Eawag:
Swiss Federal Institute of Aquatic Science and Technology

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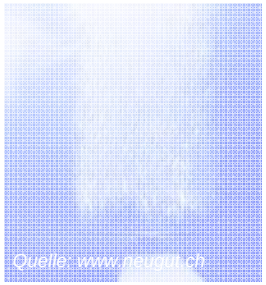
aquatic research

# Addition of Powder Activated Carbon (PAC)

## Removal of micropollutants in municipal wastewater treatment plants by powder activated carbon

Marc Böhler (Eawag, Eng)
Steffen Metzger (KomS, BW)

Workshop
“Integrative approaches to remove compounds of emerging concerns (CECs) in wastewater treatment”,
7-8.03.2017, Koblenz


Quelle: www.neugart.ch

*Ozone*

## → Ozonation

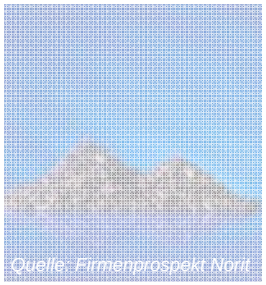
(Urs v. Gunten)


Quelle: Firmenprospekt Norit

*Powder activated carbon (PAC)*

## → Addition of PAC

(Marc Böhler)


Quelle: Firmenprospekt Norit

*Granular activated carbon (GAC)*

## → Deep bed Filtration with GAC

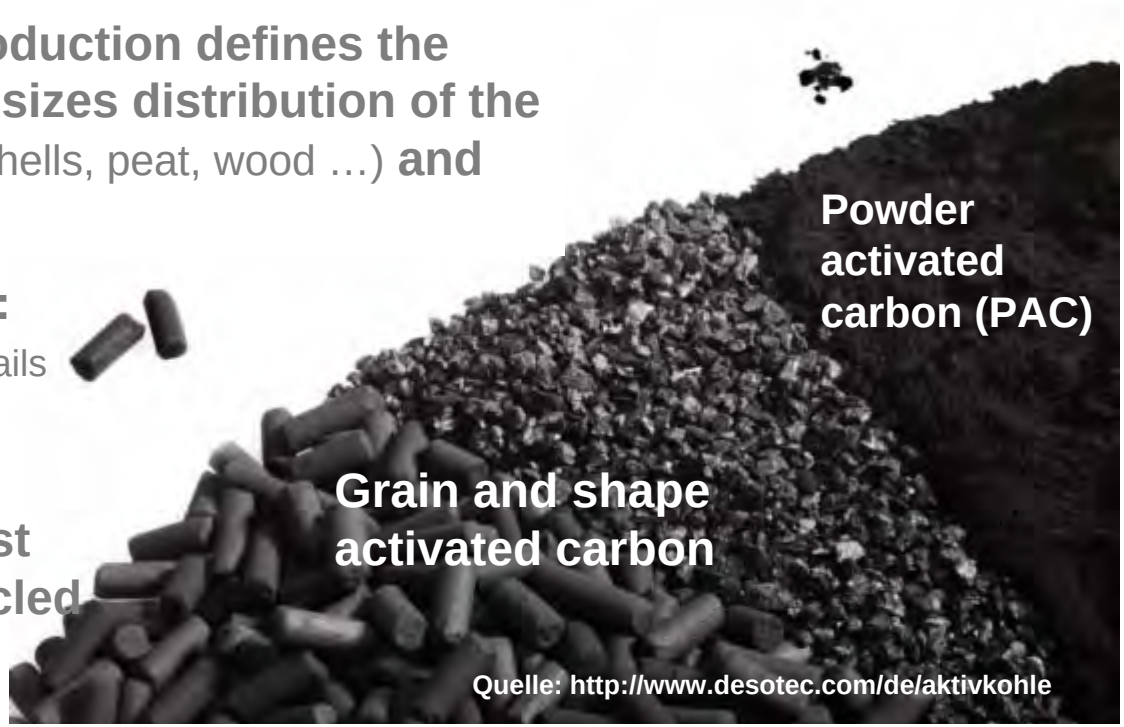
(Julian Fleiner)

## *Overview*

- Activated carbon (AC, origin, types, properties, etc..)
- Basic concept of PAC application
- Potential flow schemes of PAC addition in WWTPs
- Implementations in full and pilot scale (D & CH)
- Performance micropollutant elimination
- Effects on DOC and absorbance
- Conclusion

# *Activated carbon (origin, types, properties, etc..)*

- **AC is a powerful medium to remove organic compounds due to his high adsorptive capacity**
- **Extent of adsorption is proportional to the specific surface area, the specific surface area can be defined as that portion of the total area that is available for adsorption** (in the range of 800 – 1400 m2/gAC)
- **AC is used in gas cleaning and water treatment** (drinking water, industrial water purification, exhaust air filter, etc.)
- **Starting raw material and production defines the properties and specific pore sizes distribution of the AC** (stone / brown coal, coconut shells, peat, wood …) **and also the CO2-footprint**
- **Energy intensive production: 3.5-6.5 kg coal per kg AC** (details in KA 2016 (63), Nr. 12, report of DWA-AG-KA 8.6)
- **In contrast to GAC PAC is lost after use !! GAC can be recycled by reactivation**



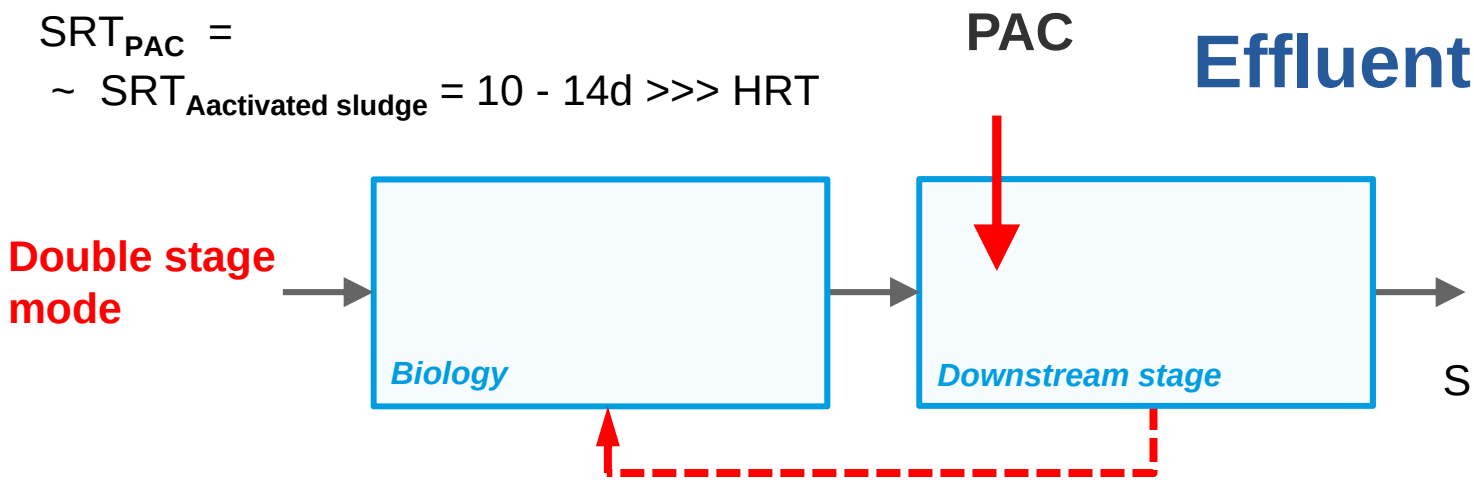
# *Basic concepts of PAC application*

## Effluent treatment

Double stage mode:

$SRT_{PAC}$ =

~ $SRT_{Aactivated\ sludge}$ = 10 - 14d >>> HRT

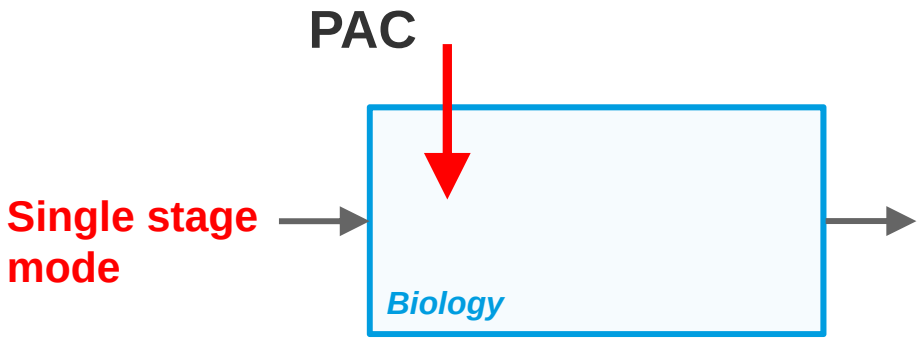



HRT in contact reactor:
≥ 0.25 – 0.5 h

$SRT_{PAC}$ in contact reactor:
≥ 2 – 4 d

**without and with PAC recycling to biology = single/double stage mode**

## Simultaneous application




Single stage mode:

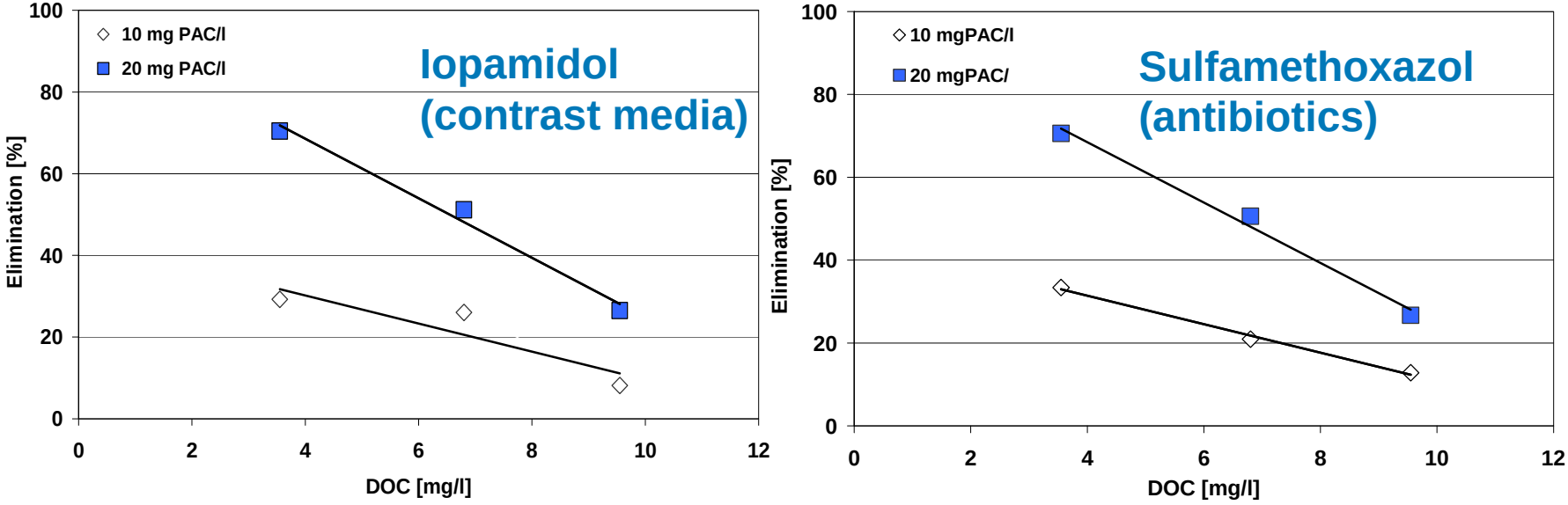
$SRT_{PAC}$ = ~ $SRT_{Aactivated\ sludge}$ = 10 - 14d >>> HRT

# *Basic concepts of PAC application*

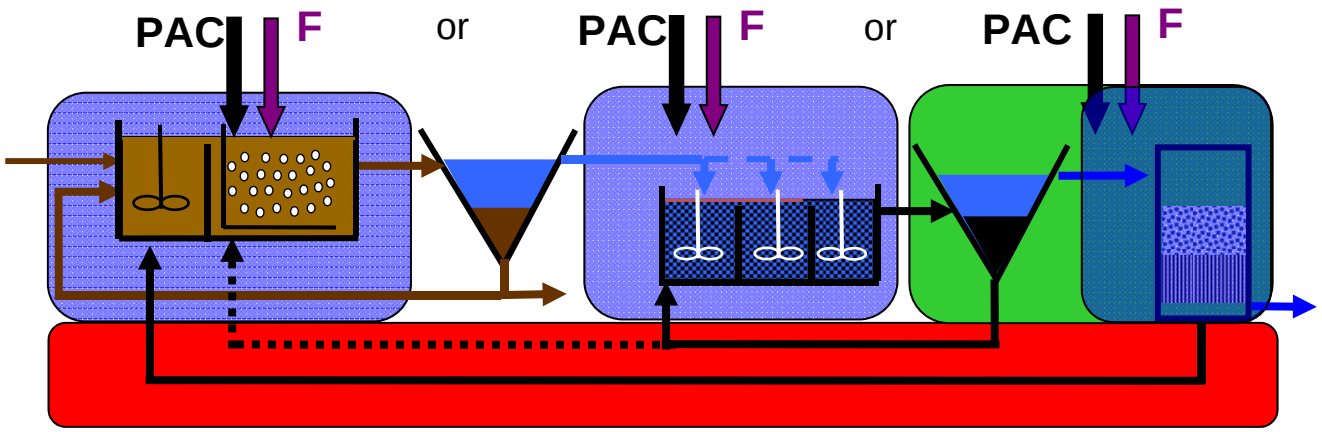
- **PAC dosage depends strongly on background DOC**

- **Adequate treatment of secondary effluent requires 10 - 20 mgPAC/L depending on DOC background concentration (5 – 10 mgDOC/L) respectively**

Batch tests:



# *Principle and options of PAC application*



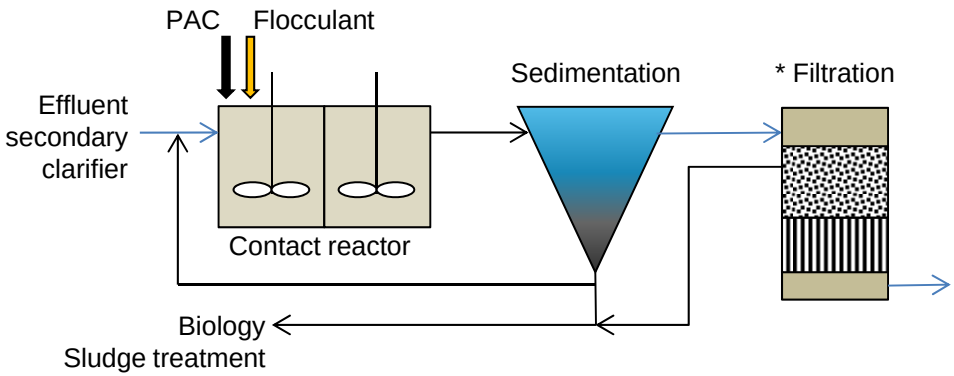

**Rezirculation** **Contact** **Separation**

**(Effluent treatment or biology)**

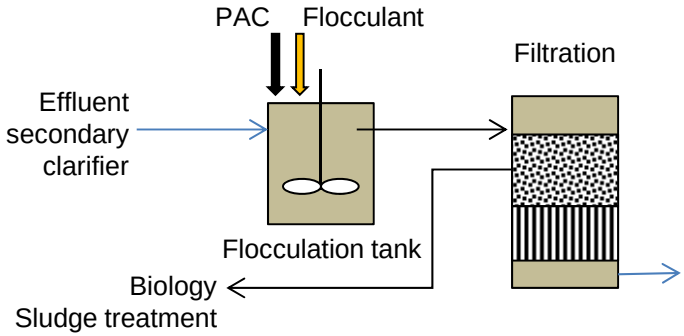
**F = flocculant (e.g. Fe or Al)**

- Process steps:
  - **Contact of wastewater – PAC**
  - **optional waste PAC recycling to biology (double stage mode) → optimal use by counter current principle**
  - **Efficient separation of PAC / wastewater → sedimentation** (HRT 2-3 h) **and filtration**

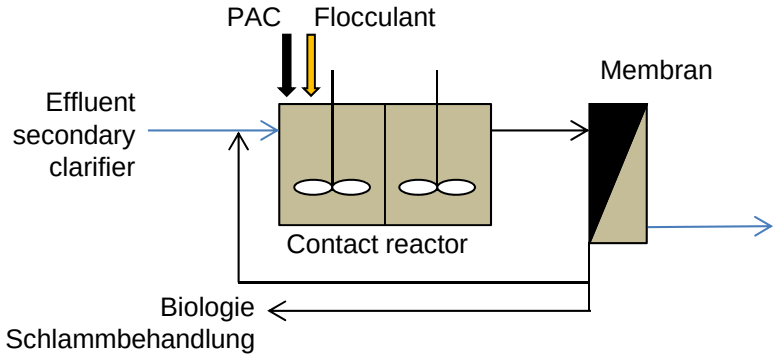
# Potential flow schemes of PAC addition in WWTPs



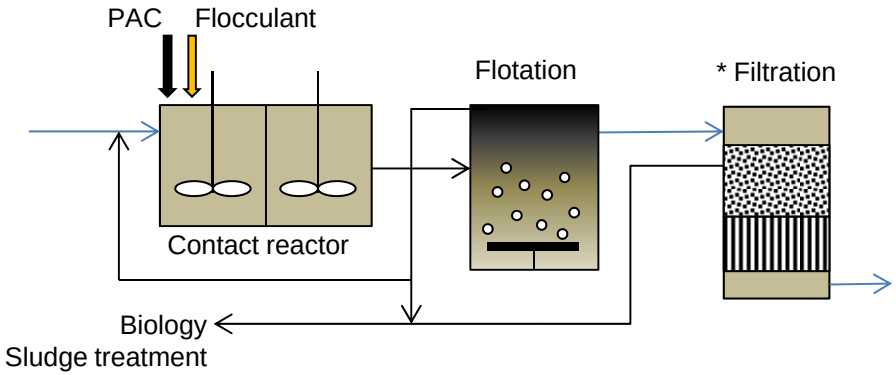

*«Ulmer-Verfahren»*




*Dosage in front of deep bed filter*




*Separation by membranes*

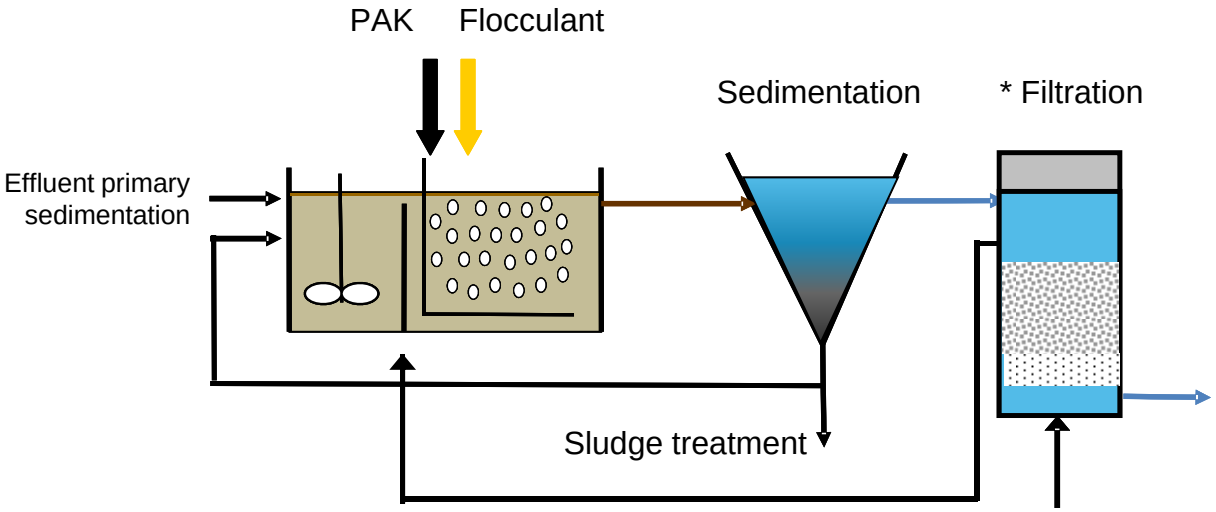



*Separation by flotation*

HRT in contact reactor ≥ 0.25 – 0.5 h

* Also a textile filter is appropriate

# *Potential flow schemes of PAC addition in WWTPs*




*Dosage into biology – simultaneous application*

* Also a textile filter is appropriate

# *Implementation «Ulmer-Verfahren»*

*WWTP Steinhäule, Neu-Ulm (D, BW)*

*WWTP Böblingen-Sindelfingen (D, BW)*

# *Implementation «Ulmer-Verfahren»*

*WWTP Langwiese, Ravensburg*

*WWTP Lahr (D, BW)*

# Implementation «Ulmer-Verfahren»



# *Implementation PAC addition to sand filtration*

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Several **full scale** and pilot tests in CH + D

- **Ulm/Neu-Ulm (D)**
- **Eawag (CH)**
- **Kloten-Opfikon (CH)**
- **Lausanne (CH)**
- **Berlin (D)**
- **Stuttgart (D)**
- **Sissach (CH)**
- **Wuppertal (D)**

