Operating experience ozonation WWTP Werdhölzli, Zurich, CH







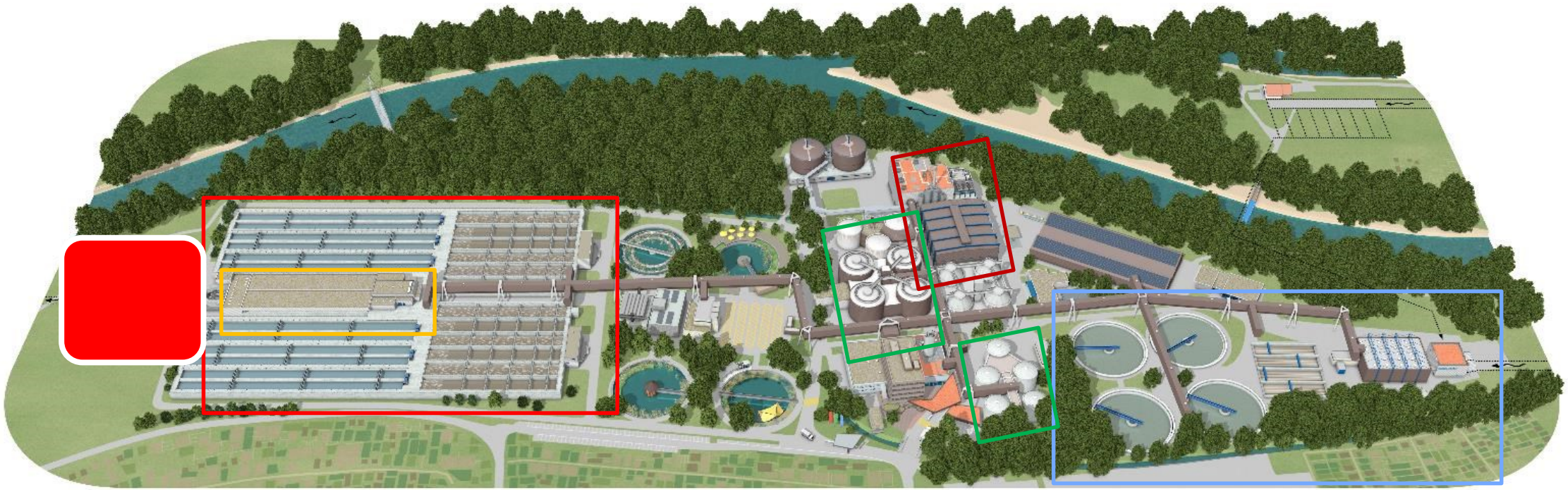
Ozonation

Christian Abegglen, Daniel Rensch

Autumn 2023

Stadt Zürich
Entsorgung + Recycling

The facilities of the Werdhölzli wastewater treatment plant



Size in pop. equiv. (PE): 670 000

Q_{max} 6000 l/s

Predominantly combined sewer system

Mech. Treatment	Screening facility, oil- /sand trap, primary clarifier
Biol. treatment	Activ. sludge treatment with alternating/intermittent nitrification/denitrification, simultaneous precipitation
Filtration	Sand filtration
Sludge treatment	Fresh sludge thickening, digestion (1-stage)
Sewage sludge	Dewatering (centrifuge), sludge incineration (+external sludge)

Film in german:
https://youtu.be/cgyZjPFgC1M?si=_rHmjo6lpspJZYYu
Film in english:
https://youtu.be/XjEuWLr78b8?si=qqz1ZiDFzq_KiyWM

Ozonation

Preliminary work / process selection



Study for the space requirement

Project start

Procedural suitability Ozonation



Kick-off planner



Groundbreaking



Commissioning start

"Test operation"

2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Procedural decision: Ozone, eventually Ozone GAK

GSchG (water protection act) decided

Construction

GSchG in force

Project completion

Start "Regular operation"

