Eawag:
Swiss Federal Institute of Aquatic Science and Technology

eawag aquatic research

The Swiss approach in reducing micropollutants in wastewater

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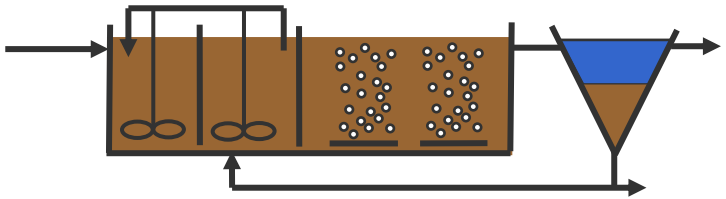
Platform «Process Engineering Micropollutants»

STOWA Workshop: Beating micropollutants in WWTPs, Nov. 5 2019, Aquatech Expo RAI, Amsterdam, NL

Situation in Switzerland

97% of the people are connected to a wastewater treatment plant (WWTP)

Treatment at WWTP:



- BOD degradation
- + P precipitation
- + Nitrification
- (+ Denitrification) / (+ Biological P elimination) / (+ Sand filtration)

➔ Good water quality

➔ prerequisite for advanced treatment (low DOC, NO_2)

But: micropollutants are not well removed

- Locations with **exceedance of chronic quality standard** in Swiss rivers
- precautionary principle: **Protection of drinking water resources**

Swiss strategy: Focused upgrade

The new Swiss Water Protection Act is in force since January 2016

Gool: Abatement of micropollutants by 80% with advanced treatment until 2040

Load-reduction + «up-stream» responsibility

Large WWTP > 80'000 inhabitants

Quality control of drinking water resources

WWTP > 24'000 inhabitants discharging into lakes

WWTP > 8'000 inhabitants in special hydrogeological situations

Protection of sensitive water bodies

WWTP > 8'000 inhabitants discharging into stretches with inadequate dilution (>10% share of wastewater)

- 130 WWTPs upgraded
- 70% of inhabitants

Legal basis – financing and control

- Total investment costs: about 1.2 billion Euros
- Financing: Polluter pays Principle
  - Government introduced a wastewater tax for WWTP (2016-2040) 9 CHF (about 8 euros) per person and year
  - WWTPs get paid 75% of investment costs for upgrade
  - Upgraded WWTPs do not have to pay wastewater tax (but have higher operating costs)
- Costs: 0.02-0.25 CHF/m^3 (will be evaluated in detail by VSA in 2020)
- Elimination goal: 80% (inflow WWTP – outflow WWTP) for a list of 12 substances

Amisulpride	Diclofenac	Benzotriazole
Carbamazepine	Hydrochlorothiazide	Methylbenzotriazole
Citalopram	Metoprolol	Candesartan
Clarithromycin	Venlafaxine	Irbesartan