*Pilot filter Eawag 2008*

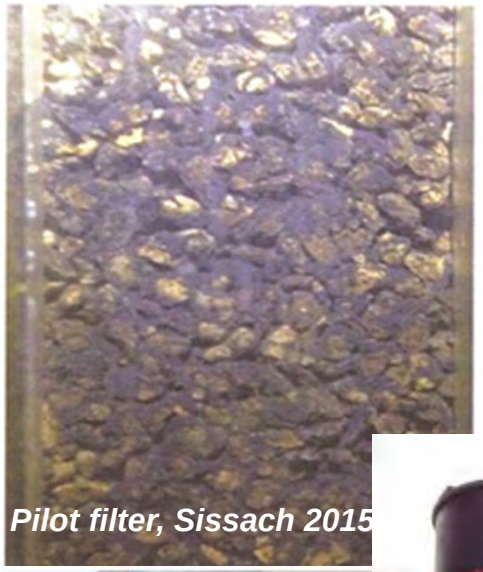

*Pilot filter, Sissach 2015*

Photo: M. Baggenstos (WABAG)
VSA-Tagung 2016, Emmetten, CH


*WWTP Ergolz (Sissach,*

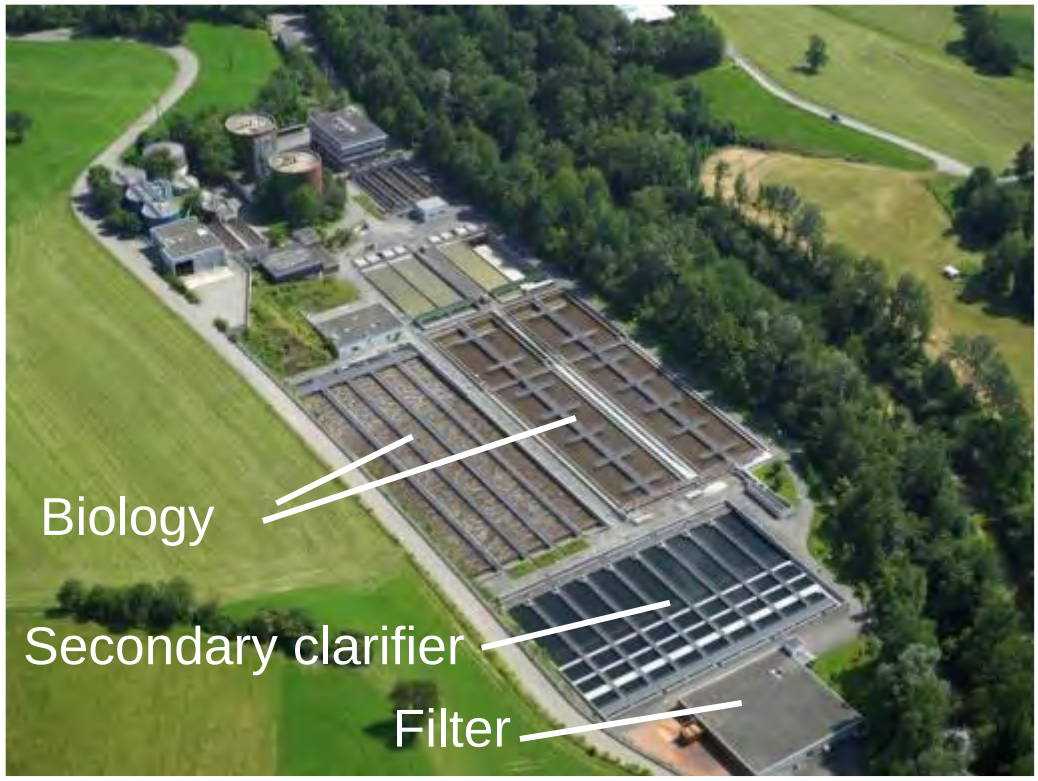
*WWTP Kloten-Opfikon (2010, CH)*

https://www.eawag.ch/fileadmin/Domain1/Abteilungen/eng/projekte/abwasser/Aktivkohle/abschlussbericht_aktivkohle.pdf

*WWTP Buchenhofen, Wuppertal*

Quelle: https://www.lanuv.nrw.de/uploads/tx_mmkresearchprojects/Abschlussbericht_MikroFlock.pdf

