



Modelling Micropollutants in Integrated Urban Wastewater Systems

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MICROPOLLUTANTS – A COMPLEX ISSUE

“More than 100,000 chemicals are (pre-)registered at the European Chemical Agency (ECHA)”

*“More than 3,000 active **pharmaceutical** products are produced in the EU, of which 2,200 are considered critical (i.e., of common use among the population)”*

*“According to OECD, over 4,700 CAS number of **PFAS** have been recorded... with 182 compounds detected in wastewater and sewage sludge”*

Franco et al. (20210), Arvaniti et al. (2024), European Medicines Agency (2023)



EU UWWTD REGULATION – AND BEYOND

Catchments and WRRFs



Official Journal
of the European Union 2024/3019

DIRECTIVE (EU) 2024/3019 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

of 27 November 2024

concerning urban wastewater treatment

- Combined sewer overflows to be reduced to 2% of dry weather **loads**
- By 2045, removal > 80% for **12 micropollutants** through advanced treatment in WWTPs



1.2 – 1.8 bn
EUR per year

Integrated modelling as key tool to:

- *Gain holistic understanding of micropollutant fate*
- *Reduce / optimize monitoring costs*
- *Prioritize interventions and investments*

Recipients

[Home](#) > [Press](#) > [Press releases](#)

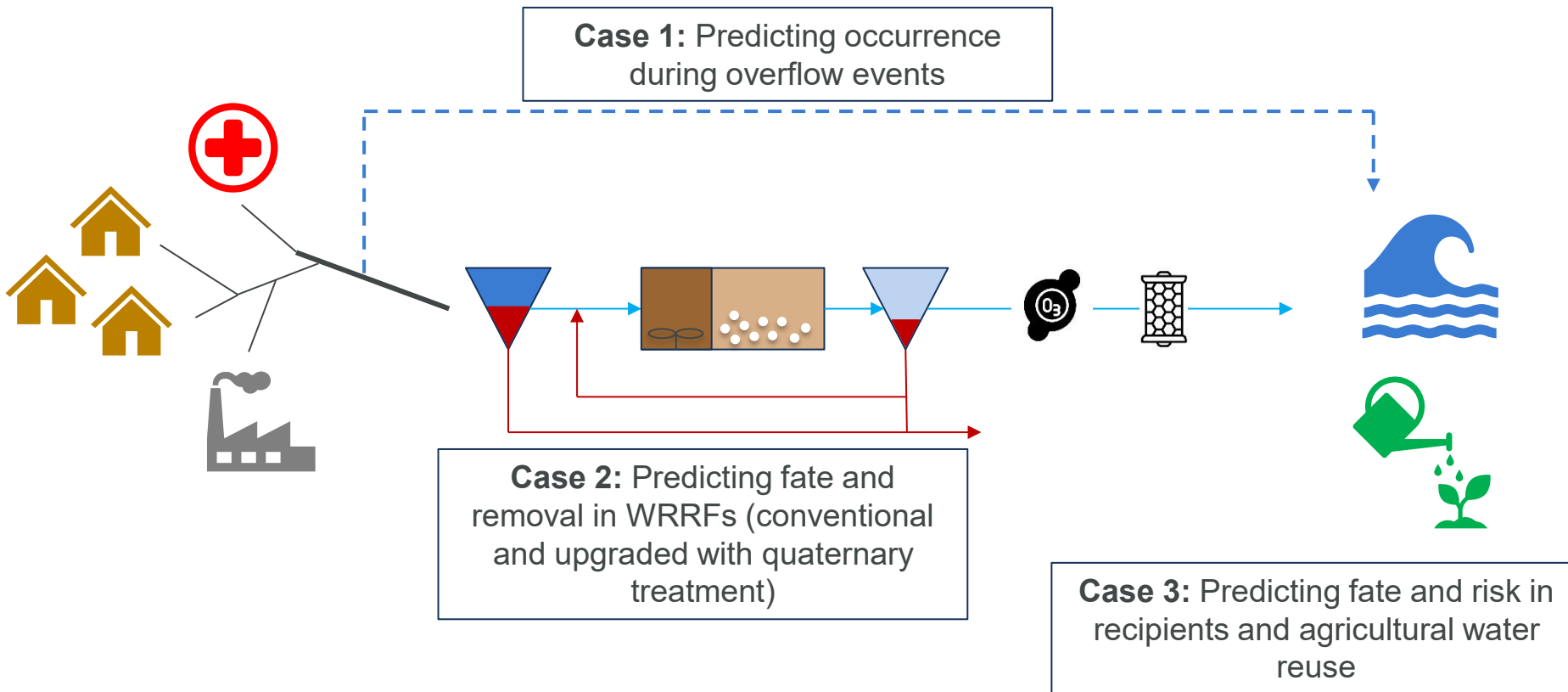
Council of the EU | Press release | 23 September 2025 19:52

