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Review

Forward osmosis for application in wastewater treatment: A review

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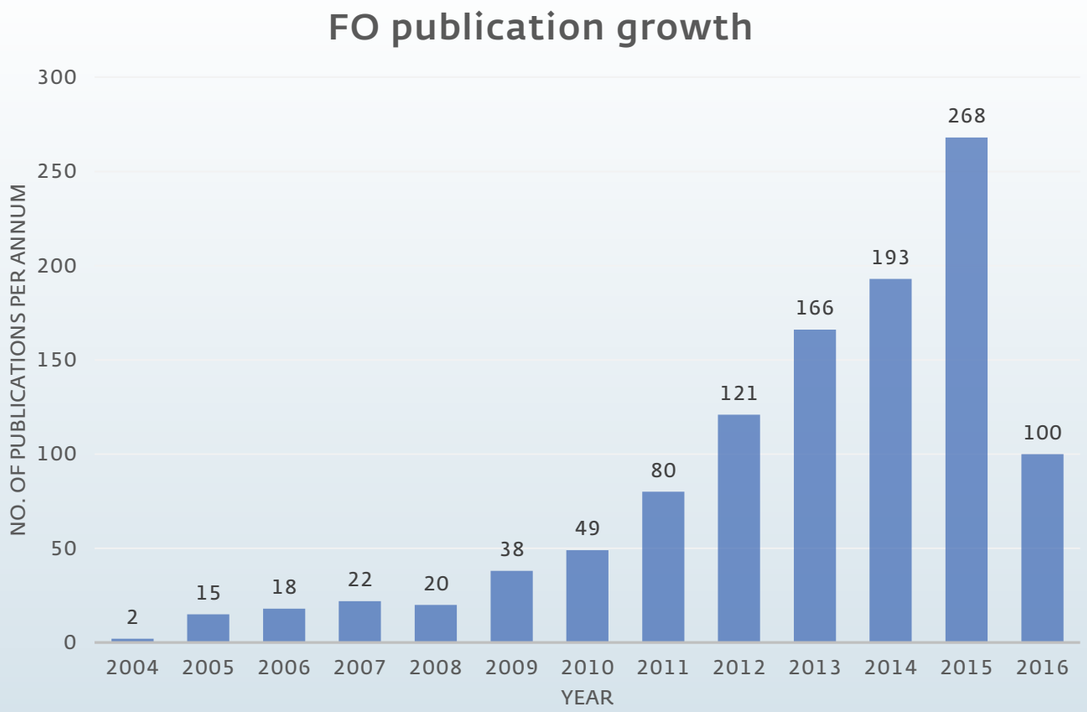
ARTICLE INFO

ABSTRACT

Review paper Forward Osmosis (FO)

Number of FO publications



FO publication growth from 2004-2016

Sewer Mining

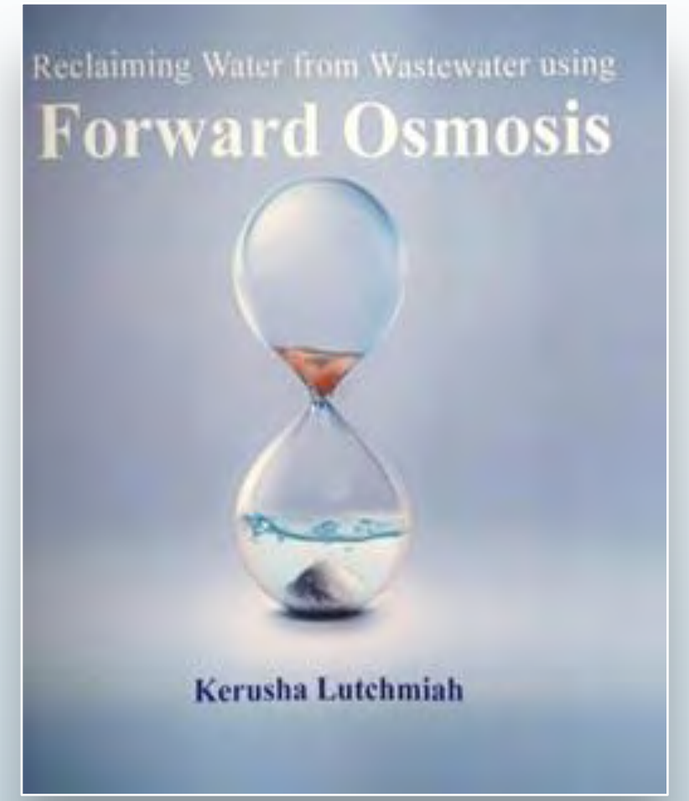
PhD thesis of Dr. Lutchmiah (2010-2014)

Aim:
Obtaining water and energy from wastewater at optimised performance and operationally stable conditions

Various topics

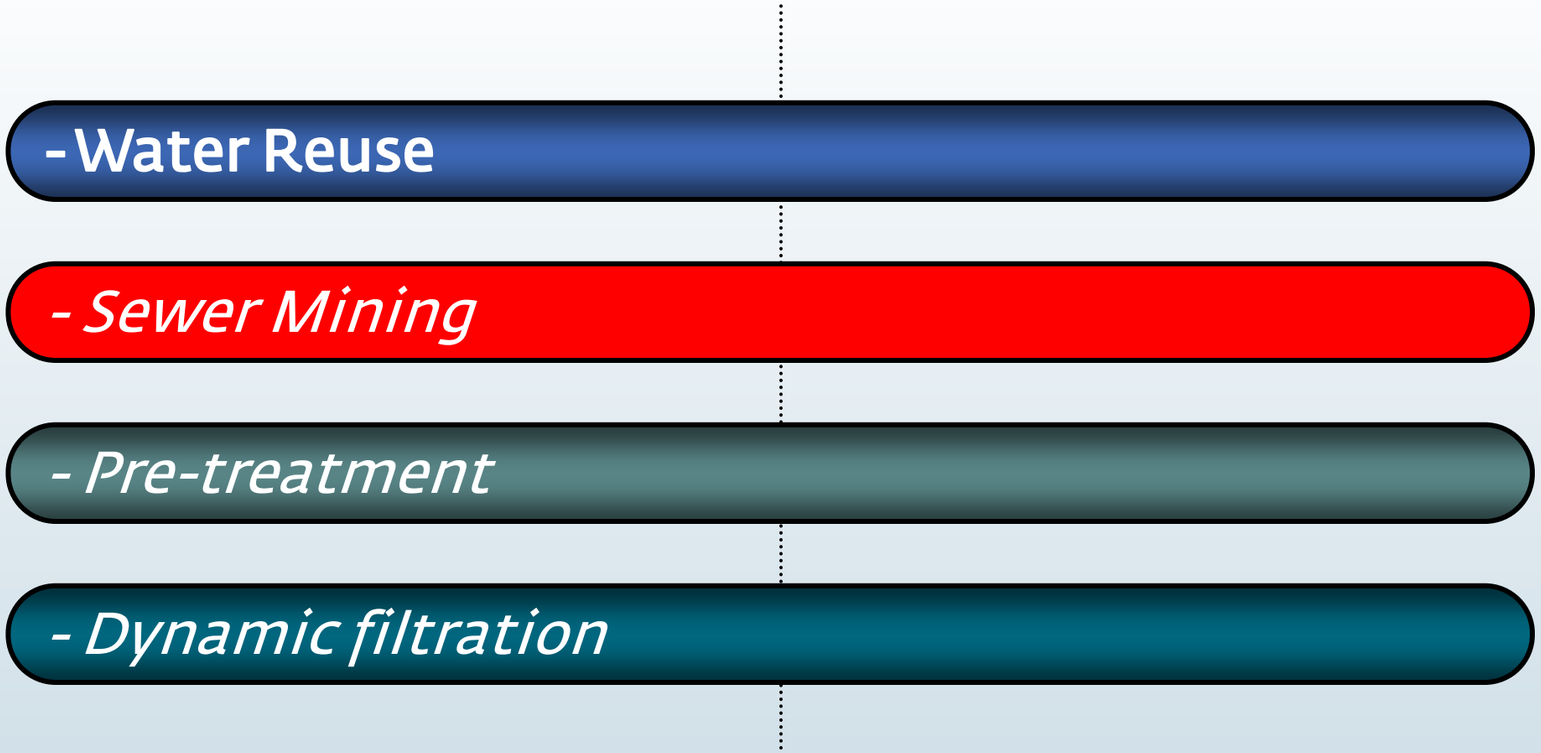
- **Review on forward osmosis in wastewater** (1)
- Alternative draw solutions
- Pressure assisted osmosis (PAO)
- Fouling of FO membranes using wastewater
- Modelling FO-RO systems
- Scaling-up FO to pilot-scale