## First permanent realization at WWTP Schönau (CH, Kt. Zug)




https://www.zg.ch/behoerden/weitere-organisationen/gvrz/klaeranlage-schoenau

# *Implementation PAC addition to biology*

**Pilot studies in half scale:**

- **Eawag**
- **WWTP Steinhäule, Neu-Ulm**
- **WWTP Schönau**

**Studies in full scale:**

- **WWTP Flos, Wetzikon (CH)**
- **WWTP Emmingen-Liptingen (D)**

*WWTP Schönau (Cham,*

*WWTP Flos (Wetzikon, CH)*

*Bildquelle: Thomann, IB Holinger, Versuche auf der ARA Wetzikon, CH*

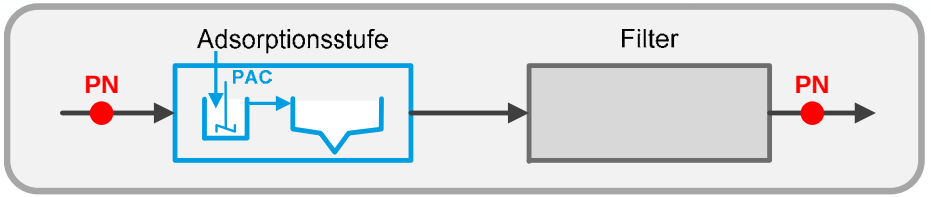
*WWTP Emmingen-Liptingen (D, BW)*

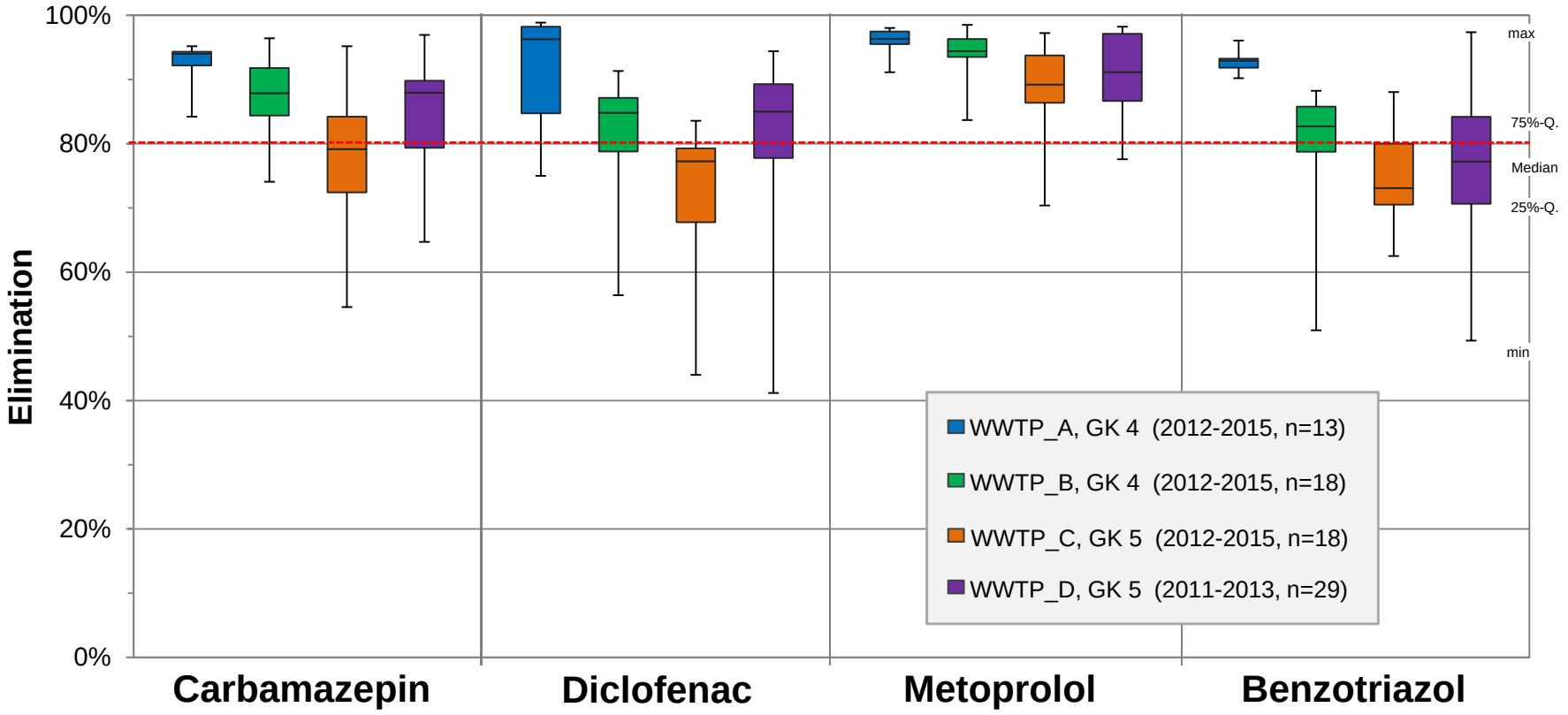
*Bildquelle: JIB Jedele und Partner*

# Performance micropollutant elimination

## «Ulmer-Verfahren» in single stage mode

*Average dosage = 10 mg PAC/L*



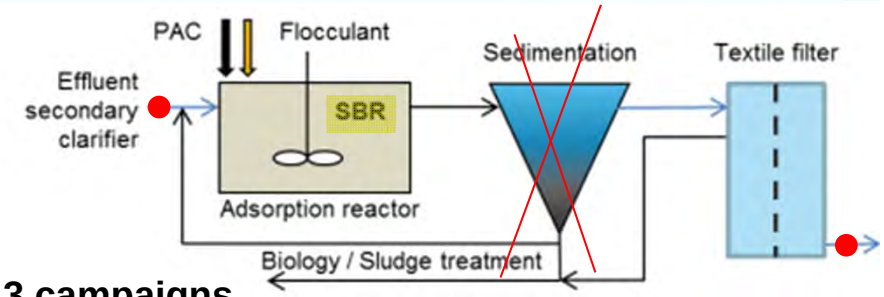



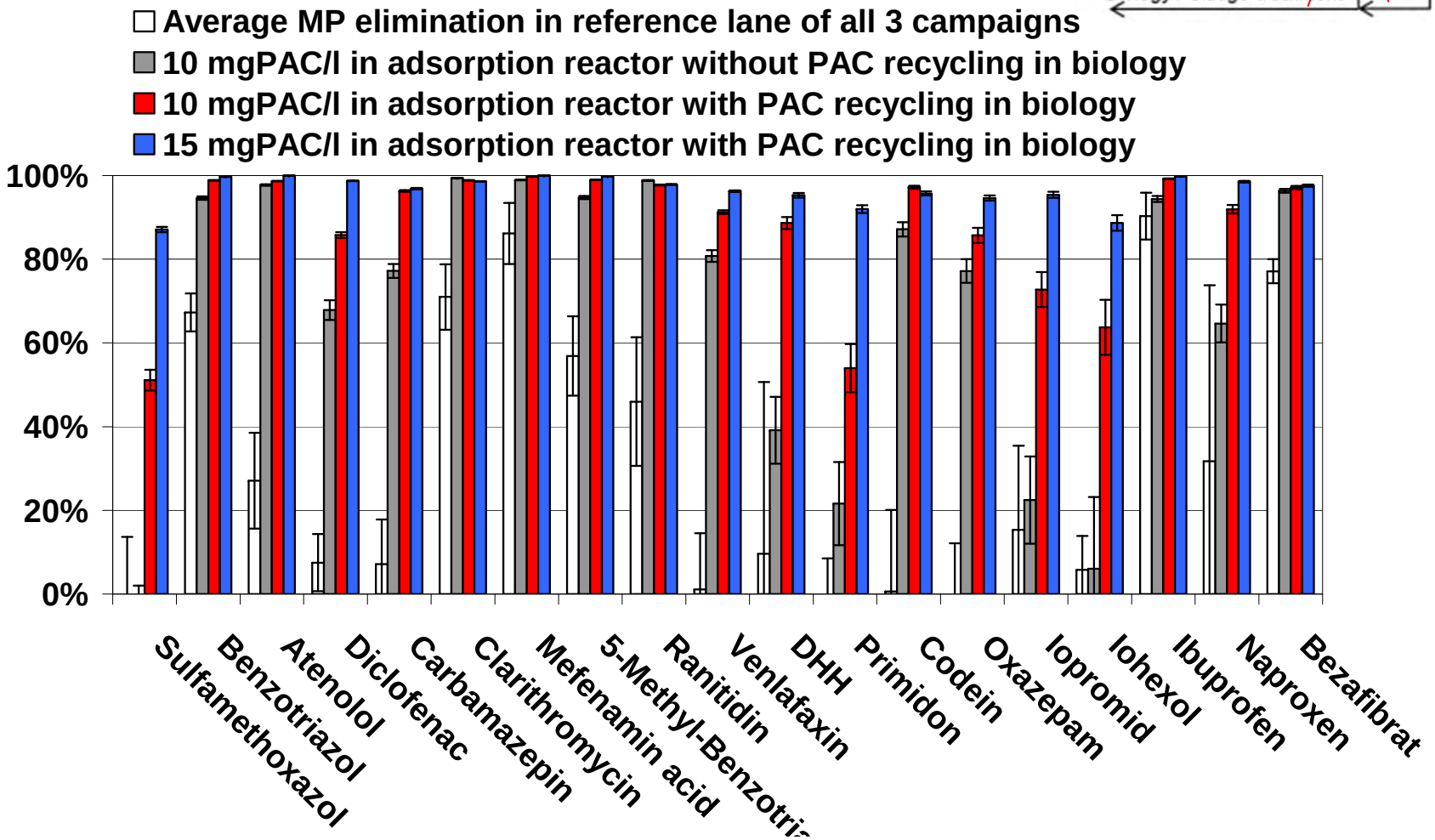

Source: KomS, BW
Steffen Metzger

