EFFICIENT TREATMENT OF PHARMACEUTICAL RESIDUE AT SOURCE - EPIC

FINAL REPORT: WP2 - Development of new Cleantech solutions

Finnish Environment Institute (SYKE)
Lappeenranta University of Technology (LUT) &
Subcontractor Law and Water

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Further information of WP2:

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Partners – Development of new Cleantech solutions (WP2)

- Work Package Coordinator: LUT
  - Mika Mänttäri, Marjatta Louhi-Kultanen (→ 12/2017), Petri Ajo (→ 11/2018), Timo Vornamo, Mari Kallioinen

- Partner: SYKE, TYKS, Subcontractor Law and Water & Rinnekoti Foundation
  - Jyrki Laitinen, Lauri Äystö, Taina Nystén (SYKE)
  - Kari Kandelberg (TYKS)
  - Niina Vieno (Law and Water)
  - Petri Wegelius, Timo Turunen, Janne Haataja, Tarmo Koskinen, Pentti Viitakangas (Rinnekoti Foundation)

Need – Development of new Cleantech solutions

- Existing wastewater treatment processes (CAS, conventional activated sludge process) remove significant amount of micropollutants but not all
- Compounds which are typically not removed are e.g. hydrochlorothiazide, carbamazepine, citalopram, diclofenac, metoprolol, atenolol

→**Tertiary treatment technologies are needed**

- The aim was to study the efficiency of different technologies in the removal and degradation of pharmaceutical compounds. Especially the aim was to purify wastewater in the place where they are formed.

Approach -Description of activities (1/2)

Development of new Cleantech solutions

Studied effluents

Studied wastewaters	DOC mg/L	COD mg/L	Conductivity mS/cm	P_{tot} mg/L	N_{tot} mg/l	Diclofenac µg/L	Citalopram µg/L
Rinnekoti, incoming wastewater	62	173	0.82	5.9	45	0.05	0.34
Rinnekoti after CAS treatment	5.4	48	0.46	0.2	4	0.33	0.26
Hospital wastewater	200	793	1.15	5.5	63	0.60	0.23
Urea	-	5360	22	190	3950	9.8	2.5

Studied technologies for removal of micropollutants

- Membrane filtration: Ultrafiltration (UF), Nanofiltration (NF) & Reverse osmosis (RO)
- Oxidation: Pulsed corona discharge method (PCD)
- Adsorption: Activated carbon (only few experiments)

- Both laboratory and pilot scale experiments were made

Approach -Description of activities (2/2)

Development of new Cleantech solutions

- **Pilot-scale testing facility at Turku University Hospital (TYKS)**
  - Suitable testing site for sampling and pilot-scale testing of reducing pharmaceutical residues is identified at TYKS.
  - Untreated wastewater can be taken from sewer pipe where wastewater flows from selected department where amount of hospital beds is about 100.
  - Equipment directly linked to sampling is installed.

Main outputs - Development of new Cleantech solutions (1/5)

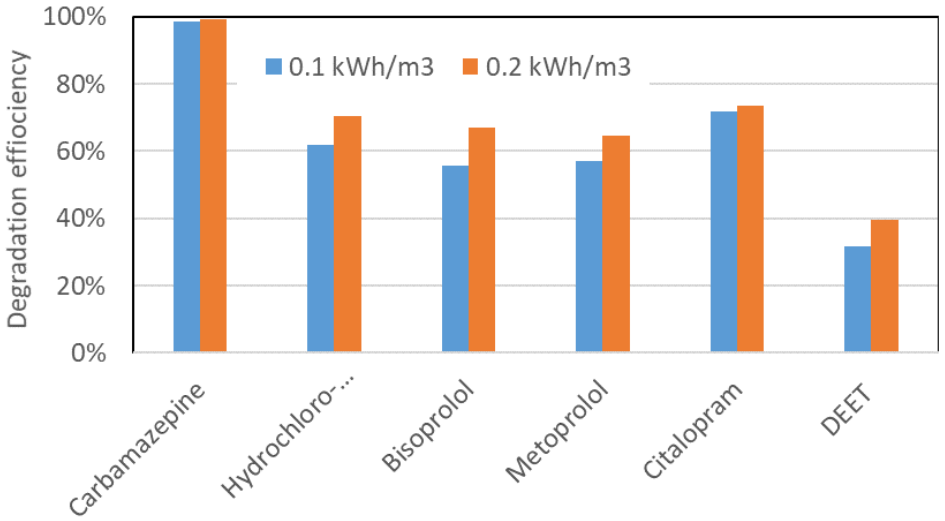
Activated carbon

- Well known technology for removal of pharmaceutical compounds from waters
- Typically >90% removal efficiency as a tertiary treatment
- Separation of activated carbon especially PAC (powdered activated carbon) after treatment from water is challenging
- Based on the literature the environmental footprint of activated carbon treatment is high (https://aaltodoc.aalto.fi/handle/123456789/42720)

