Danish BAT for hospital wastewater treatment - Full scale treatment of hospital wastewater consisting of MBR, ozone and GAC

Ulf Nielsen, P. E. Jørgensen, M. M. Klausen, J. Søholm, J. Tuerk

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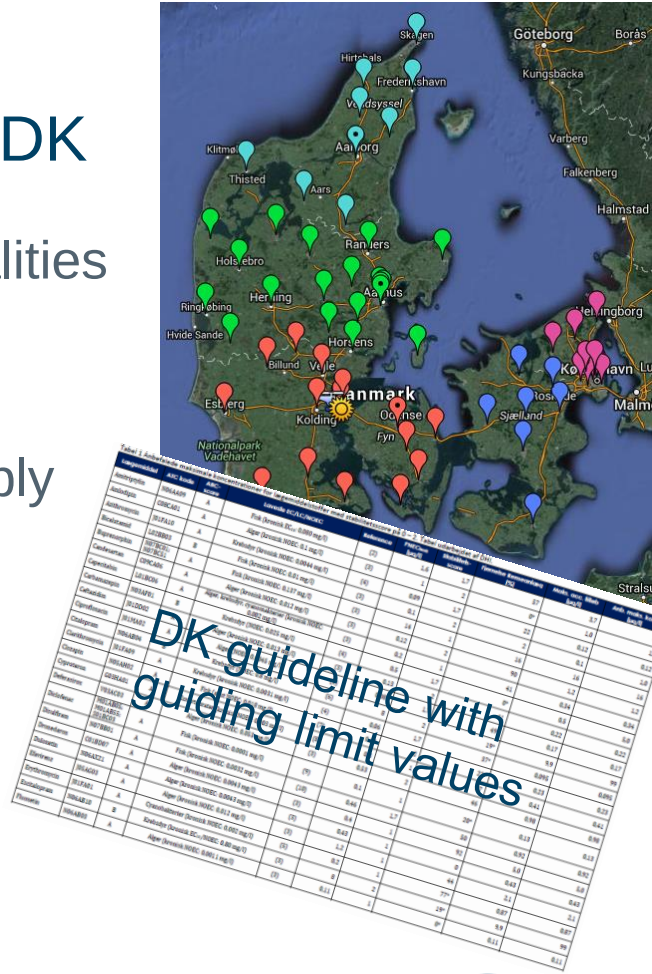
Background
Hospitals are regulated like industries in DK

- Wastewater permits are issued by the municipalities
- Guiding limit values for 40 hazardous pharmaceuticals (API's)
- According to Danish law hospitals have to comply with BAT on wastewater treatment

- But what is BAT for treatment of hospital wastewater?



Full scale test plant at a large university hospital

Herlev University hospital

- 850 beds
- All major clinical specialities (cancer etc.)
- Water consumption: 170.000 m^3/y

