

From **VANDALF**: Linking of Chemical and Toxicological Fingerprints to **DAWN**: Predicting removal efficiencies in the 4th treatment

Innovationspartnerskab for teknisk vand -
Vandrensningsteknologiens blinde vinkler #1

Alba Rodríguez Otero, Jan H. Christensen

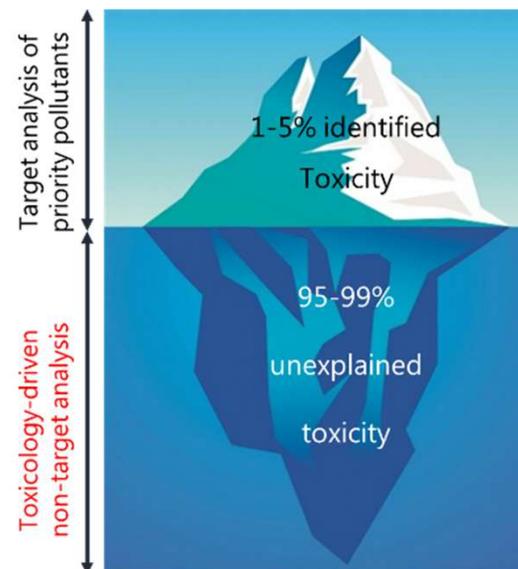
25th February 2026

KØBENHAVNS UNIVERSITET

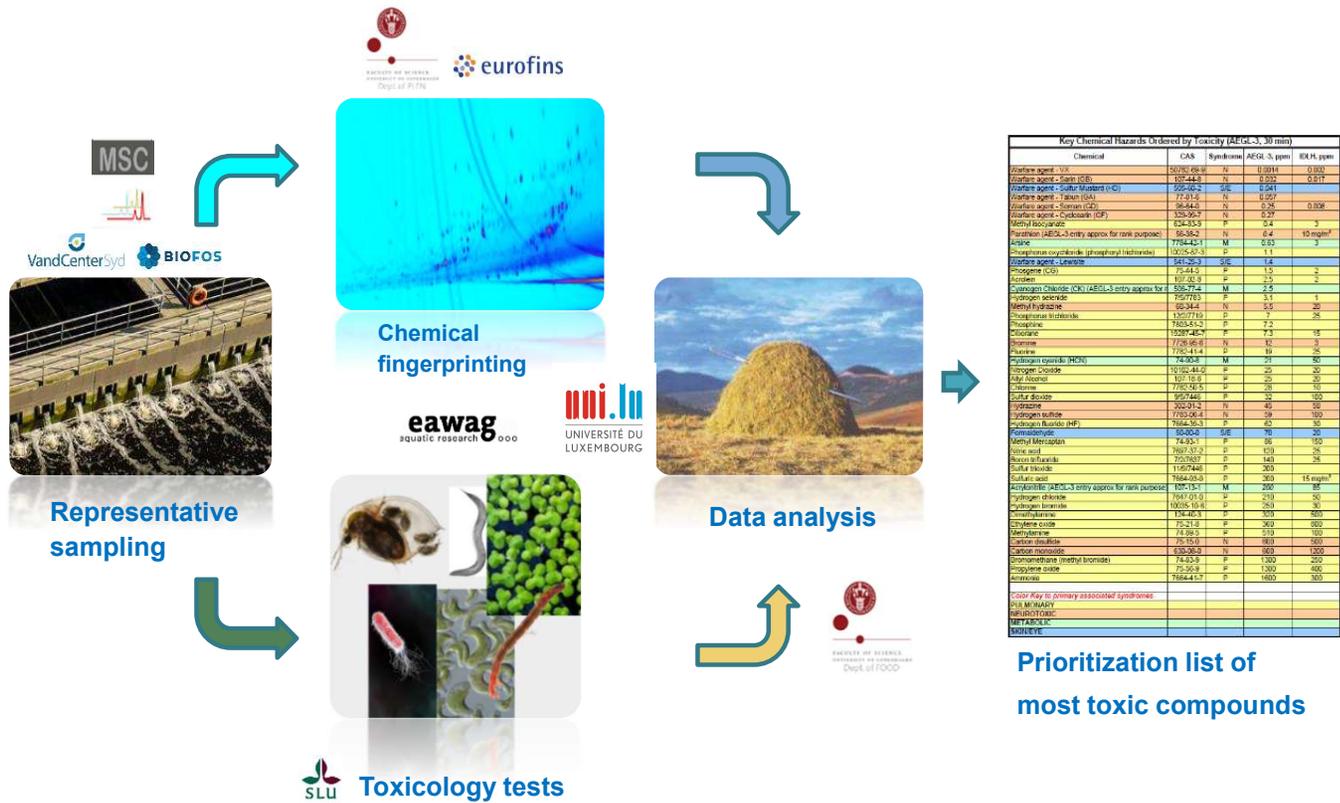


VANDALF project vision (2019-2024)

The overall vision of VANDALF is:
to develop and implement flexible and dynamic effect-based tools **to identify the chemicals causing the remaining 95-99% of toxicity in effluent water.**