Water pollution: Council and Parliament reach provisional deal to update priority substances in surface and ground waters

Environmental Quality Standards (EQS) = limit concentrations in recipients for **47 micropollutants**

- 24 PFAS
- 23 new substances (e.g., Bisphenol A, pharmaceuticals)

INTEGRATED MODELLING OF MICROPOLLUTANTS – OVERVIEW OF APPLICATIONS



ACKNOWLEDGMENTS



POLITECNICO
MILANO 1863



Jessica Ianes



*Riccardo Delli
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Manuela Antonelli



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Enrico Remigi



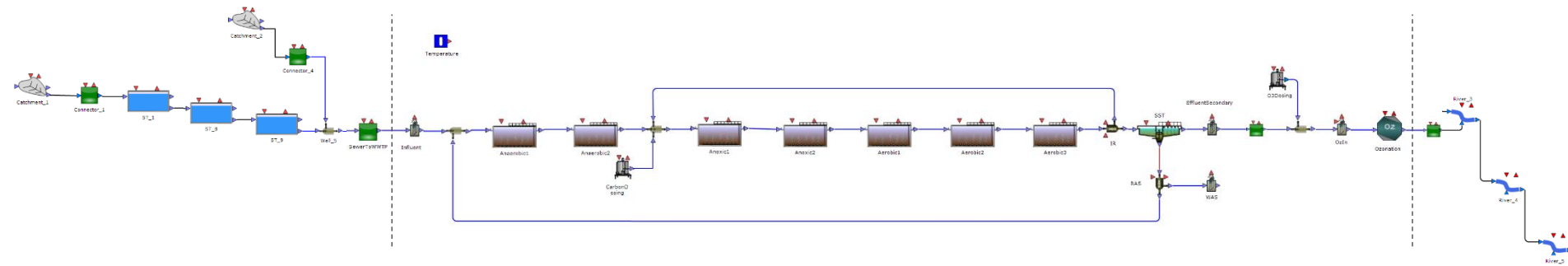
THE MODELLING FRAMEWORK



Catchment

WRRF

Recipient





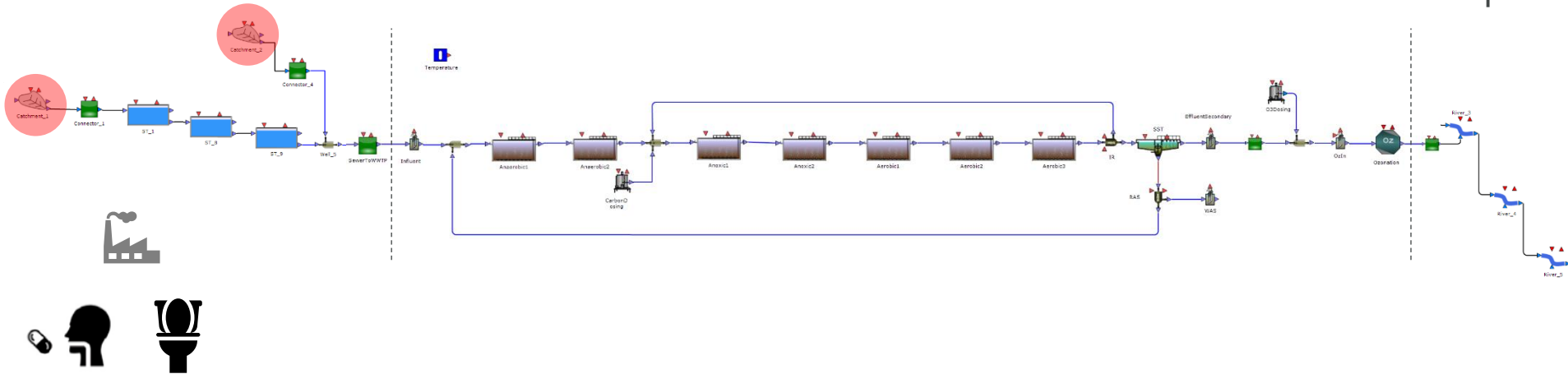
THE MODELLING FRAMEWORK



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WRRF