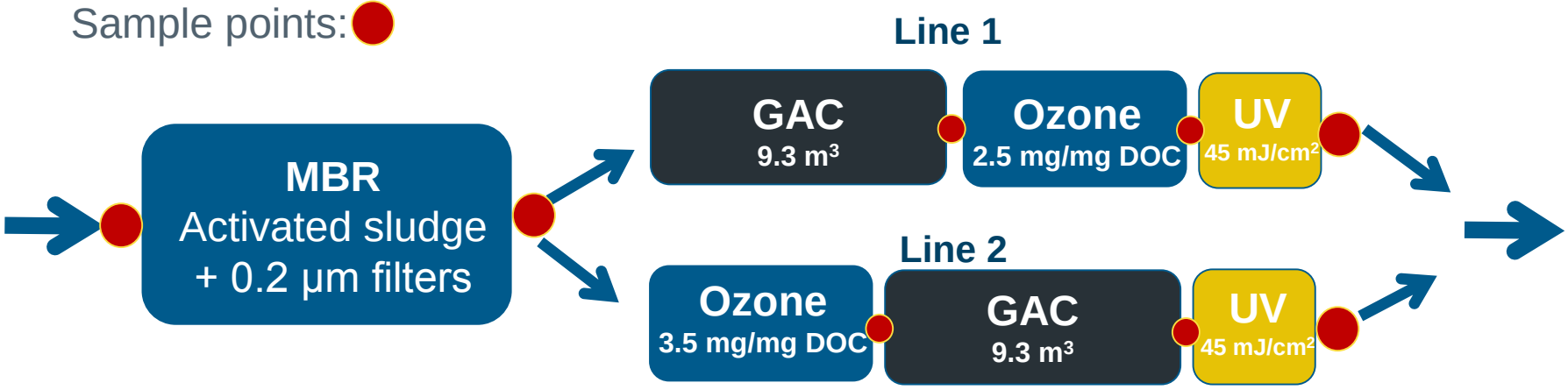
Full scale test treatment plant

- Constructed in 2013-14. Operated since May 2014
- Full solution with **water, air and sludge treatment**
- Private-Public innovation Partnership (PPP)

Setup of the treatment plant

Membrane BioReactor (MBR) plus two test lines for polishing :

Sample points:



Overview of treatment plant

Process tanks

Polishing lines
1. GAC + Ozone + UV
2. Ozone + GAC + UV

Ceramic membrane filtration

Sludge drying to 80% dry matter

Air treatment for odour/patogen removal using photoionization (UV+GAC)

Sludge bags and screenings for incineration
Pick-up 2/wk
District heating produced

Test period and plan

Monitoring of pharmaceuticals (API's):

131 API's plus metabolites analysed

118 samples analysed(N)

Performed by IUTA and Eurofins

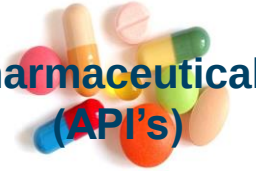
Start
May 2014

1 mo

1 year

End
Nov. 2015

Air sampling

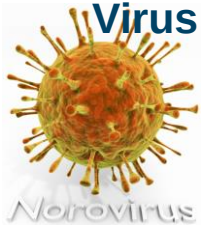


Pharmaceuticals (API's)

