KWB

Evaluation of post-treatment options after ozonation of secondary effluent

Dr. Ulf Miehe

13th IWA International Conference on Water Reclamatic and Reuse

15.-19. January 2023, Chennai, India

Upcoming) European Union legal framework

Water protection

veral EU directives will be amended
Water Framework Directive
Groundwater Directive
Environmental Quality Standards Directive
Urban Wastewater Treatment Directive

blished **proposals** also demand micropollutant
moval at WWTPs with >100.000 p.e.
10.000 p.e. in sensitive areas)

tablished technologies
Ozonation
Powdered activated carbon
Granular activated carbon

ment.ec.europa.eu/publications/proposal-amending-water-directives_en
ment.ec.europa.eu/publications/proposal-revised-urban-wastewater-treatment-directive_en

Water reuse

Minimum requirements for water reuse in agriculture were defined in EU Regulation 2020/741 (will be enforced from 26.06.2023)

Treatment targets focus on microbiological indicator parameters / disinfection

Reclaimed water quality class	Indicative technology target	*E. coli* (number/100 ml)
A	Secondary treatment, filtration, and disinfection	≤ 10
B	Secondary treatment, and disinfection	≤ 100
C	Secondary treatment, and disinfection	≤ 1 000
D	Secondary treatment, and disinfection	≤ 10 000

(EU regulation 2020/741, table 2 – shortened)

apitalize on synergy effects

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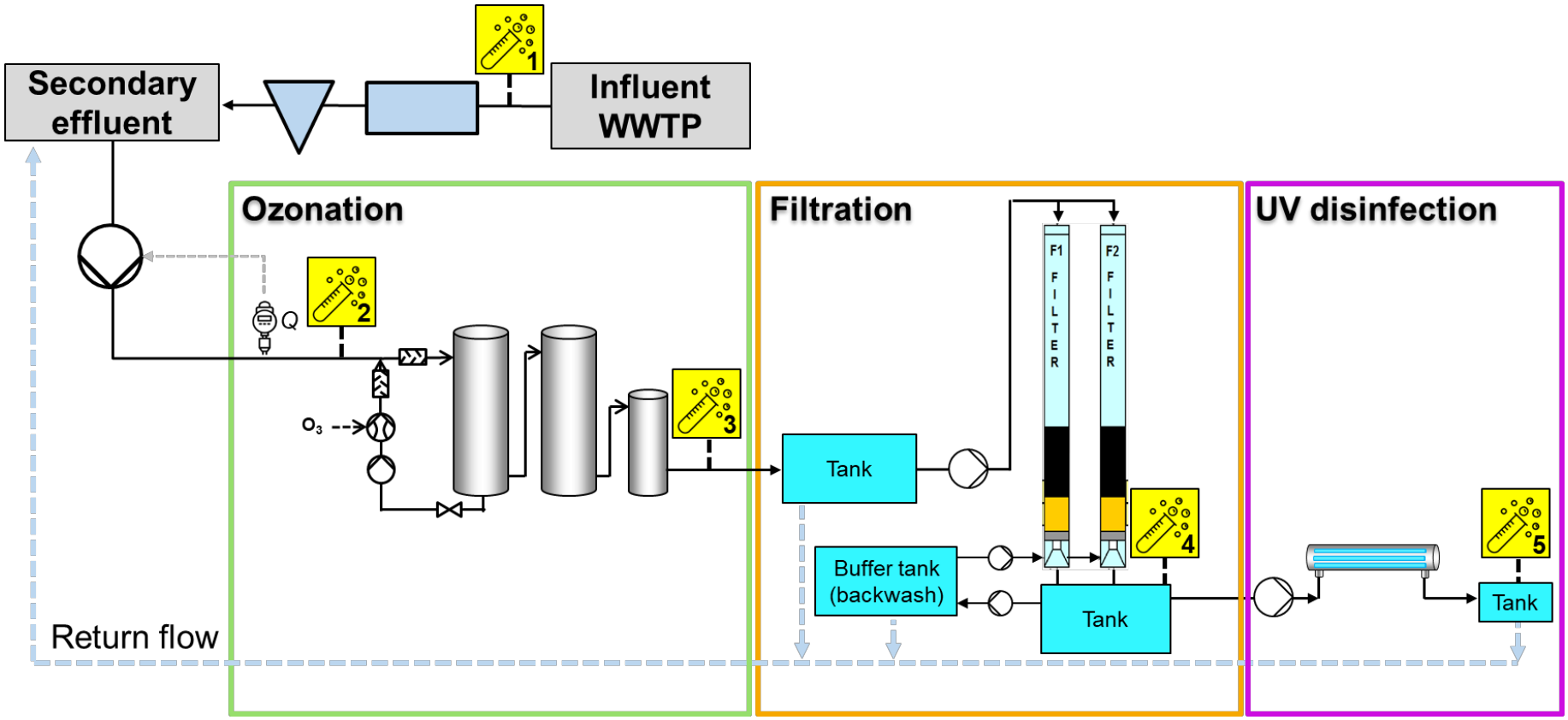
If removal of micropollutants is mandatory (e.g. via ozonation or activated carbon), then it's just a small step further to achieve water reuse



removal of micropollutants

disinfection / water reuse

Ozonation

Ozone

- is generated from oxygen
- alters/destroys molecular structure, often no (full) mineralisation takes place
- high energy demand (≈ 10 kWh/kg O_3) for production, carbon footprint depends on local energy mix

Applications

- Drinking water: removal of smell/taste and colour
- Industry: COD reduction (along with post-treatment)
- Micropollutant removal
- Disinfection

