# Phosphorus recovery from wastewater

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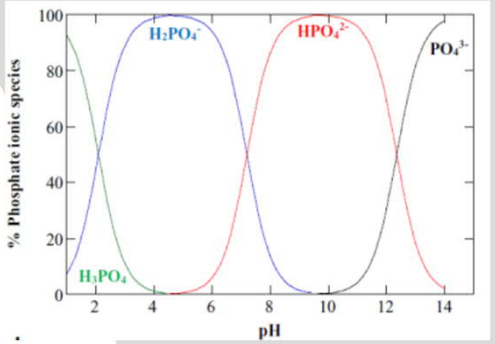
**Hanna Kyllönen, Antti Grönroos, Juha Heikkinen and Joni Lehto**
**VTT, Finland**

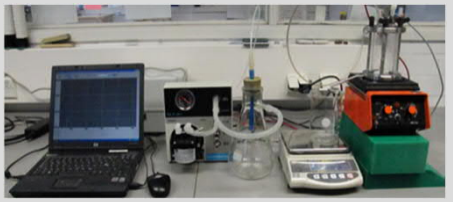
# Background to technologies

- Phosphate precipitation
  - Within coagulation (calcium, ferric, aluminium coagulants), as hydroxylapatite($Ca_{10}(PO_4)_6(OH)_2$), or as struvite ($NH_4MgPO_4 \cdot 6H_2O$)
- Membranes
  - Removal/recovery of precipitates using micro- or ultrafiltration
  - Ions concentration by nanofiltration (NF), reverse osmosis (RO) or electrodialysis (ED)
- Adsorption to:
  - Metal (Ca, Mg, Fe, Al) oxides, carbonates or hydroxides
  - Clay, sand
  - Organic adsorbents: granulated activated carbon (GAC), ion exchange resins, biochar, side streams such as bio/agrowaste or lignocellulosic materials
  - Slags, ash




Chen et al. DOI: 10.3390/membranes11080594

# Materials and methods at lab scale



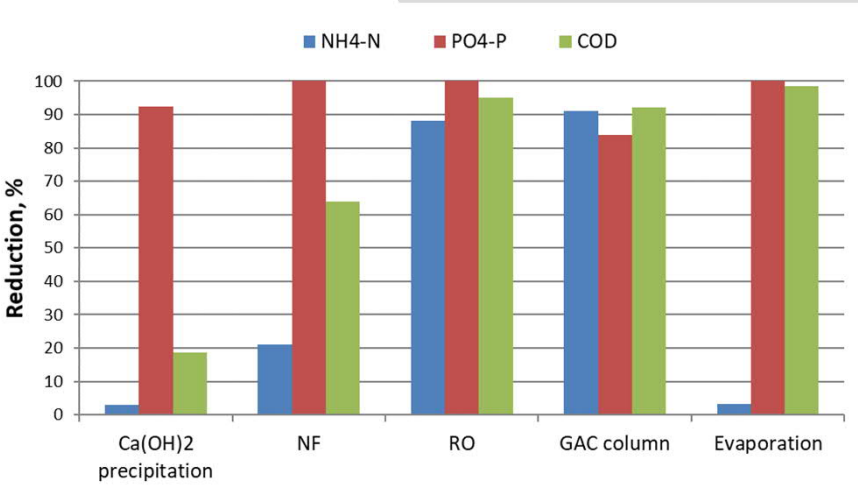
- Wastewater: municipal/fish industry effluent
  - Phosphate phosphorus (PO4-P) content 16 mg/l and 6 mg/l respectively
- Pre-treatment
  - Flocculation aided belt filtration (no phosphorus removal by coagulation) to decrease amount of solid impurities
- Recovery technologies for soluble phosphorus
  - Precipitation as calcium phosphate using lime ($Ca(OH)_2$)
  - Concentration by membranes at reasonable water recovery (WR)
    - Nanofiltration (NF) using NF270
    - Reverse osmosis (RO) using XLE
  - Concentration by evaporation, T = 80°C
  - Adsorption by granulated activated carbon (GAC)
- Recovery as a part of wastewater treatment in a Resource container

