Eawag:
Swiss Federal Institute of Aquatic
Science and Technology

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aquatic research

Progress made and challenges in abatement technologies for municipal wastewater: the Swiss case

Christa S. McArdell
christa.mcardell@eawag.ch

with input Juliane Hollender

Norman / AQUAlity workshop, 6 March 2019, Paris, France

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The new Swiss Water Protection Act in force since January 2016

- ✓ Abatement of micropollutants by 80% in selected WWTPs
- ✓ Implementation until 2040

- Driving forces
- Effects of micropollutants
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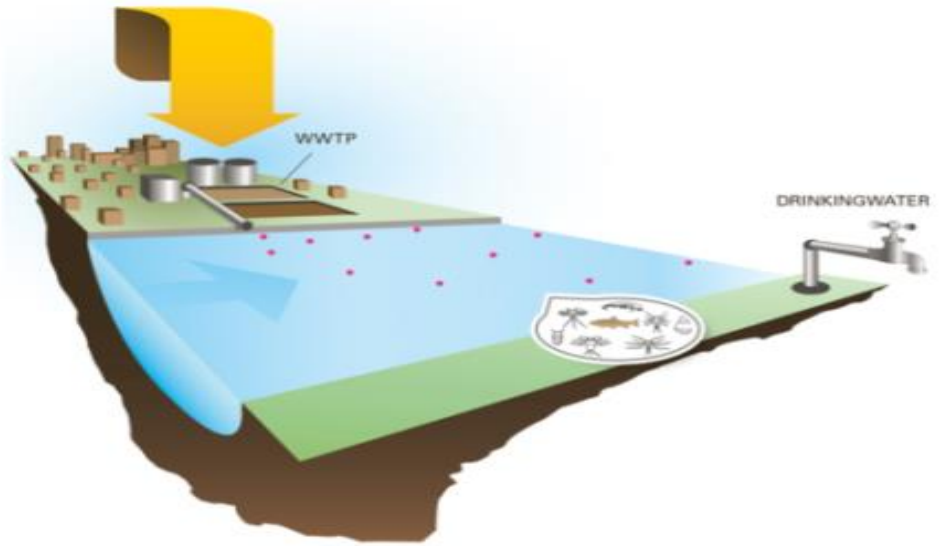
- Evaluation of performance
- Example ozonation at WWTP Neugut



Eggen et al. ES&T (2014) 48, 7683

Implementation of water protection act

Locations with exceedance of chronic quality standard

Protection of drinking water resources (precautionary principal)

Responsibility as «up-stream» country

➢ The Swiss government decided: There is need for action

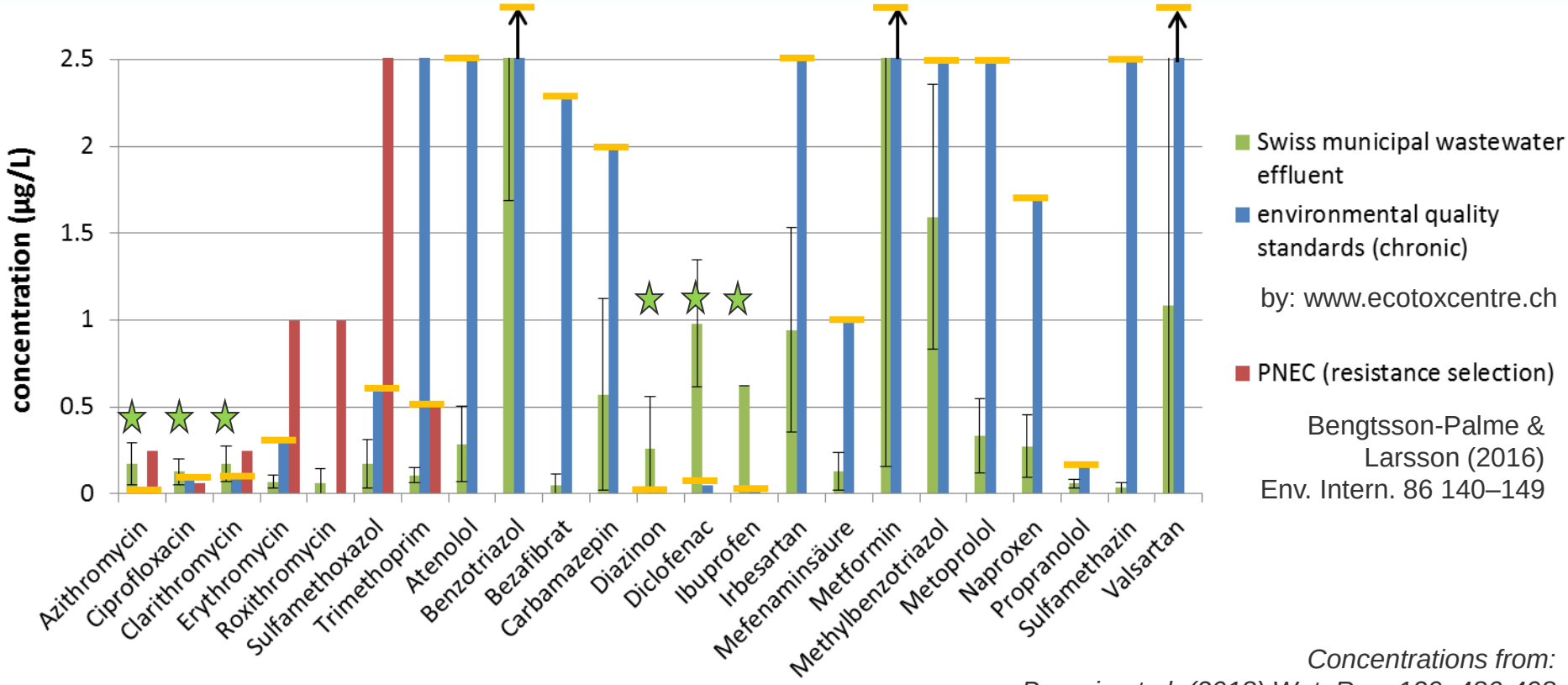
- 10 year process
- Pilot tests (project Micropoll) => basis for decision finding
- Collaboration with authorities and all relevant stakeholders
- Two public consultations
- «willingness to pay»:

Cost-Benefit Analysis of the Swiss National Policy on Reducing Micropollutants in Treated Wastewater

Logar et al. ES&T (2014) 48, 12500−12508

- Pragmatic approach for evaluation:
  Abatement of 12 indicator substances

Effects of urban micropollutants

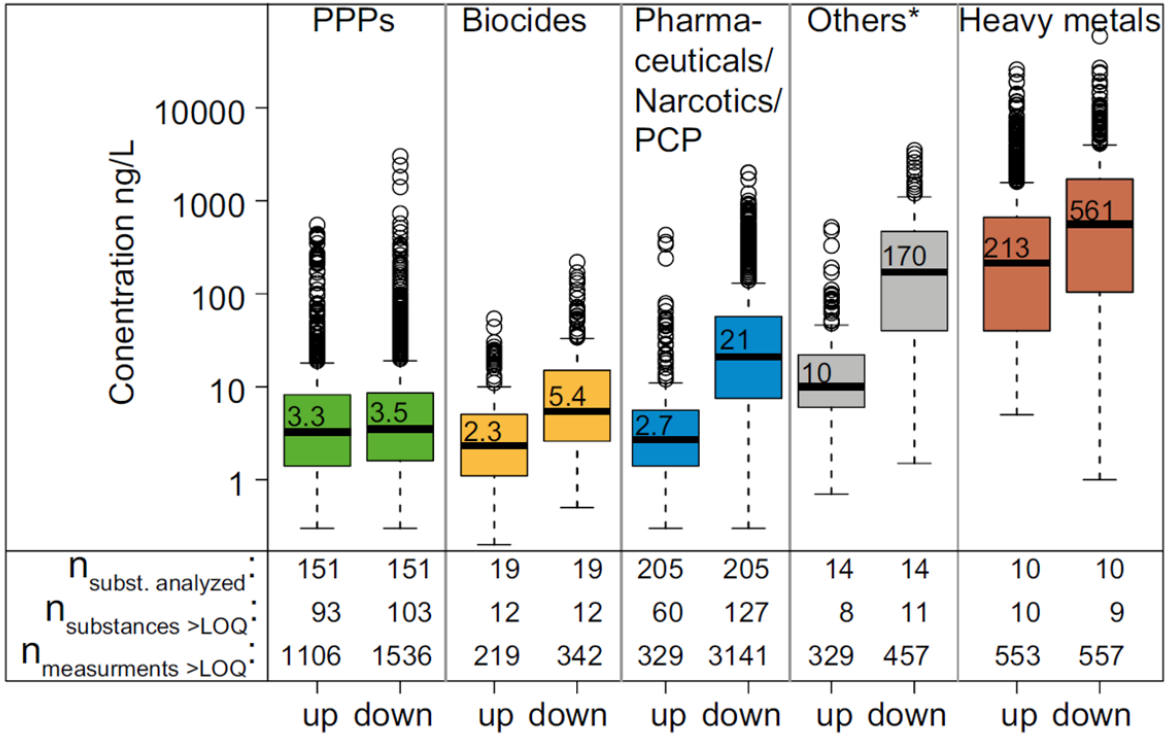


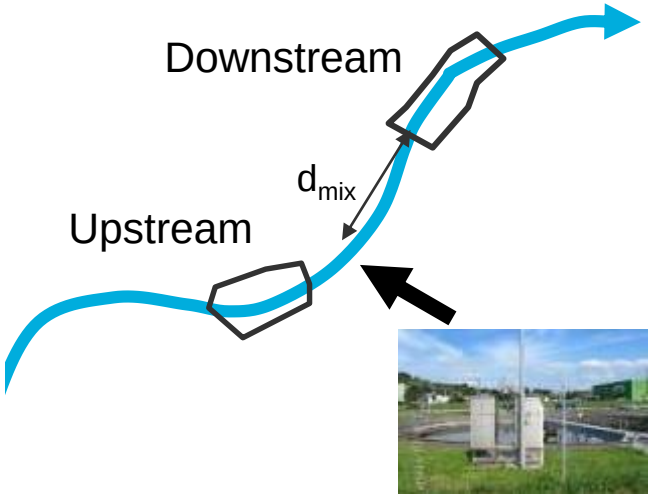
★Substances for which chronic quality standards are exceeded

Concentrations from:
Bourgin et al. (2018) Wat. Res. 129, 486-498
Otto et al. Fachbericht Eawag (2014)

