Ontwikkeling van Nieuwe Afvalwater-Zuiveringstechnologieën bij WUR

Norbert Kuipers, Wageningen Food & Biobased Research (WFBR, part of the WUR)

To increase the Potential of Water to improve the Quality of Life

"PRAKTIJKCASES BEHANDELING INDUSTRIEEL AFVALWATER"

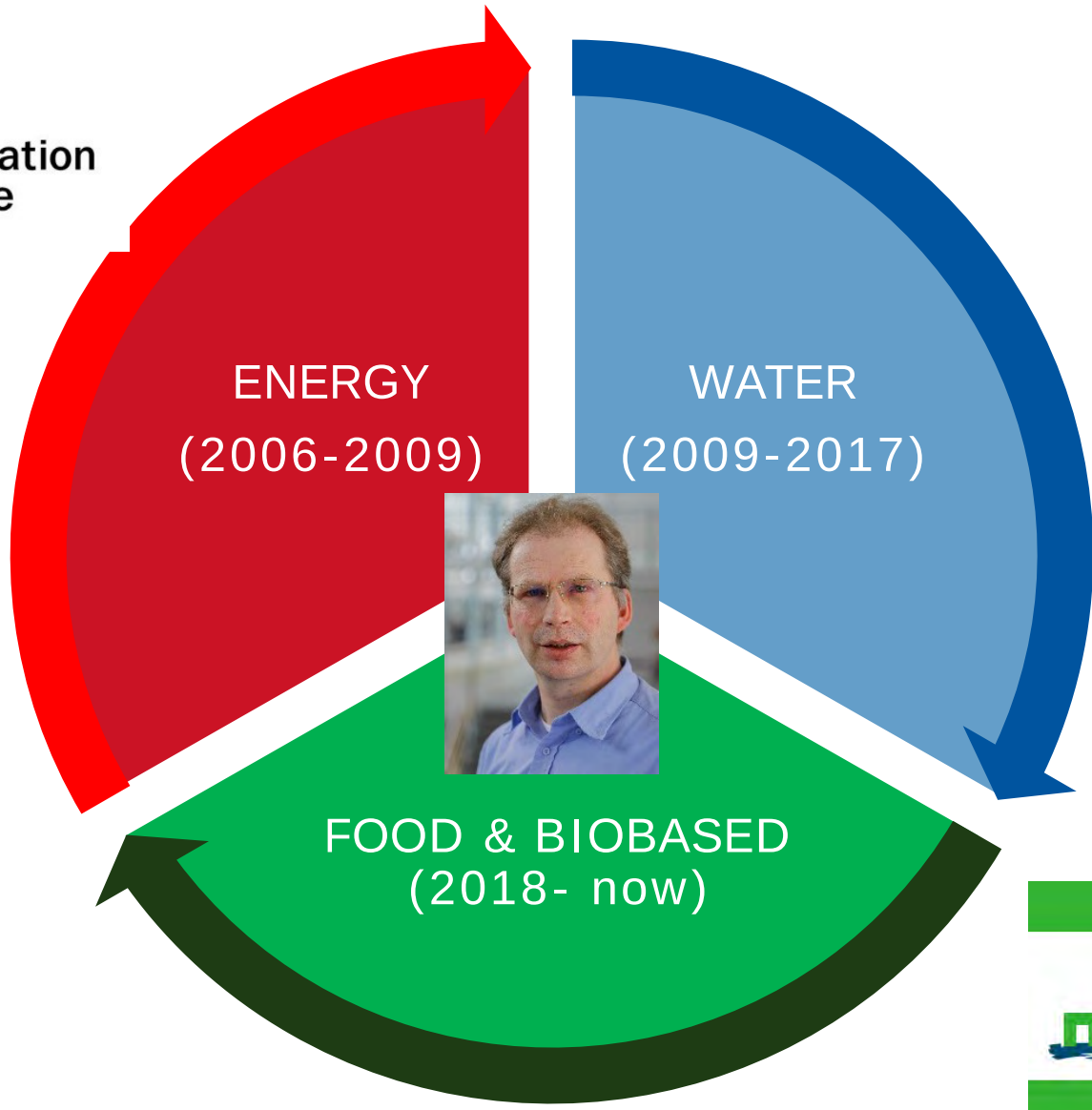
Stichting Kennisuitwisseling Industriële Watertechnologie (SKIW)

1 november 2023 in Zutphen

Background Norbert Kuipers

TNO innovation for life

University of Twente
The Netherlands



TNO innovation for life

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Research institute
Wageningen Food
& Biobased
Research

Programme: Circular Water Technologies (Irma Steemers)

Accelerate the transition to a circular and biobased economy by *closing the water & nutrients loop*, *preventing aquatic pollution* and *introducing biobased & energy efficient technologies*

- Water of fitting quality
- Sufficient availability of (fresh) water
- Prevent water pollution and recover valuable compounds
- Decrease the carbon footprint of water use

