Prioritisation of chemicals and effects in waste-water effluents for improved mitigation measures

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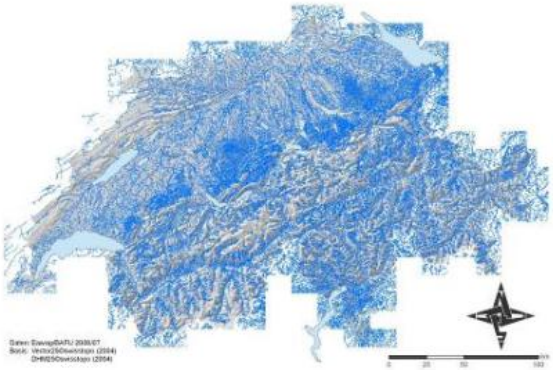
Content

Project «Strategy Micropoll» :

- Financed by the Swiss Federal Office for the Environment, 2006-12
- Micropollutants from treated wastewater
- Feasible approach for practice in Switzerland

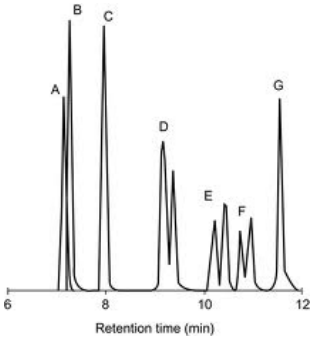
Where?

Situation analysis



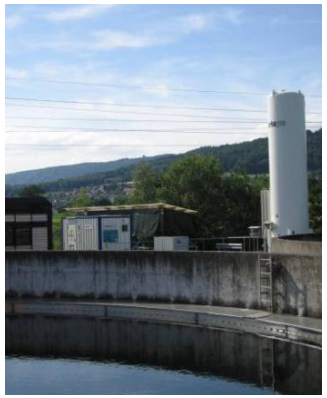
Which substances?

Assessment of substances



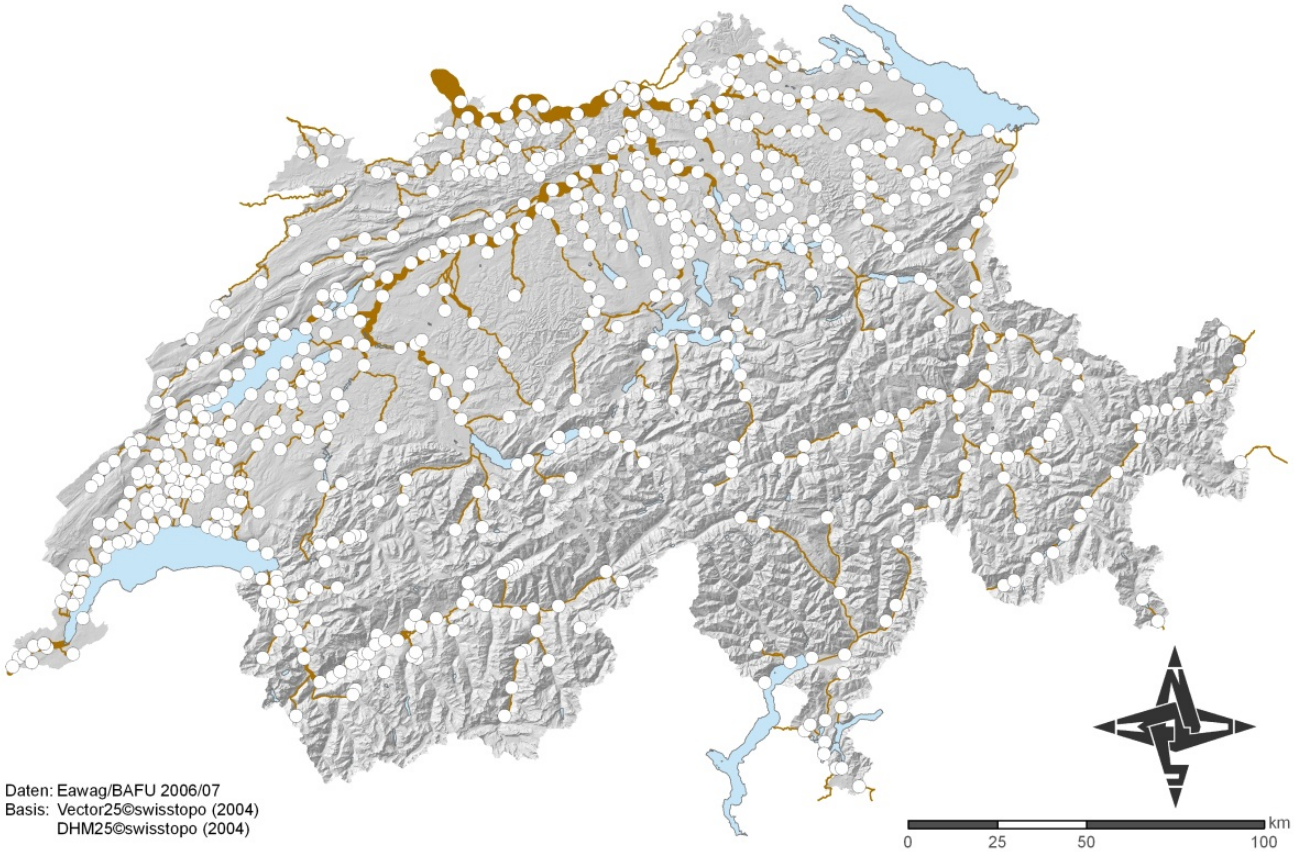
Which measures?