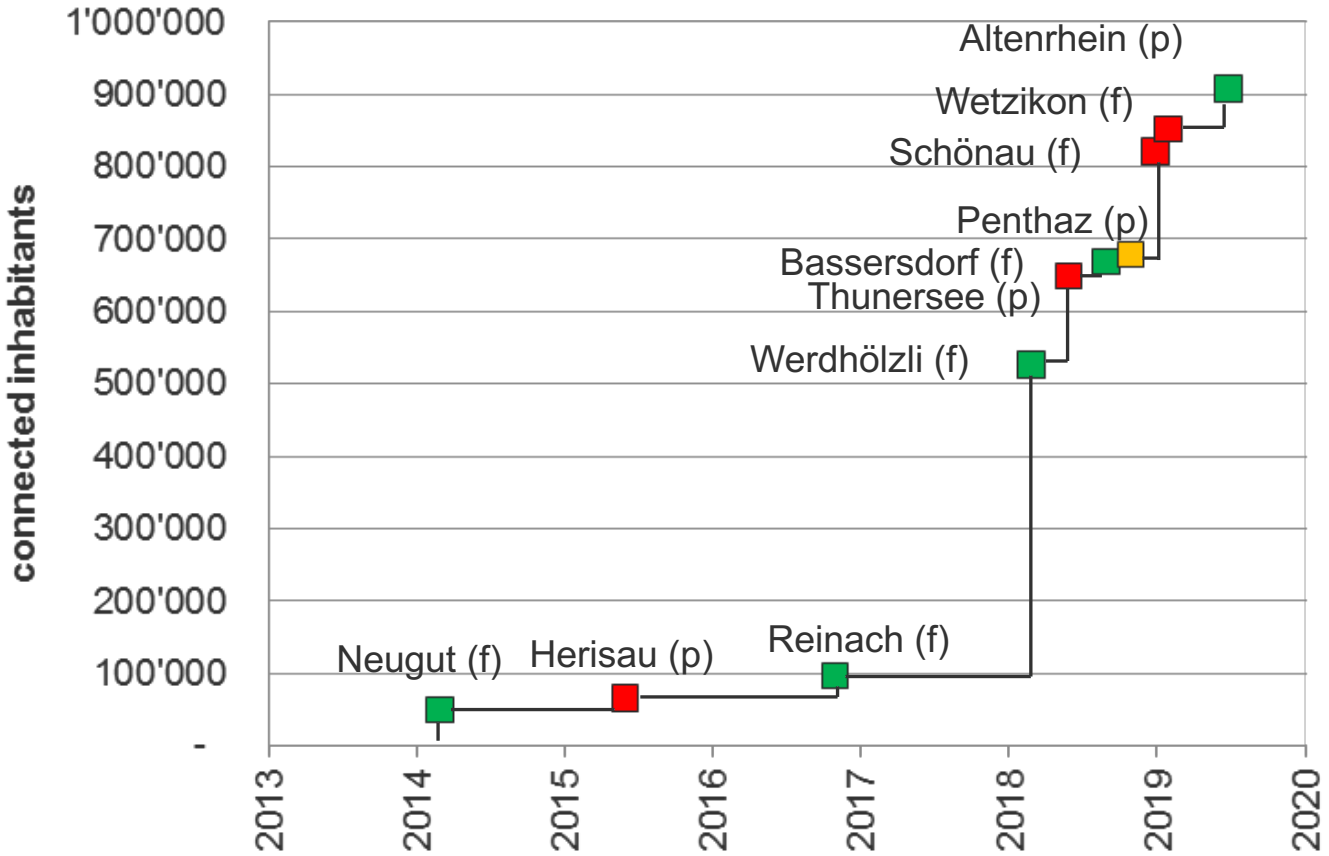
Selection of 12 substances

12 substances are **representative** for organic micropollutants
Not based on high risk chemicals (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

Full-scale plants in operation (Sept. 2019)