PHD THESIS DR. LUTCHMIAH



(1) Lutchmiah, K., A.R.D. Verliefde, K. Roest, L.C. Rietveld, E.R. Cornelissen, Forward osmosis for application in wastewater treatment: A review, Water Research 58 (2014)

Outline of presentation



Background (1)

Need for high quality water – re-use of water

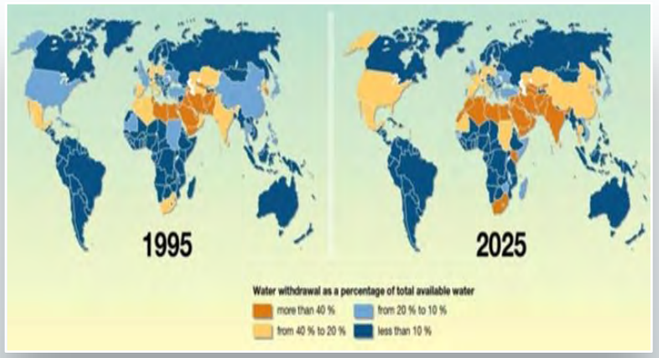
Increasing need for high quality water

- Increase in salinity of groundwater
- Variations quality/quantity of surface waters
- Decreasing availability of these sources

Growing interest in reuse of water for high quality purposes

- Secondary effluent as possible source

WATER WITHDRAWAL AS A PERCENTAGE OF TOTAL AVAILABLE WATER



EFFLUENT AS A POSSIBLE SOURCE OF HIGH QUALITY WATER

Background (2)

State of the art re-use schemes

State of the art technology

- **Pretreatment - Ultrafiltration (UF) - Reverse Osmosis (RO)**
- **Examples are WF21, NEWater, IWVA, WCRS Brisbane, etc.**

Limitations

- **Operational problems of state of the art technology (fouling)**
- **Energy demand of water production is high**
- **Need for concentrate disposal**
- **Logistics: distance WWTP from end user**

NEWATER INSTALLATION OF PUB IN SINGAPORE

REVERSE OSMOSIS AS THE HEART OF A REUSE INSTALLATION

Integrated water cycle

wastewater

Water system

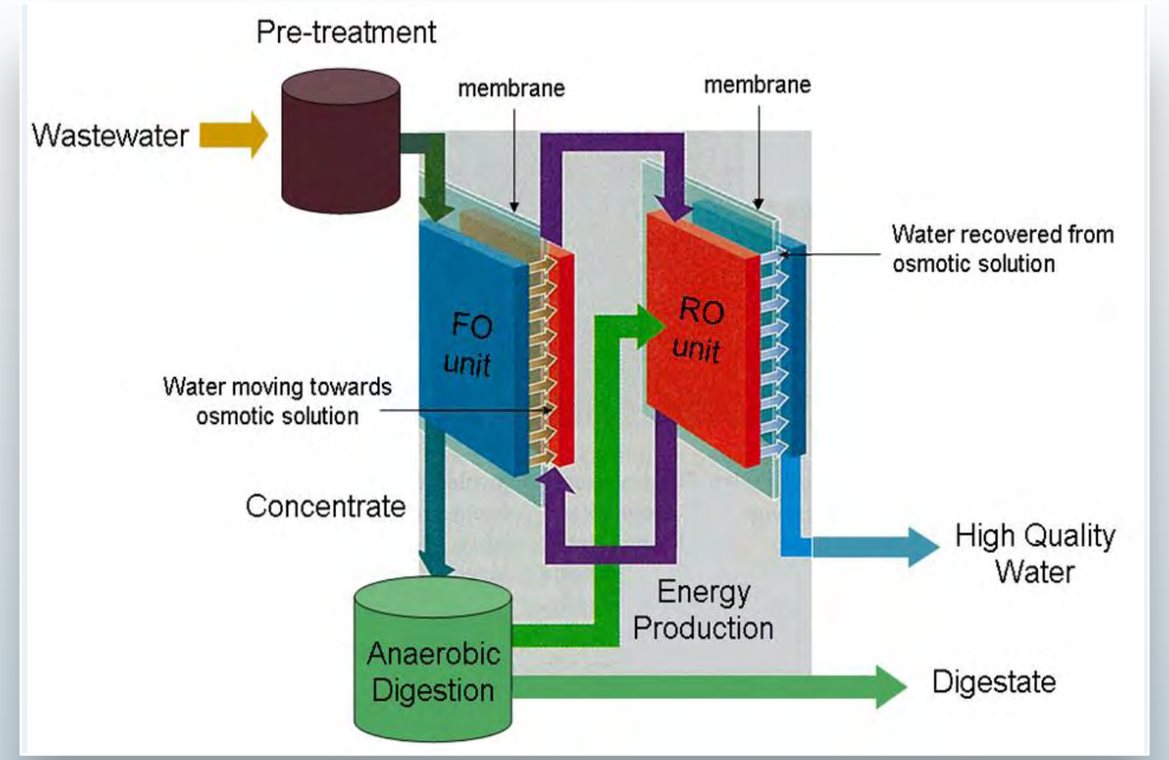
KWR

Drinking water

Sewer Mining Concept

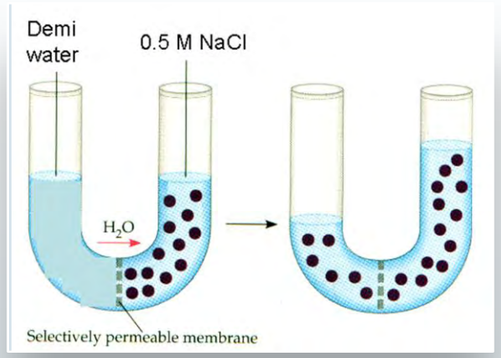
Novel concept for re-use of water and energy (2009)

1. Pre-treatment
2. Forward osmosis
3. Re-concentration
4. Digestion



SEWER MINING CONCEPT

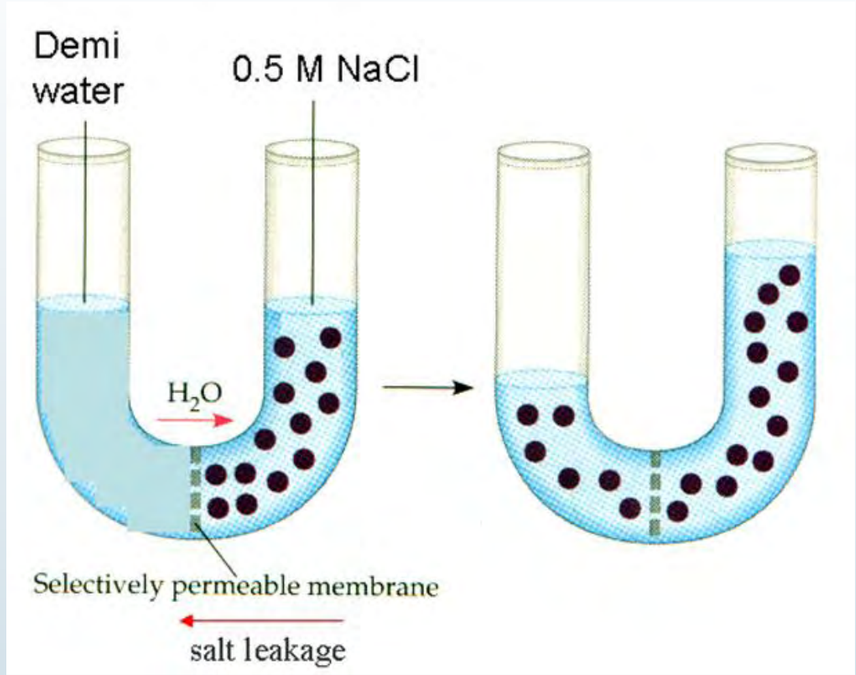
PRINCIPLE OF FORWARD OSMOSIS (FO)