# Technology comparison at lab scale

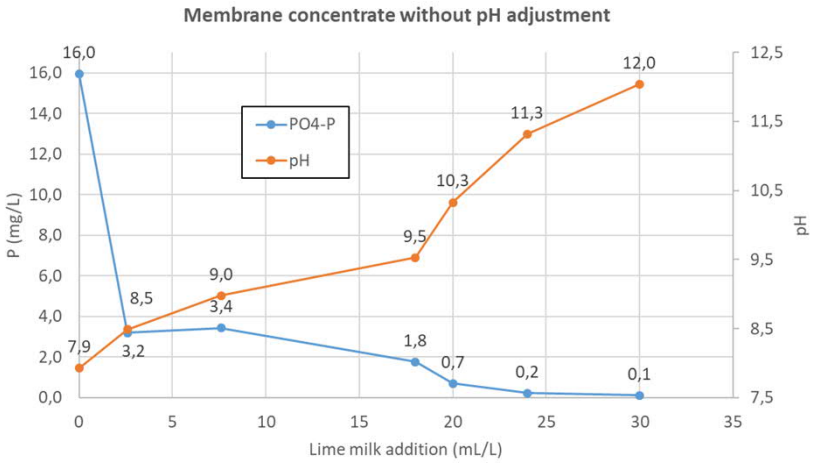
For nutrient and carbon products

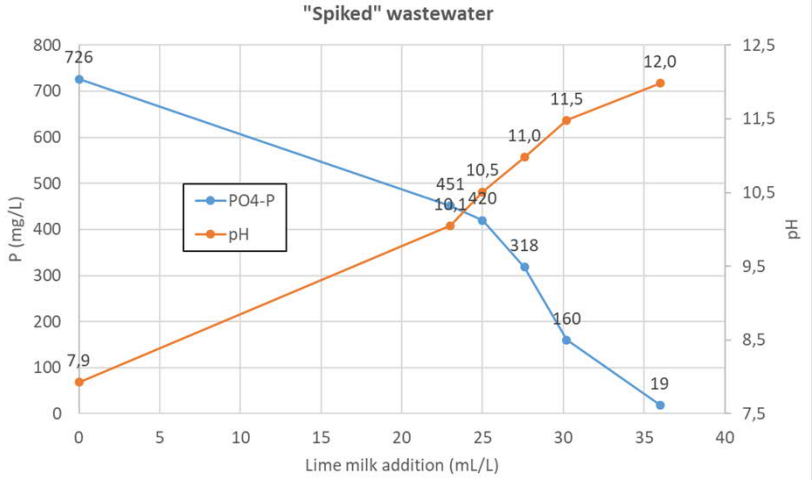
- Lime precipitated PO4-P product having low impurity content, pH > 10
- NF and RO rejected PO4-P well but did not fractionate PO4-P from ammonium-nitrogen (NH4-N) or organics measured as COD, fouling and scaling issues at high WR
- GAC removed PO4-P only 80% and did not fractionate from NH4-N or organics
- Evaporation concentrated PO4-P well and fractionated it at alkaline pH from NH4-N

→ PO4-P precipitation for the membrane concentrate at high pH for subsequent ammonia recovery by membrane contactor