Measures



Situation analysis: Mass Flow Model

Switzerland
~6‘000 km river stretches containing treated wastewater,
742 wastewater treatment plants (>500 PE)
>14‘000 digitized stretches

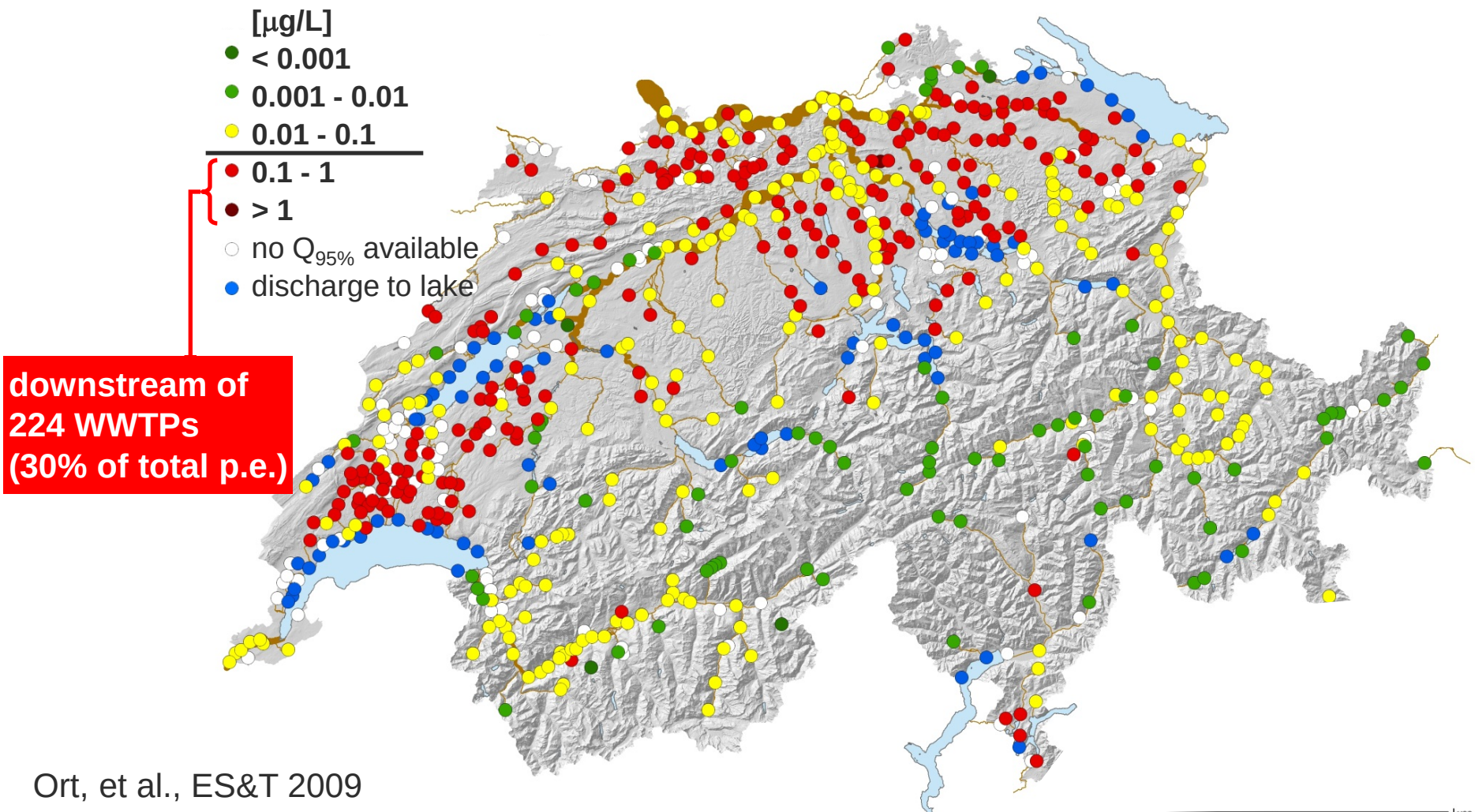


Ort, et al., ES&T 2009