# Performance micropollutant elimination

## «Ulmer-Verfahren»
## in single vs. double stage mode

*PAC dosage = 10 vs. 15 mg PAC/L*



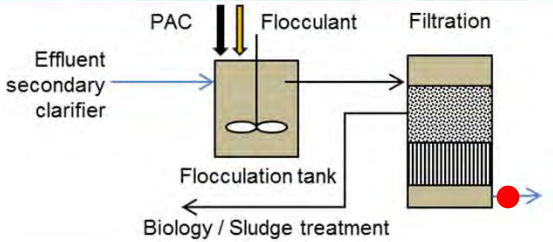



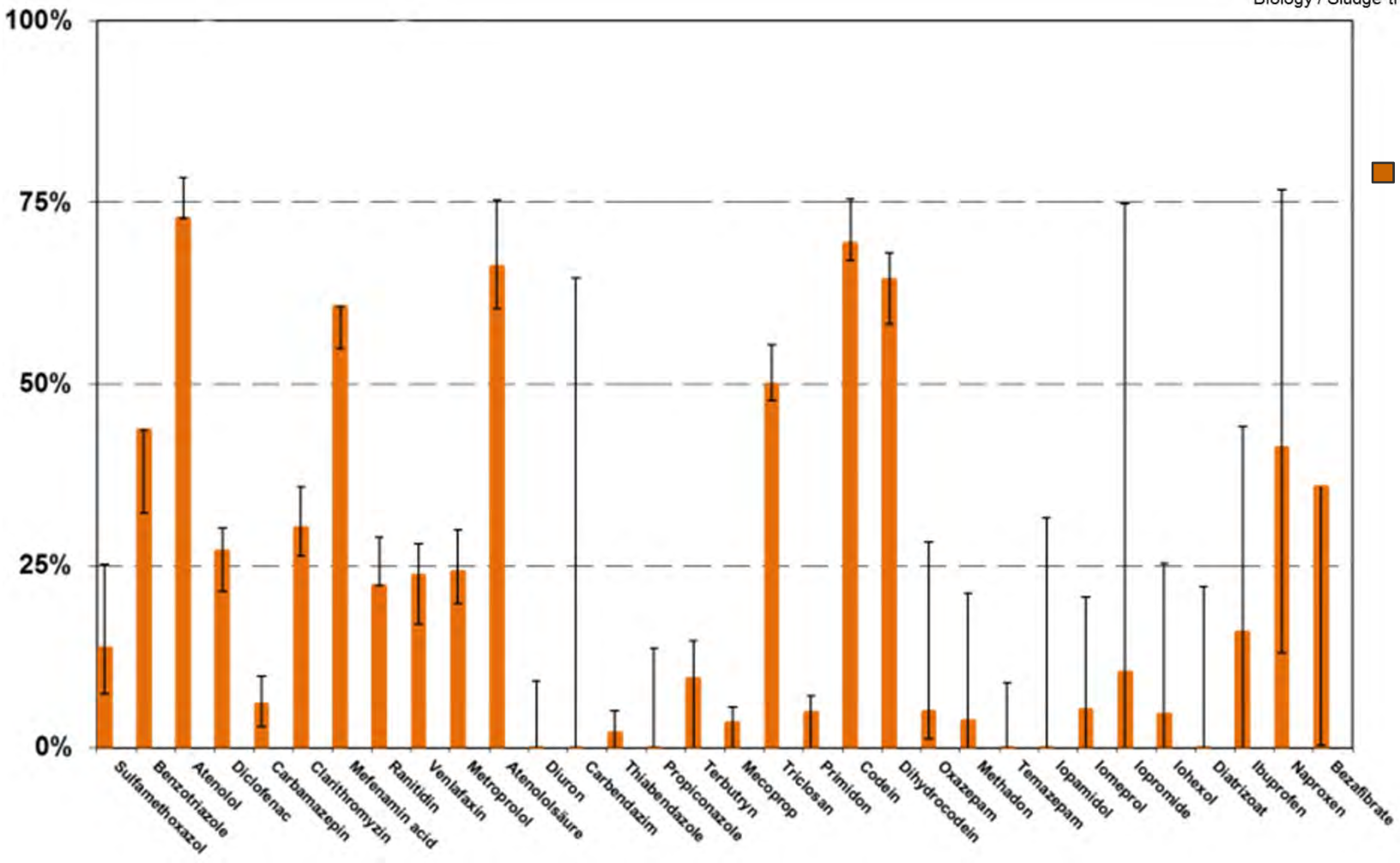

**Source:**
Boehler, M.; Zwickenpflug, B; Hollender, J.; Thernes, J.; Joss, A. and Siegrist, H. (2012): Removal of micropollutants in municipal wastewater treatment plants by powder-activated carbon. Water Sci Technol., Vol. 66 Issue: 10, pp. 2115-21

# Performance micropollutant elimination

## Dosage in front of deep bed filter in **double stage mode**

*Average PAC dosage = 15 mg PAC/L*



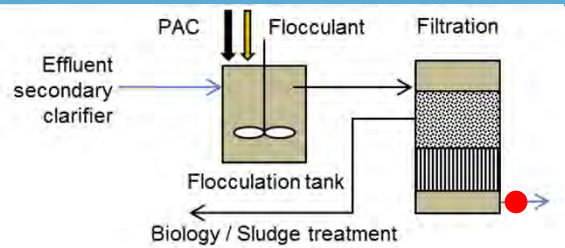

Relative Elimination:

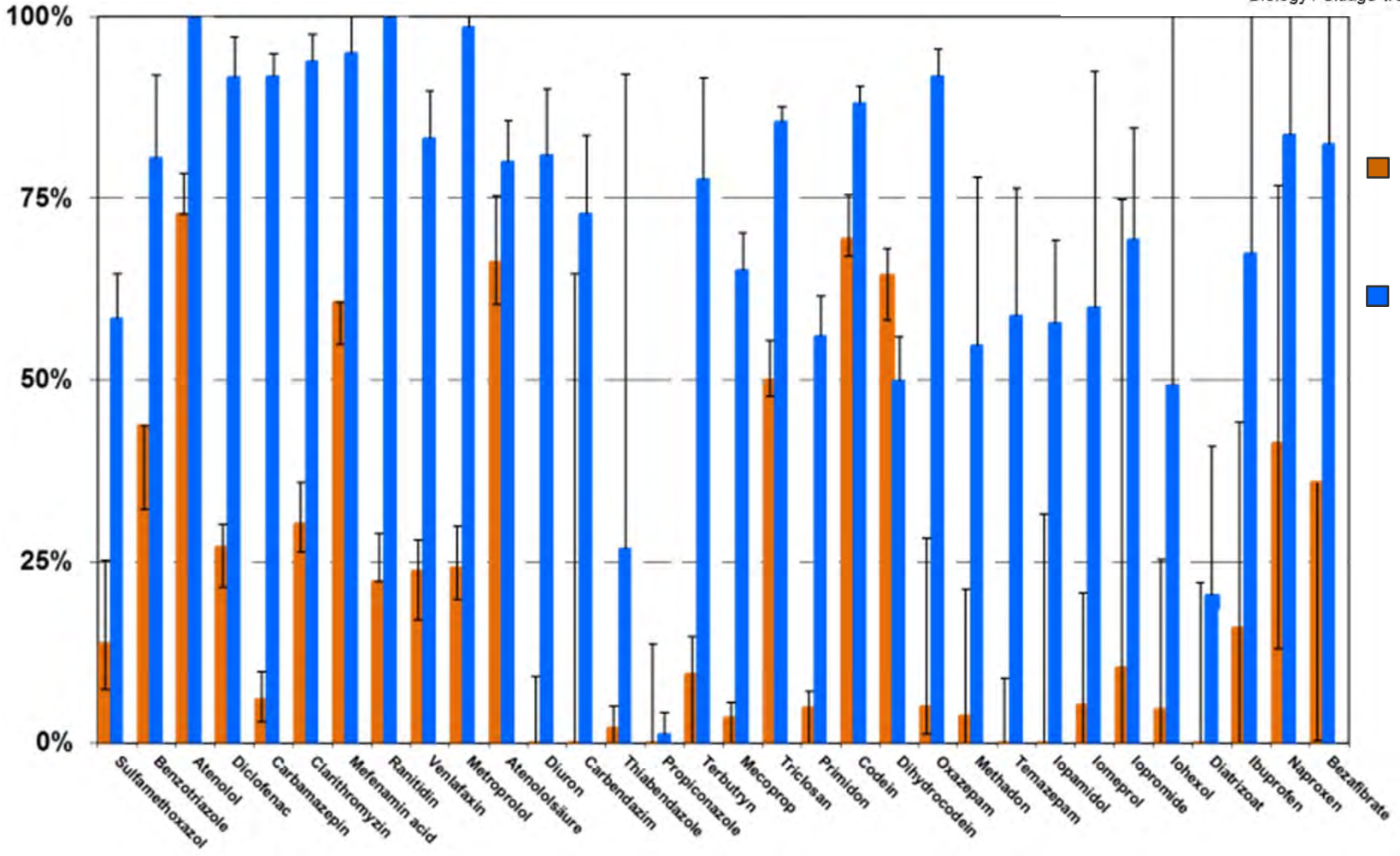
- Reference lane without PAC addition

# Performance micropollutant elimination

## Dosage in front of deep bed filter in **double stage mode**

*Average PAC dosage = 15 mg PAC/L*



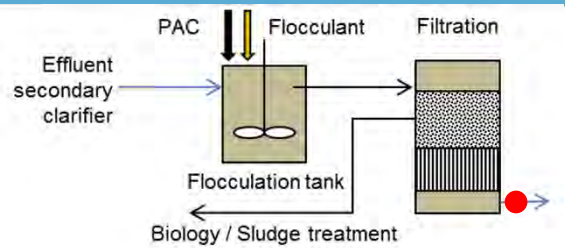

Relative Elimination:

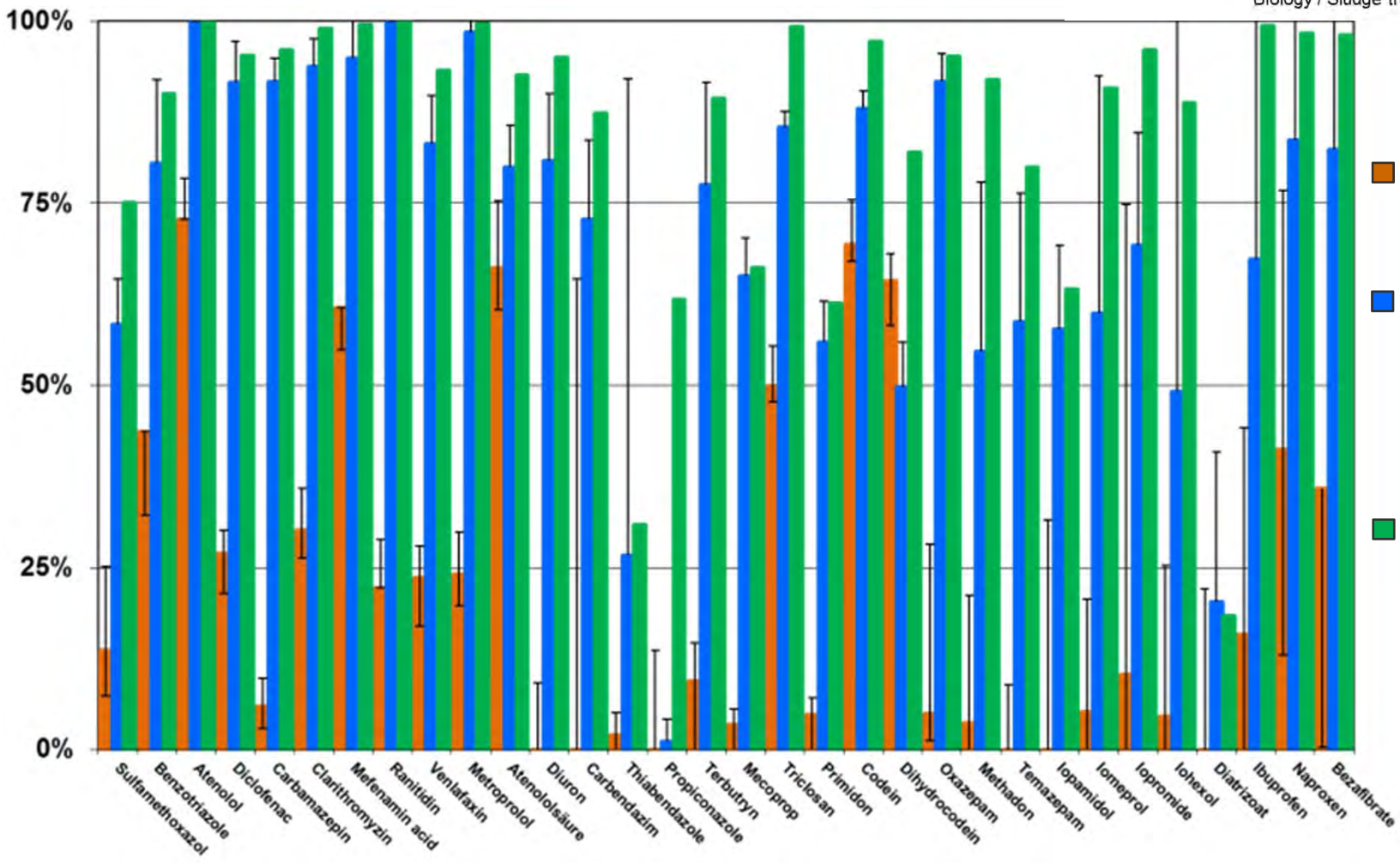
- Reference lane without PAC addition
- PAC lane referred to the effluent secondary clarifier

# Performance micropollutant elimination

## Dosage in front of deep bed filter in **double stage mode**

*Average PAC dosage = 15 mg PAC/L*



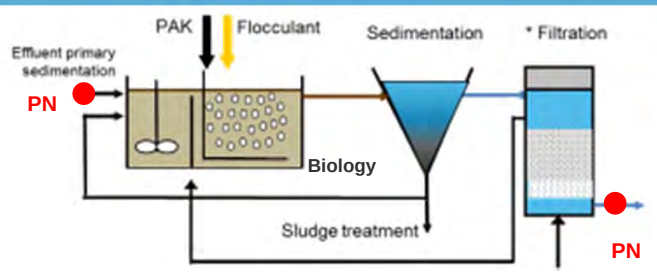

Relative Elimination:

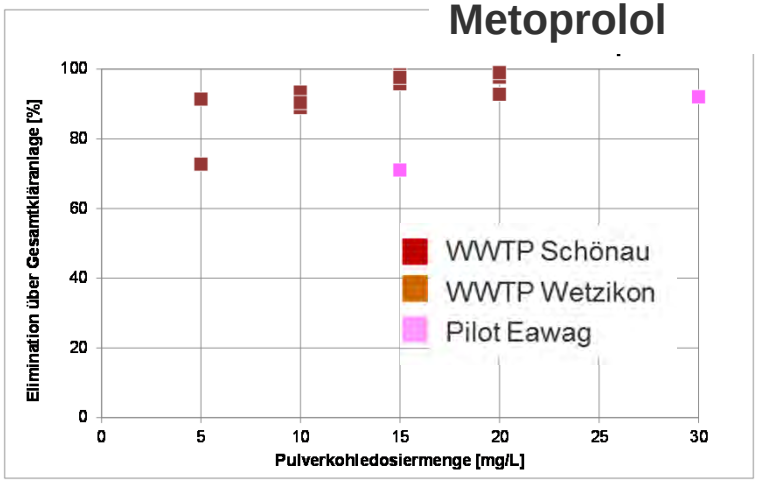
- Reference lane without PAC addition
- PAC lane referred to the effluent secondary clarifier
- Total elimination PAC lane referred to the effluent primary sedimentation

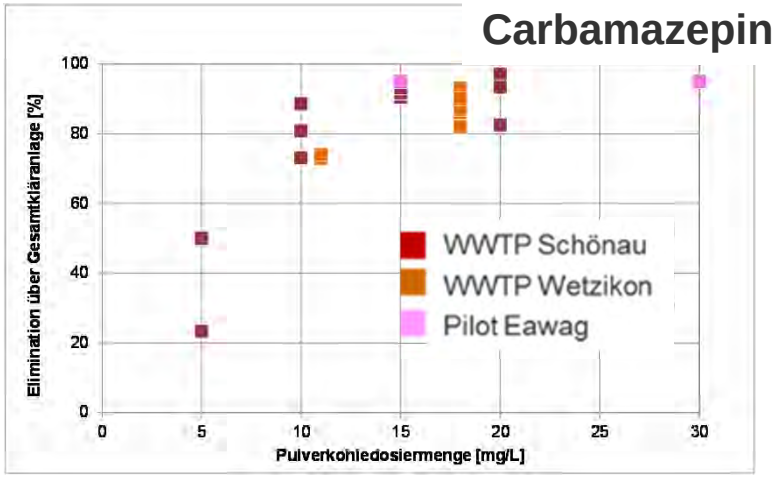
# Performance micropollutant elimination