Recipient





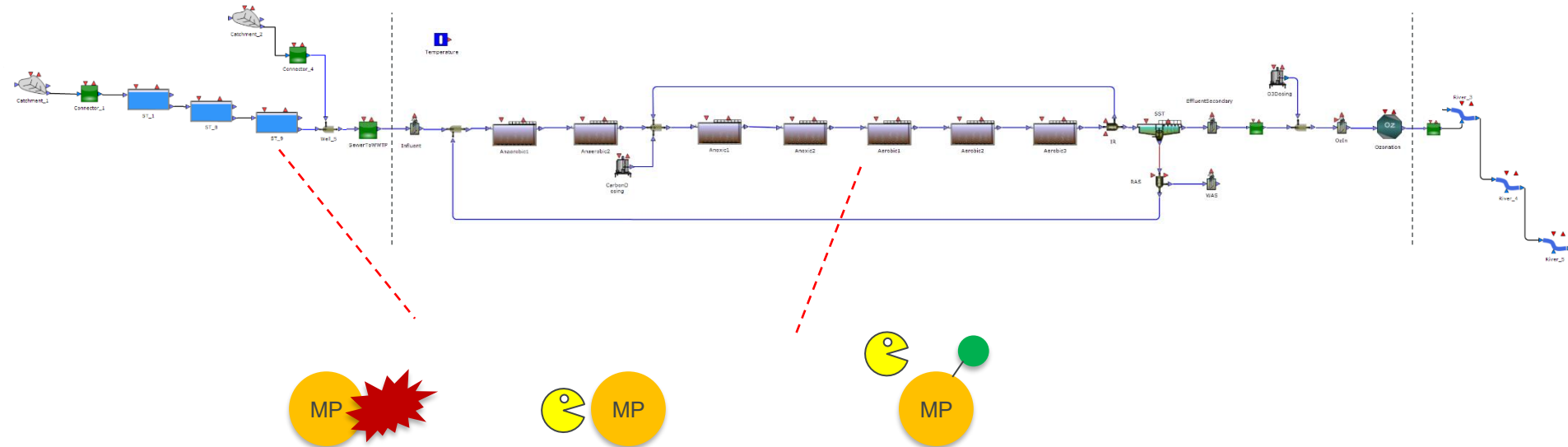
THE MODELLING FRAMEWORK



Catchment

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	S_{MP}	X_{MP}	$S_{MP,conj, gluc}$	Process rate [$g_{MP} l^{-1} d^{-1}$] ^b
Deconjugation	$+f_{dec}^d$		-1	$k_{dec} S_{MP, conj, gluc}$
Sorption ^a	-1	+1		$k_{sor} C_{TS} S_{MP}$
Desorption ^a	+1	-1		$\frac{k_{des} X_{MP}}{K_d}$
Aerobic biodegradation ^a	-1			$\alpha_{oxygen} k_{aer} S_{MP}$
Anaerobic/anoxic biodegradation ^{a,c}	-1			$(1 - \alpha_{oxygen}) k_{anox} S_{MP}$



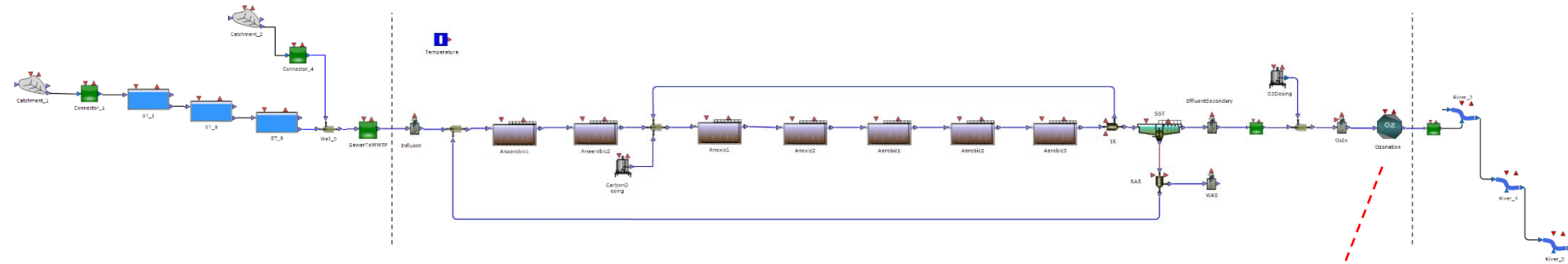
THE MODELLING FRAMEWORK



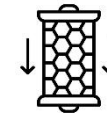
Catchment

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Ozonation
(reactivity with O₃, HO•)



Granular Activated Carbon (GAC)