Diclofenac in Rivers including metabolites, modeled at base flow $Q_{95\%}$

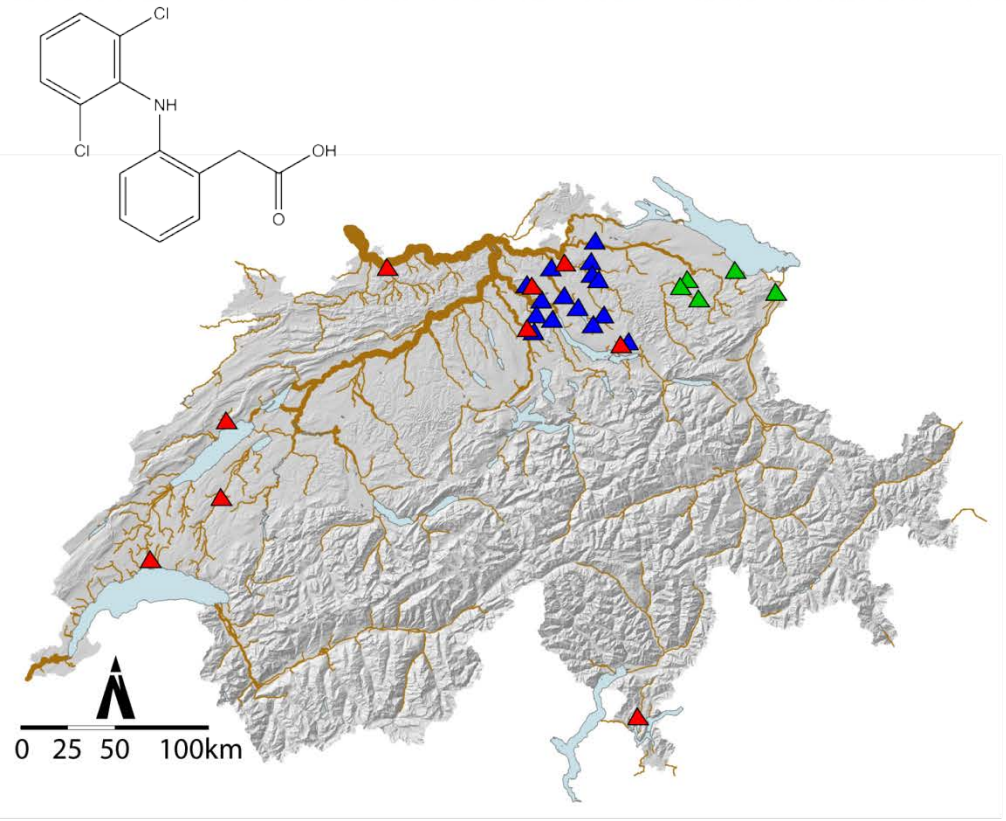
Assumptions

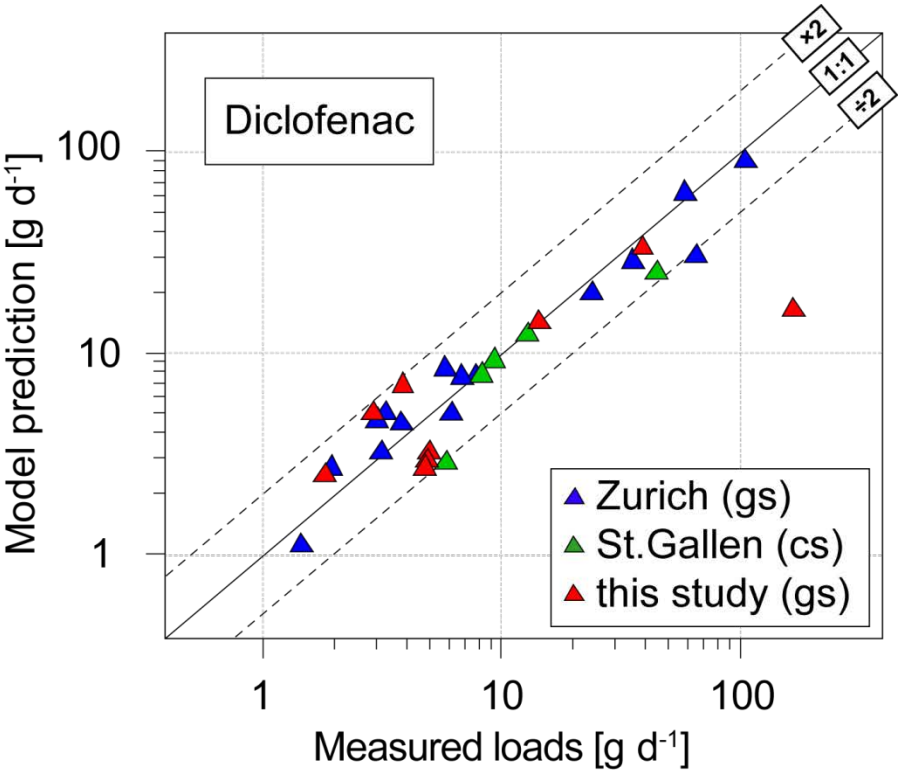
- Consumption 4 t/y,
- 15% unchanged to sewer
- Elimination in WWTP ∅ 25%
- No degradation in receiving waters



