# Research questions

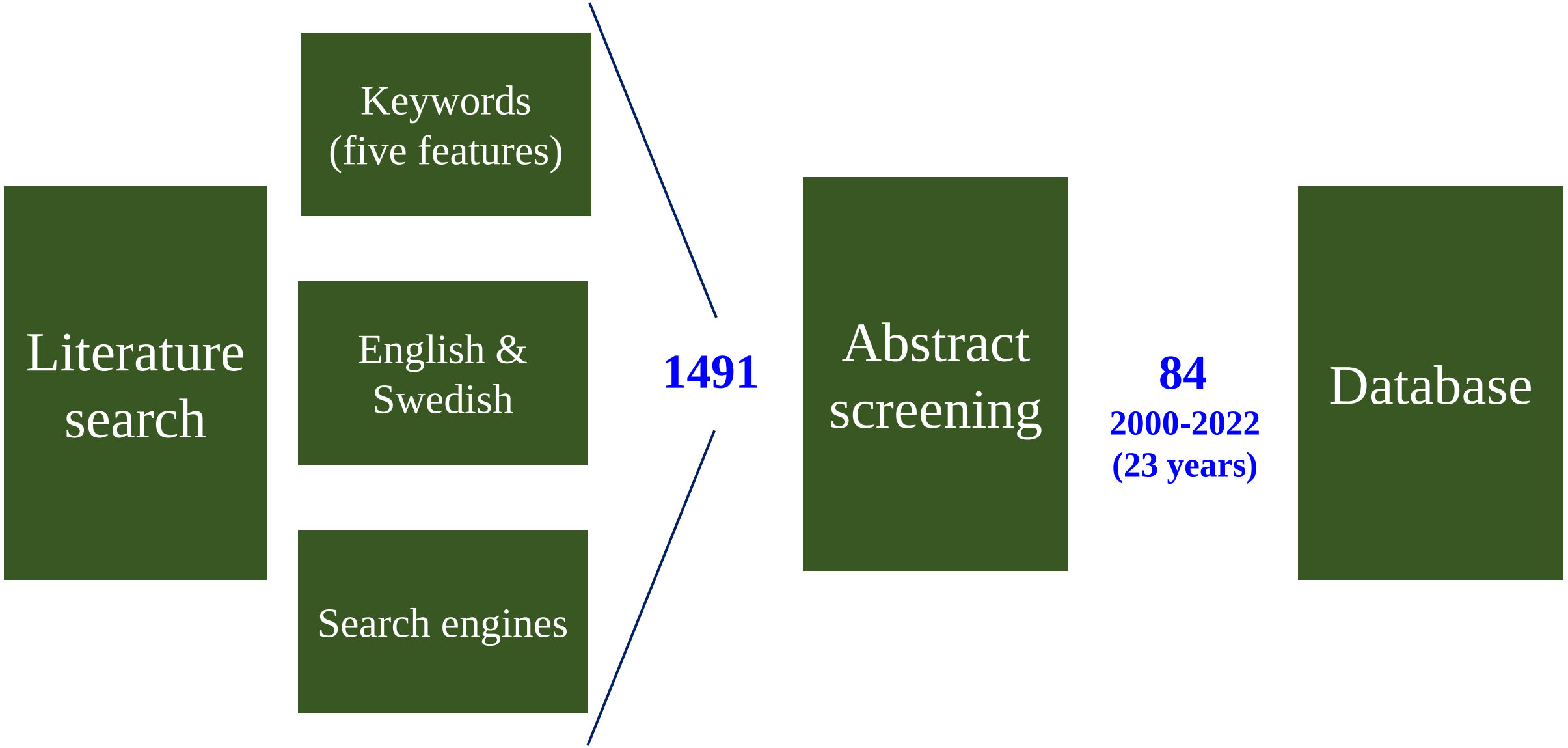
*1. Which chemical pollutants are of high concern, as potential obstacles to sustainable wastewater reuse?*

*2. To what extent do these pollutants impact on environmental and human health? How can their risks and hazards be assessed?*

*3. How can advanced treatment techniques help remove these pollutants to enable safer reuse?*

*4. What are the factors influencing the potential for wastewater reuse across countries?*

# Methodology – National literature review and synthesis workflow




U.A. Khan, P. Löffler, F. Spilsbury, K. Wiberg, C. Stålsby Lundborg & F.Y. Lai. *2024*. Towards sustainable water reuse: A critical review and meta-analysis of emerging chemical contaminants with risk-based evaluation, health hazard prediction and prioritization for assessment of effluent water quality. *Journal of Hazardous Materials*, 480, 136175.

# Methodology – Meta-analysis workflow

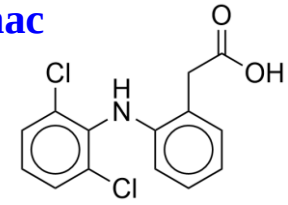
Database

~15 000 data entries
Swedish effluent wastewater
(municipal & domestic settings)

