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Full scale ozonation of WWTP effluent followed by sandfiltration

Saskia Zimmermann,
S. Brocker, B. Escher, P.A. Hansen, J. Hollender, S. Koepke, M. Krauss, H.F. Larsen, A. Magdeburg, C.S. McArdell, J. Oehlmann, C. Ort, D. Rensch, H. Siegrist, H. Singer, D. Stalter, M. Suter, U. von Gunten

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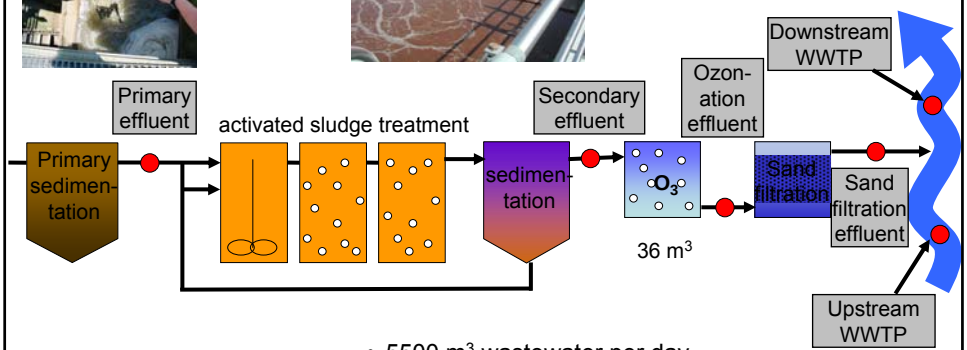
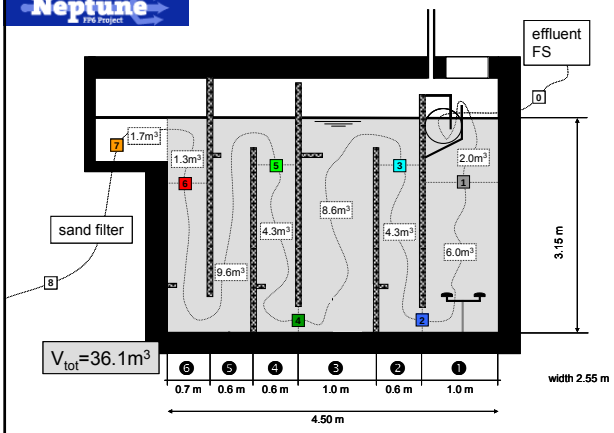
Full scale ozonation at WWTP Regensdorf



- sampling points
- 5500 m³ wastewater per day under dry weather conditions (25.000 population equivalents)

Ozonation



Ozone dosing

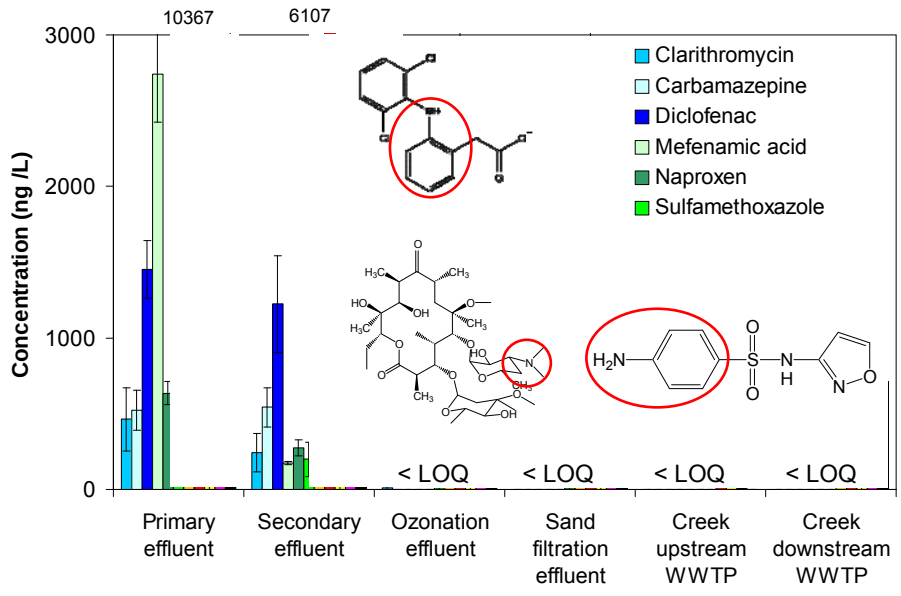
- DOC-load proportional
- flow proportional