Ort, et al., ES&T 2009

Diclofenac: Prediction vs. Measurements





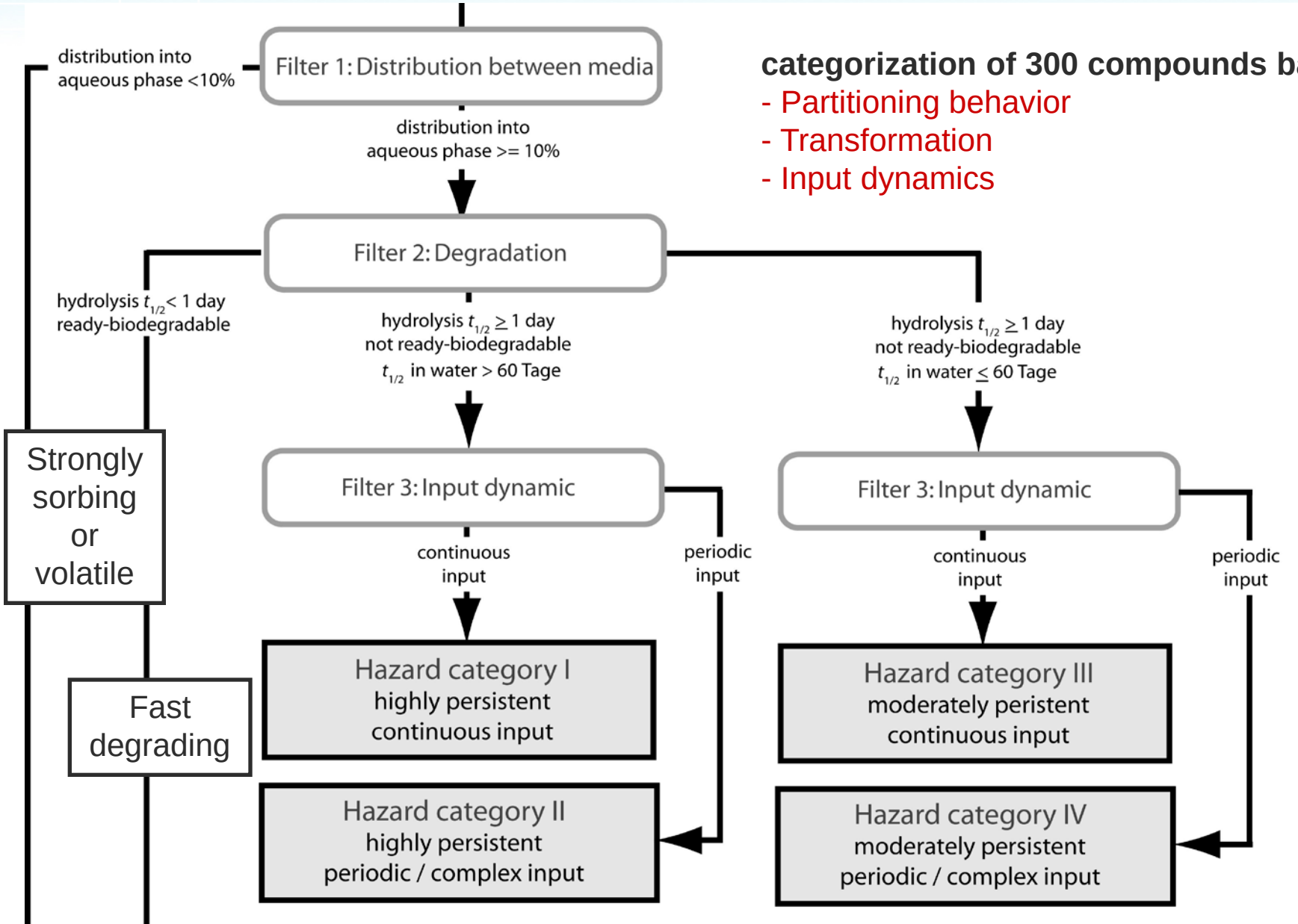
Ort, et al., ES&T 2009

Priorization of urban substances for monitoring

- **Usage is permitted in CH**
- **Continuous input:**
  pharmaceuticals, biocides
- **Distribution:**
  into aqueous phase ≥ 10 %
- **Persistence:**
  not-readily biodegradable, $t_{1/2}$ > 60 d
  no hydrolysis $t_{1/2}$ ≥ 1 d
- **Widespread occurrence**
  > 20 %
- **High specific toxicity**
  e.g. estrogens