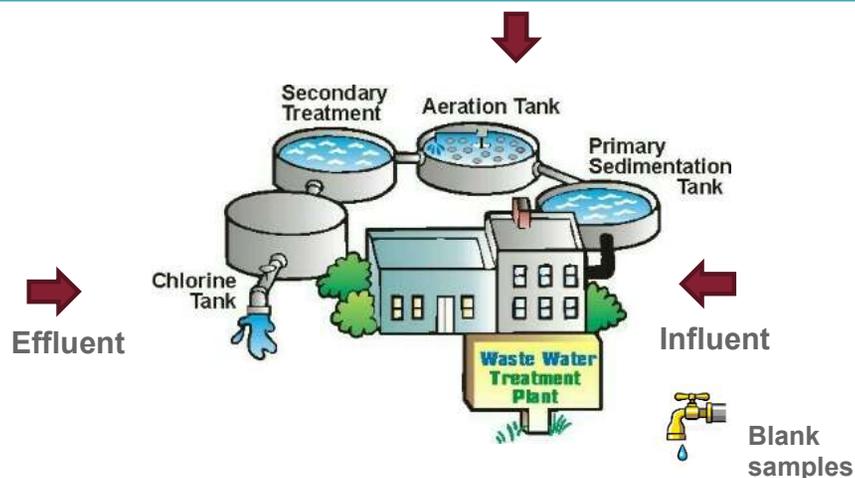


The VANDALF concept

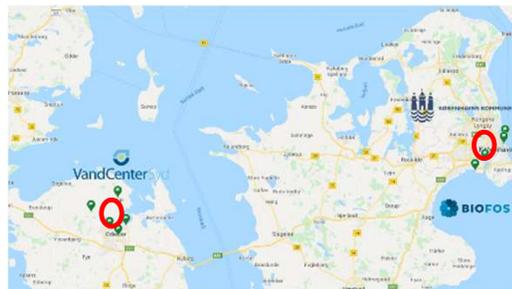




VANDALF sampling phases



	Capacity (PE)
Lynette (RL)	1,000,000
Avedøre (RA)	400,000
Damhusåen (RD)	350,000
Ejby mølle (EM) [†]	385,000
Odense NV (NV) [†]	48,300
Odense NE (NE) [†]	30,000
Otterup (OT) [*]	20,000
Søndersø (SØ) [*]	12,500



Mechanical treatment, biological treatment, chemical treatment FeCl_3
[†]contact filter, ^{*}lagoon filter

Phase 1: Screening (summer 2020)
 8 WWTP – 53 samples:
 11 Influent samples
 9 Mechanical treatment samples
 26 Effluent samples
 7 Field blanks

Phase 2: Optimisation (spring 2021)
 2 WWTP (NV & RD) – 58 samples:
 4 influent samples
 45 Effluent samples
 9 Field blank samples

Phase 3: Test

WWTP	Damhusåen	Nord Vest
Online	>4000	
Influent samples	12	7
Effluent samples	180	35
Container blanks	12	3
Field blanks	6	3
Total	210	~50

Phase 4: Validation
 250 samples - Fall 2023 to Winter 2024

VANDALF Phase 1

From Target to NTS of wastewater



Environmental Science and Pollution Research
<https://doi.org/10.1007/s11356-023-30331-z>

RESEARCH ARTICLE

Catchment area, fate, and environmental risks investigation of micropollutants in Danish wastewater

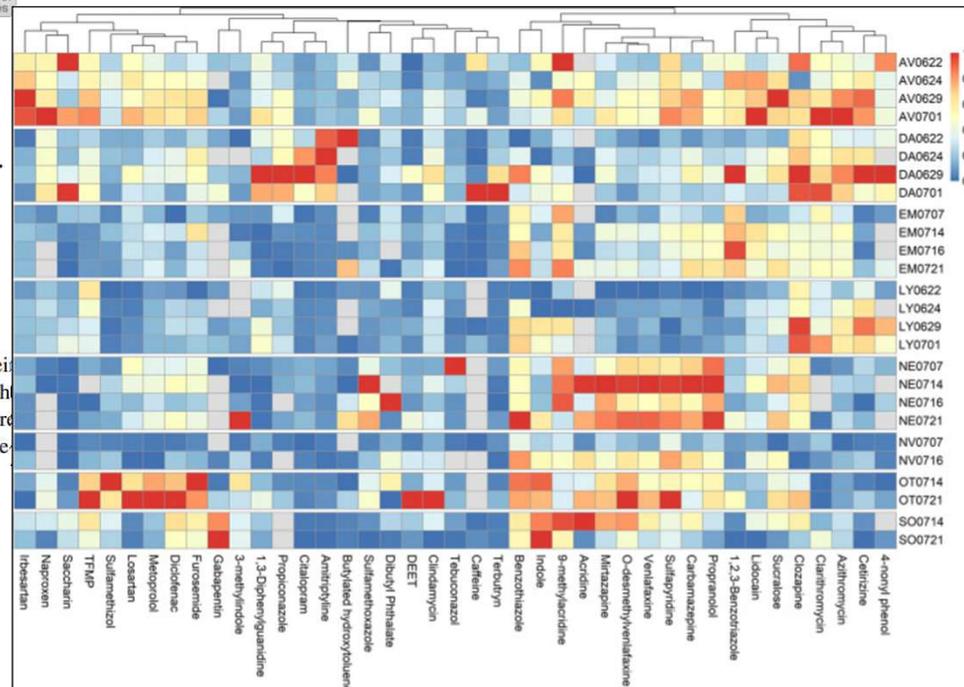
Kristoffer Kilpinen^{1,2} · Jason Devers¹ · Mafalda Castro³ · Selina Tisler¹ · Mathias B. Jørgensen⁴ · Peter Mortensen² · Jan H. Christensen¹

Received: 6 February 2023 / Accepted: 4 October 2023
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Abstract

This study aimed to investigate the spatial distribution of micropollutants in wastewater related to catchment area, and their environmental risks and fate. About 24-h flow proportional effluent ($n=26$) wastewater samples were collected from eight WWTPs across Denmark. From five of these WWTPs corresponding influent samples ($n=20$) were collected. Samples were enriched by multi-layer solid phase and analysed by liquid chromatography–high-resolution mass spectrometry and compared

Demonstrated through sales data that wastewater-based epidemiology can reliably predict consumption patterns within the catchment area.