Sampling

- 11 sampling campaigns (0 – 1.16 g_{O3}/g_{DOC})
- 24h- or 48h-volume proportional composite samples
- Fitration on-site (0.7 µm glassfiber filters)

Elimination efficiency – micropollutants

5 sampling campaigns: 0.62 ± 0.05 g_{O3}/g_{DOC}



Elimination efficiency – micropollutants

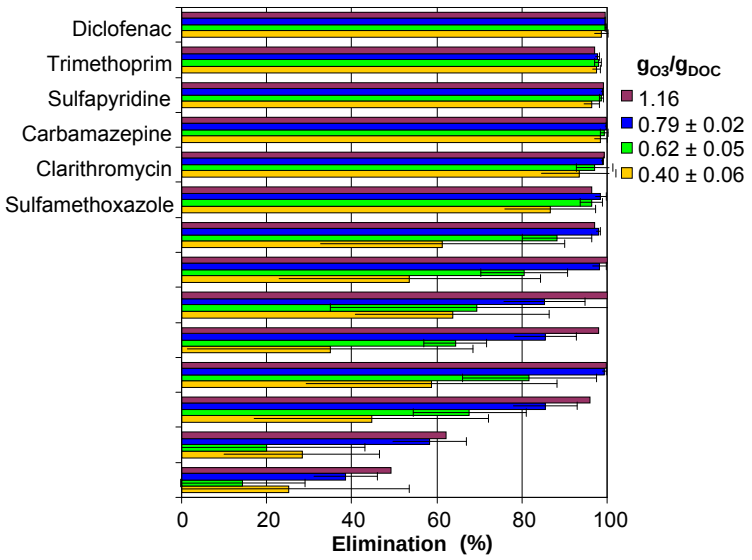
5 sampling campaigns: 0.62 ± 0.05 g_{O3}/g_{DOC}

	Number	Secondary Effluent >15 ng/L	Ozonation effluent > 15 ng/L	Ozonation effluent > 100 ng/L
Pharmaceuticals	14	13	4	Atenolol
Antibiotics	10	6	0	
X-Ray contrast media	6	6	5	Diatrizoate, Iopromide
Biocides/Pesticides	10	5	3	Mecoprop
Corrosion inhibitor	2	2	2	(Methyl)-Benzotriazol
Endocrine disruptors	4	1	0	
Metabolites	7	1	1	
Total	**53**	**34**	**15**	**6**

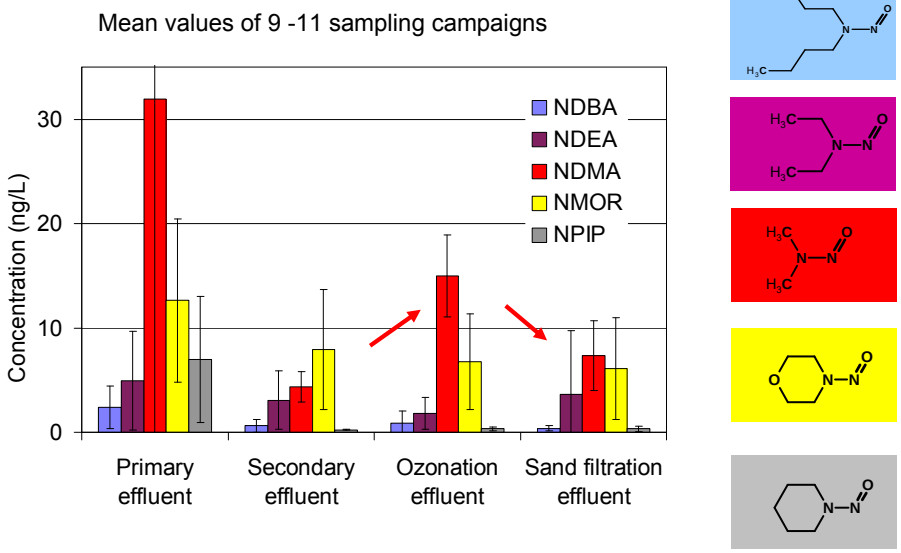
Load reduction per year: ➔~ 1 kg Carbamazepine
➔~ 2 kg Diclofenac
➔~ 6 kg Benzotriazole

Effect of ozone concentration on elimination efficiency

Calculation: 100 – 100 *$c_{after\ ozonation}$/ $c_{secondary\ effluent}$



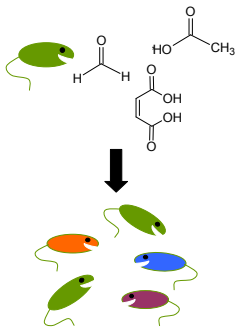
Cancerogenic nitrosamines - byproducts of ozonation?



