Aalto University
School of Engineering

HSY

Raed Al-Juboori

NPHarvest: Novel nitrogen and phosphorus recovery process: pilot scale field experiments and future prospects

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Pilot equipment and process

Key findings

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- **Phosphorus**
- **P sludge hygienic quality**
- **Membrane robustness**
- **Economic feasibility**

Push towards future

Concussions

Pilot Equipment and Process

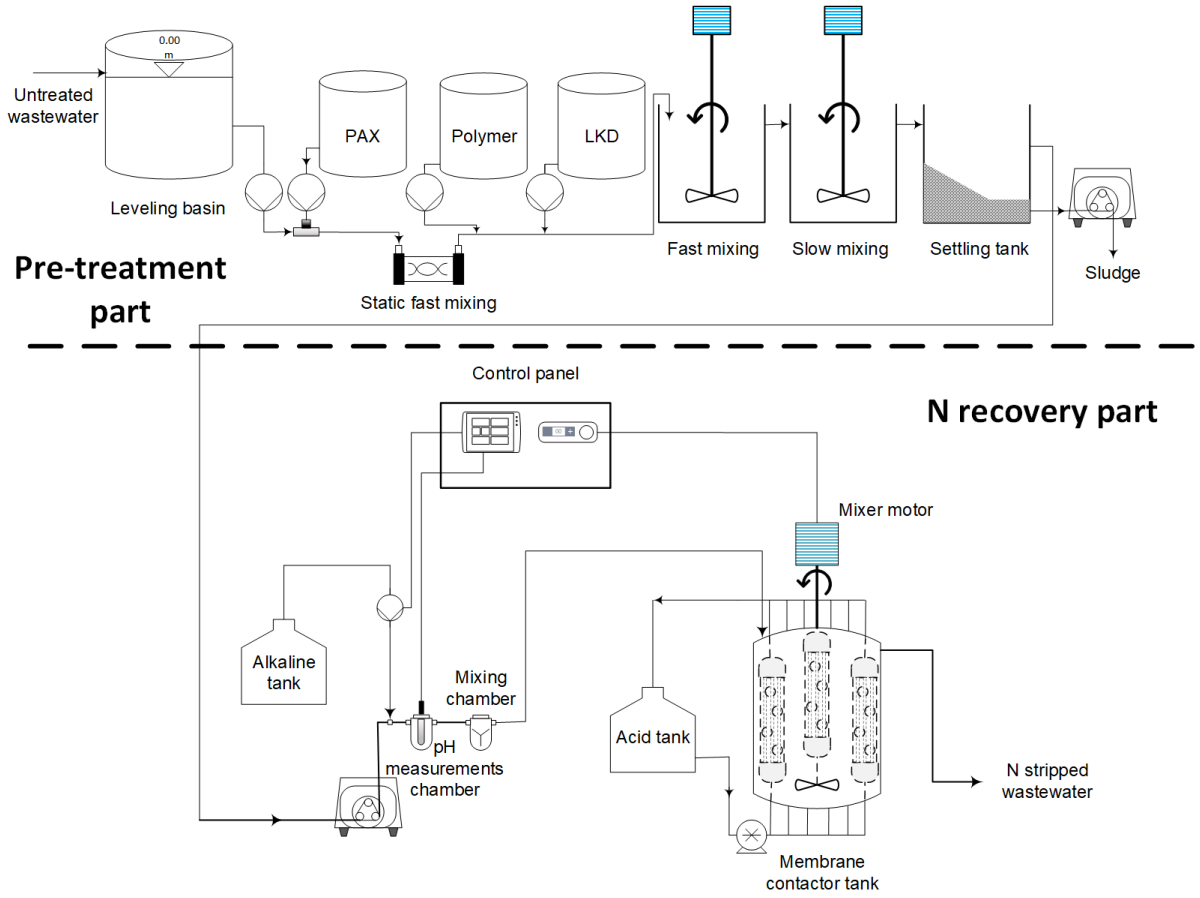
NPHarvest

- Ammonia recovery through hydrophobic membrane stripping
- Phosphorus recovery in hygienized sludge with lime-ballast sedimentation

- Pre-treatment removes P and SS
- Membranes capture N to ammonium salts
- Reactor is designed to tolerate high SS concentrations

