Life cycle assessment of advanced waste water treatment

Micropollutant removal

Ozonation as example

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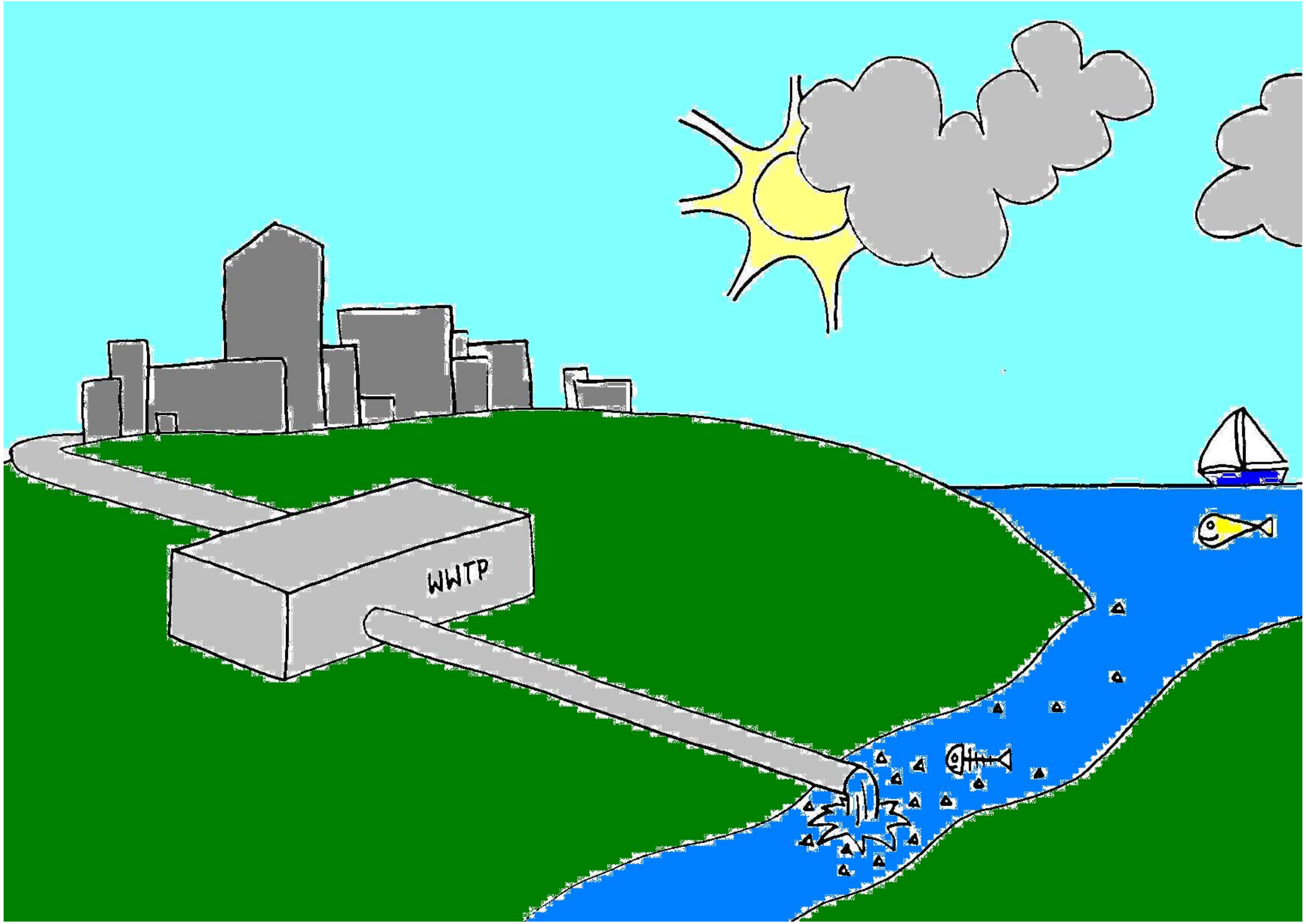
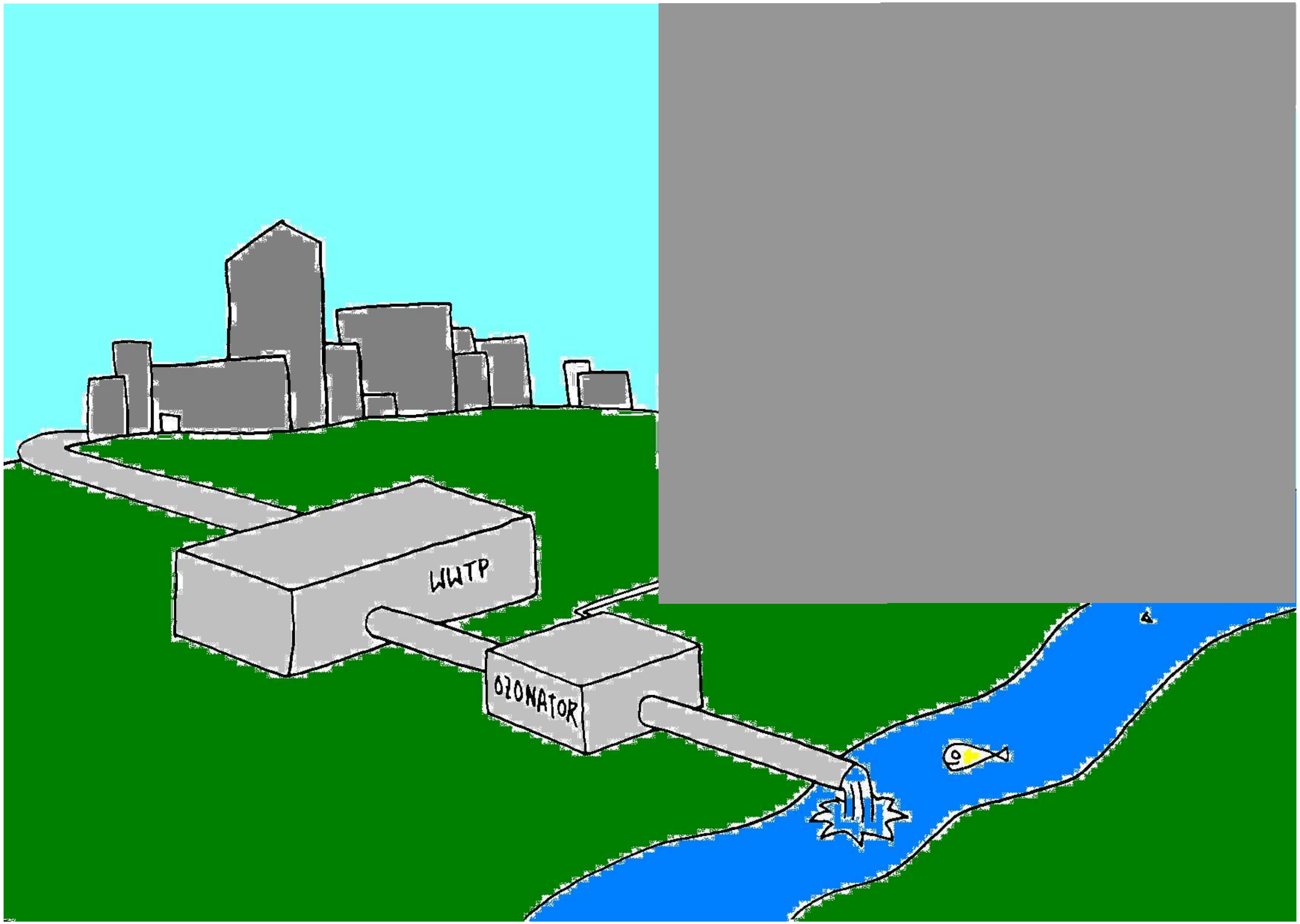
Outline

- The holistic challenge when introducing new waste water treatment technologies for micropollutants removal; avoid sub optimisation
- Avoided and induced impacts
- Characteristics of life cycle assessment (LCA)
- Modelling LCA on ozonation
- Characterisation of incoming water
- Environmental sustainability profiles for ozonation
- The effect of including sand filtration
- Conclusion and further research