Propositions

I. Water Treatment for Circularity
II. Water Technology for Energy Production
III. Biobased Products for Water Treatment

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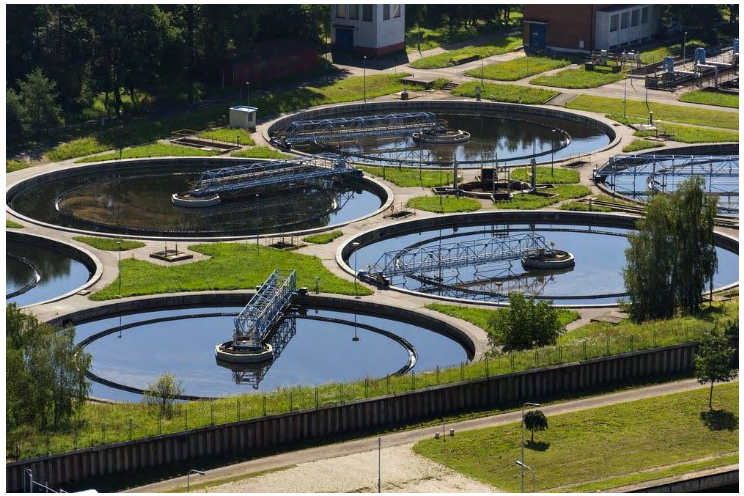
Expertise: Separation & Purification (S&P) (Tania Mubita)

- Purification
- Separation
- Desalination
- Cascading
- Microbiological safety
- Recovery of water & nutrients
- Elimination of toxic substances
- Data, monitoring and modelling



Physical-chemical-biological technologies (membrane hybrids)

- Pressure: MF, UF, NF, RO
- Temperature: Membrane Distillation, Osmotic Distillation
- Concentration: FO, Pertraction (Emulsion)
- Affinity: Chromatography, Ad/Desorption
- Electrical: ED: Conventional / Selective / Bipolar Membranes
- Magnetic: Adsorption
- Oxidation: Electrosynthesis / Biological / UV / Light

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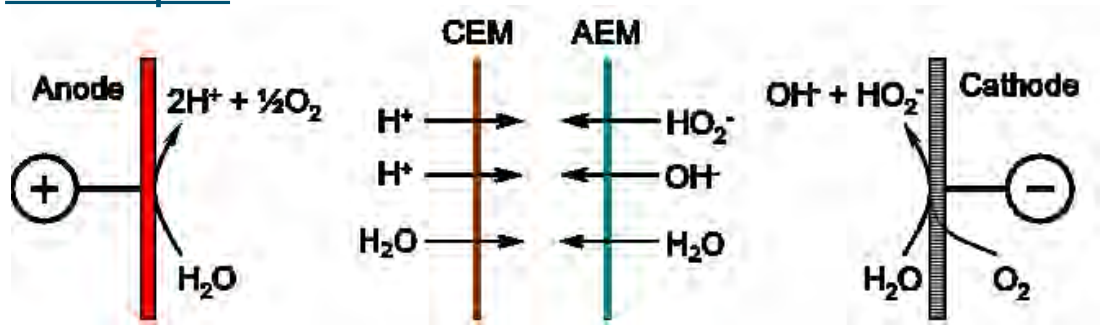
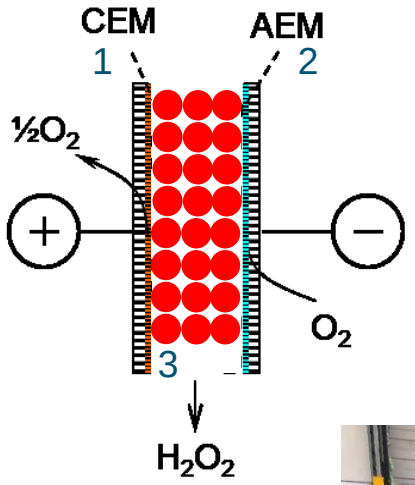
Microbiological Safety & Elimination of Toxic Substances

Hydrogen Peroxide: Project Green Oxidants (running)

Principle



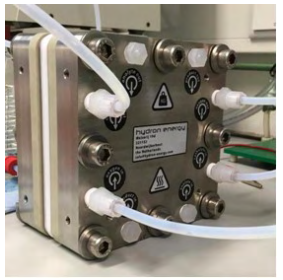


Membrane electrode assemblies
1. CEM-anode assembly
2. AEM-cathode assembly

Solid Polymer Electrolyte
3. SPE (Ion Exchange Resin)

Aims

- H_2O_2 concentrations up to 10 wt%
- Electricity consumption: 5-10 kWh/kg H_2O_2
- Stable materials (electrodes, membranes, SPE)



Opportunities Green Oxidants

- Onsite, on-demand synthesis of green oxidants (H_2O_2, peracetic acid)
- High purity H_2O_2; produced only from air, water & electricity
- No addition of stabilisers or chemicals (no by-products)