GAC parameters

© DHI

Sludge-parameters

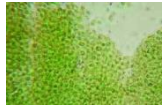


Virus

Volatile substances

Radio-activity

Ecotoxicity

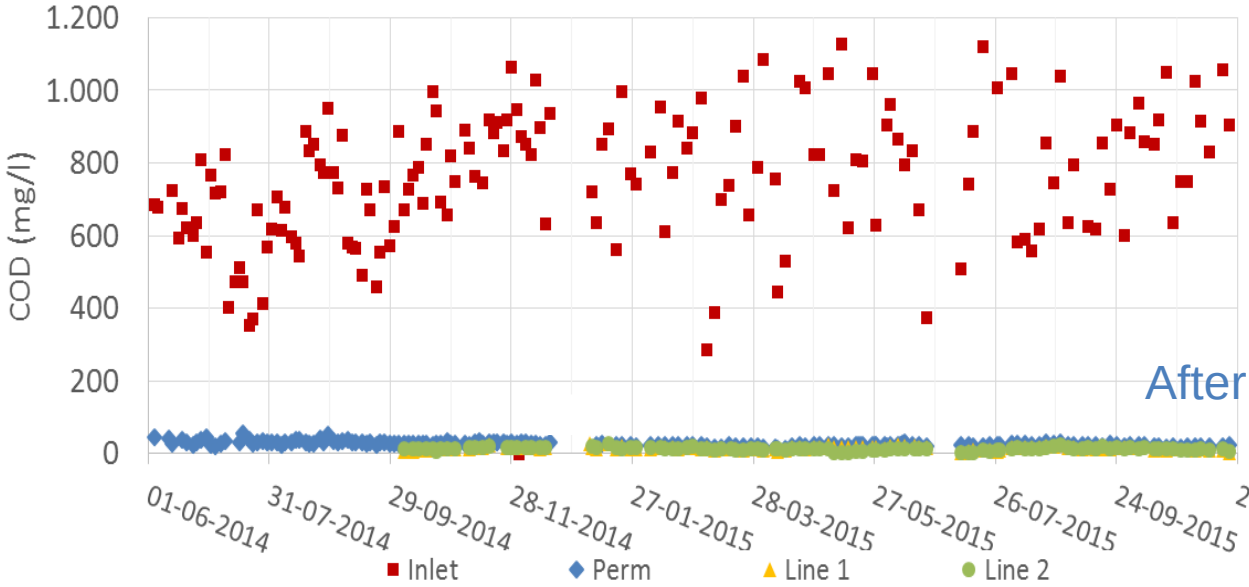


Estrogenic activity

Operation parameters

DHI

Results - COD
Stable removal

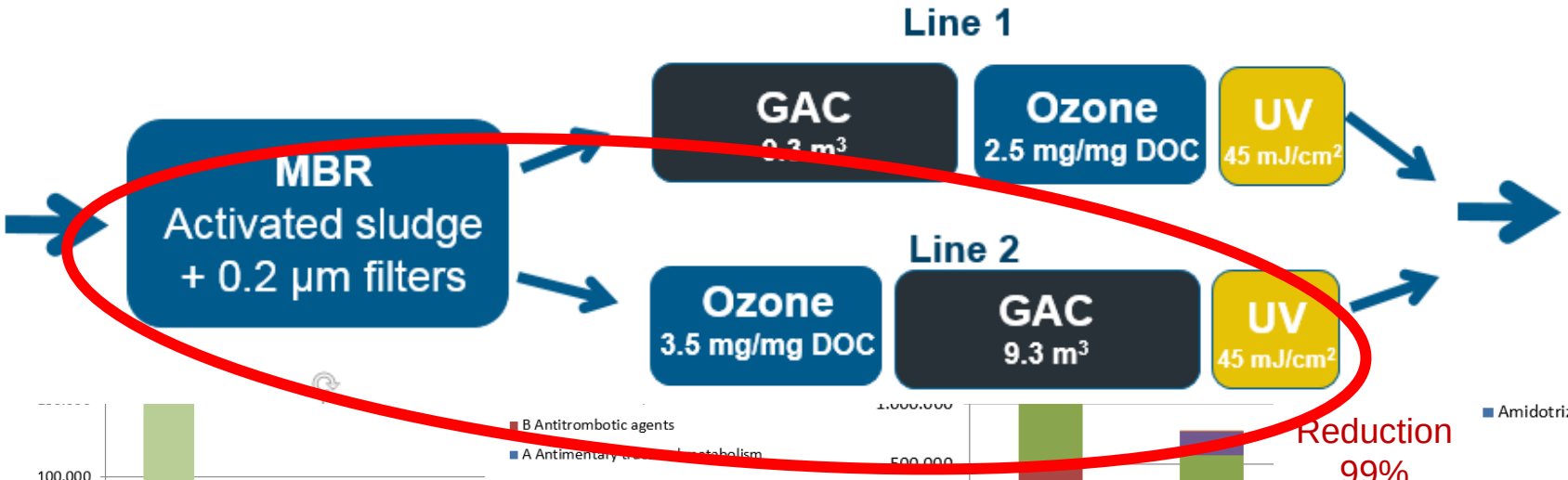


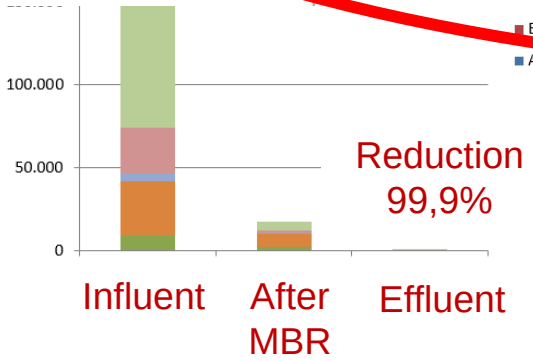
Inlet: 400-1.100 mg/l

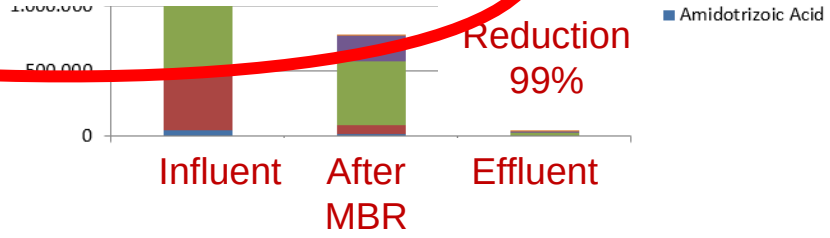
After MBR(permeate): ~ 25 mg/l

Effluent: 10-20 mg/l

Efficient removal of pharmaceuticals (API's)
Most efficient setup: MBR-Ozone-GAC (Line 2)