Peter Augusto Hansen



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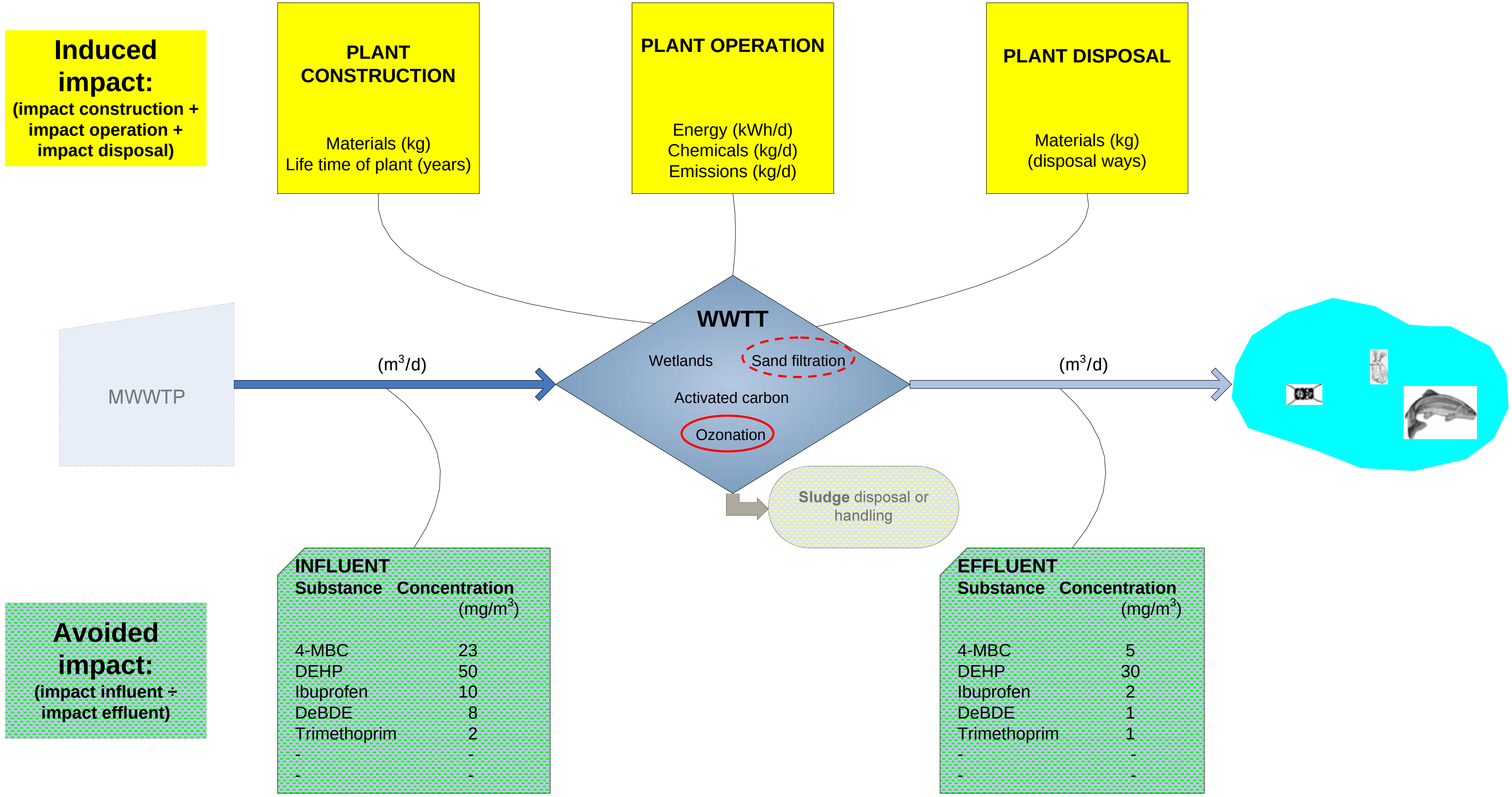
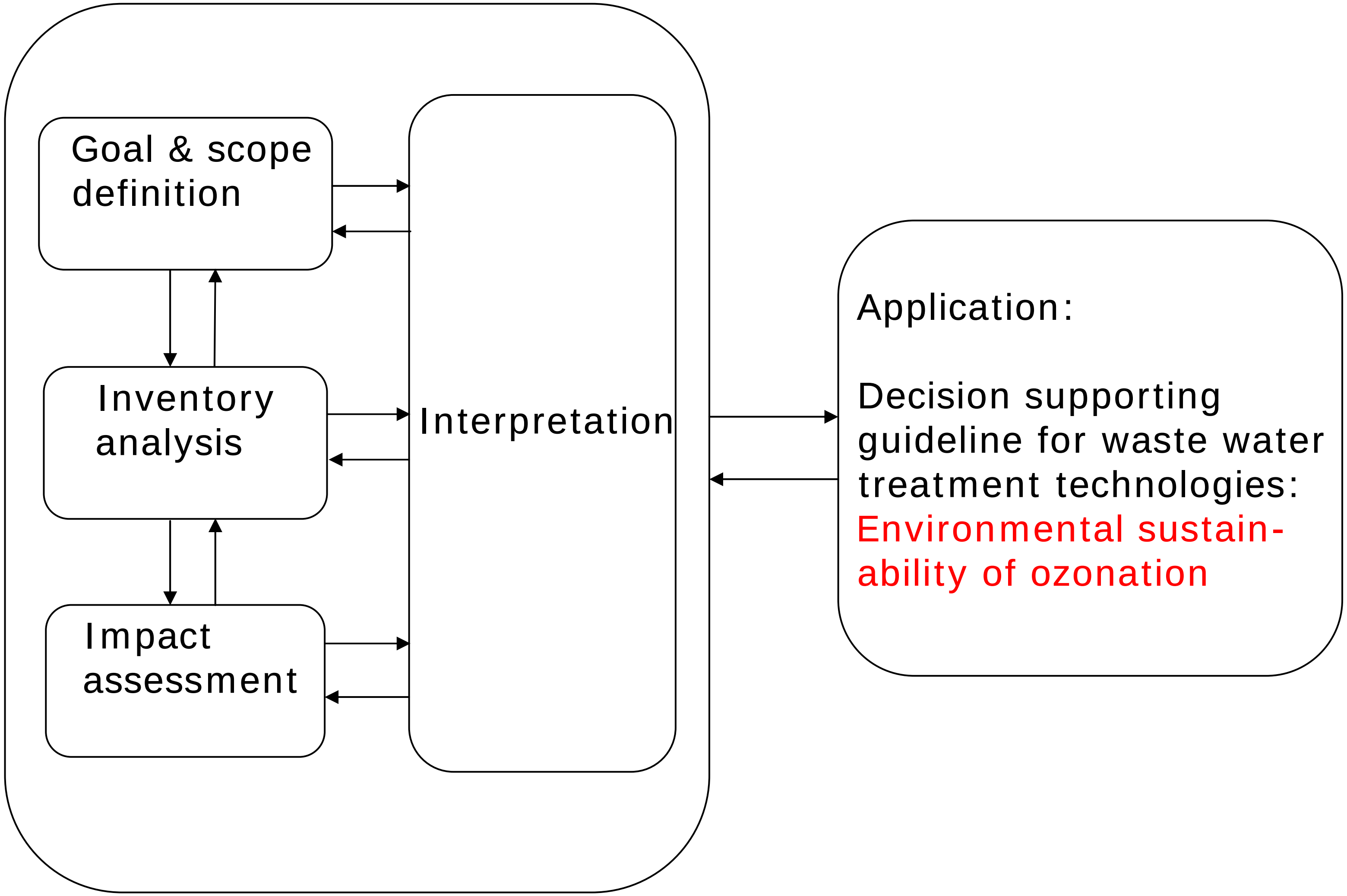
End-of-line technologies



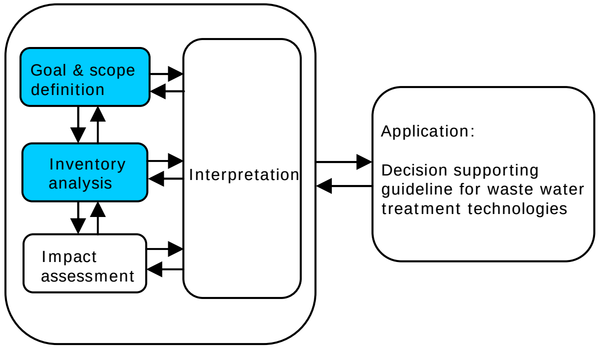
Characteristics of LCA

- A decision supporting tool
- Focus on services typically represented by a product (the "functional unit", fu). In this case: Treatment of one cubic meter waste water (all impacts related to this unit)
- Comparative (relative statements). In this case: Comparing induced impacts with avoided impacts regarding ozonation
- Holistic perspective
  - life cycle from cradle to grave
  - all relevant environmental impacts or damages to 'areas of protection'. In this case: Global warming, eutrofication, acidification, ecotoxicity……..
  - resource consumption (biotic and abiotic). This case: Metals (Ni), fossil fuels, ….. (NOT INCLUDED HERE)
- Aggregation over time and space
  - life cycle is global
  - life cycle may span over decades or even centuries

Elements of life cycle assessment (LCA)

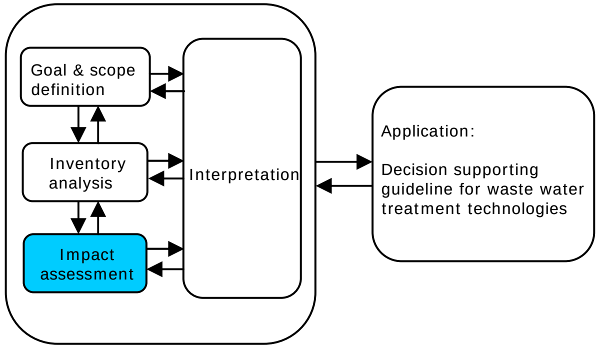


Goal and scope, and inventory



- Goal
  - An assessment of the environmental sustainability of ozonation
- Scope
  - Comparative LCA: Induced impacts as compared to avoided impacts
  - Functional Unit(s): 1 m^3 secondary MWWTP effluent water with well defined composition as regards content of micropollutants and more
- Inventory
  - collecting in- and output data for all processes

Life cycle impact assessment (LCIA)



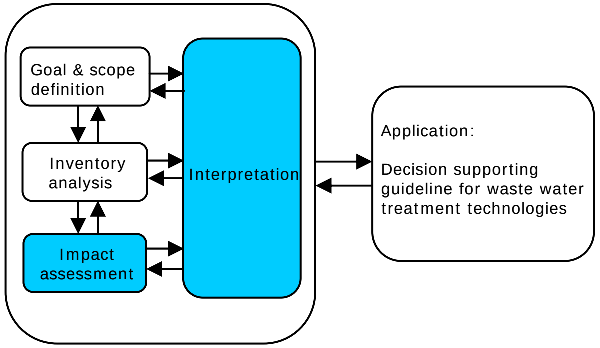
Classification: *"What does this emission or consumption contribute to?"*

- Assignment of emissions and consumptions to impact categories according to their potential effects
  - Global warming (e.g. CO_2, CH_4)
  - Acidification (e.g. NO_2, SO_3)
  - Ecotoxicity (e.g. pharmaceuticals, heavy metals)
  - Human toxicity (e.g. benzene, PAH's)
  - ………..

