

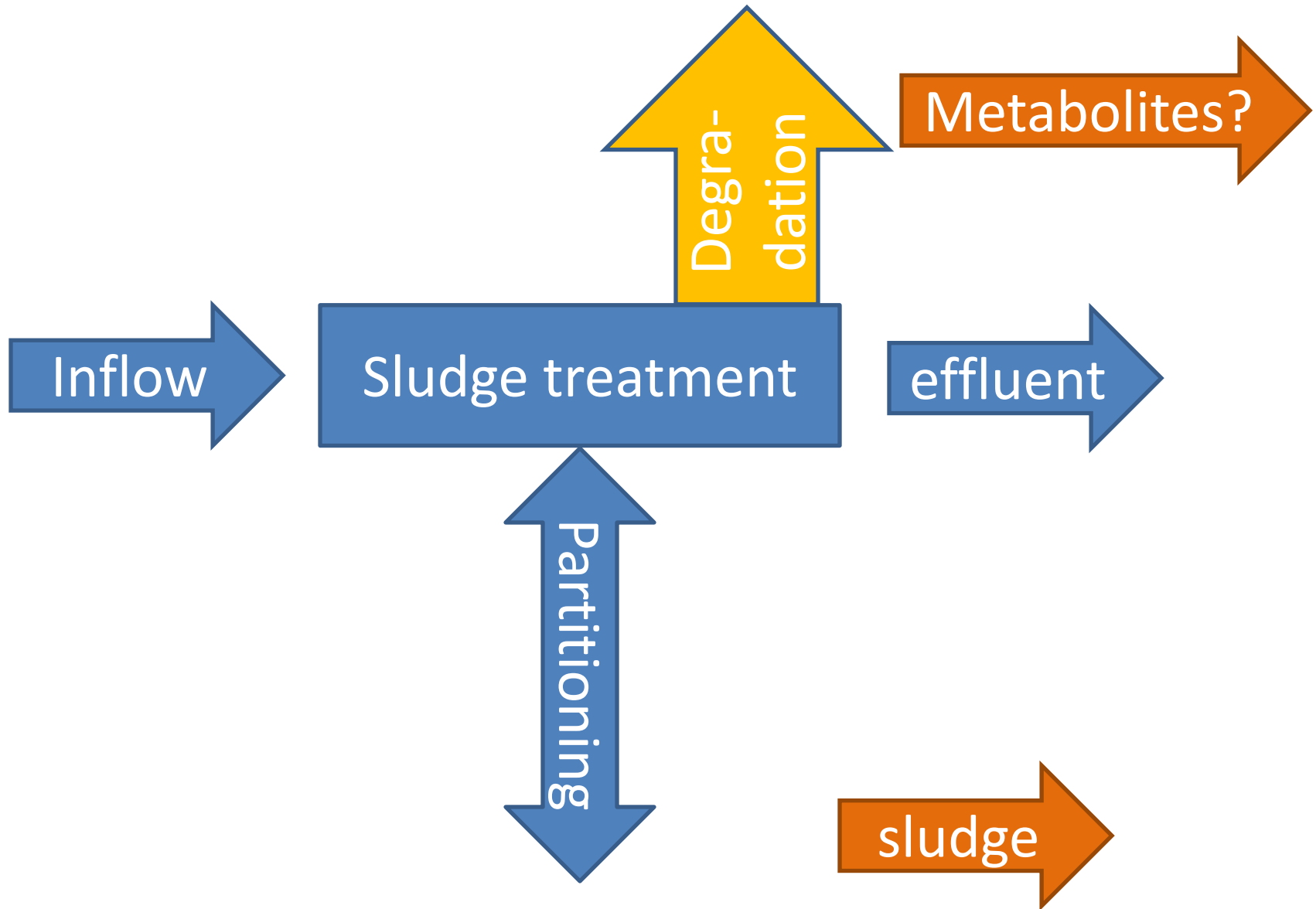


Removal of pharmaceuticals in different activated sludge wastewater treatment plants in comparison to biofilm and ozonation

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Micro-pollutants in activated sludge treatment



