

OPTIMISATION OF ADVANCED OXIDATION/REDUCTION IN VIEW OF MICRO-POLLUTANT REMOVAL FROM (WASTE) WATER

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Interreg
Vlaanderen-Nederland



Gefinancierd door
de Europese Unie



Schone Waterlopen door O3G

 VLAKWA

 vito

 Waterschap
De Dommel

 Aquafin

 AM TEAM
Advanced Modeling for process optimization

 PURE
BLUE

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 CAPTURE



Ministerie van Economische Zaken
en Klimaat

Provincie Noord-Brabant

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Oost-Vlaanderen

SITUATING THE PROBLEM



SITUATING THE PROBLEM IN BELGIUM

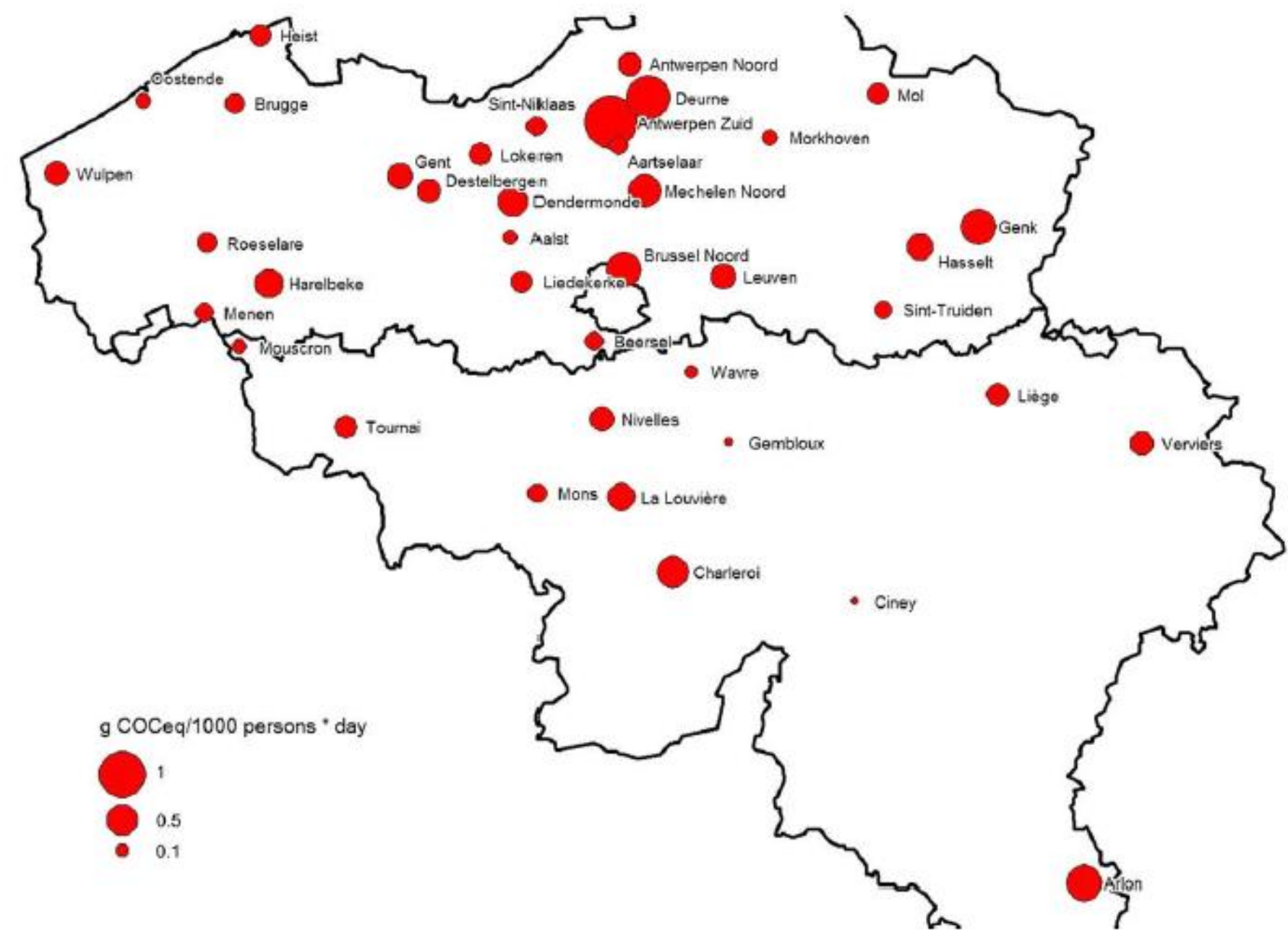
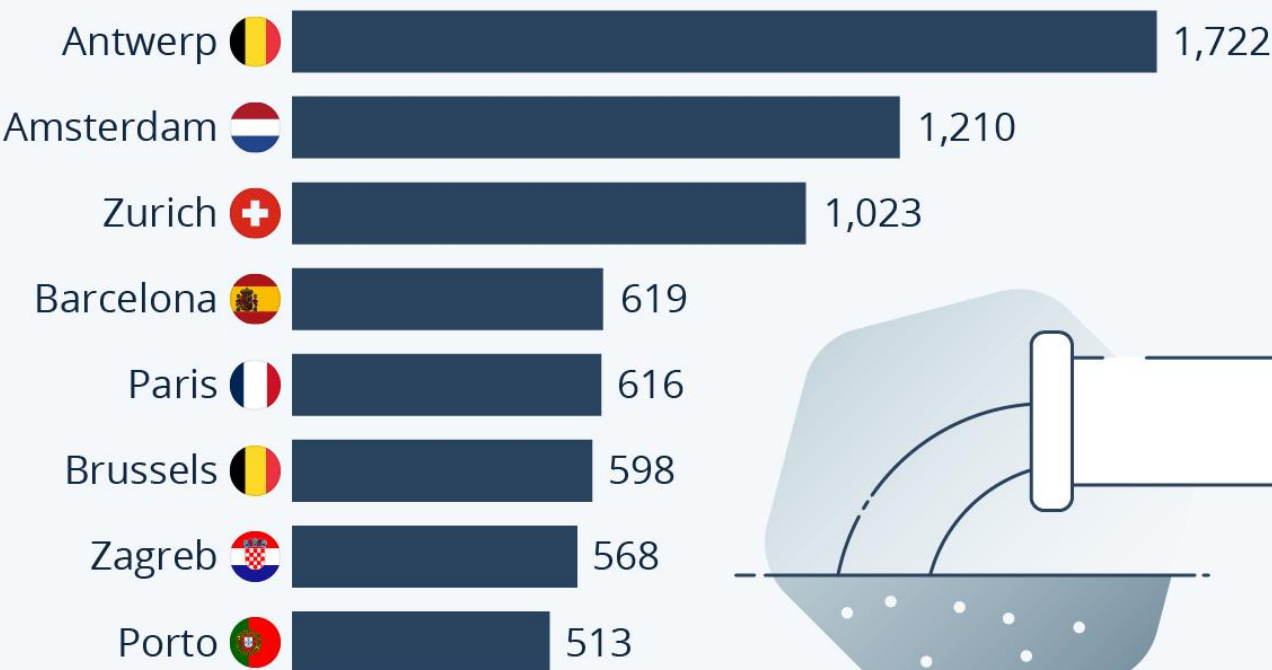


Fig. 1. Locations and results (in COC equivalents in g/day per 1000 inhabitants) of WWTP water samples collected during weekend.

Down the Drain: Tracking Cocaine Levels in Wastewater

Cocaine found in wastewater in selected European cities in 2023 (mg/1,000 people/day)



Based on the analysis of 88 cities in 23 EU countries and Turkey
Source: European Monitoring Centre for Drugs and Drug Addiction



statista



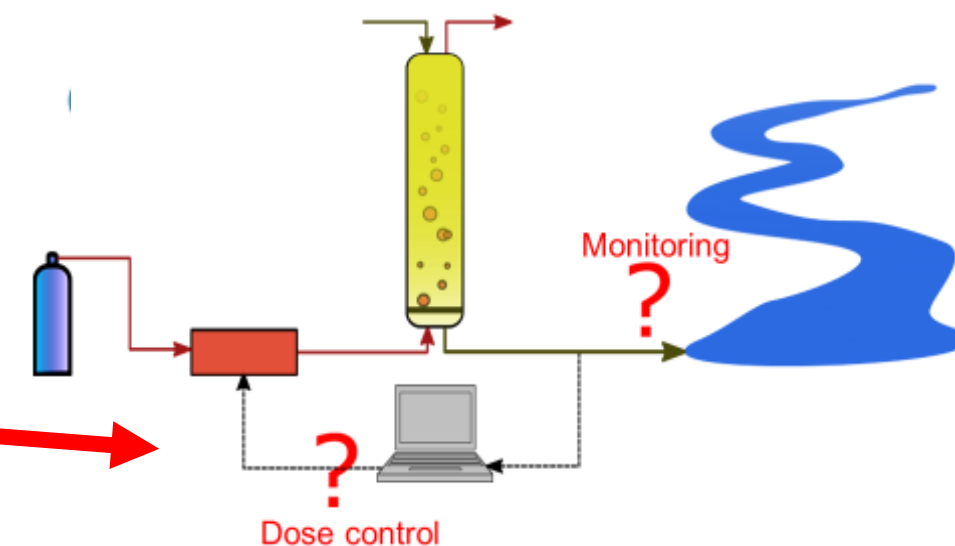
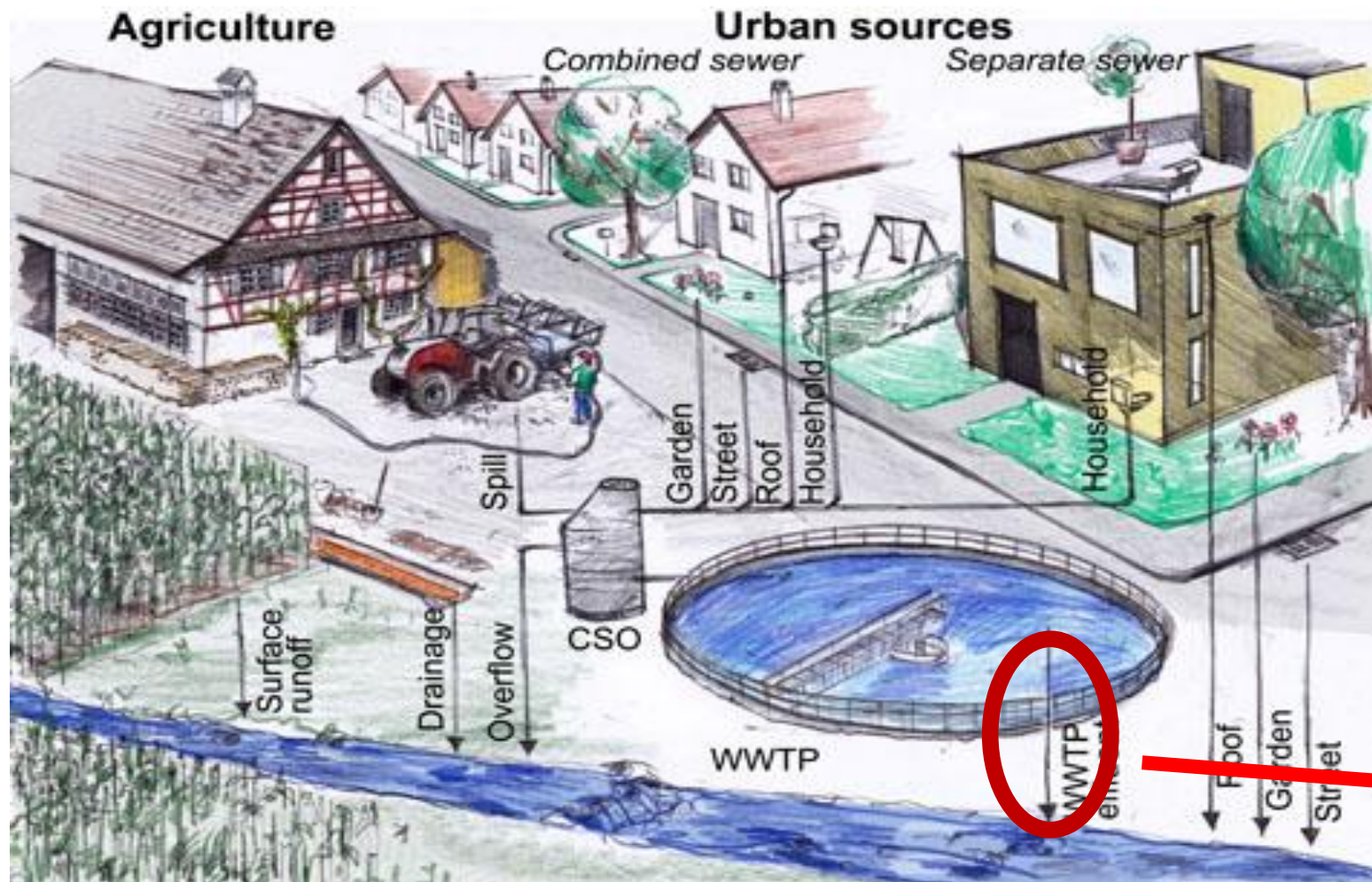
Climate > News