16 ≥ WWTPs in DE / CH already use full-scale ozonation for micropollutant removal…
and even more are planning to do so

isinfection: *E. coli*

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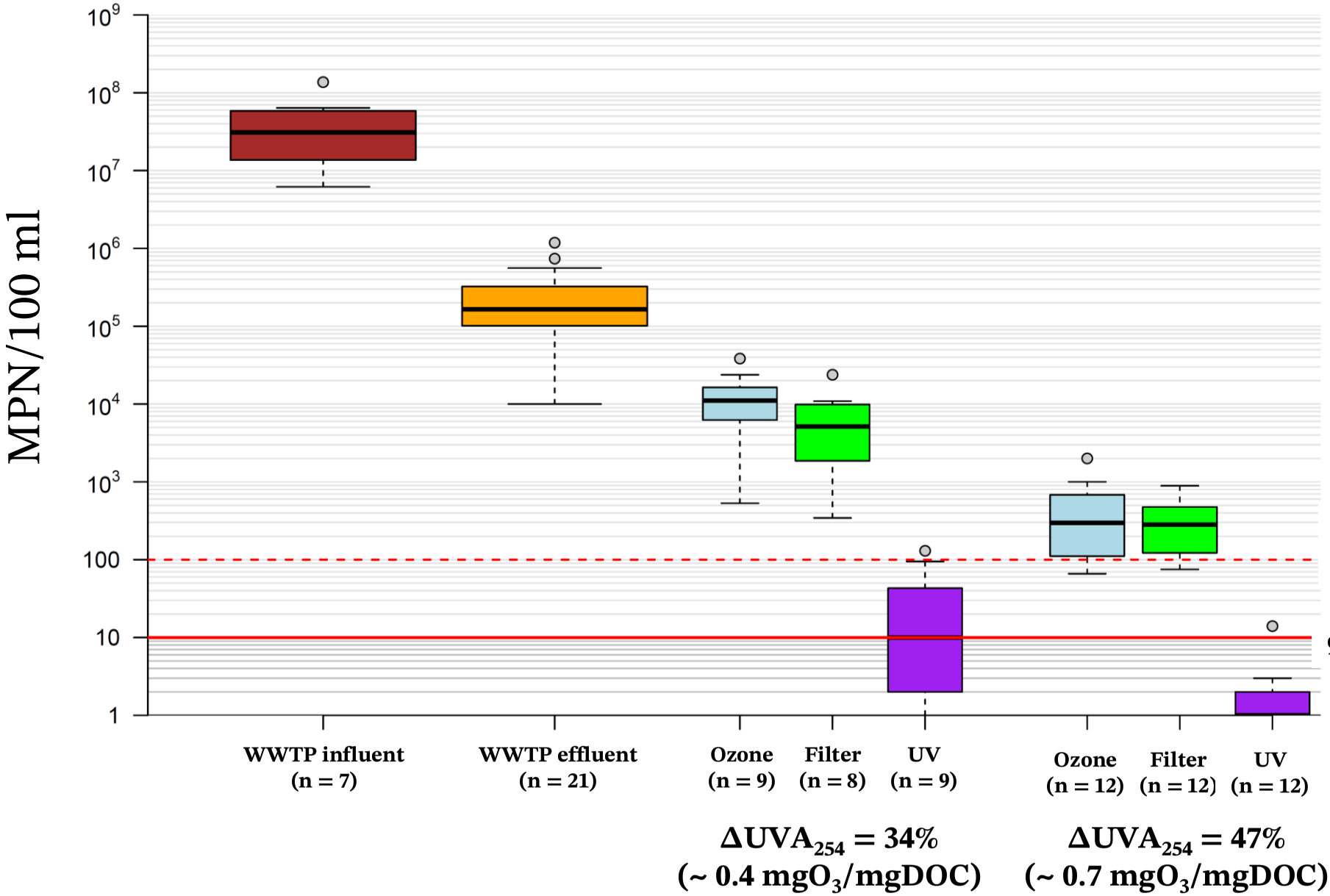

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Class A (unrestricted irrigation) max. limit

90% of samples

isinfection: *Clostridium perfringens*

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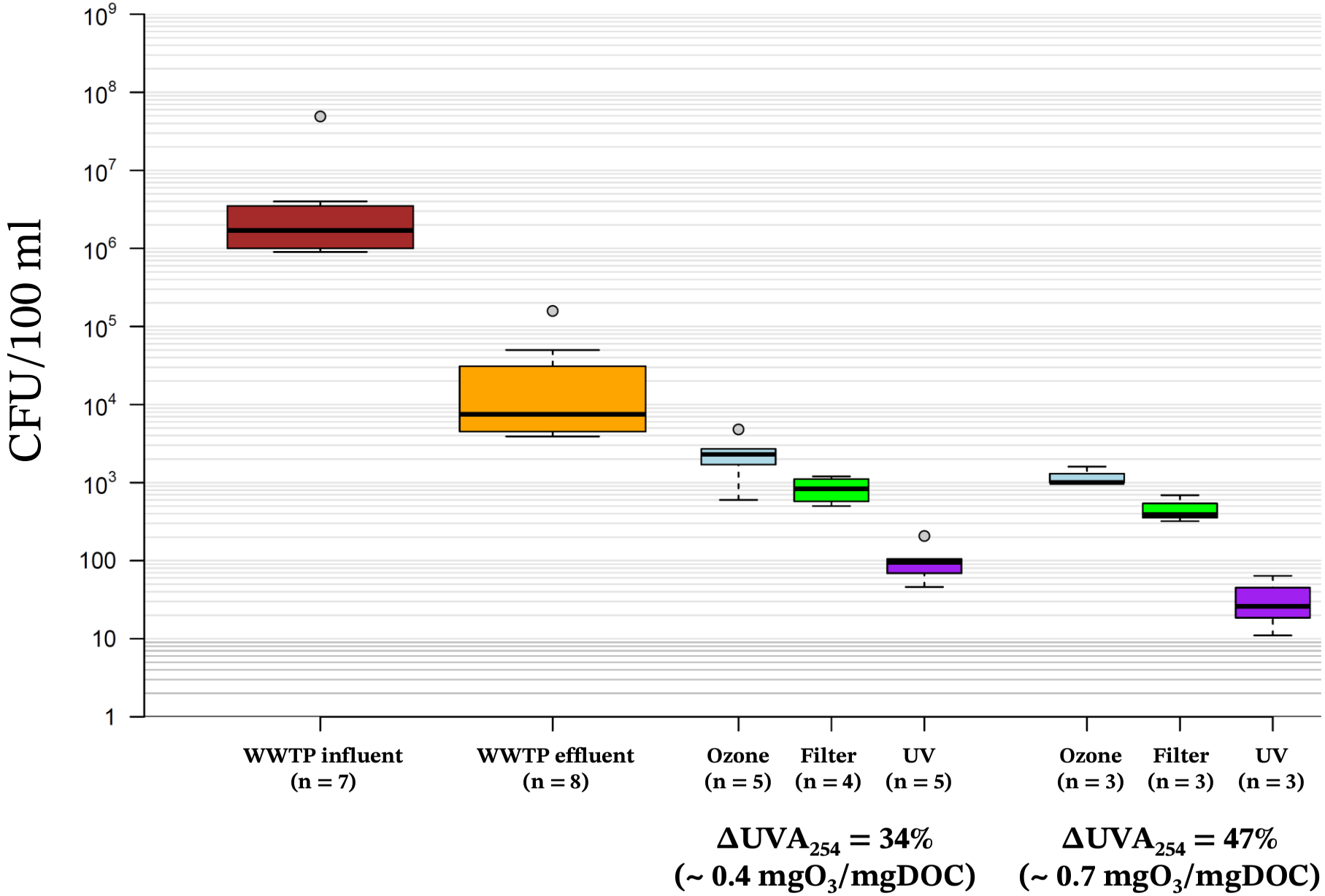