SLUDGE DIGESTORS

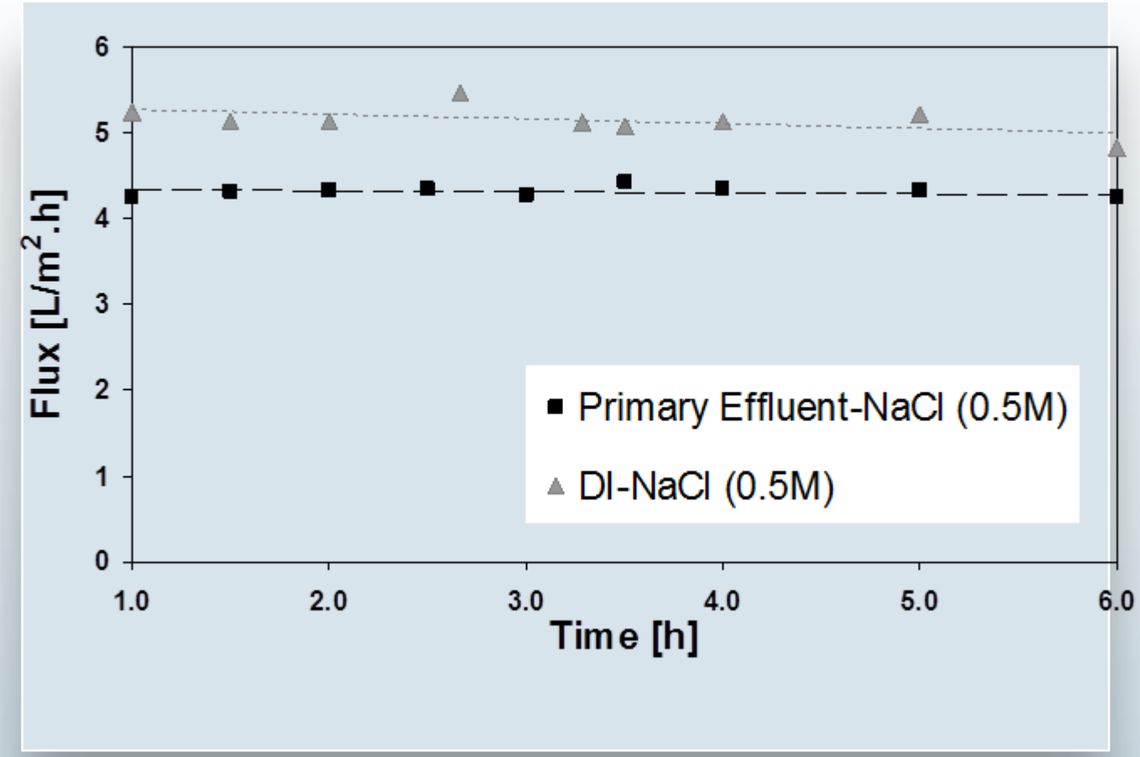
Forward Osmosis process

- A natural process
- Water flux and salt flux
- An osmotically-driven membrane process
- Production of high quality water
    - dilute osmotic solution
    - concentrate feed (i.e. sewage)