Micro-pollutants in activated sludge treatment II

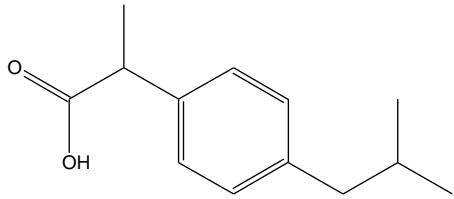
Typically 10 g/L sludge are generated

If lg partition constant is 3: 50% of compound is in sludge

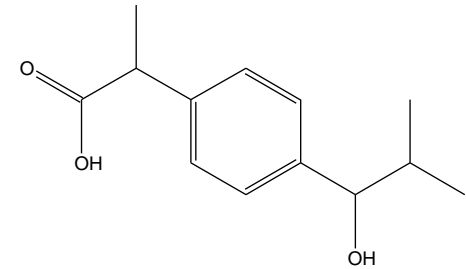
If lg partition constant is 4: 90% of compound is in sludge

lg partition constant = pKow

Degradation



Ibuprofen



Hydroxy-Ibuprofen



CO₂, H₂O, Biomass

Degradation

Are all sludges similar?

Systematic comparison of different sludges

- **Sludges were sampled at the respective WWTP**
- **They were used in lab for incubation studies under normalised aerobic conditions**
- **Samples were taken and analysed for pharmaceuticals – for kinetic data**

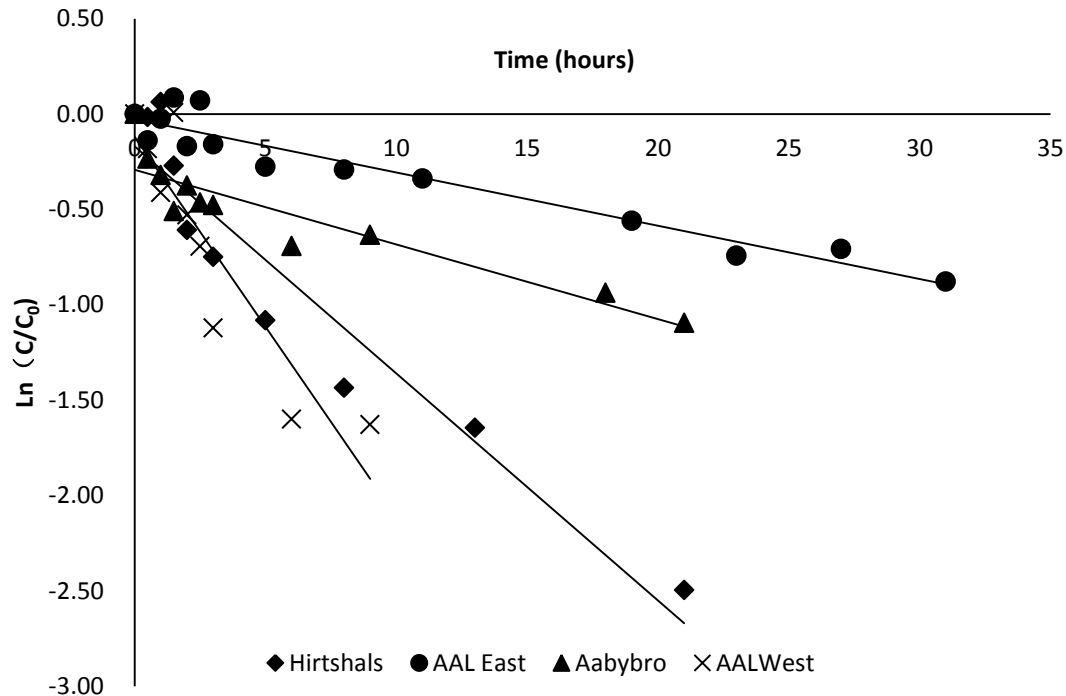
WWTPs used:

Name	PE	COD / BOD	Temp [°C]	SRT [d]	HRT [h]	VS [g/L]	N	P
Aalborg-West	300.000	2.7	12	14	22	2.45	Alternating DN in aeration	Biological-sidestream hydrol.
Aalborg-East	100.000	2.9	11	31	35	3.17	Alternating DN in aeration	Biological-sidestream hydrol.
Aabybro	11.000	2.1	11	47	21	4.51	Upstream DN	FeSO4
Hirtshals	62.700	2.0	7	20	42	3.93	Alternating DN in aeration	Biological-upstream hydrol.