isinfection: somatic coliphages

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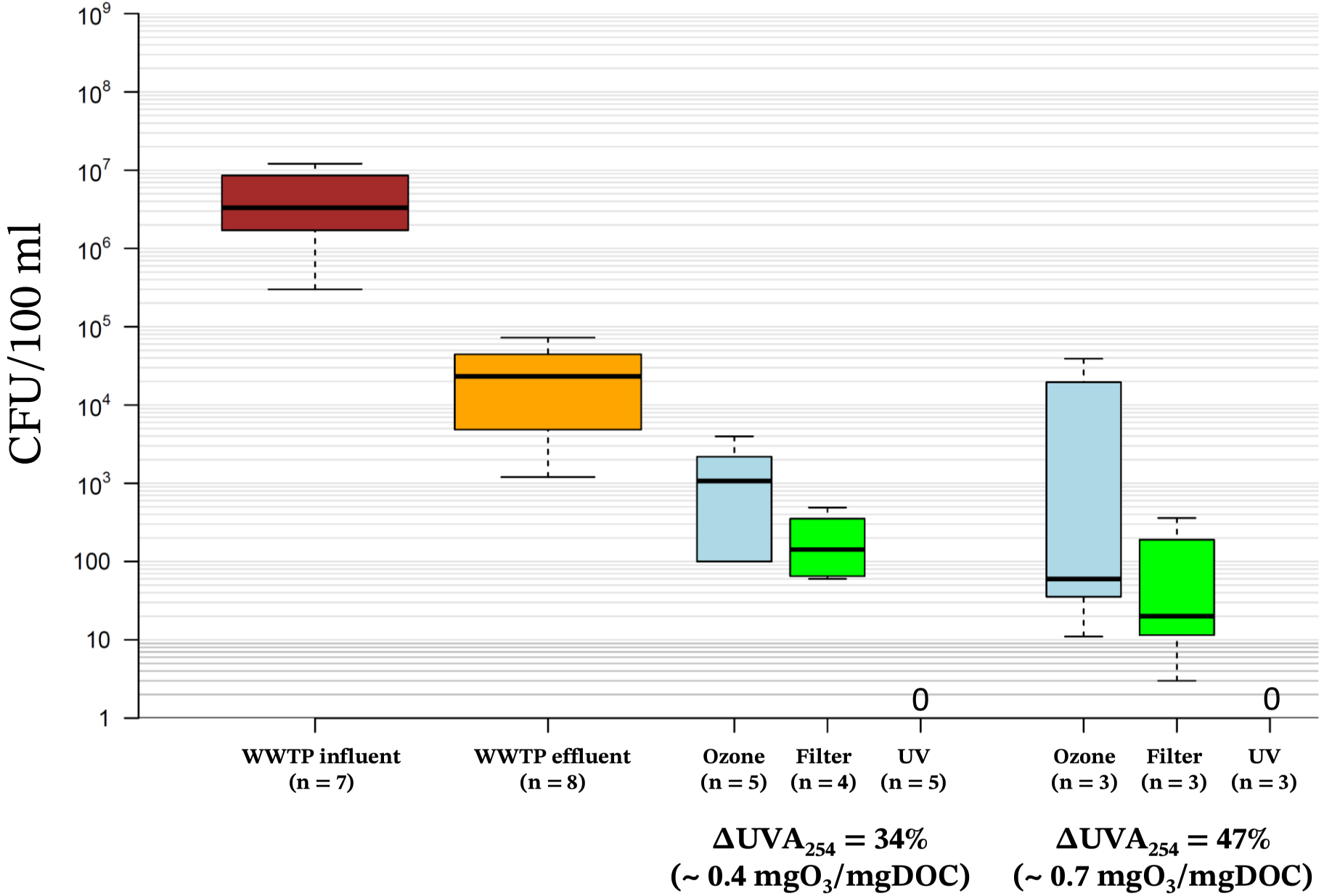
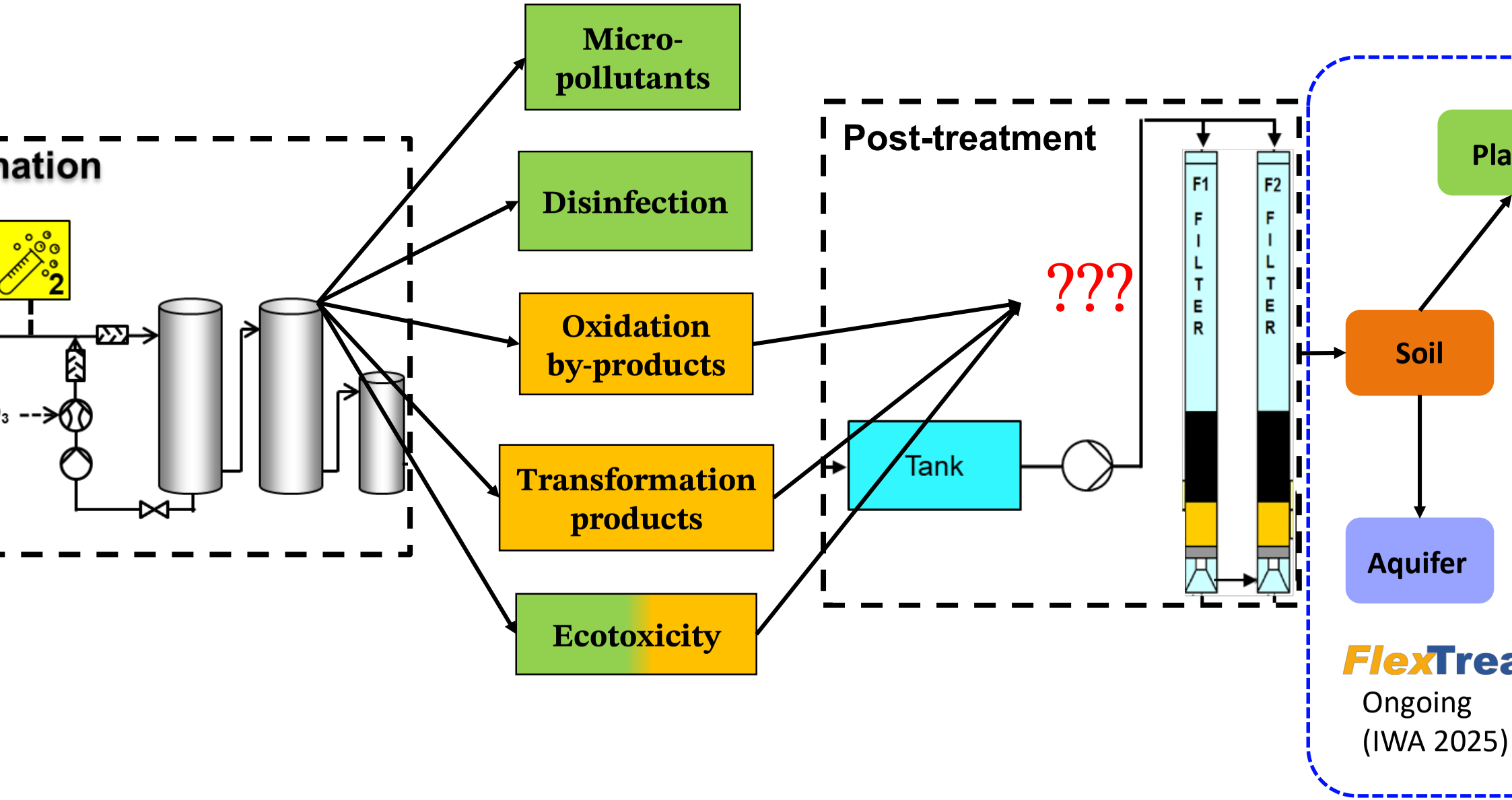
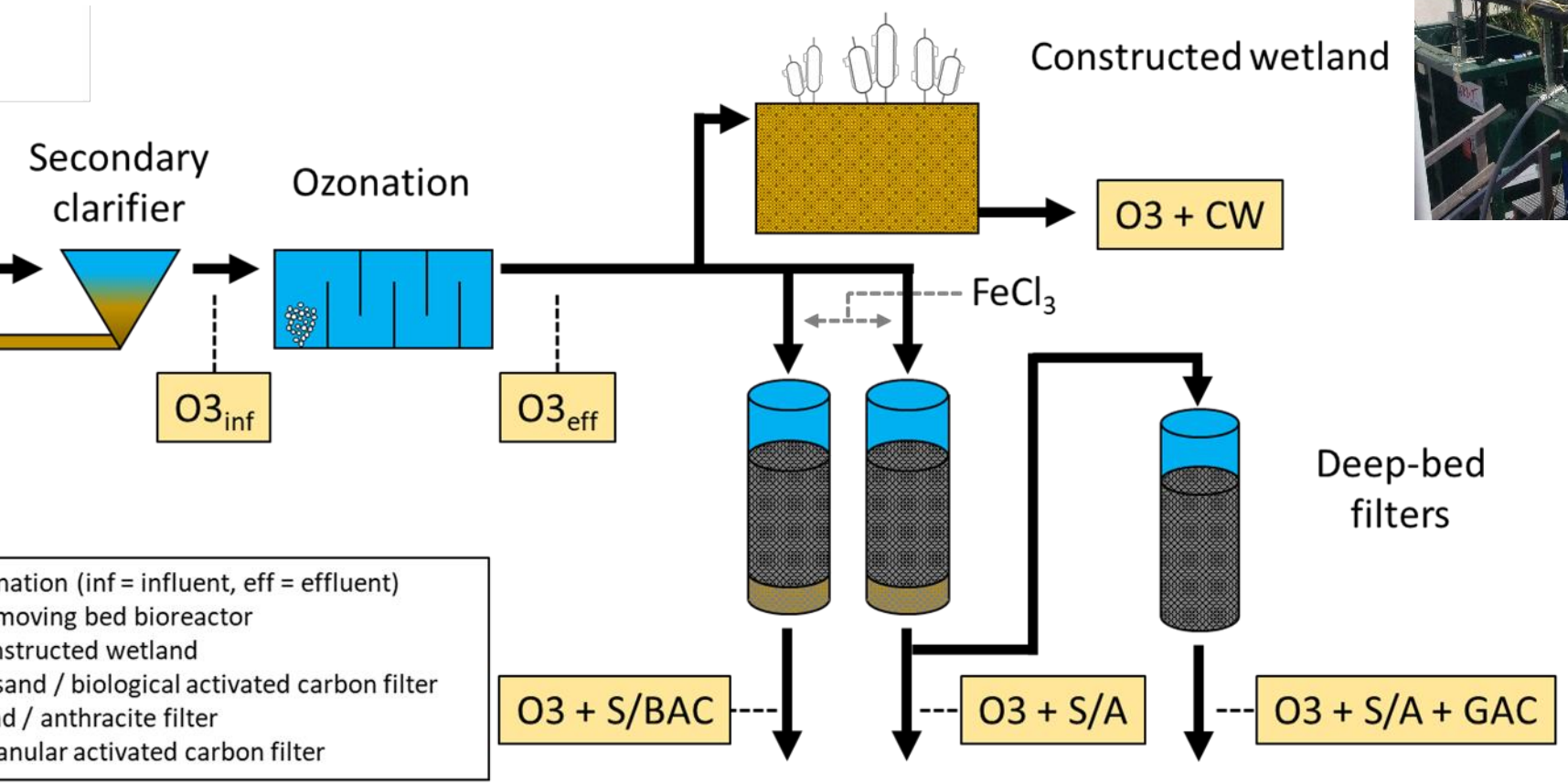