Monitoring period: May to November 2015

API's measured below $PNEC_{Freshwater}$ or LOD in effluent

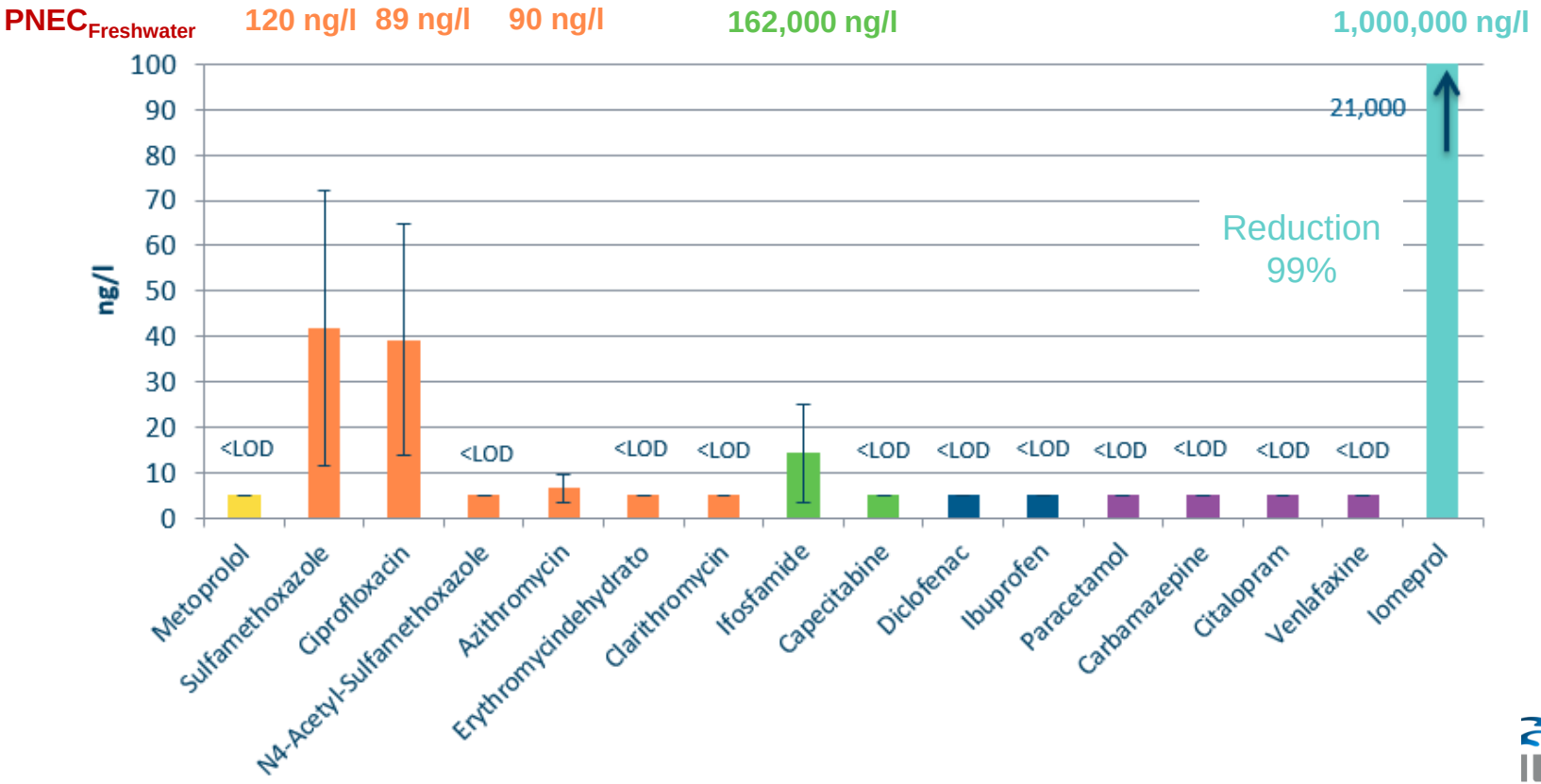
Ratio $MEC/PNEC_{Freshwater}$ in the brackets