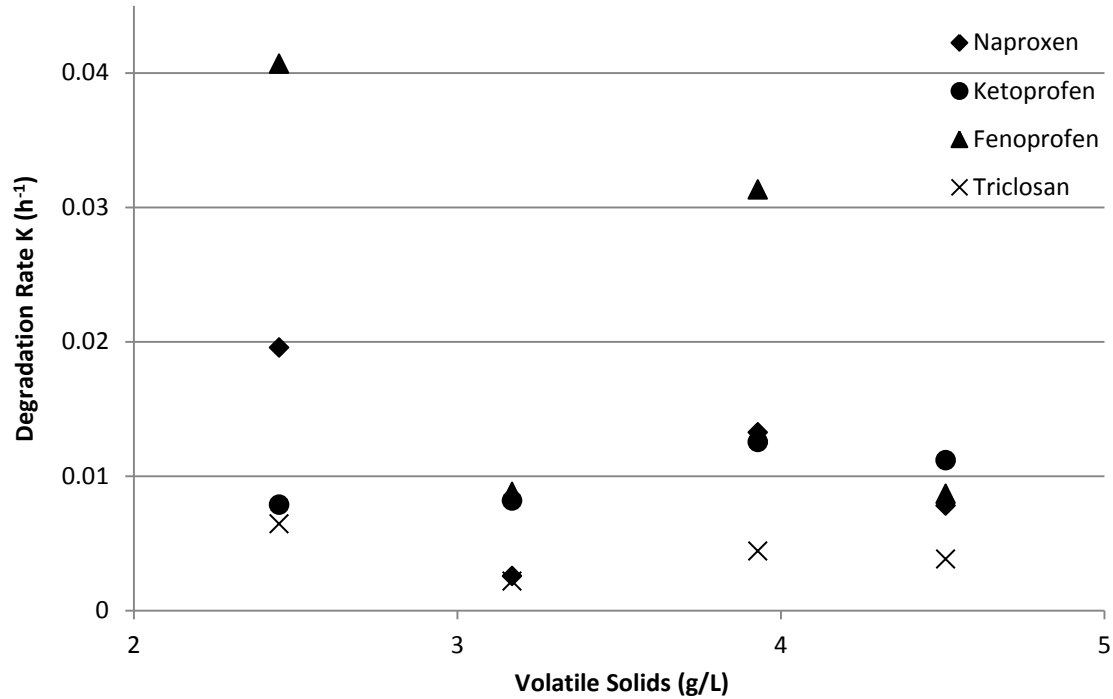
First order reaction rate constants

WWTP	Compounds	Degradation rate	k	Half-Life	R ²
		%	h ⁻¹	[h ⁻¹]	
Aalborg West	Naproxen	90	0.0196	15	0.85
	Ketoprofen	90	0.0079	36	0.79
	Fenoprofen	90	0.0407	7	0.90
	Carbamazepine	-	-	-	-
	Triclosan	85	0.0065	44	0.97
	Dichlofenac	-	-	-	-
Aalborg East	Naproxen	46	0.0026	86	0.67
	Ketoprofen	77	0.0082	27	0.85
	Fenoprofen	55	0.0088	25	0.92
	Carbamazepine	82	-	70	0.45
	Triclosan	61	0.0022	100	0.94
	Dichlofenac	-	-	-	-
Aalbybro	Naproxen	62	0.0278	6	0.77
	Ketoprofen	78	0.0112	14	0.77
	Fenoprofen	65	0.0087	18	0.84
	Carbamazepine	-	-	-	-
	Triclosan	85	0.0038	40	0.97
	Dichlofenac	-	-	-	-
Hirtshals	Naproxen	90	0.0132	13	0.91
	Ketoprofen	94	0.0125	14	0.96
	Fenoprofen	90	0.0813	2	0.83
	Carbamazepine	-	-	-	-
	Triclosan	91	0.0044	40	0.98
	Dichlofenac	-	-	-	-

