PAC addition to remove micropollutants: promising flow schemes

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Overview

- Introduction: potential flow schemes
- PAC: Results from pilot- and full scale experiments
  - Single stage addition: to effluent or to biology
  - Two stage application: PAC recycling to biology
- Results from GAC application (BioMAC)
- Energy and costs
- Conclusions - Outlook

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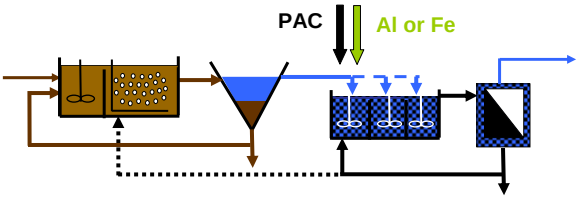
Introduction – potential flow schemes

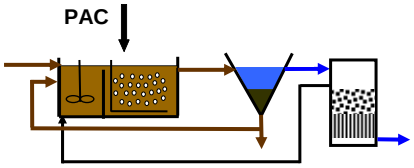
- PAC/flocculant addition to a contact/flocculation tank with additional sedimentation or membrane separation for PAC recycling
- After the sedimentation a filter is needed to reduce PAC loss



Sedimentation followed by filtration or membrane separation

Alternatives:

- PAC addition to filtration
- PAC additon directly to activated sludge system



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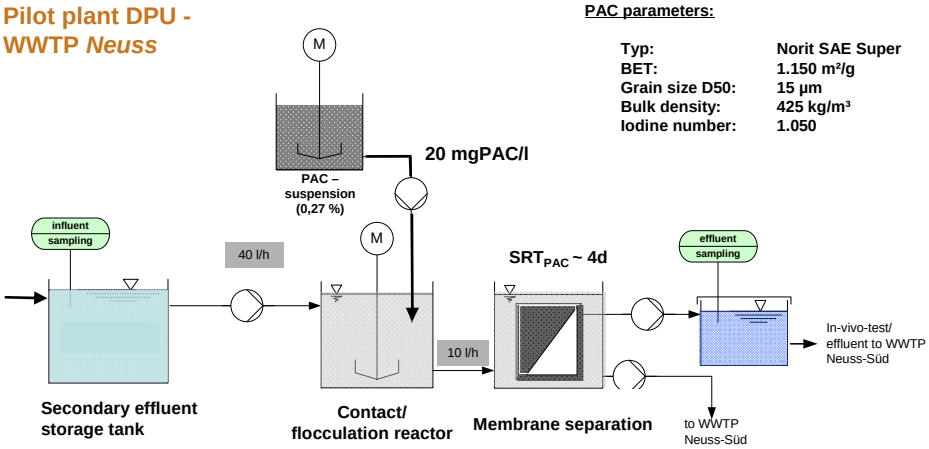
PAC addition to secondary effluent with membrane separation (single stage treatment)

Pilot plant DPU - WWTP *Neuss*

PAC parameters:

Typ:	**Norit SAE Super**
BET:	**1.150 m²/g**
Grain size D50:	**15 µm**
Bulk density:	**425 kg/m³**
Iodine number:	**1.050**