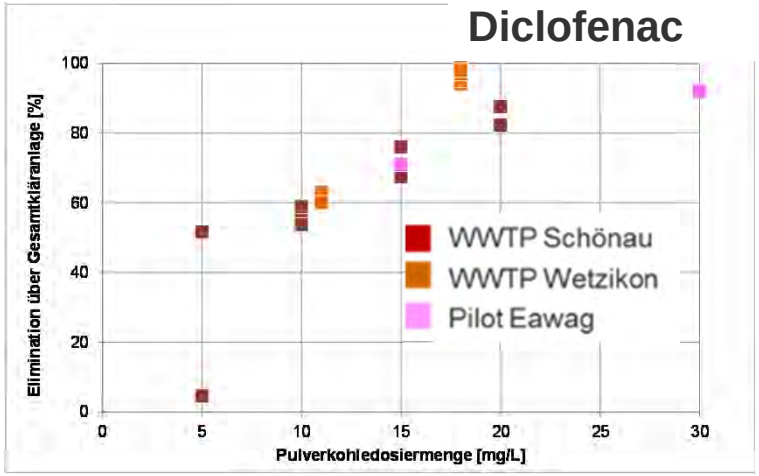
## Dosage into biology – simultaneous application

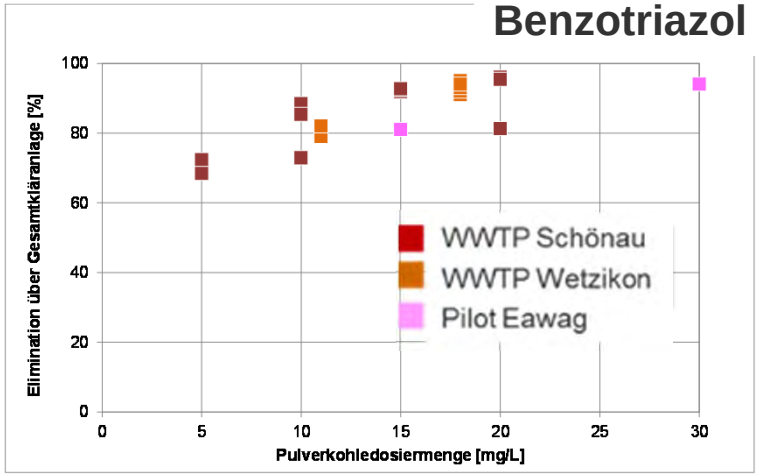
### Average PAC dosage = 5; 10; 15; 20; 30 mg PAC/L



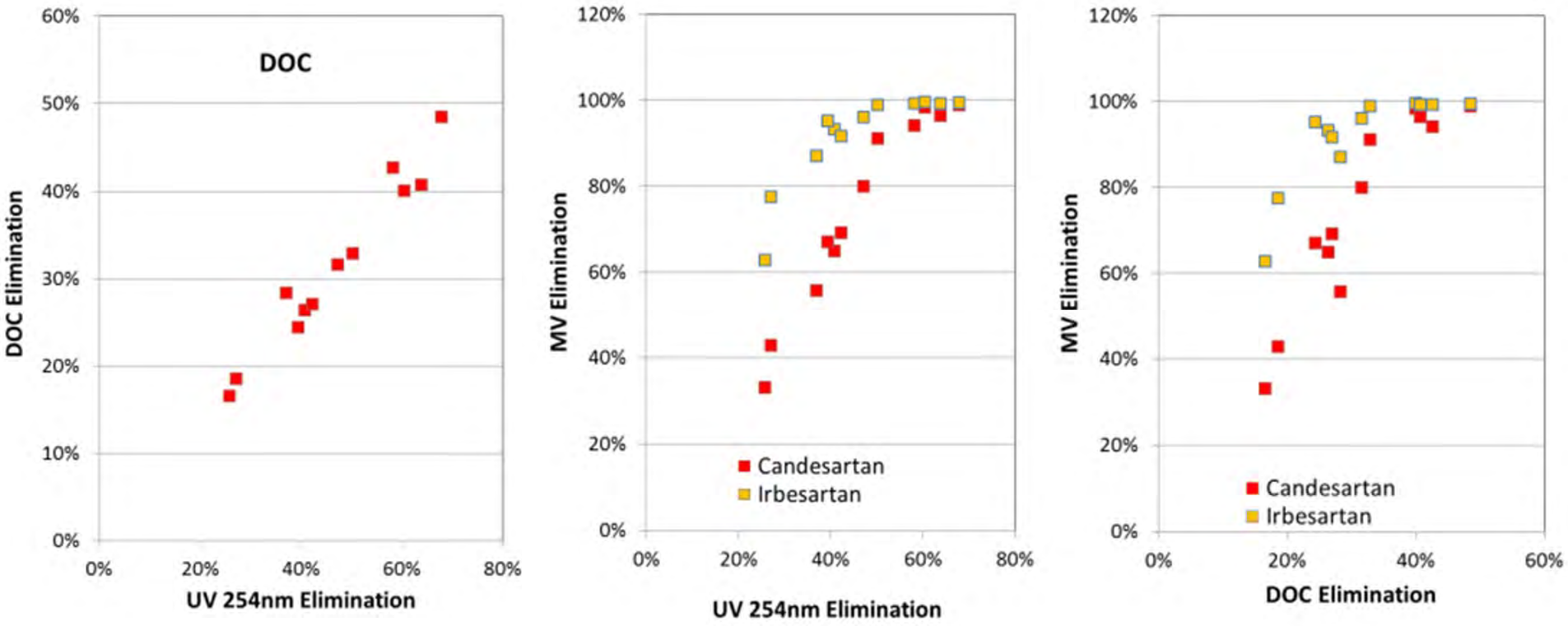




**Source:**
**Rößler & Metzger:** Untersuchungen zur Spurenstoffelimination mittels simultaner Pulveraktivkohledosierung auf der ARA Schönau, Abschlussbericht
**Obrecht et al.:** PAK-Dosierung ins Belebungsverfahren; Aqua & Gas Nr. 2 / 2015
**Boehler et al.** WS&T 2012

# *Effects on absorbance and DOC*

- **DOC and MP reduction results in a decrease of absorbance**
- **In PAC applications DOC reduction correlates quite well with elimination of MPs**

Batch tests 15 / 30 mg/L; 6 different types of PAC




M. Boehler / C. McArdell (2017): Internal report Eawag / Abwasserverband Glarnerland

## *Conclusion*

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- The MP elimination efficiency of the presented PAC applications in WWTPs is comparable to ozonation (> 80%)

- Sorption efficiency of PAC is reduced with increasing DOC, therefore an effluent treatment should be favored

- Adequate treatment of secondary effluent requires 10 - 20 gPAC/$m^3$ depending on DOC background concentration (5 – 10 gDOC/$m^3$ ) respectively

- **PAC recycling into the biology clearly increases elimination efficiency**

  - due to counter current application of PAC

  - due to reduction of DOC in biology

- PAC dosage results in an increase of sludge production of approximately 5-10% (10-20 gPAC/$m^3$)

- PAC dosage with recycling to biology showed **no negative effect on biological treatment and activated sludge properties**

- **The measurement of the absorbance is a useful tool for the monitoring of the MP elimination of a PAC application as well for a control of the quality of the PAC**

# Effect of contact time / sludge age of PAC