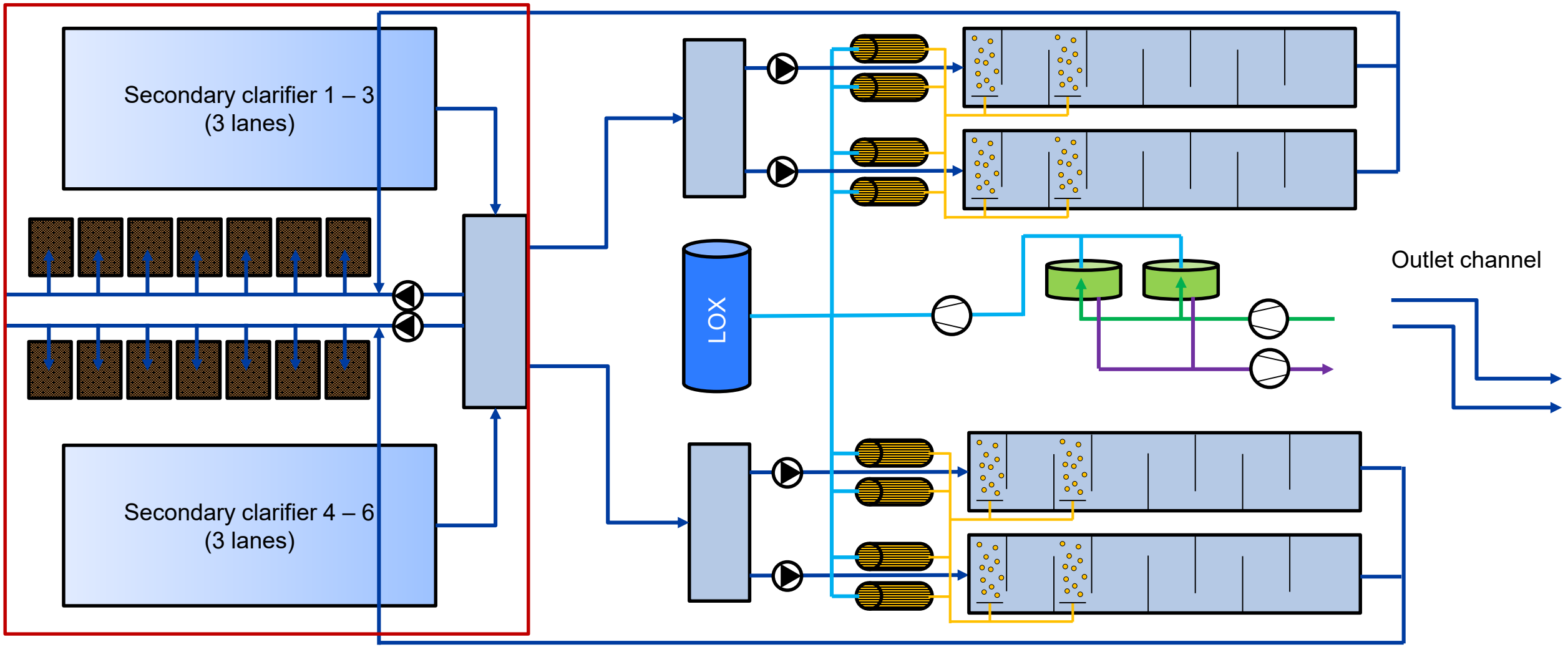
Protokoll	**Kick-off-Sitzung Mikroverunreinigung**
Datum/Zeit	15. August 2013, 8.00 bis 10.15 Uhr
Ort	Sitzungszimmer Grande 2
Vorsitz	Peter Wiederkehr

Bundesgesetz über den Schutz der Gewässer
(Gewässerschutzgesetz, GSchG)