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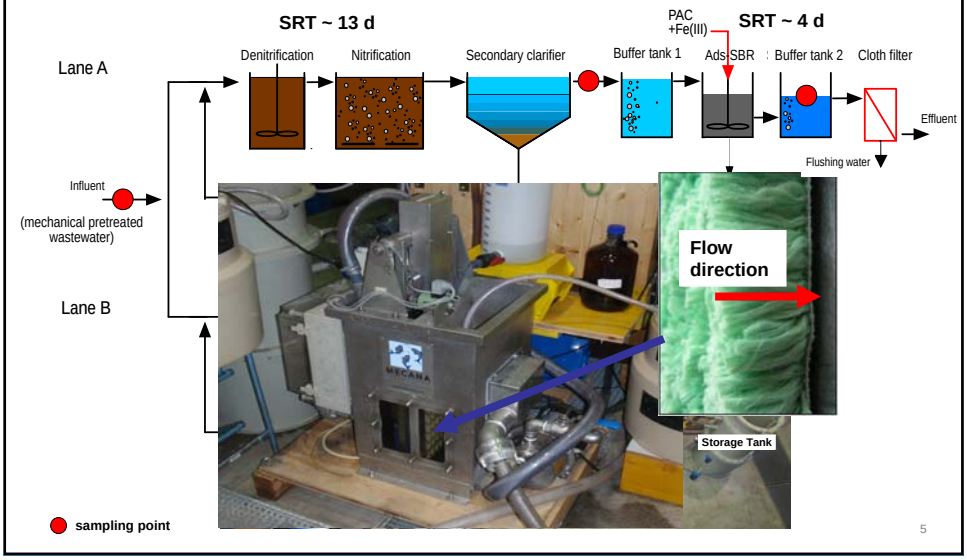
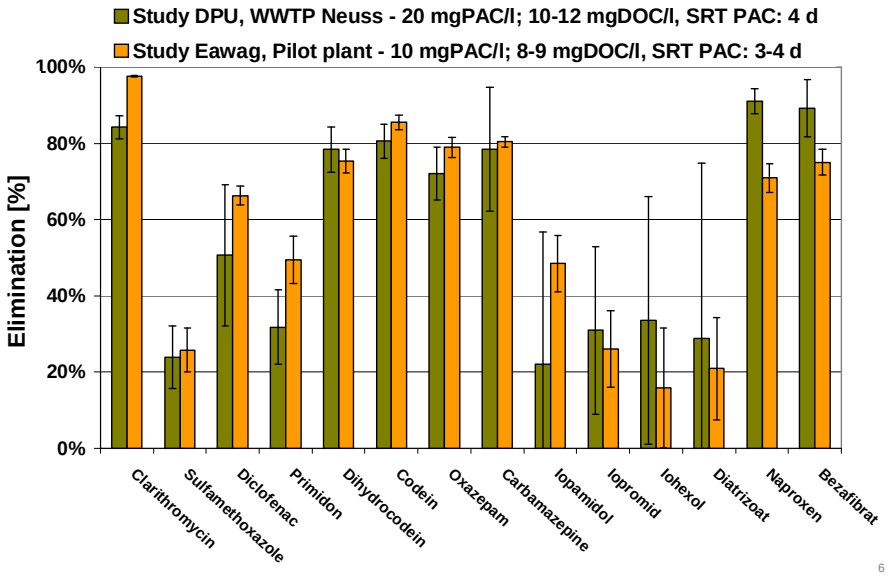
PAC addition to secondary effluent with additional sedimentation (SBR, single stage treatment)

Pilot plant Eawag



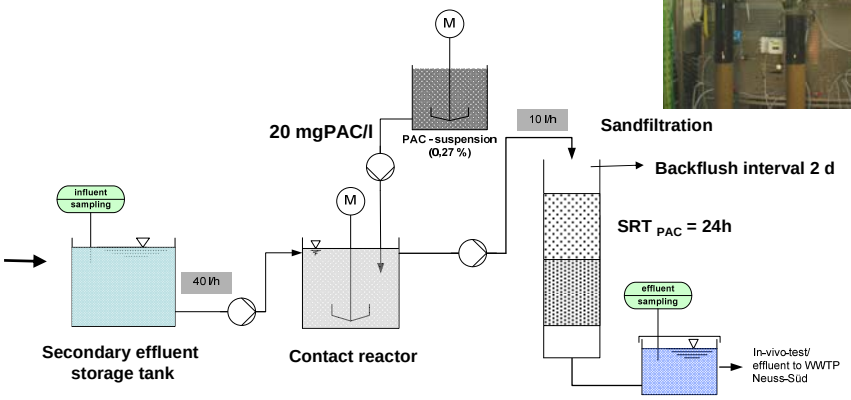
Results: PAC addition to secondary effluent with SBR and membrane separation (single stage treat.)