Characterisation: *"How much may it contribute?"*

- Quantification of contributions to the different impact categories (e.g. multiplying the characterisation factors for each chemical by the emitted amount)
- Example: Emission of 100g CO_2 + 100g CH_4 contributes with: 100*1g CO_2-eq/g CO_2 + 100*25g CO_2-eq/g CH_4 = 2600 g CO_2-eq

Life cycle impact assessment (LCIA) and interpretation



Normalisation: *"Is that much?"*

- Expression of the impact potentials relative to a reference situation (EDIP: person-equivalence), e.g. NR: 8,700 kg CO_2-eq/pers/year.
  - Example: If the treatment of 1 m^3 waste water (1 fu) results in a total emission of 0.5 kg CO_2-eq => Normalized impact potential: 0.5/8,700 = 0.057 mPE/fu

Valuation: *"Is it important?"*

- Ranking, grouping or assignment of weights to the different impact potentials (EDIP: political reduction targets), e.g. for global warming the targeted 10 years reduction 20% => WF=1/(1-0.2) = 1.3.
  - Example: Weighted impact potential: 1.3*0.057 = 0.074 mPET/fu

Interpretation: *"Which alternative is better and what determines it?"*

- Is ozonation worth it in an environmental sustainability context or should we avoid it
- Identification of hot spots
- Sensitivity analysis: Effect of including more micropollutants
- Sensitivity analysis: Effect of using alternative valuation principles

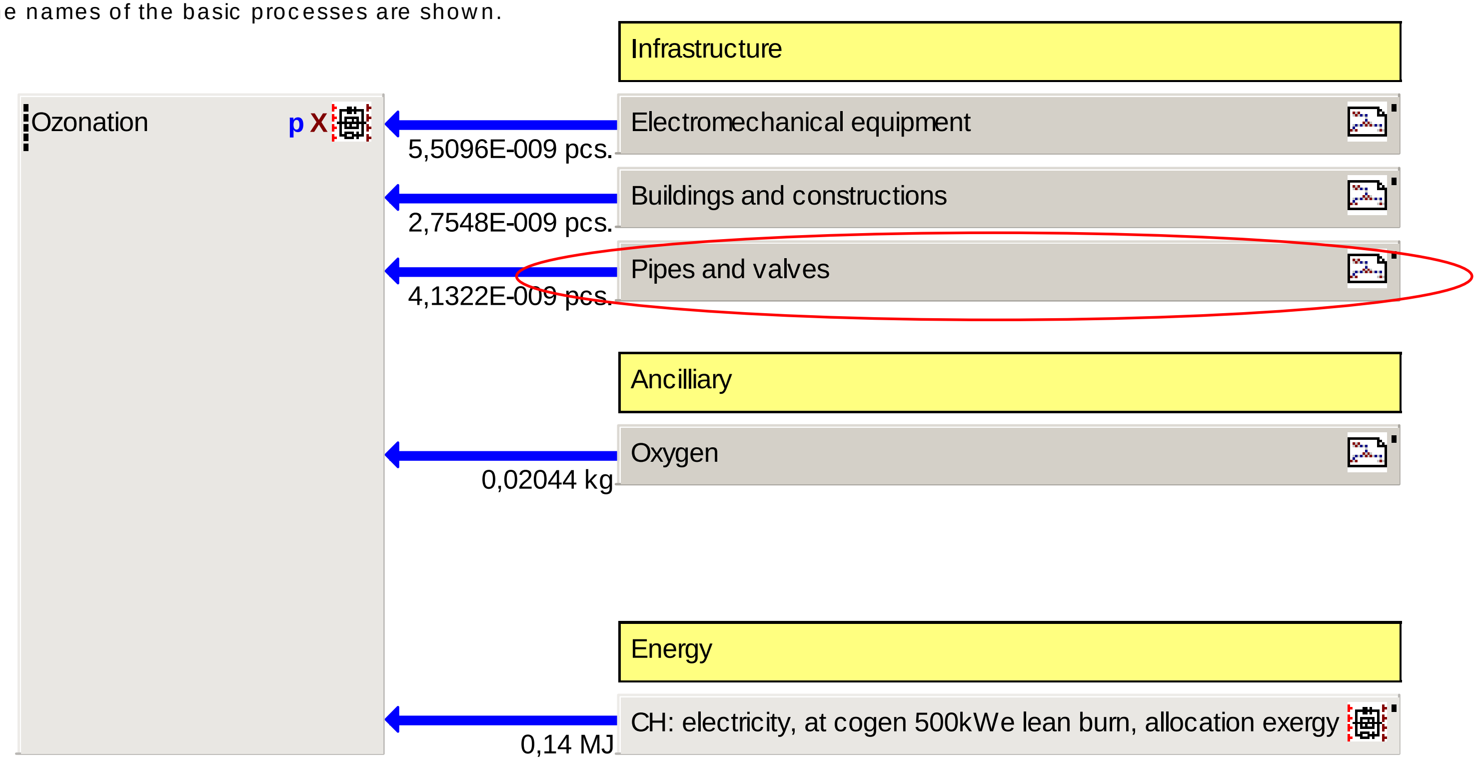
Modelling LCA on ozonation; Main plan

(physical inventory)

Ozonation (2.8gO3/m3WW, Hunziker)-hfl-March-2009

GaBi 4 process plan:Reference quantities

The names of the basic processes are shown.



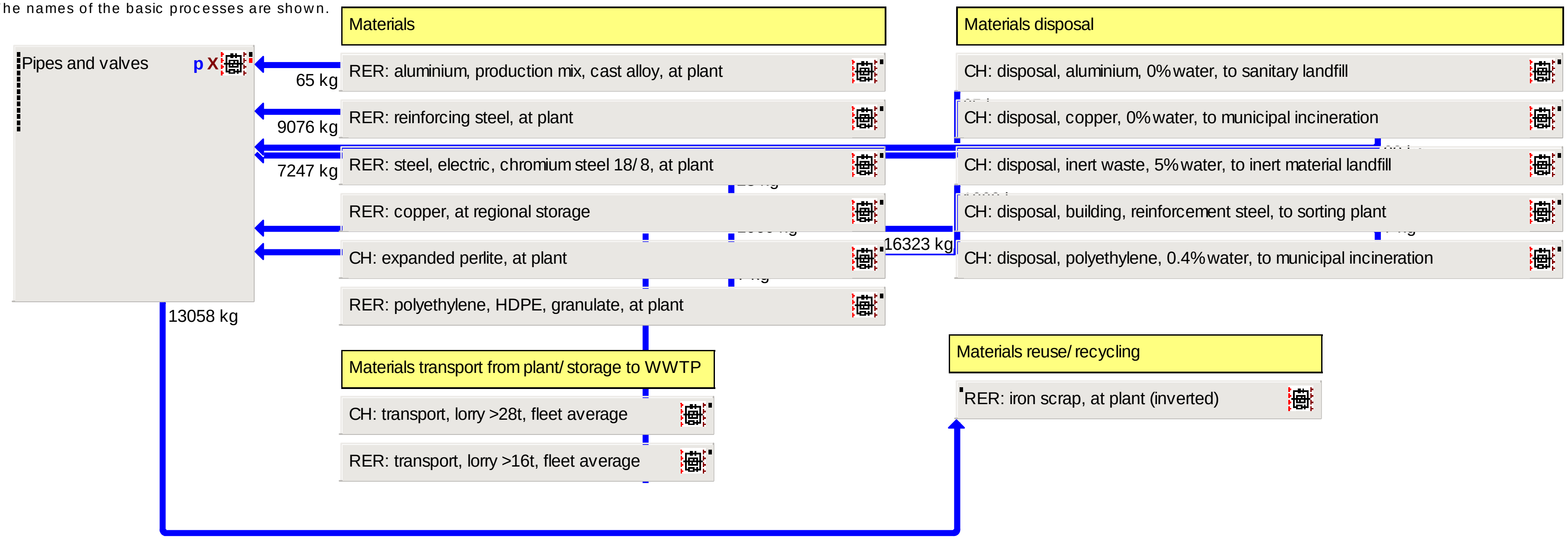
Modelling LCA on ozonation; Sub-plan

(physical inventory)

Pipes and valves

GaBi 4 process plan:Reference quantities

The names of the basic processes are shown.