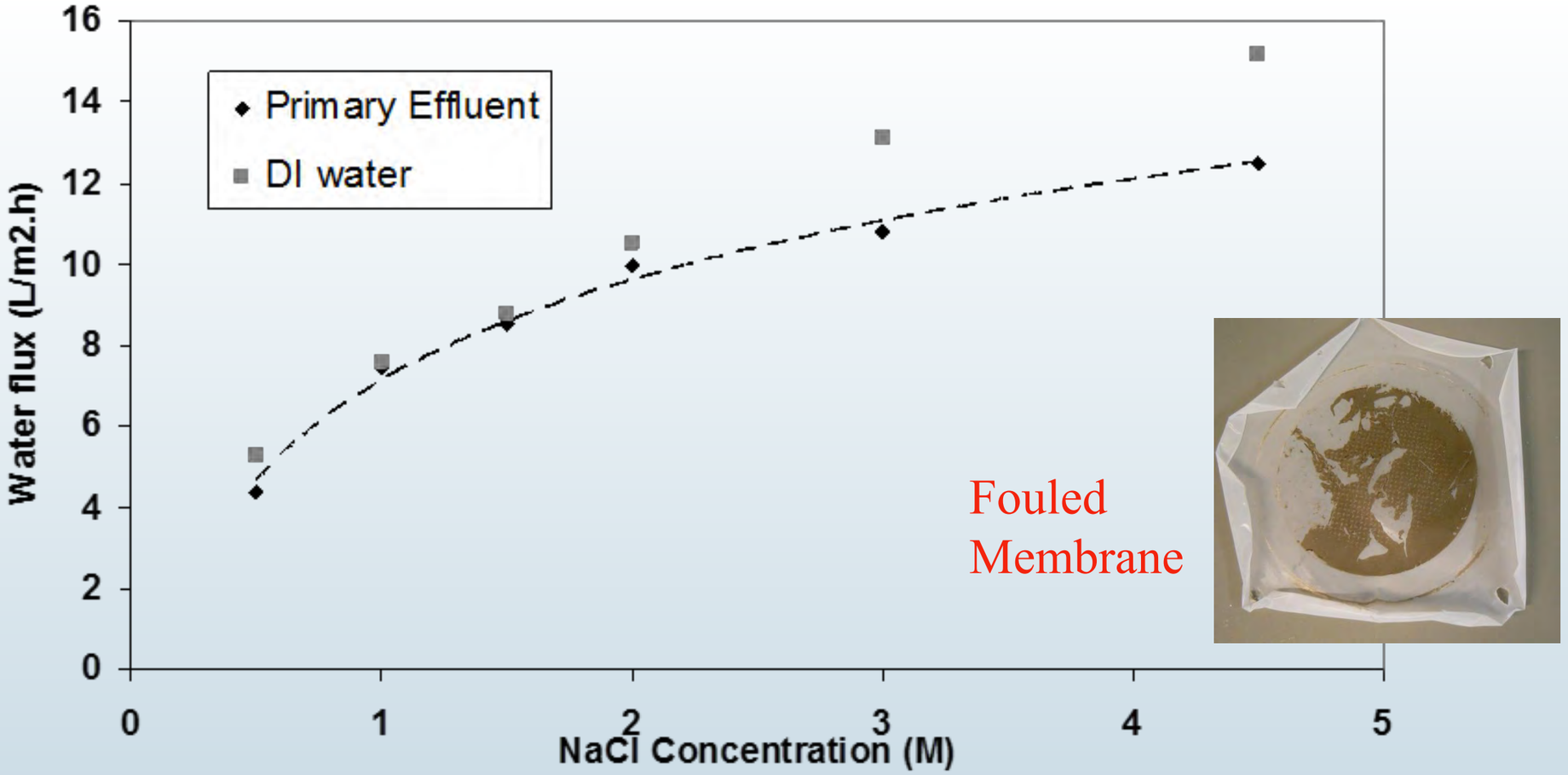
FO: DI vs Settled Sewage

Comparison of feeds



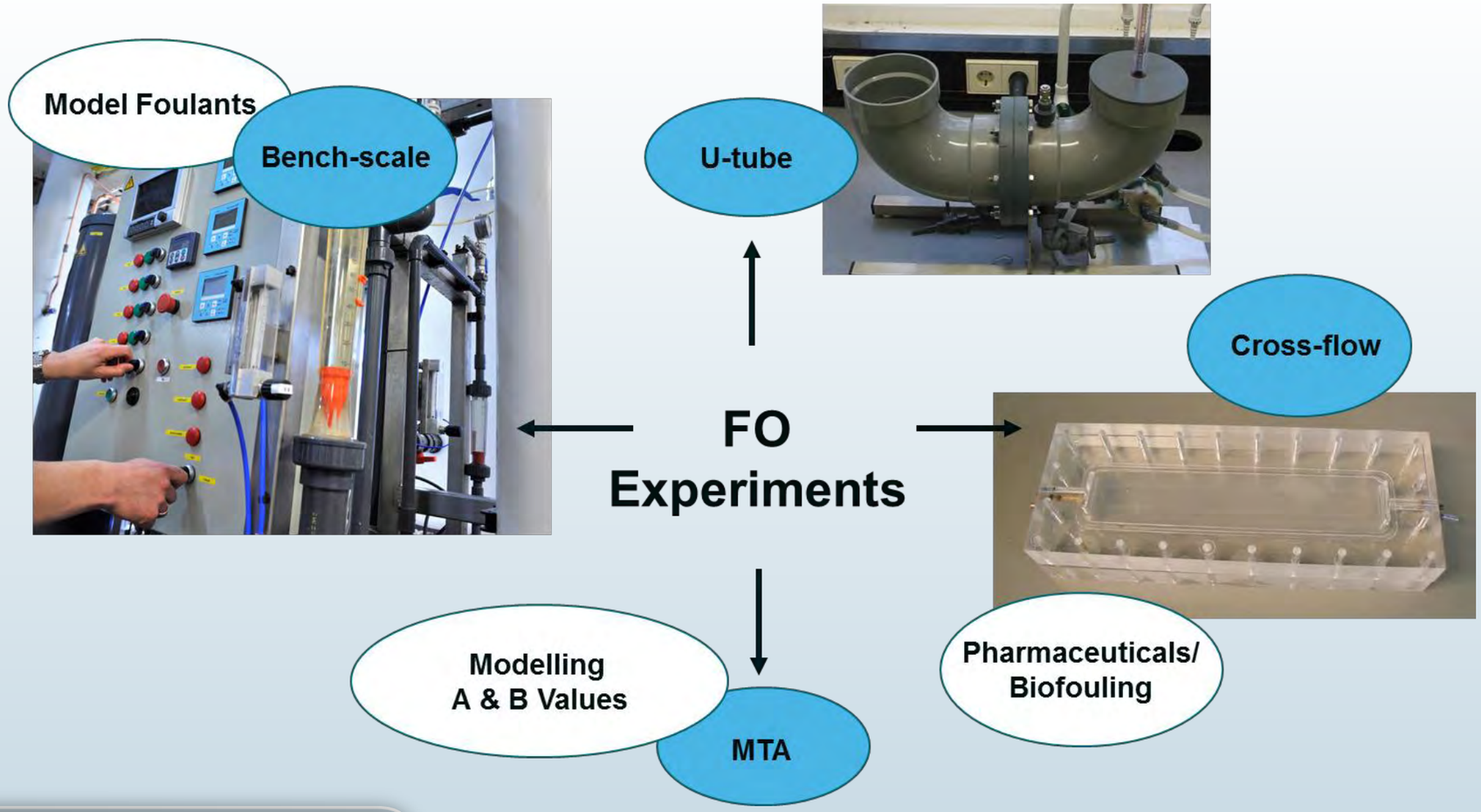
Comparison of feeds

Forward Osmosis



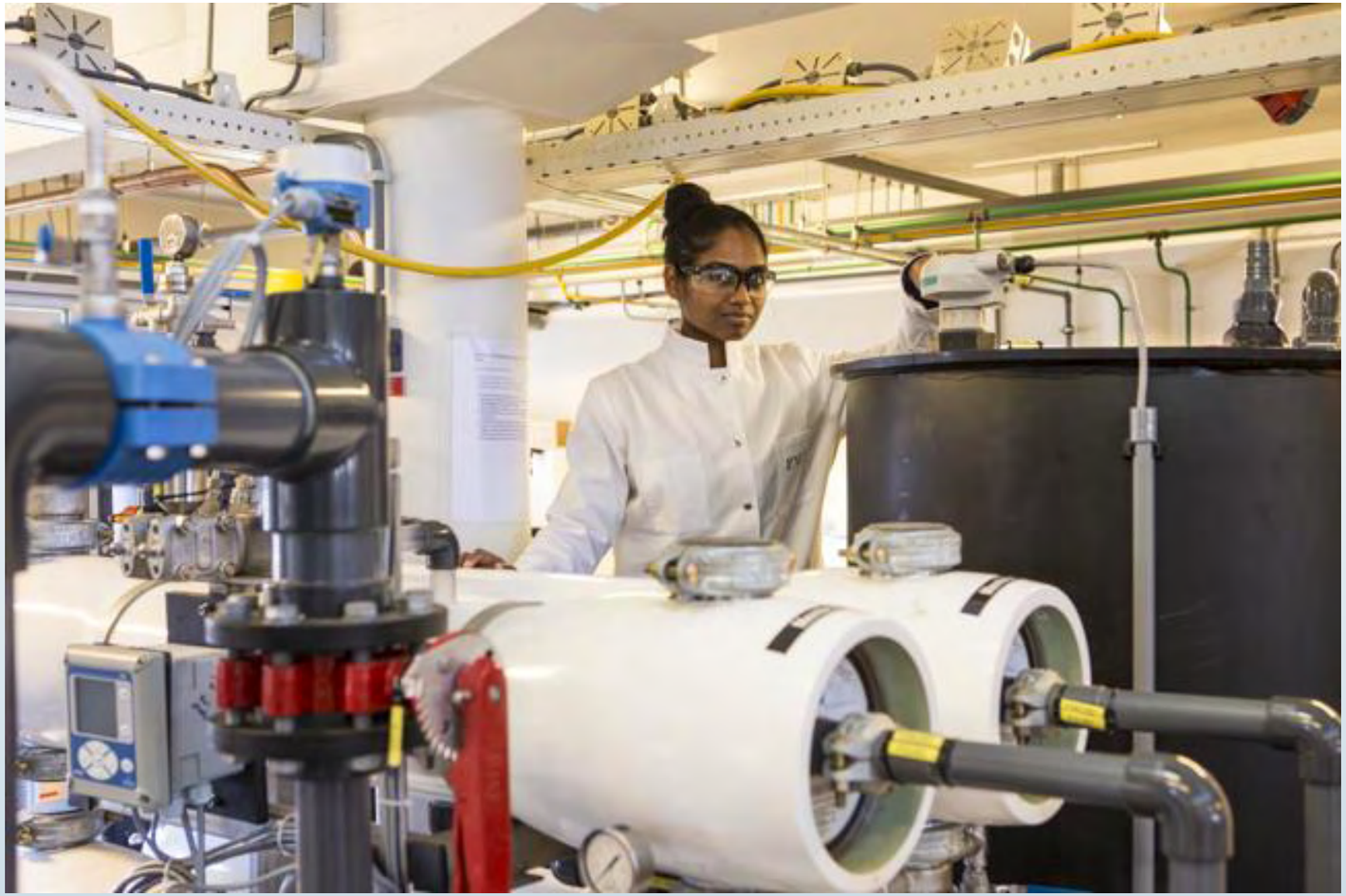
Fouled Membrane

Experimental overview

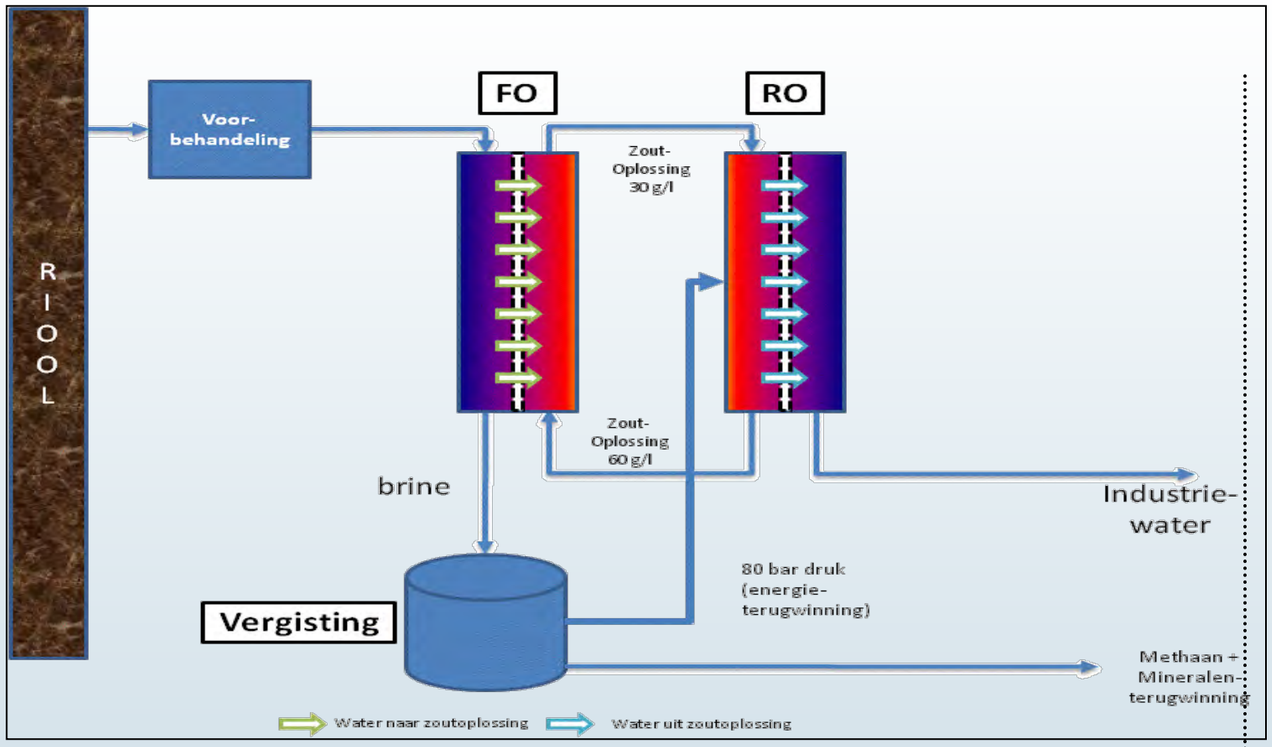


Experimental overview

Pilot



Sewer Mining



Clean water production (FO-RO)