Piloting streams

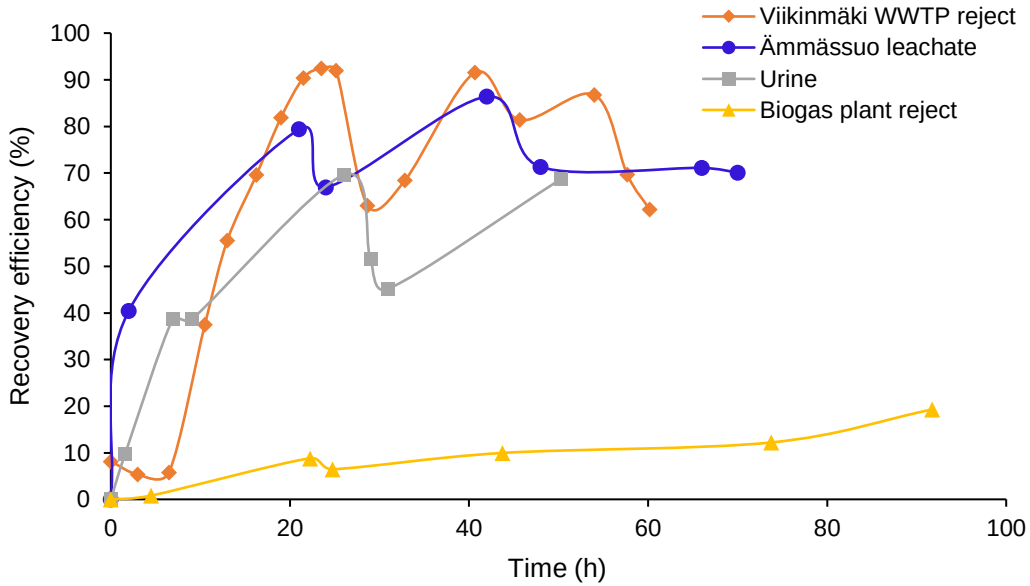
- WWTP reject water
- Biogas plant reject water
- Separately collected urine
- Landfill leachate

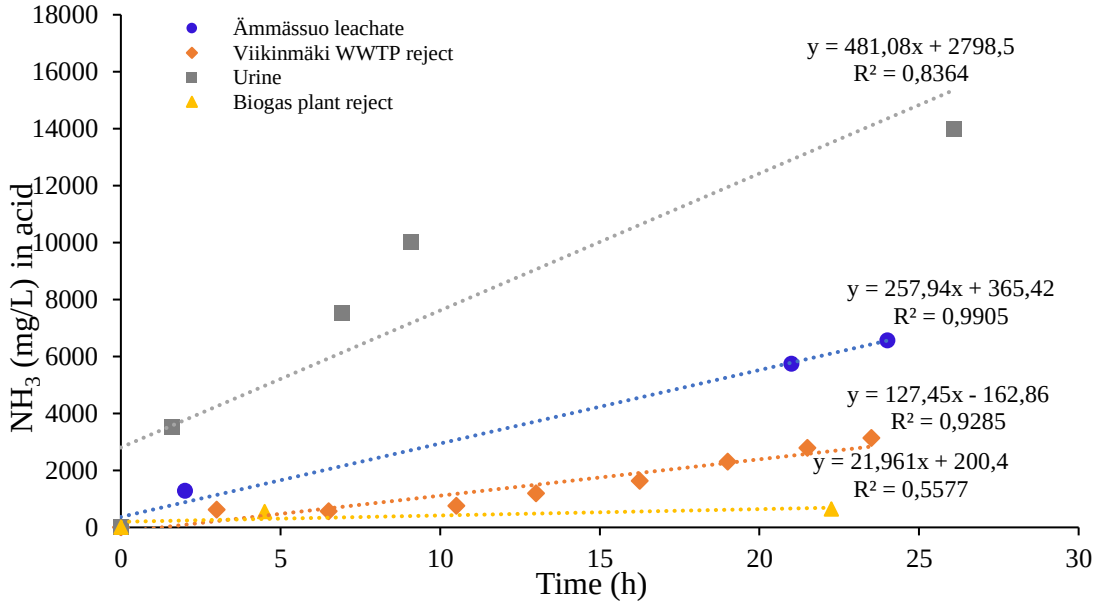


Key Findings: Nitrogen

Ammonia transfer rate

- **Is proportional to c(NH_3) difference across the membrane**
- **Is inversely proportional to SS concentration in the bulk liquid**