Main outputs (2/5)

PCD oxidation

- Degraded most of residual pharmaceuticals with as low energy consumption as 0.1-0.2 kWh/m^3 water when CAS treated water was oxidized
- Direct oxidation of wastewaters or membrane concentrates obviously needs more energy, at least 30 times more
- No effect to the total amount of organic compounds or nutrients
- Oxidation of pharmaceutical compounds in urea needs more energy, on average about 40% degradation efficiency was achieved at 3.5 kwh/m^3



Degradation efficiency of PCD oxidation for not so readily oxidized pharmaceutical compounds (effluent was purified beforehand by activated sludge treatment)

Main outputs (3/5)

Membrane filtration after CAS

- NF permeated some of pharmaceuticals e.g. hydrochloro-thiazide
  - Retention of specific pharmaceutical compounds depended its molecular properties not only molar mass
- RO retained >95% of pharmaceutical compounds

Comparison of drinking water quality parameters with the measured values from tertiary RO permeate

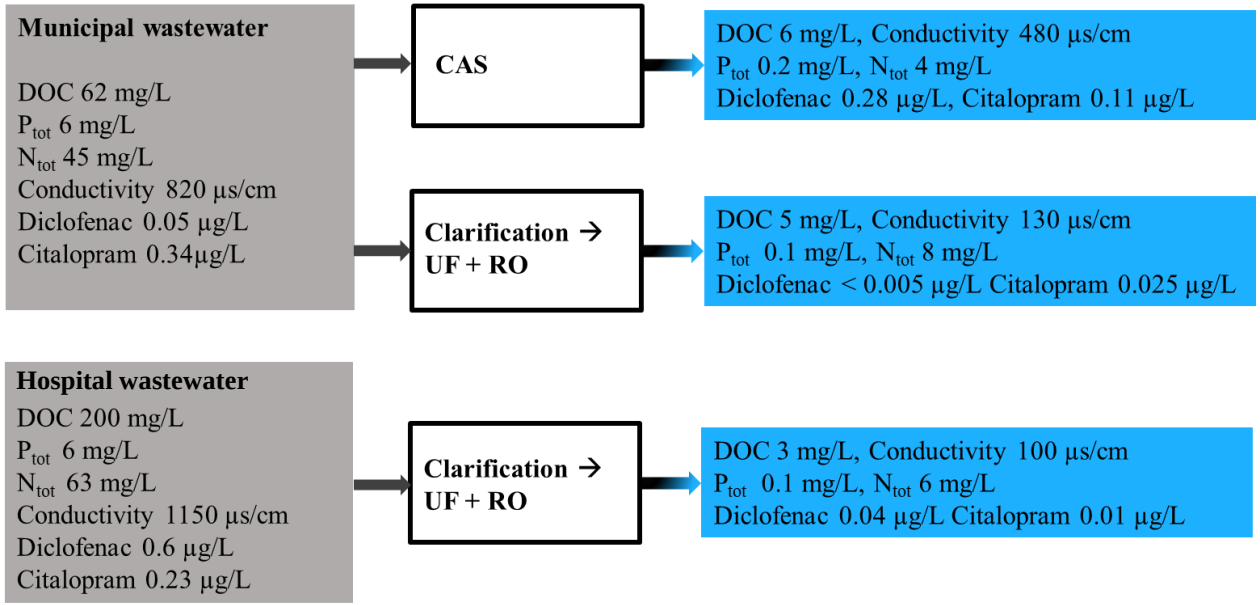
	Drinking water, max values *	**CAS + RO**
COD	5 mg/L	**0.3 mg/L**
TOC	4 mg/L (recommended)	
Conductivity	2500 µS/cm	**< 100 µS/cm**
NO3-	50 mg/L	**0.5 mg/L (N_{tot})**
NO2-	0.5 mg/L	
pH	6.5-9.5	**7.4**
Total amount of pharmaceutical/pesticides		**~ 0.2 µg/L**
Pesticides	0.5 µg/L	

* https://www.who.int/water_sanitation_health/publications/drinking-water-quality-guidelines-4-including-1st-addendum/en/