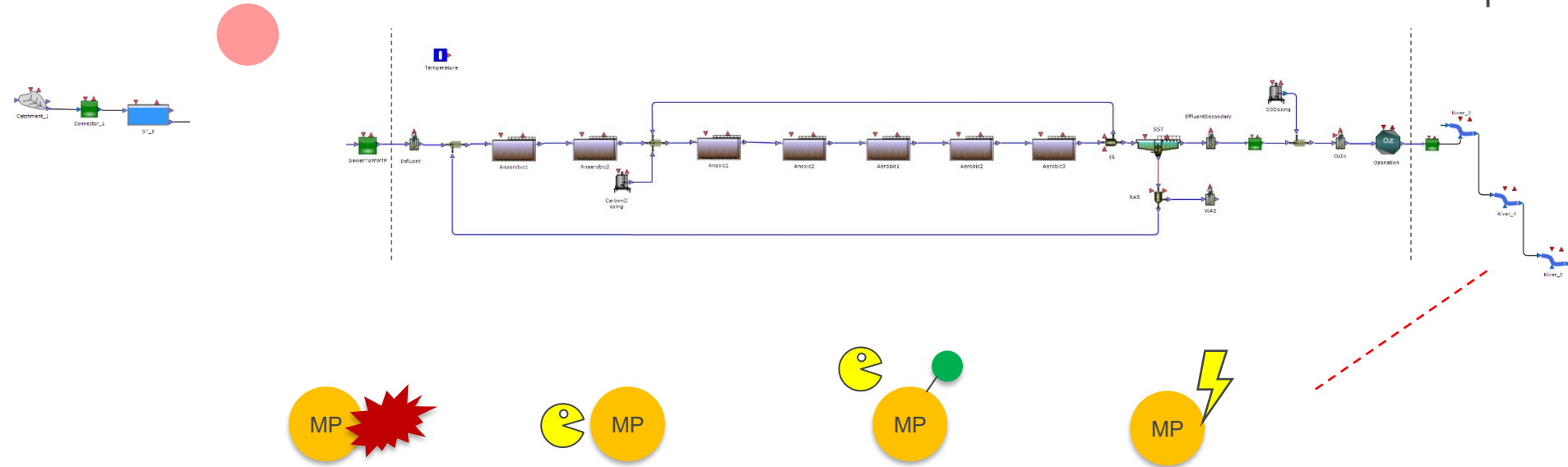
THE MODELLING FRAMEWORK



Catchment

WRRF

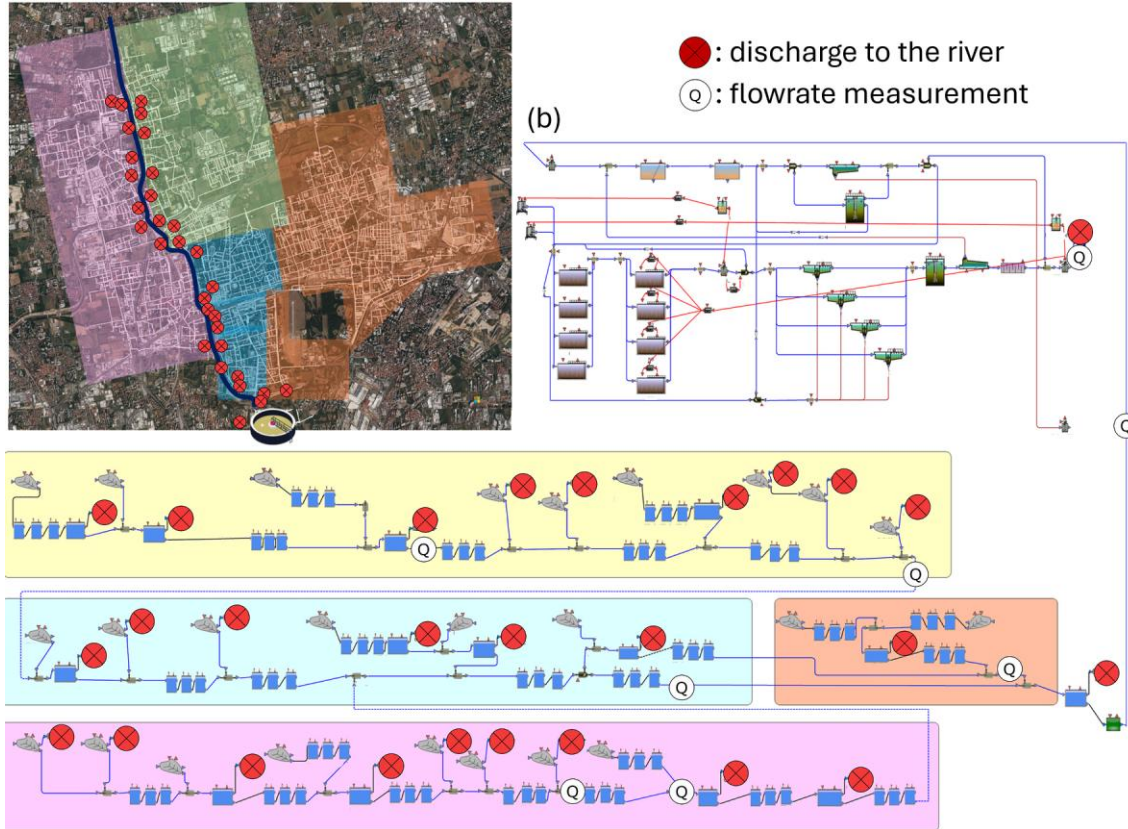
Recipient



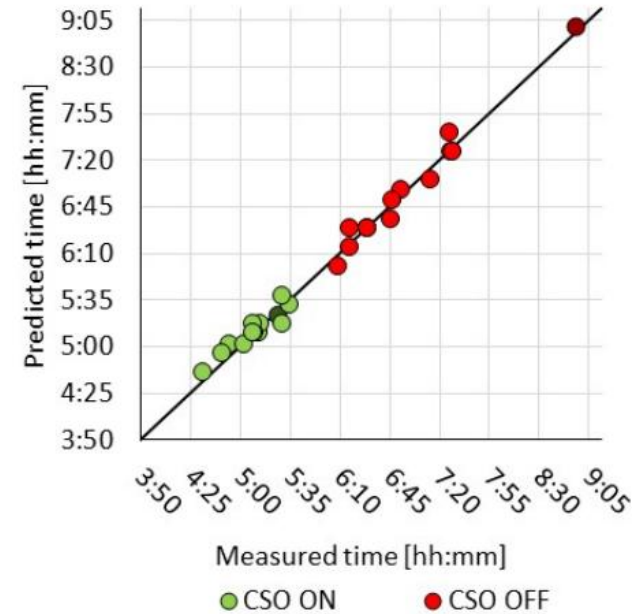
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Aerobic biodegradation ^b	-1			$\alpha_{oxygen} k_{aer} S_{MP}$