All elimination efficiencies referring to secondary effluent

PAC addition to secondary effluent with sand filtration (single stage treatment)

Pilot plant DPU - WWTP *Neuss*



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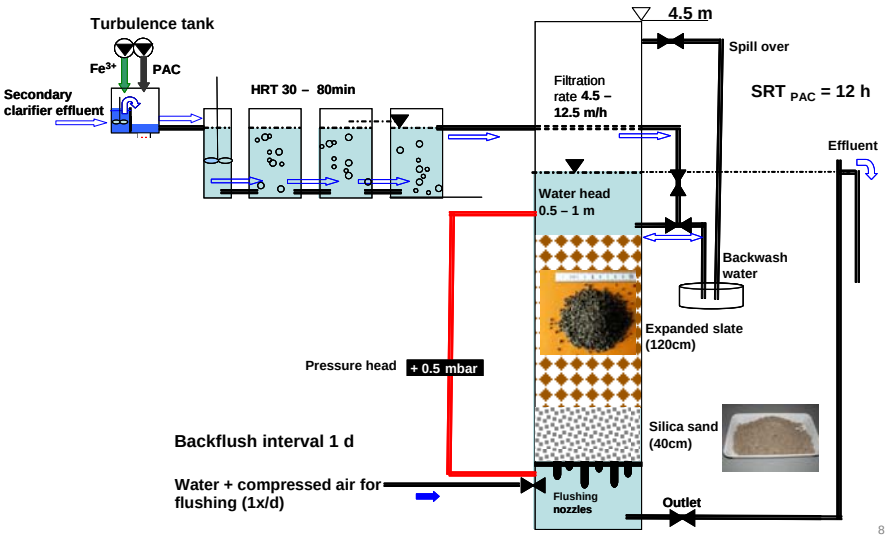
PAC addition to secondary effluent with sand filtration (single stage treatment)

Pilot plant Eawag



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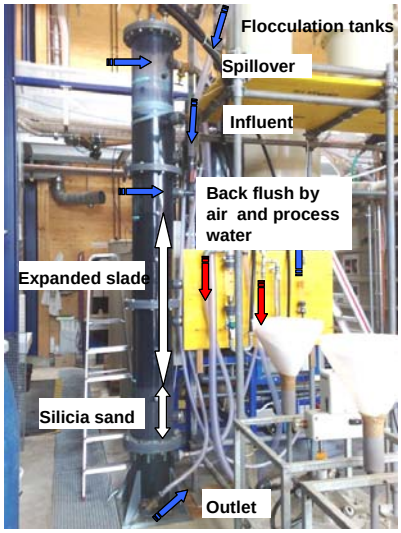
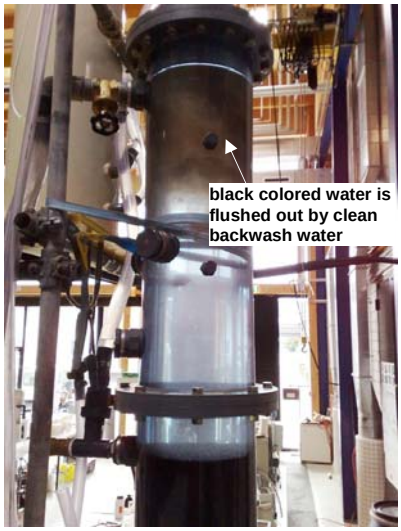
PAC addition to secondary effluent with sand filtration (single stage treatment)