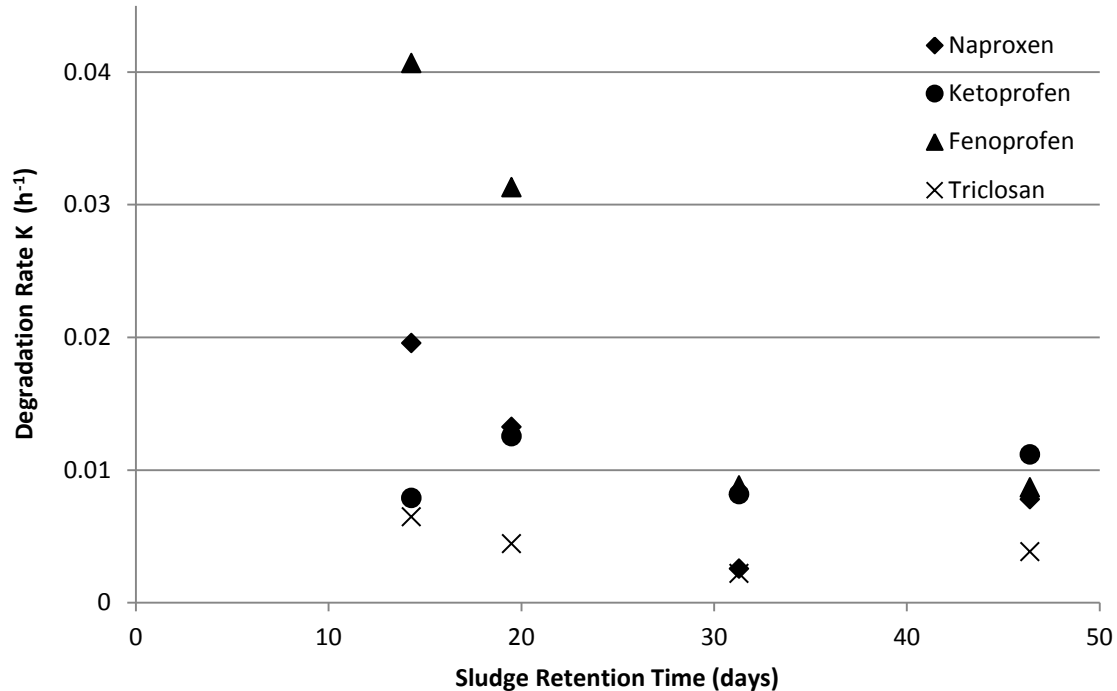
Degradation of Fenoprofen in in sludge from four different WWTPs (AAL : Aalborg).



Degradation rate k in dependence of biomass expressed as volatile solids (VS).