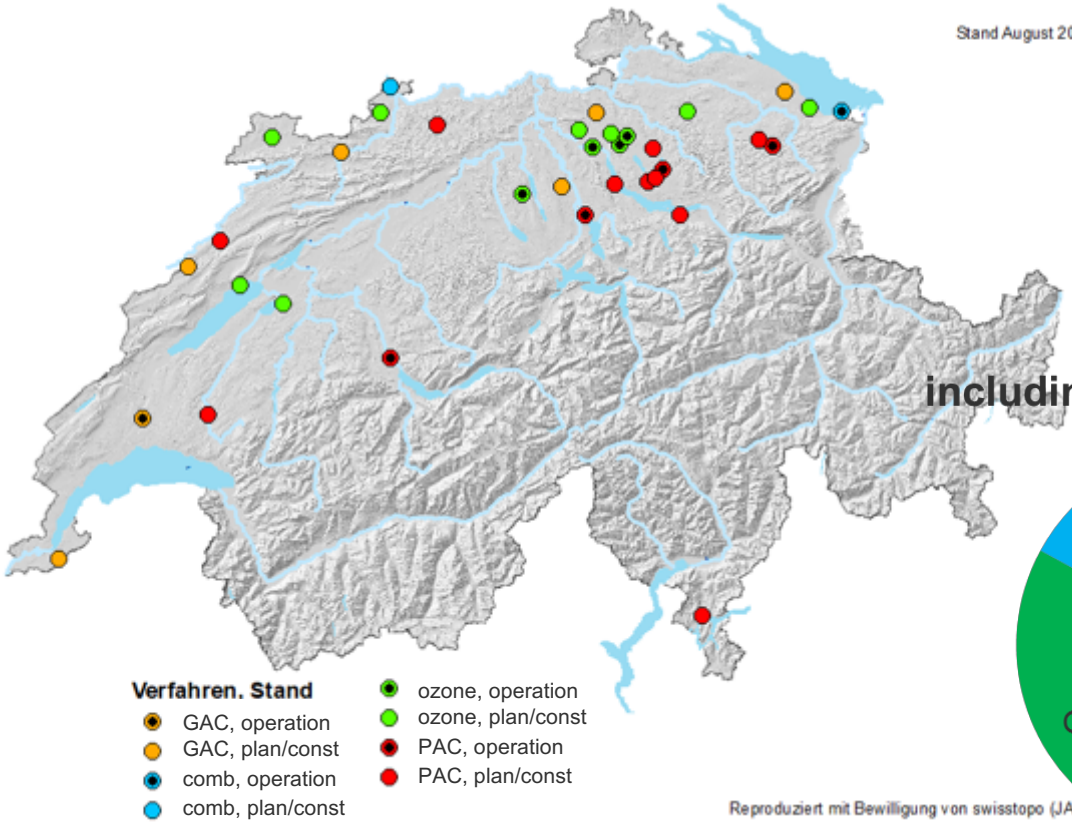
Ozonation

PAK

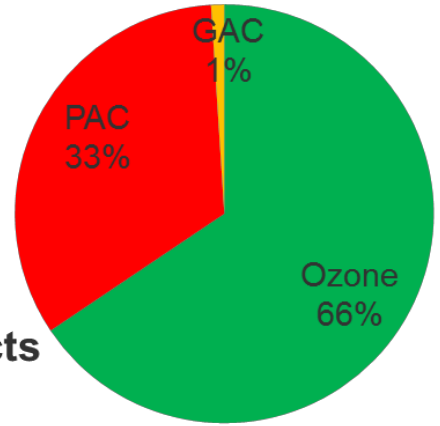
GAK

f: full treatment
p: partial treatment

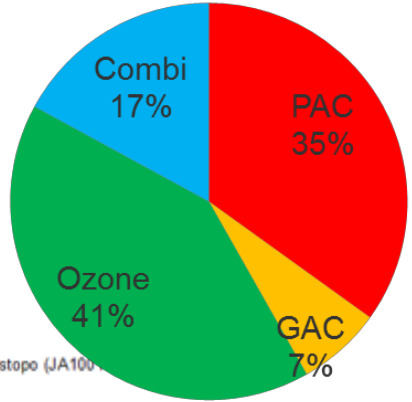