Characteristics of incoming water (secondary effluent water)

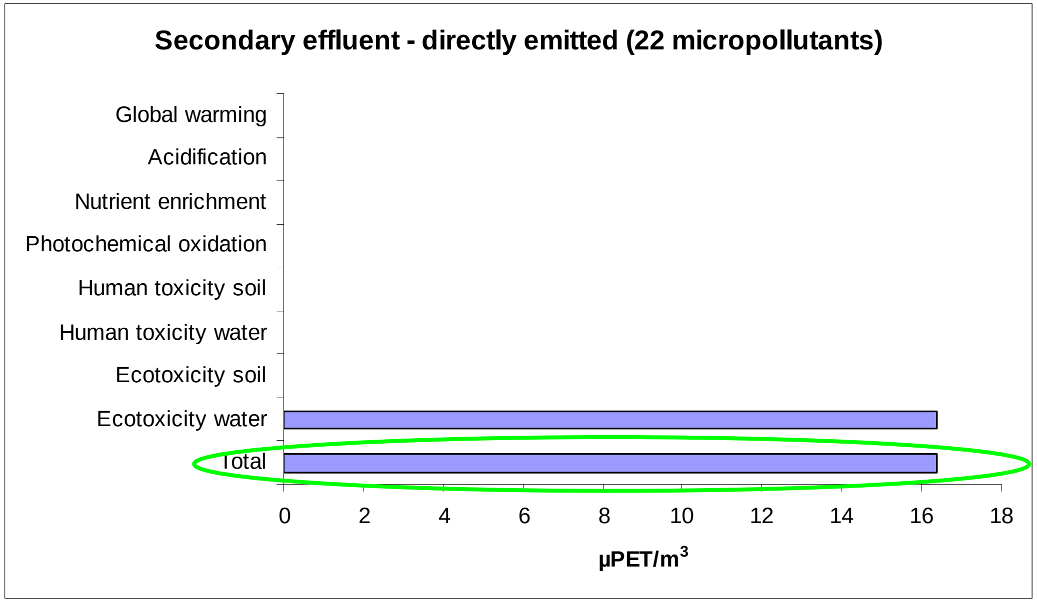
(functional inventory)

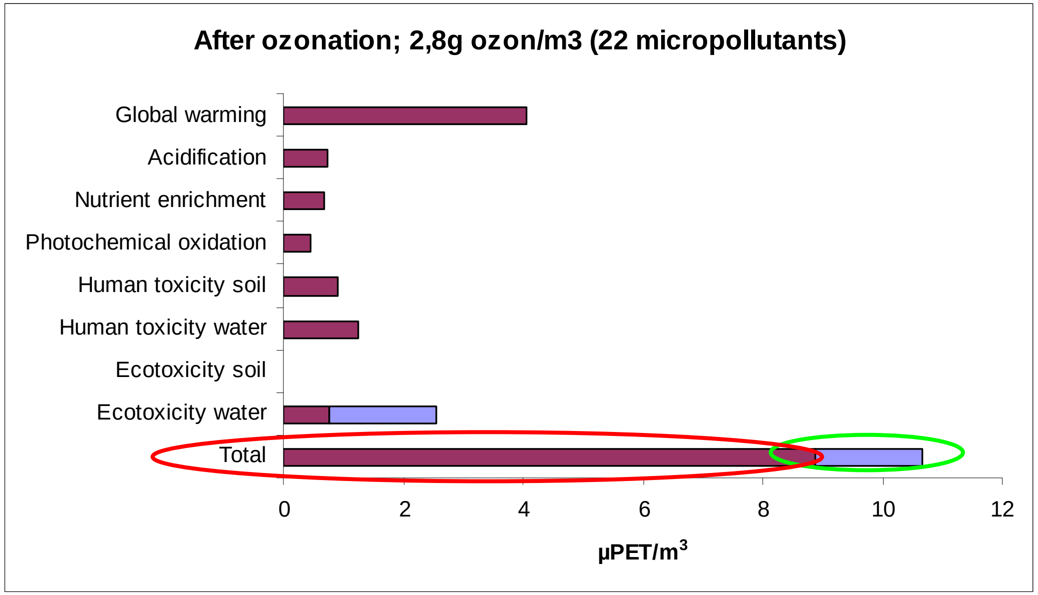
	Inlet conc. (ng/L)	Removal rate (2,8 g O_3/m^3)	PNEC (µg/L)	More rigoruos tired RA based PNECs (µg/L)
Atenolol	1400	0,90	330	
Bezafibrat	170	0,82	2,3	
Carbamazepin	1100	1,00	2,5	0,5
Clarithromycin	210	0,98	0,31	
Clindamycin	24	0,98	8,5	
Clofibrinsäure	120	n/a	25	5
Diatrizoate	3200	0,31	11000	
Diclofenac	2600	1,00	100	0,1
Erythromycin	130	0,41	0,20	0,02
Ibuprofen	130	n/a	96	3
Iohexol	540	0,00	7400000	
Iopamidol	1700	0,00	380000	
Iopromid	1700	0,19	100000	
Metoprolol	410	0,94	76	7,3
Naproxen	400	0,98	190	
NDMA (N-nitrosodimethylamin)	57	-3,08	40	
Primidon	330	0,55	1400	
Propanolol	120	0,92	0,050	
Roxithromycin	76	0,79	2,8	
Sotalol	370	0,98	300	
Sulfamethoxazol	910	0,99	0,59	0,15
Trimethoprim	200	0,98	800	

(data on removal rates from MicroPoll; personal communication with Juliane Hollender)

LCA impact profiles

(weighting factor = 1 for all impact categories)



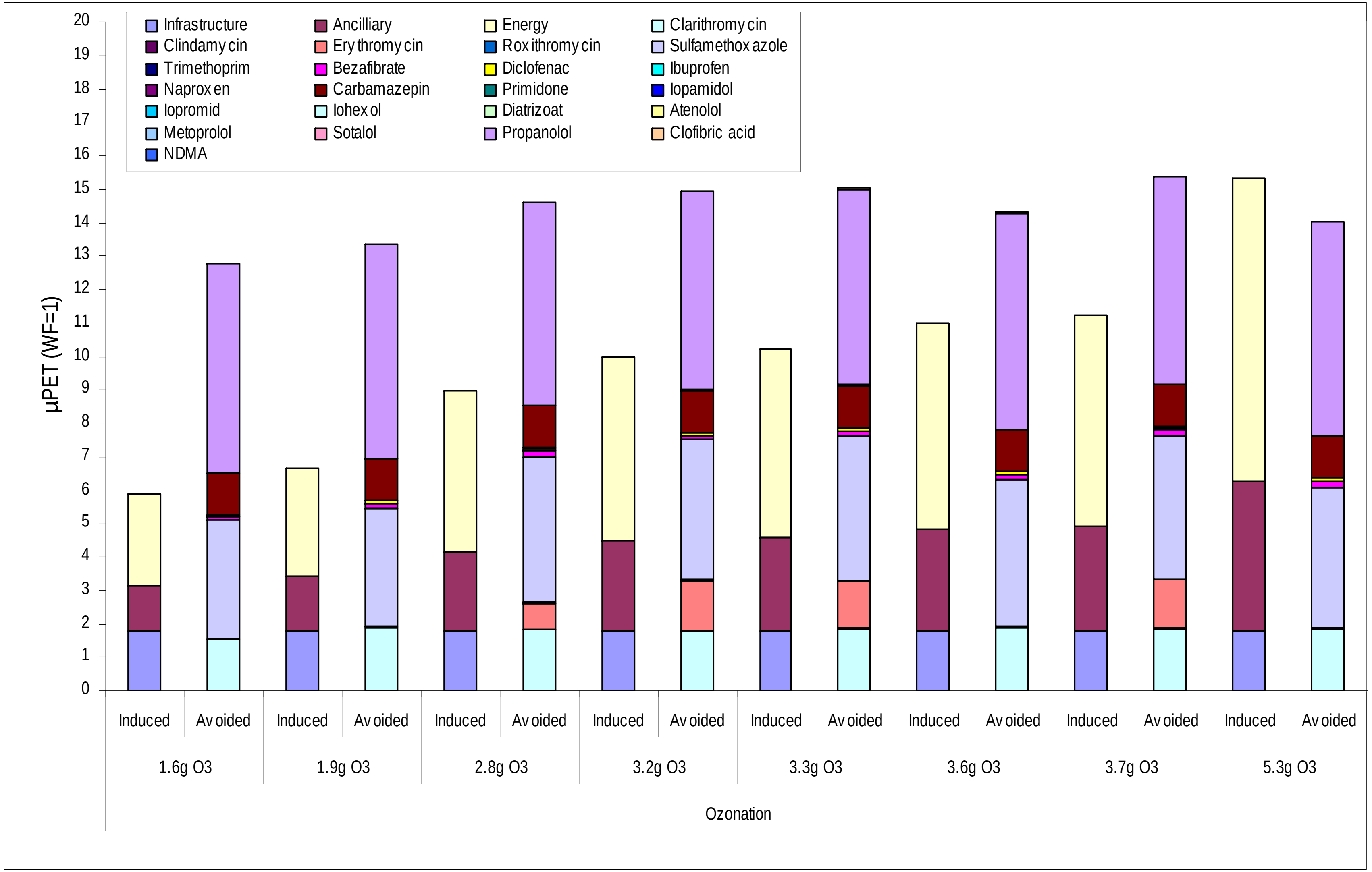


Avoided: 14,6 µPET/m3

Induced: 8,9 µPET/m3

Environmental sustainability profiles; ozonation

(22 micropollutants; weighting factor = 1 for all impact categories)