VANDALF Phase 1

From Target to NTS of wastewater



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Water Research

journal homepage: www.elsevier.com/locate/watres





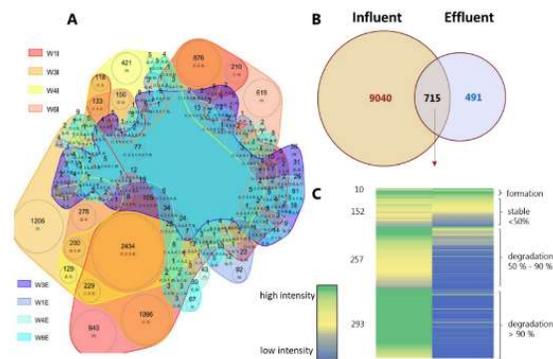
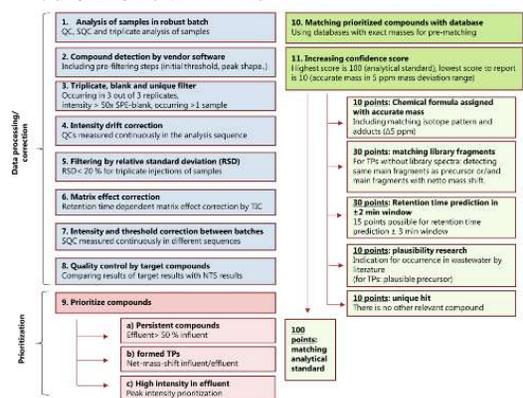
From data to reliable conclusions: Identification and comparison of persistent micropollutants and transformation products in 37 wastewater samples by non-target screening prioritization

Selina Tisler^{a,*}, Nikolina Engler^a, Mathias B. Jørgensen^b, Kristoffer Kilpinen^{a,c}, Giorgio Tomasi^a, Jan H. Christensen^a