Pilot plant Eawag





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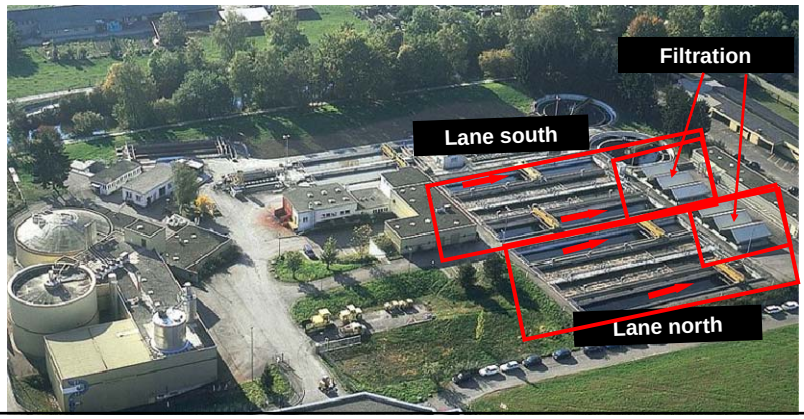
Full-scale experiments at WWTP Opfikon

Activated sludge system with two lanes for nitrification and denitrification for 60‘000 PE, each lane has two biology tanks with two secondary clarifiers

Each lane has one flocculation reactor followed by four two layer filters

Fe and PAC were only added to the flocculation tank **(HRT = 0.9 h)** of lane south with one filter in operation **(hydraulic load 4.3 m/h, SRT of PAC in the Filter was 12 h, backflush intervall: 1x/d)**



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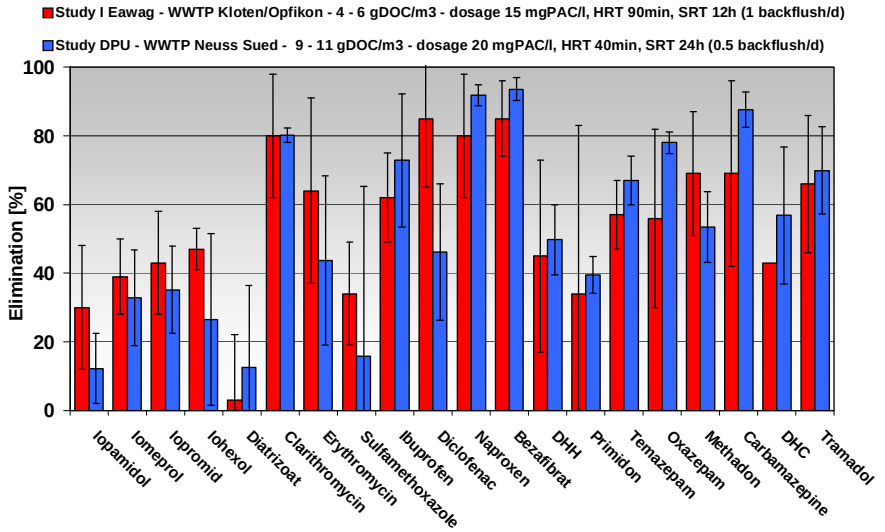
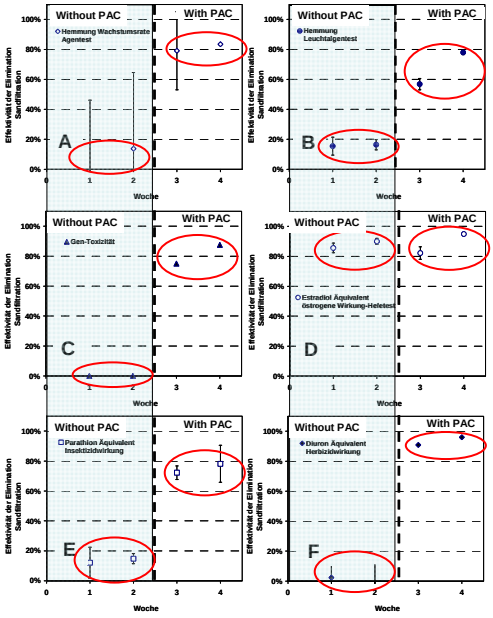
Results: PAC addition to secondary effluent with sand filtration