**~ 630 substances**

**> 20 quantifiable data points (effluent concentrations)**
**> 50% of quantifiable frequency**

**Diclofenac**




**~ 160 quantifiable data points**
**~ 180 total number of entries**
**93% quantifiable frequency**

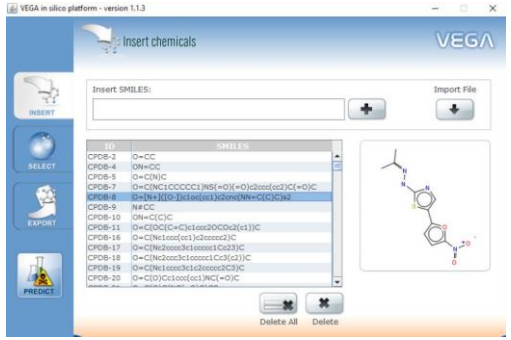
**~130 substances**

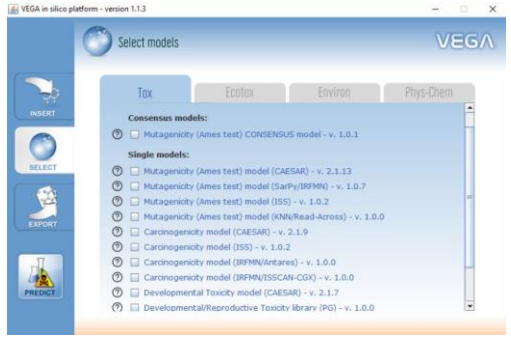
**PFDS**


**2 quantifiable data points**
**~ 50 total number of entries**
**4% quantifiable frequency**

U.A. Khan, P. Löffler, F. Spilsbury, K. Wiberg, C. Stålsby Lundborg & F.Y. Lai. *2024*. Towards sustainable water reuse: A critical review and meta-analysis of emerging chemical contaminants with risk-based evaluation, health hazard prediction and prioritization for assessment of effluent water quality. *Journal of Hazardous Materials*, 480, 136175.

# Risk and hazard evaluations of chemicals for effluent water quality




VEGA

By EC-funded LIFE project CONCERT REACH

**Ecological risk assessment**

Risk quotient ($RQ_{max}$) $= \frac{MEC_{eff,max}}{PNEC}$

Risk quotient ($RQ_{95\%tile}$) $= \frac{MEC_{eff,95\%tile}}{PNEC}$

Frequency of Exceedance (FoE) $= \frac{No.\,of\ data\ points\ exceeded\ PNEC}{Total\ no.\,of\ data\ points}$

PNEC: predicted no effect concentrations for aquatic species (USEPA, ECHA & FASS)

**Environmental health hazard**

Persistency

Mobility

Bioaccumulation

**Human health hazard**

Mutagenicity

Carcinogenicity

Estrogen effects

…..

U.A. Khan, P. Löffler, F. Spilsbury, K. Wiberg, C. Stålsby Lundborg & F.Y. Lai. *2024*. Towards sustainable water reuse: A critical review and meta-analysis of emerging chemical contaminants with risk-based evaluation, health hazard prediction and prioritization for assessment of effluent water quality. *Journal of Hazardous Materials*, 480, 136175.

Löffler P., Escher B.I., Baduel C., Virta M.P. & Lai F.Y. *2023*. Antimicrobial transformation products (TPs) in the aquatic environment: Global occurrence, ecotoxicological risks, and potential of antibiotic resistance. *Environmental Science & Technology*, 2023, 9474. [The 2023 ES&T Best Paper Awards]

SLU

# Risk and hazard evaluations of chemicals for effluent water quality

Prioritised chemical list

1) _____
2) _____
3) _____
4) _____
5) .....

## *Criteria and scoring*

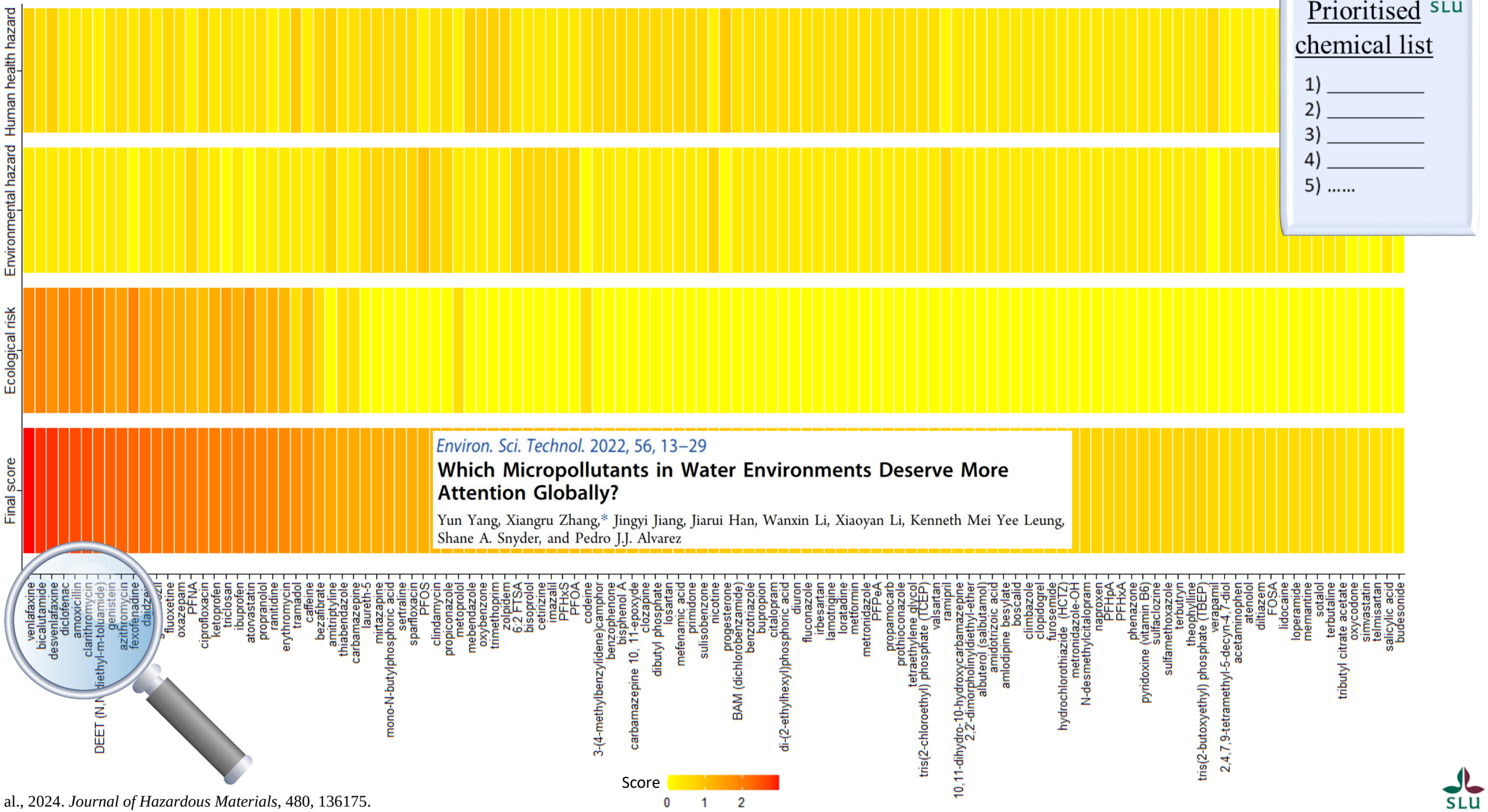
| Ecological risk assessment | Environmental health hazard | Human health hazard | |
|---|---|---|---|
| *Applied practice* | *REACH Guidelines* | *Applied practice* | |
| *Score 1 (RQ>1 = risk)* | *Score 1 (risk)* | *Score 1 (active)* | |
| *Score 0 (RQ<1 = no risk)* | *Score 0 (no risk)* | *Score 0 (inactive)* | |
| Risk quotient ($RQ_{max}$) $= \frac{MEC_{eff,max}}{PNEC}$ | Persistency | Mutagenicity | |
| Risk quotient ($RQ_{95\%tile}$) $= \frac{MEC_{eff,95\%tile}}{PNEC}$ | Mobility | Carcinogenicity | |
| | Bioaccumulation | Estrogen effects | |
| | | ..... | |
| $\bar{X} + FoE$ | $\bar{X}$ | $\bar{X}$ | = Final score |