Eels are getting high on cocaine in Britain's drug-polluted rivers



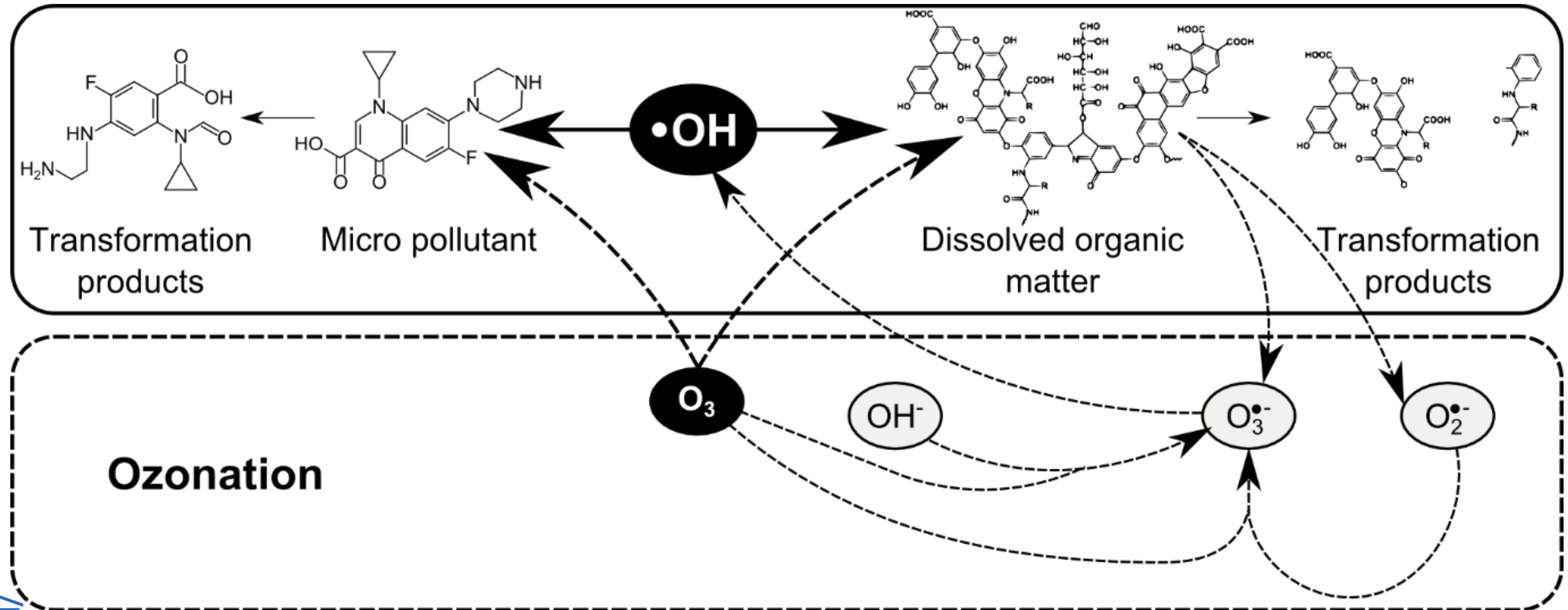
THE SOLUTION?

- Limited biodegradation
- “Law of conservation of misery”
 - > Tertiary treatment with ozone based processes



THE SOLUTION?

- Tertiary treatment with ozone based processes





Status and needs for online control of tertiary ozone-based water treatment: use of surrogate correlation models for removal of trace organic contaminants

Emma Deniere · Michael Chys · Wim Audenaert · Ingmar Nopens · Herman Van Langenhove · Stijn Van Hulle · Kristof Demeestere

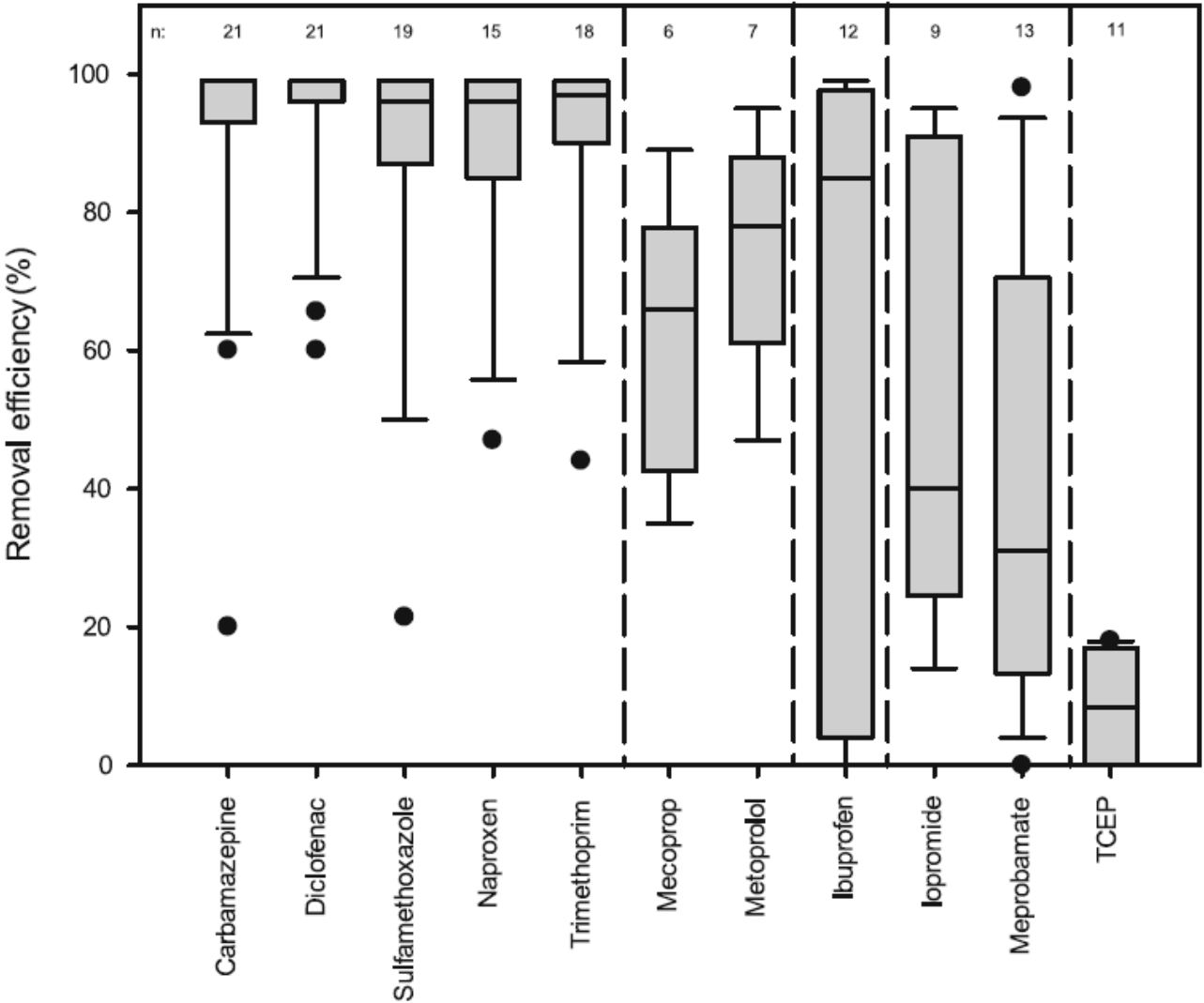


Fig. 2 Summary of removal efficiencies of TrOCs that can be classified as group I (carbamazepine, diclofenac, sulfamethoxazole, naproxen and trimethoprim), group II (mecoprop and metoprolol), group III (ibuprofen), group IV (iopromide and meprobamate) and group V (TCEP) compounds. Data is

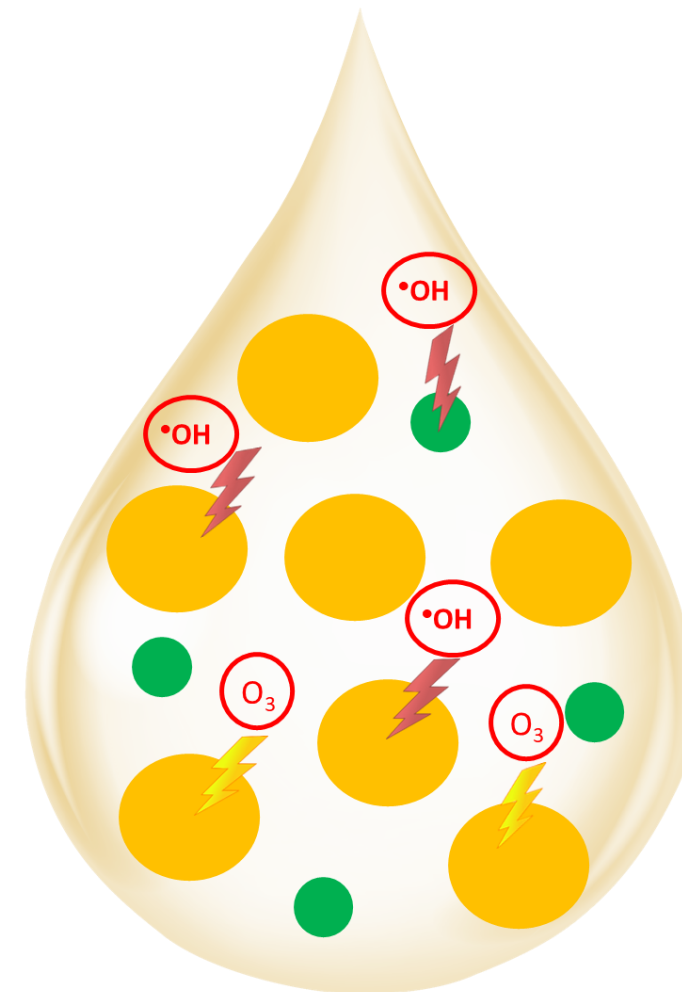
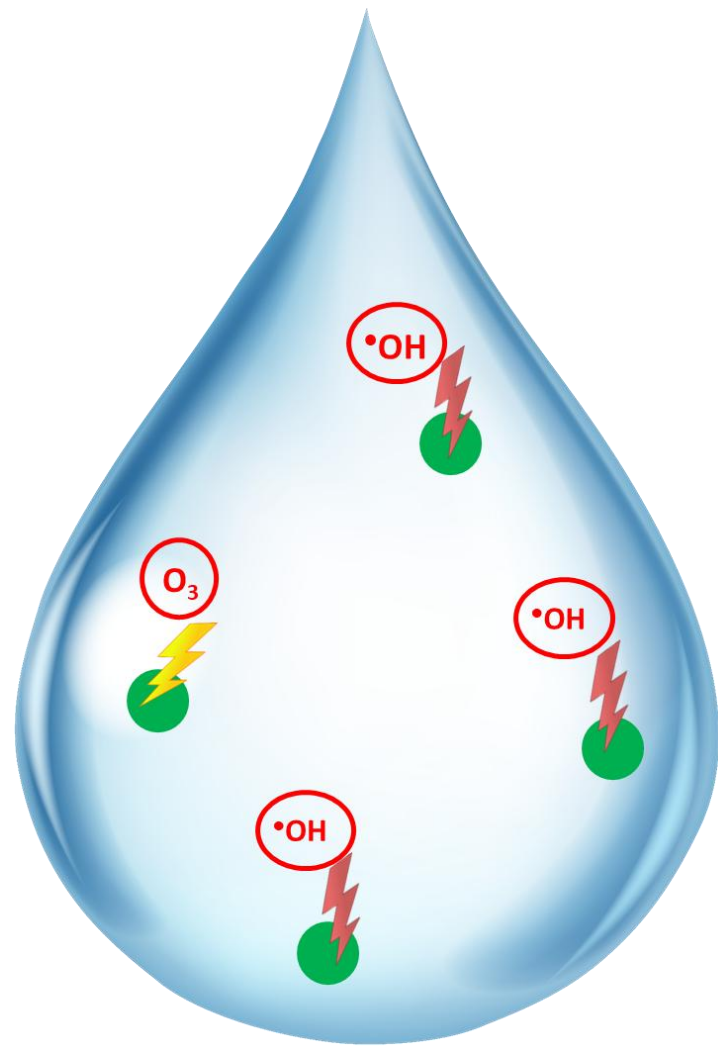
extracted from Blackburn et al. (2016); Gerrity et al. (2012); Hollender et al. (2009); Leikam and Huber (2015); Park et al. (2017); Pisarenko et al. (2012); Singh et al. (2015); Snyder et al. (2006); Wert et al. (2009)

Table 1 Different groups of TrOCs defined by their specific second order reaction rate constants for both direct ($k_{O_3,TrOC,pH7}$) and indirect ($k_{OH,TrOC,pH7}$) ozonation reactions (Gerrity et al. 2012; Lee et al. 2013)

Group	Description	$k_{O_3,TrOC,pH7}(M^{-1} s^{-1})$	$k_{OH,TrOC,pH7}(10^9 M^{-1} s^{-1})$
I	High reactivity with both ozone and $\cdot OH$	$\geq 10^5$	≥ 5
II	Moderate reactivity with ozone and high reactivity with $\cdot OH$	$< 10^5$ and ≥ 10	≥ 5
III	Low reactivity with ozone and high reactivity with $\cdot OH$	< 10	≥ 5
IV	Low reactivity with ozone and moderate reactivity with $\cdot OH$	< 10	< 5 and ≥ 1
V	Low reactivity with both ozone and $\cdot OH$	< 10	< 1