Status Quo on upgraded WWTPs



plants in operation



including planned projects

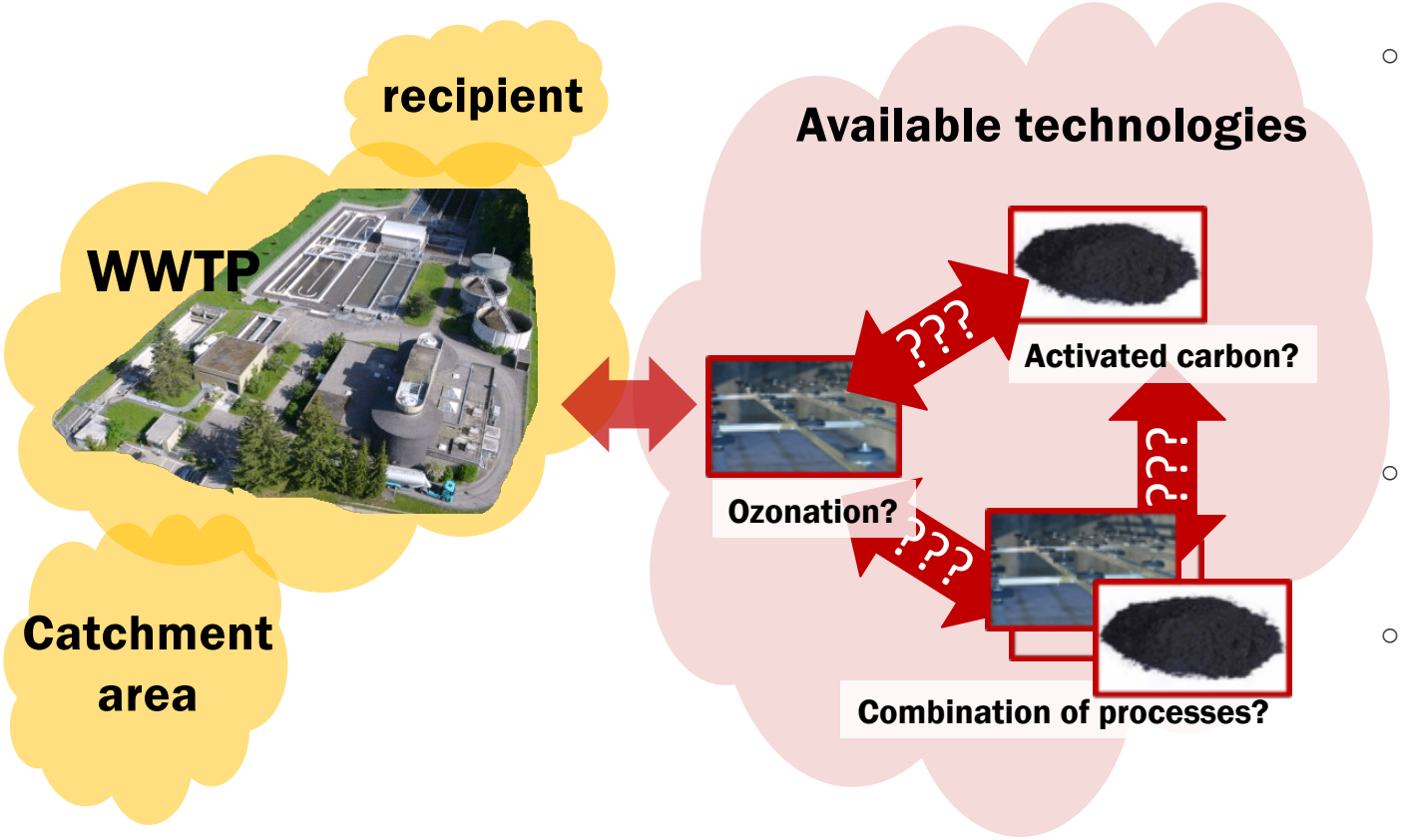


(relative to connected inhabitants)

Technologies in Switzerland (Sept. 2019)