All Elimination rates referring to secondary effluent

All trials without PAC recycling via back flush water into biology

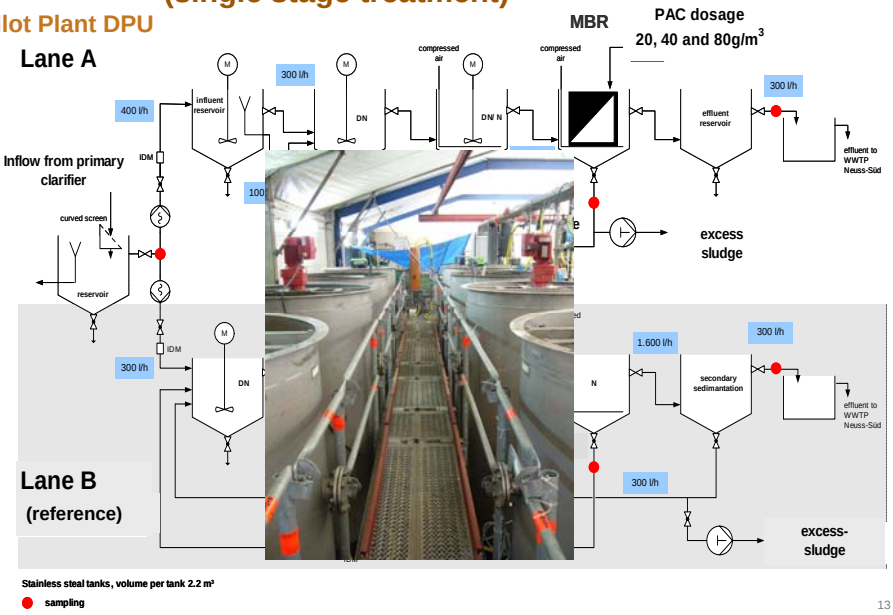
Results: PAC addition to secondary effluent with sand filtration - Eco-toxicity tests



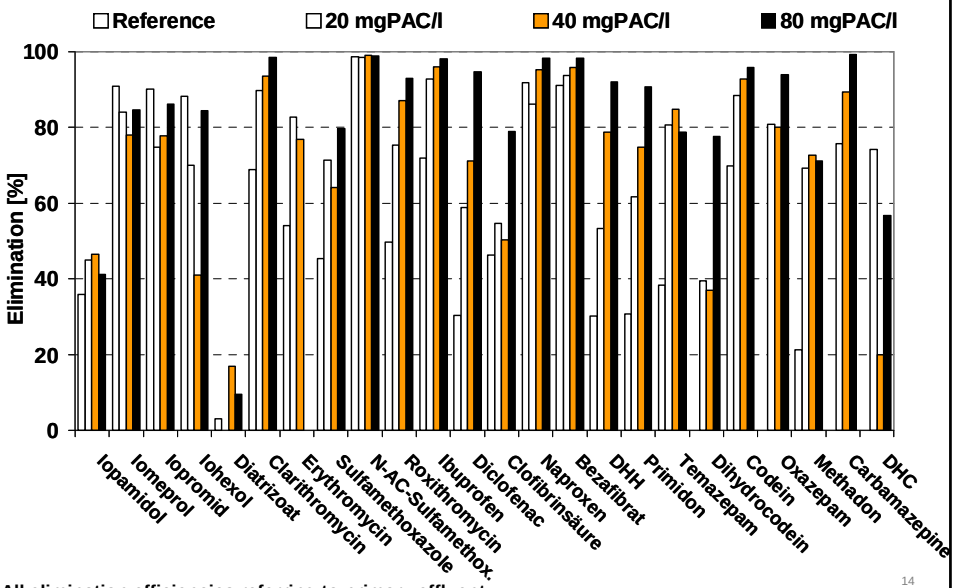
In 5 of 6 test the negativ impact of the wastewater could be clearly reduced by PAC additon