Oxidation by-products

Bromate

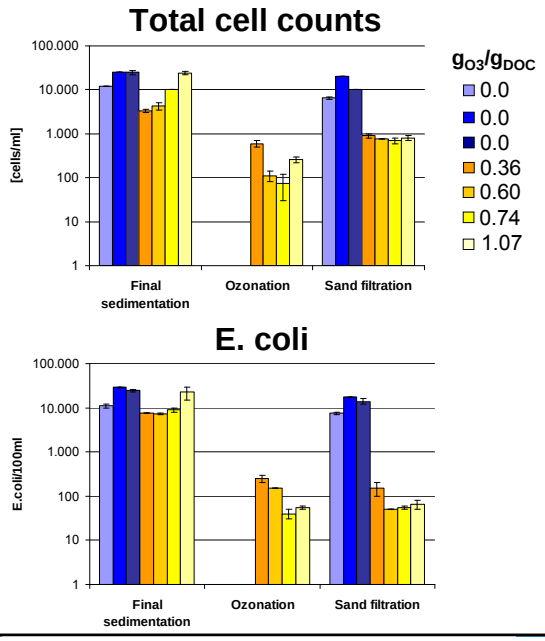
- influent bromide levels ~30 µg/L
- 7.4 ug/L for the highest ozone dose of 1.2 g_{O3}/g_{DOC}
- bromate < drinking water standard (10 µg/L)
- bromate < proposed ecotoxicological threshold (3 mg/L)



Assimilable Organic Carbon (AOC)

- influent AOC levels 100 – 200 µg/L
- increases up to 700 µg/L
- SF decreases it by max. 50%

Disinfection

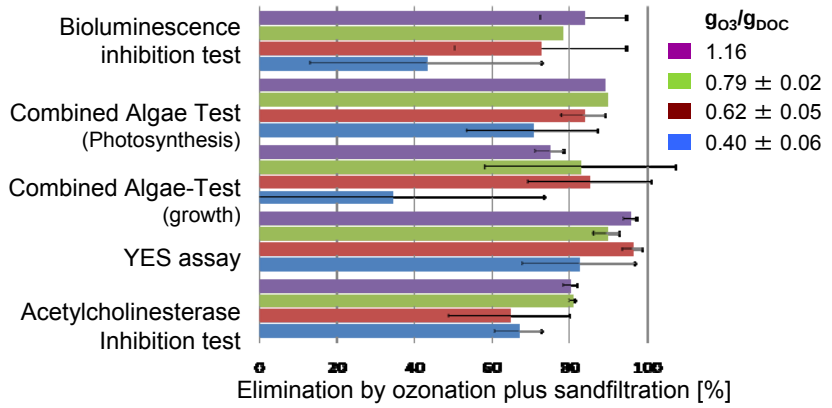


Toxic effects: mode-of-action based battery

Extraction of organic micropollutants and effect assessment of extracts

	Mode of action	Bioassay	Targeted chemicals
Non specific toxicity	baseline toxicity	Bioluminiscence inhibition assay	all chemicals
Specific toxicity	Phytotoxicity photosynthesis inhibition	Imaging-PAM	Triazine and phenylurea herbicides
	estrogenic effects	YES	Estrogens, estrogenic Industrial chemicals
	acetylcholinesterase (AChE) inhibition	AChE	Organophosphates, carbamate insecticides
Reactive toxicity	genotoxicity	*umuC*	Chlorinated byproducts, Aromatic amines, PAH

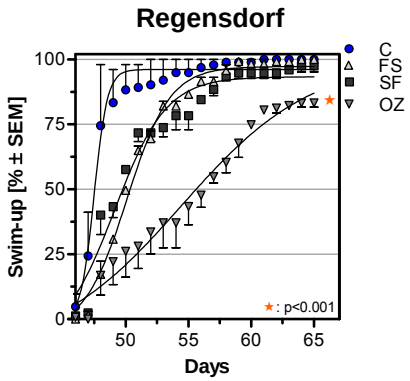
Elimination efficiency – toxic effects

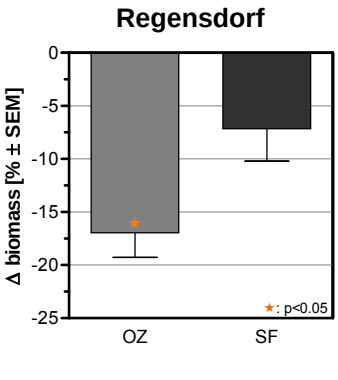


- at 0.62 g O_3/g DOC 65- 95 % elimination of the toxic effect
- Specific, receptor-mediated effects better removed than non-specific toxicity (ozone causes transformation not mineralisation)
- no significant formation of toxic or genotoxic byproducts