Influent	After MBR	Effluent
Atorvastatin (0.6 - 6.5)	Azithromycin (2.3 -8.1)	No pharmaceuticals exceeding $PNEC_{Freshwater}$
Azithromycin (2.8 - 21)	Carbamazepine (0.7 - 1.3)	
Capecitabine (0.1 - 11)	Cefalexin (LOD - 3.2)	No API's measured above PNEC
Carbamazepine (LOD - 2.0)	Ciprofloxacin (4.6 - 93)	
Cefalexin (LOD - 8.4)	Clarithromycin (2.2 - 10)	
Ciprofloxacin (20 - 303)	Diclofenac (4.2 - 11)	
Clarithromycin (1.7 - 130)	Erythromycin (0.3 - 1.1)	
Diclofenac ((3.0 - 11)	Iomeprol (LOD - 1.0)	
Erythromycin (0.3 - 26)	N4-Acetyl-Sulfamethoxazole (0.4 - 1.9)	
Ibuprofen (1.5 - 13)	Ofloxacin (LOD - 1.5)	
Iomeprol (0.2 - 5)	Sulfamethoxazole (11 - 64)	
Metonidazole (LOD - 2.1)	Tramadol (1.2 - 2.0)	
N4-Acetyl-Sulfamethoxazole (15 - 108)	Venlafaxine (5.2 - 7.7)	
Ofloxacin (LOD - 3.3)	Zopiclone (0.6 - 4.7)	
Paracetamol (6.5 - 87)		
Prednisolon (LOD - 16)		
Sulfamethoxazole (21 - 133)		
Sulfapyridin (0.1 - 3.7)		
Tramadol (LOD - 4.2)		
Venlafaxine (2.5 - 11)		
Zopiclone (LOD - 5.3)		