CHALLENGES

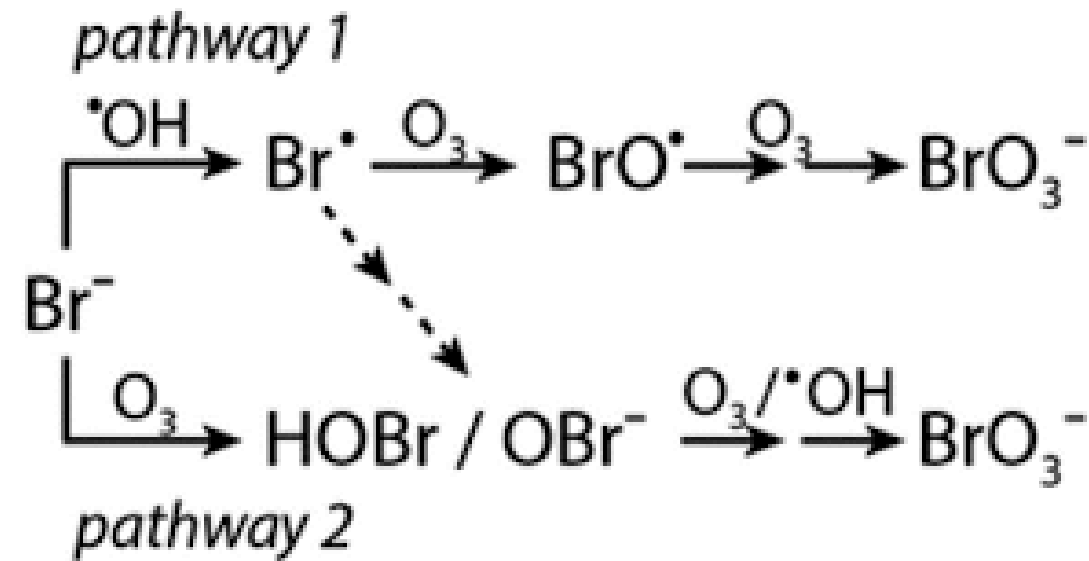
- Reactions with NOM and scavengers



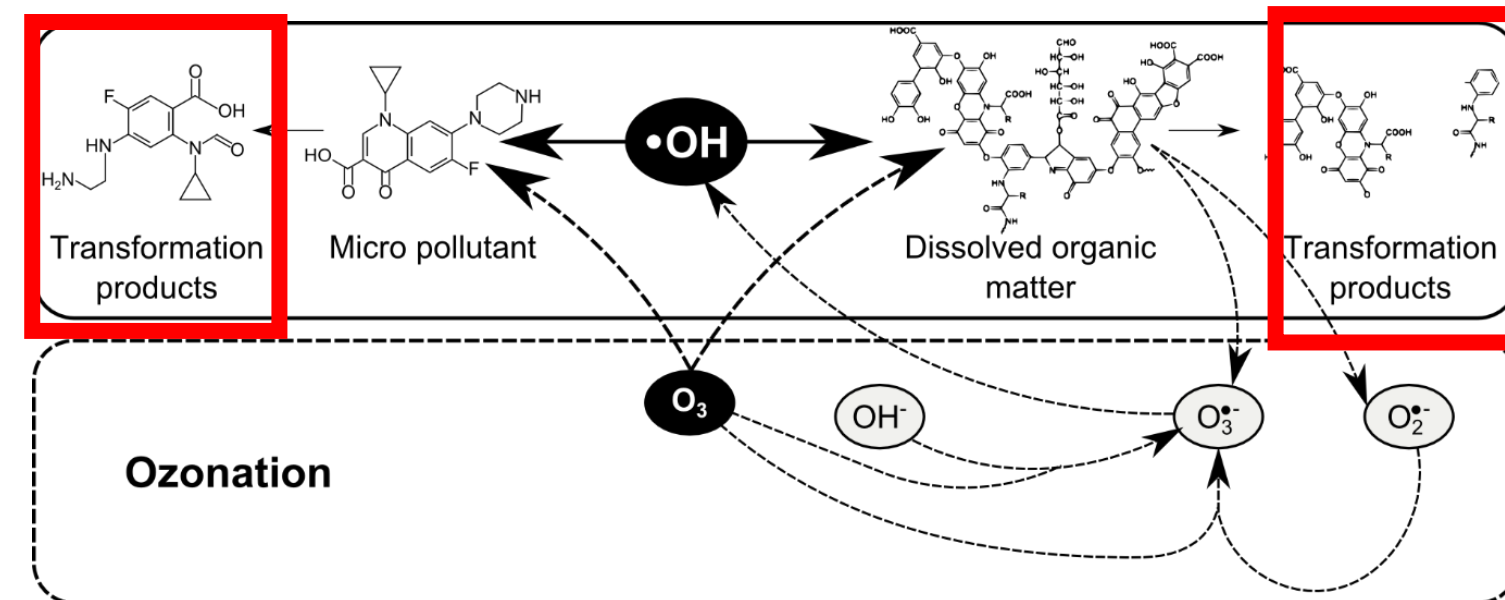
CHALLENGES

– Challenges: oxidation products

– Bromate

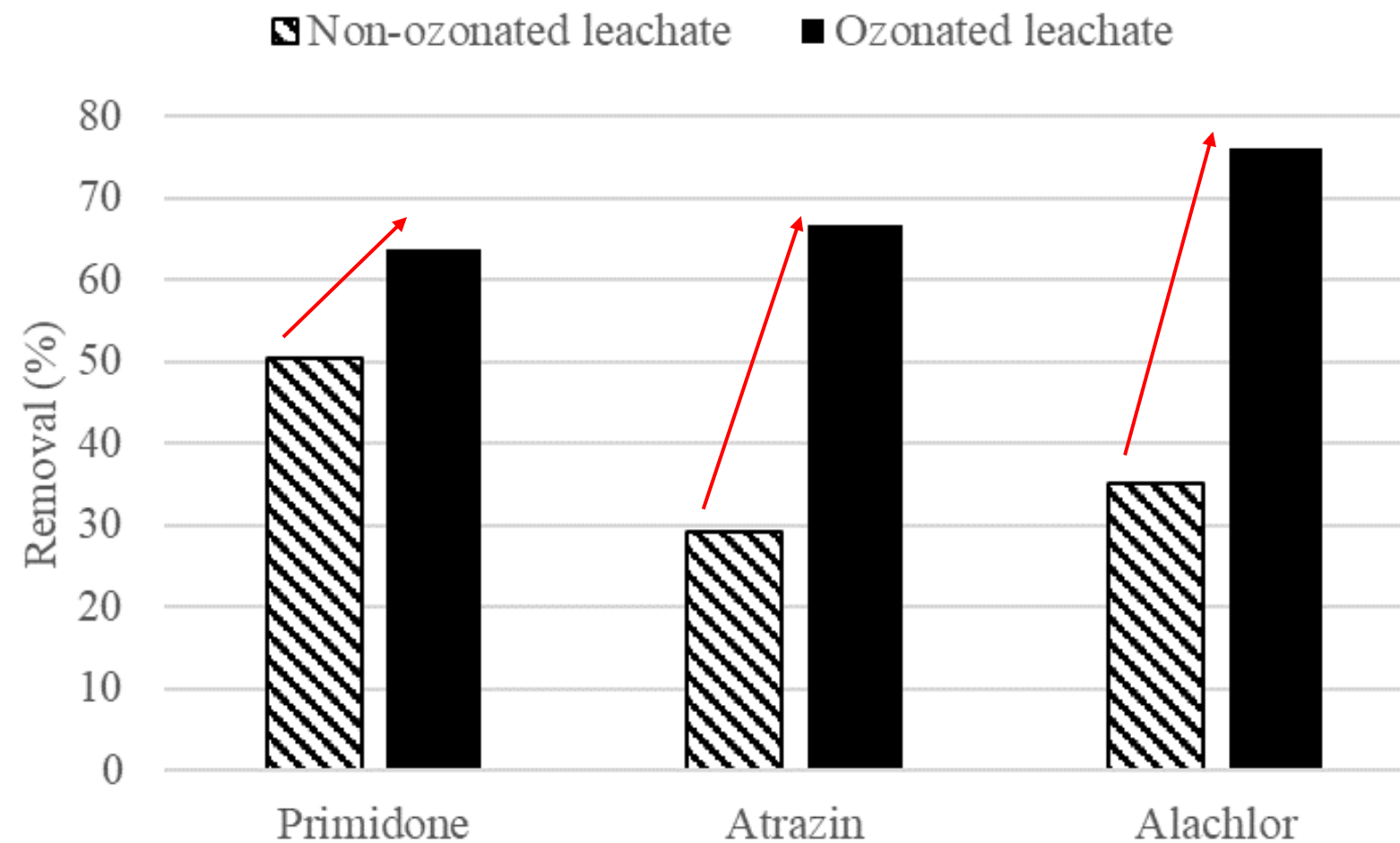
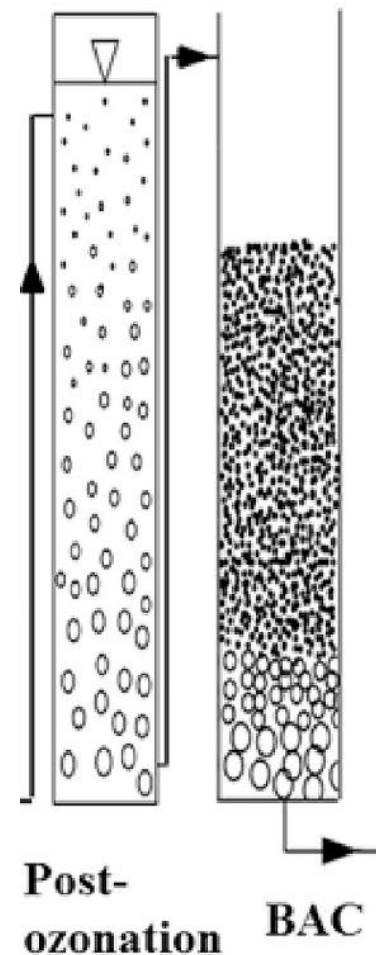


– Transformation products



O₃&GAC POST FILTRATION

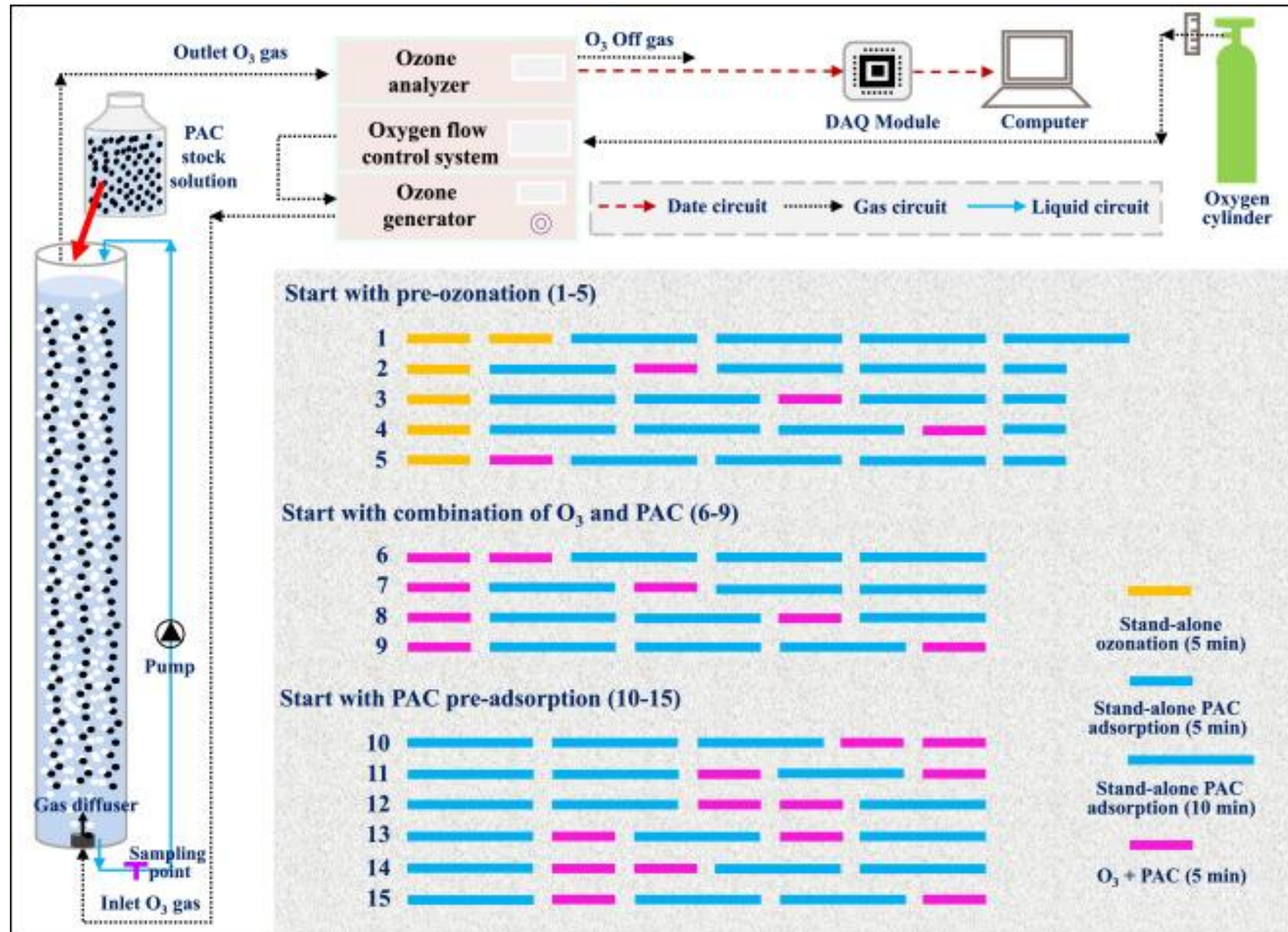
- Combination improves removal
 - Removal @ 0,4 gGAC/l dose