Less fouling

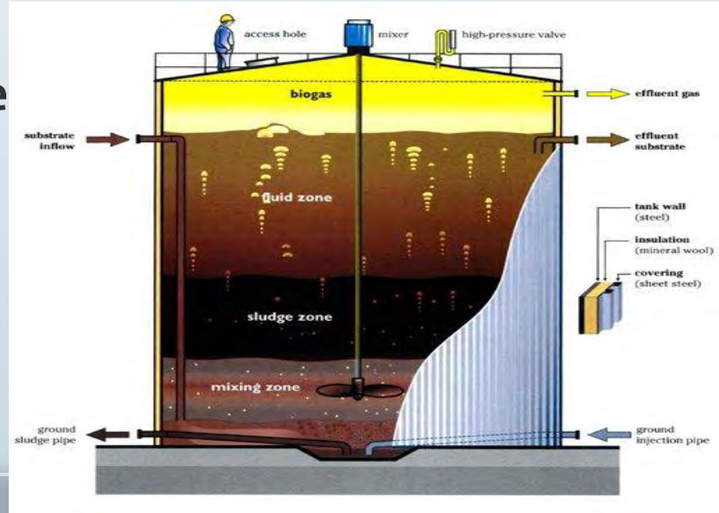
Removal of emerging compounds (hormones, PPCPs, etc.)

Energy production

Digestion of concentrated sewage

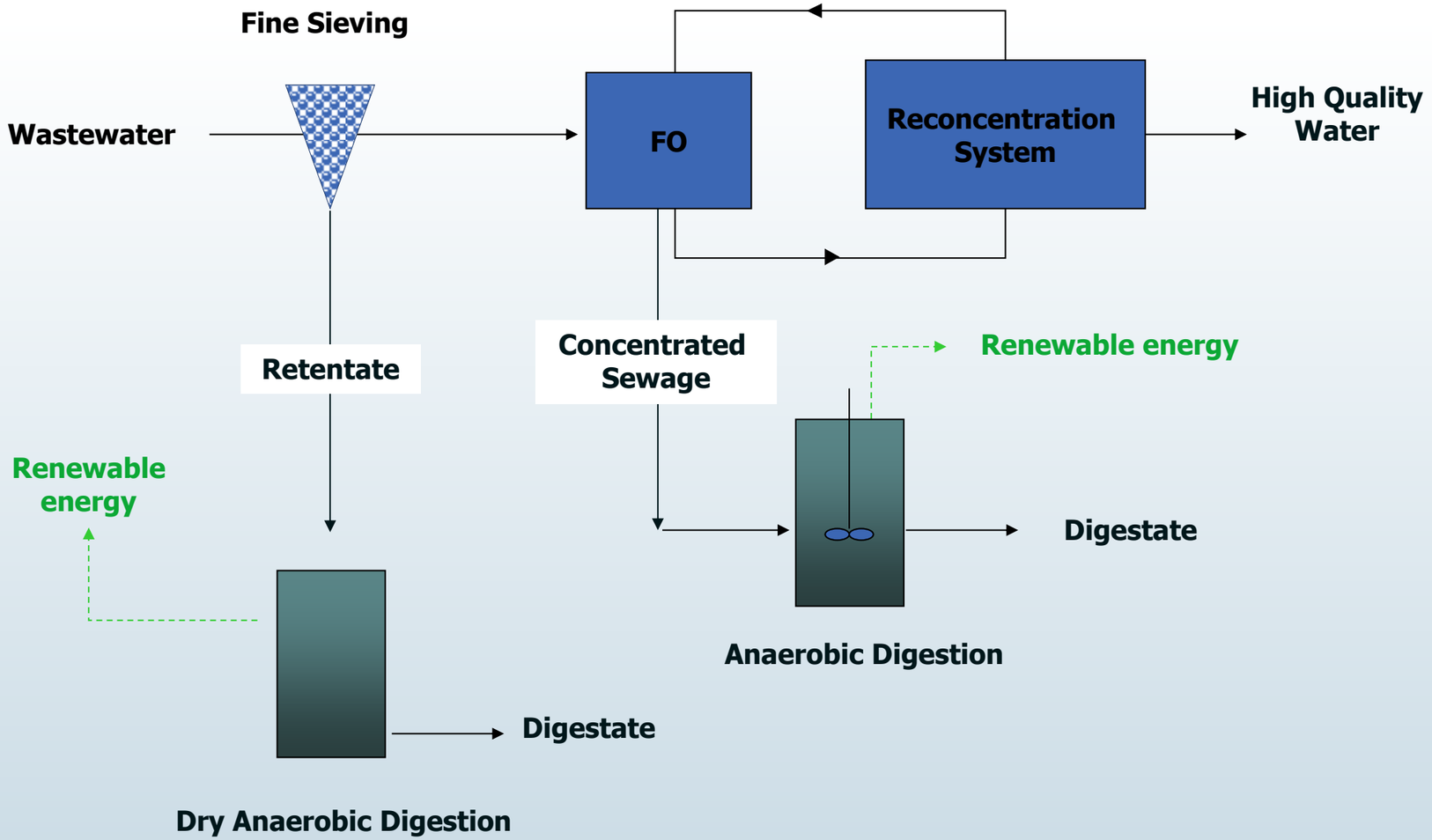
Nutrient recovery

Concentrated digestate



Broader Innowater consortium

Water, Energy & Nutrients



Options for pre-treatment

Solids separation

- **Settlers**
  - State-of-the-art
- **Influent fine-sieves**
  - Currently implemented
  - Mainly cellulose removal
- **Membrane bioreactor**
- **Ceramic filtration**
- **Dynamic filtration**
  - Shorter sludge residence time
  - Smaller footprint

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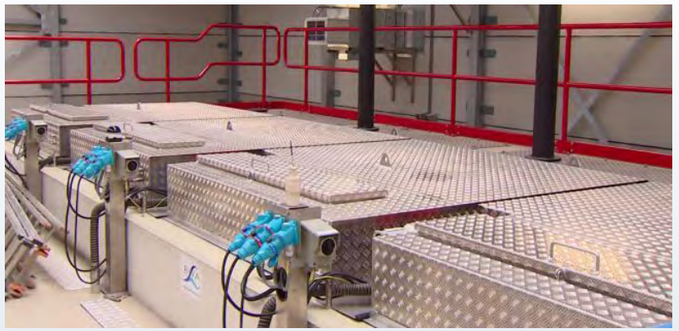

Influent fine-sieves

Screencap (www.screencap.eu)

- Finescreen supported biological wastewater treatment to enhance plant capacity
- Full scale pilot at Waste Water Treatment Plant Aarle Rixtel (NL)
- Impact on downstream processes
- Started 1 November 2014, with 3 years duration