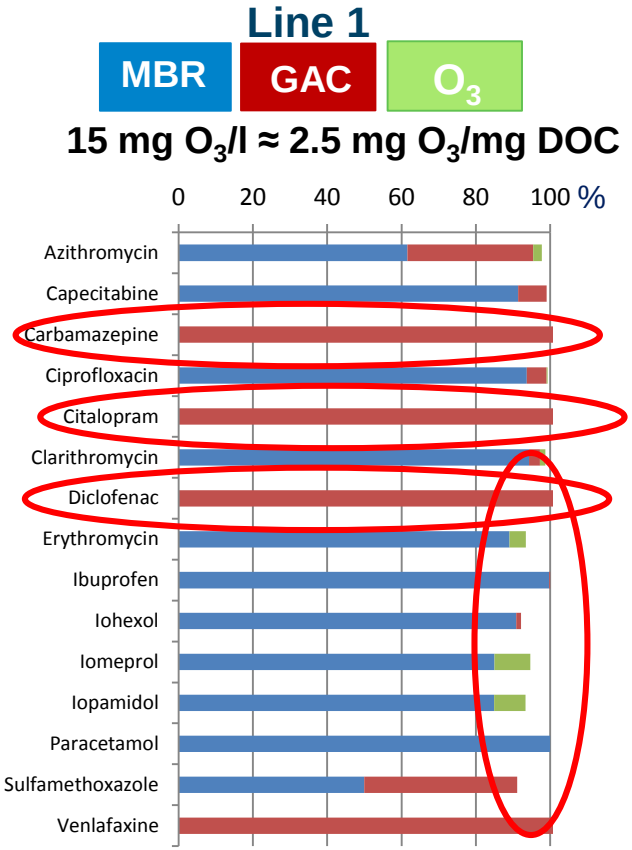
21 API's measured above PNEC

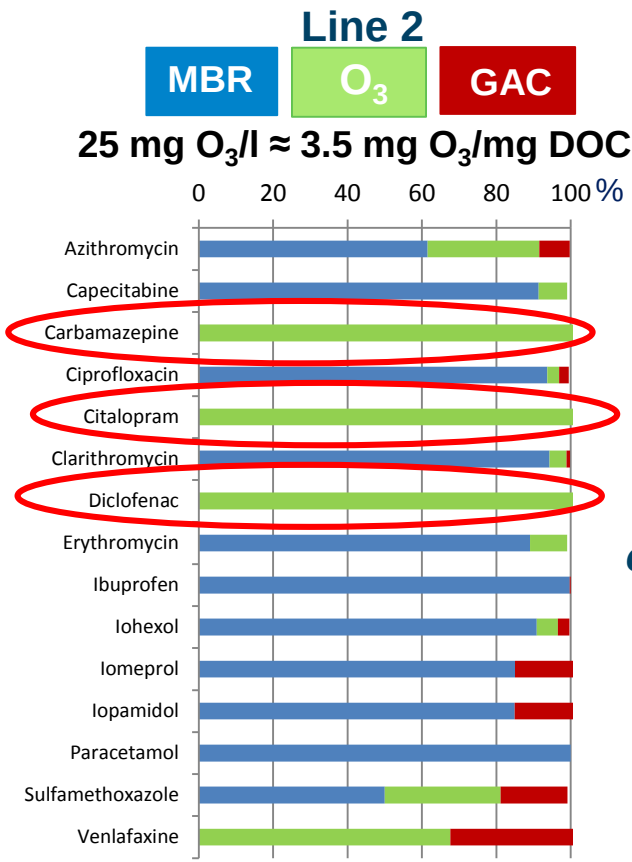
14 API's measured above PNEC

Indicator substances measured in effluent
Measured below $PNEC_{Freshwater}$



The polishing process that comes first removes most MBR-Ozone-GAC (Line 2) gives the best total removal