Frequency of Exceedance (FoE) $= \frac{No.\,of\ data\ points\ exceeded\ PNEC}{Total\ no.\,of\ data\ points}$


U.A. Khan, P. Löffler, F. Spilsbury, K. Wiberg, C. Stålsby Lundborg & F.Y. Lai. *2024*. Towards sustainable water reuse: A critical review and meta-analysis of emerging chemical contaminants with risk-based evaluation, health hazard prediction and prioritization for assessment of effluent water quality. *Journal of Hazardous Materials*, 480, 136175.

Löffler P., Escher B.I., Baduel C., Virta M.P. & Lai F.Y. *2023*. Antimicrobial transformation products (TPs) in the aquatic environment: Global occurrence, ecotoxicological risks, and potential of antibiotic resistance. *Environmental Science & Technology*, 2023, 9474. [The 2023 ES&T Best Paper Awards]

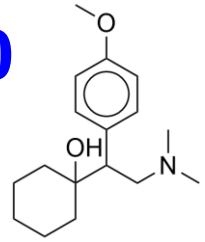
# Prioritised chemicals in effluent wastewater of Sweden



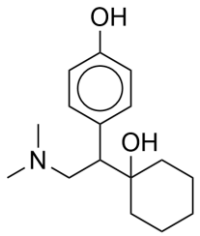

Khan et al., 2024. *Journal of Hazardous Materials*, 480, 136175.

# Prioritised chemicals in effluent wastewater of Sweden

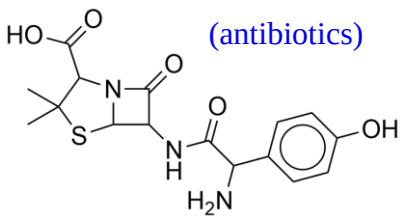
## Top-10



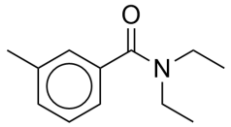
Venlafaxine
(antidepressants)



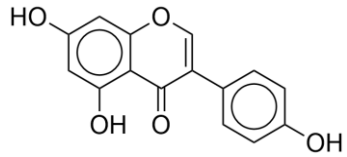
Desvenlafaxine
(metabolites)



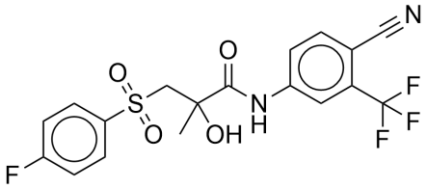
Amoxicillin
(antibiotics)



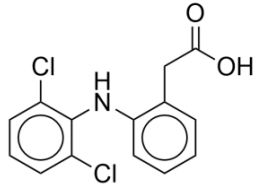
DEET
(insecticides)



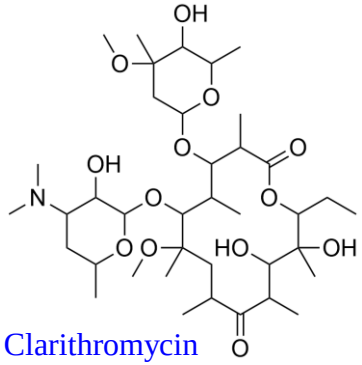
Genistein
(personal care products)