Environmental sustainability profiles; ozonation

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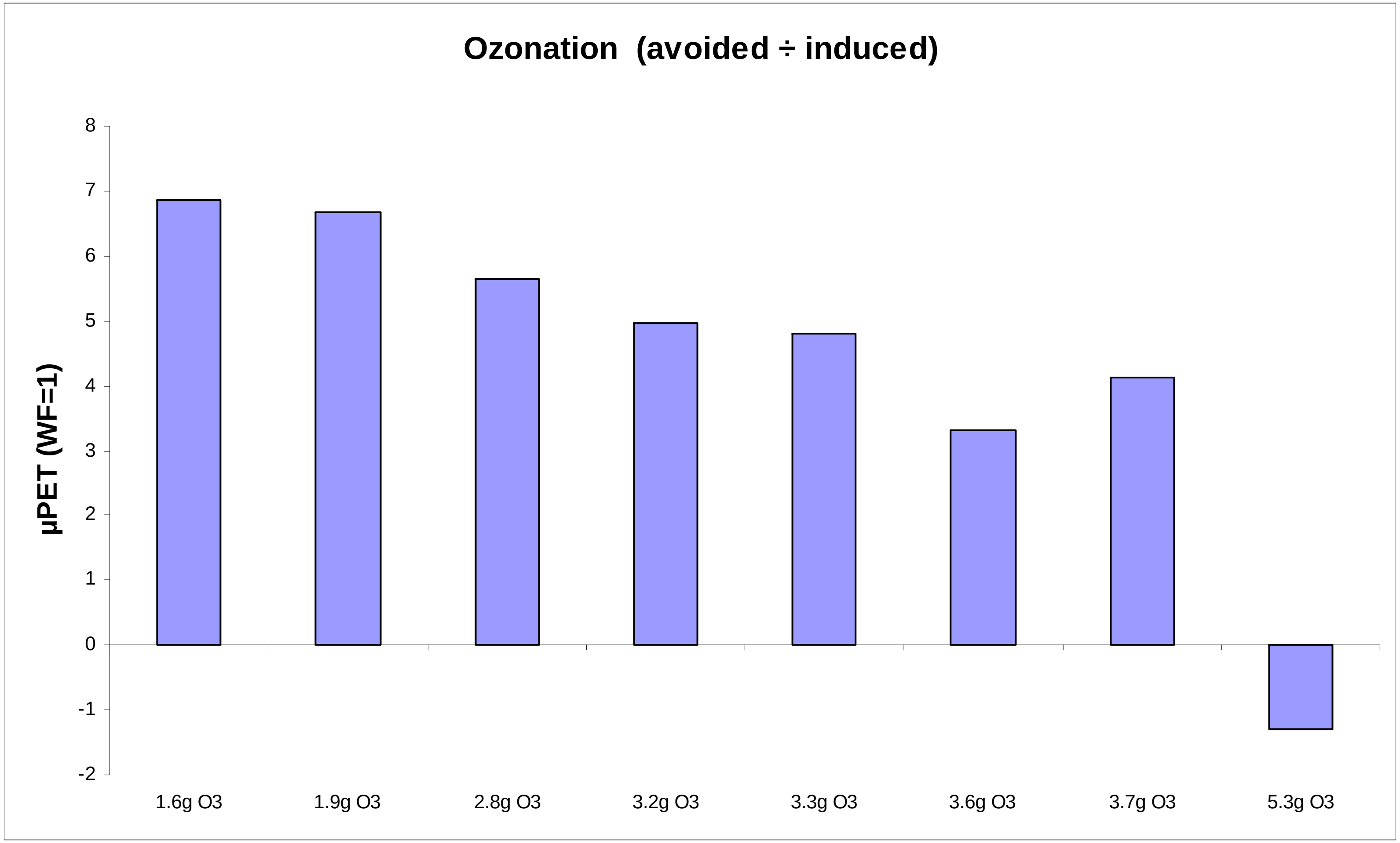

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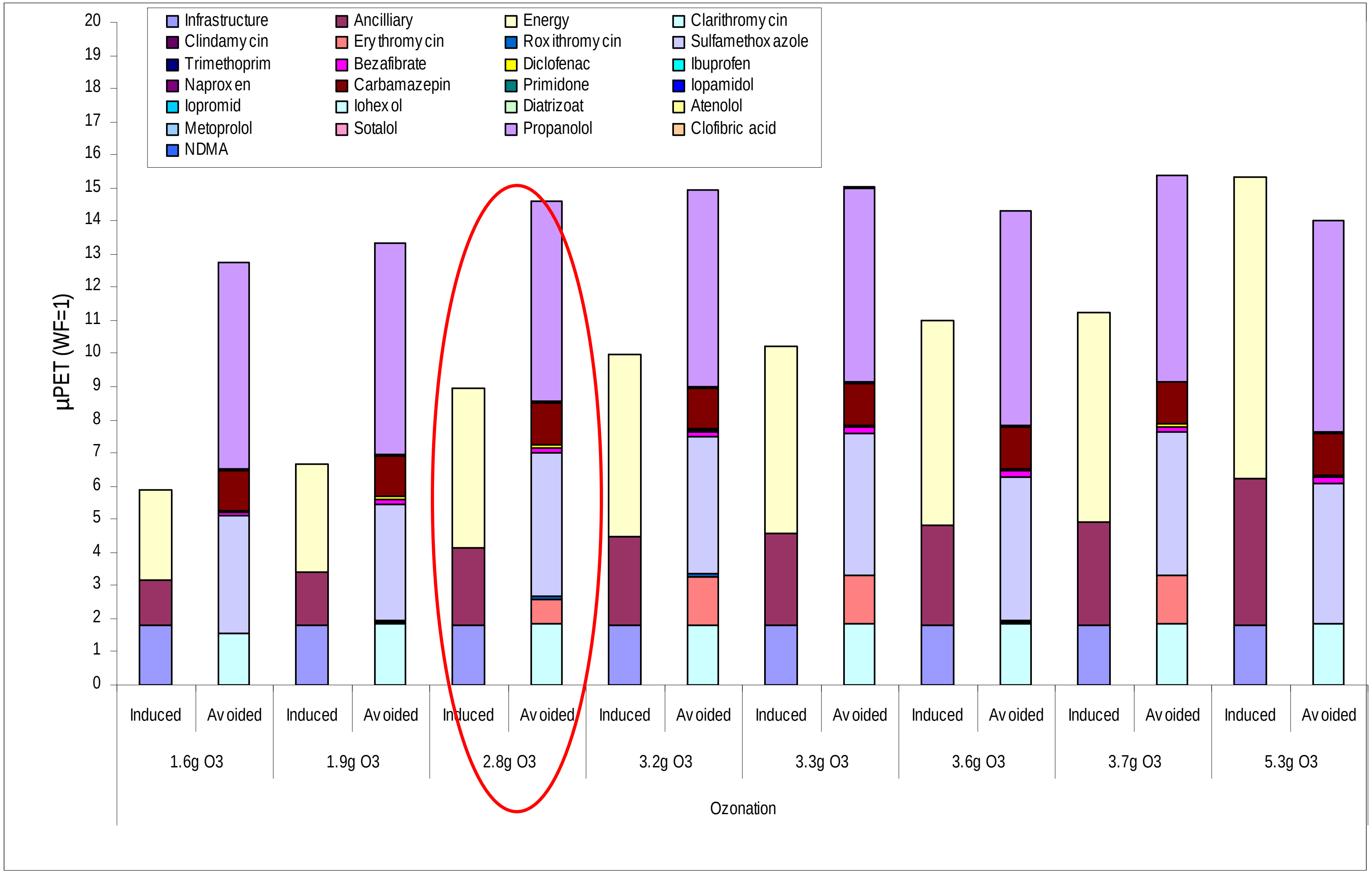
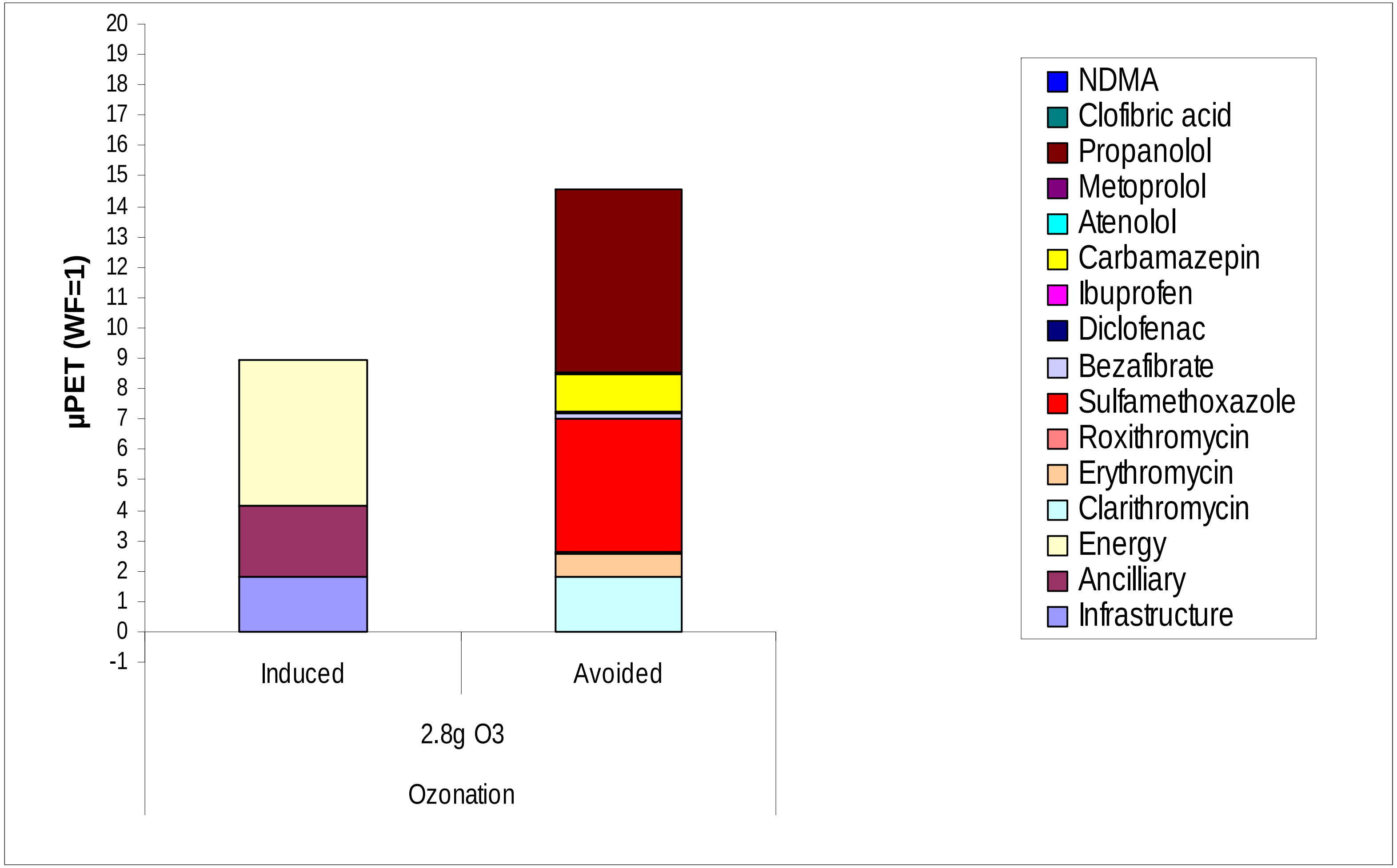