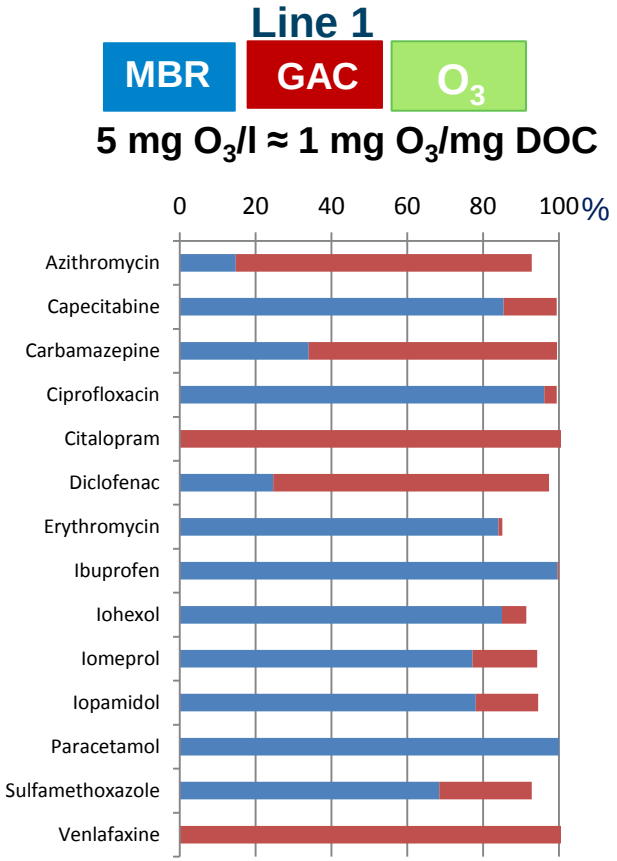


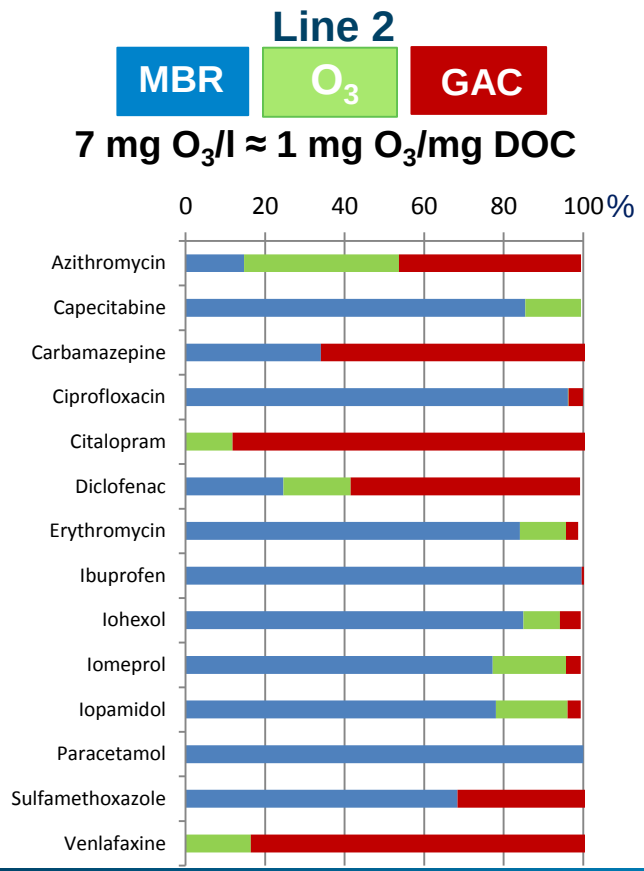
June 10 2015

No bromate formation after ozonation (< 2 µg/l)

WHO guideline (2005): 10 µg/l

Lower ozone dosages gives significantly less removal by ozone

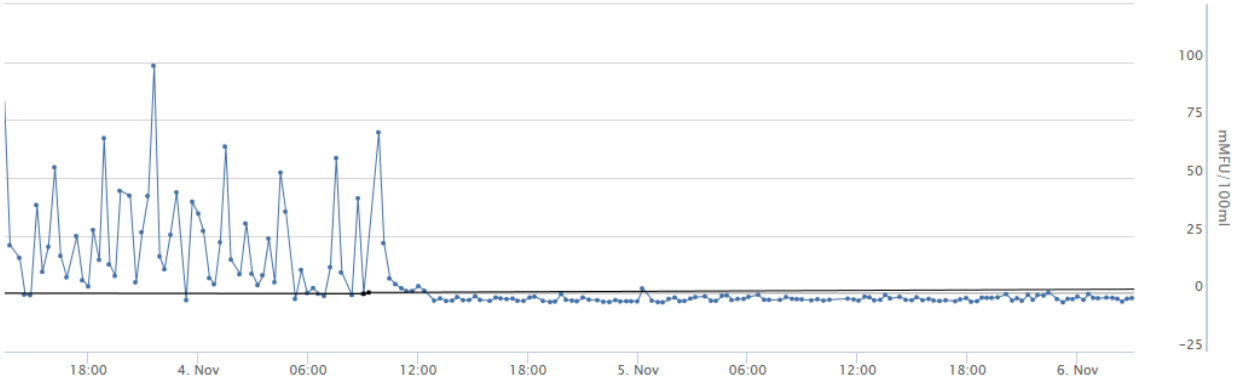




June 11 2015

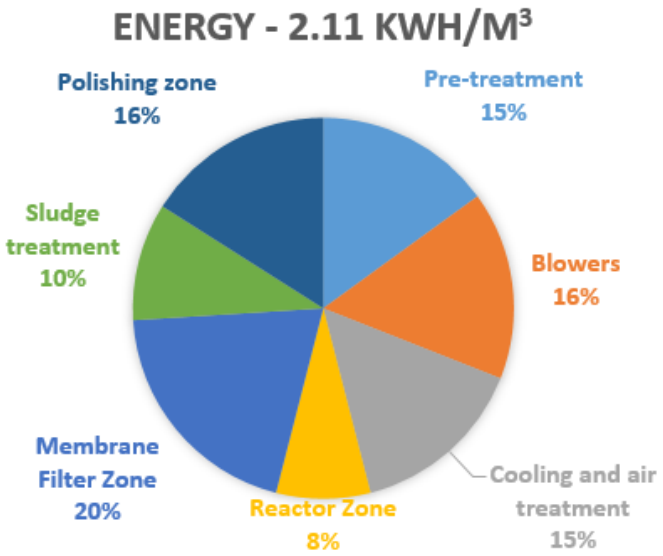
MBR membrane leakage control system
Online *E. Coli* monitoring in the permeate