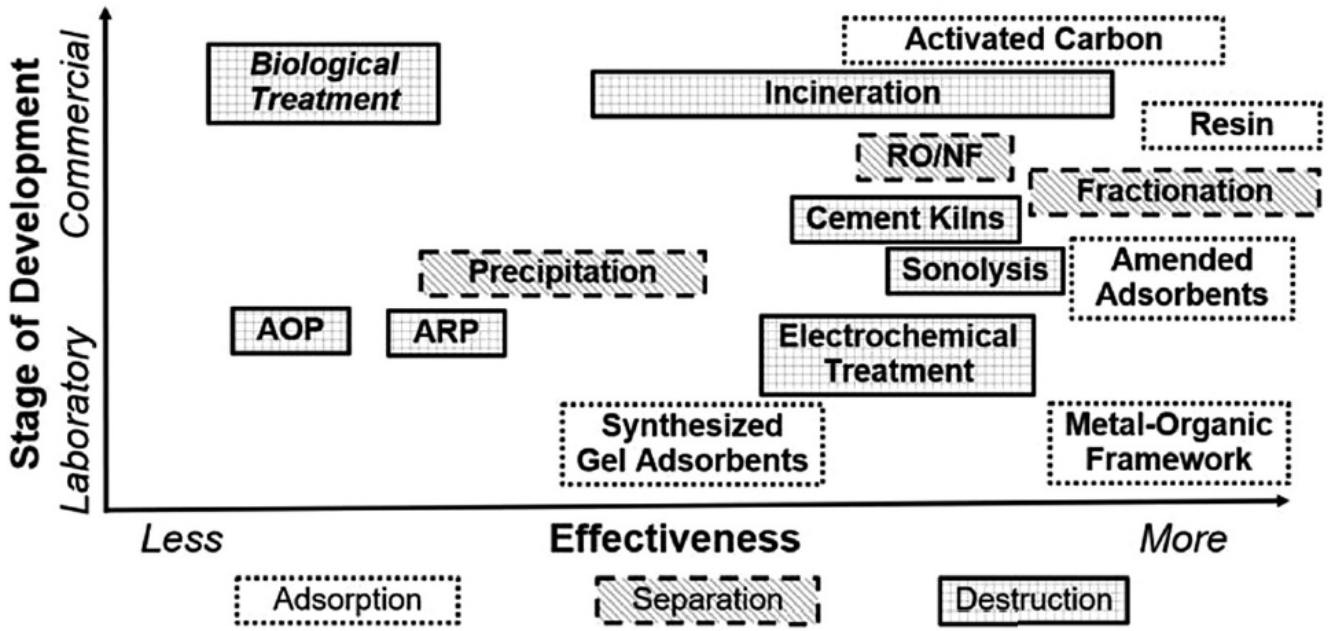
PFAS: Microbial Conversion & Separation/Destruction (running, idea)

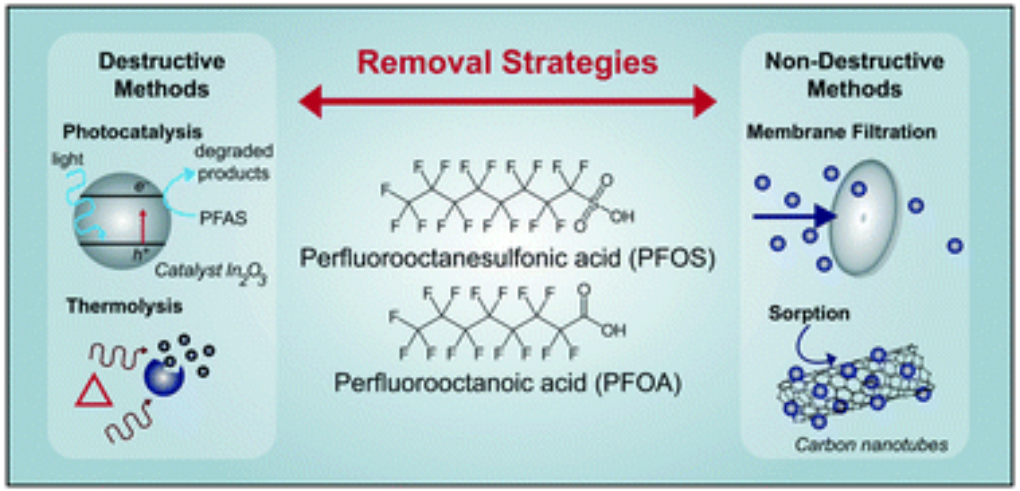
Approach (average concentration: 325 ng/L)

- *Microbial conversion of PFAS*
- *Adsorption, (electro)membrane treatment, or AOP*
- *New detection method for sensor development*

Contribution

- *Prevent contamination of drinking water sources*
- *Decentralized water treatment*





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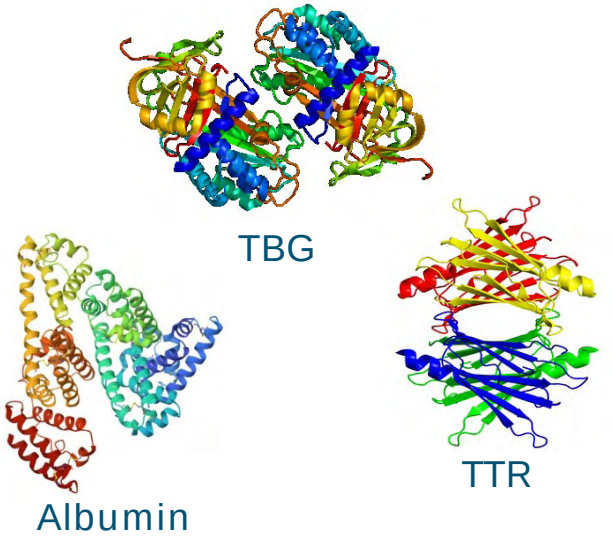
PFAS: New Detection Method for Sensor Development (idea)

Approach

- *High-throughput well-plate assay: detect effect of class of chemicals (structural information is not needed !)*



Background

- *Detection of 3 blood proteins (transporting thyroid hormones T3 & T4)*
- *PFAS molecules compete with T3/T4 for binding to these proteins*

Test format

- *Printing array of TBG, TTR and ALB spots in wells of microtiter plate*
- *Adding fixed amount of labelled PFAS molecule together with sample*
- *If PFAS molecules are present in sample: competition with labelled compound for binding to proteins; to a various extent per protein*
- *Signal profiles will reveal whether PFAS molecules are present*