Environmental sustainability profiles; ozonation

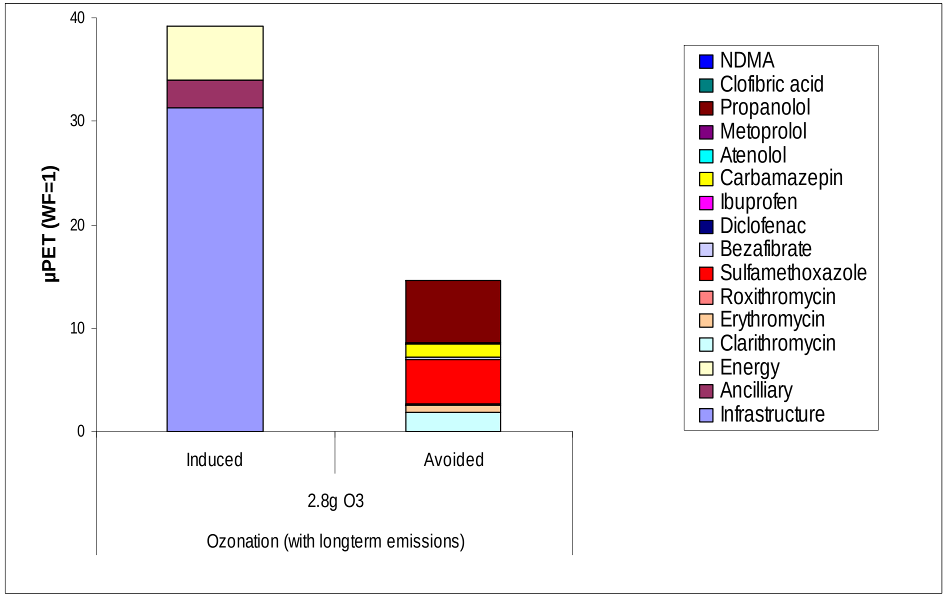
(22 micropollutants (only significant ones shown); weighting factor = 1 for all impact categories)



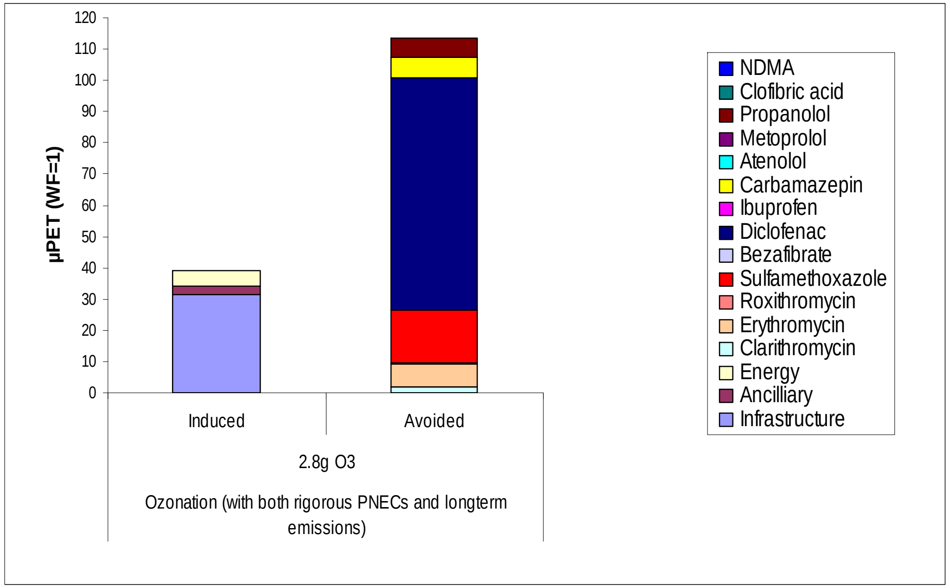
Environmental sustainability profiles; ozonation