Änderung vom 21. März 2014



Layout

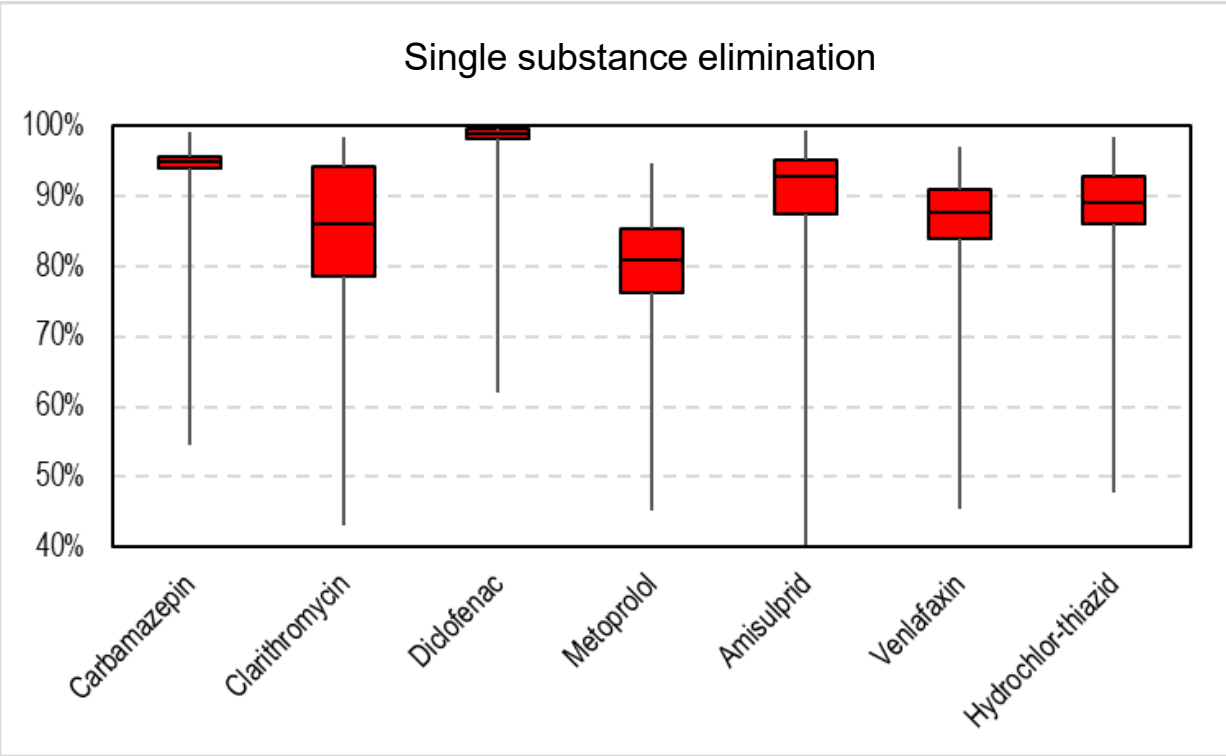

Secondary clarifier 1 – 3
(3 lanes)
Secondary clarifier 4 – 6
(3 lanes)
LOX
Outlet channel

Key figures Ozonation

Plant section	Technology	Dimension	Quality
Oxygen generation	1 VPSA-Plant	170 to 400 Nm^3_{O2}/h 220 to 520 kg_{O2}/h	90 - 94% O_2
Oxygen-Backup	1 LOX-Tank	60 m^3 ≈ 68'000 kg	>99.9% O_2
Ozone generation	8 Ozone generators 4 on each side	each 0 to 19 kg_{O3}/h	0 – 14% O_3
Pumping station	16 centrifugal pumps 4 for each reactor	each 250 to 700 l/s	
Ozone reactors	4 Reactors, 2 for each side	each 1535 m^3	12 to 100 min residence time
Residual ozone detroyer	4 ROV 1 for each side		

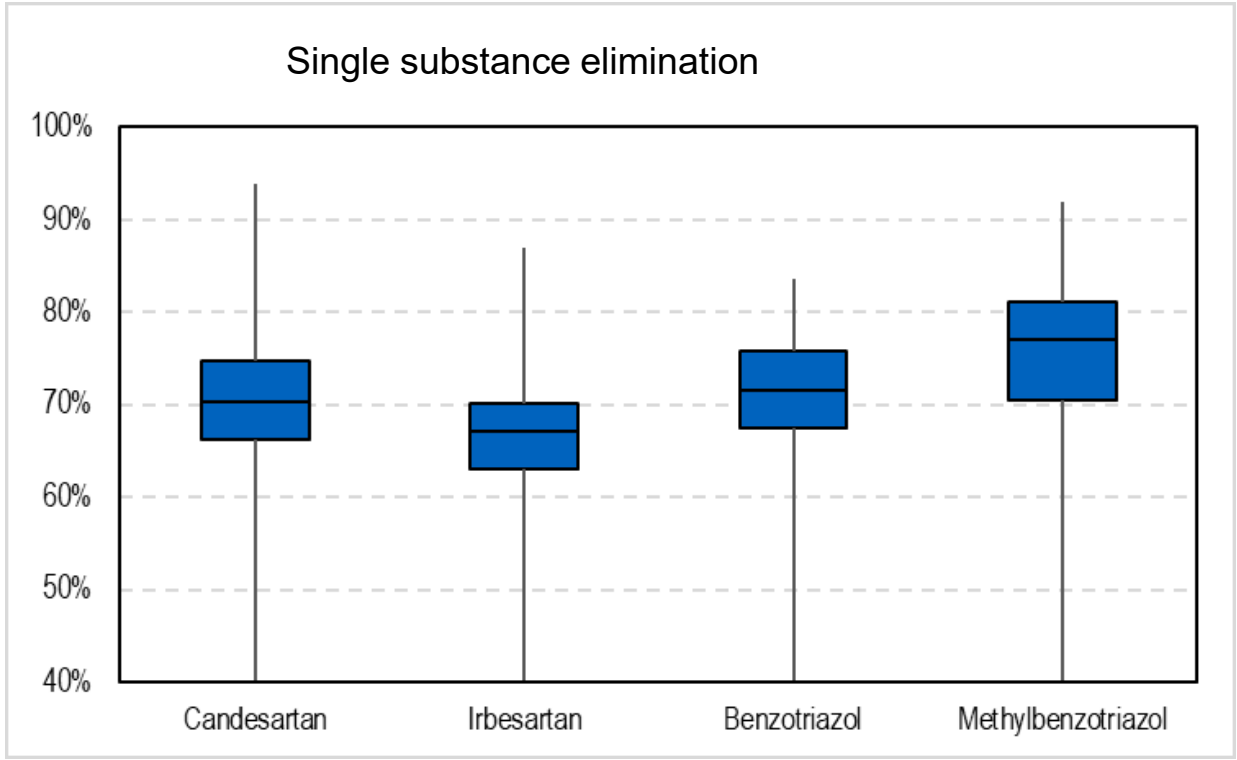
Elimination of micropollutants

Elimination of micropollutants (single substances)