Chemical exposure in river water determined with online-SPE-LC-HRMS/MS

- Online-SPE-LC-HRMS/MS analysis
- 257 of 389 substances detected





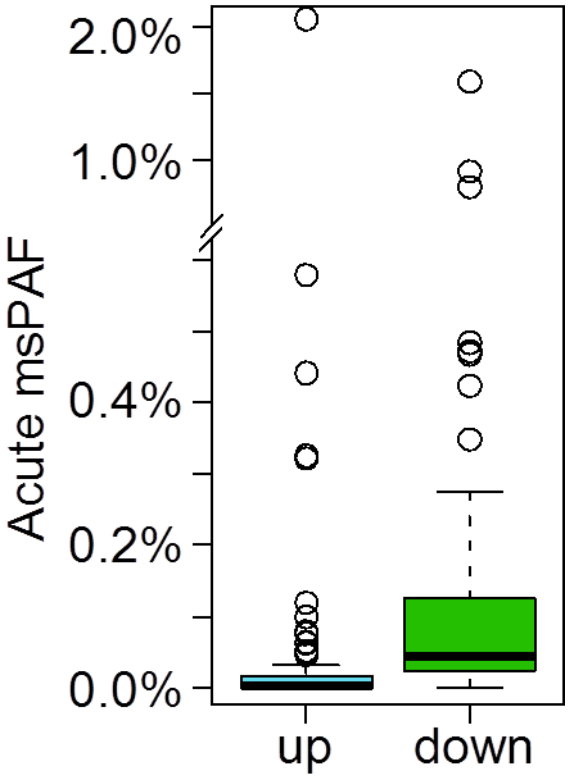
24 WWTPs:

- no WWTP upstream
- >20% wastewater downstream

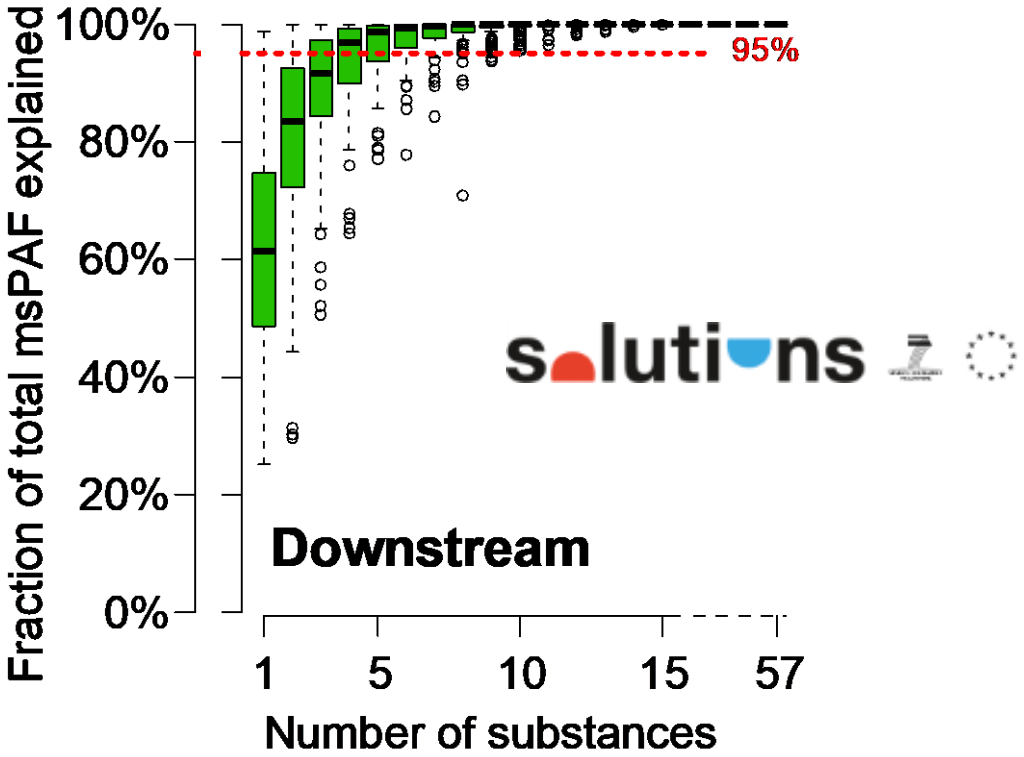
www.ecoimpact.ch
Munz et al. 2017,
Wat Res 110, 366-377
Slide courtesy Juliane Hollender

Risk assessment:

msPAF – multi-substance Potentially Affected Fraction of species



Number of substances explaining the risk:

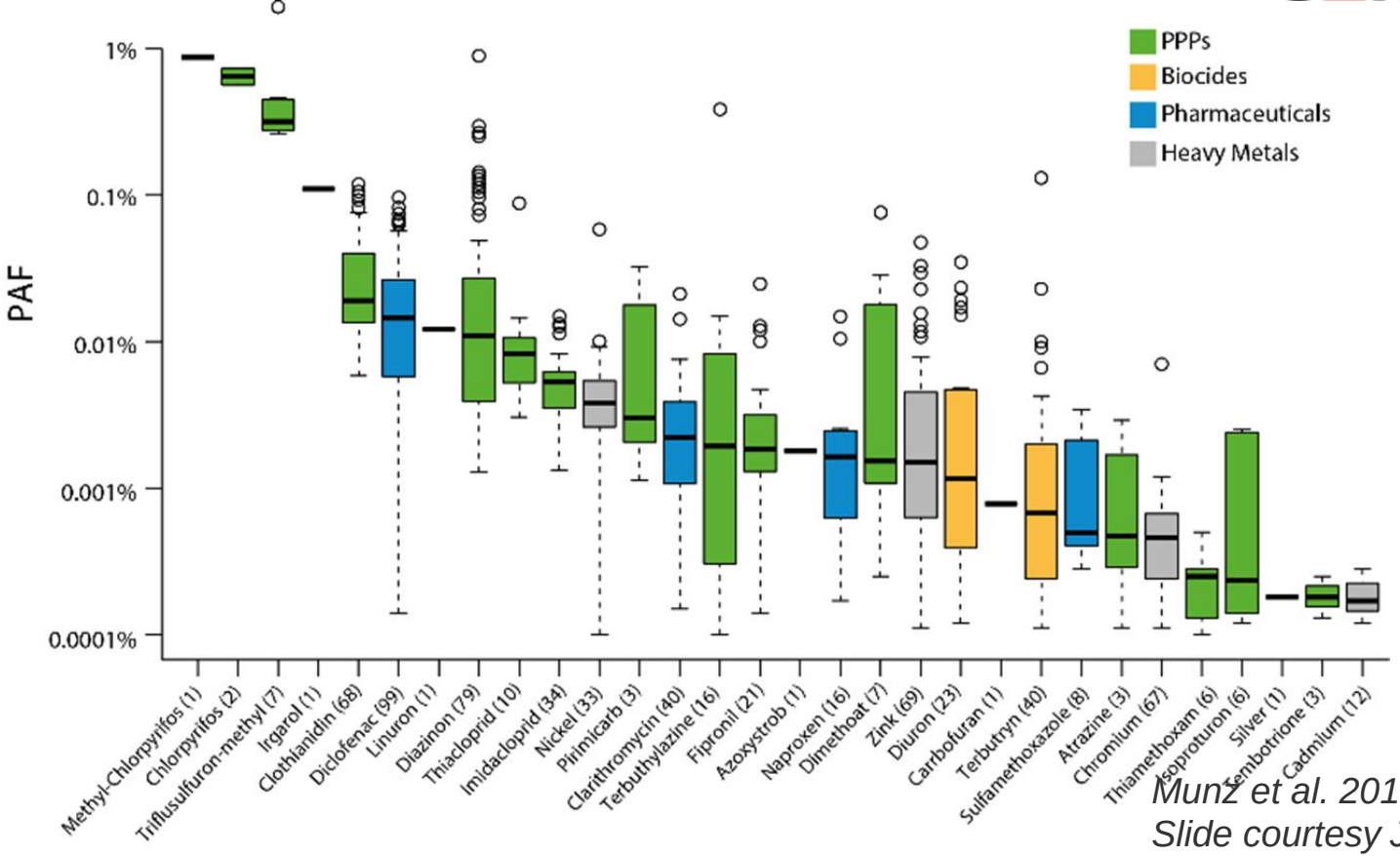


➢ **Only a few substances drive overall risk**

Munz et al. 2017, Wat Res 110, 366-377
Slide courtesy Juliane Hollender

Risk drivers

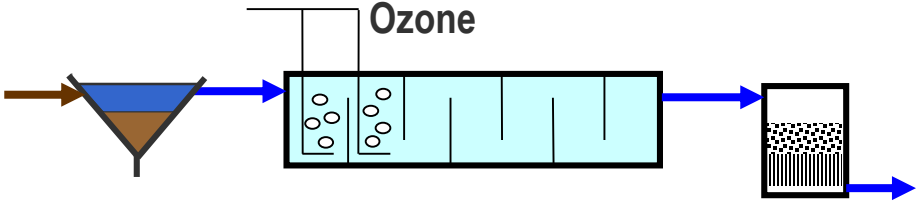
…are mainly pesticides and diclofenac



Munz et al. 2017, Wat Res 110, 366-377
Slide courtesy Juliane Hollender

Economic technological options

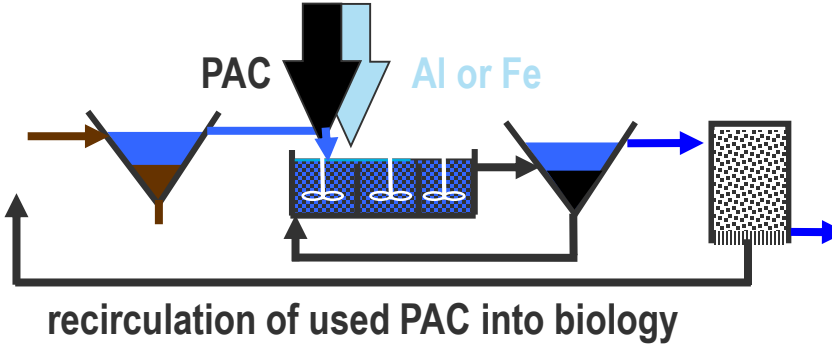
Ozonation



- Has relatively small footprint
- biologically active post-treatment (sand filter) is needed to reduce potentially toxic biodegradable reaction products
- Ozone consumption increases with increasing DOC and nitrite content
- Not suitable for every wastewater (test)