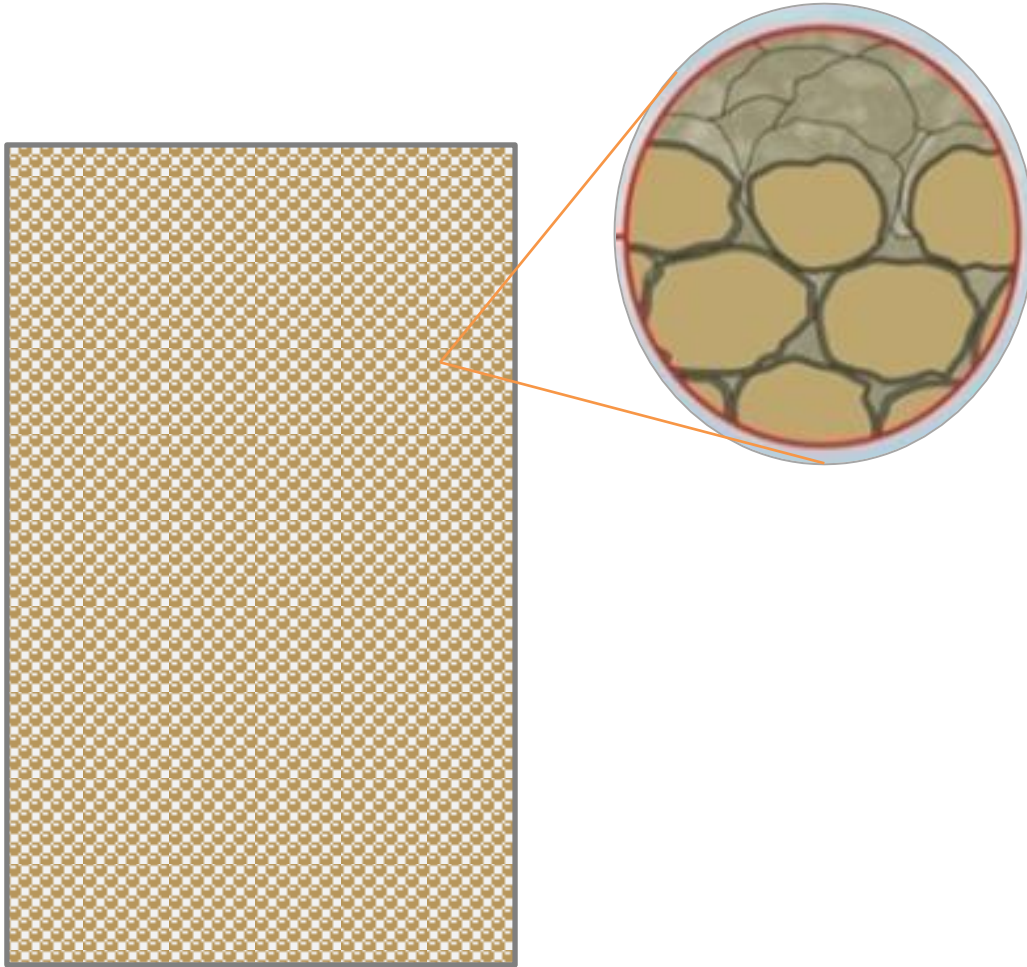
Degradation rate k as a function of sludge retention time (SRT).



Status on sludge

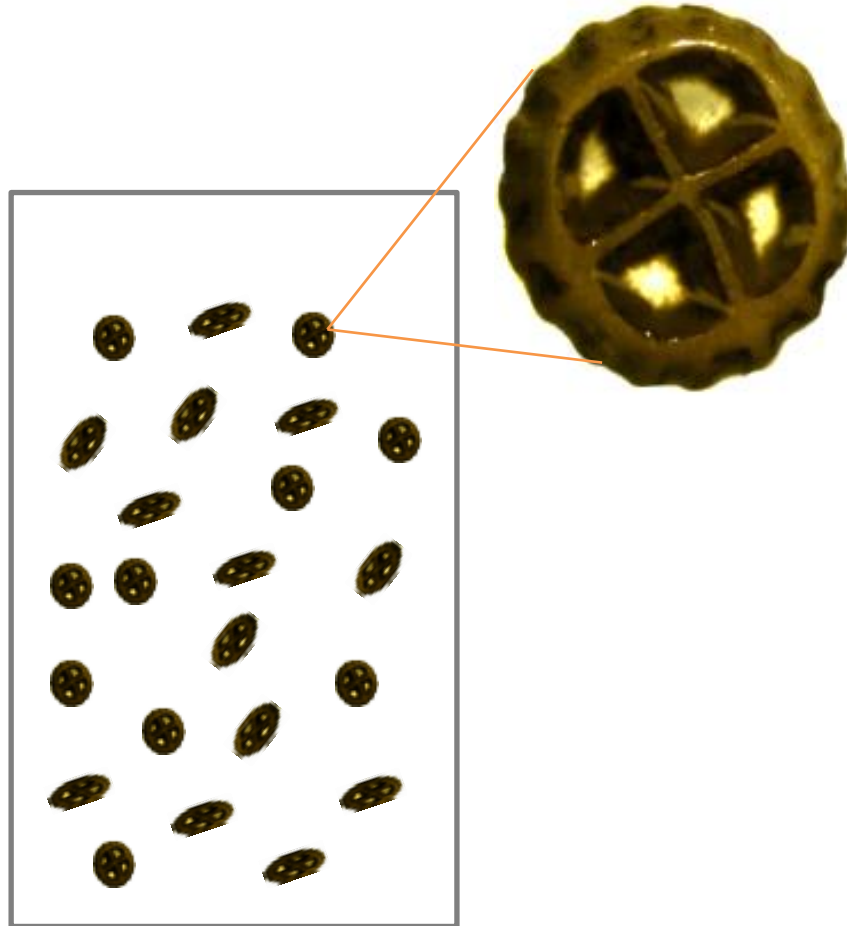
- Classical activated sludge can degrade some compounds
- It is difficult to predict which plant will be able to remove how well.
- Some compounds cannot be removed (Diclofenac, Carbamazepine, X-ray contrast media)
- Diclofenac and Carbamazepine can be removed with polishing ozonation, while X-ray contrast media cannot
- Ozonation is energy craving
- What can be achieved with biofilms?