Fish early life stage toxicity test

Swim-up and biomass comparison
(*Oncorhynchus mykiss* larvae)





- Delayed swim-up after OZ
- Reduced biomass after OZ
- No significant effect after sand filtration

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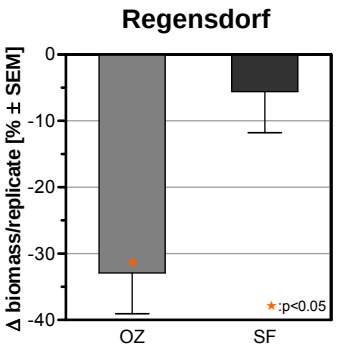
Lumbriculus toxicity test

Biomass comparison



- Considerable decrease of biomass and reproduction after OZ
- No significant effect after sand filtration

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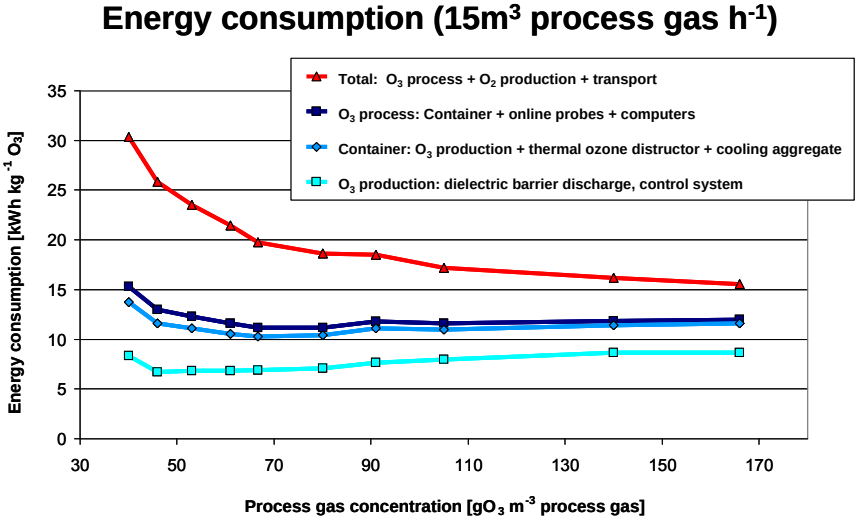
Energy consumption for O_2 and O_3



Estimated yearly costs ozonation step at WWTP Regensdorf

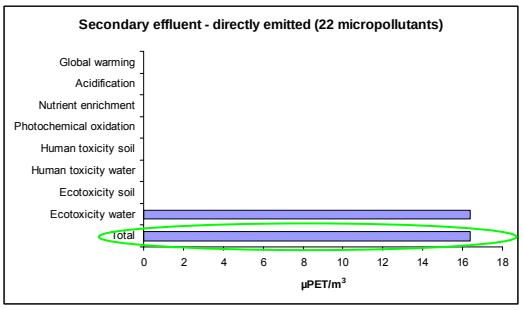
		Unit
Investment (15a / 4%) [a]	105'000	€/a
Personnel [b]	20'000	€ /a
Maintenance	20'000	€ /a
Oxygen [c]	24'000	€ /a
Energy [d]	7'000	€ /a
Total	**176'000**	**€ /a**
Spec. Costs (for 3 Mio. m³ wastewater / a)	**0.06**	**€ /m³ wastewater**

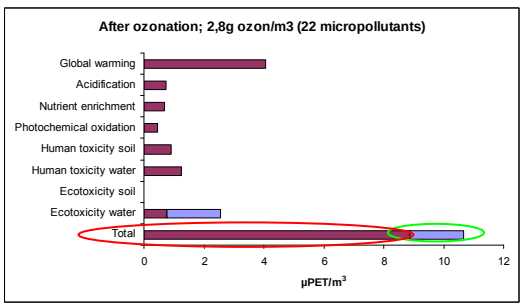
[a]payback period 15 years, linear amortization with 4 % interest
[b]based on 700 h/year internal personnel plus external personnel for maintenance of DOC sensor, ozone dissolved measurement and gas warn devices
[c]based on 0.22 €/kg_{O2}
[d]based on energy costs of 0.058 €/kWh