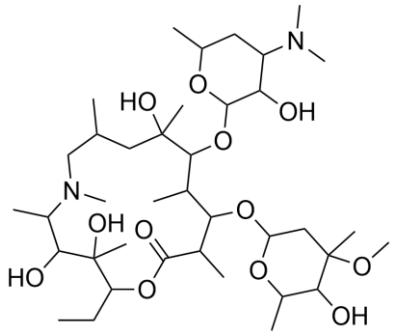
Bicalutamide
(anti-androgens)



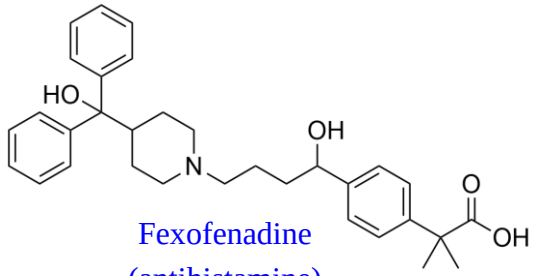
Diclofenac
(anti-inflammatory)



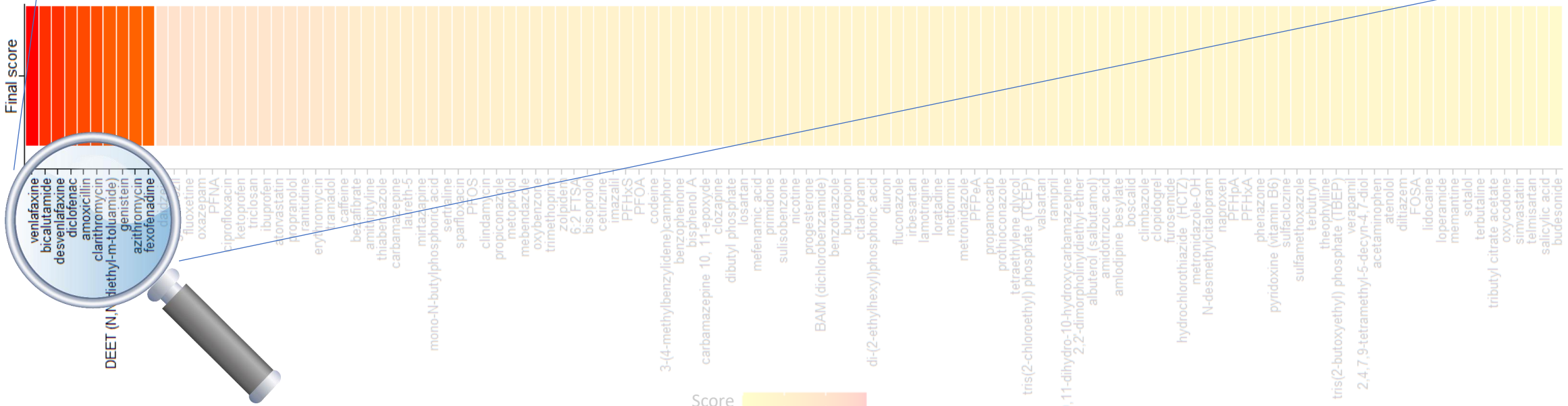
Clarithromycin
(antibiotics)



Azithromycin
(antibiotics)



Fexofenadine
(antihistamine)

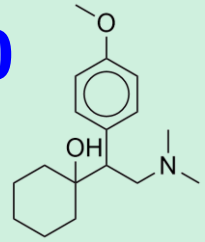



Khan et al., 2024. *Journal of Hazardous Materials*, 480, 136175.

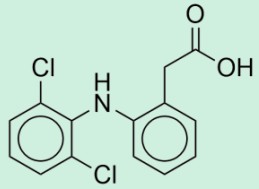
# Prioritised chemicals in effluent wastewater of Sweden

## Top-10

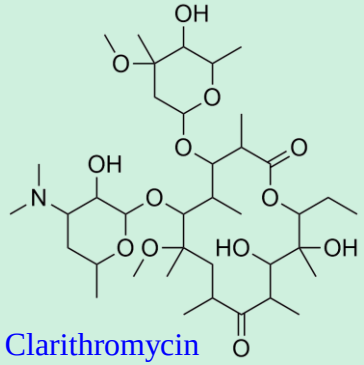
## EU UWTD (2024/3019)



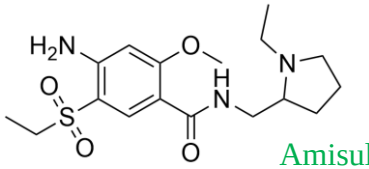
Venlafaxine
(antidepressants)



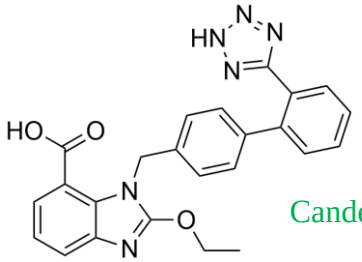
Diclofenac
(anti-inflammatory)



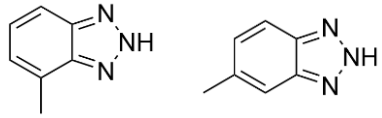
Clarithromycin
(antibiotics)