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^c E

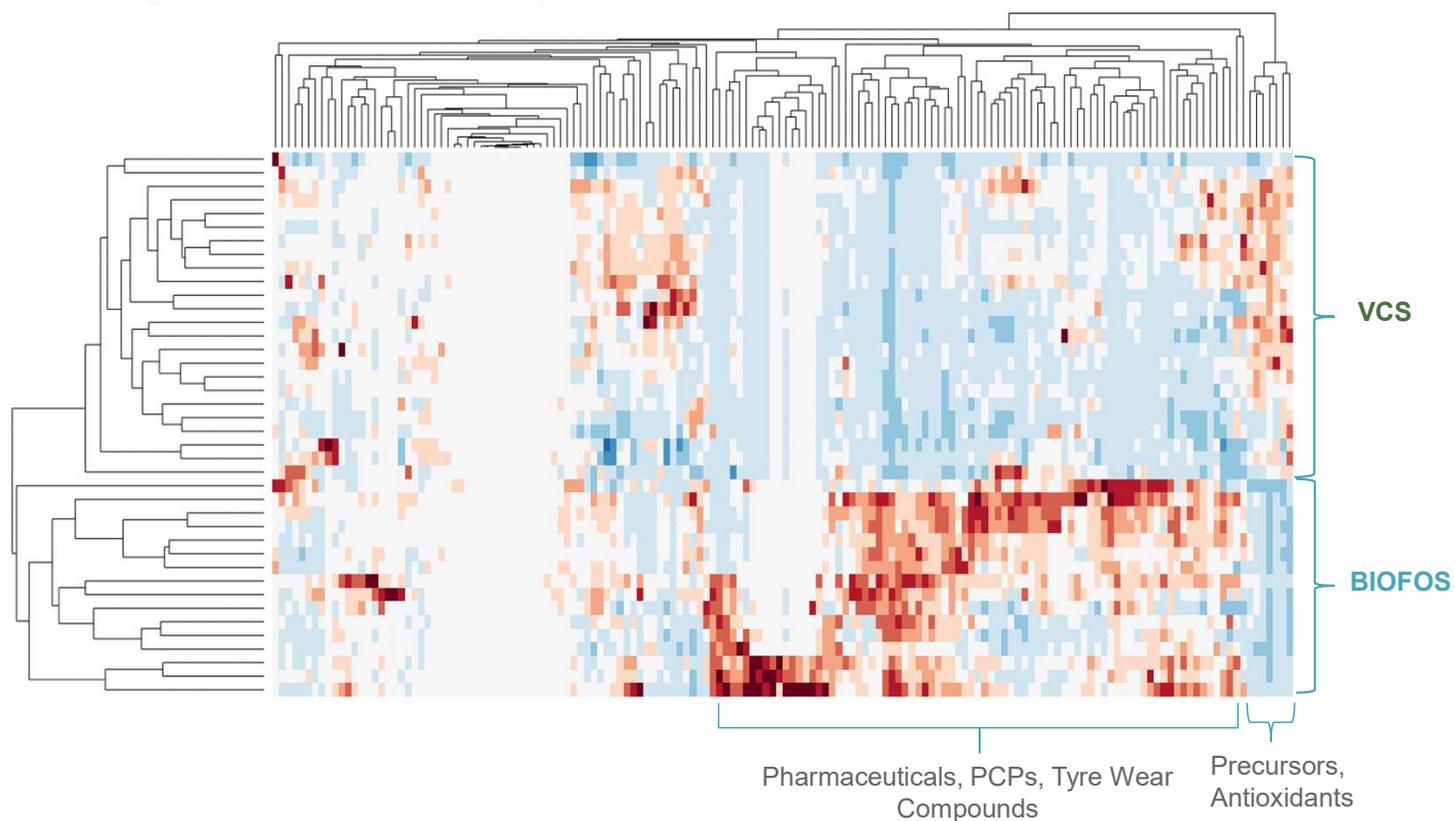


VANDALF Phase 2

Linking chemical and toxicological fingerprints



Suspect screening analysis of GC×GC-HRMS data

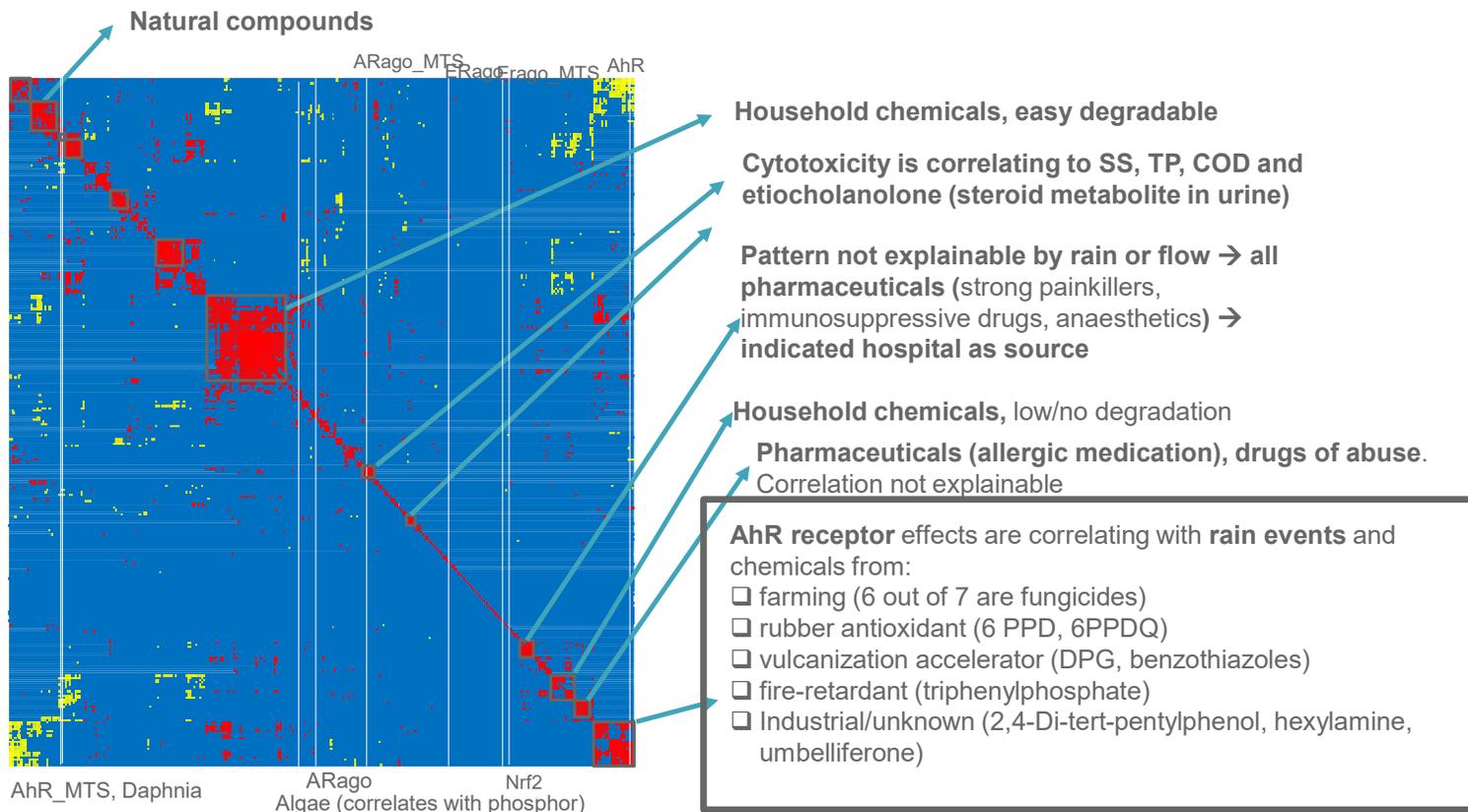


VANDALF Phase 2

Linking chemical and toxicological fingerprints

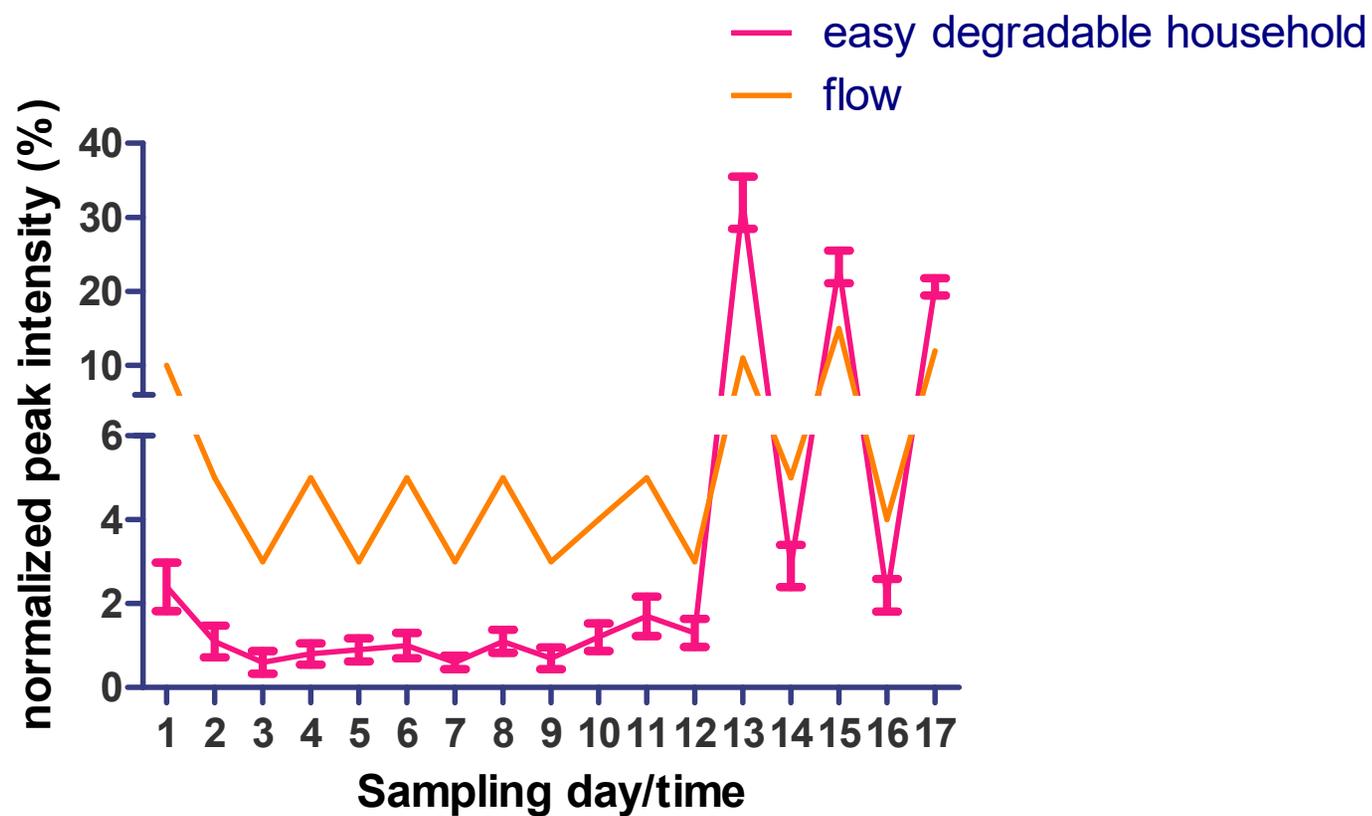


WWTP 2



VANDALF Phase 2

Linking chemical and toxicological fingerprints