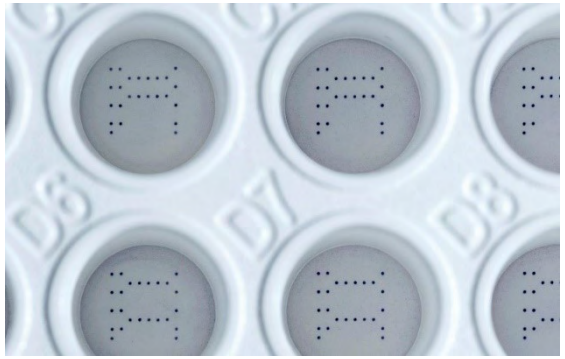


Plate Image Reader

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Recovery / Reuse of Water & Brine Treatment

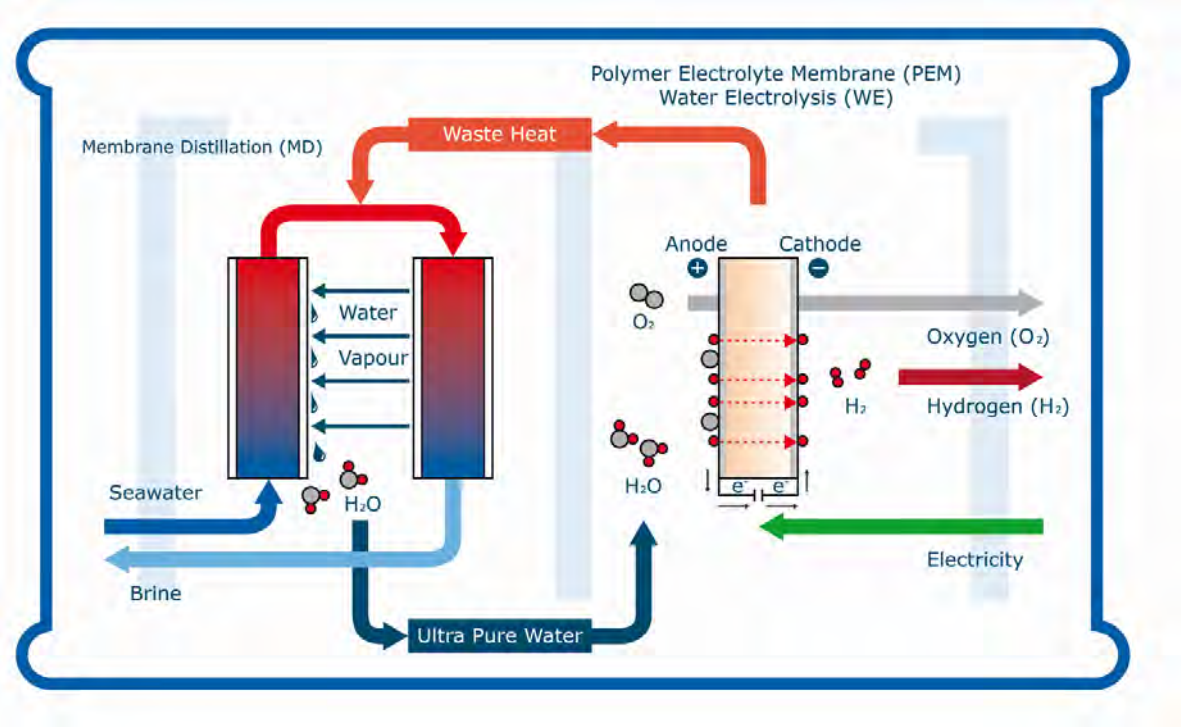
Water: Project Sea2H2 - H_2 & Pure Water from Seawater (realized)

Opportunities seawater MD

- *Decentralised (drinking) water production in harbours/off shore (water barge)*
- *MLD & Salt valorisation from brines*

Demo results

- *Successful heat & pure water integration*
- *High distillate quality: < 10 µS/cm (< 5 ppm)*
- *Electricity consumption relative to RO = 1/10*
- *Highly adaptive to PEMWE operation conditions, water need and available heat*



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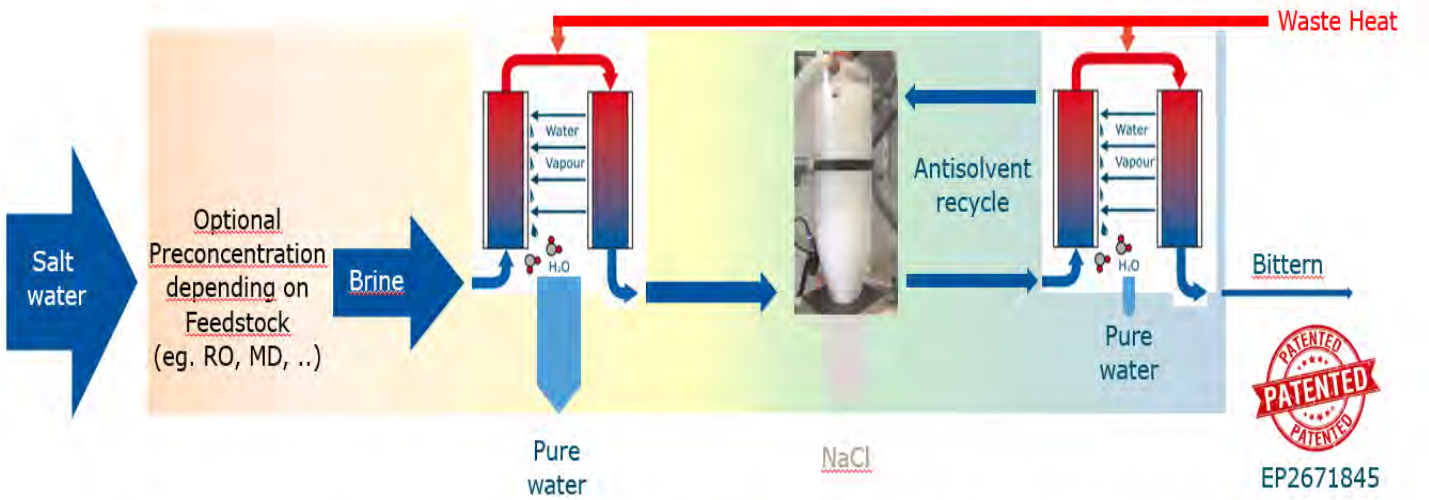
hydron