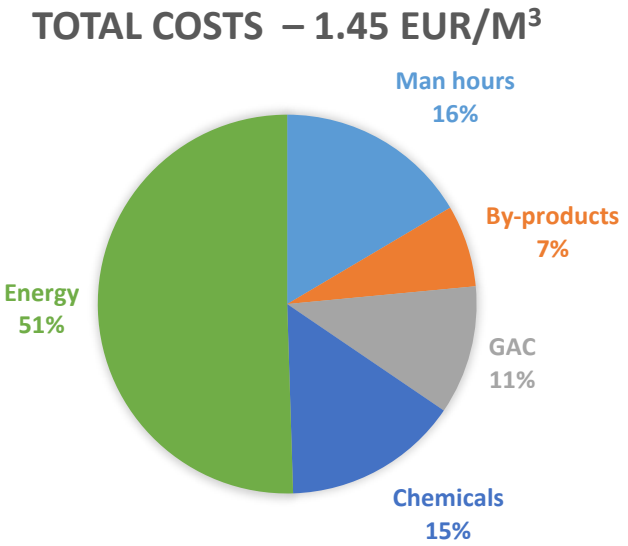
- Ceramic 200 nm pore size membranes
- If no *E. Coli* in the permeate – no leakage!
- Online monitoring of *E. Coli* specific enzyme activity (Beta-glucoronidase) – controlled by growth tests (IDEXX)
- Monitored every 15-30 minutes (LOD: 20-100 MPN/100 ML)



Energy and economy

- Total operating and maintenance costs: 1.45 EURO/m^3
- Total investment cost: 3.3-4.7m EURO (new plant)





Simpel pay back period, saving the sewer-tax:

4 m EURO/0.4m EURO/y = 10 years

Yearly savings: 200.000 m3/year*15 DKK(25,54-10.87) = 3 mio DKK/year ~ 0.4m EURO/year

Conclusions (1)

- The plant is now considered as BAT for treatment of hospital wastewater in Denmark
- The **MBR-Ozone-GAC** sequence is the most efficient setup
- All monitored API's in the outlet are **below PNEC or LOD**
- An efficient **membrane leakage control system** developed
- Ozone-dosage around **3.5 mg/mg DOC gives the best removal**. No critical bromate formation is seen.
- 1/3 of the GAC filters have been changed per year in the two years operation period. **Breakthrough of API's does not seem to be critical within this change interval**

Conclusions(2) and next steps

- Total operation and maintenance costs **1.45 EURO/m^3**

Next steps 2016-2017:

- The treated water will be discharged to the local stream
- 10.000 m^3/year will be reused as cooling water at the hospital

Thanks for your attention!

Funding:

The Market Development Fund

Herlev Kommune

REGION Herlev Hospital

COPENHAGEN Welcome to Denmark

BIOFOS

Cooperation partners:

GRUNDFOS

iuta

DHI The expert in WATER ENVIRONMENTS

Contact:

Ulf Nielsen, DHI uln@dhigroup.com

Cell: +45 6162 7277

DHI

Conclusions on treatment efficiency

Parameters	Raw untreated wastewater	Treated wastewater
Toxic and persistant antibiotics (ciprofloxacine, clarithromycin and sulfamethoxazole) and painkiller (diclofenac)	Factor 10-180 exceedings of effect limits (PNEC) for water living organisms	No exceedings of of effect limits (PNEC) for water living organisms
Contrast media (e.g. iomeprol)	High concentration (2,5-7 mg/l)	99 % removal
Antibiotic resitant bacterier	High occurence of multi resistant bacterier	No fecal or multi resistant bacteria
Fish fry (zebra fish)	100 % mortality within 96 hours	0 % mortalitet within 96 timer
Crustacean (daphnies)	No offsprings (all test animals died)	Offsprings survives as in clean water controls
Estrogenic activity	Estrogen effects	No estrogen effects