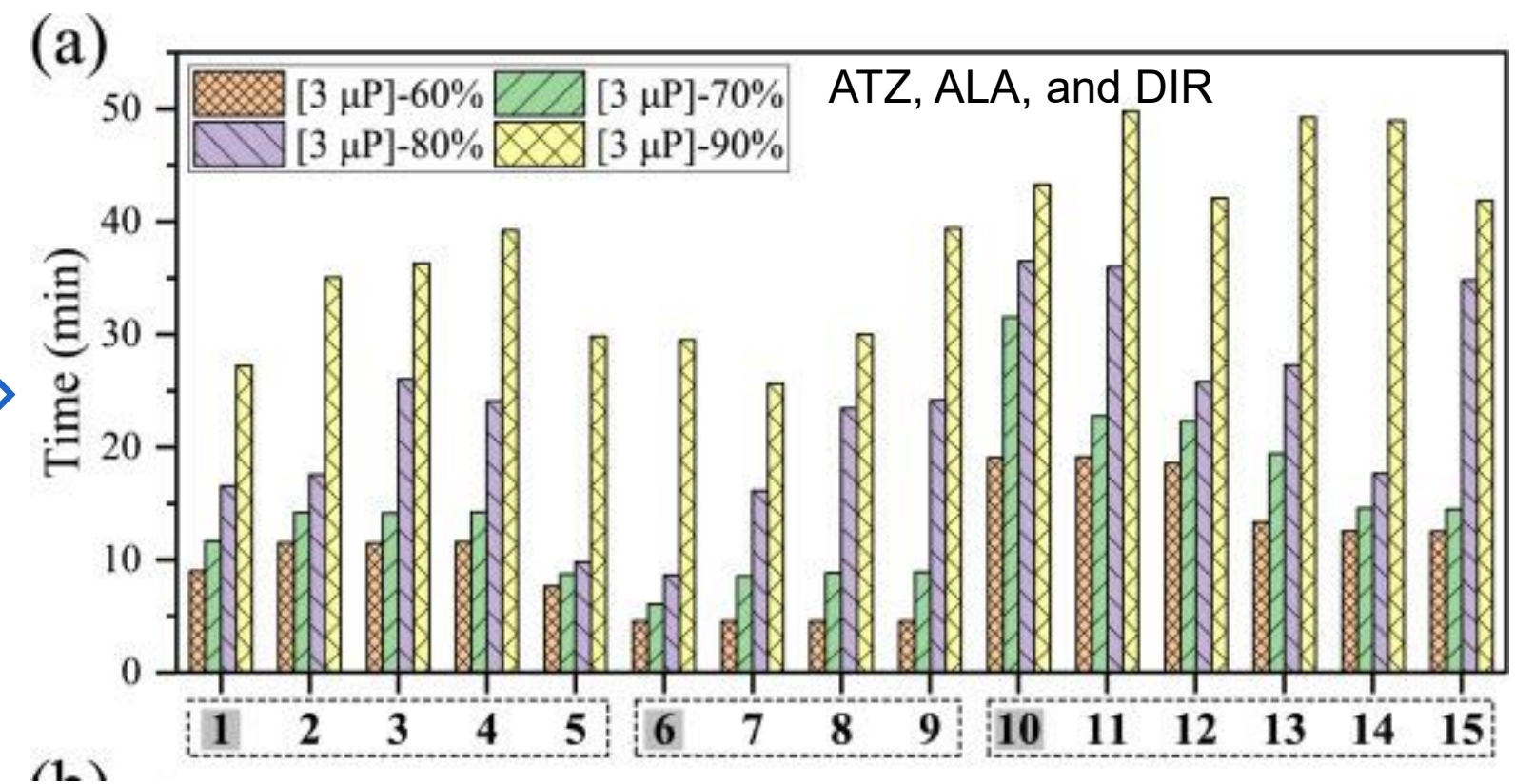
Increased polarity, but less bulk organic material so less load to the activated carbon

O₃&GAC POST FILTRATION

– Which sequence (O₃+PAC)?



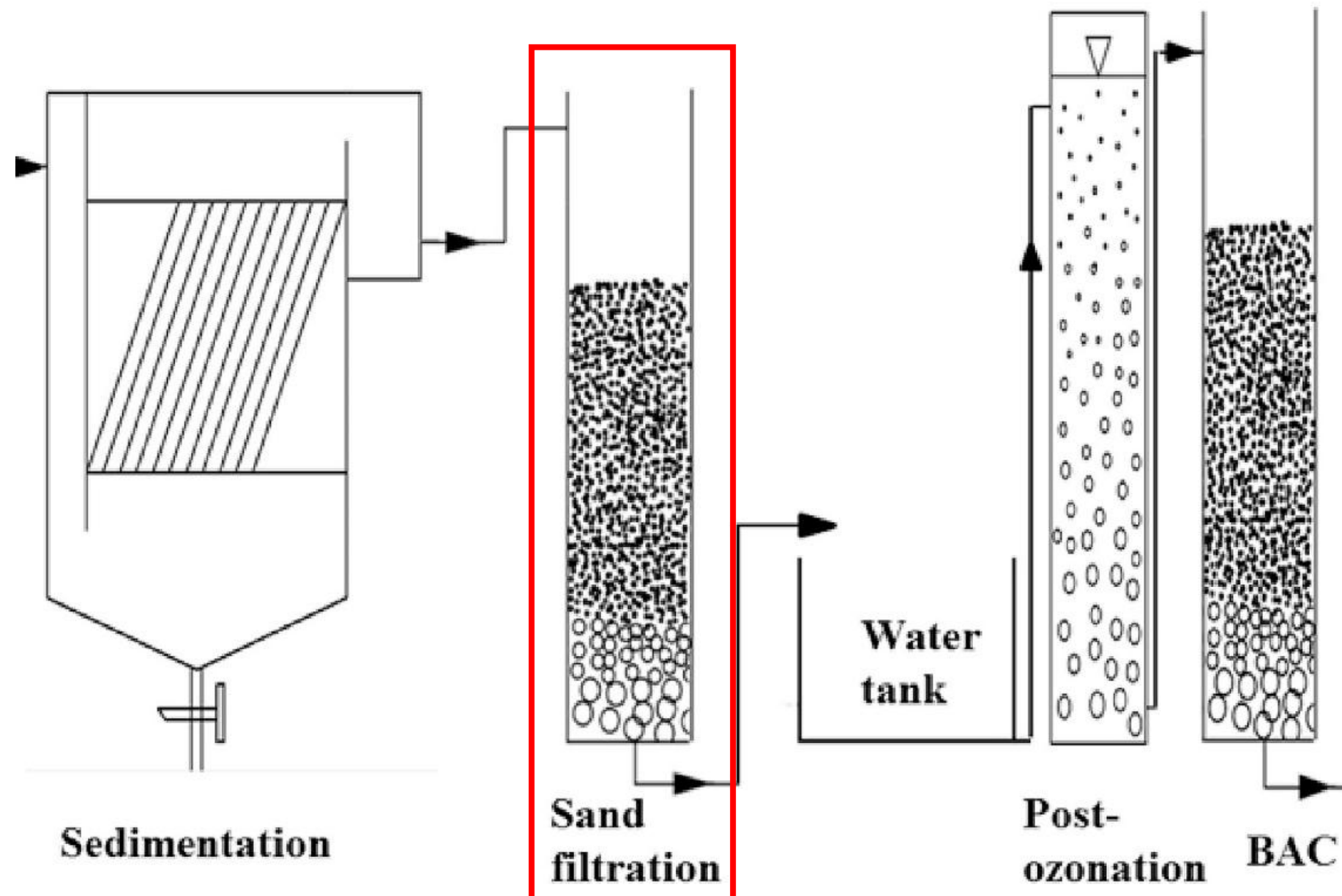
Time needed for x% removal: the lower the better



O₃ first!...or O₃&PAC together

PREFILTRATION

- Remove (part) of the scavengers...
 - Sand, ALEX or AC



PRE-FILTRATION

- Remove (part) of the scavengers
 - increases μP removal -> less O_3 dose required

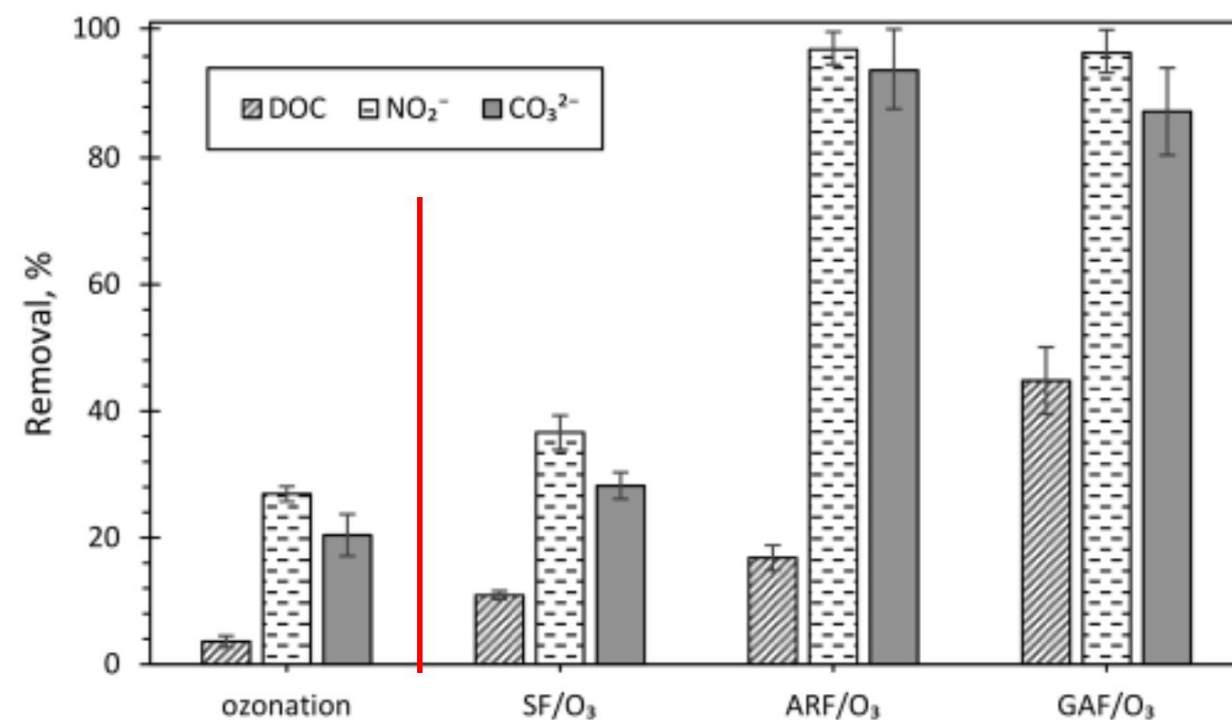


Figure 2. Removal of DOC, NO_2^- , and CO_3^{2-} via ozonation and combined filtration-ozonation (O_3 dose = 0.1 g O_3 /g DOC).