zonation – intended vs. unintended effects?



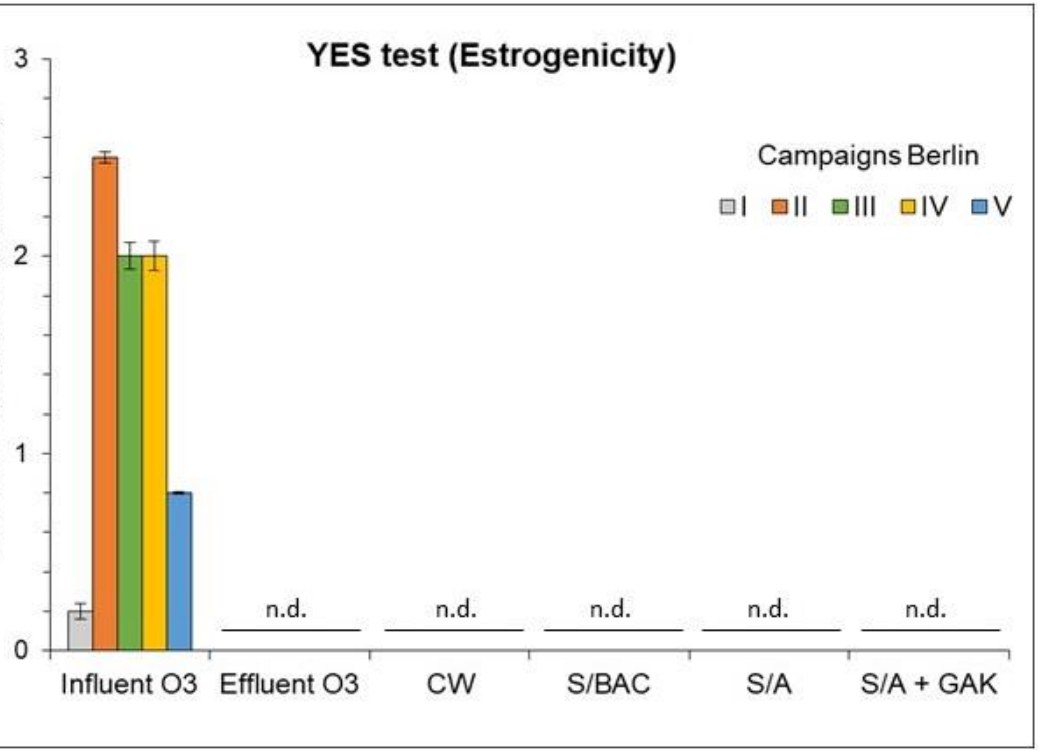
zonation post-treatment



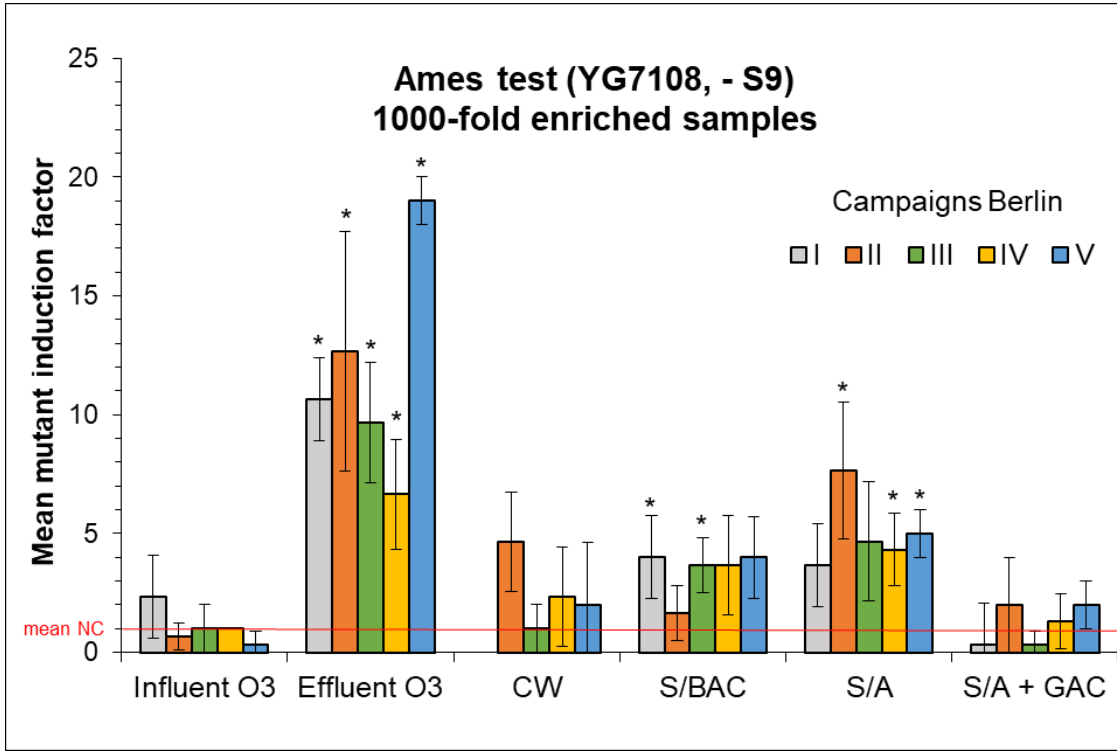
(2020). *Impact of ozonation and post-treatment on ecotoxicological endpoints, water quality, APIs and transformation products. CWPharma project report for GoA3.3: Comparison of post-treatment options.*

cotoxicity tests

17 ecotoxicological tests were performed by IOS (PL), LIAE (LV), and UBA (DE)
→ most of them showed no (systematic) effect at an enrichment factor of 10