Anaerobic/anoxic biodegradation ^{b,c}	-1			$(1 - \alpha_{oxygen}) k_{anox} S_{MP}$
Photodegradation	-1			$k_{photo} S_{MP}$

CASE 1: MICROPOLLUTANTS IN OVERFLOWS

Model set-up



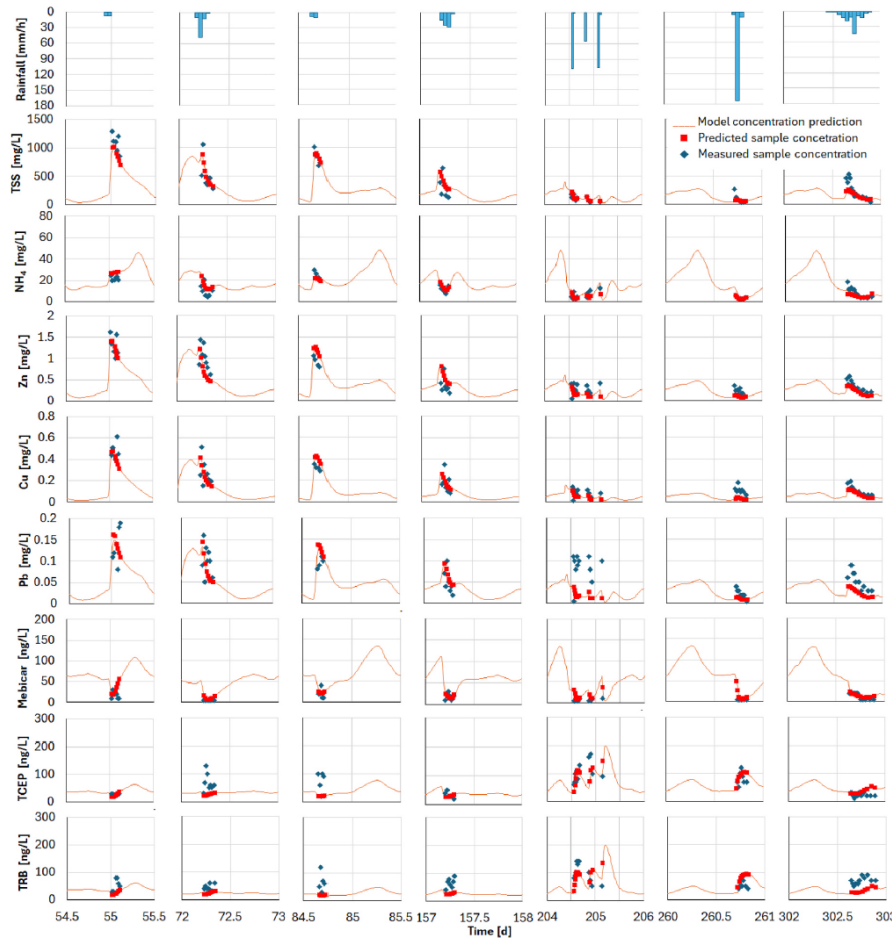
Model calibration (quantity)