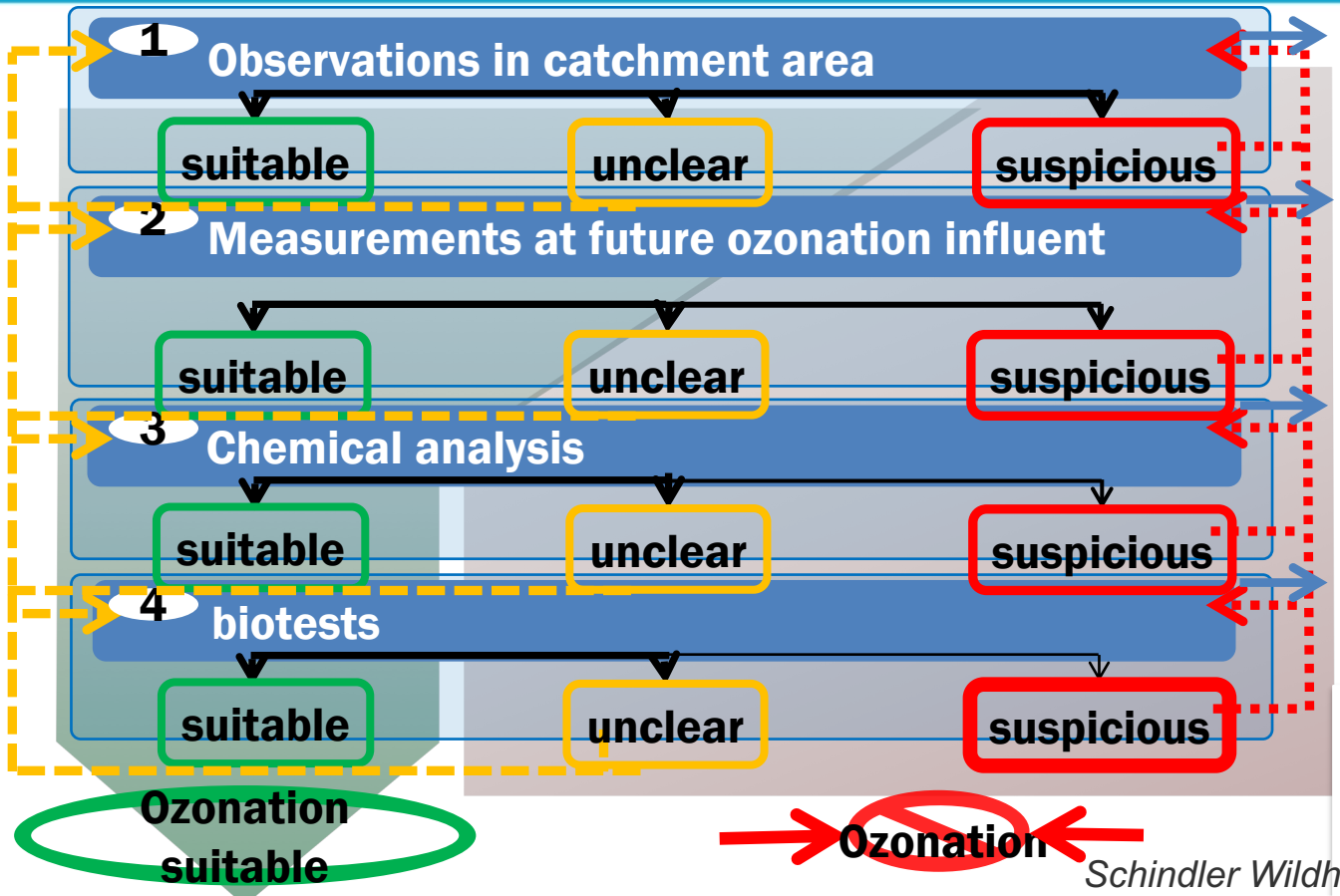
Selected process	WWTP
Ozonation + sand filtration	Neugut, Oberwynental, Bassersdorf. Werdhölzli (operation), Kloten Opfikon, Morgenthal, Porrentruy, Neuenburg (construction), Neuenburg, Furthof/Buchs, Aadorf, Birsig, Seeland Süd/Murten-Kerzers (planning)
PAC with sedimentation and sand filtration	Herisau, Thunersee (operation), Flawil-Oberglatt (construction), Fehraltorf (planning)
PAC addition onto sand filtration	Schönau-Cham (operation), La Chaux-de-Fonds, Lachen Untermarch, Egg-Oetwil am See, Ergolz 1, Bioggio, Gossau Grüningen (planning)
PAC addition into biology	Wetzikon (operation), Zimmerberg
GAC in moving bed	Penthaz (operation), Delémont, Niederglatt, Luzern, Niederglatt (planning)
GAC filter	Muri, Moos (planning)
Combination ozonation and AC	Altenrhein (operation), ProRheno, Glarnerland (planning)

Process selection



- Collaborative decision: Authorities, WWTP operators, Engineers, suppliers, scientific experts (Eawag, other research institutes)
- Often pilot scale experiments (reports and publication)
- VSA ensures knowledge transfer **(www.micropoll.ch)**

Advanced decision tool for ozonation



- Industries, incineration?
- Future developments?

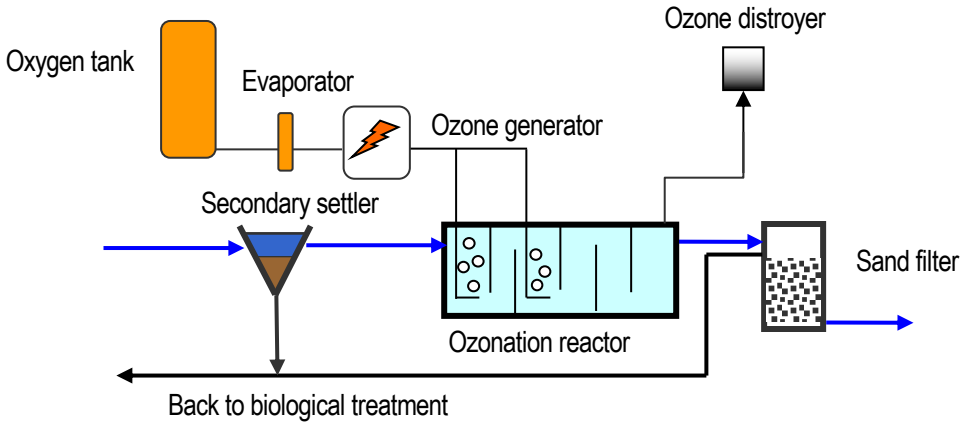
- Bromide (Chrome)
- NDMA

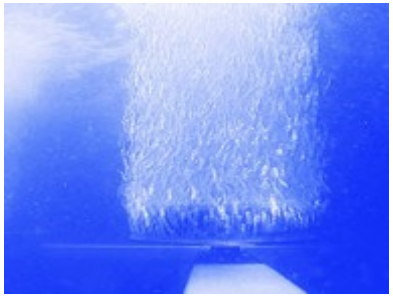
- O_3 and OH• exposure in a "normal" range ?
- Elimination of reference compounds?