Estrogenicity already completely removed by ozone



➔ Biological post-treatment needed
(*significant differences to the negative control)

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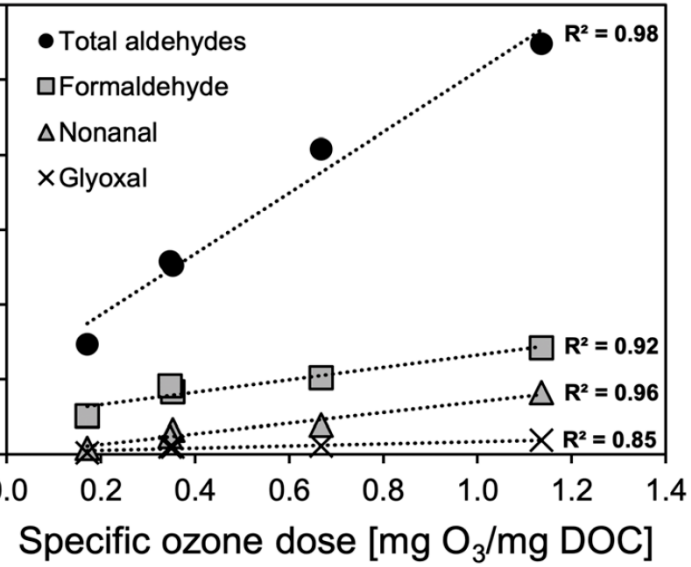
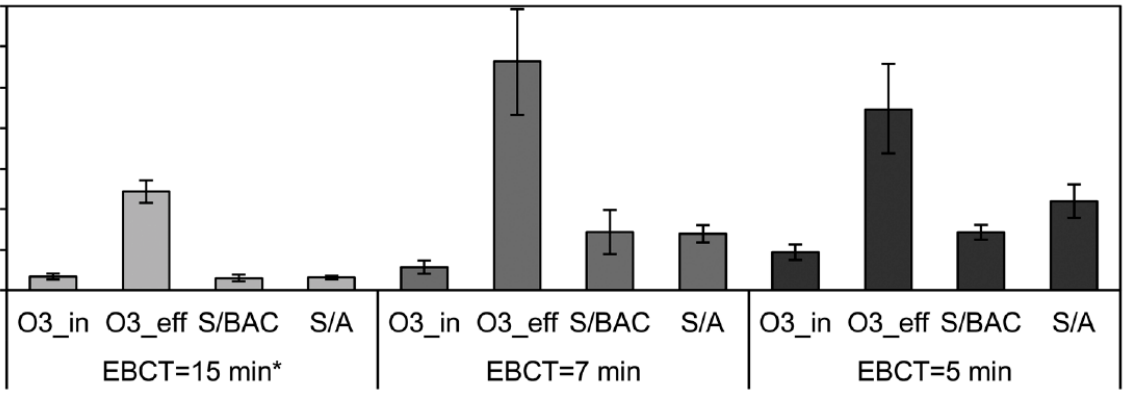
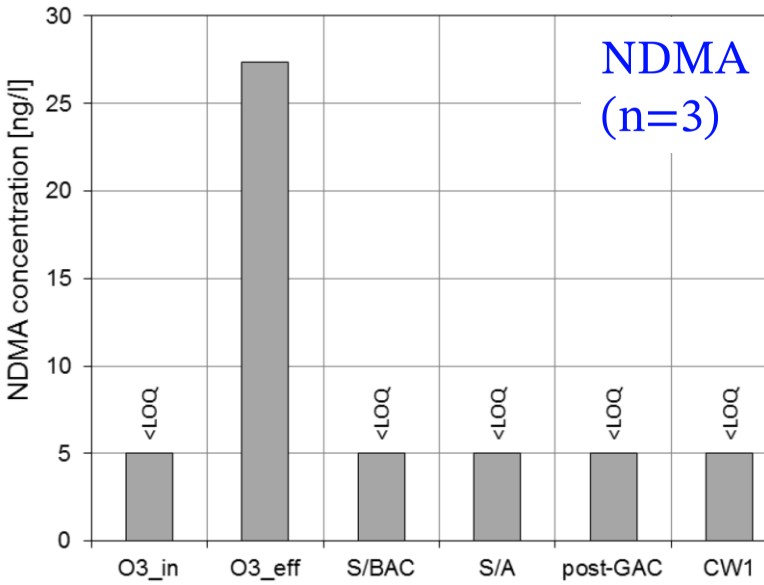
xidation by-products