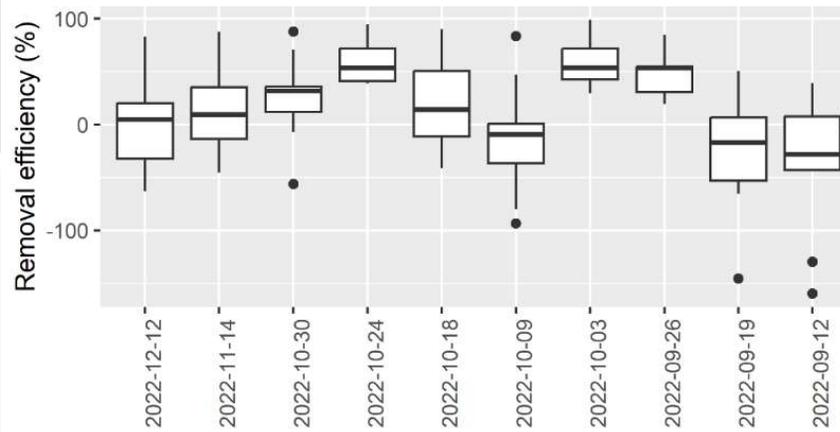
VANDALF

Treatment efficiencies



Expectations of a new urban wastewater directive in this connection there has been increased focus on 12 pharmaceuticals

- Amisulpride
- Diclofenac
- Benzotriazole,
- Carbamazepine,
- Hydrochlorothiazide,
- Methylbenzotriazole,
- Citalopram
- Metoprolol
- Candesartan
- Clarithromycin
- Venlafaxine
- og Irbesartan



Removal of the 12 focus substances fluctuates over time!