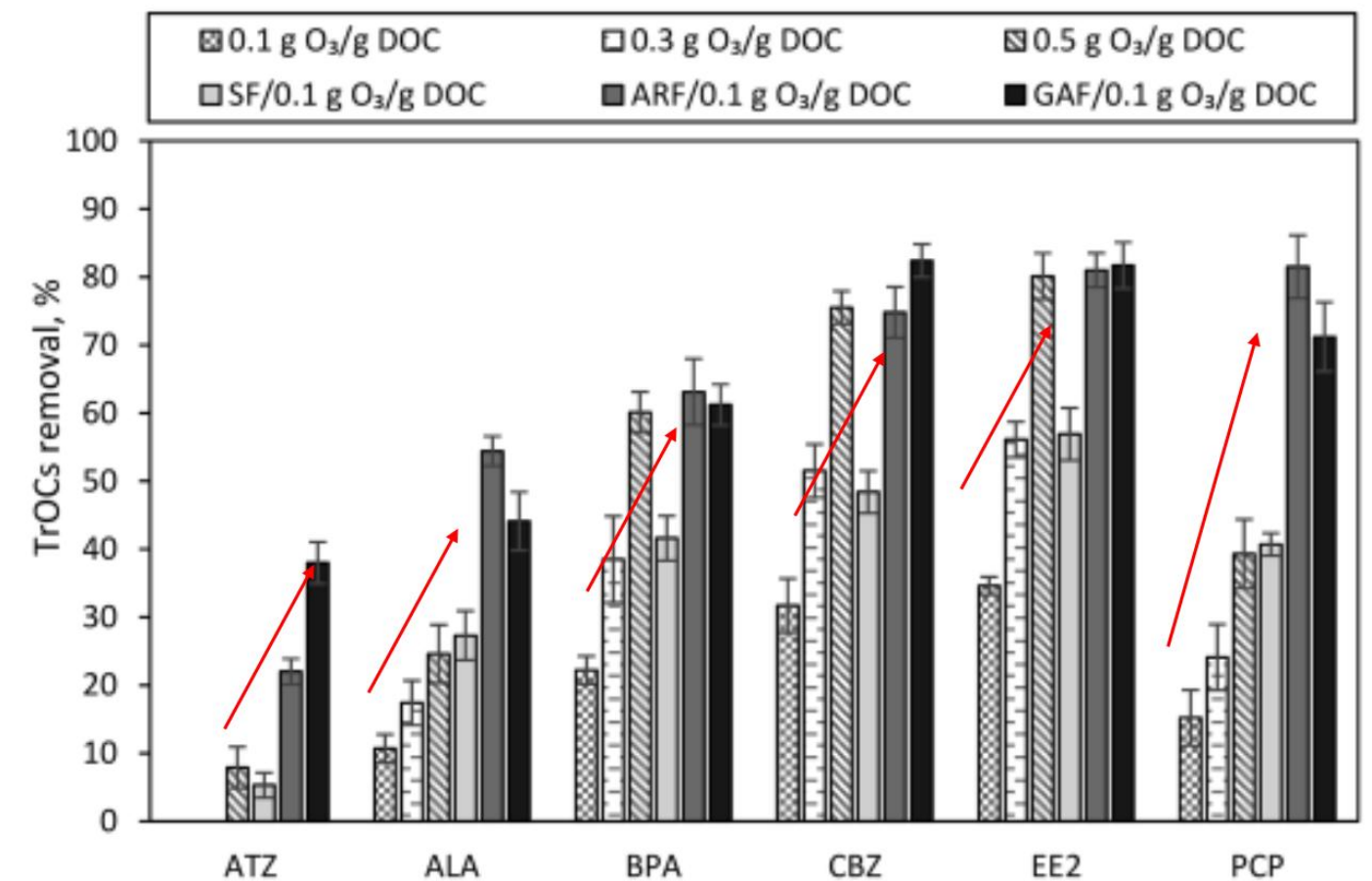
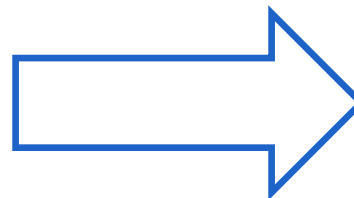
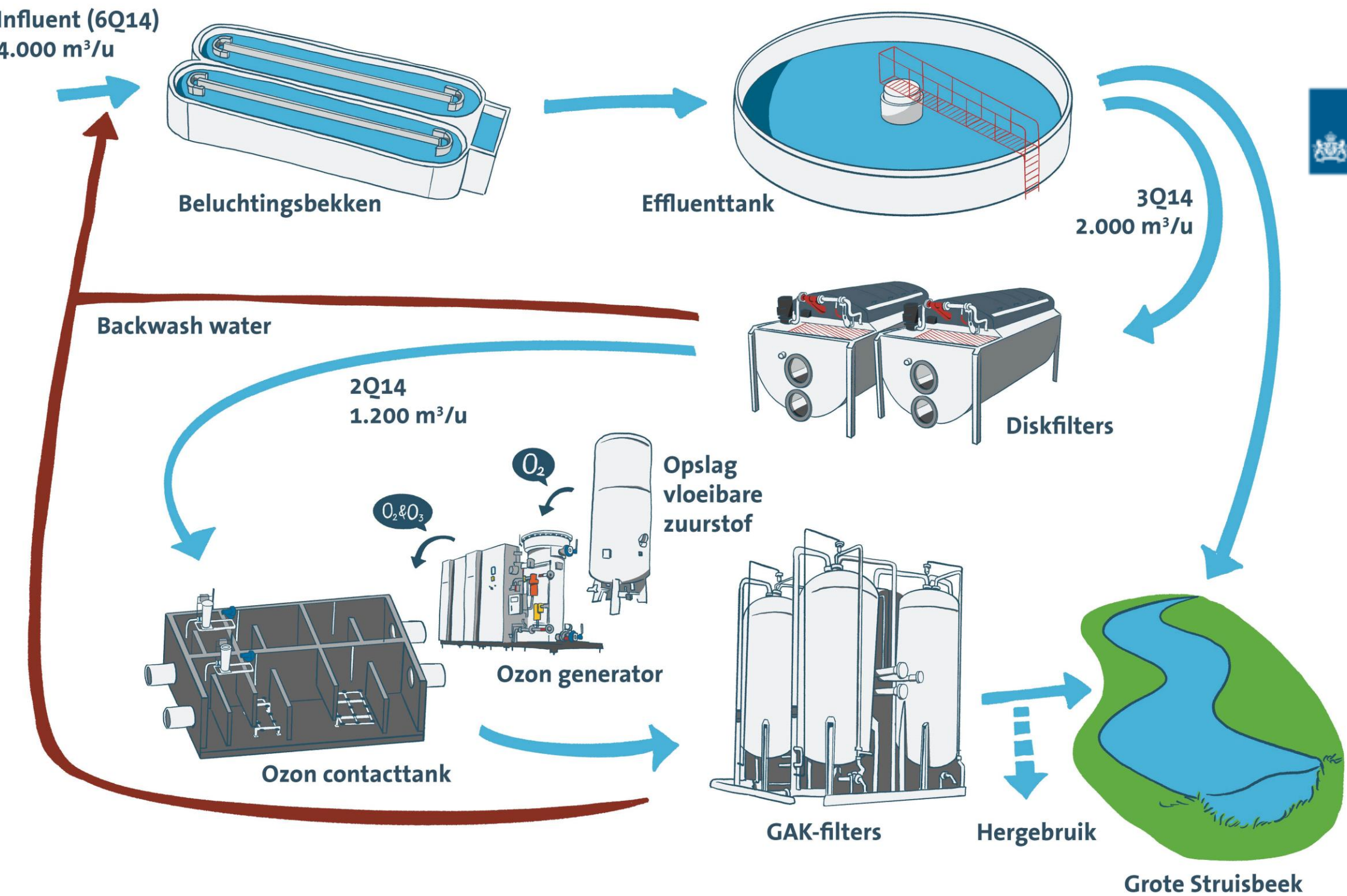


Figure 3. Elimination of TrOCs in effluent after ozonation and combined filtration-ozonation at different ozone doses.

FULL-SCALE @ AQUAFIN (AND DE DOMMEL)

Processchema nazuivering



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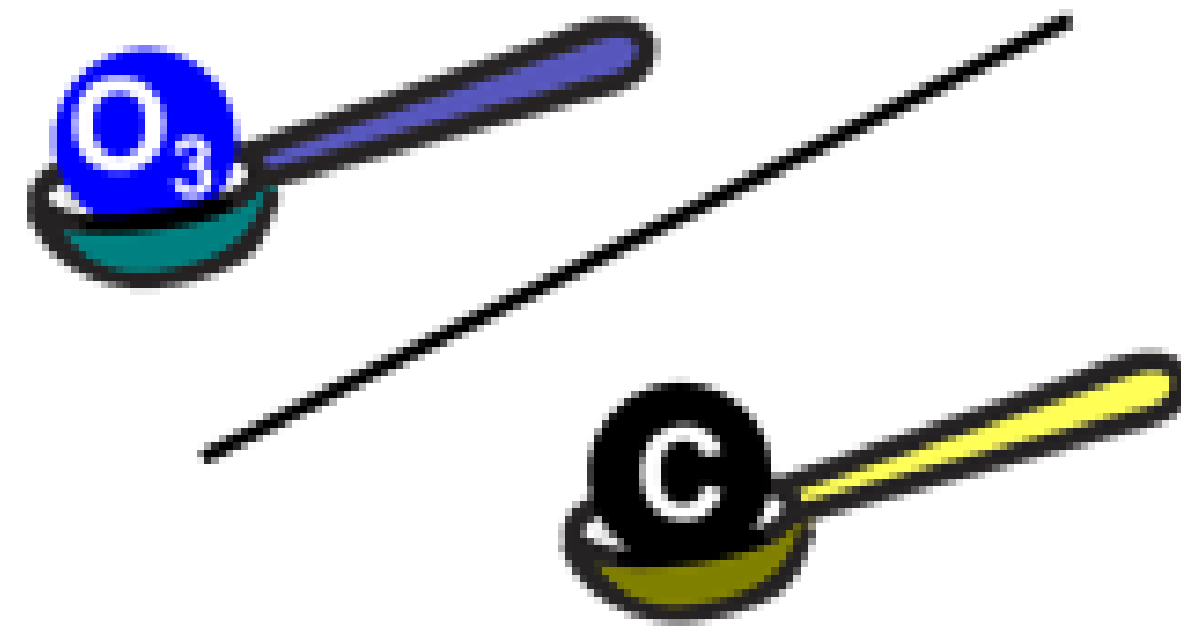
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Oost-Vlaanderen



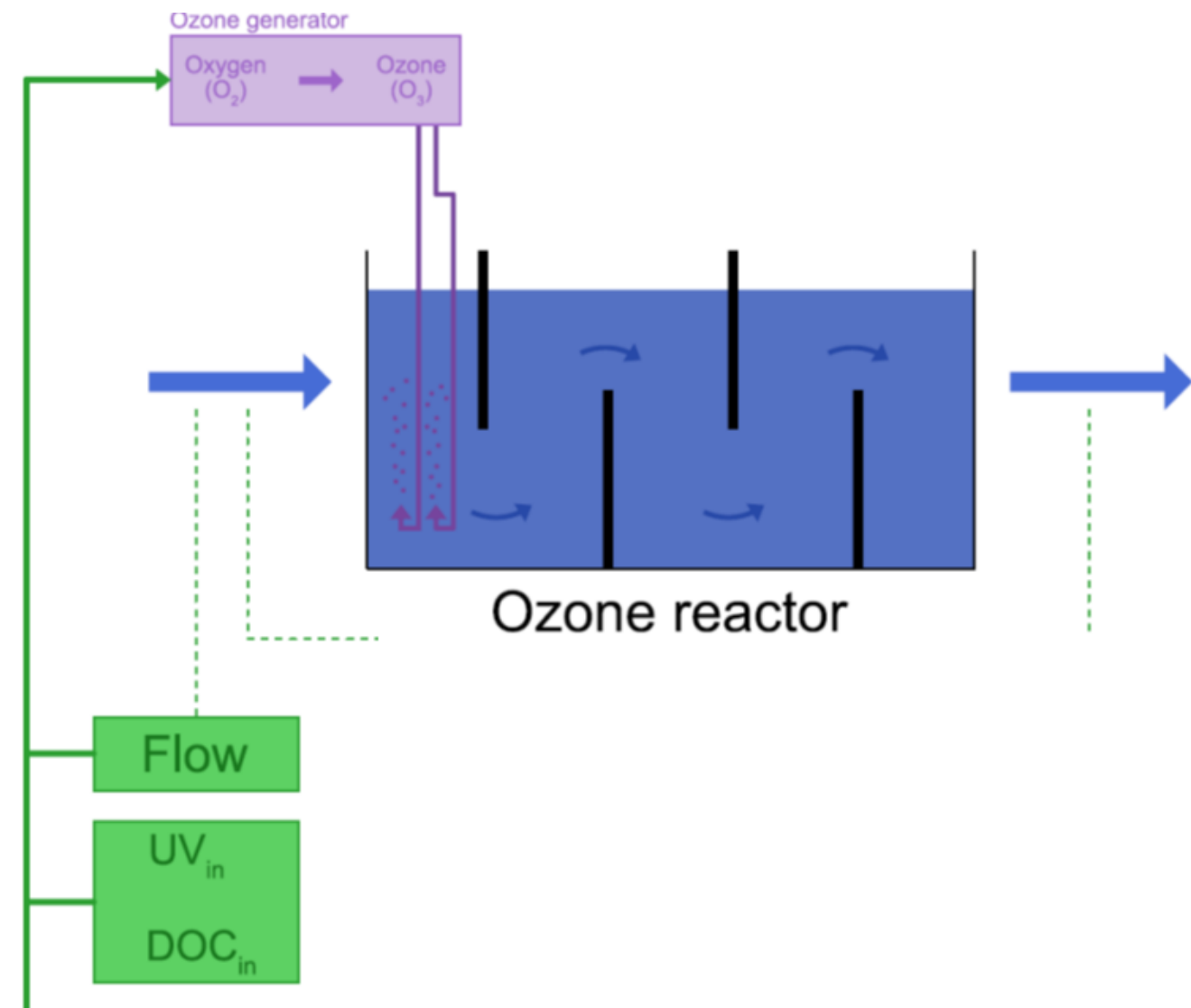
DOSING OPTIMISATION

- Classic feed forward
 - Flow based
 - Load based



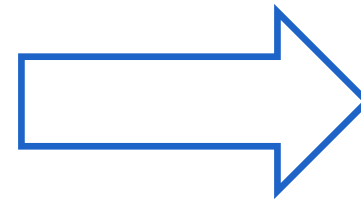
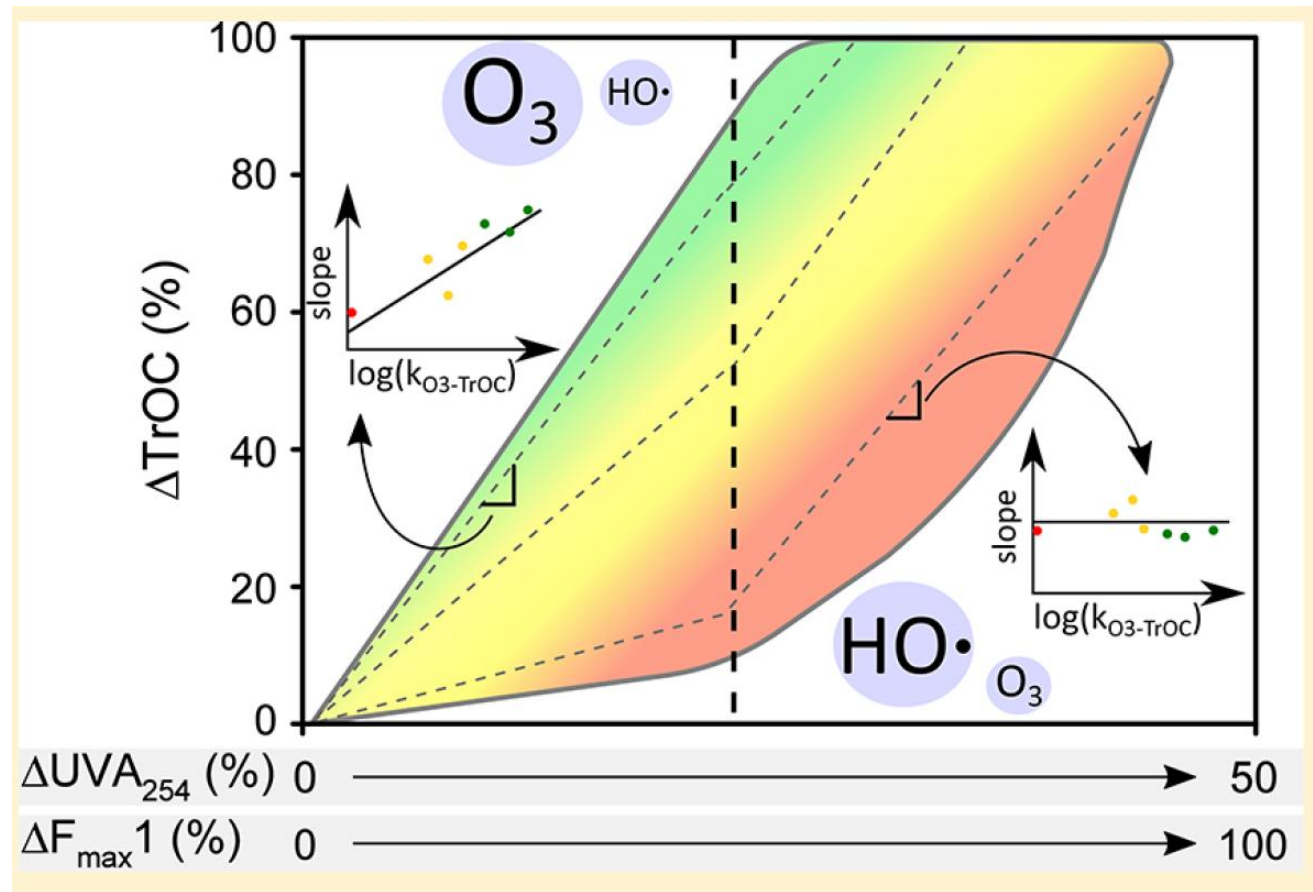
DOSING OPTIMISATION