Waterschap Aa en Maas

BWA

KWR Watercycle Research Institute

screencap

Co-funded by the Eco-innovation Initiative of the European Union

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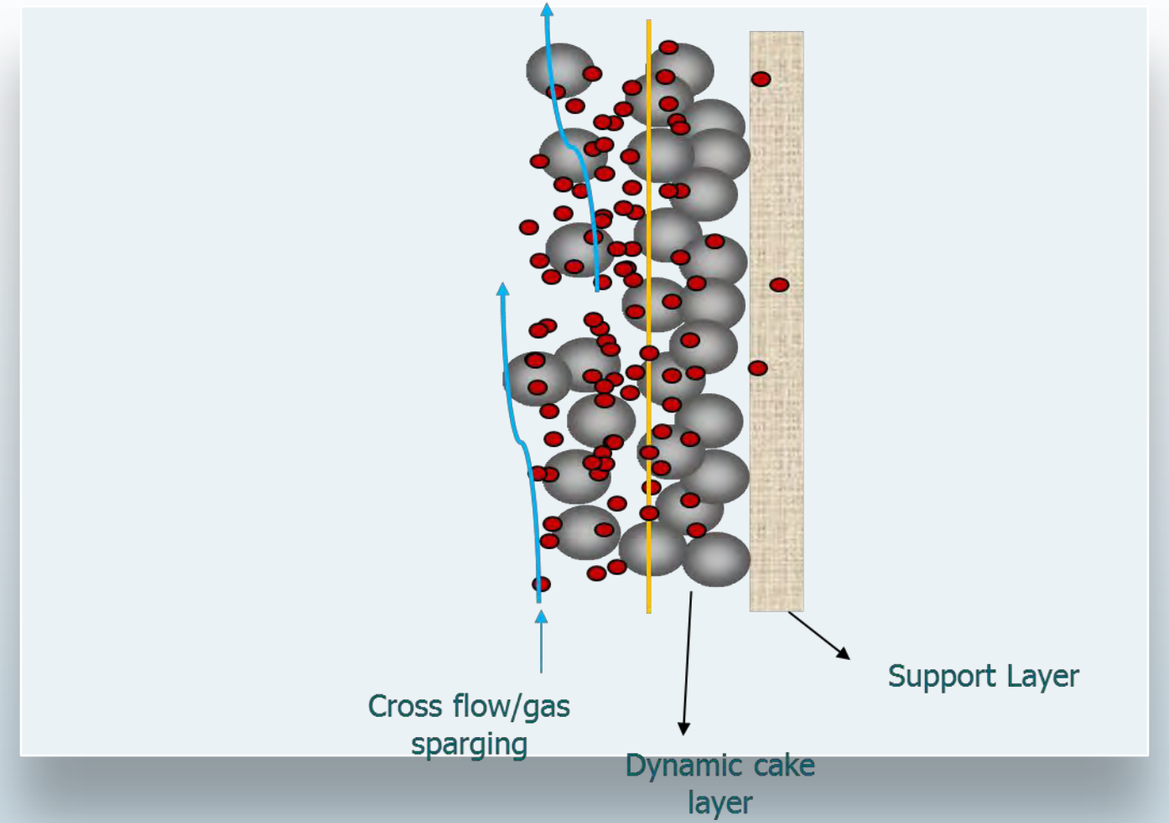
Dynamic filtration principles

STOWA Report 2011-w06

- **Dynamic membrane: cheap, relative coarse filter material (pore sizes from 3 to 500 µm) as support layer, on which arises a natural cake layer which is denser and ultimately responsible for the filtration**
- **Also called**
  - Coarse pore filtration
  - Secondary membrane filtration
  - Self-forming dynamic membranes
- **Dynamic filtration is an alternative to settling tanks and membrane bioreactors**

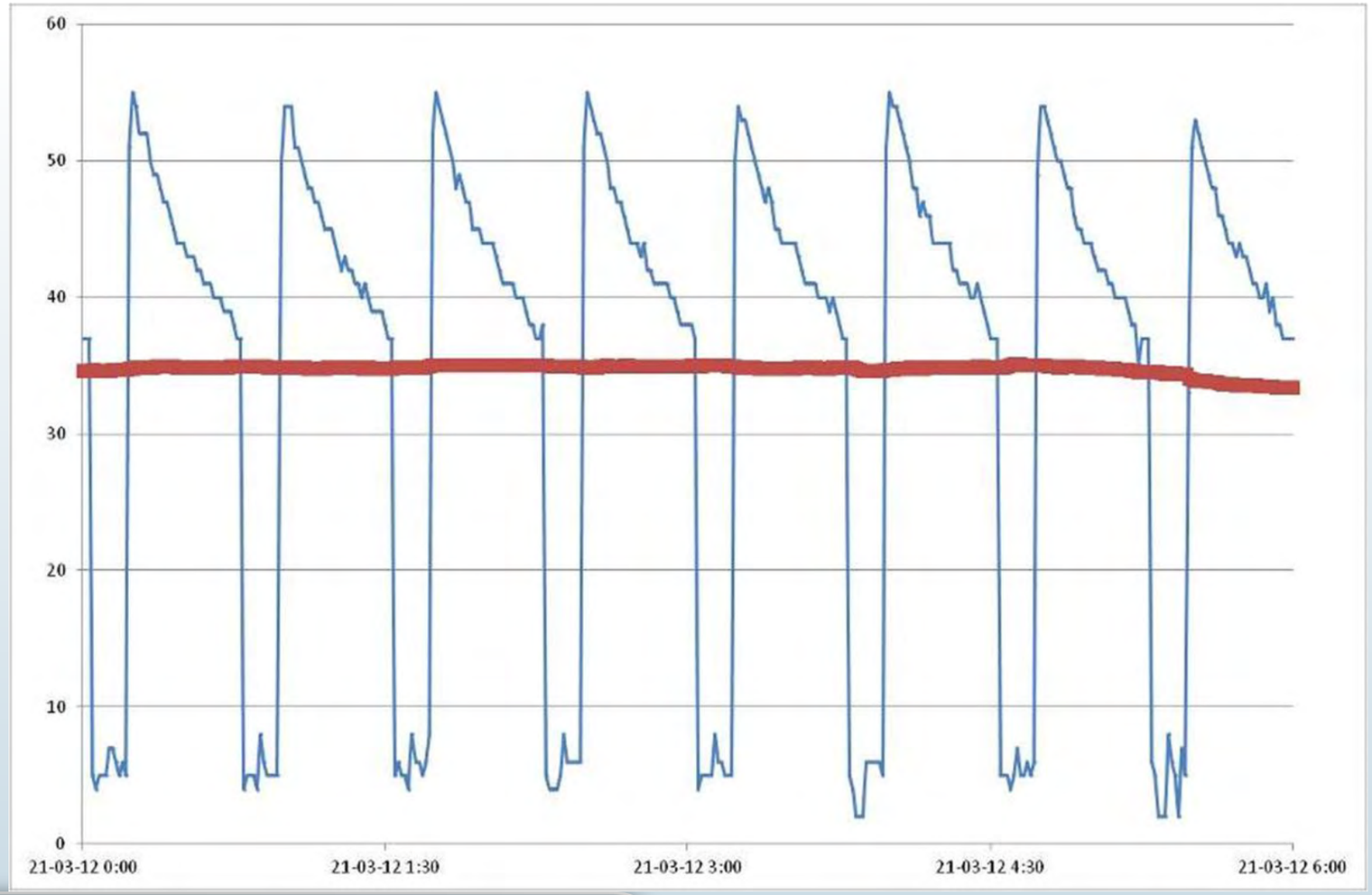


Dynamic filtration module

Dynamic filtration module

Dynamic filtration

Flux profiles (45 minutes runs, delta-P = 17 cm H2O)