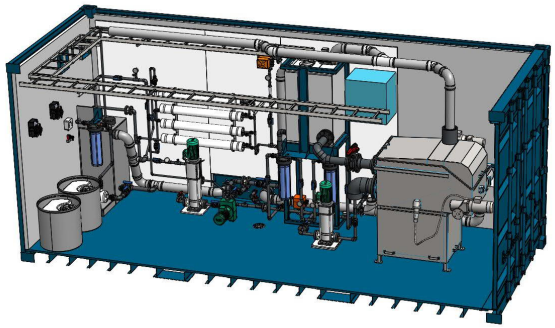
# Phosphorus precipitation

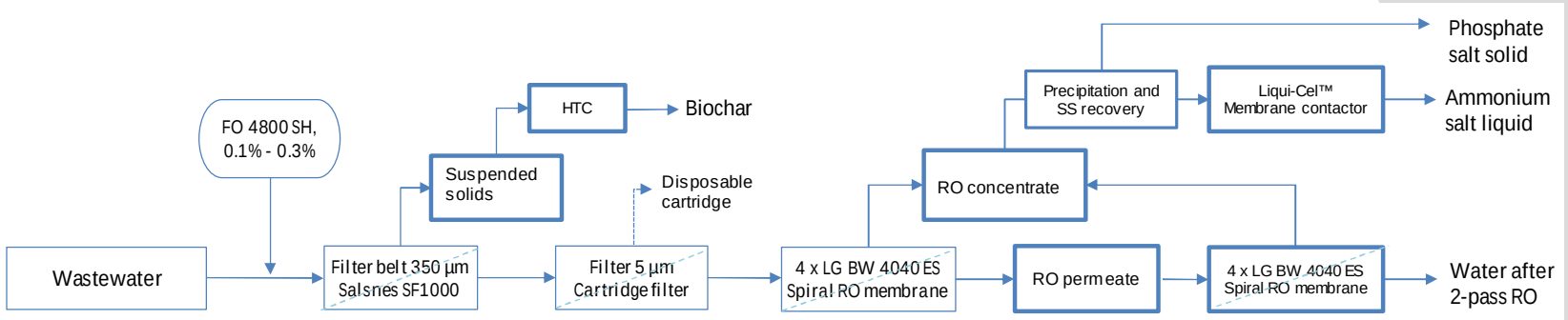



- Lime needed for phosphate precipitation was not directly proportional to phosphate concentration in the wastewater
  - Lime was presumed to be consumed also for calcium carbonate precipitation
- pH adjustment was needed with metal salt addition, pH increase could also be made using sodium hydroxide

# Phosphorus precipitation as a part of Resource container concept





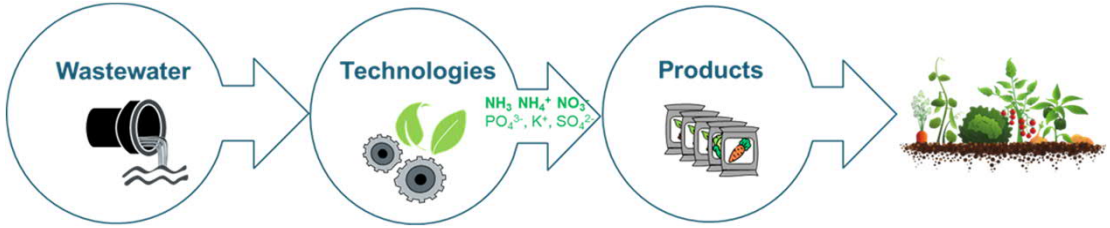
# Conclusions

- Pre-treatment is essential to decrease amount of impurities
- Recovery of phosphorus can well be done using lime when
  - Cost-effective precipitation method is needed
  - pH increase is needed before subsequent nutrient, e.g. nitrogen, recovery
- pH increase is relevant in phosphorus precipitation, thus
  - Wastewater is worth to be concentrated to decrease need of pH chemical and increase of nutrient concentrations for recovery

# TYPKI - Resource-wise nutrient recovery from industrial wastewater

- Tighter limits on nutrient discharge imposed
- Potential for raw materials lurking in wastewater

→ Solutions for treatment of industrial wastewater and recovery of nutrients from concentrate hence answering the challenge of ZLD




**Nutrient sources N, P, K, S, Mg, Ca**: Concentrates from wastewater purification to be utilized or safely deposited

**Recovery and refinement**:
- Precipitation
- Adsorption
- Membranes
- Electrochemistry
- Evaporation

**For use**:
- Reuse water
- Chemical additives
- Adhesives for cementation
- Fertilizer additives

**Impact**:
- More usable water
- Less discharge
- Increased nutrient self-sufficiency
- Better business

| | |
|---|---|
| Schedule: | Feb 2021-Jan 2023 |
| Budget: | EUR 1.03 million |
| Financer: | Business Finland and the participants |
| Participants: | VTT, University of Oulu, Tapojärvi, Aquaminerals, BioSO4, Brightplus, Industrial Water, Agnico Eagle, Gasum, Hannukainen Mining, Valmet, Yara Suomi |

Info: hanna.kyllonen@vtt.fi, www.typki.fi

VTT

# beyond

## the obvious

**Hanna Kyllönen**
**Hanna.kyllonen@vtt.fi**