PAC addition to the activated sludge system (single stage treatment)

Pilot Plant DPU



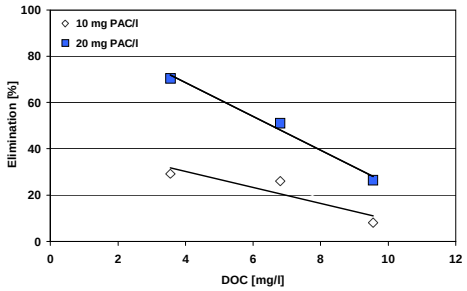
Results: PAC addition to the activated sludge system



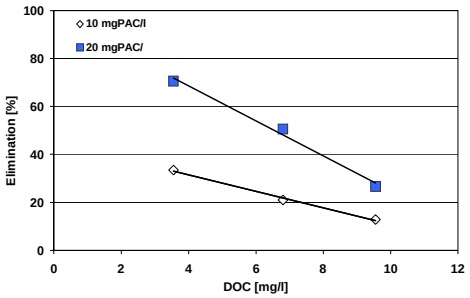
All elimination efficiencies referring to primary effluent

Results: Effect of background DOC

Iopamidol



Sulfamethoxazole



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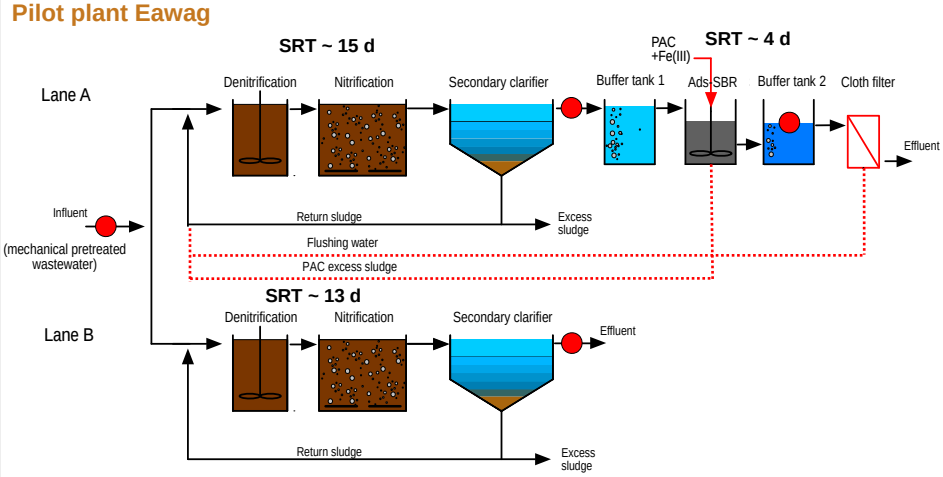
PAC addition to secondary effluent with additional sedimentation (SBR, two stage application)

Pilot plant Eawag



sampling point

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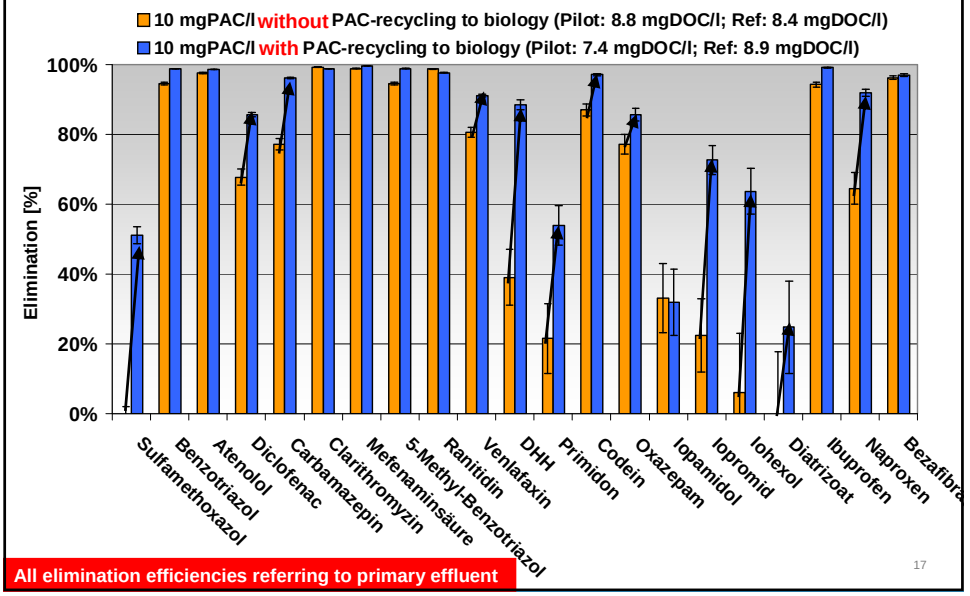
Results: PAC addition to secondary effluent with additional sedimentation (SBR)