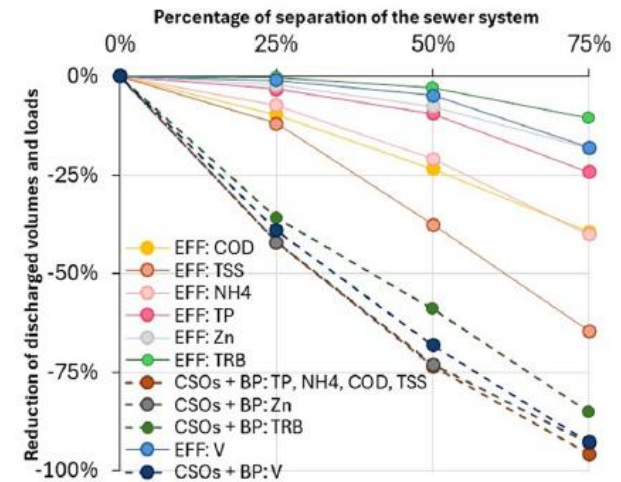


CASE 1: MICROPOLLUTANTS IN OVERFLOWS

Prediction of concentrations in overflows (WWTP bypass)



Assessment of interventions (sewer separation / soil infiltration)

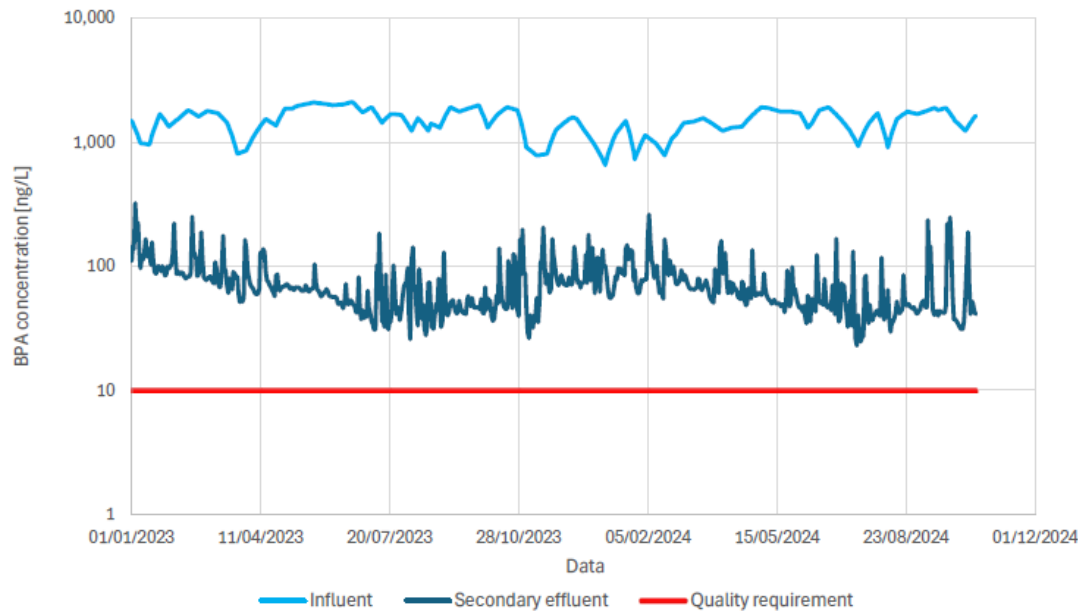




CASE 2: MICROPOLLUTANTS REMOVAL IN WRRFS

Bisphenol A (BPA): Not targeted by EU UWWTD, but EQS of 10 ng/L in recipients (Denmark)