- Ames test
- combined algae assay
- *C. dubia* reproduction test
- (fish embryo toxicity test)
- (umuC)
- (Bioluminescence inhib.)

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

Ozonation





Source: ARA Neugut

Source: ARA Neugut

Ozonation reactor

- 6-8 m water depth
- 6-8 chambers
- Ozone dosage in chambers 1 (or 1+3)
- Injectors or diffusors
- 0.4-0.6 $gO_3/gDOC$
- HRT minimal 13 min

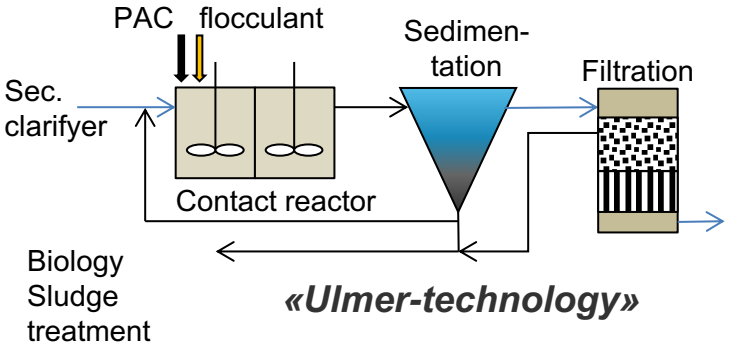
Ozonation in full scale

WWTP Neugut Dübendorf
www.neugut.ch

WWTP Werdhölzli, Zürich
www.erz.ch

- economic, technically feasible, robust in operation
- 0.4 – 0.6 $gO_3/gDOC$; Regulation of ozone dose via ΔSAK_{254} (UV absorption in-out)
- biologically active post-treatment (e.g. sand filtration) is needed

PAC in separate contact reactor



- PAC dosage about 1.5 gPAC/gDOC
- PAC-separation by e.g. sand filtration, cloth filter
- PAC recirculation into biological treatment required enough capacity

WWTP Bachwis, Herisau
www.arabachwis.ch

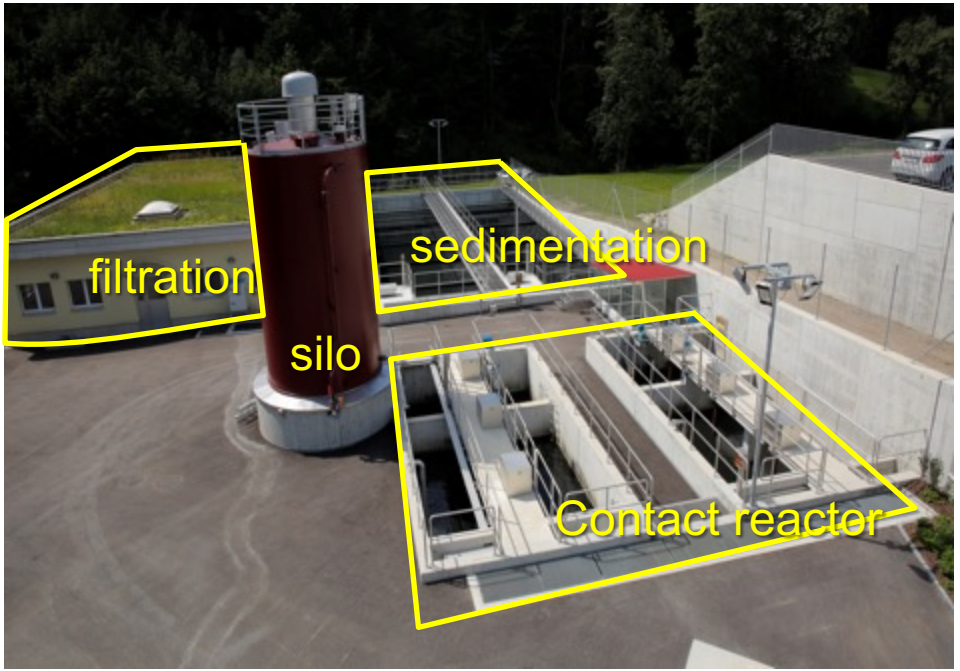
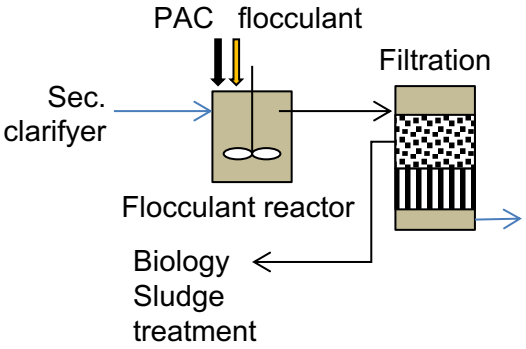