Aldehydes

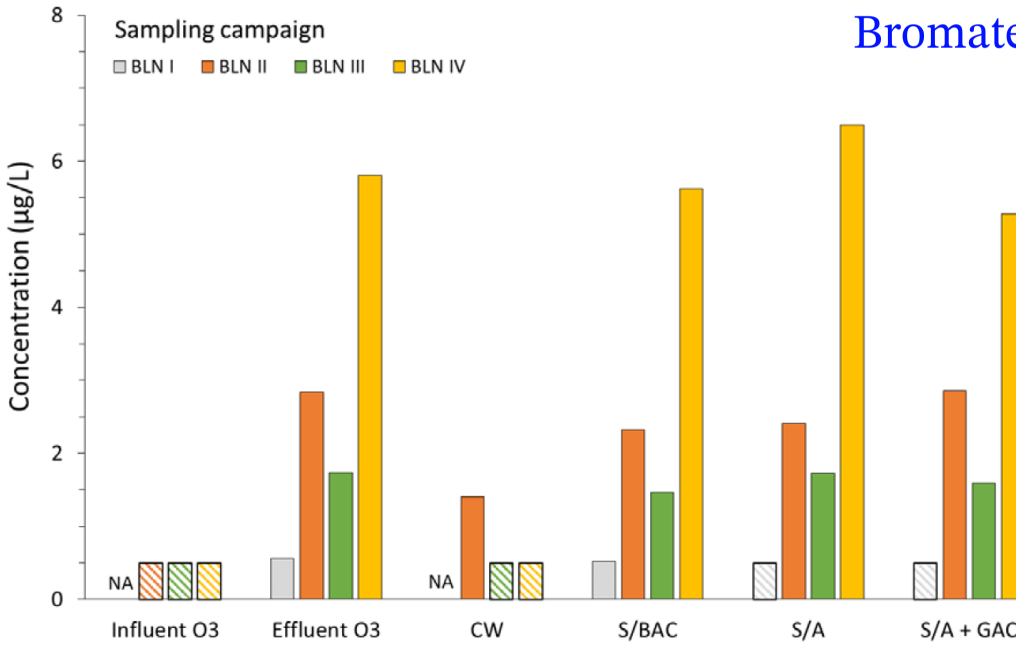
Sauter, D., et al. (2020)





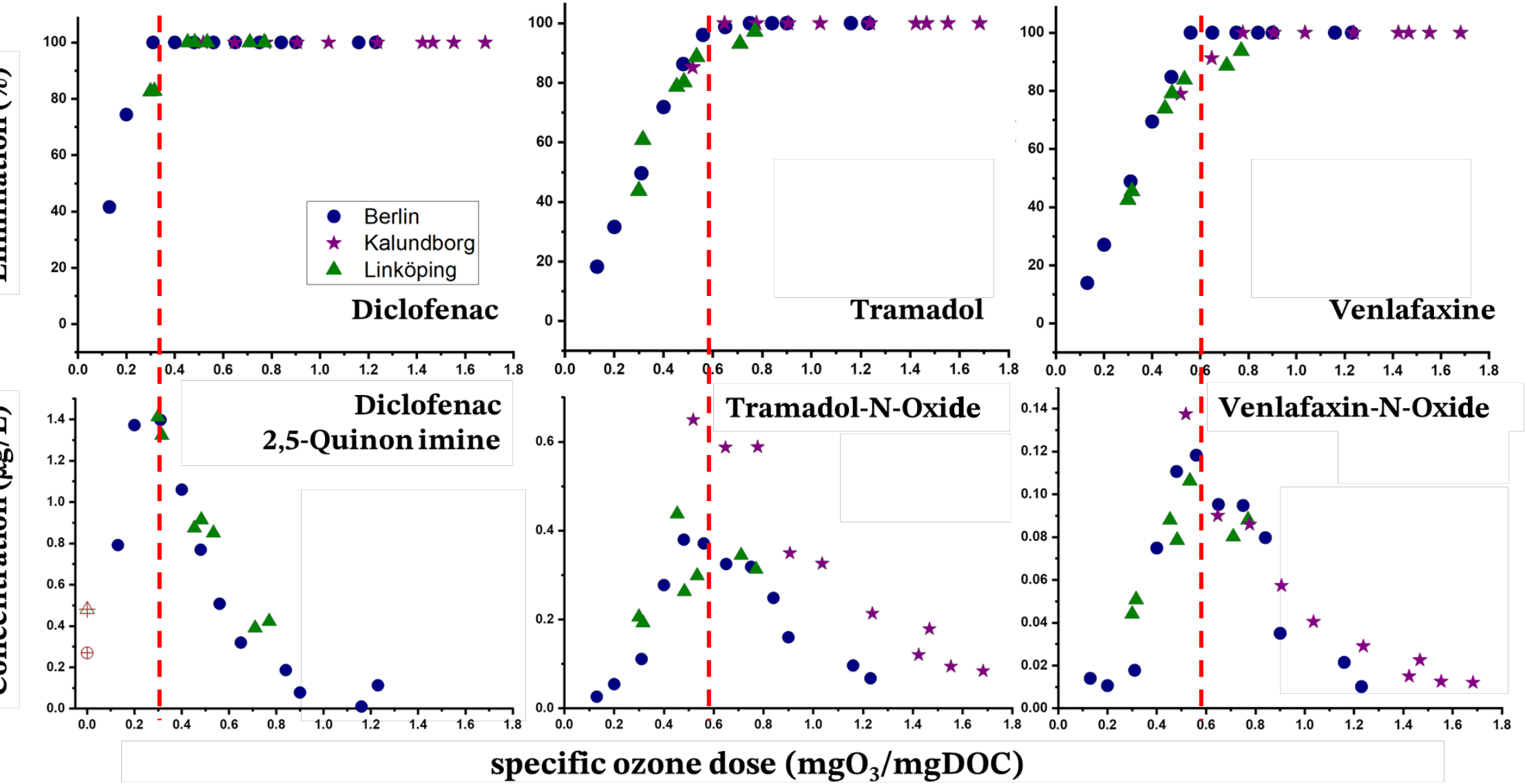
NDMA (n=3)