Group 1 (very good removal)

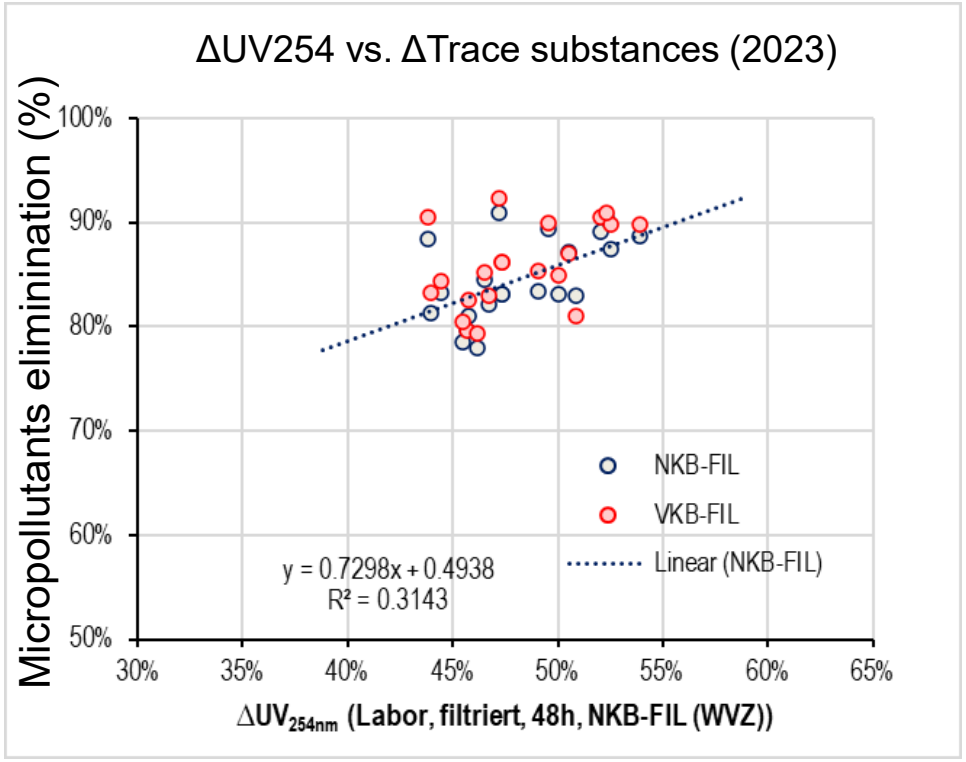
- Problem during sample filtration → Effect on CIT, AMI, MET
- 2023 analytical adjustments → positive effects (Filter, BG)

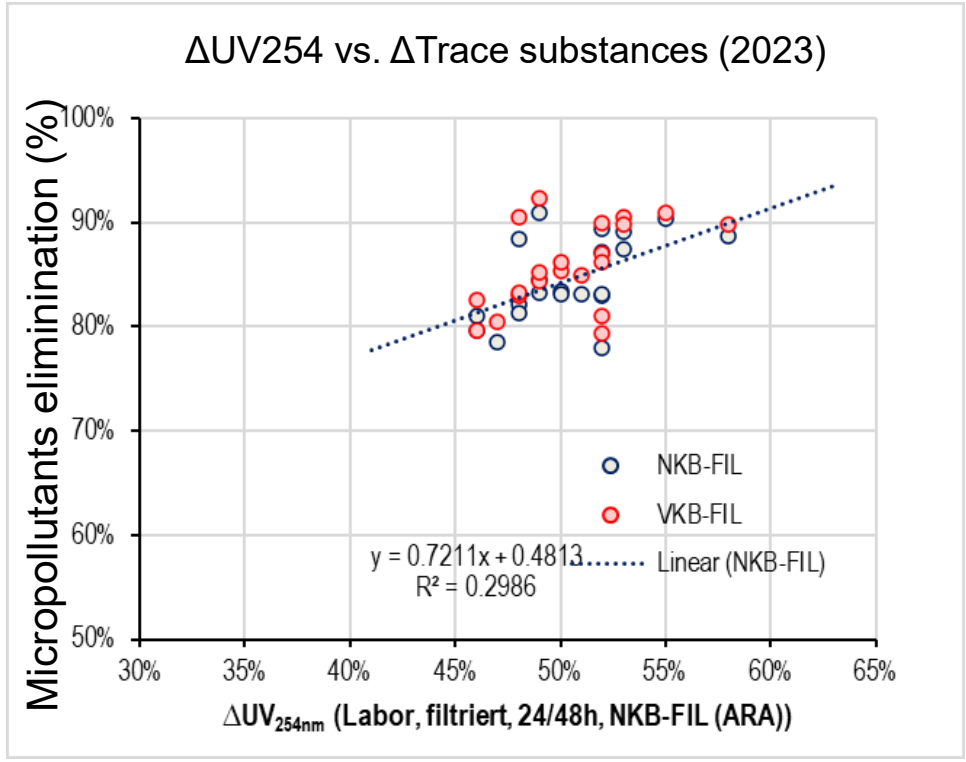


Group 2 (good removal)