Götz et al., Environ Sci Pollut Res 2009

Prioritisation scheme for Swiss relevant micropollutants

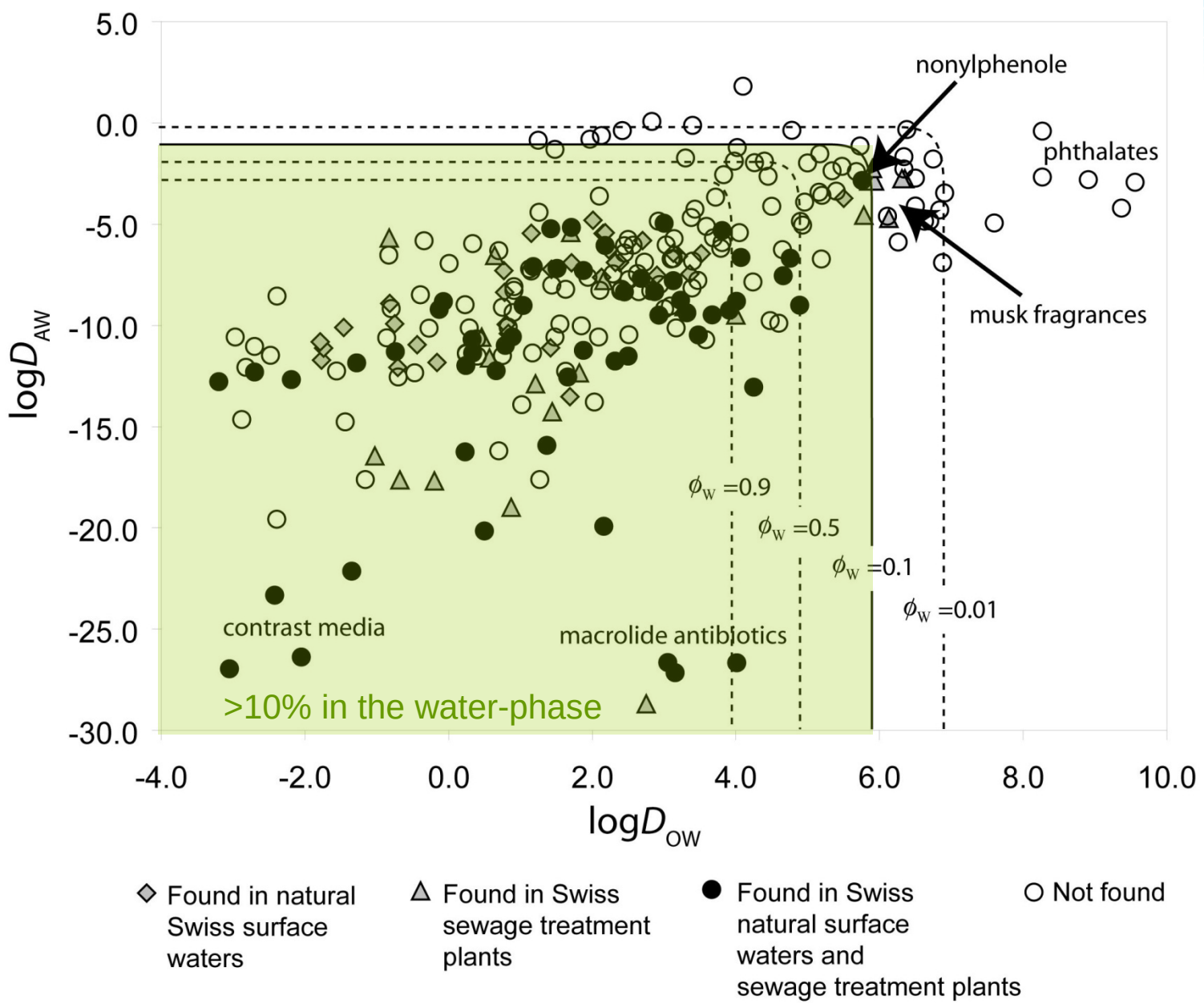


categorization of 300 compounds based on

- Partitioning behavior
- Transformation
- Input dynamics

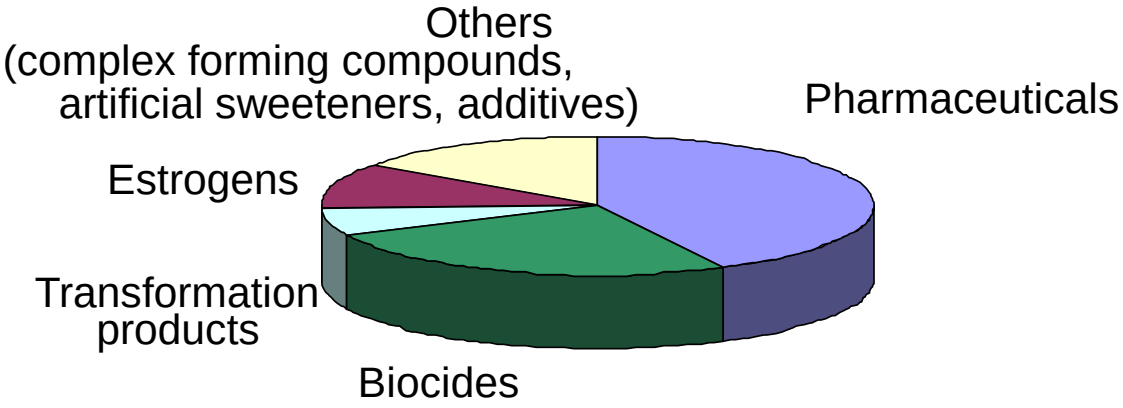
Götz et al., Environ Sci Pollut Res 2010

Categorization: Filter 1 distribution



Relevant substances & Environmental Quality Standards

I. List of 47 substances



II. Proposals for EQS

by Ecotox center according to Technical Guidance EU

oekotoxzentrum
centre ecotox

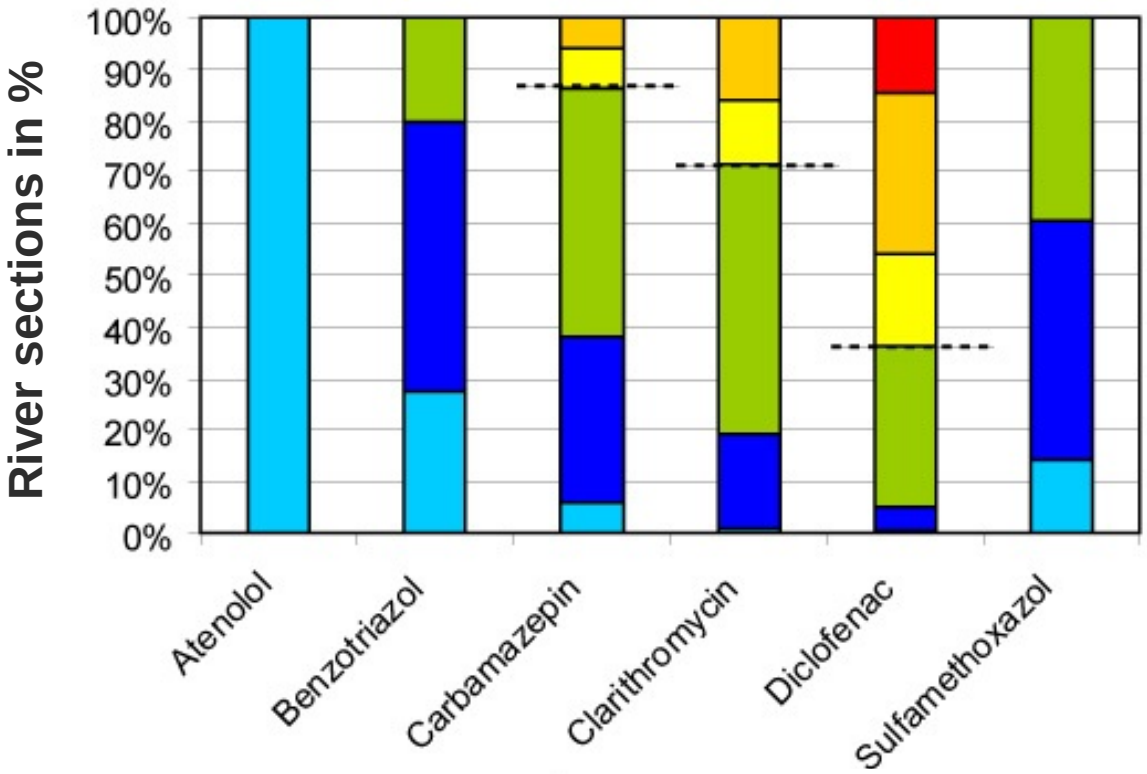
Schweizerisches Zentrum für angewandte
Oekotoxikologie | Eawag-EPFL

III. Monitoring concept

Götz et al., ESPR 2010; GWA 2010, assessment report 2011

Assessment of freshwater quality

Modeling of concentration at $Q_{95\%}$ of 543 river sections and comparison with anual average EQS



Substance	AA-EQS (µg/L)
Atenolol	150
Benzotriazole	30
Carbamazepine	0.5
Clarithromycin	0.06
Diclofenac	0.05
Sulfamethoxazole	0.12