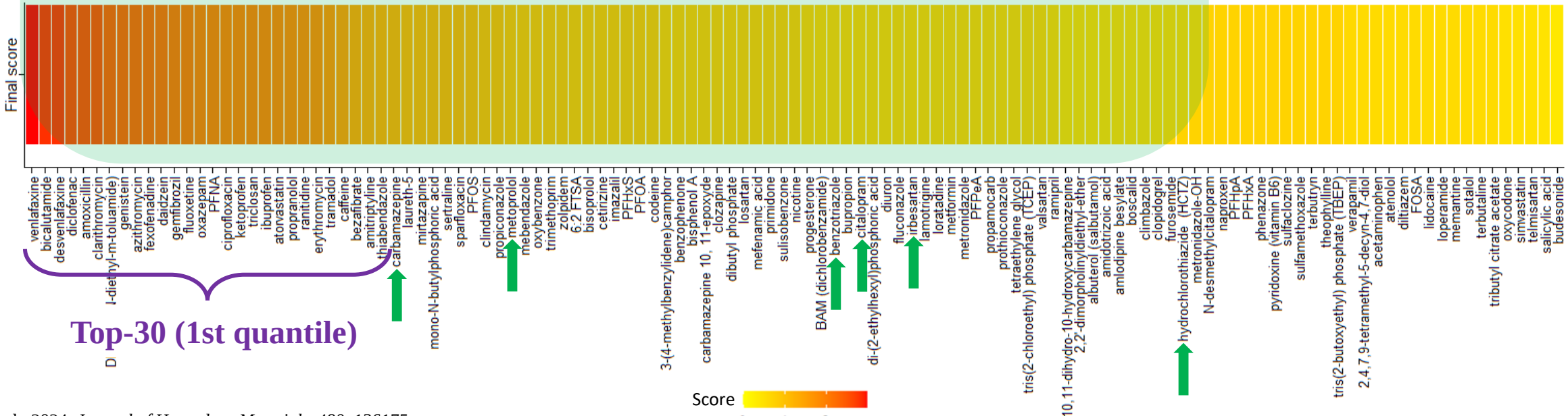
Amisulpride



Candesartan



4- or 5-Methylbenzotriazole isomers



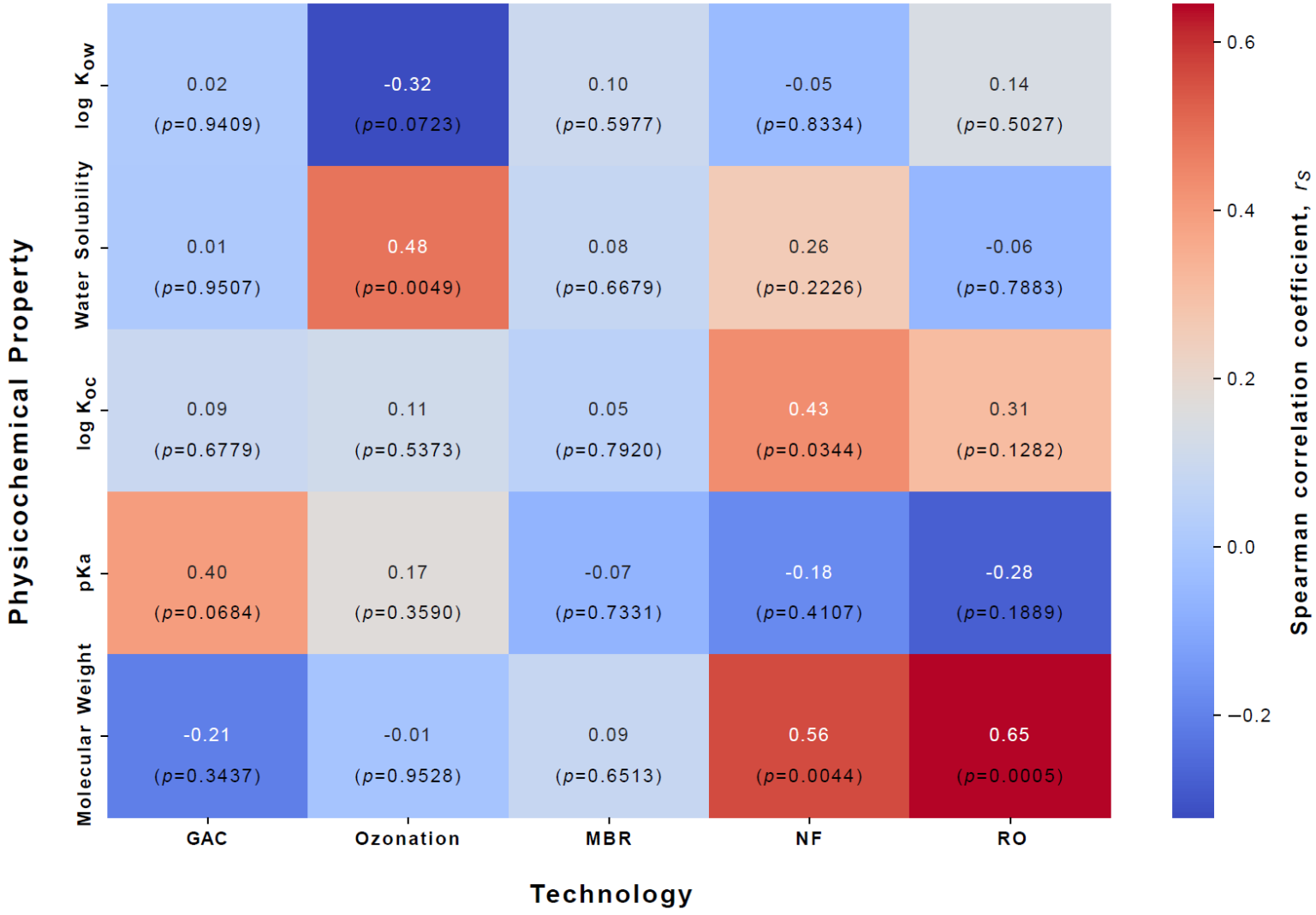

Khan et al., 2024. *Journal of Hazardous Materials*, 480, 136175.