Schindler Wildhaber et al. Wat Res. 2015, 75, 324

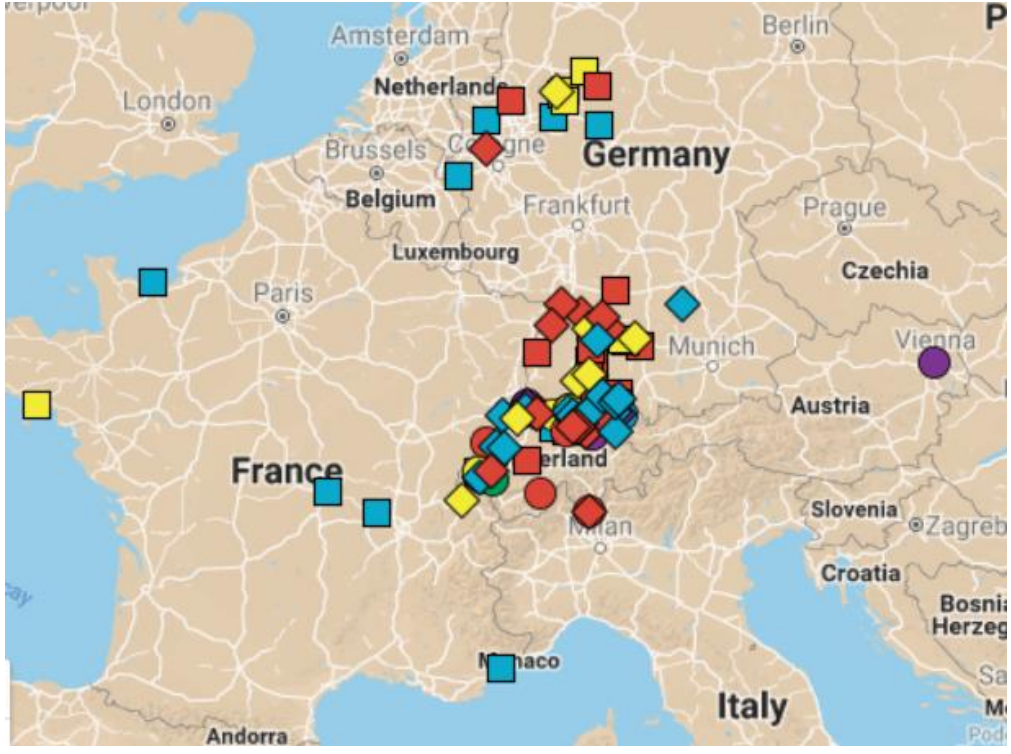
powdered activated carbon



- Larger footprint
- Co-occurring DOC removal
- recycling PAC to biology reduces PAC consumption ➔ capacity in biology needed
- PAC is incinerated with excess sludge
- new projects to produce regional biochar

Platform of VSA (Swiss Water Association)

VSA platform «Process Engineering Micropollutants» (www.micropoll.ch): knowledge sharing, acting as an interface between research and practice



Ozonation
ferrate
PAK
combination
GAK

- Running
- Under construction
- Study

Running as of March 2019:

Country	PAC	GAC	Ozone
Switzerland	4	1	4
Germany	14	4	4
France	-	-	4
Total	**18**	**5**	**12**

Requirements for new technologies

- Other technologies are possible
- Abatement of MPs by 80%
- No formation of problematic transformation products

Plattform „Verfahrenstechnik Mikroverunreinigungen“
www.micropoll.ch

VSA

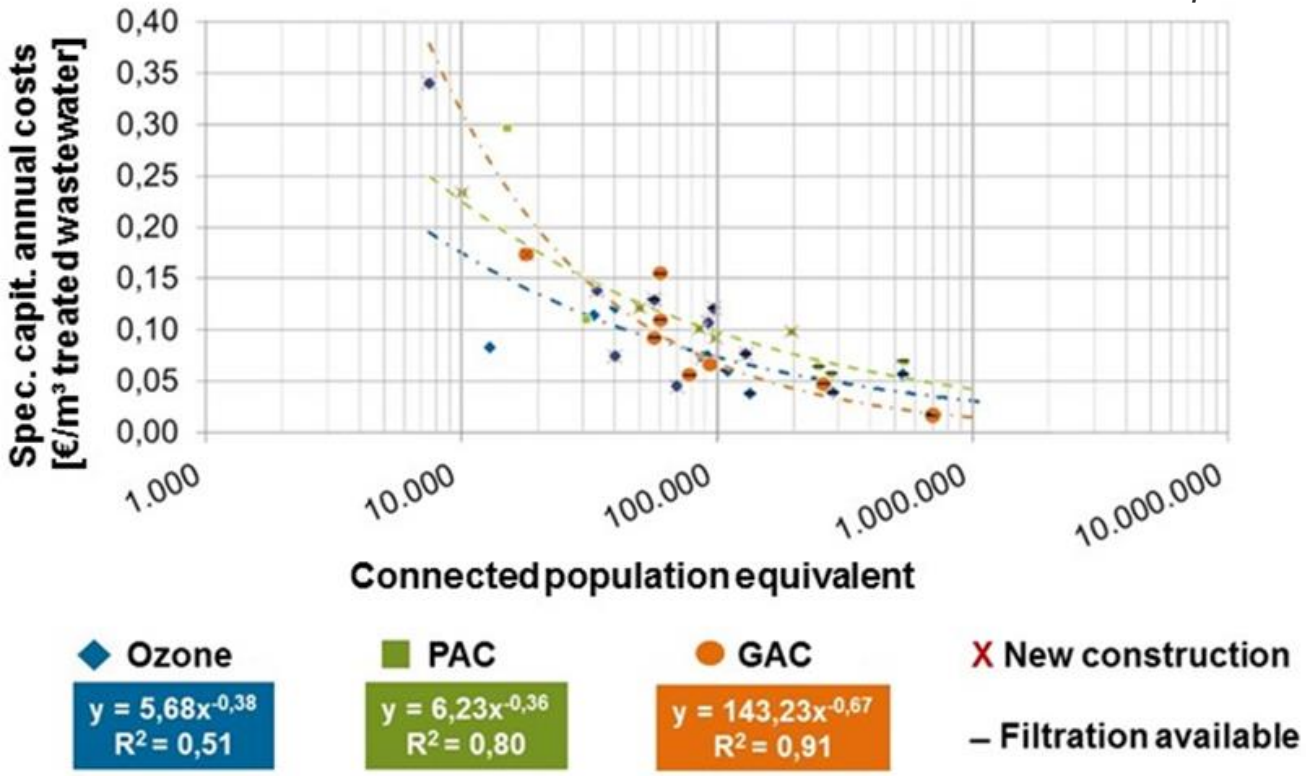
Anforderungen an neue Verfahren zur Spurenstoffelimination auf ARA in der Schweiz