PEC < AA-EQS

- very high quality
-
- good quality

PEC > AA-EQS

- moderate quality
-
- bad quality

Selection of Treatment processes at WWTPs

Requirements

- Elimination of a broad range of compounds
- No formation of problematic products
- Cost efficiency
- Good technical implementation

Ozonation pilot plant at Regensdorf

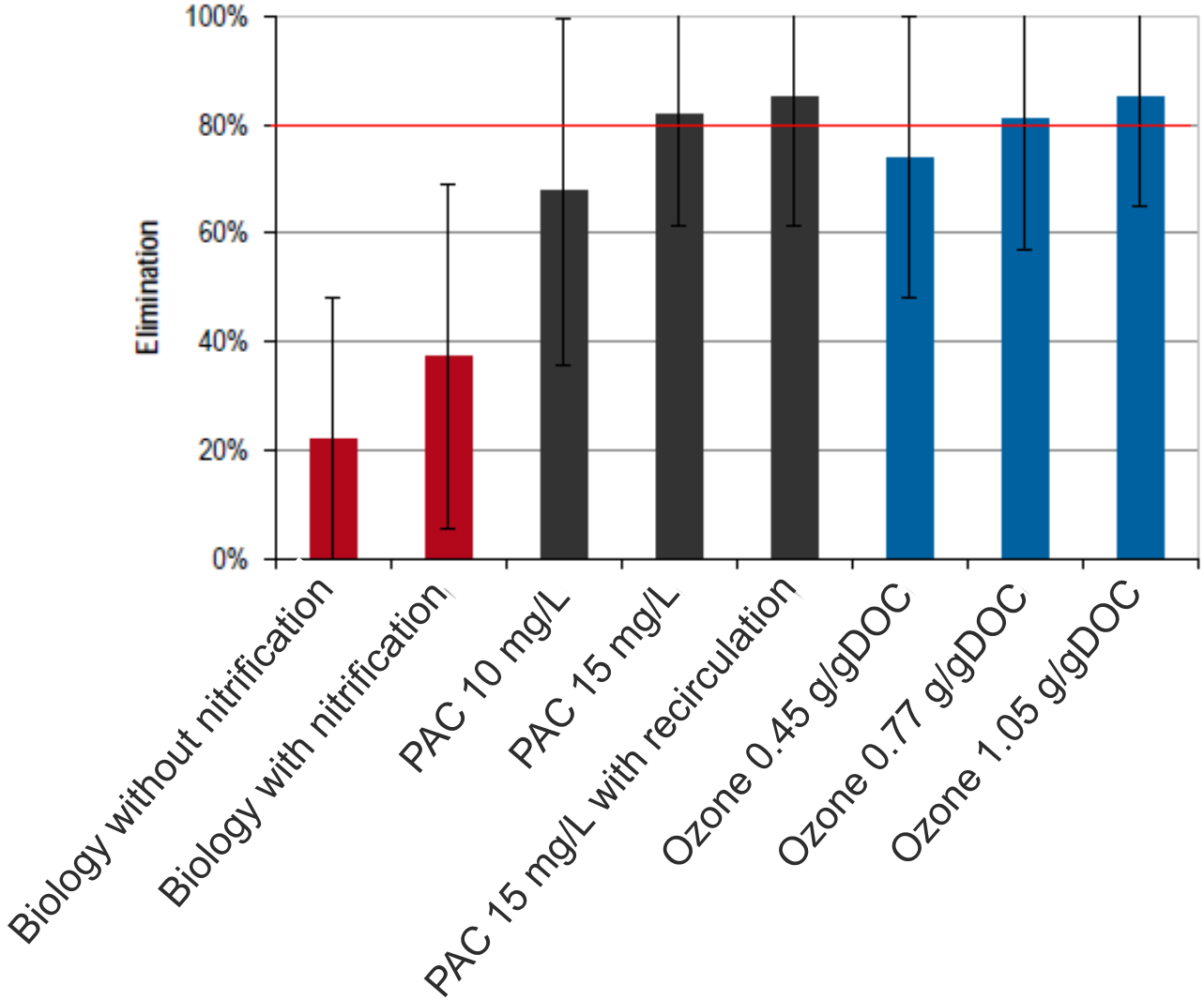
Foto Christian Abegglen

Activated carbon adsorption pilot plant at Lausanne

Foto Christian Abegglen

Comparison of ozonation vs. powdered activated carbon

Elimination of 40 - 60 substances

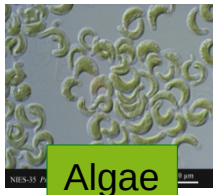


Data from Hollender et al., ES&T 2009; Margot et al., report 2010; Böhler et al., WST 2012