- All substances in sufficient concentration
- good correlation among each other

Elimination of micropollutants (total) vs. ΔUV254 (Laboratory, online)





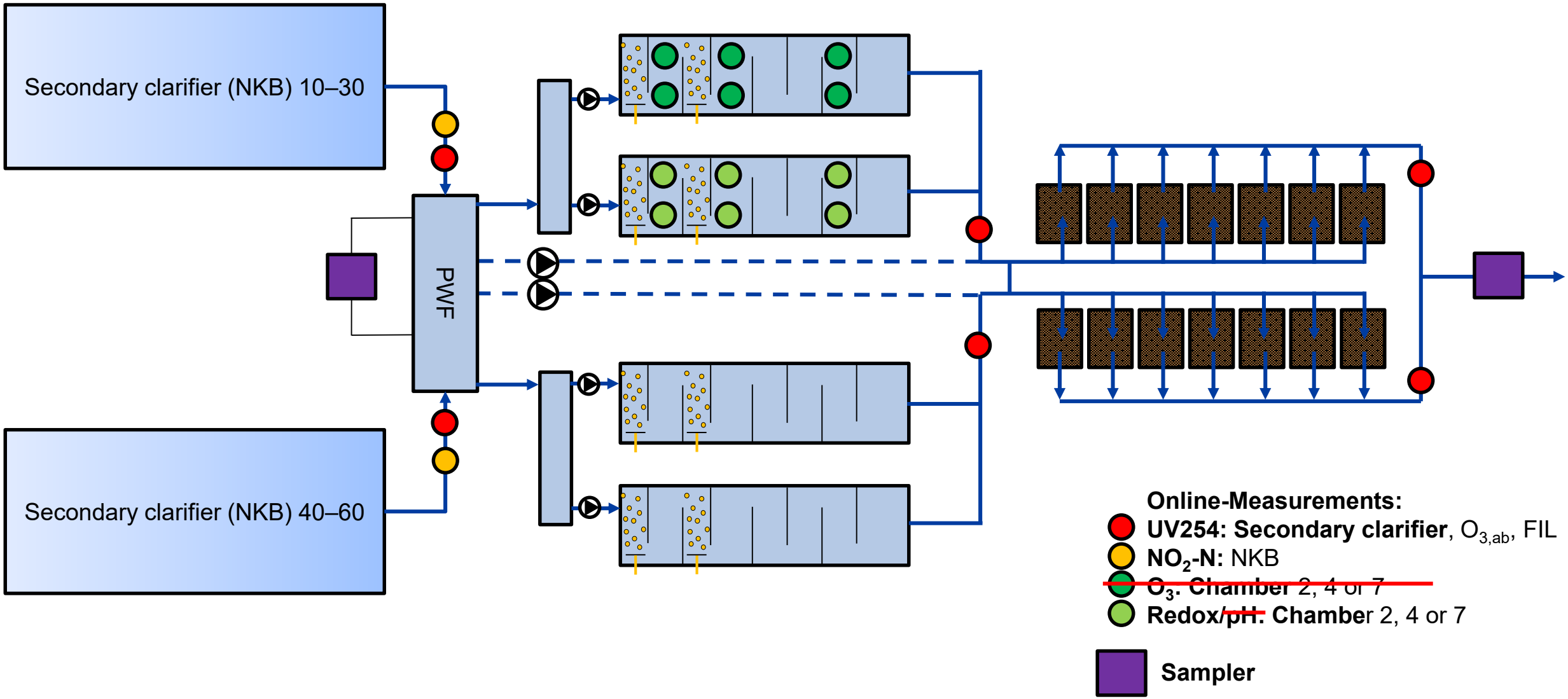
Laboratory measurement (Secondary clarifier (NKB-FIL))
Mixed sample 48h (Q-prop.)

Laboratory measurement (Secondary clarifier (NKB-FIL))
Mixed samples 1 to 2x 24h (Q-prop.)