Removal in conventional treatment



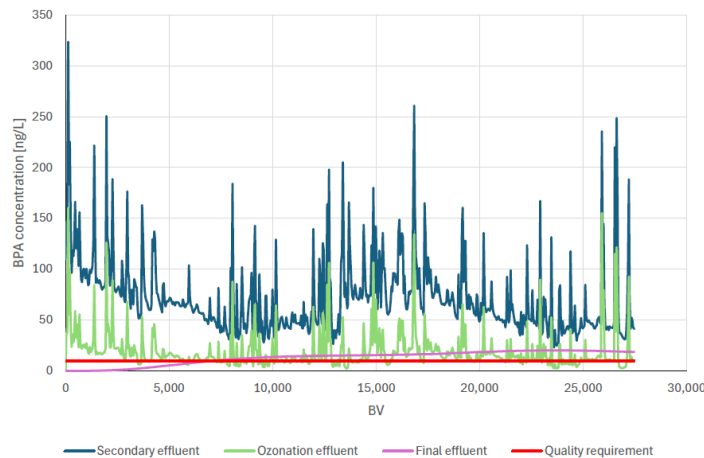
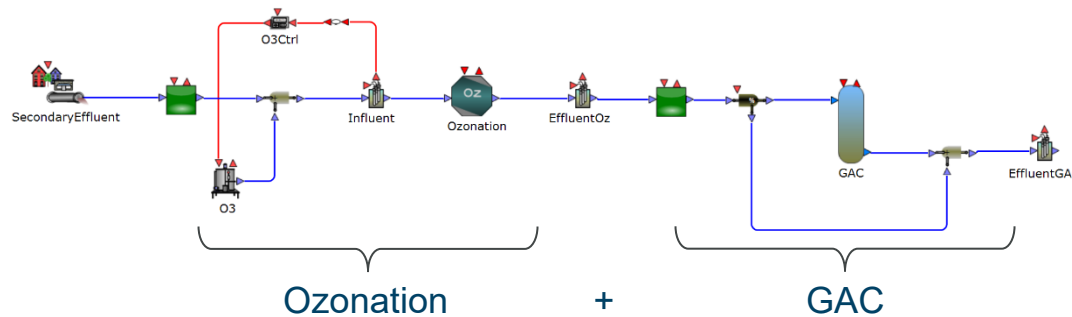
- Removal efficiency > 80% (EU UWWTD)
- **Effluent concentration > EQS**



CASE 2: MICROPOLLUTANTS REMOVAL IN WRRFS

Bisphenol A (BPA): Not targeted by EU UWWTD, but EQS of 10 ng/L in recipients (Denmark)

Upgrade with quaternary treatment

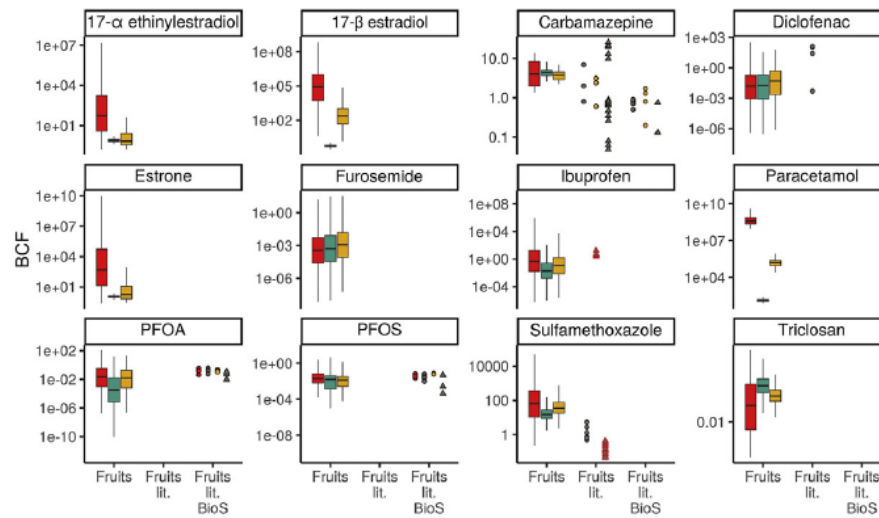
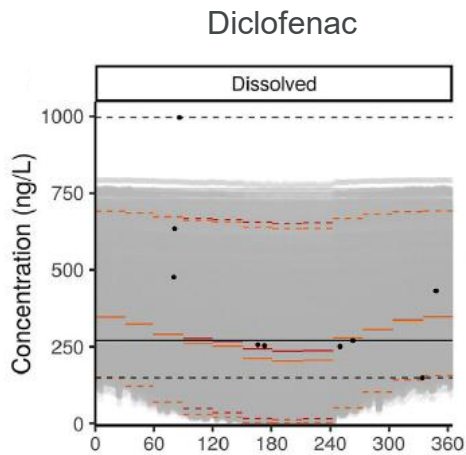
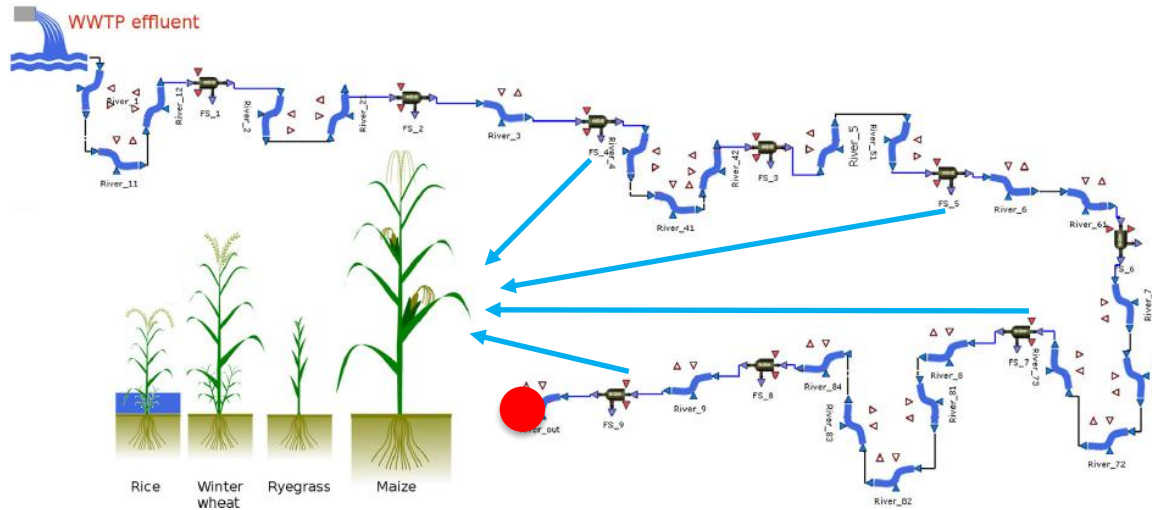