- Minimizing additional discharge of solids (e.g. PAC)
- Large-scale experiments at differing operating conditions at a municipal WWTP
- Pilot scale experiments must be accompanied scientifically, stakeholders are actively involved, authorities and VSA are informed
- Transparent and comprehensible documentation
- Economics competitive to ozonation / AC

Economics

Specific capital annual costs of advanced treatment

Antakyali D. 2017, kompetenzzentrum-mikroschadstoffe.NRW



Rizzo et al. 2019, STOTEN 655, 986–1008

Evaluating effectiveness of measures: selection of 12 indicator substances

Substance	class	Elimination with ozone / PAC
Amisulpride	antipsychotic	Very good (>80%)
Carbamazepine	antiepileptic	Very good
Citalopram	antidepressant	Very good
Clarithromycin	macrolide antibacterial	Very good
Diclofenac	antiinflammatory / antirheumatic	Very good
Hydrochlorothiazide	diuretic	Very good
Metoprolol	beta blocking agent	Very good
Venlafaxine	antidepressant	Very good
Benzotriazole	corrosion inhibitor	good (50-80%)
Methylbenzotriazole	corrosion inhibitor	good
Candesartan	antihypertensive agent, angiotensin II antagonist	good
Irbesartan	dito	good/ Very good

Selection of four substances

Selection of two substances

Götz et al., AQUA&GAS (2015), 2, 34-40

Reasoning for selection of 12 substances

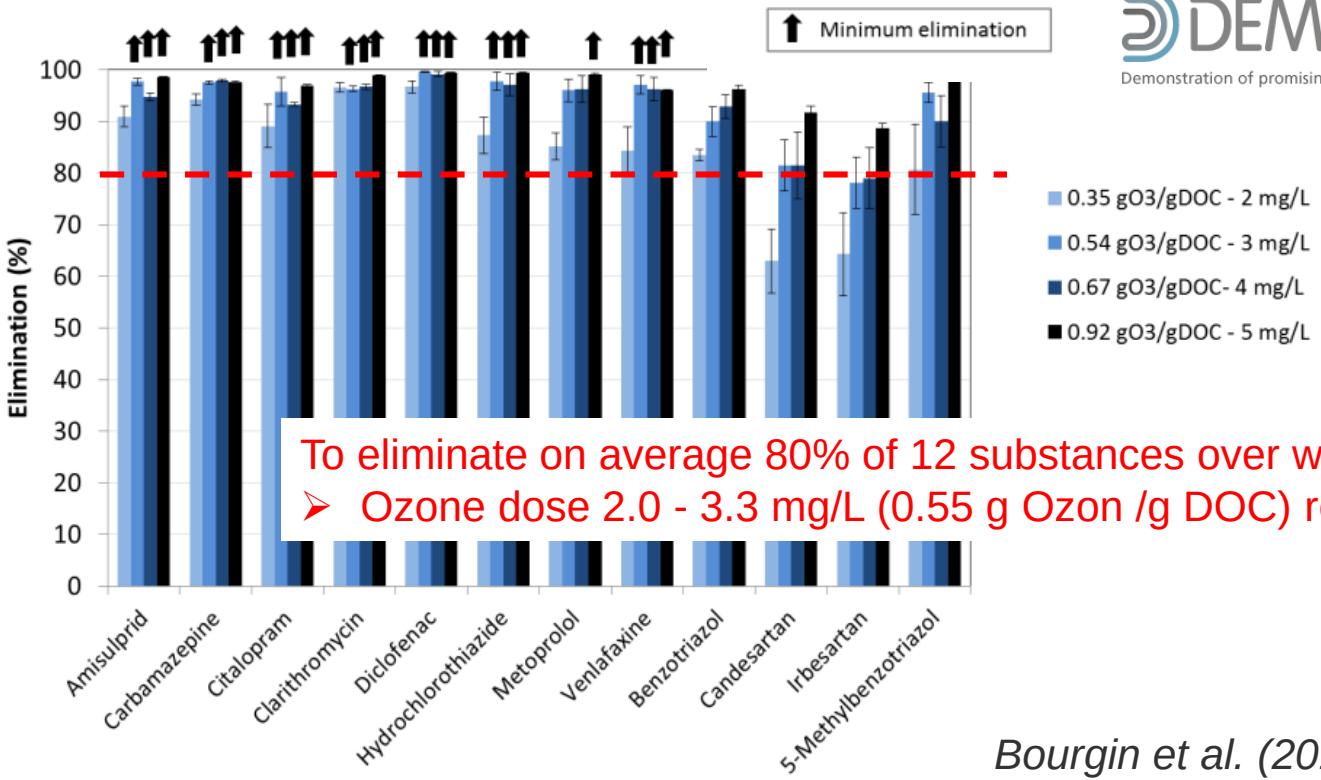
12 substances are **representative** for organic micropollutants
Not selected for their effect (but, e.g. hormones are also abated)