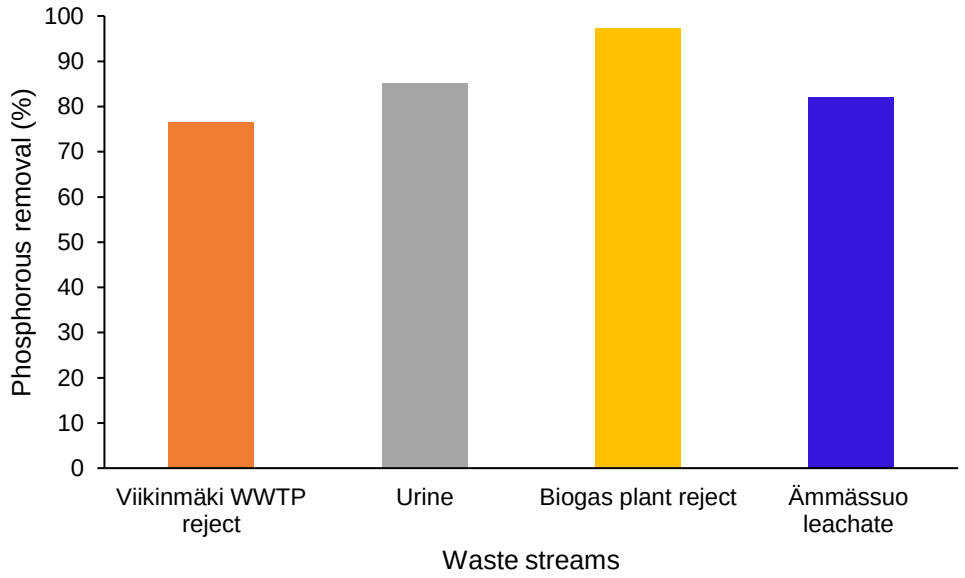
Ammonia recovery efficiency

- **Depends on hydraulic retention time (HRT)**
- **70-90 % recovery efficiencies were achieved with HRTs between 2 and 8 hours**

Key Findings: Phosphorus & hygienic quality

P recovery was high throughout the tests

- **P is bound in the sludge with PAX and/or lime products**
- **High pH is an advantage for floc formation and hygienic quality of the sludge**



Measured species	Reject stream	Ammonium sulphate	Hygienized sludge
E.coli (CFU/ml)	400	<0.01	<1
Salmonella	Detected	Not detected	Not detected
Sulfite reducing Clostridia spores (CFU/ml)	4 800	<0.01	2 300
Sulfite reducing Clostridia, vegetative cells (CFU/ml)	18 000	<0.01	3 600

Hygienic quality (WWTP sludge)

- **Active bacteria are wiped but spores and vegetative cells remain in the sludge**
- **Sludge needs processing due to pharmaceutical trace substances**