Bioassays

Different trophical levels and modes of action

Primary producers



Algae

Duckweed

Primary consumers

Water flea

Detritus feeders

Lumbriculus

Snail

Shredders

Gammarus

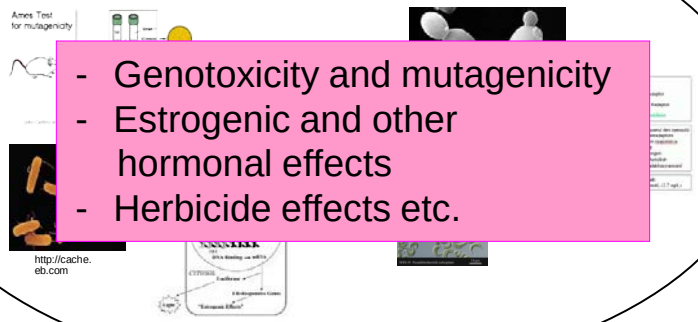
Secondary consumers

Rainbow trout

Ecosystem effects

Destruents

Specific modes of action

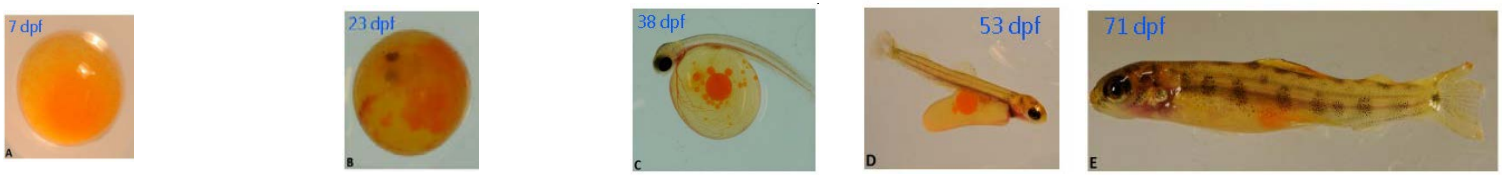


- Genotoxicity and mutagenicity
- Estrogenic and other hormonal effects
- Herbicide effects etc.

oekotoxzentrum
centre ecotox

Results of bioassays

- **Specific modes of action: (SPE enrichment)**
  Significant reduction of effects by O_3 and PAC (> 70 %)
  (estrogens > 75 %, glucocorticoids > 60%, progesterones >70%, photosynthesis inhibition > 80 %)
  no mutagenic or genotoxic effects detected
- **No effects in standardized in-vivo tests**, but tests mostly not sensitive enough
- **Leaf-shredding invertebrate** (Gammarus fossarum): higher feeding rate after O_3
- **Worm test** (Lumbriculus variegatus): lower biomass production after O_3 and PAC (perhaps less nutrients)
- **Fish early life stage test**: in Regensdorf (not Lausanne) after ozonation slower development and smaller fish weight, but elimination after sandfiltration



Exposure of embryos **Hatching** **Swim up**

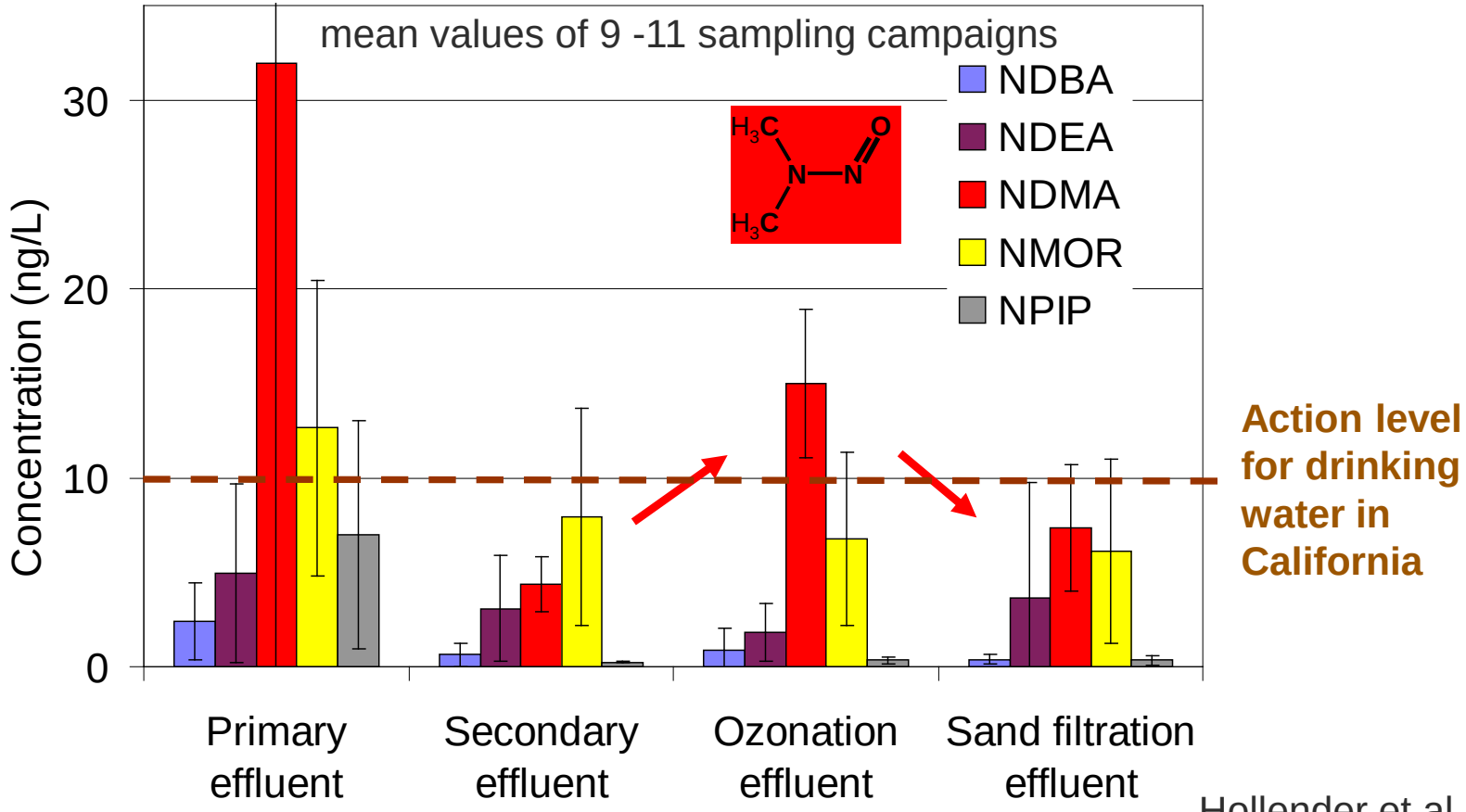
0-----5----10-----15-----20-----25-----30-----35-----40-----45-----50-----55-----60-----65----69 days

Stalter et al., Wat. Res. 2010, Bundschuh, Wat. Res. 2011; ECT 2011; Kienle et al. Ecotoxcenter 2011

Toxic transformation products or by-products of the ozonation?