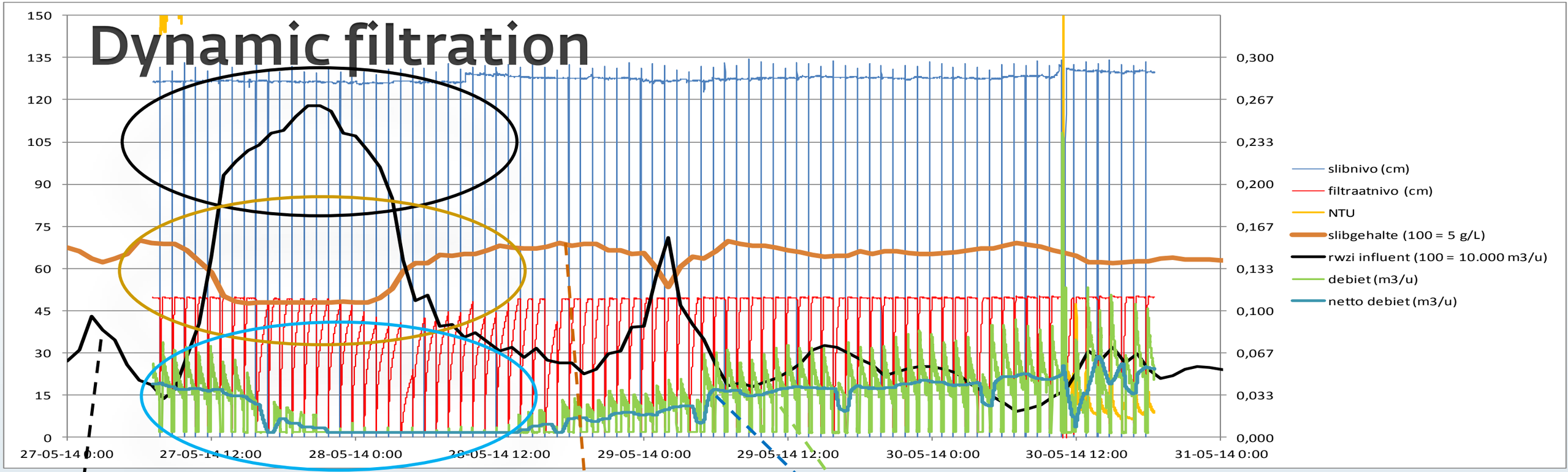


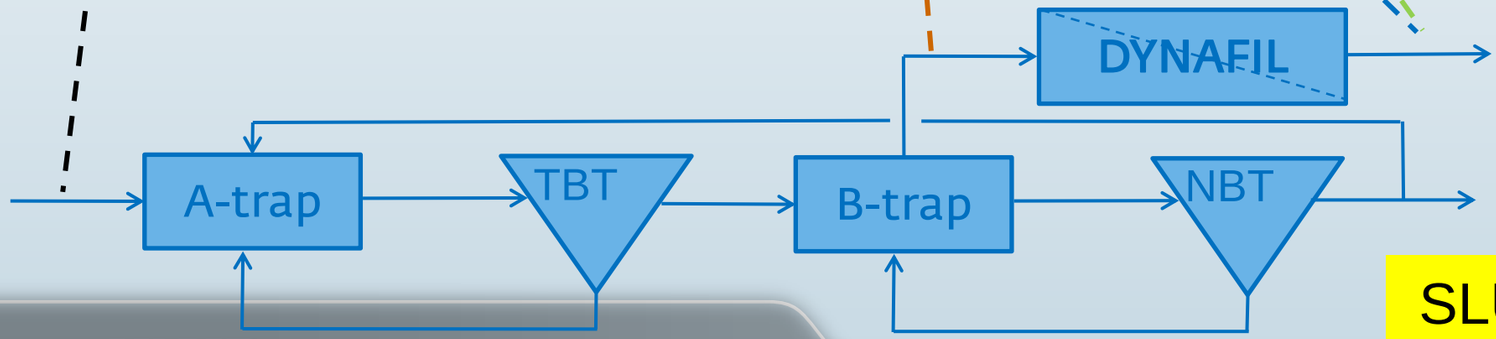
Flux in liter per square meter per hour

Blue = measured

Red = run-averaged

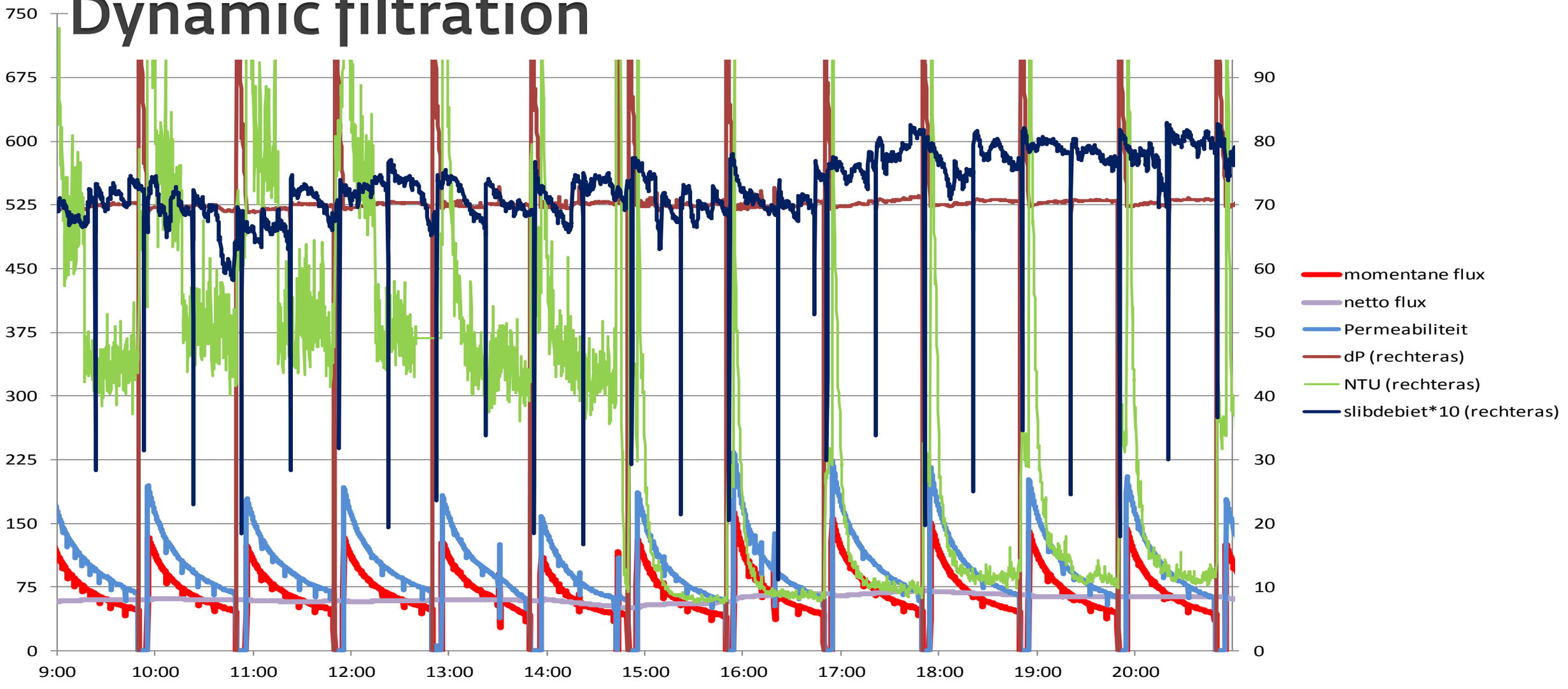
Dynamic filtration





SLUDGE MORFOLOGY & FLUX (RWF)