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

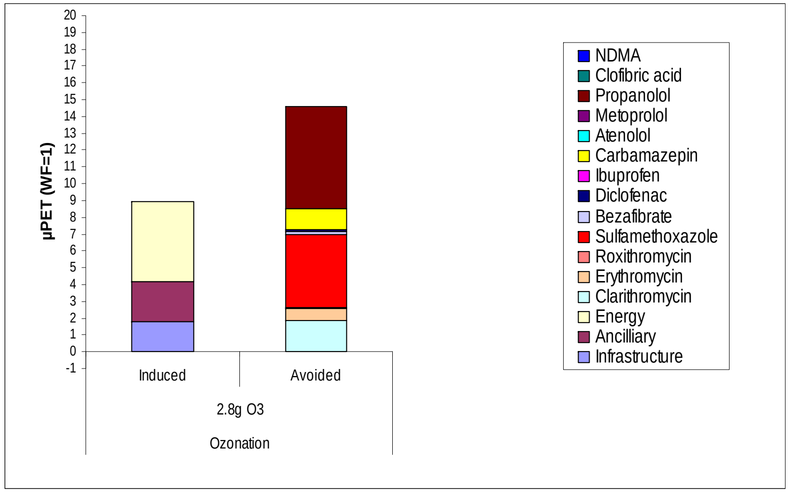
Including longterm emissions



Including both longterm emissions and rigorous PNECs

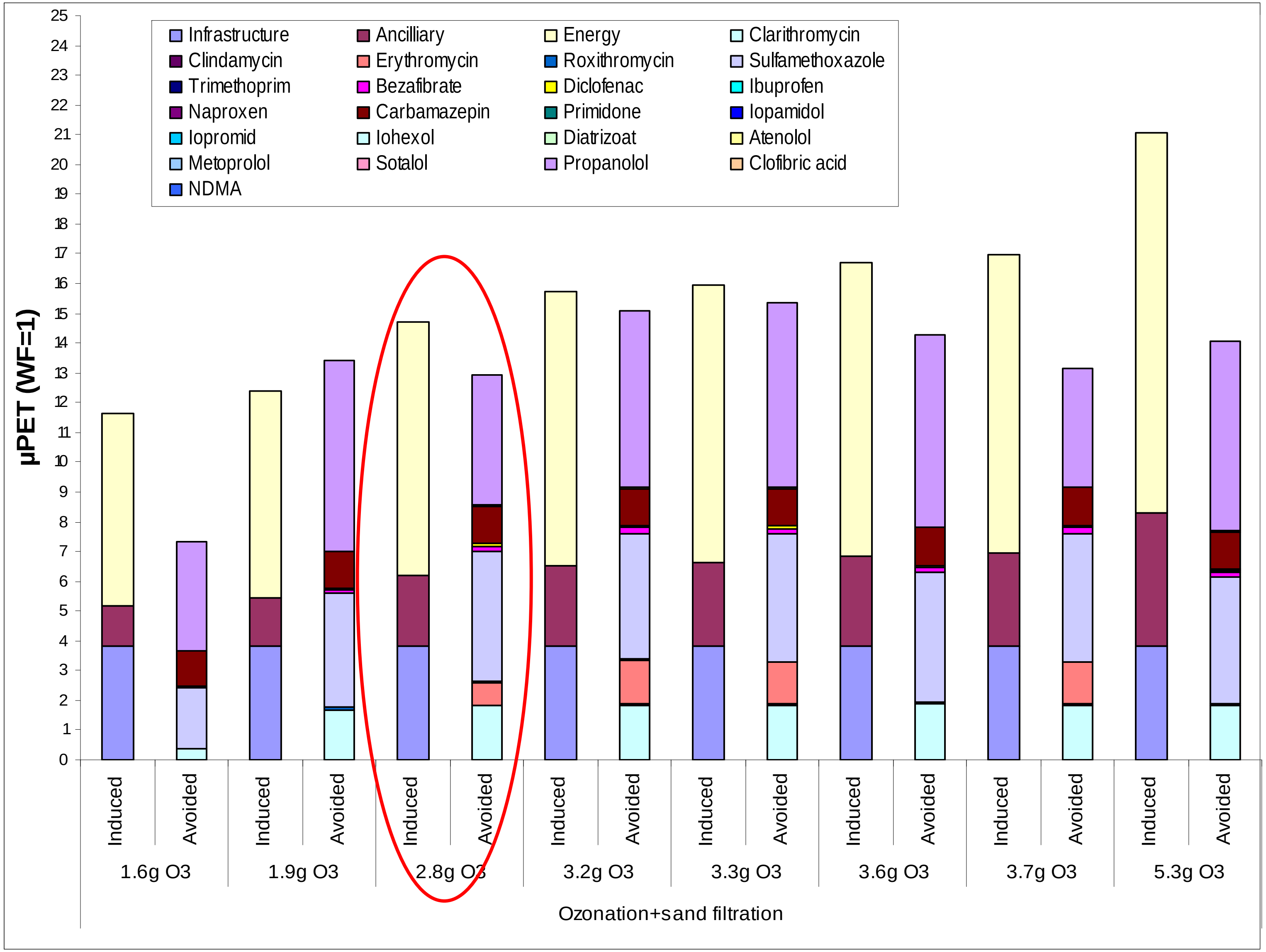


No longterm emissions, no rigorous PNECs



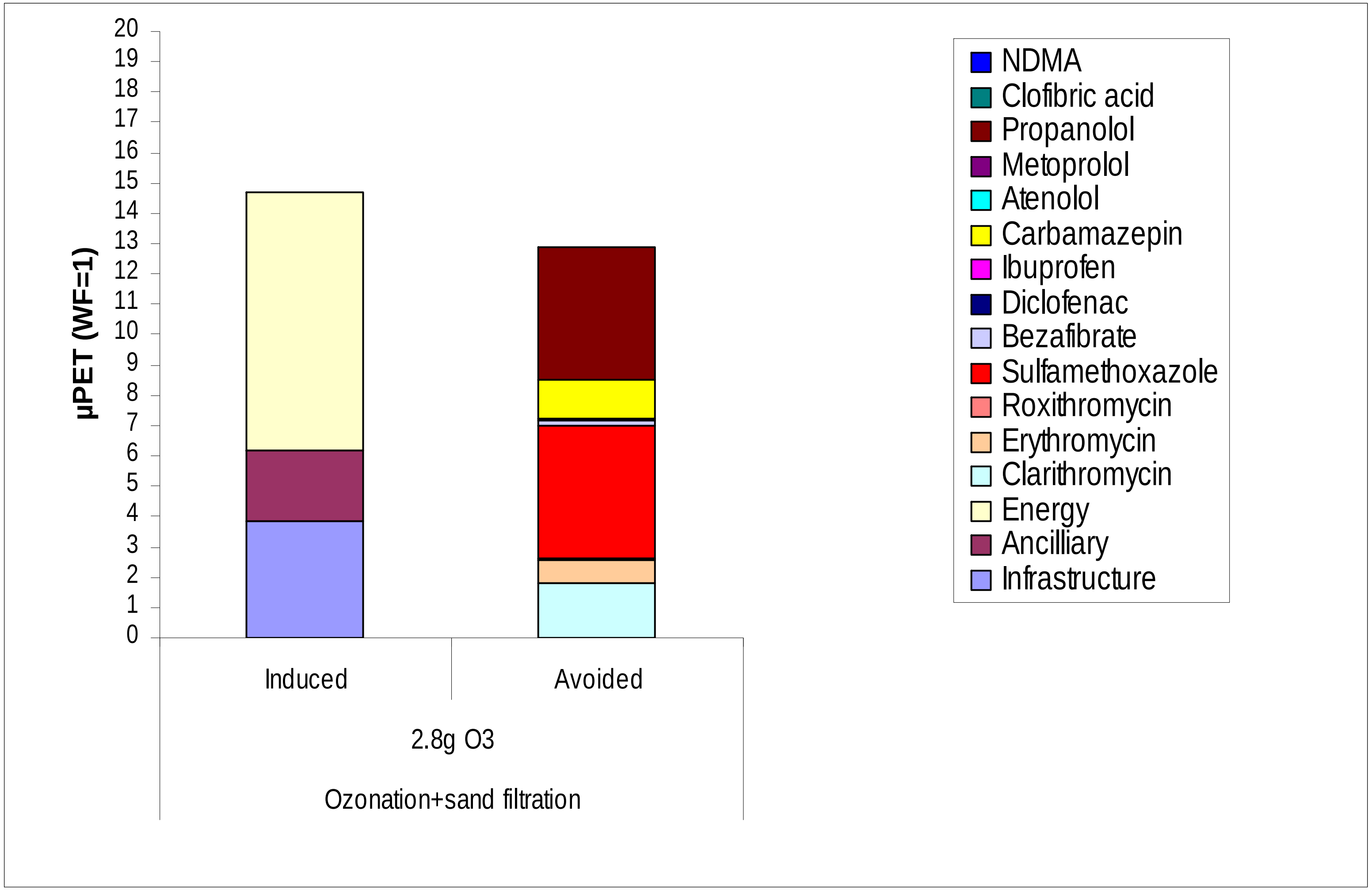
Environmental sustainability profiles; ozonation + sand filtration

removal of aldehydes and WET (22 micropollutants; weighting factor = 1 for all impact categories)



Environmental sustainability profiles; ozonation + sand filtration

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



Effect of including more micropollutants

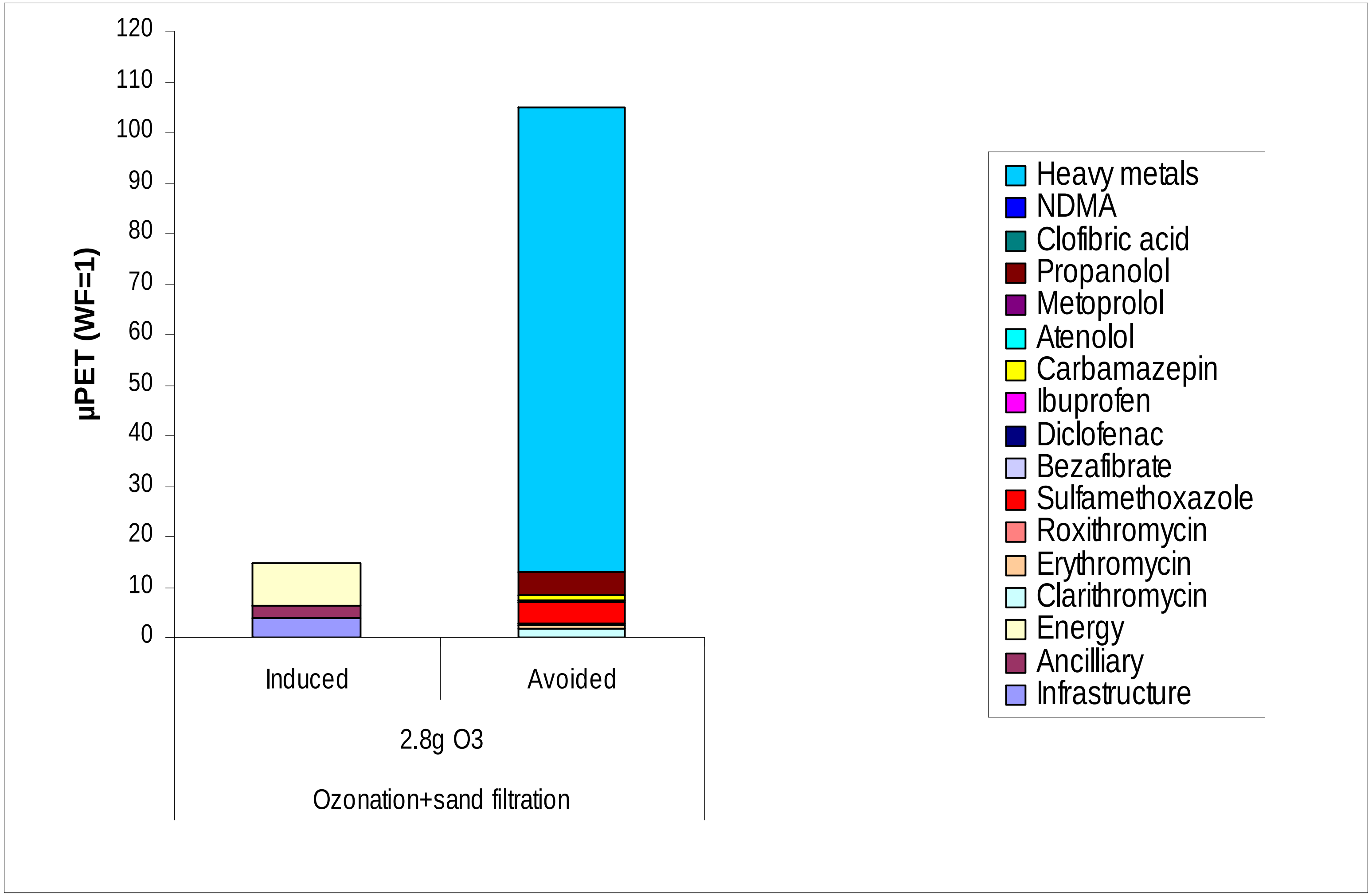
ozonation + sand filtration

	Secondary effluent	After sandfiltration	Removal rate
Total suspended solids TSS (mg/L)	8	2	0,75

	mg/kg TSS in secondary sludge
Cd	0,33
Hg	0,74
As	14
Ni	21
Cr	56
Pb	100
Cu	270
Mn	480
Zn	530