Filtered sample
Micropollutants: Primary clarifier (VKB-FIL)/Secondary clarifier (NKB-FIL)

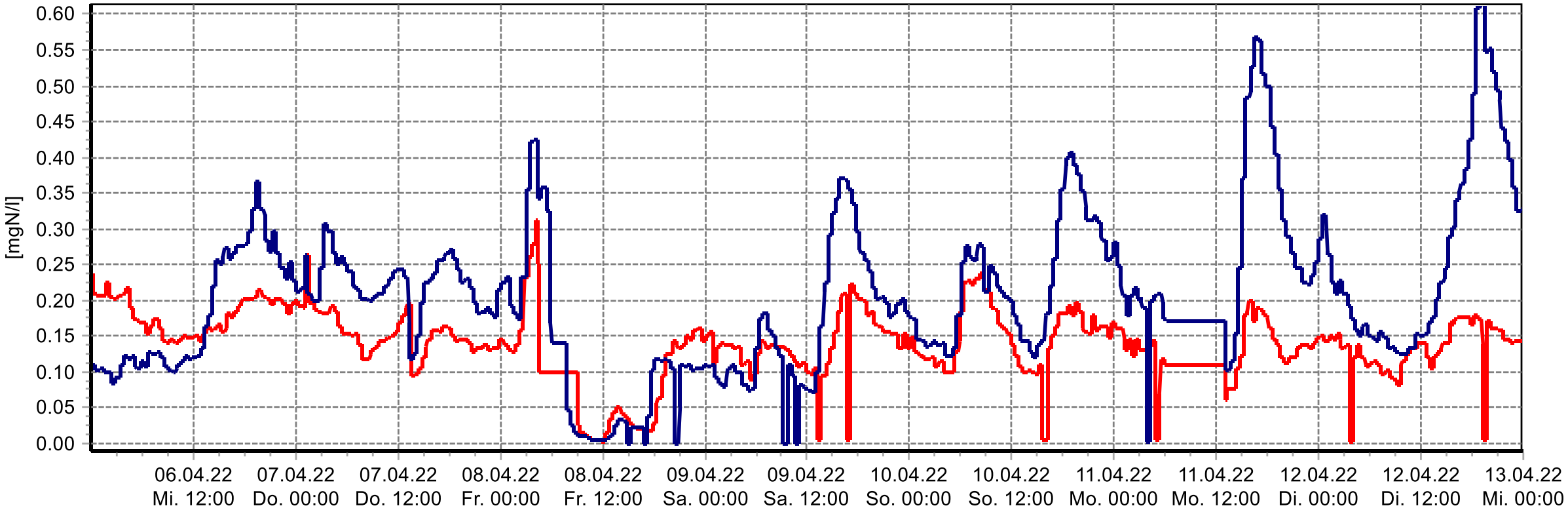
Measurement concept and control

Online - measurement concept

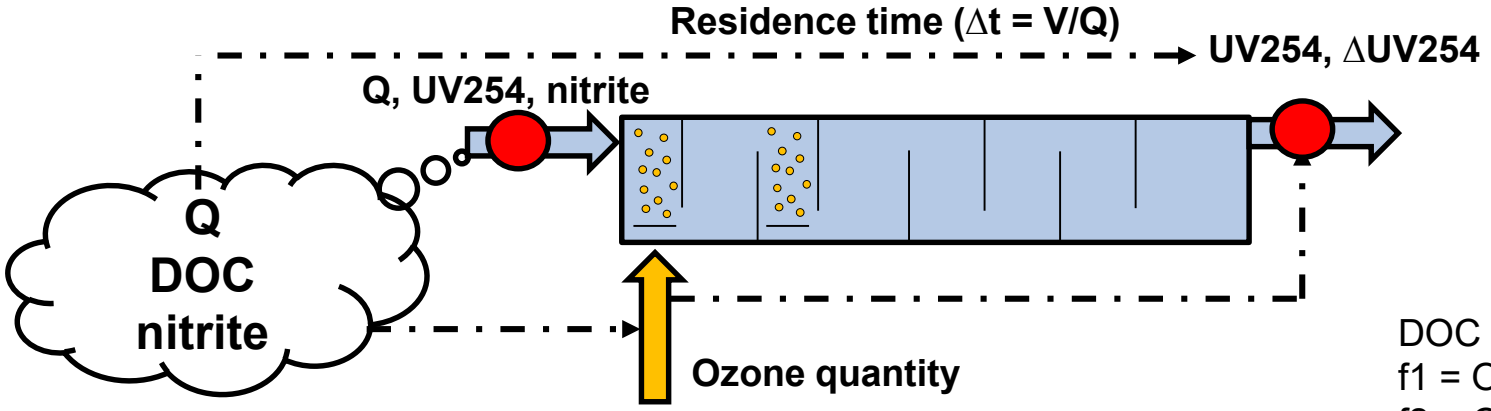


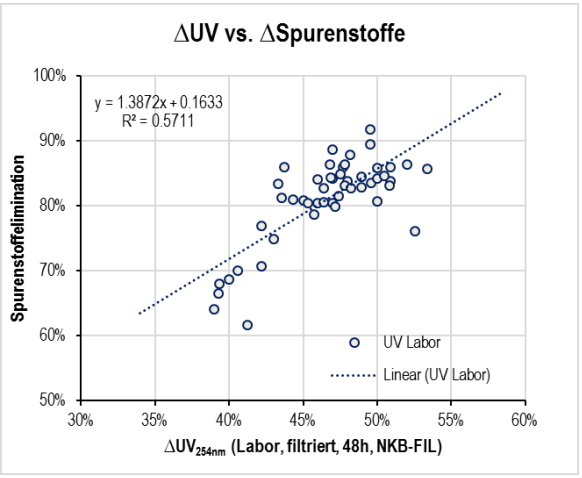
Influent fluctuations

- Temporarily increased **nitrite vallues** (temporarily daily course, rainy weather)
- Alternation dry-/rainy weather



Ozone input





DOC = $UV254_{in}$ * f_{DOC}
f1 = Ozone dose (Quantity / Water volume)