Rijksdienst voor Ondernemend Nederland

Water & Salts: Brine & Concentrate Treatment (submitted project proposal)

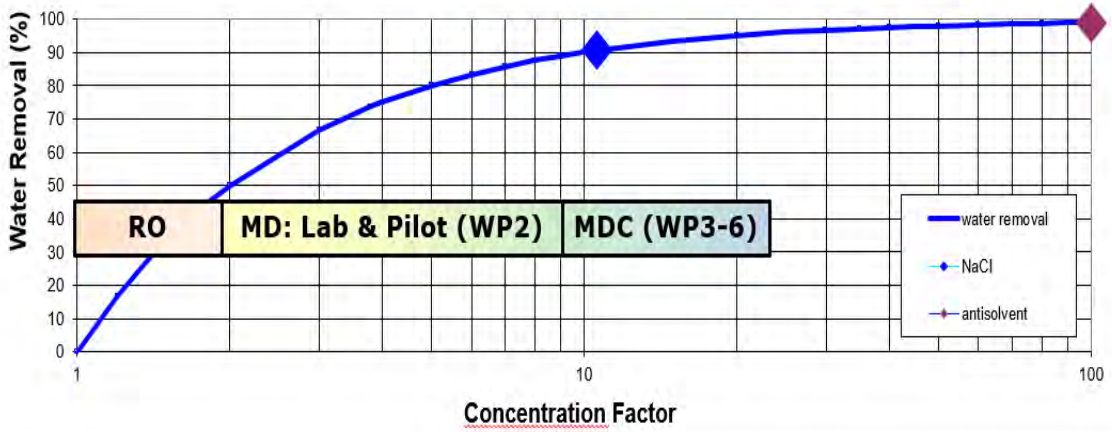
Principle

1. *Dewatering of salt feedstock to near salt saturation (NaCl) using MD1*
2. *Recovery of salt (NaCl) using antisolvent crystallization*
3. *Antisolvent recovery using MD2*



Opportunities

- *Treatment of brines*
- *Fresh water supply*
- *Re-use of clean water*
- *Re-use of salt*
- *Separation and recovery of salts*
- *Markets: food & biobased, water treatment, chemical, etc.*



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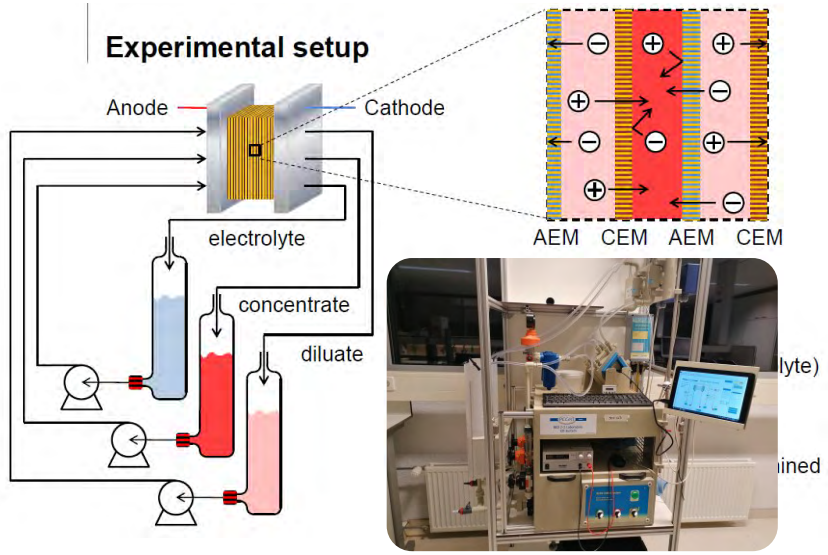
Recovery (& Conversion) of Salts

Project Selective Electrodialysis (SED) (running)