Photo: A. Joss / Photo : H. Messmer, August 2015

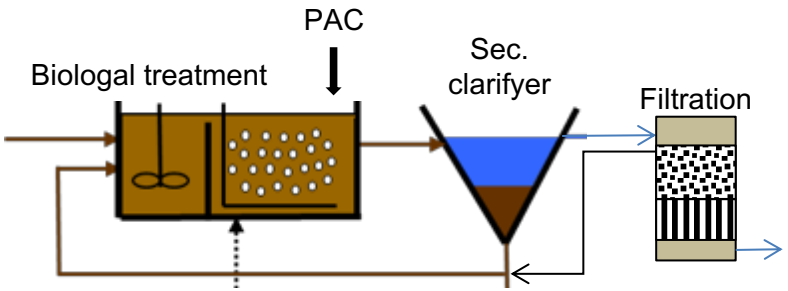
PAC onto sand filter



- PAC dosage about 1.5 gPAC/gDOC
- Dosage of flocculant very important for retention of PAC
- Sand filtration as reaction zone and retention of PAC (double-layer filter recommended)

WWTP Schönau, Cham
www.zg.ch/behoerden/weitere-organisationen/gvrz/klaeranlage-schoenau

PAC directly into biology



- Higher PAC dosage compared to post-treatment expected (about 2-3 gPAC/gDOC)
- Sand filtration necessary for PAC separation (sand filter, dynasand-, cloth filter)
- biological treatment needs enough capacity

WWTP Wetzikon, ZH
www.araflos.ch

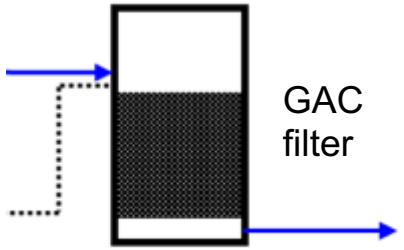
PAC treatment

- Robust and efficient technology to remove MPs
- Generally higher DOC removal compared to ozonation
- ΔSAK_{254} (UV absorption in-out) for monitoring
- addition of a flocculant (4–15 mg $FeCl_3$/L or 0.1–0.4 gFe/gPAC)
- Filter is needed to retain PAC
- Several AC products on the market: quality control is difficult (appropriate methods are currently tested)
- PAC regeneration is not possible and needs to be incinerated

Siegrist et al. (2018) IWA book

GAC treatment

- comparable AC dose as with PAC possible
- no additives necessary
- simple in operation
- existing sand filters could be converted to GAC filters
- GAC can be regenerated (lower CO_2 emission)



Granular activated carbon filters:

tested in different projects, no full scale application yet

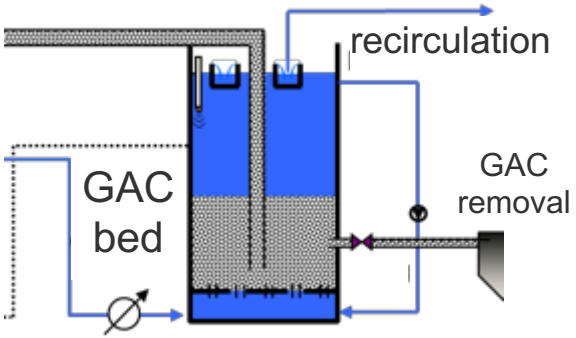
- implication of lower elimination at rain events
- Dimensioning parameters not clear, economic efficiency unclear