# Maximum removal of our priority chemicals (top-30 (Q1)) & EU UWTD by advanced treatment technologies – literature review with international scientific studies (n=56, year 2007–2023)

| | GAC | Ozonation | MBR | NF | RO |
|---|---|---|---|---|---|
| **Average RE (%)** | 94.0 | 86.2 | 65.9 | 88.1 | 91.9 |
| Venlafaxine | 100.0 | 96.3 | 43.0 | 99.2 | 99.0 |
| Bicalutamide | No data | 40.0 | No data | 74.0 | No data |
| Desvenlafaxine | No data | No data | 64.2 | No data | No data |
| Diclofenac | 100.0 | 100.0 | 21.0 | 93.0 | 100.0 |
| Amoxicillin | No data | No data | 80.0 | 100.0 | 99.7 |
| Clarithromycin | 100.0 | 100.0 | 100.0 | 100.0 | 99.9 |
| Deet (n,n-diethyl-m-toluamide) | 17.2 | 80.0 | 27.0 | 95.0 | 84.0 |
| Genistein | No data | No data | 96.7 | 100.0 | 100.0 |
| Azithromycin | 98.9 | 100.0 | 78.0 | 99.9 | 100.0 |
| Fexofenadine | 90.0 | 96.0 | 45.0 | No data | No data |
| Daidzein | No data | No data | No data | No data | No data |
| Gemfibrozil | 96.9 | 90.0 | 95.0 | 94.0 | 100.0 |
| Fluoxetine | 100.0 | 100.0 | 70.0 | 97.0 | 99.2 |
| Oxazepam | 94.0 | 83.3 | 2.3 | No data | No data |
| PFNA | No data | 50.9 | No data | No data | 100.0 |
| Ciprofloxacin | 82.3 | 100.0 | 71.4 | 98.1 | 100.0 |
| Ketoprofen | 100.0 | 99.2 | 100.0 | 90.9 | 15.1 |
| Triclosan | 100.0 | 75.8 | 98.0 | No data | 59.2 |
| Ibuprofen | 100.0 | 57.0 | 90.0 | 85.7 | 95.9 |
| Atorvastatin | No data | No data | 99.0 | 93.0 | No data |
| Propranolol | 100.0 | 87.0 | 65.5 | 30.0 | 97.0 |
| Ranitidine | No data | 100.0 | 92.0 | 98.9 | 99.0 |
| Erythromycin | 100.0 | 100.0 | 59.0 | 100.0 | 100.0 |
| Tramadol | 100.0 | 100.0 | No data | 99.6 | 98.8 |
| Caffeine | 99.9 | 85.0 | 97.7 | 74.0 | 97.8 |
| Bezafibrate | No data | 60.0 | 96.0 | 93.1 | 99.5 |
| Amitriptyline | No data | 92.0 | 98.0 | 98.0 | No data |
| Thiabendazole | No data | 100.0 | 8.0 | No data | No data |
| Carbamazepine | 100.0 | 100.0 | 13.2 | 84.0 | 99.6 |
| Laureth-5 | No data | No data | No data | No data | No data |
| Amisulprid | No data | 100.0 | No data | No data | No data |
| Citalopram | 90.0 | 62.0 | 42.0 | 99.6 | No data |
| Hydrochlorothiazide (HCTZ) | 99.7 | 99.0 | 66.3 | No data | 99.9 |
| Metoprolol | 100.0 | 96.3 | 40.0 | No data | 98.7 |
| Benzotriazole | 100.0 | 98.0 | 97.2 | 17.0 | 70.5 |
| Candesartan | No data | 82.0 | No data | No data | No data |
| Irbesartan | 92.0 | 39.0 | 21.3 | No data | No data |
| Methyl benzotriazole | No data | 99.0 | No data | No data | 85.1 |