- Classic feed forward
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 - Load based

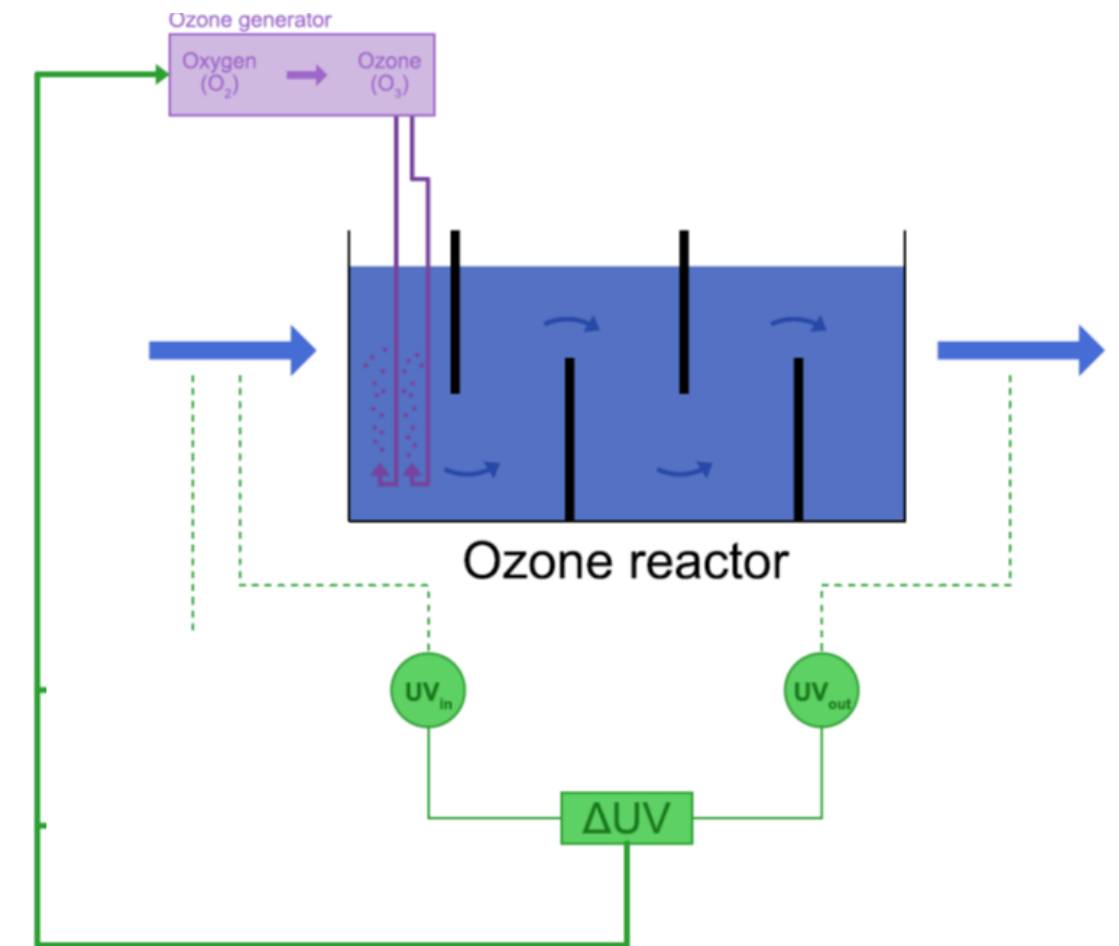
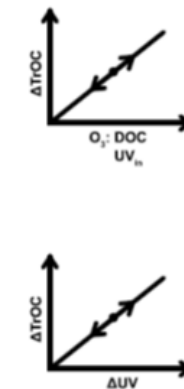


DOSING OPTIMISATION

- Control based on ΔUV_{254}



Models:

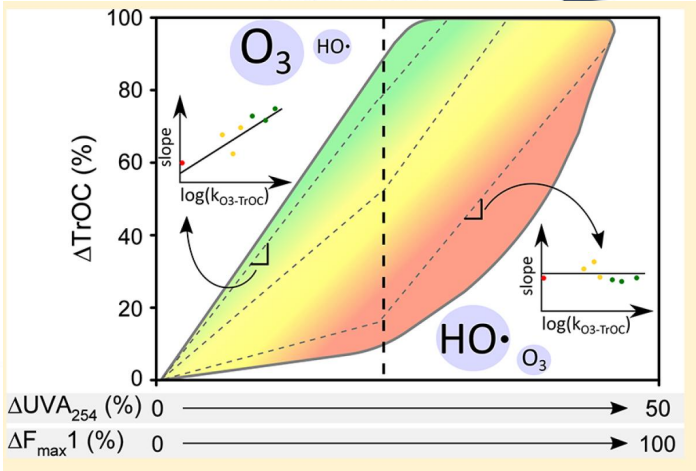
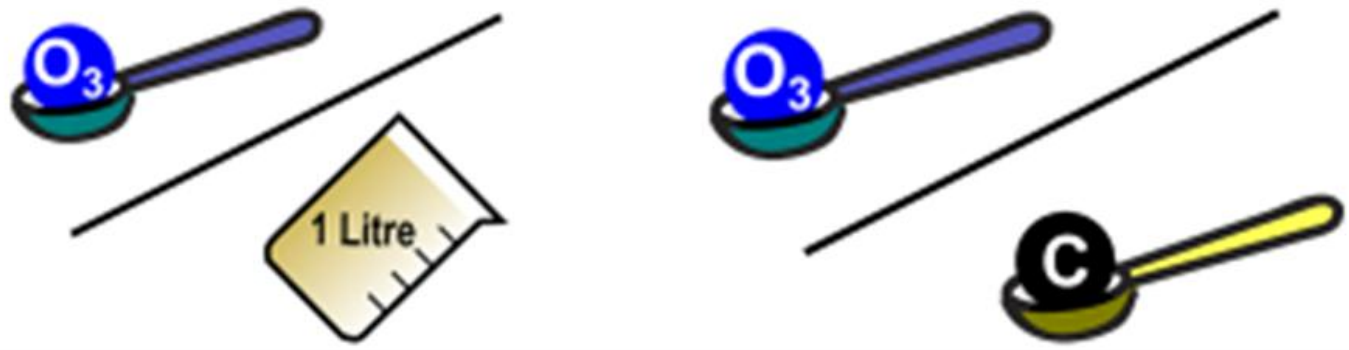
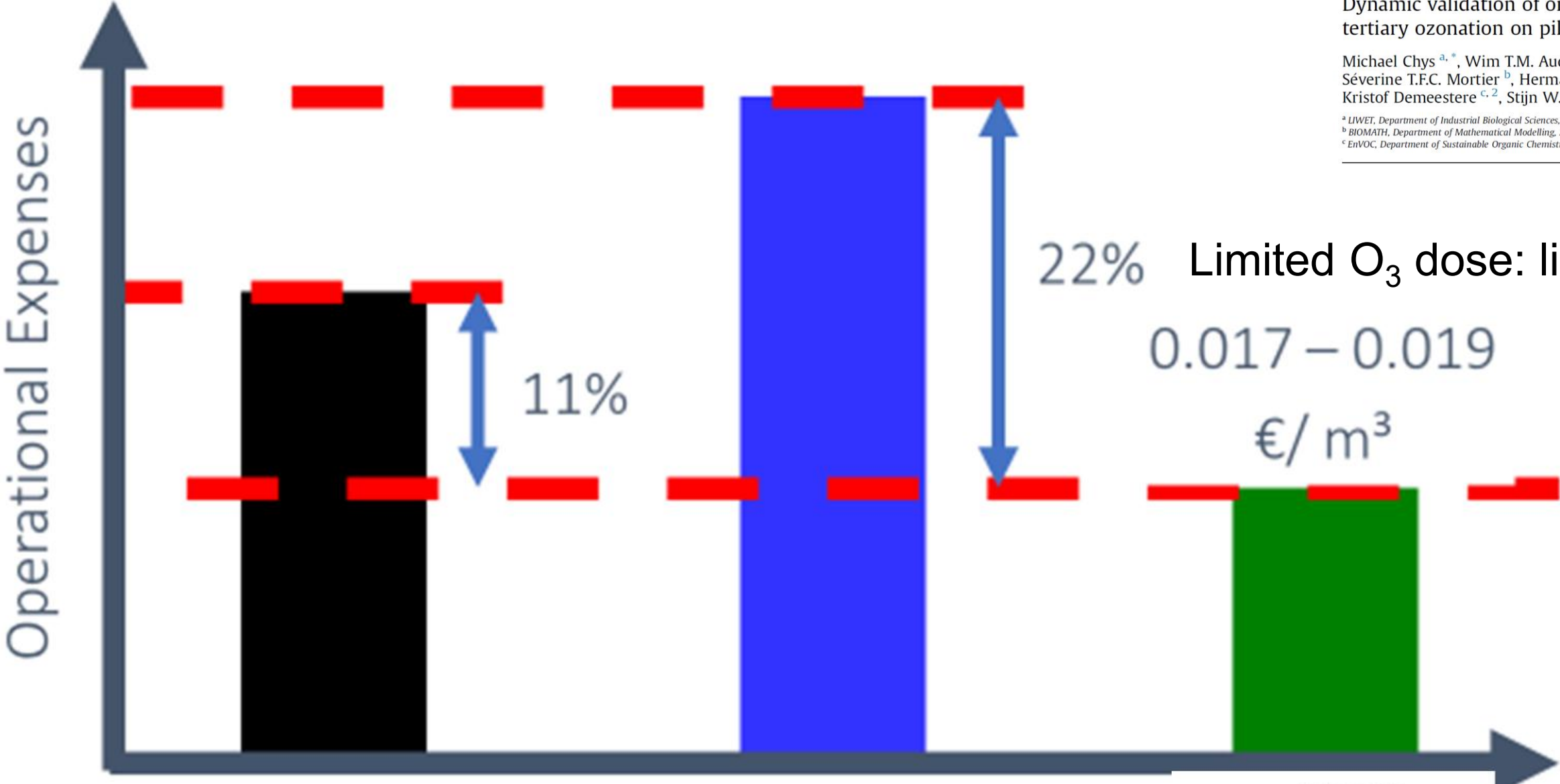


DOSING OPTIMISATION

Dynamic validation of online applied and surrogate-based models for tertiary ozonation on pilot-scale

Michael Chys ^{a,*}, Wim T.M. Audenaert ^{a,b,1}, Jan Vangrinsven ^{a,c}, Michael Bauwens ^{a,c}, Séverine T.F.C. Mortier ^b, Herman Van Langenhove ^c, Ingmar Nopens ^b, Kristof Demeestere ^{c,2}, Stijn W.H. Van Hulle ^{a,2}

^a LIWET, Department of Industrial Biological Sciences, Ghent University Campus Kortrijk, Graaf Karel de Goedelaan 5, B-8500, Kortrijk, Belgium
^b BIOMATH, Department of Mathematical Modelling, Statistics and Bioinformatics, Ghent University, Coupure Links 653, B-9000, Ghent, Belgium
^c EnVOC, Department of Sustainable Organic Chemistry and Technology, Ghent University, Coupure Links 653, B-9000, Ghent, Belgium