Combination of ozonation and GAC as the most suitable solution

- 3-times lower ozone dose ($0.2 \text{ gO}_3/\text{gDOC}$) as compared to ozonation alone
- 2-times higher lifetime of GAC (172 days) as compared to GAC alone



CASE 3: MICROPOLLUTANTS RISKS IN RECIPIENTS (WATER-FOOD NEXUS)




No risk through dietary intake

WANT TO KNOW MORE?




Journal of Environmental Management 398 (2026) 128516

Contents lists available at [ScienceDirect](#)



Journal of Environmental Management

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



Research article

Modeling an integrated urban wastewater system to assess (micro-)pollutant discharge under dry- and wet-weather: mitigation strategies and climate change scenarios

Jessica Ianes^{a,*}, Fabio Polese^b, Beatrice Cantoni^a, Enrico Ulisse Remigi^b, Luca Vezzaro^c, Manuela Antonelli^{a,*}



Science of the Total Environment 856 (2023) 159200

Contents lists available at [ScienceDirect](#)



Science of the Total Environment

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



Modelling and prediction of the effect of operational parameters on the fate of contaminants of emerging concern in WWTPs

Marco Gabrielli^a, Riccardo Delli Compagni^a, Lucia Gusmaroli^{b,c}, Francesca Malpei^a, Fabio Polese^d, Gianluigi Buttiglieri^{b,c}, Manuela Antonelli^a, Andrea Turolla^{a,*}



Water Research 184 (2020) 116097

Contents lists available at [ScienceDirect](#)



Water Research

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




Modelling the fate of micropollutants in integrated urban wastewater systems: Extending the applicability to pharmaceuticals

Riccardo Delli Compagni^{a,*}, Fabio Polese^{b,c}, Kerstin J.F. von Borries^b, Zhen Zhang^b, Andrea Turolla^a, Manuela Antonelli^{a,*}, Luca Vezzaro^b




Chemosphere 242 (2020) 125185

Contents lists available at [ScienceDirect](#)



Chemosphere

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Risk assessment of contaminants of emerging concern in the context of wastewater reuse for irrigation: An integrated modelling approach

Riccardo Delli Compagni^a, Marco Gabrielli^a, Fabio Polese^{b,c}, Andrea Turolla^a, Stefan Trapp^b, Luca Vezzaro^b, Manuela Antonelli^{a,*}



Technical Abstract

14-18 June 2026

Quaternary treatments for micropollutants removal in WWTPs: a techno-economic modelling approach

J. Ianes*, S. Piraldi*, F. Polese**, K. B. Kjær**, E. Remigi**, B. Cantoni*, M. Antonelli*



CLOSING REMARKS

- Complex landscape for micropollutants
 - Balance between risk mitigation and economics
 - EU UWWTD vs Water Framework Directive

- Integrated modelling is the answer!