Main outputs (4/5)

Direct membrane filtration after clarification of wastewater

- Equal or better water quality was achieved with two stage membrane filtration compared to CAS treatment, especially when pharmaceutical compounds are considered



Main outputs (5/5)

Membrane filtration

- Reverse osmosis retained more than 95% of almost all pharmaceutical compounds
- Reverse osmosis for the wastewater purified by CAS process leads to water quality which corresponds to the drinking water quality when quality parameters such as nitrogen, COD, pesticides are compared
- Direct membrane filtration of clarified wastewater with UF and RO membranes leads to better water quality than CAS process

Main outputs: Publications
Development of new Cleantech solutions

- Articles
  - Ajo P., Preis S., Vornamo T., Mänttäri M., Kallioinen M., Louhi-Kultanena M. 2018. Hospital Wastewater Treatment with Pilot-Scale Pulsed Corona Discharge for Removal of Pharmaceutical Residues. Journal of Environmental Chemical Engineering. Vol 6, Issue 2.
  - Mänttäri, M., Vornamo, T. & Kallioinen, M. 2020. Tekniikat lääkeaineiden poistamiseen jätevesistä. Vesitalous 1/2020: 13 - 16.

Benefits and influence – Development of new Cleantech solutions (1/4)

- The EPIC project increased understanding of limitations and advantages of different treatment methods
- Adsorption, oxidation and membrane filtration are all technically suitable and rather efficient methods for the removal of pharmaceutical compounds from CAS treated wastewaters
- However, all methods have limitations and challenges e.g.
  - how to separate, regenerate or dispose of used adsorbent?
  - what are oxidation by-products, especially their harmfulness?
  - how to manage fouling in membrane filtration and treat membrane concentrates?

Benefits and influence of the project – Development of new Cleantech solutions (2/4)

- If the only goal is to remove micropollutants and the treated wastewater is already well purified the PCD oxidation is very promising methods → most of the micropollutants are removed at energy doses around 0.1 kWh/m^3
- However, if the removal of nutrients, pathogens, microplastic, etc. are also considered then membrane based processes are superior

Benefits and influence of the project – Development of new Cleantech solutions (3/4)

Treatment at a primary emission source

- Possible but more challenging
  - Concentration of dissolved organic compounds is significantly higher than in the discharge water of CAS treatment

  → oxidation efficiency and filtration capacity decreases
  - At a minimum solid-liquid separation is needed prior to the oxidation and adsorption
- Full-scale example, Herlev hospital in Denmark*
  - Comprehensive purification of wastewater, not only micropollutants
  - Operation and maintenance cost 1.45 €/m^3

* https://www.dhigroup.com/-/media/shared%20content/global/news/2016/08/evaluation%20report.pdf

Benefits and influence – Development of new Cleantech solutions (3/4)

- A more deep analysis related to the results will be published in two scientific articles which are under preparation.
- The results will also be utilised in the ongoing SUDDEN project where the aim is to improve the understanding of separation and degradation mechanisms.
- It should be kept in mind that the water after CAS treatment contains also small amount of other type of impurities than pharmaceuticals such as nutrients, pathogens, microplastics, organic compounds, salts etc. Therefore, their removal should also be taken into account when the efficiency of wastewater treatment processes are enhanced.
- Membrane filtration, especially reverse osmosis, is the only technology capable to remove these substances almost completely

Collaboration

Partners

BUSINESS FINLAND

SYKE

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI
FARMASIAN TIEDEKUNTA
FARMACEUTISKA FAKULTETEN
FACULTY OF PHARMACY

LUT University

LAKI ja VESI

Vantaanjoen ja Helsingin seudun vesiensuojeluyhdistys ry

Vesihuoltolaitosten kehittämisrahasto

Kymen Vesi Oy

HSY

Lappeenrannan energia oy

Turun seudun puhdistamo Oy

HUS

eksote

VARSINAIS-SUOMEN SAIRAANHOITOPIIRI

Rinnekoti-Säätiö

SYKE

WatMan

Watrec

WAPULEC
Water and air treatment

Collaboration/Stakeholders

- Financers (steering group)
- Healthcare operators: hospitals & Rinnekoti Foundation
- MWWTPs
- Technology providers, consulting companies, other related enterprises: Wapulec Oy, Pharem Biotech Ab, Grundfos Biobooster A/S, various discussions with representatives of several companies
- Scientific community: research institutes, universities, projects SUDDEN

Further information

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