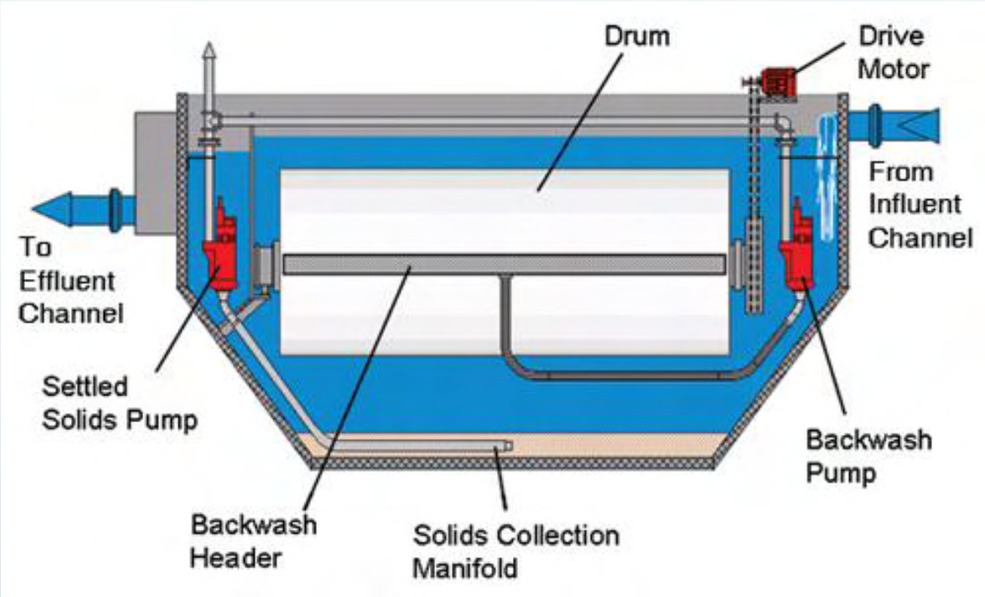
Dynamic filtration

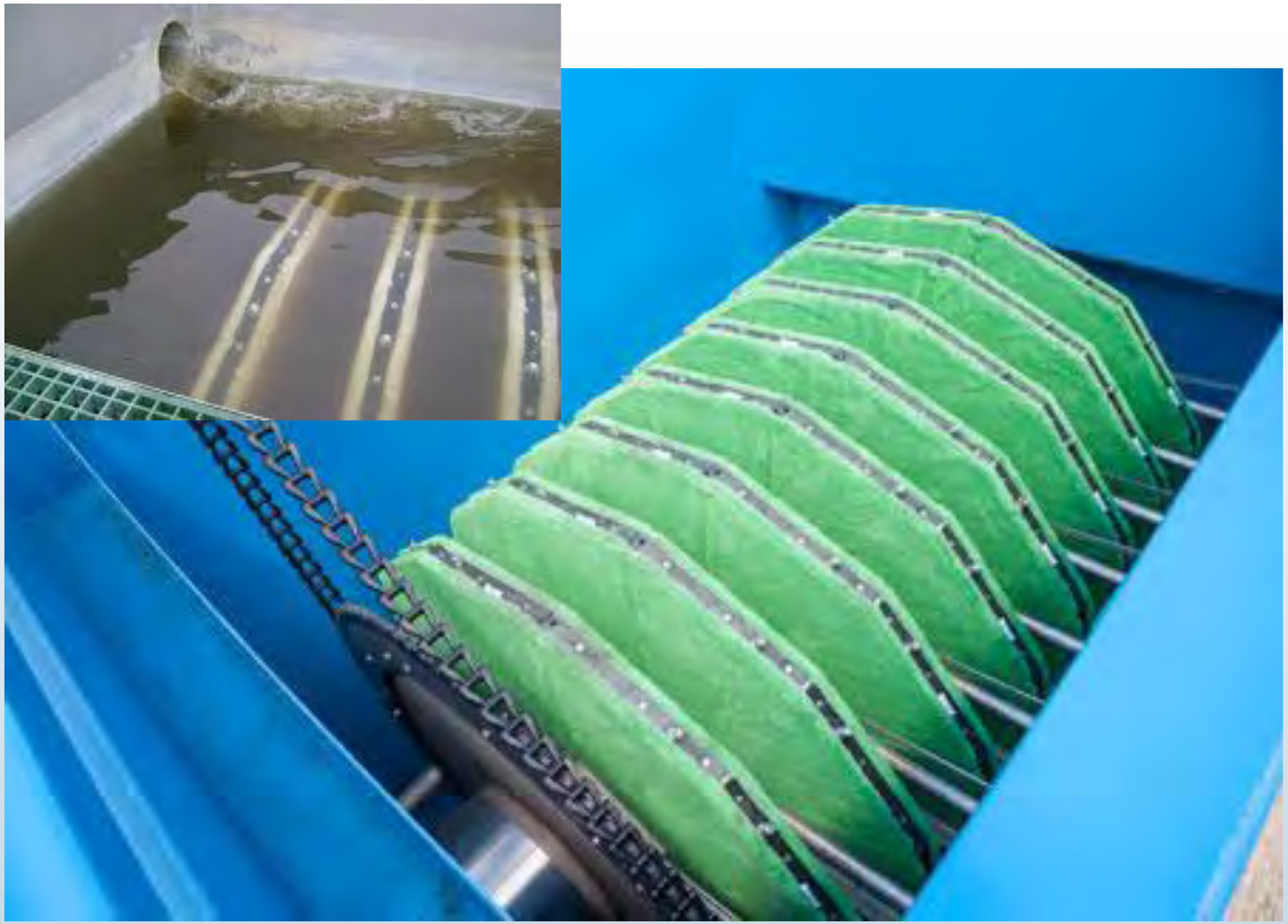


Cloth media filtration

Dynamic filtration

- **On the market**
  - Different systems
  - Commercially available





Summary Wastewater Resources

Nutrients, Energy & Water

Sewer Mining

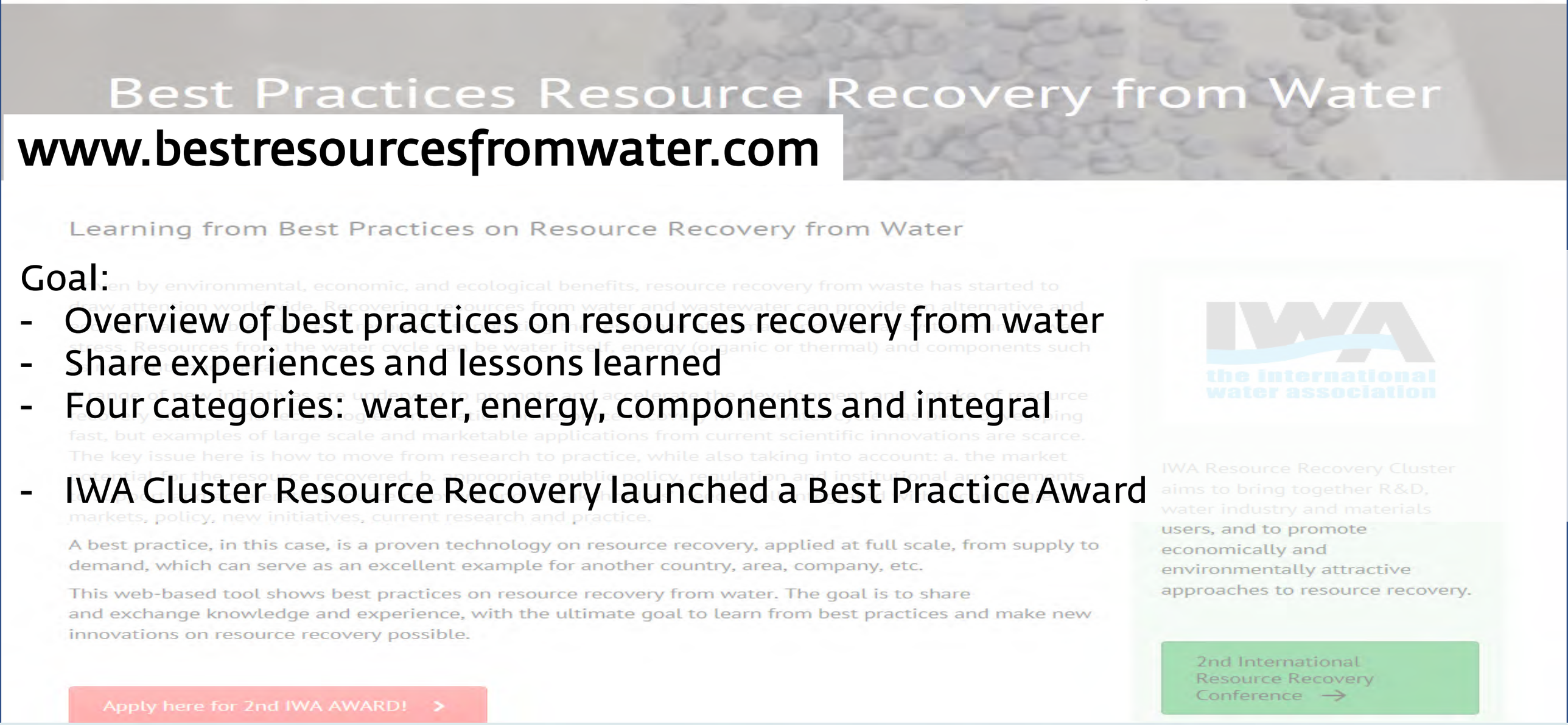
- **Forward Osmosis, re-concentration, digestion, nutrient recovery**
- **Forward Osmosis performance depends on:**
  - Temperature, membrane type & orientation, draw solution type & concentration, feed type
- **Low-fouling (reversible), high quality water, energy saving**

Dynamic Filtration

- **Low delta-P needed**
  - Relative stable flux, except with Rain Water Flow
- **Back wash required**
  - Partially effective → needs optimization
- **Mono filament carrier material**
  - Acceptable filtrate quality
  - Flux is related to the sludge quality

www.bestresourcesfromwater.com

Kees Roest – KWR Watercycle Research Institute



www.bestresourcesfromwater.com

Goal:

- Overview of best practices on resources recovery from water
- Share experiences and lessons learned
- Four categories: water, energy, components and integral
- IWA Cluster Resource Recovery launched a Best Practice Award

This activity is co-financed with TKI-funding from the Topconsortia for Knowledge & Innovation (TKI's) of the Ministry of Economic Affairs.

Project researchers

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EVTP01084

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@KWR_Water

Stelling

- **Innovatie en vooruitgang is een risico. Publieke partijen kunnen risico's dragen, dus daar moeten de risico's genomen worden.**