f2 = Ozone (Quantity / Quantity DOC)
f3 = Ozone dose nitrite (3.43 gO_3/gNO_2-N)
f4 = regulated correction factor (0.5 to 1.5)

Dosing options Ozone:

Ozone input [kg/h] = Q * f1 — Proportional to flow

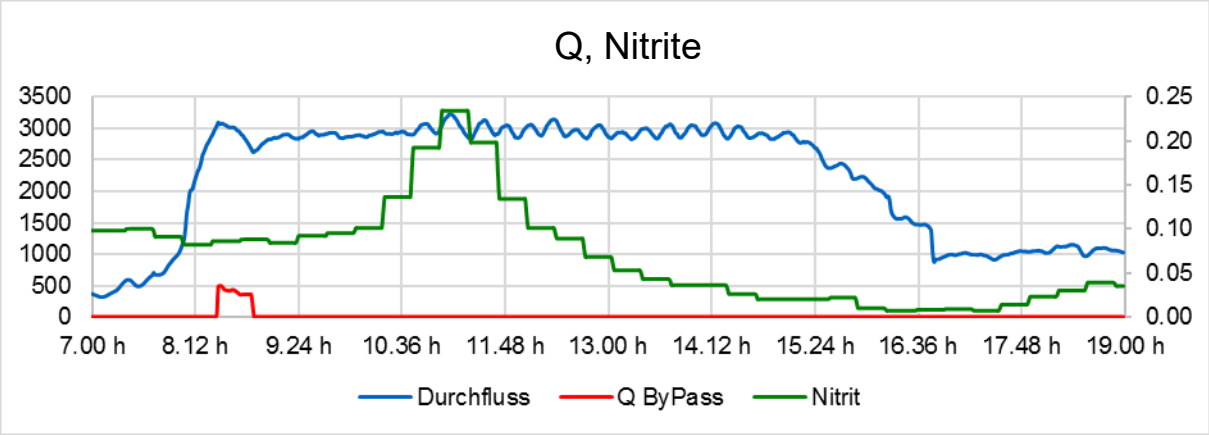
Ozone input [kg/h] = Q * (DOC * f2 + NO_2-N * f3) — DOC-proportional, incl. NO_2-Compensation

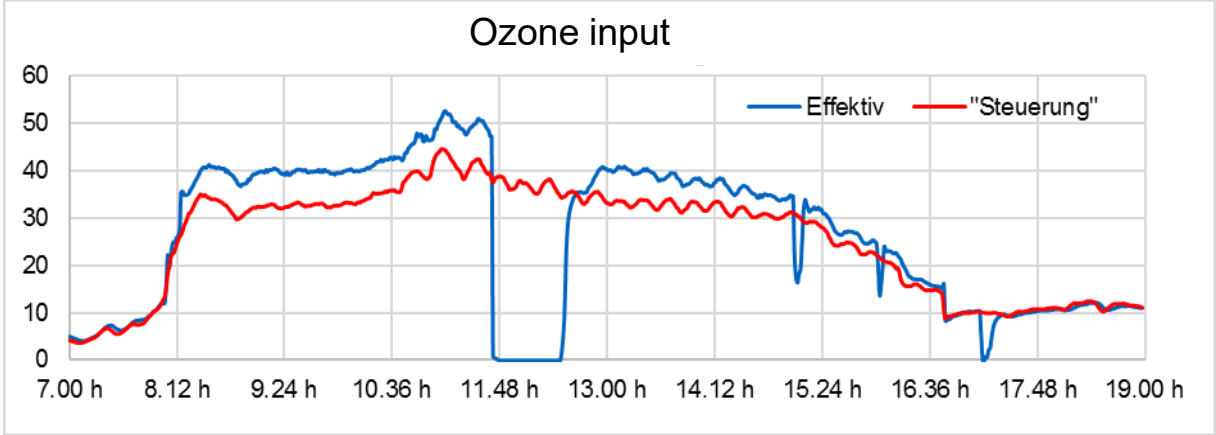
Ozone input [kg/h] = Q * (DOC * f2 + NO_2-N * f3) * f4 — DOC-proportional with ΔUV254-Correction