Granular activated carbon in a moving bed:

tested and in operation in WWTP Penthaz

GAC in moving bed

GAC addition



- Smaller particle size (0.5-0.8 mm), µ-GAC
- GAC batch dosing every 2 days (about 2 gGAC/gDOC)
- GAC bed height: 1.5 m at rest, 2.2 m in expansion
- GAC retention time 100 d
- GAC retention > 97%

WWTP Penthaz
www.stepdepenthaz.ch
Photos: Triform SA

Combined treatment

ozonation + GAC:

in operation in WWTP Altenrhein (since Sept. 2019):

- Pre-ozonation with 0.15-0.3 gO_3/gDOC
- 8 parallel GAC filters
- GAC Filter height 1.8 m
- Average EBCT GAC 20 min

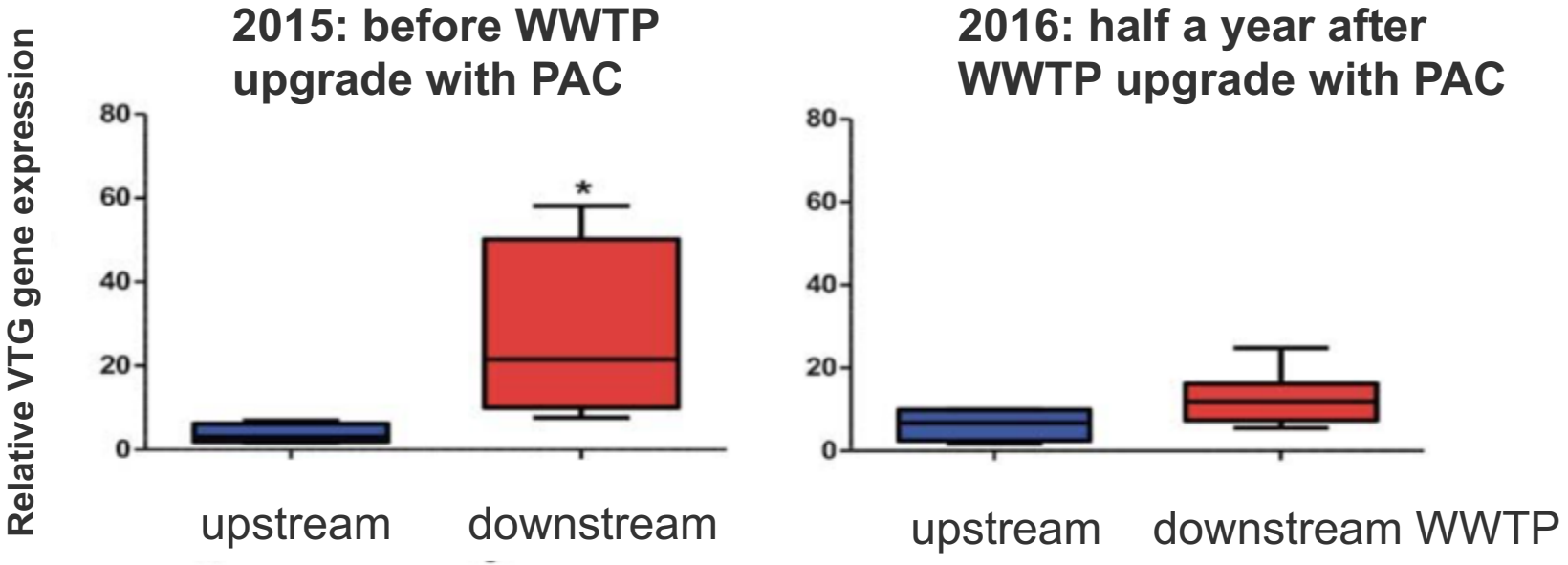
ozonation + PAC:

tested in WWTP Pro Rheno

WWTP Altenrhein
www.ava-altenrhein.ch

Impact on Ecosystem

Vitellogenin gene expression in male fish cells as indicator for estrogenic activity



Zöllig et al. (2017) A&G Nr. 1, 14-23

Conclusion – Swiss approach

- Knowledge gain from pilot tests and first full-scale realizations
- Transparent knowledge transfer
- Success story
- VSA Platform supports all stakeholders involved
  www.micropoll.ch,
  info@micropoll.ch
- Research still ongoing

Swimming in the Rhine in Basel