Biofilm reactors – porous media

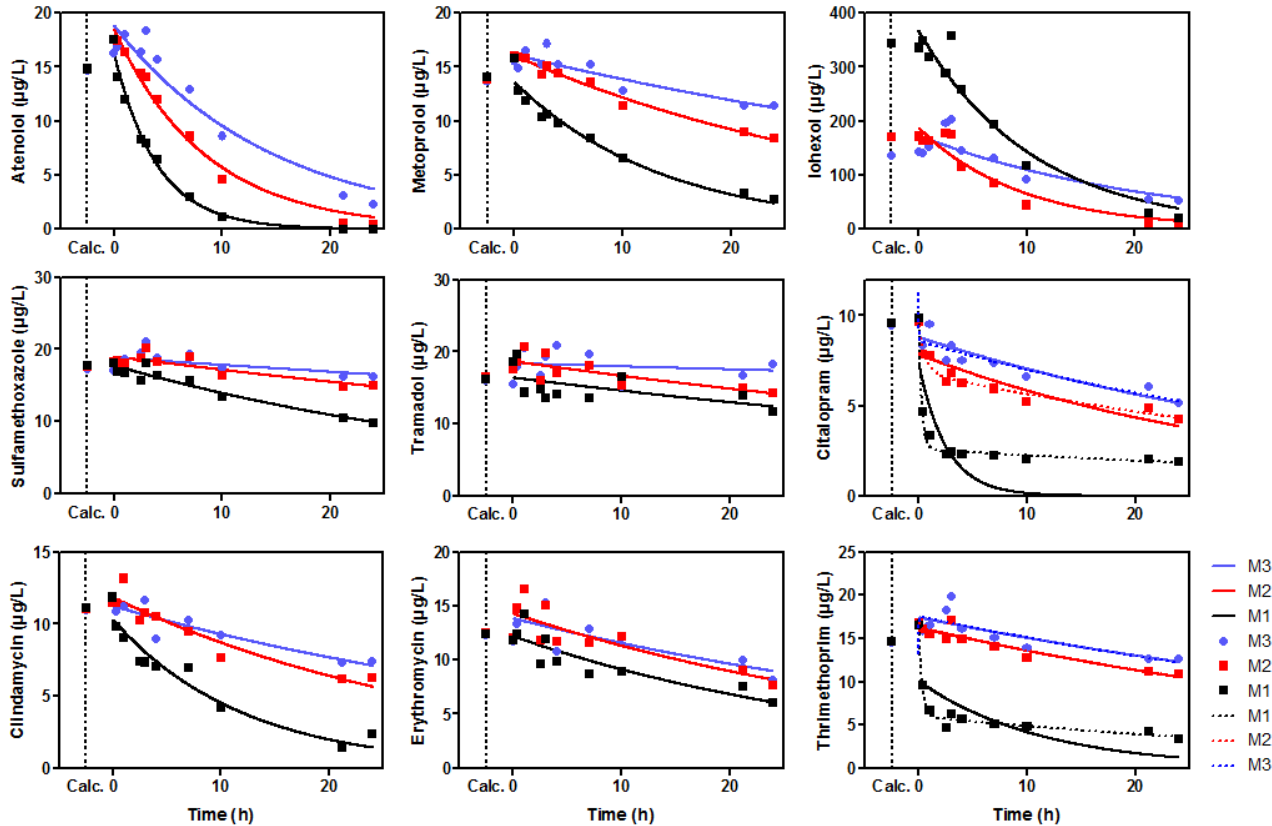


Grains
Biofilm

Biofilm reactors – Moving bed biofilm reactor (MBBR)