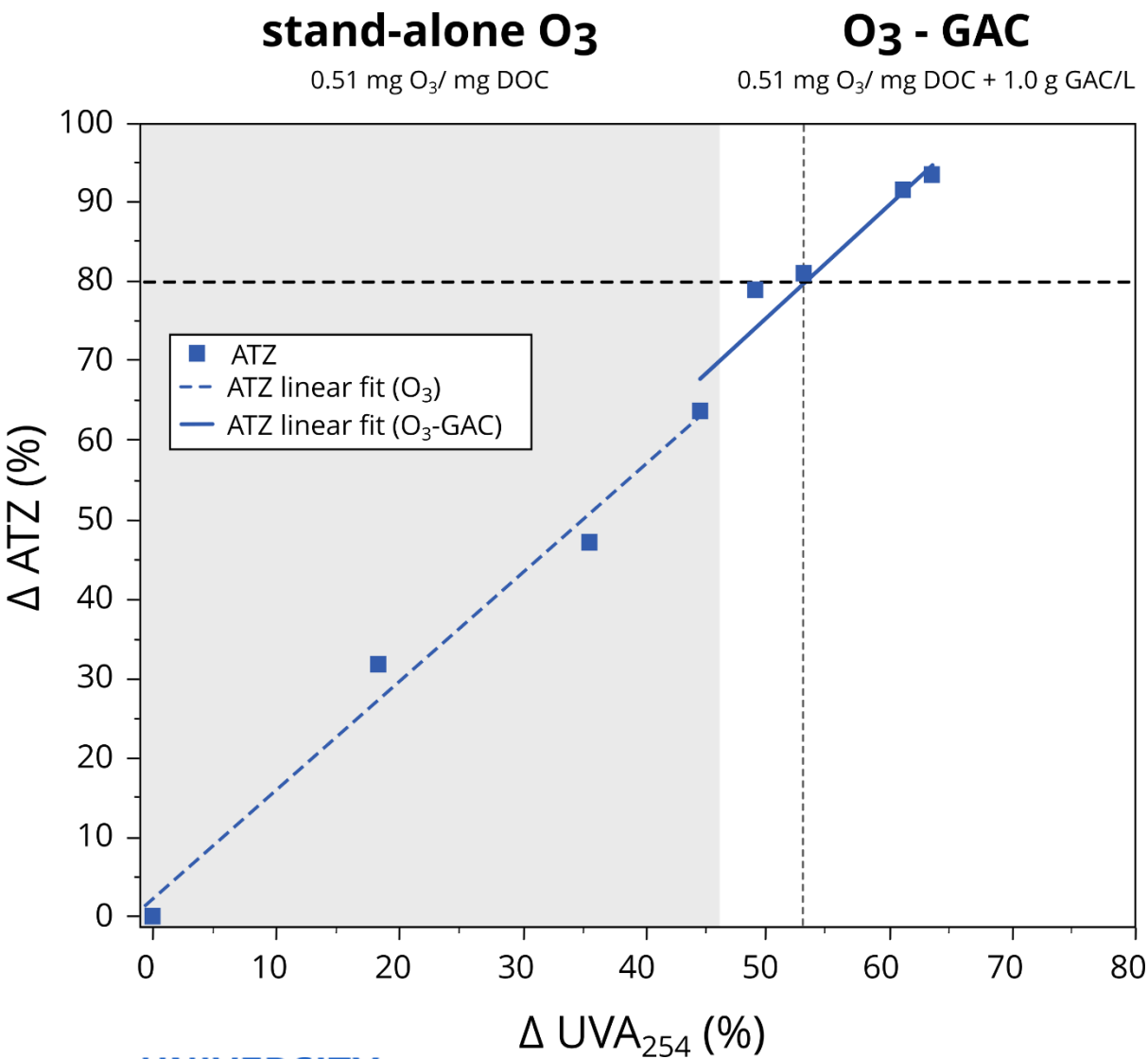
DOSING OPTIMISATION



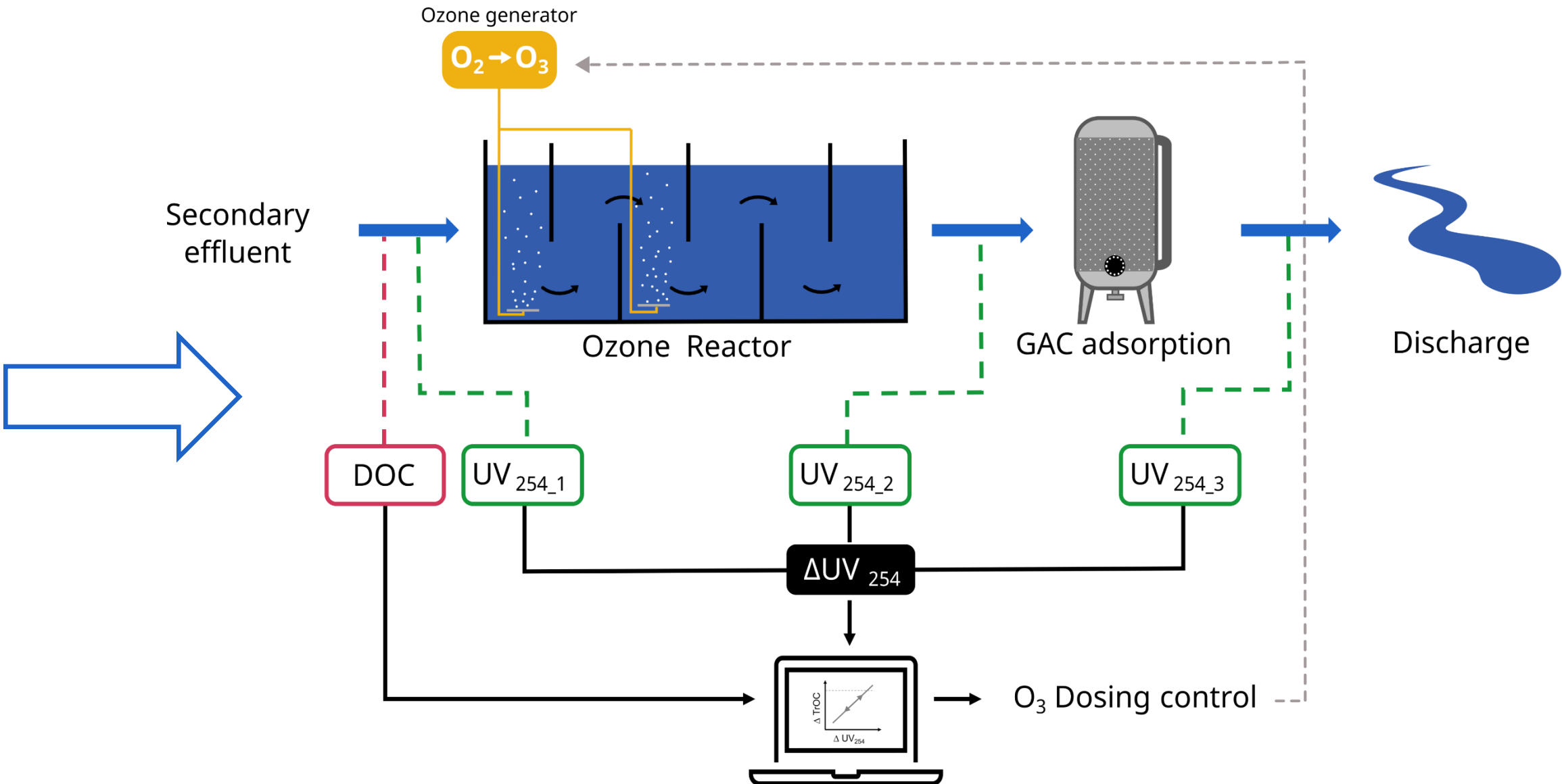
– O₃+AC: control based on ΔUV_{254}

Integrated spectral based monitoring, optimization and control of the combined ozonation and powdered activated carbon adsorption process to remove organic micropollutants from secondary effluent

Tao Zhang^{a, d, e}, Liuchun Zheng^b, Xueting Yang^c, Kristof Demeestere^{d, e}, Stijn W.H. Van Hulle^{a, e}

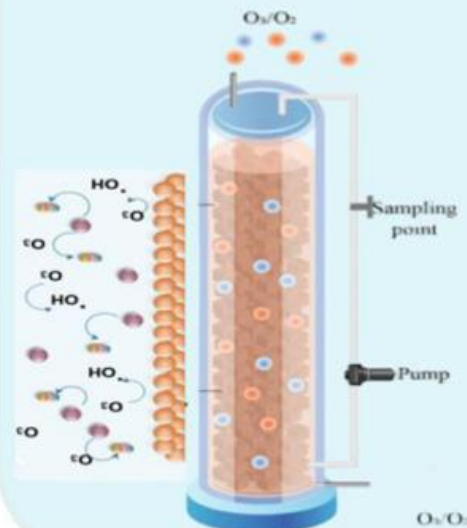


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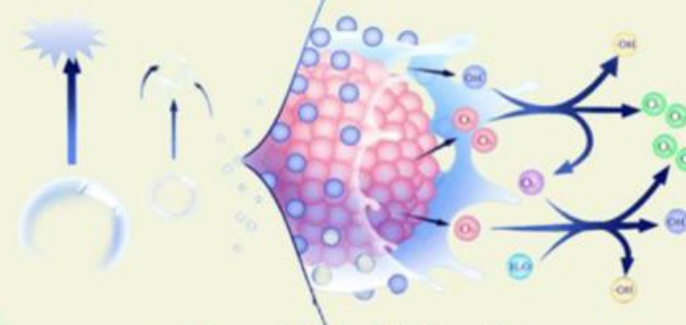
OTHER OPTIMIZATION POSSIBILITIES

Adding active components



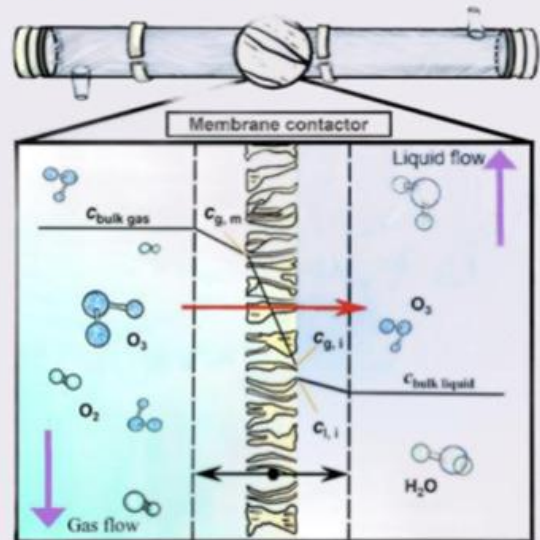
- Large contact surface area
 - Catalytic sites
 - Low cost
- No additional energy input

Utilizing micro/nano bubbles



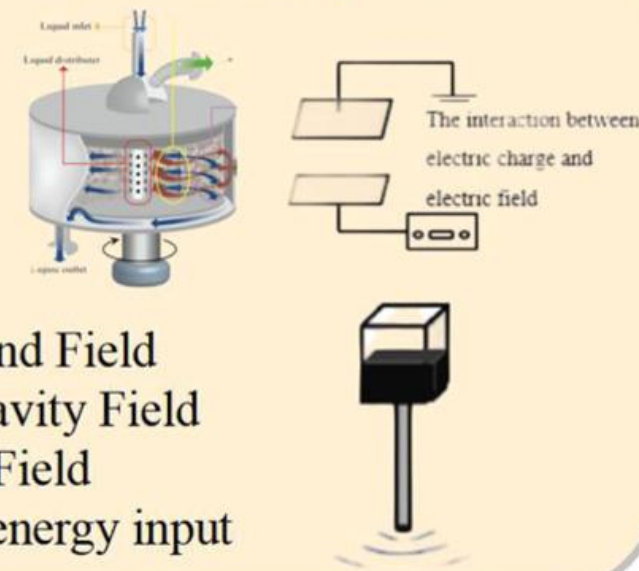
- Small bubble size
 - Large interfacial area
 - High internal pressures
- Additional energy input

Applying Membrane

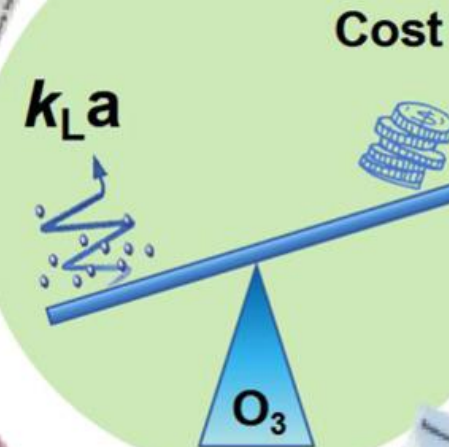


- Large contact surface area
 - High driving force
 - Membrane fouling
- Additional energy input

Adding external physical fields



- Ultrasound Field
 - Hypergravity Field
 - Electric Field
- Additional energy input



O₃



Water Research 288 (2026) 124719

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Water Research

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



Intensification of ozone gas/liquid mass transfer and ozonation efficiency:
A critical review

Xuetong Yang^{a,*}, Tao Zhang^b, Ze Liu^c, Rui Zhang^b, Changtao Chen^b, Zhengyao Li^{a,*},
Kristof Demeestere^d, Stijn W.H. Van Hulle^b

^a School of Resources and Safety Engineering, University of Science and Technology Beijing, Beijing 100083, China