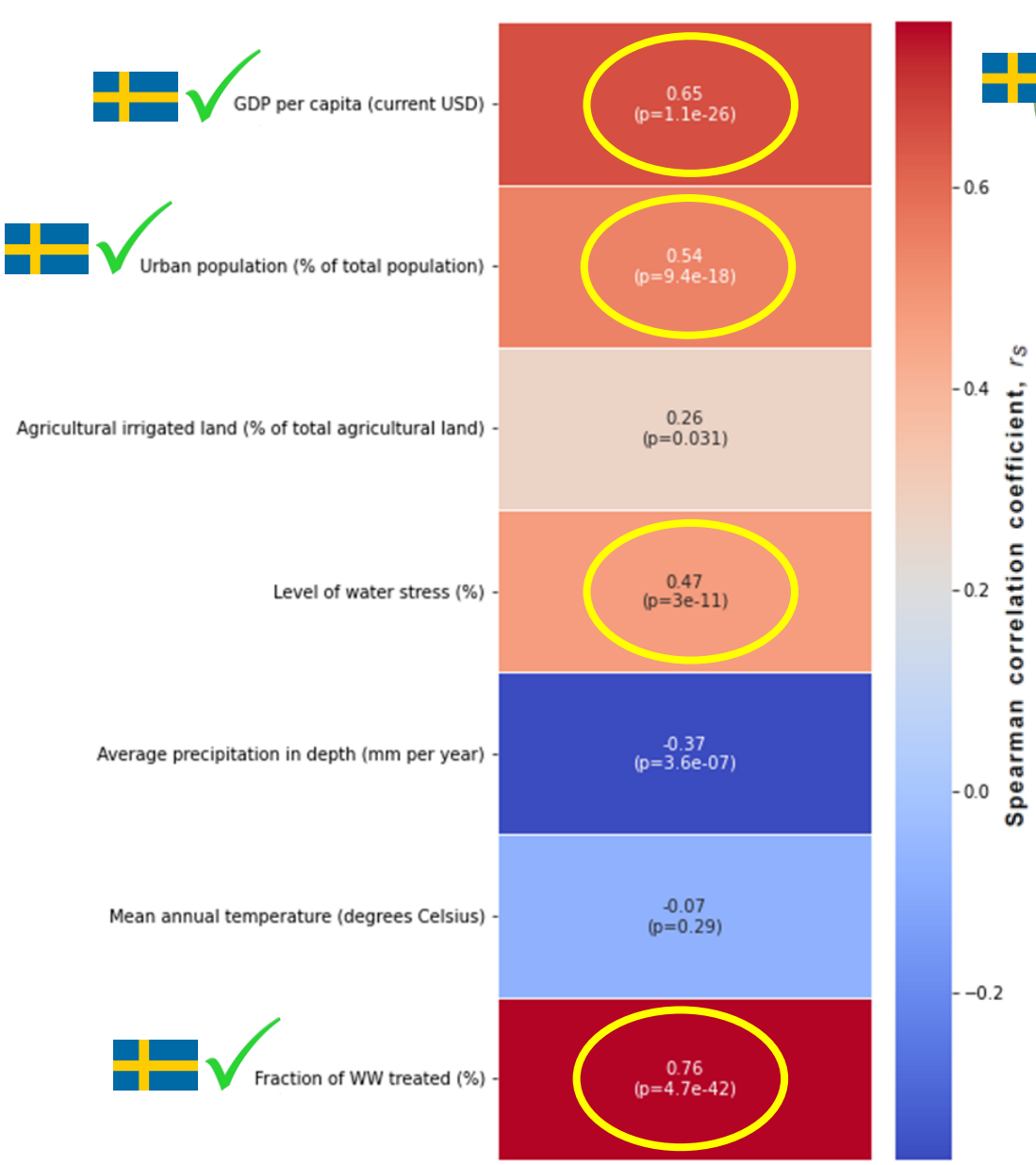
Khan et al., manuscript in preparation.

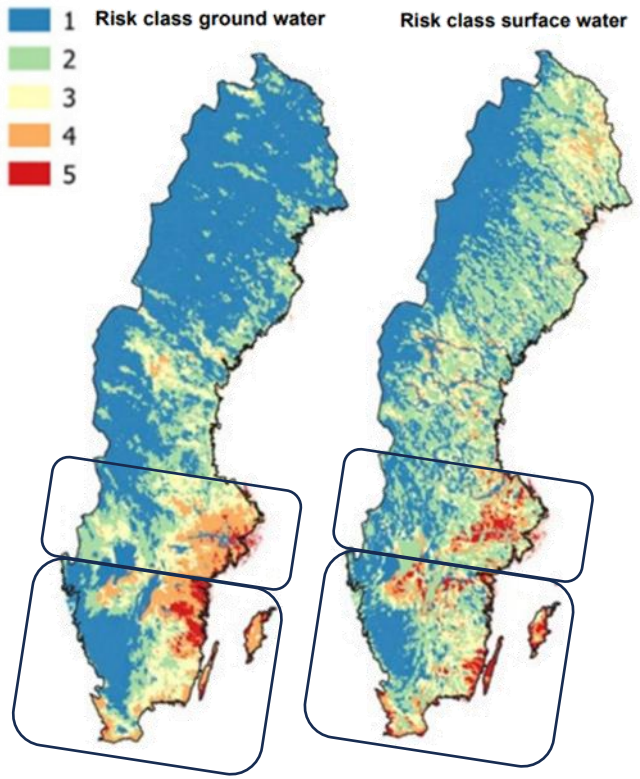
# Linking chemical property to their removals in advanced treatment technologies



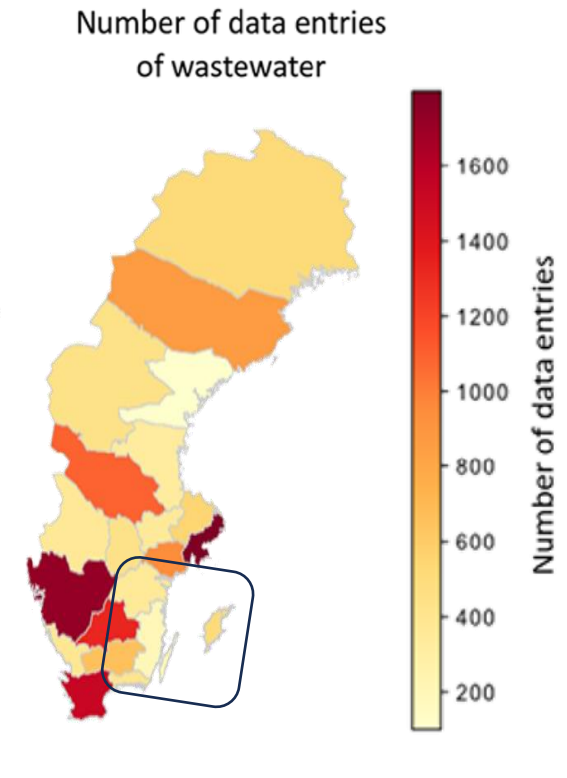

Khan et al., manuscript in preparation.