VANDALF Treatment efficiencies

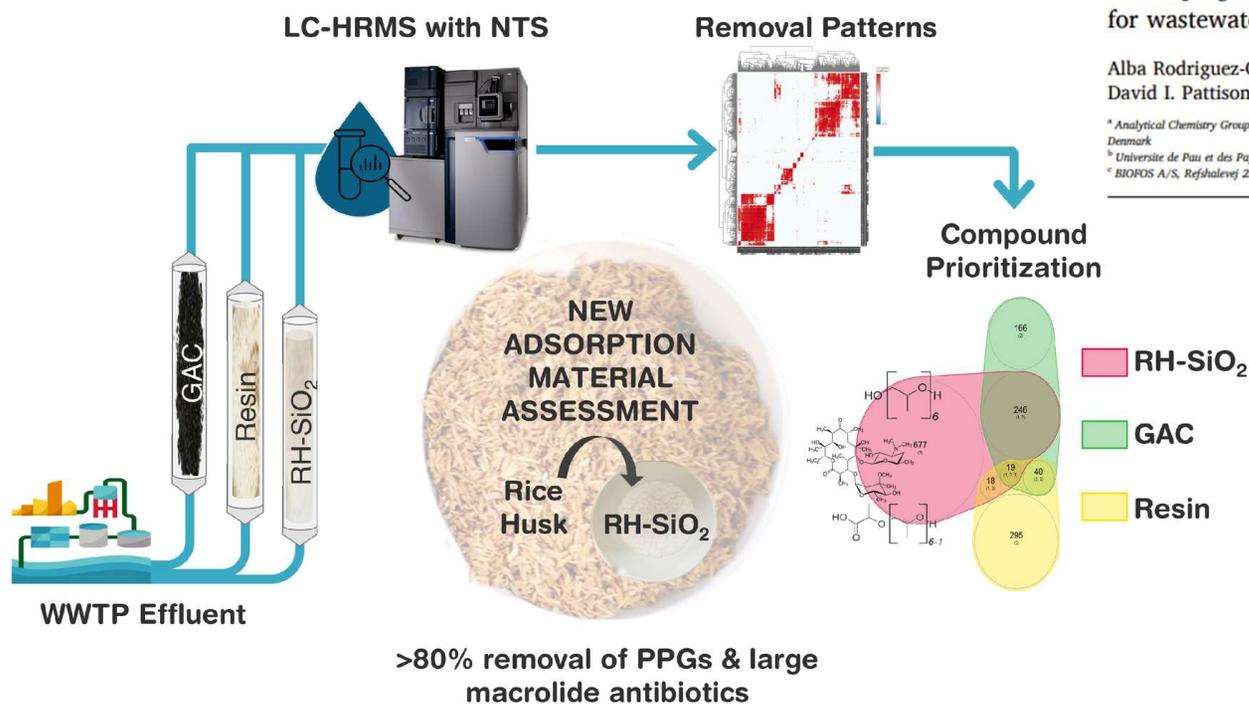


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Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat



Developing a cost and time efficient strategy for assessing novel materials for wastewater treatment with non-target screening analysis

Alba Rodriguez-Otero^{a,b,*}, Selina Tisler^a, Lisa M. Reinhardt^a, Mathias B. Jørgensen^c, David I. Pattison^a, Brice Bouyssiere^b, Jan H. Christensen^a

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DAWN

Data-driven Assessment for
Quaternary Wastewater
Treatment

Innovationsfonden 2025 - 2028



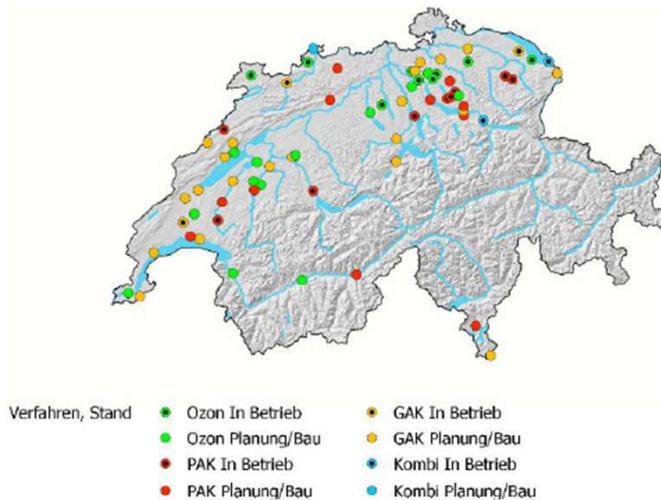
Industrial Postdoc by the IFD



Context for DAWN – Why focus on the Quaternary Treatment?

- **EU’s revised Urban Wastewater Directive** quaternary treatment by **2045** for plants serving $\geq 10,000$ PE. By **2033** first full-scale plants must be **operational** ($\geq 150,000$ PE).
- **Quaternary treatments** should achieve: **average 80% removal** of 6 out of 12 target MPs.
- **International experience: Cost-effectiveness** varies with process design—no one-size-fits-all solution.

Switzerland: Ozonation / GAC



Germany: PAC dominates



The challenge of choosing the quaternary treatment

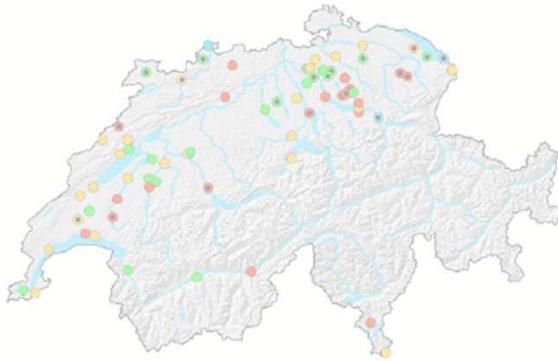
Future:

Stricter limits for **other substances**
Focus on **energy neutrality, carbon footprint** and **circular economy**



New treatments or configurations : need of a deeper and efficient characterization that supports scaling up!