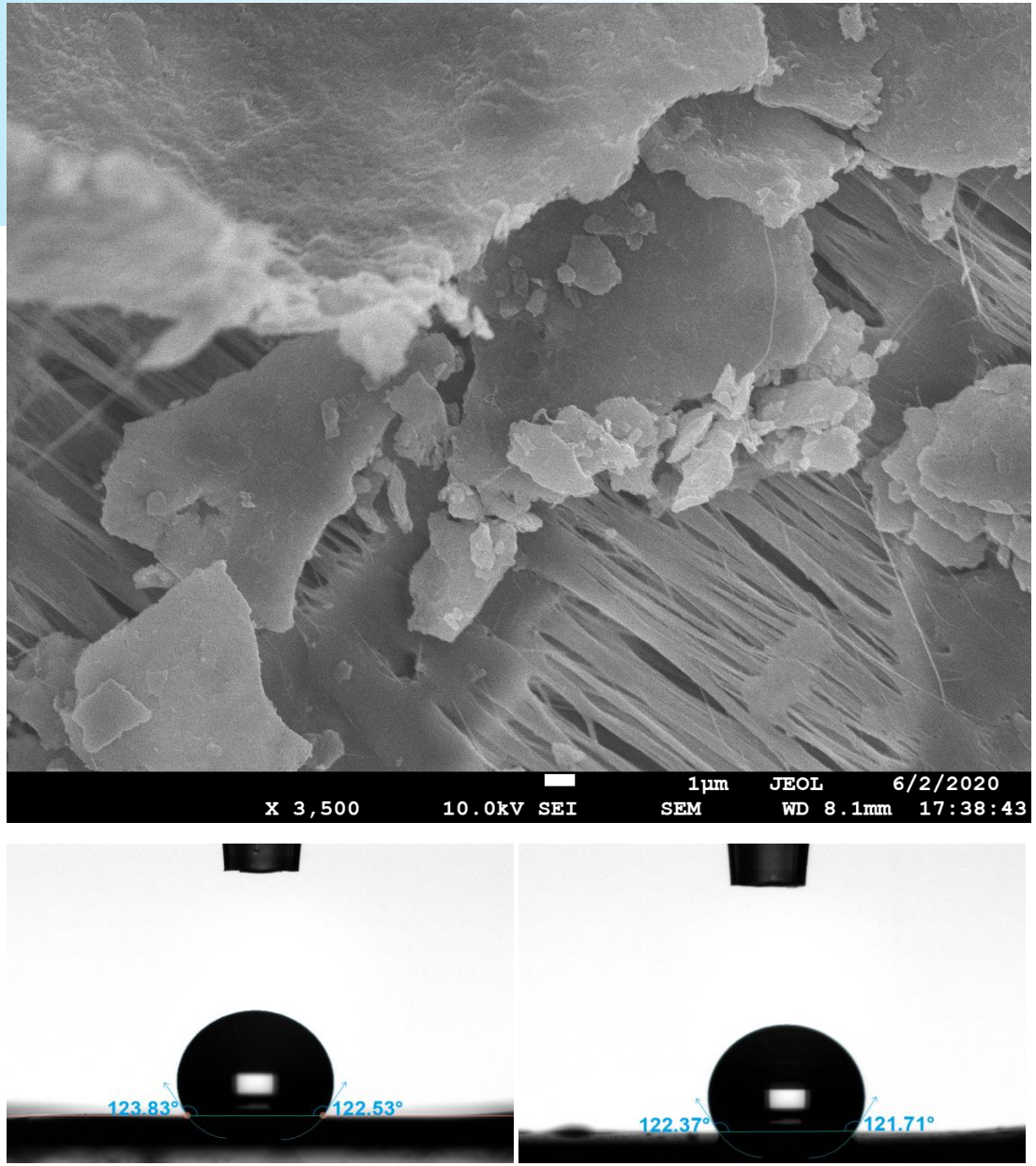
Key Findings: Membrane robustness

Membranes are the most critical and expensive part of the equipment

The membrane was used with four different streams over a 9-month period.

The longest consecutive contact time with bulk liquid was 2 months.

- **Some fouling was observed**
- **But it did not decrease the membrane performance nor loss of hydrophobicity**



Contact angle of (a) virgin and (b) fouled membranes.

Key Findings: Economic feasibility

Process energy and chemical costs were compared to existing industrial solutions' values

NPHarvest – at its unoptimized state and small scale – is cost-comparable to existing solutions

NPHarvest costs are between 2.5 and 5 €/m³ influent stream

Competitors' examples are at 4.7 and 8.9 €/m³ respectively

In WWTPs the process also decreases energy, lime and methanol consumption (not included in the calculation)

	Industrial evaporation stripper	Small industrial stripper	NPHarvest @ Ämmässuo leachate	NPHarvest @ Viikinmäki WWTP reject	NPHarvest with Urine
Flow rate (m3/year)	190000	6752.5	350	473	1165
Energy (kWh/m3)	46	68.7	8.8	34	11.4
NaOH (99 %) (kg/m3)	0.1	2.7	5.4	-	-
HNO3 (>80 %) (kg/m3)	0.1	-	-	-	
H2SO4 (98 %) (kg/m3)	-	4.6	1.9	0.7	2.0
Ca(OH)2 (kg/m3)	-	-	-	9.2	4.6
LKD (kg/m3)	-	-		4.6	-
PAX XL 100 (30-40 %) (kg/m3)	-	-	-	5.4	-
Polymer (kg/m3)	-	-	-	0.001	-
Recovery %	95	-	80	85	70
Energy costs €/m3	4.60	6.87	0.88	3.37	1.14
Chemical costs €/m3	0.07	2.00	2.55	1.79	1.24
Cost sum €/m3	**4.67**	**8.87**	**3.43**	**5.16**	**2.38**