Bromate



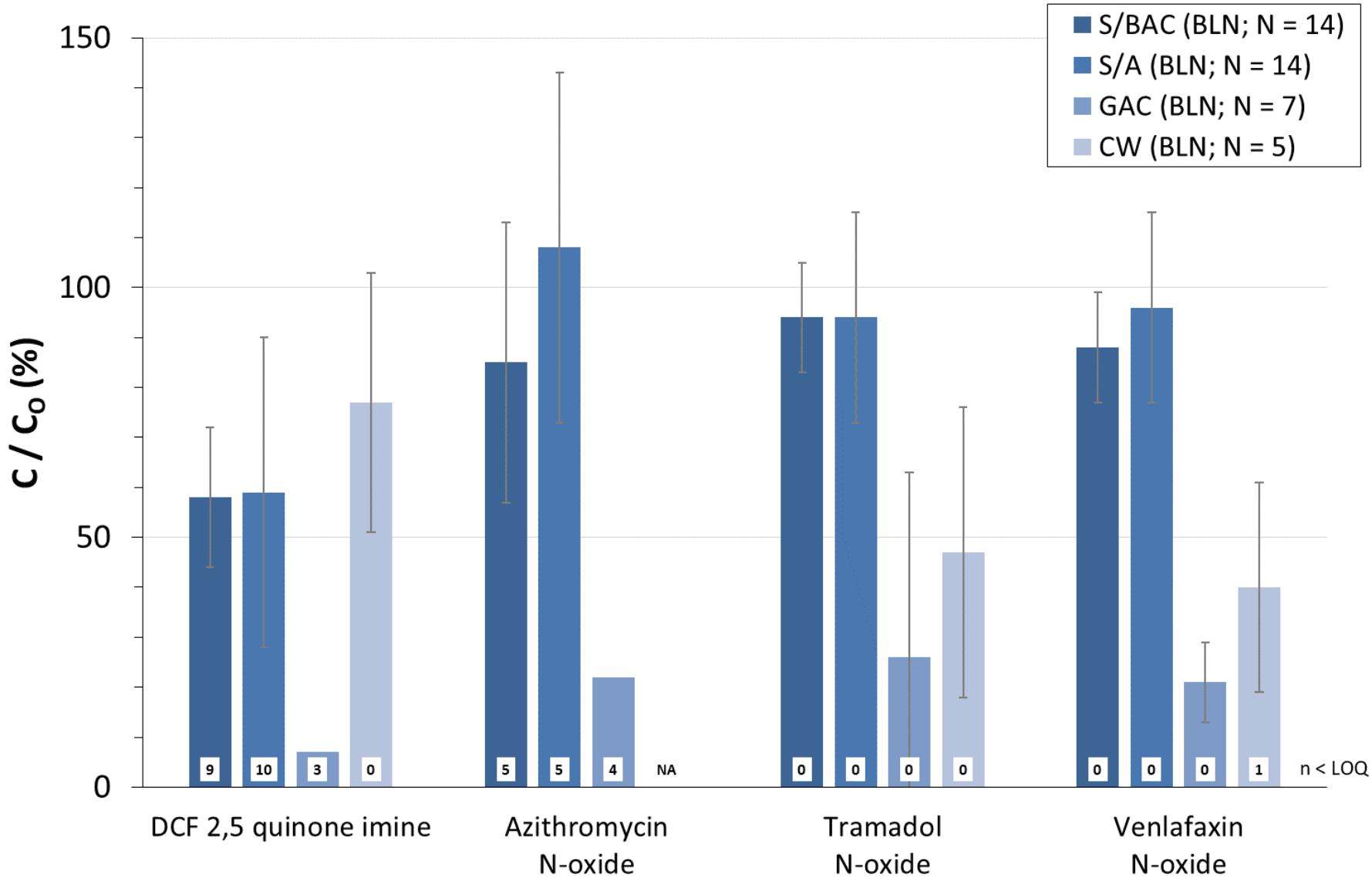
(2020). "Deep-bed filters as post-treatment for ozonation in tertiary municipal wastewater treatment: impact of design and operation on treatment goals." Environmental Science: Water Research & Technology.
l. (2019). Deliverable 3.2. Combining constructed wetlands and engineered treatment for surface water protection. Project AquaNES. Demonstrating synergies in combined natural and engineered processes for water treatment systems.
(2020). Impact of ozonation and post-treatment on ecotoxicological endpoints, water quality, APIs and transformation products. CWPharma project report for GoA3.3: Comparison of post-treatment options.

ransformation products



(2020). Impact of ozonation and post-treatment on ecotoxicological endpoints, water quality, APIs and transformation products. CWPharma project report for GoA3.3: Comparison of post-treatment options.

mpact of post-treatment on ozonation TPs



(2020). *Impact of ozonation and post-treatment on ecotoxicological endpoints, water quality, APIs and transformation products. CWPharma project report for GoA3.3: Comparison of post-treatment options.*

ummary: post-treatment impacts

Berlin WWTP

Ecotoxicity	**Ozonation**	**S/BAC**	**S/A**	**GAC**	**CW**
YES test (Estrogenicity)	↓	No effects detected			
Ames (YG7108, -S9)	↑	↓	↓	↓	↓

Oxidation by-products	**Ozonation**	**S/BAC**	**S/A**	**GAC**	**CW**
Bromate	↑	→	→	→	↓
NDMA	↑	↓	↓	↓	↓
Aldehydes	↑	↓	↓	NA	↓

Transformation products	**Ozonation**	**S/BAC**	**S/A**	**GAC**	**CW**
Diclofenac 2,5-Quinonimine	↑	↓	↓	↓	→
N-Oxides (Azithromycin, Tramadol, Venlafaxine)	↑	→	→	↓	↓*

Legend for OBPs and TPs:
↑ = concentration increase > 25%
→ = concentration change < 25%
↓ = concentration decrease > 25%

* NA for Azithro

onclusions

- Micropollutant removal and treatment for water reuse have significant synergy effects
- Ozonation designed for micropollutant removal increases the overall disinfection performance
- Combining ozone & filtration as pre-treatment for reliable UV disinfection
- Post-treatment after ozonation is recommended to prevent the release of TP / OBP / potential mutagenicity to the environment
- All tested post-treatments removed easily biodegradable substances (aldehydes, NDMA)
- No removal of N-oxides in dual media filters, but in constructed wetland (+) and GAC filter (++)
- Only the constructed wetland was able to reduce bromate concentrations

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Authors:

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Ulf Miehe

ulf.miehe@
kompetenz-wasser.de

+49 (0)30 536 53 821

@kompetenzwasser

@Kompetenzzentrum Wasser Be

www.kompetenz-wasser.de

mpetenzzentrum Wasser Berlin gGmbH
erostraße 24, 10709 Berlin