Switzerland: Ozonation / GAC



Verfahren, Stand	Symbol	Verfahren
Ozon In Betrieb	Green circle	Ozon
Ozon Planung/Bau	Light green circle	Ozon
GAK In Betrieb	Yellow circle	GAK
GAK Planung/Bau	Light yellow circle	GAK
PAK In Betrieb	Red circle	PAK
PAK Planung/Bau	Light red circle	PAK
Kombi In Betrieb	Blue circle	Kombi
Kombi Planung/Bau	Light blue circle	Kombi

Germany: PAC dominates



Verfahren	Status
Adsorptiv - GAK	<input checked="" type="checkbox"/>
Adsorptiv - PAK	<input checked="" type="checkbox"/>
Oxidativ	<input checked="" type="checkbox"/>
Kombination	<input checked="" type="checkbox"/>
Sonderverfahren	<input checked="" type="checkbox"/>



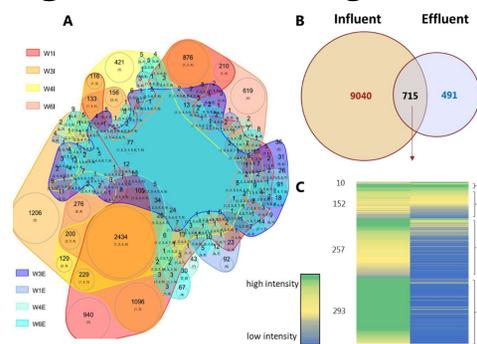
Efficient and deeper evaluation of quaternary treatments

Traditional approach for evaluating quaternary treatments at lab-scale:

- Limited MPs dataset
- Use of synthetic wastewater
- Use of one type of wastewater

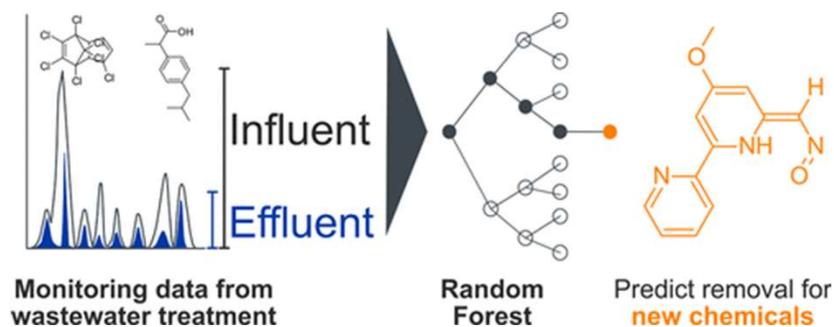


Broader screening of MPs: Non-target screening (NTS)



Danish WWTPs (Vandaf project, Tisler et al. *Water Res.* (2022))

Large datasets of RE% for MPs → Input for prediction tools



Phases of the DAWN project

P1 Assessment and modelling of quaternary treatment options

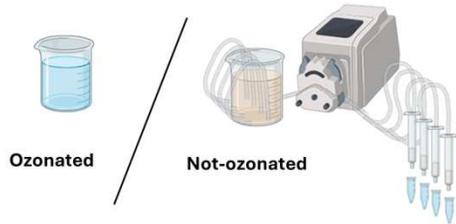
P2 Analysis of quaternary treatment dynamics

P3 Pilot-scale treatment evaluation

Lab-scale testing to evaluate treatment performance >10.000 BVs of wastewater:

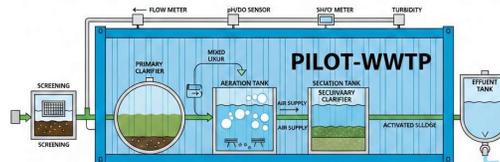
Rapid Small-Scale Columns Tests (RSSCTs)