- Only parents compounds (no transformation products)
- Can be easily and routinely measured in one analytical method (at cantonal or private labs)
- Occurring in bigger WWTPs at measureable concentration (influent concentration 10x LOQ in effluent)
- Degraded to less than 50% in biological treatment
- Similar abatement in advanced treatment (not favoring ozone or AC)
- Continuous discharge into WWTP

➢ Mainly pharmaceuticals fulfill these criteria

Elimination of indicator substances

Ozonation at WWTP Neugut (first Swiss plant upgraded)



DEMEAU
Demonstration of promising technologies to address emerging pollutants in water and waste water

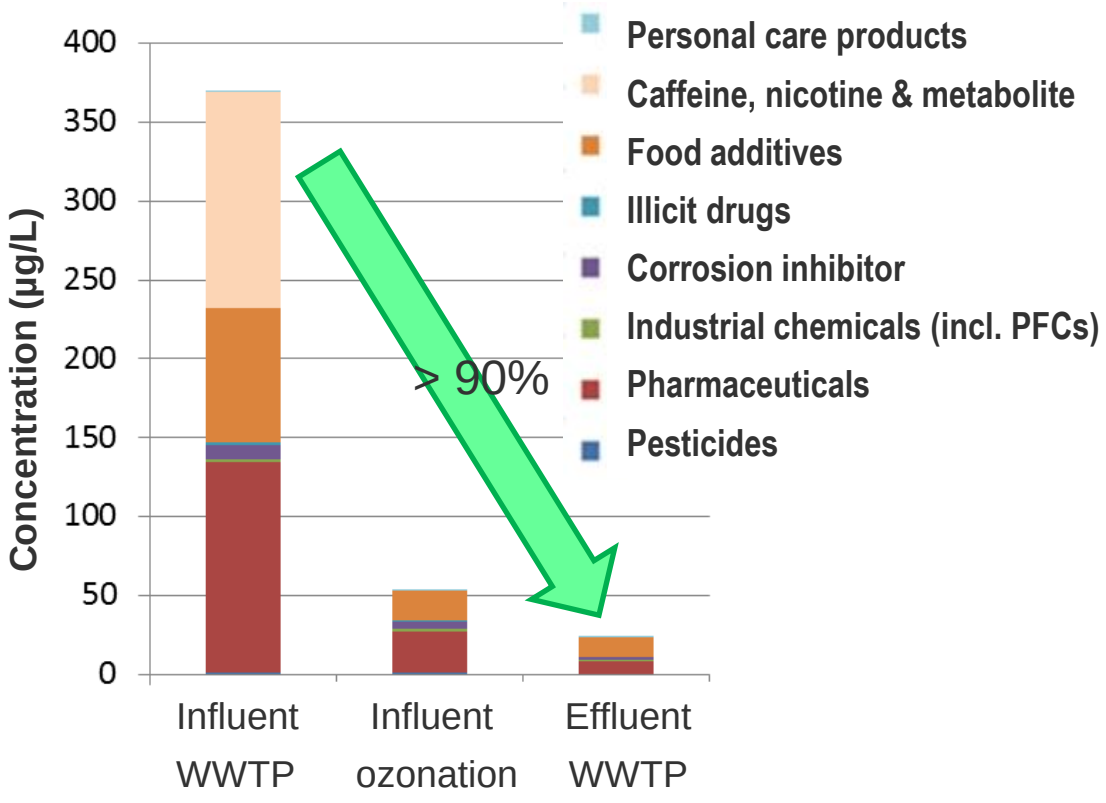
www.demeau-fp7.eu
(EU Grant no. 308339)

To eliminate on average 80% of 12 substances over whole plant:

- Ozone dose 2.0 - 3.3 mg/L (0.55 g Ozon /g DOC) recommended

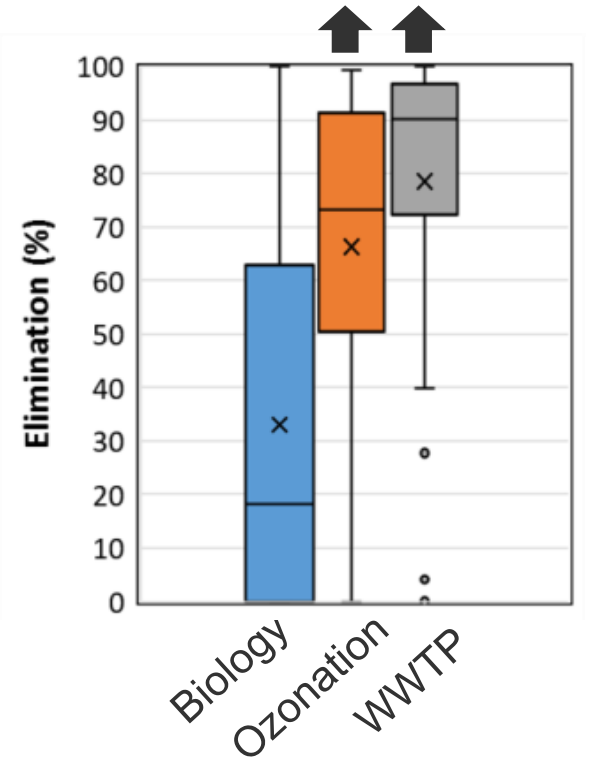
Bourgin et al. (2018) Wat. Res. 129, 486-498