- ***without sand filtration***

LCA impact profiles

(weighting factor = 1 for all impact categories)



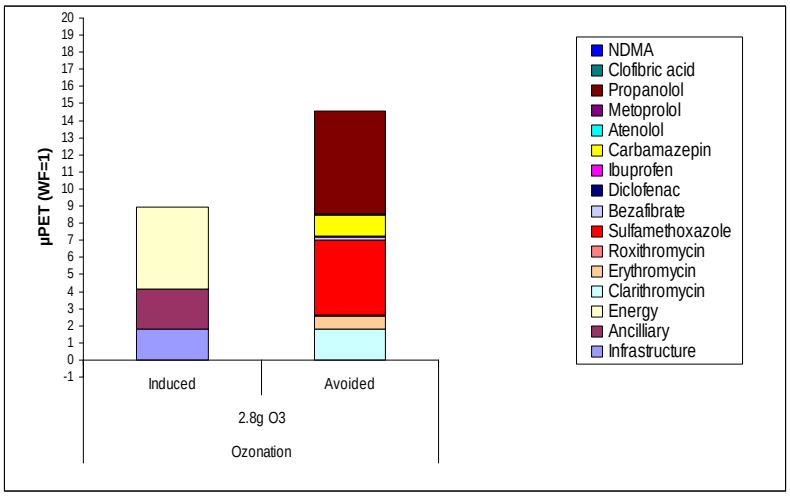


Avoided: 14,6 µPET/m3

Induced: 8,9 µPET/m3

Environmental sustainability profiles: ozonation

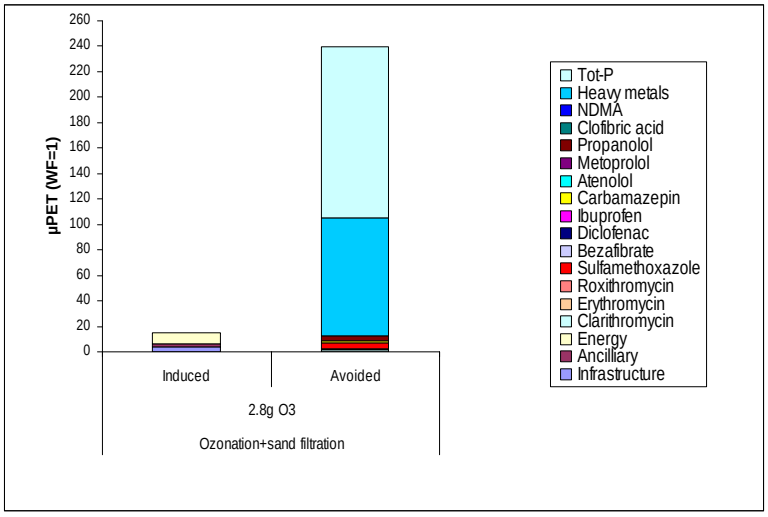
(22 micropollutants (only significant ones shown); weighting factor = 1 for all impact categories)



Environmental sustainability profiles: ozonation + sand filtration

(31 micropollutants + P (only significant ones shown); weighting factor = 1 for all impact categories)

	Secondary effluent	After sandfiltration	Removal rate
Tot-P (mg/l)	0,8	0,3	0,625



Conclusions

- Efficient technique for the transformation of micropollutants and for disinfection purposes
- Ecotoxicity results are controversial (improvement vs. no effect); ongoing need for clarification
- Sand filtration recommended as barrier for the elimination of some oxidation by-products formed during ozonation (NDMA, AOC)
- Specific costs ~0.06 €/m^3 wastewater
  (ozonation without sand filtration; including both investment and operation costs)
- LCA: Ozonation most probably environmentally sustainable; including sand filtration significantly improves sustainability profile

Acknowledgments

- This study was part of the EU Neptune project (Contract No 036845, SUSTDEV-2005-3.II.3.2), which was financially supported by grants obtained from the EU Commission within the Energy, Global Change and Ecosystems Program of the Sixth Framework (FP6-2005-Global-4)
- BAFU Switzerland
- AWEL Kanton Zürich

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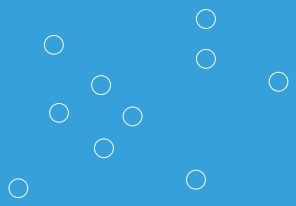

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