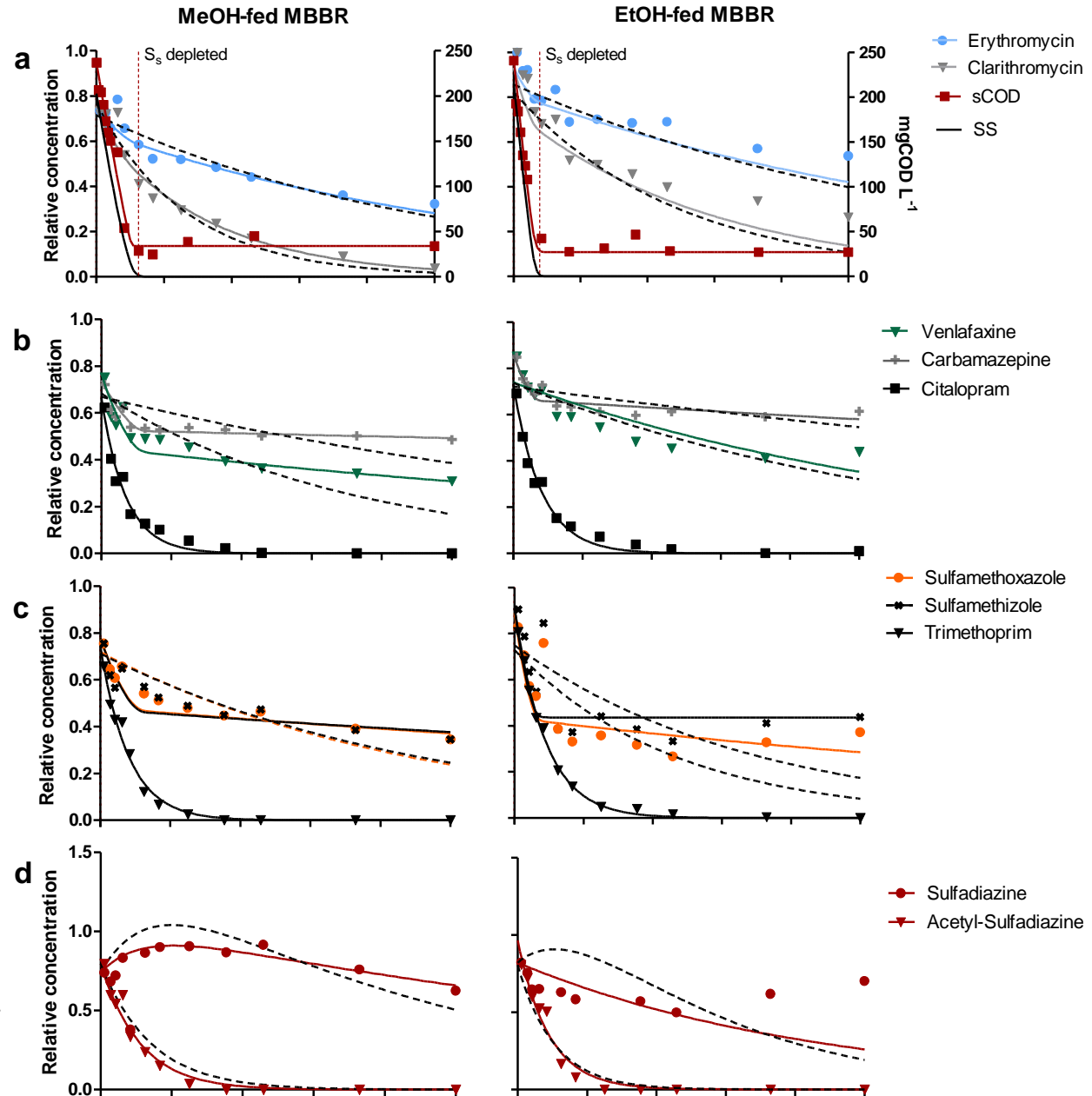
Staged aerobic MBBR



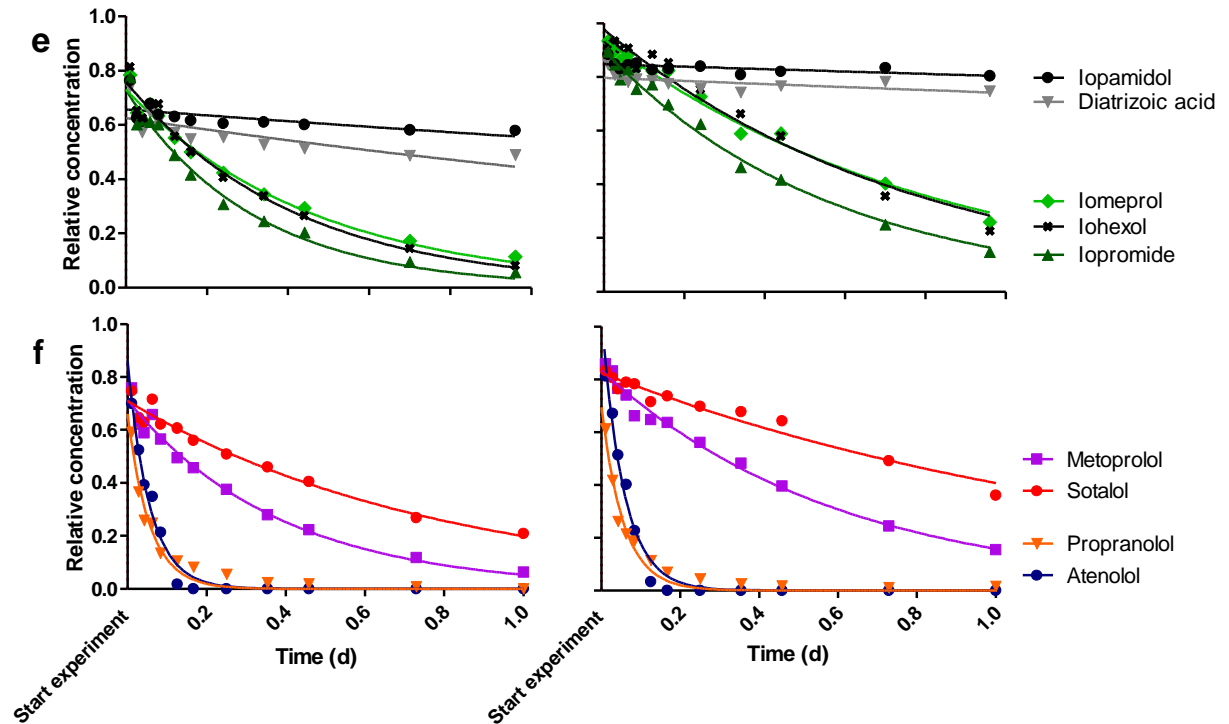
- 21/26 compounds degraded >20%
- First order kinetics for most compounds
- Two phase kinetics for four compounds
- While M1 degrades faster, has M3 usually the more effective biomass

Including removal for Diclofenac, Carbamazepine, X-ray contrast compounds

Single stage denitrifying MBBR



Single stage denitrifying MBBR



- Denitrifying MBBR is nearly as effective as aerobic
- MeOH reactor does a bit better than the EtOH reactor
- Diclofenac cannot be degraded under denitrifying conditions
- Carbamazepine and X-ray contrast compounds can be degraded under denitrifying conditions

Conclusions:

- **MBBRs might be a suitable alternative for removing organic micro-pollutants**
- **Currently residence times of 20 h would be needed to break down sufficient amounts of pollutants**
- **Co-degradation and starvation are most probably the most relevant process.**
- **It is difficult to foresee reactor parameters for fully optimised co-degradation/starvation reactors**


















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Persistence of compound groups in wastewater treatment

	CAS	Ozonation	Biofilm
X-ray contrast media			
Beta-blockers			
Diclofenac/ Carbamazepine			 ?
Ibuprofen			
Sulfonamides	:-/		
Macrocyclic antibiotics			 ?