Environmental sustainability profiles; ozonation + sand filtration

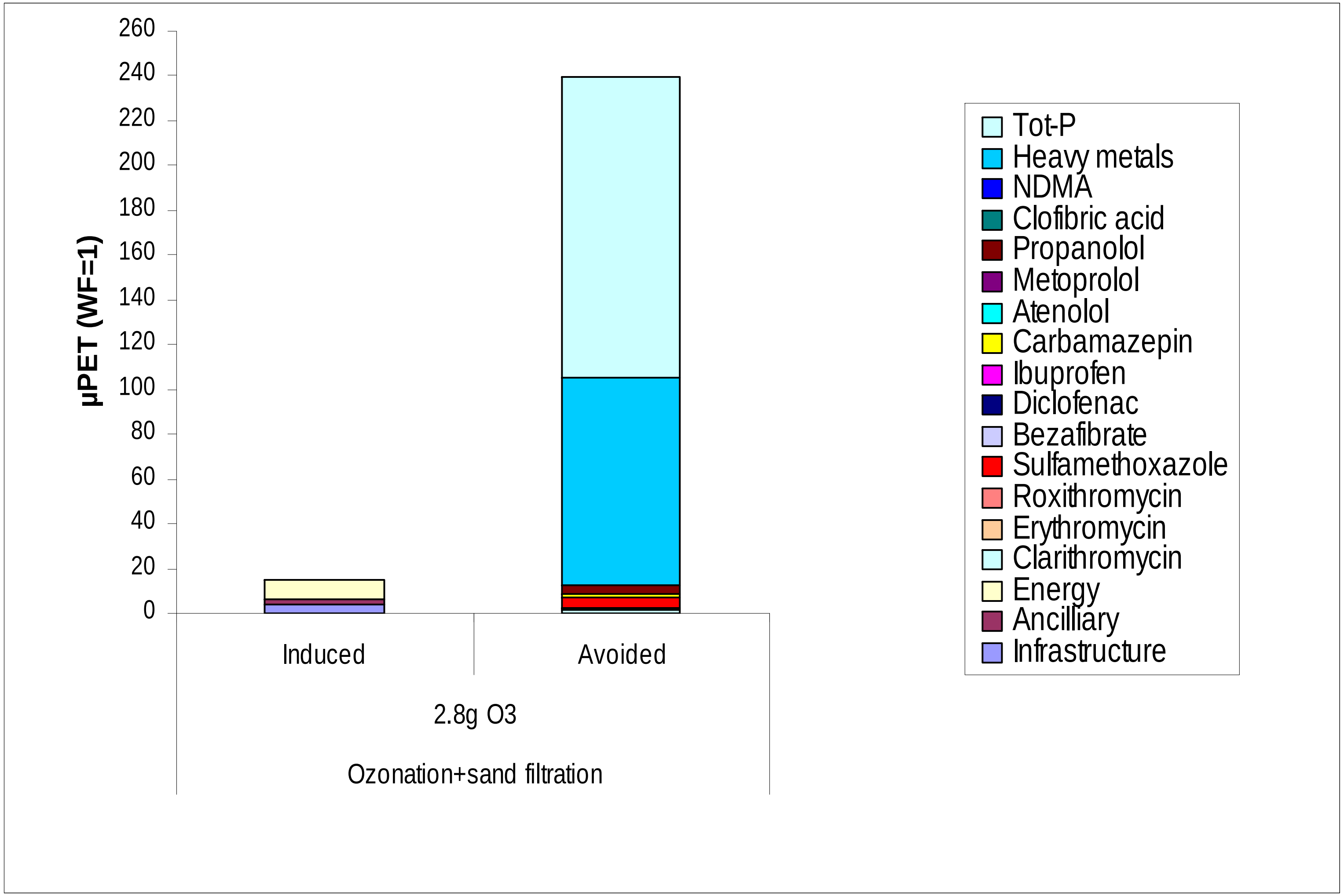
(**31** micropollutants (only significant ones shown); weighting factor = 1 for all impact categories)



Environmental sustainability profiles; ozonation + sand filtration

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

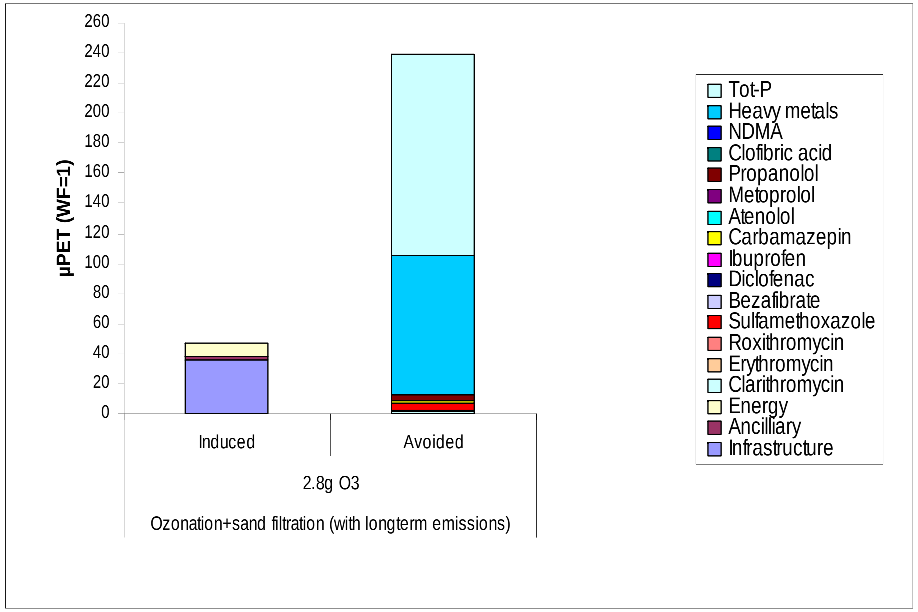
	Secondary effluent	After sandfiltration	Removal rate
Tot-P (mg/l)	0,8	0,3	0,625



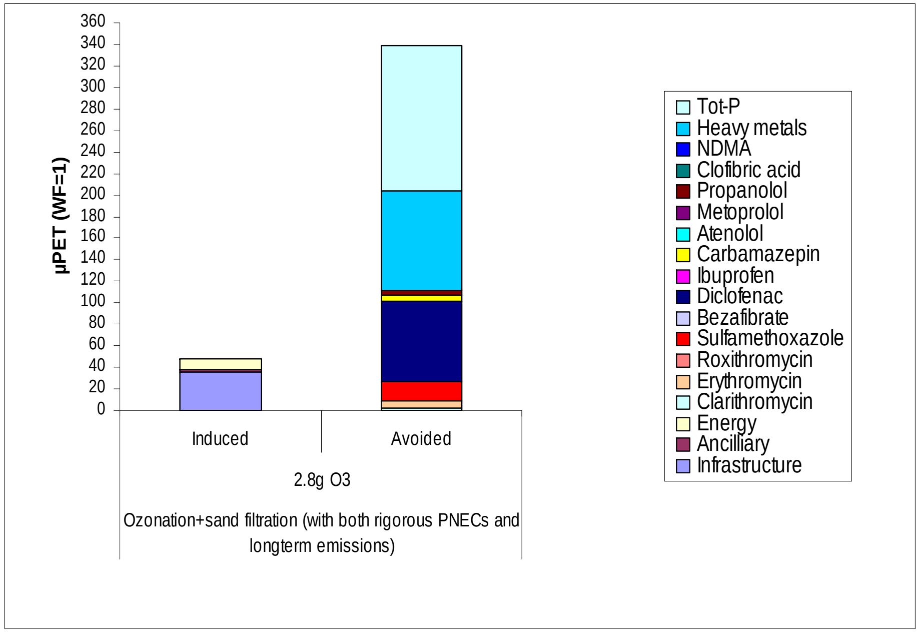
Environmental sustainability profiles; ozonation + sand filtration

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

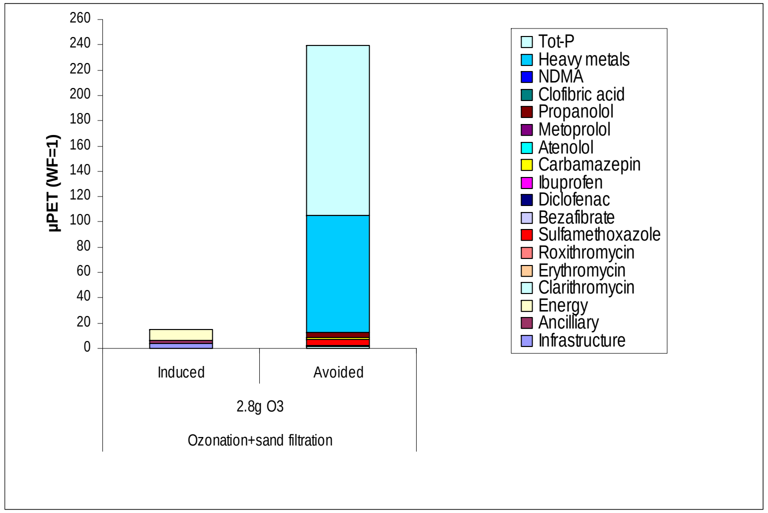
Including longterm emissions



Including both longterm emissions and rigorous PNECs



No longterm emissions



Conclusions and further research

Conclusions

- ✓ Based on the given assumptions results indicate that ozonation used for removal of organic micropollutants most probably is environmentally sustainable, i.e. avoided potential impacts are higher than induced potential impacts
- ✓ However, problems with whole effluent toxicity and aldehydes
- ✓ Including sand filtration (removal of heavy metals and tot-P) significantly improves the sustainability profile
- ✓ Focusing on global warming a weighting factor of at least 30 – 45 is needed in order to reach a break-even between induced and avoided impacts for ozonation combined with sand filtration

Improvements/further research

- ❖ Including more micropollutants
- ❖ Including pathogens
- ❖ Improving the methodology on longterm emissions
- ❖ Including new methodology on the ecotoxicity impact category (average toxicity, PAF)
- ❖ Including economy (cost-efficiency)

Thank you for your attention

Acknowledgment

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