- **Bromate:** depends on bromide concentrations, in CH concentrations < PNEC
- **Nitrosamines**: depends on precursors, no values above 10 ng/L

➡ post-treatment like sand filtration recommended



Hollender et al., ES&T 2009

Swiss action plan – current status

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Modification of Swiss law on water protection approved by government

Elimination of micropollutants by 80% in wastewater treatment

Technical measures should be taken at:

- Large WWTPs to reduce high loads (>80.000 inhabitants)
- WWTPs at surface waters with a high wastewater load (> 10%) to improve the ecological status (> 8.000 inhabitants, > 24.000 at lakes)
- WWTPs at surface water that are used for drinking water abstraction (precautionary principle)

- **Ca. 100 WWTPs affected**
- **Investment: ca. 1 billion Euro within 20 years**
- **Subsidy: 75% investment from wastewater fee per inhabitant (max. 7.5 €/p/a)**

Swiss action plan – current status

- **Feature article on the Swiss strategy in ES&T online**

Environmental Science & Technology

Feature

pubs.acs.org/est

Reducing the Discharge of Micropollutants in the Aquatic Environment: The Benefits of Upgrading Wastewater Treatment Plants

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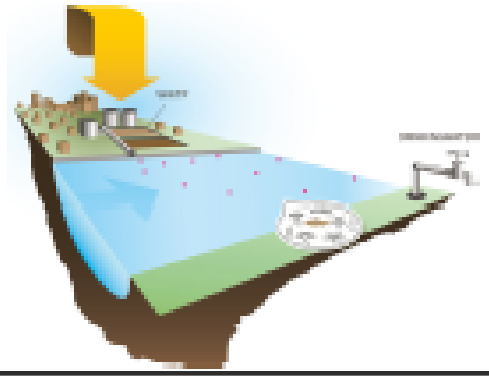


water bodies at some stage in their lifecycle. For this transfer of chemicals to water bodies, several flow paths need to be considered (Figure 1). Diffuse sources of contaminants include transport from agricultural land and runoff from urban areas where surface waters may be polluted by biocides and other chemicals leaching from building facades, automobile emissions, tire wear and dry and wet atmospheric deposition.[3,4] In developed countries with existing sewer systems, wastewater from households and industry is a major source of chemicals entering the aquatic environment despite the treatment taking place in the wastewater treatment plants.[5,6] Additionally, untreated wastewater can also be discharged via combined

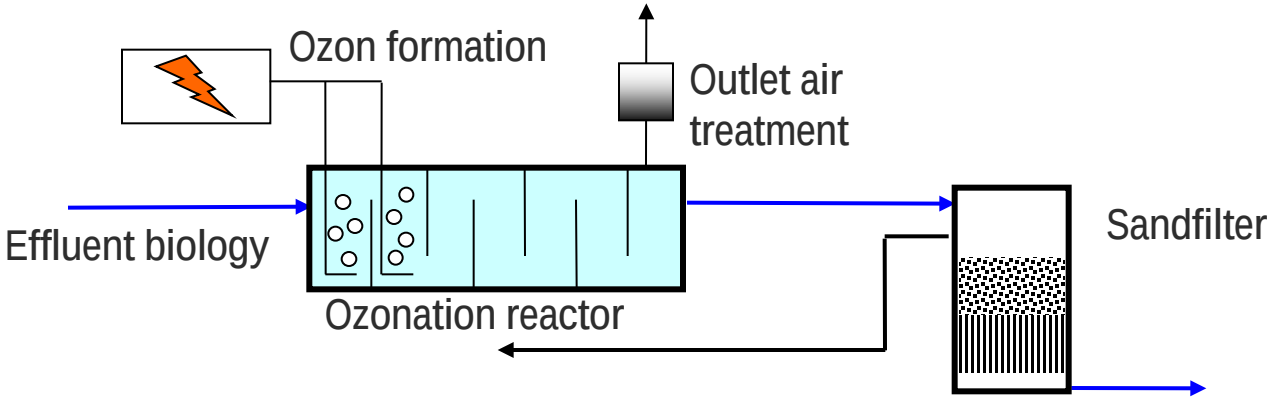
Selection of indicator compounds for evaluation of wastewater treatment

Prioritiziation 2009

5 compounds: high occurrence, persistent in WWTP, simple analytics, medium to good elimination by advanced treatment (O_3, PAK): benzotriazol, carbamazepine, diclofenac, sulfamethoxazole, mecoprop

Ongoing re-evalution in 2014:

- Suspect screening & exposure modelling of 900 pharmaceuticals in WWTP effluent: 28 newly detected pharmaceuticals verified with standards (Singer et al., in preparation)
- Evaluation of occurrence and treatment efficiency in several WWTPs with PAK, O_3



Conclusions

- Swiss relevant urban micropollutants as well as indicator compounds for control of wastewater treatment have been prioritized using exposure data and properties and in the following EQS have been proposed
- Concentrations of various substances are in the range of expected effects
- Water quality of surface waters can be improved by measures at WWTPs (ozonation, activated carbon)
- Careful selection of WWTPs where treatment is upgraded using exposure modelling to be cost-efficient
- Other mitigation measures (e.g at the source) should be taken into account

Future action

- Continuous update of relevant micropollutants using suspect & non-target screening
- Micropollutants from diffuse sources – importance, mitigation measures
- Improvement of biotests (suitability, reproducibility, cause-effect)
- Improvement of effect monitoring in surface waters
- EQS for more substances needed

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