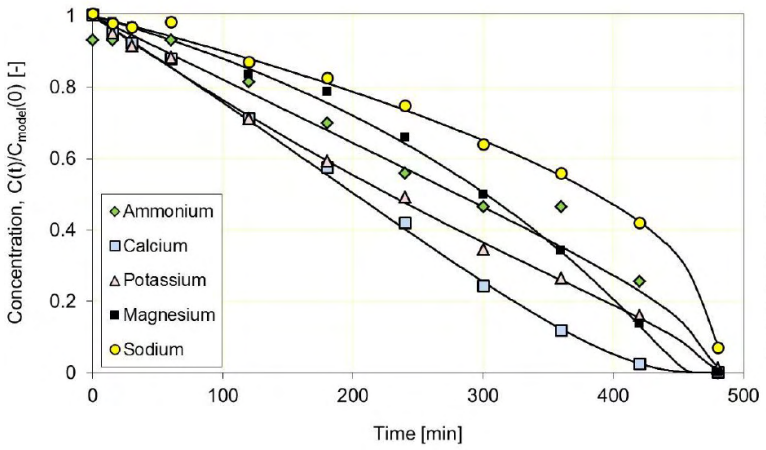


Applications

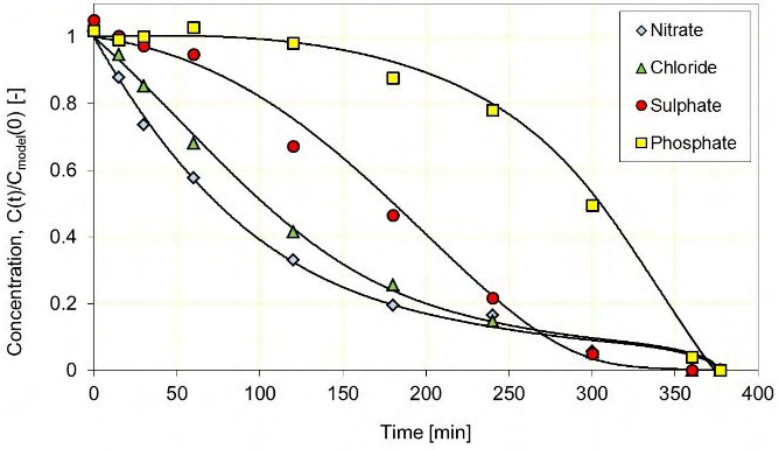
- *Electrodialysis with ion-selective membranes*
- *Ion separation of same / different charge*
- *Inorganic / organic ions (acid, base, salt)*
- *Typical cations: $Na^+/K^+/NH_4^+/Ca^{2+}/Mg^{2+}/..$*
- *Typical anions: $HPO_4^{2-}/SO_4^{2-}/NO_3^-/Cl^-/...$*

Opportunities SED

- *Product (nutrients) recovery*
- *Contaminant removal*
- *Food & chemical industries*
- *Horticulture, water treatment*



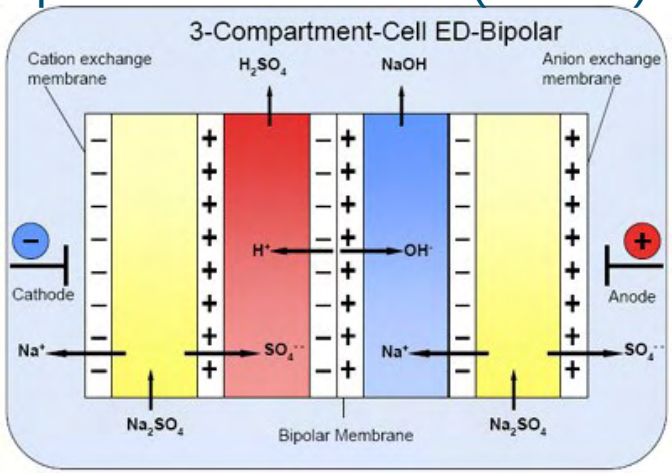
Cation concentrations in diluate vs time



Anion concentrations in diluate vs time

Salt Conversion to Acid & Base: Project Solidarity (running)

Bipolar Membranes (EDBM)

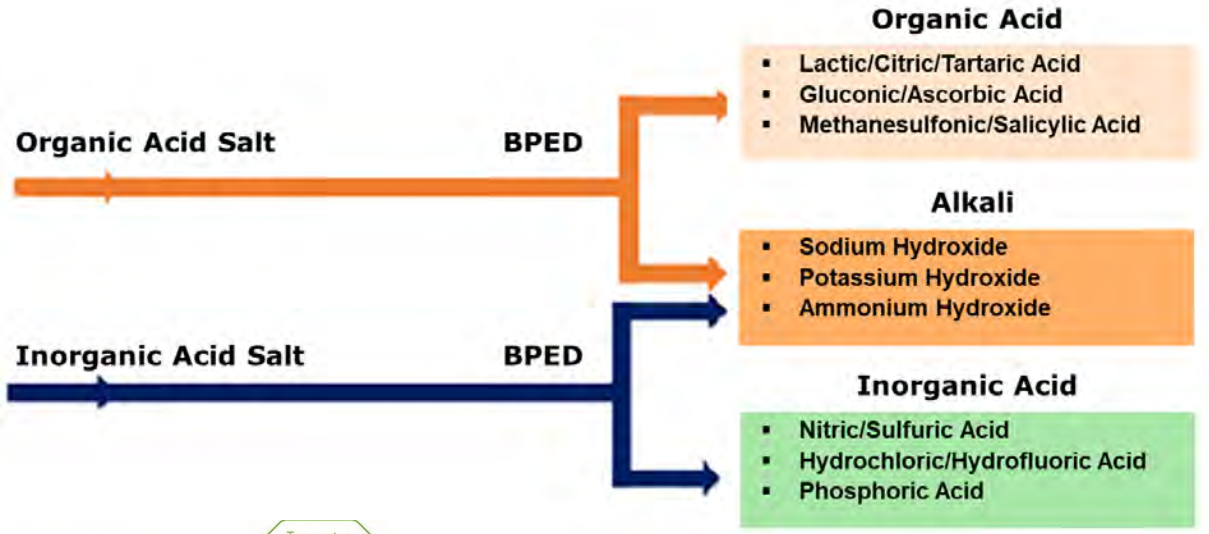


Activities

- *Removal & conversion of salt into acid & base: $MX \rightarrow HX + MOH$ ($Na_2SO_4 \rightarrow H_2SO_4 + NaOH$)*
- *Membrane screening for specific application*
- *Evaluation Key Performance Indicators*
- *Demonstration on location*
- *Techno-economic-ecologic evaluation*