Pilot plant Eawag



All elimination efficiencies referring to primary effluent

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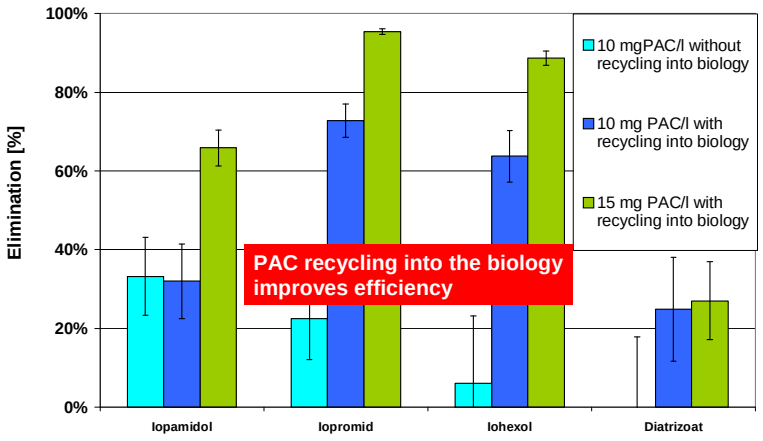
Results: PAC addition to secondary effluent with additional sedimentation (SBR)

Pilot plant Eawag

Relative elimination of contrast media with different PAC applications



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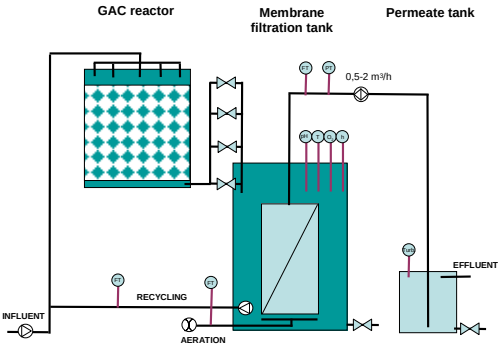
All elimination efficiencies referring to primary effluent

Secondary effluent treatment with GAC - BioMAC concept

Pilot plant Aquafin



Combination of adsorption, biodegradation and filtration
Evaluated on lab scale and pilot scale

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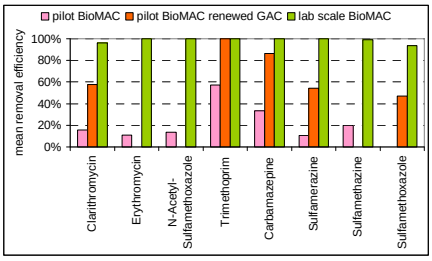
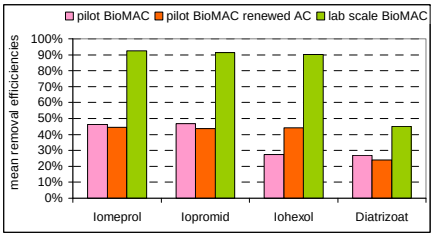
Results: Secondary effluent treatment with GAC (BioMAC concept)