Overall Elimination at WWTP Neugut



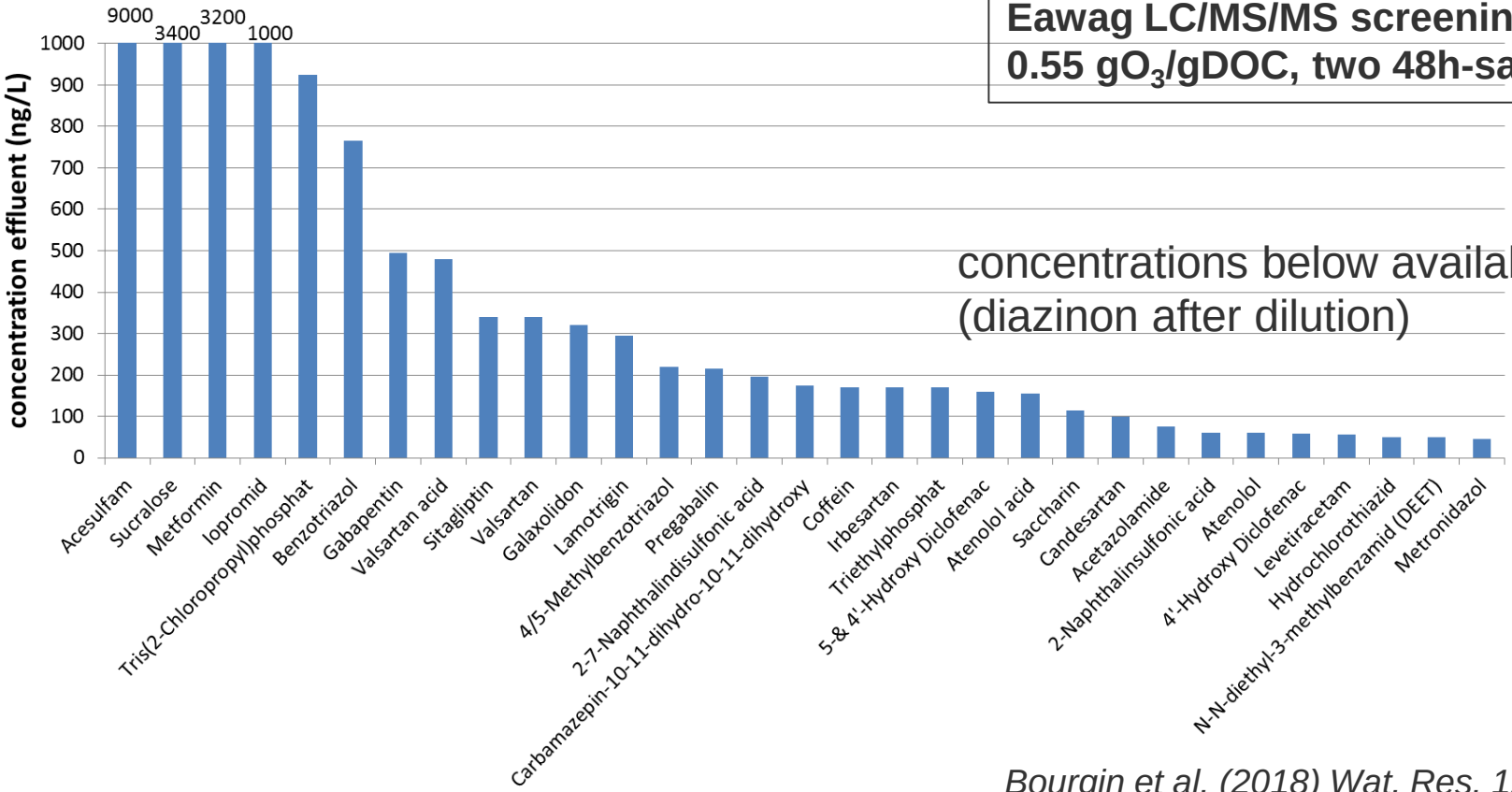
Bourgin et al. (2018) Wat. Res. 129, 486-498

Eawag LC/MS/MS screening (n=550)
0.55 gO_3/gDOC, two 48h-samples



Effluent concentrations at WWTP Neugut

Eawag LC/MS/MS screening (n=550)
0.55 gO_3/gDOC, two 48h-samples



concentrations below available EQS
(diazinon after dilution)

Bourgin et al. (2018) Wat. Res. 129, 486-498

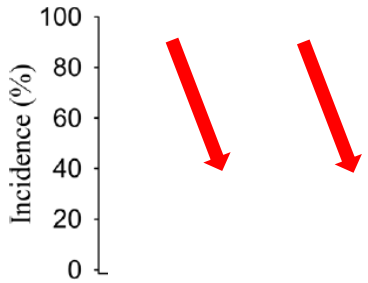
Well performing biological treatment

Advantage nitrification:
- Reduction of DOC (less ozone / carbon needed)
- no nitrite (less ozone needed)
- only minor MP elimination (30-50%), but can be crucial

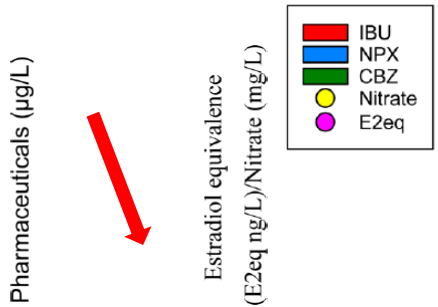
Falas et al. 2016, Wat. Res. 95, 240-249

Catchment Grand River, Canada, before and after upgrade with nitrification

Intersex incidence in male rainbow fish:



WWTP effluent characteristics:



Hicks et al. 2017, ES&T 51, 1811−1819