Opportunities EDBM

- *Integrate onsite acid & base formation with pH-dependent processes (e.g. precipitation)*
- *Novel applications include CO_2 capture, energy storage, wastewater treatment and selective product recovery*



Removal & Recovery of Nutrients

Ammonia: Project Denutritor® (Type of Biofilter) (running)

Demo results for ammonia

- *Biological conversion (nitrification) of ammonia into nitrate*
- *Ammonia concentration far below drinking water standards*
- *No accumulation of nitrite*

Demo results for Assimilable Organic Carbon (AOC)

- *Reduction concentration of AOC thus preventing biofouling downstream for e.g. RO-systems or cooling water*

Opportunities Denutritor

- *Rain- and surface water applications*

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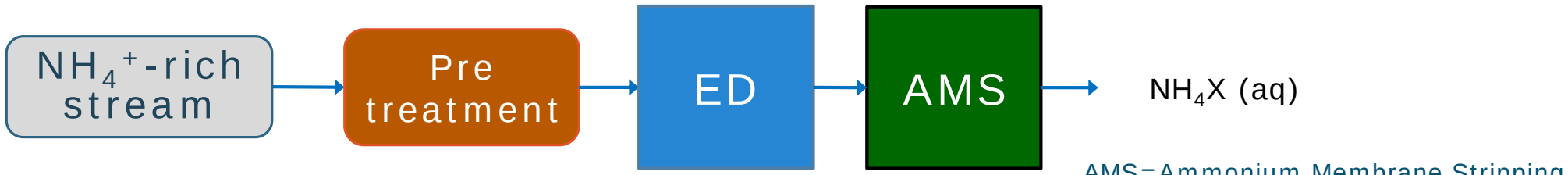
Ammonium: Valorization of Biomass (Biovalor) (running)

Aim

- *To evaluate the implementation of an integrated process to maximize ammonium recovery from residual organic streams*

Approach

- *Evaluation of electrically driven processes to*
  - *Remove and concentrate ammonium (ED)*
  - *Produce higher value products (EDBM)*
- *AMS to produce ammonium salts*



AMS=Ammonium Membrane Stripping

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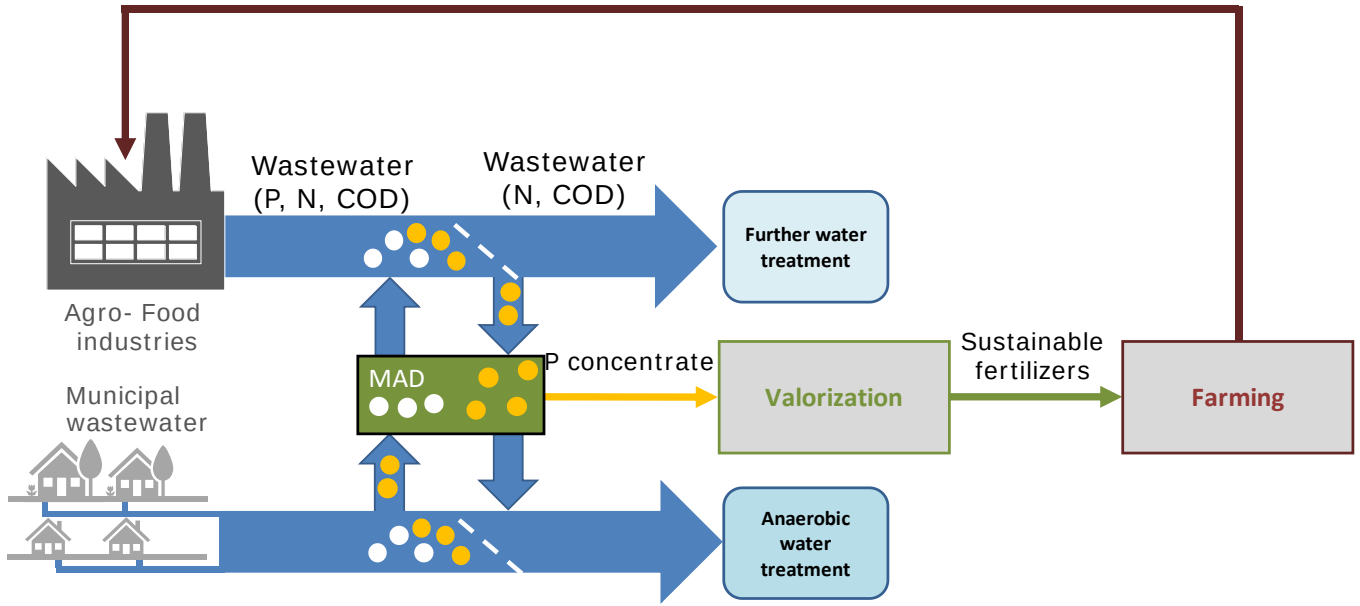
TOPSECTOR TUINBOUW & UITGANGSMATERIALEN
Topsector Agri& Food

Phosphate: Project Magnetic Adsorption Desorption (MAD) (running)