PAC in batch reactor

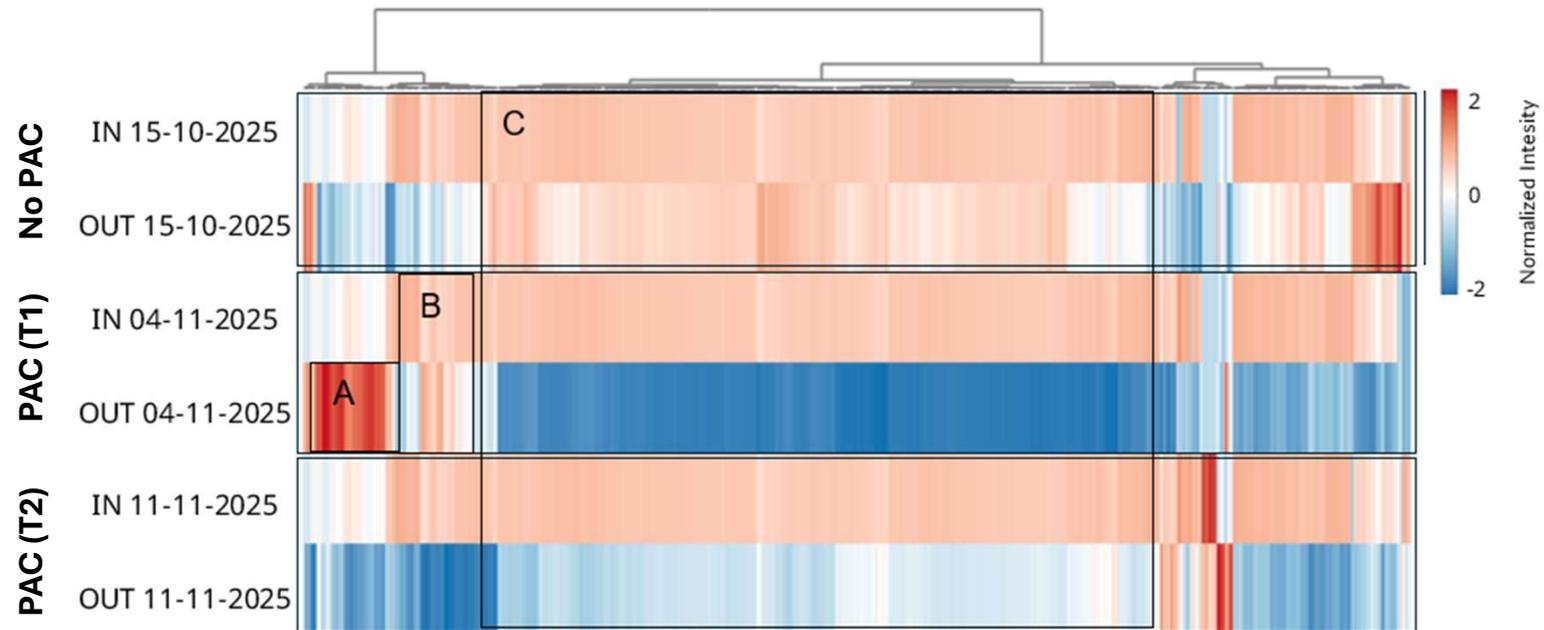


Characterization : RP-LC-HRMS with NTS
Modelling to predict degradation and breakthrough behaviour
Comparison lab-scale data vs pilot data

Wastewater samples with different compositions



Example: Samples taken from a pilot filter with PAC in a WWTP – Assessment of removal efficiency through NTS



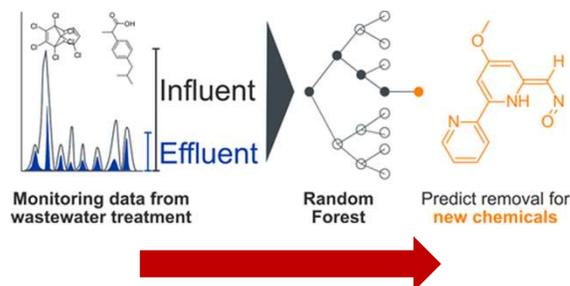
Heatmap of the 836 detected features. Colour intensity represents feature abundance, where red indicates intensities in the outlet the same as in the inlet and blue indicates lower intensity in the outlet than in the inlet.



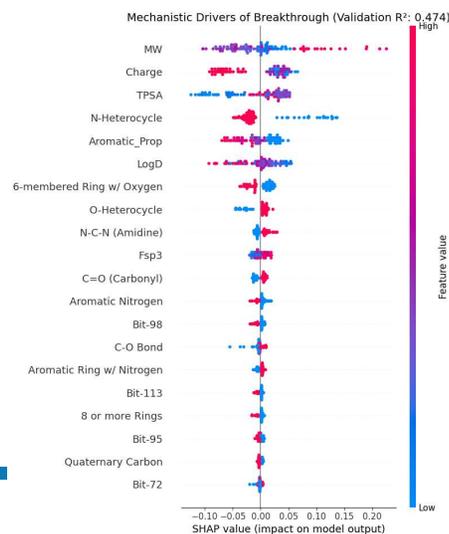
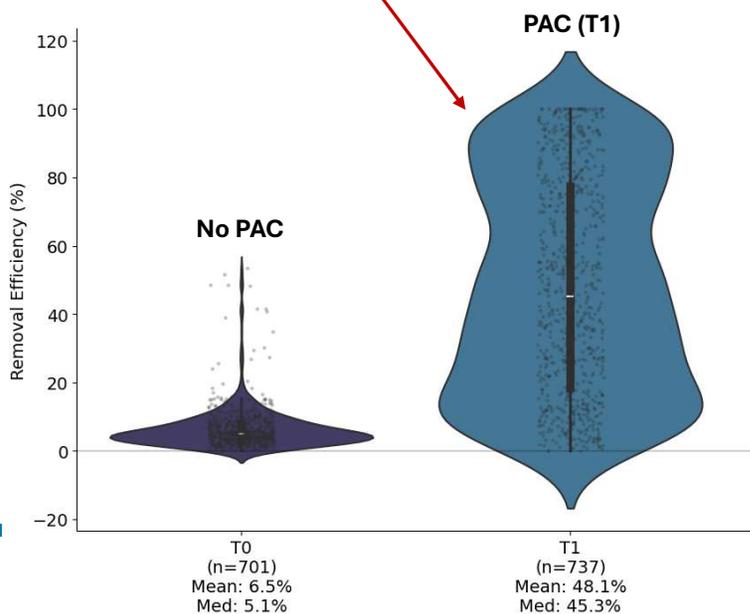
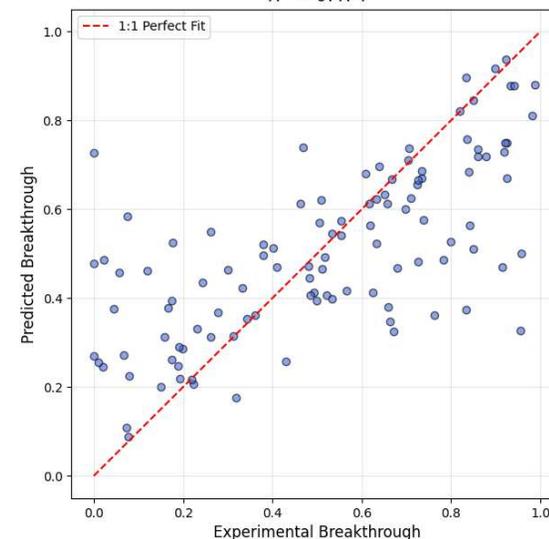
Example: Samples taken from a pilot filter with PAC in a WWTP –

Assessment of removal efficiency through NTS

In the **T1 sample**, the **RE%** of the target compounds was high enough to comply with the **UWWTD** (Urban Wastewater Treatment Directive).



Model Validation (n=110 Hidden Compounds)
 $R^2 = 0.474$



ACKNOWLEDGEMENTS AND THANK YOU!

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