- Results lab scale testing
  - Antibiotics removal > 95%
  - Iodinated contrast media removal > 80% (except diatrizoate)
  - Acidic pharmaceuticals removal
  - Complete removal pathogens
  - Significant decrease in estrogenic and anti-androgenic activity
  - Results suggest contribution of adsorption and biological activity
- Results pilot scale less positive
  - Temperature influence?
  - Activated carbon saturation?
- Further research needed
  - Cost optimization
  - Temperature influence
  - Added value of biological activity on GAC lifetime





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Energy and costs

Treatment	Dosage [mg L^{-1}]	Electrical energy [kWh m^{-3} ww]	Primary energy [kWh m^{-3} ww]	Annual Costs[c]	
				30'000 p.e. [€ m^{-3} ww]	500'000 p.e. [€ m^{-3} ww]
O_3	3[a] - 10	0.05[b] - 0.15	0.15 - 0.45	0.07[d] - 0.1	0.02[d] - 0.03
O_3 incl. sand filter	3[a] - 10	0.1 - 0.2[e]	0.3 - 0.6	0.15[d] - 0.2	0.05[d] - 0.07
PAC	10 - 20	0.005[f]	0.35 - 0.7[g]	0.15 - 0.2	0.06 - 0.08
PAC incl. sand filter	10 - 20	0.05[e,f]	0.5 - 0.8[g]	0.25 - 0.3	0.09 - 0.11

[a] Ø Operating conditions @ WWTP Regensdorf (5mg DOC L^{-1} ≅ 600g O_3 kg^{-1} DOC)
[b] Measured @ WWTP Regensdorf (production of O_3 (incl. O_2), thermal residual-O_3 destructor, control system, cooling aggregate ≅ 15kWh kg^{-1} O_3)
[c] Detailed, realistic cost study by Hunziker Ltd. (~300L c^{-1} d^{-1} ⇒ 100m^3 c^{-1} y^{-1})
[d] extrapolated from O_3 5-10mg L^{-1}
[e] Sand filter (experience from conventional treatment)
[f] Mixing (experience from conventional treatment)
[g] Primary energy consumption of PAC (no regeneration) 3.5 kg carbon needed for 1 kgPAC: 3.5kgC/kgPAC x 2.7kgCOD/kgC x 14MJ/kgCOD / 3.6MJ/kWh = 35kWh/kgPAC

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Conclusions

- Sorption efficiency of PAC reduced with increasing DOC
- Adequate treatment of secondary effluent requires 10 - 20 gPAC/m^3 depending on DOC background concentration (5 – 10 gDOC/m^3) respectively
- High dosages of PAC (80 gPAC/m^3) directly into the activated sludge can not be justified due to the low additional benefit compared to lower dosages (40 gPAC/m^3)
- PAC dosage results in an increase of sludge production of approximately 5-10% (10-20 gPAC/m^3)
- Investment and operation costs (incl. filtration) amount to 0.1-0.3 € m^{-3} for PAC addition with flocculation, sedimentation and filtration (~15 – 45 €/(PE·a)
- **PAC recycling into the biology (counterflow) clearly increases elimination efficiency**

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Outlook

Further tests with pilot plant Eawag
(Winter/Spring 2010)

- Dosage of 20 and 40 mgPAC/l into the biology
- Behaviour of the loaded PAC in the digestion step – desorption of adsorbed micropollutants?
- Batchtests – inhibition of the nitrifiers by PAC?

Second full scale application - sandfiltration at WWTP Kloten/Opfikon
(Summer 2010)

- Repetition and optimisation of full scale application at WWTP

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Acknowledgment

This study was part of the EU Neptune project (Contract No 036845, SUSTDEV-2005-3.II.3.2), which was financially supported by grants obtained from the EU Commission within the Energy, Global Change and Ecosystems Program of the Sixth Framework (FP6-2005-Global-4)

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