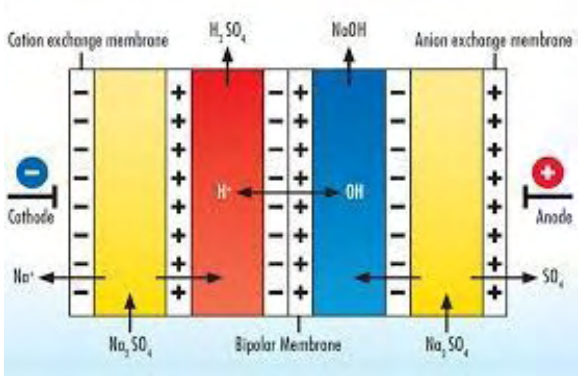
Approach

- Selective complexation of phosphate with magnetite
- Magnetic removal of complex
- Insitu recovery of phosphate & iron (using base)
- Reactivating magnetite using acid



Opportunities MAD

- Wide application range ((an)aerobic conditions)
- "In-situ" tuned ad- and desorption conditions
- Without addition of chemicals
- No discharge of salts
- Electrical & magnetic driven



Waste Water Treatment Hybrids

HYBRID: Treatment solutions to close water cycle & recover compounds (submitted proposal)

Principle of Nature Based Solutions (NBS)

- Combine the advantages of nature-based water treatment with advanced technologies

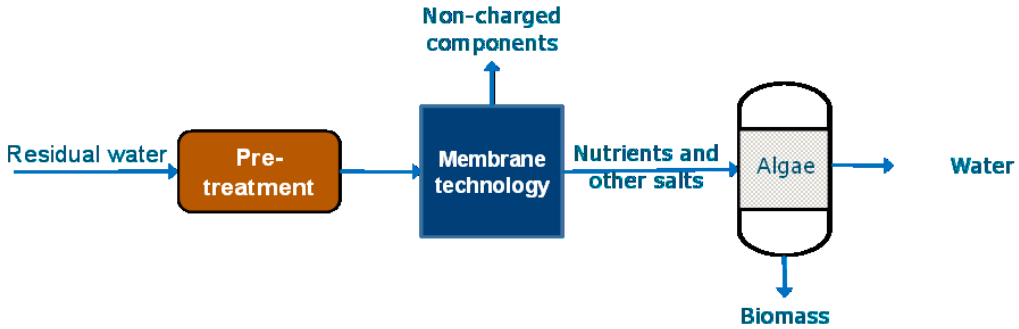
Opportunities

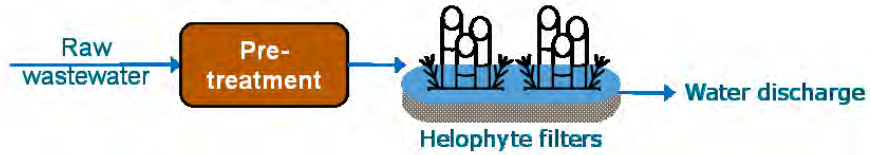
- Improve nature-based treatment e.g. by partial destruction of contaminants using technology
- Improve NBS technologies by pre- or posttreatment

Proposed Activities

- Proof of concept for selected application(s)
- Experimental demonstration & evaluation KPIs (lab)
- Option: pilot evaluation and demonstration (location)
- Process modelling and design
- Conceptual cost estimation

Possible scenarios for an integrated process





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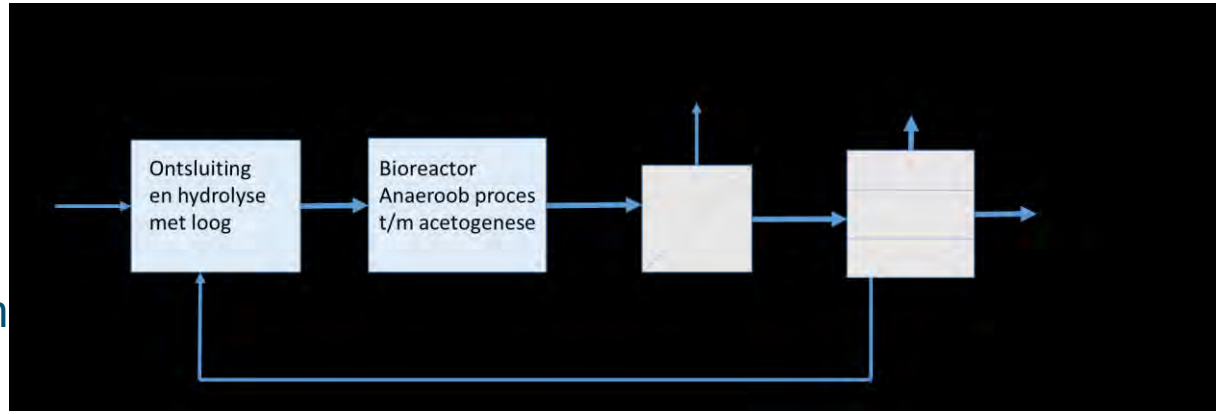
Sludge as Resource (running)

1. Sludge for production of black soldier flight larvae

- Application: chicken feed
- Input: drainage sludge or activated sludge from sewage treatment plants and from wastewater treatment plants of food companies
- Research: safety study (including transfer of contaminants to larvae, such as pesticides, heavy metals and pathogens)

2. Production of concentrated solution of volatile fatty acids from active sludge



- Volatile fatty acids as feedstock for medium chain fatty acids and PHA (bioplastic)
- Research at labscale finished
  - Sludge processing costs lower/same as curren
  - 75-80% reduction in sludge suspended solids
  - 50% conversion of organic matter into volatile fatty acids

Conclusions

- Various new technologies in development
  - Reuse and recovery of water, nutrients, and salts
  - Disinfection & decontamination
  - Hybrid systems

- Trends
  - Integrated approach (nexus)
  - Chemical free
  - Onsite solutions

Thank you for your attention!

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To explore the potential of nature to improve the quality of life