# Factors influencing cross-national differences in wastewater reuse




Stensen K., Krunegård A., Rasmusson K., Matti B. & Hjerdt, N. 2019. Sveriges vattentillgång utifrån perspektivet vattenbrist och torka – Delrapport 1 i regeringsuppdrag om åtgärder för att motverka vattenbrist i ytvattentäkter.




U.A. Khan, P. Löffler, F. Spilsbury, K. Wiberg, C. Stålsby Lundborg & F.Y. Lai. *2024*. Towards sustainable water reuse: A critical review and meta-analysis of emerging chemical contaminants with risk-based evaluation, health hazard prediction and prioritization for assessment of effluent water quality. *Journal of Hazardous Materials*, 480, 136175.

Khan et al., 2024. Naturvårdsverket Forskning Miljö, Rapport 7173.

# Take-home messages and future implications

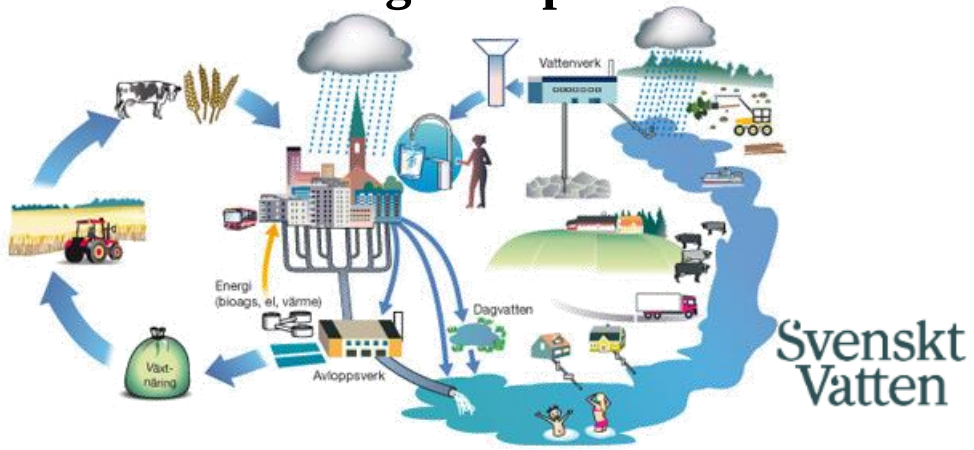

Policy decisions:
Limiting emissions (↓ ecological risk & ↑ removal)

Water reuse policy (2020/741):
Targets for assessing effluent water quality and for risk management plan

Water technical sectors:
Targets for advanced or quaternary treatments

Research:
Vattnets kreslopp

**Allt vatten hänger ihop!**



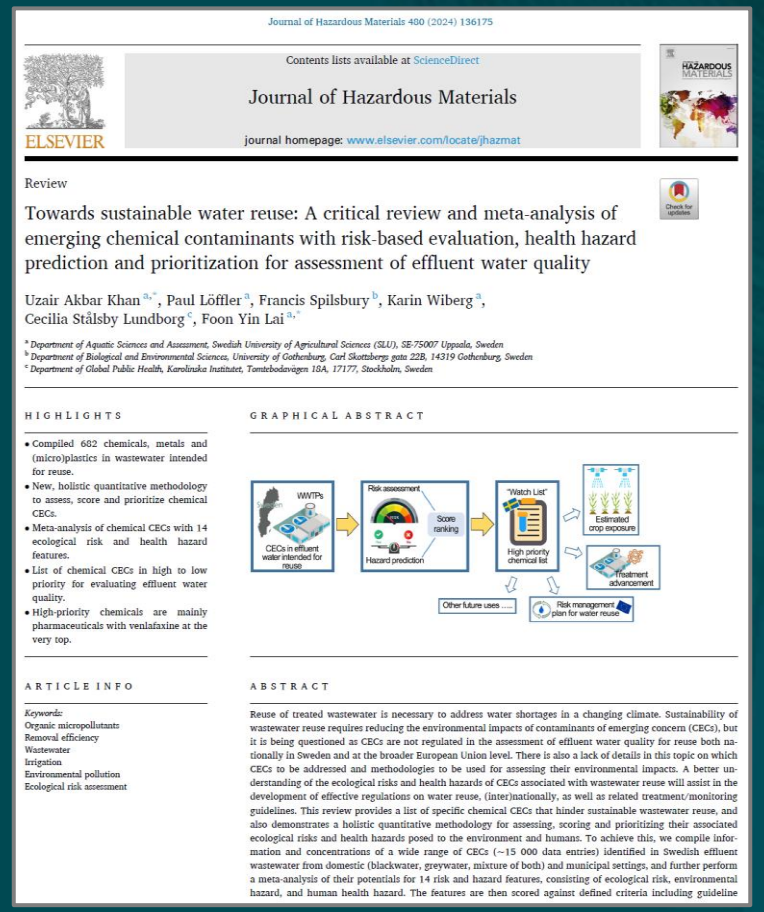
# Acknowledgement

# Tack för att ni lyssnade!!


**Reference group members**

Maximilian Lüdtke, Cezary Bose & Anna Åkerblom (Naturvårdsverket)
Margreta Lundin Unger (HaV)
Anders Finnson (Svenskt Vatten)
Lisa Reiter & Ingrid Bornfeldt Persson (Swedish Board of Agriculture)
Erika Wikdahl & Jessica Lerstorp (Österlen VA)
Shadi El Habash (Region Gotland)
Are Vallin (County Administrative Board of Kalmar)
Andreas Roos (Uddevalla Kommun)




SCIENCE AND EDUCATION FOR SUSTAINABLE LIFE