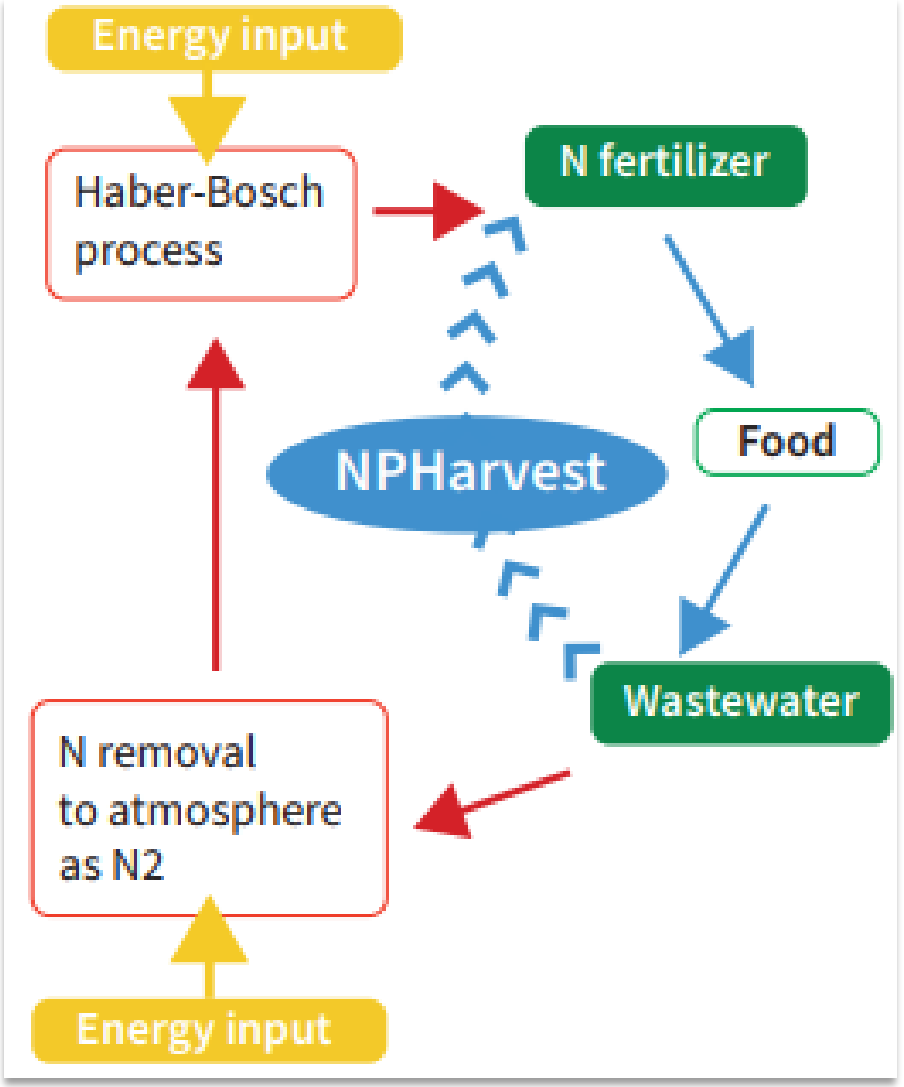
Push towards future

NPHarvest background and long-term goal is to promote nutrient utilization from wastewater

- **Nitrogen: Haber-Bosch and aeration consume large amounts of energy**
- **Phosphorus: Limited and controlled by few**

Next steps:

- **Testing with upgraded pilot equipment**
- **Investigation on how to enter market**
- **NPHarvest as start-up company**



Conclusions

NPHarvest is a nitrogen and phosphorus recovery pilot

The process has been tested and proved in versatile environments with high performance results

Still a long way to go:

- **Sludge processing**
- **Process optimization**
- **Business development**
- **Building a start-up**

Thank you for your interest on behalf of the whole team!

D. Sc (tech)
Raed Al-Juboori

M. Sc (tech)
Ilari Righetto

Professor of Practice
Anna Mikola

M. Sc (tech)
Juho Uzkurt Kaljunen

www.aalto.fi/en/npharvest

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