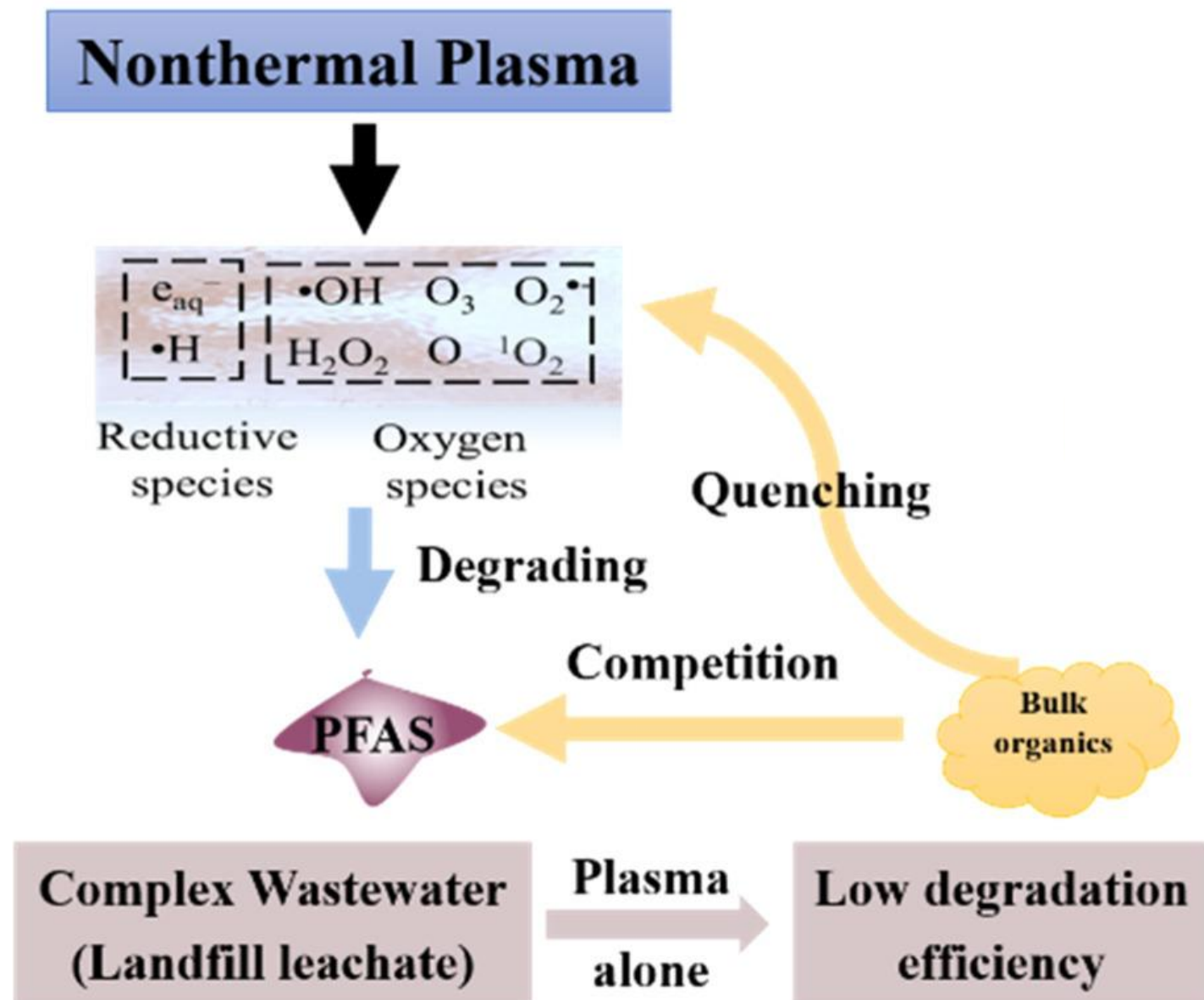
^b Research Group LIWET, Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium

^c Qinghai Provincial Key Laboratory of Geology and Environment of Salt Lakes, Qinghai Institute of Salt Lakes, Chinese Academy of Sciences, Qinghai 810008, China

^d Research Group EnVOC, Department of Green Chemistry and Technology, Faculty of Bioscience Engineering, Ghent University, Coupure links 653, B-9000 Ghent, Belgium

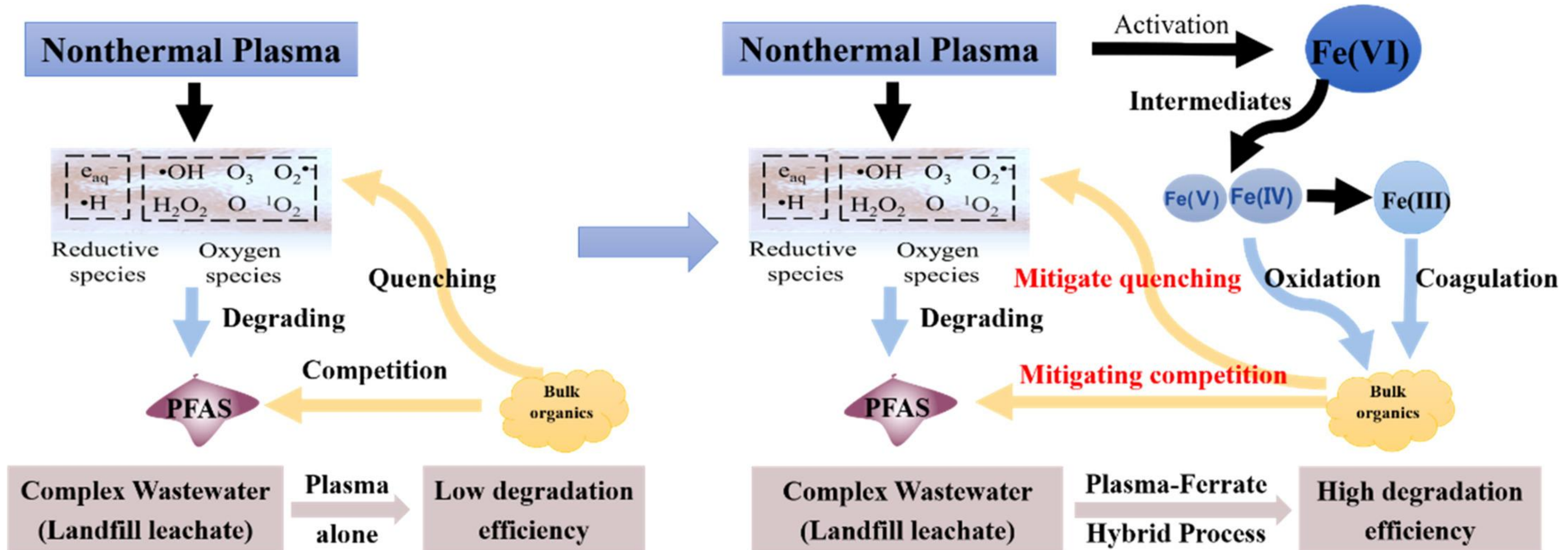
OTHER OPTIMIZATION POSSIBILITIES

- E.g. non-thermal plasma



OTHER OPTIMIZATION POSSIBILITIES

- E.g. non-thermal plasma (+ferrate)



OTHER OPTIMIZATION POSSIBILITIES

- E.g. non-thermal plasma (+ferrate)

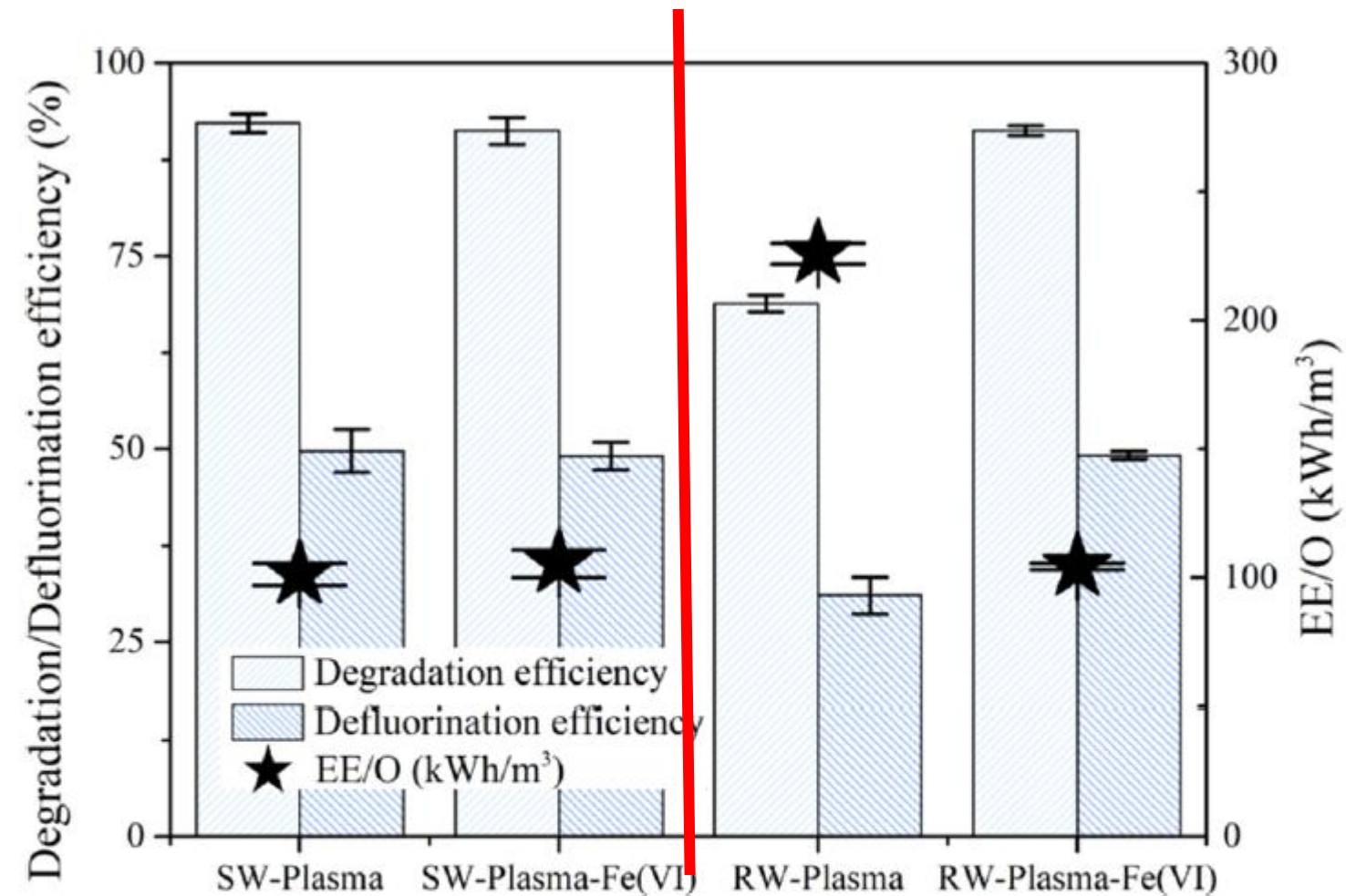


Fig. 2. Degradation efficiency, defluorination efficiency and energy consumption (EE/O) of PFOA in synthetic or real wastewater treated by different processes. Note: SW-Plasma represents synthetic wastewater treated by plasma alone, SW-Plasma-Fe(VI) represents synthetic wastewater treated by plasma and ferrate, RW-Plasma represents real wastewater treated by plasma alone after 30 min, RW-Plasma-Fe(VI) represents real wastewater treated by plasma and ferrate. The experimental conditions are identical to those described in the caption of Fig. 1.

HELP US GET A VIEW ON APPLICATION

– **Stijn Van Hulle (stijn.vanhulle@ugent.be)**

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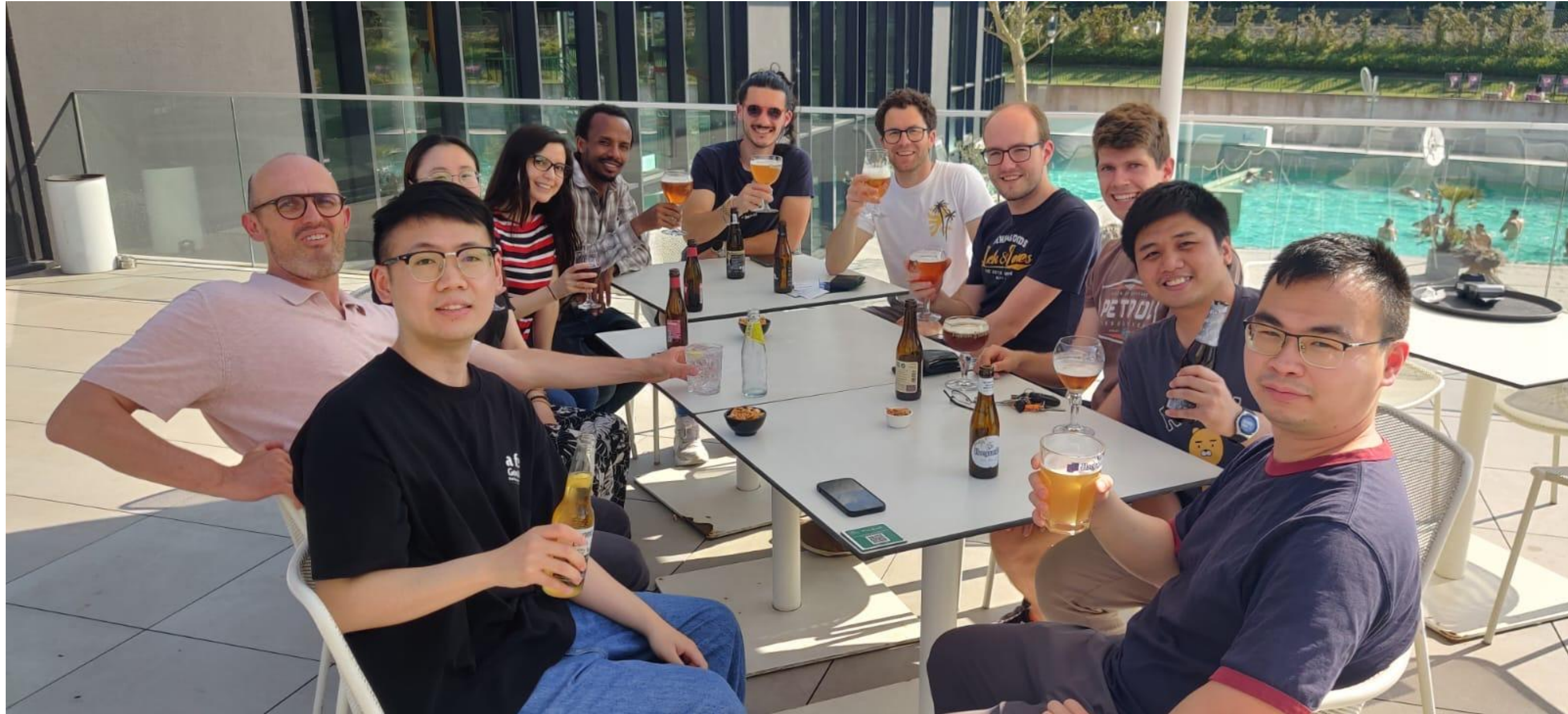
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ACKNOWLEDGMENTS



QUESTIONS?

