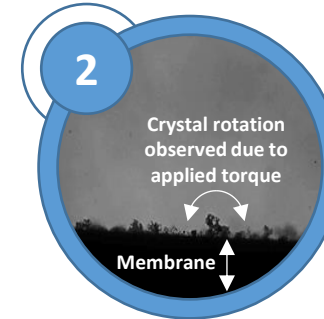
**Nutrient value £4-6 tonne<sup>-1</sup>;  
disposal cost £10 tonne<sup>-1</sup>**

*58% of land in England is designated an NVZ, limiting Nitrogen application*

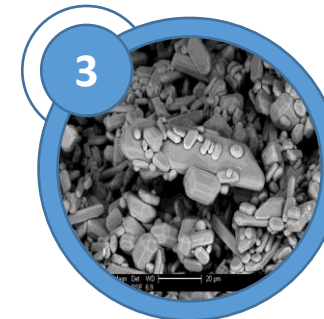
# 3.) Membrane Contactors for Ammonia Recovery



1 Nucleation at the membrane



2 Crystals growing on membrane



3 Crystals collected downstream



# 3.) Membrane Contactors for Ammonia Recovery

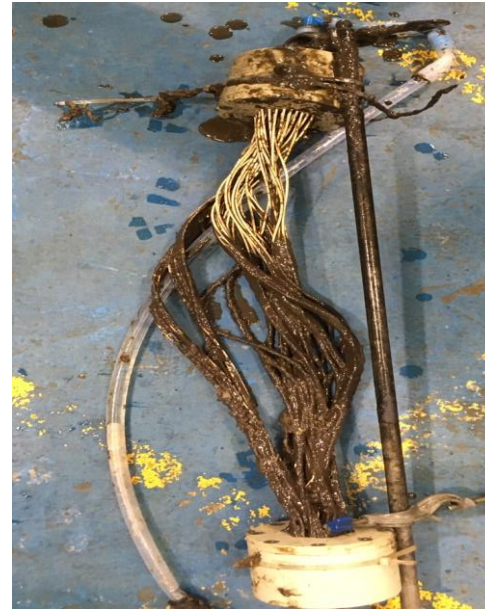
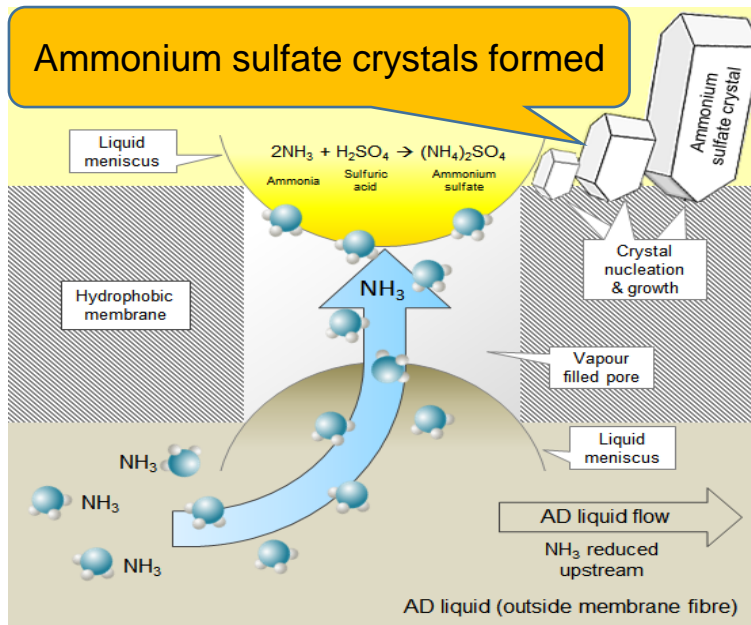
Proof of Concept



Process Optimisation



Scaled Testing







# Conclusions

- Research focuses on process engineering, tailor and adapting membrane processes to unique applications.
- Capabilities for taking technology from proof of concept to full scale testing.
- Examples:
  - Membrane distillation for water recovery from faecally contaminated urine.
  - Reverse Electrodialysis for simultaneous concentrate management and energy recovery.
  - Membrane Contactors for Ammonia Recovery.

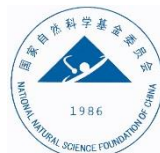


# Acknowledgements

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- *Nanomembrane toilet*: Farhad Kamranvand, Peiji Liu, Edwina Mercer
- *Ammonia Recovery*: Dr. Mehrez Hermassi, Erwan Allard, Mallek Amine



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