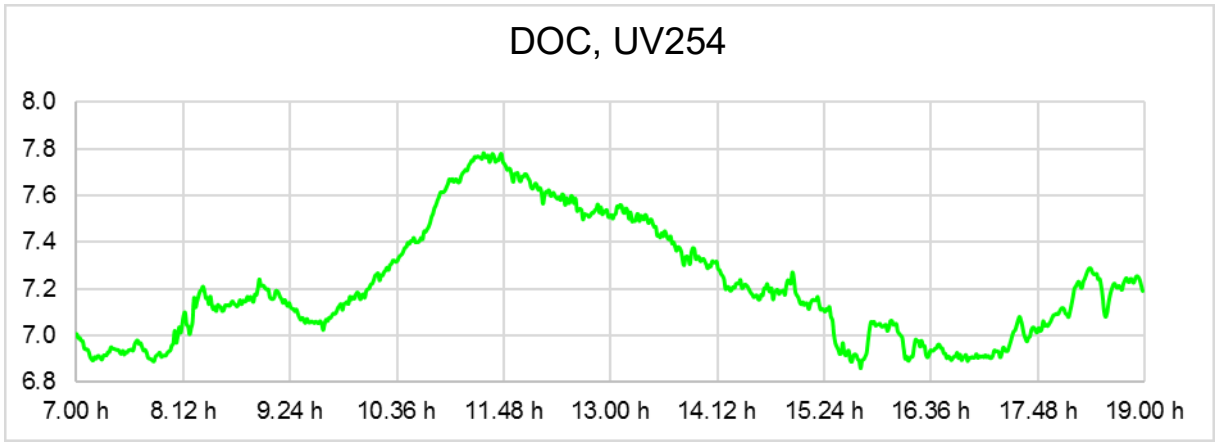
Control — Regulation

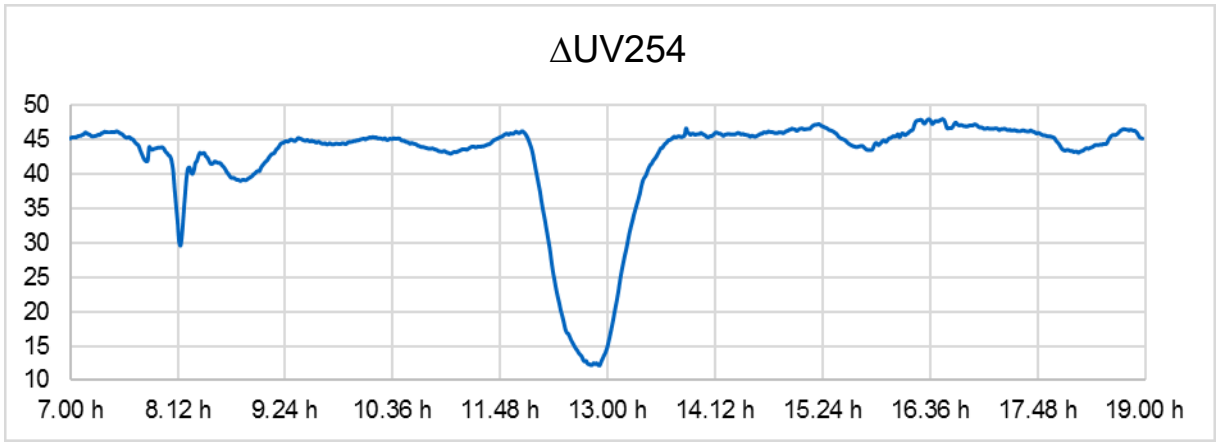
Target value = ΔUV254
Actual value = ($UV254_{ab}$(t) – $UV254_{in}$(t-Δt))/ $UV254_{in}$(t-Δt)
Control value= correction factor f4

Rain event


Q, Nitrite
3500
3000
2500
2000
1500
1000
500
0
0.25
0.20
0.15
0.10
0.05
0.00
7.00 h
8.12 h
9.24 h
10.36 h
11.48 h
13.00 h
14.12 h
15.24 h
16.36 h
17.48 h
19.00 h
Durchfluss
Q ByPass
Nitrit


Ozone input
60
50
40
30
20
10
0
Effektiv
"Steuerung"
7.00 h
8.12 h
9.24 h
10.36 h
11.48 h
13.00 h
14.12 h
15.24 h
16.36 h
17.48 h
19.00 h

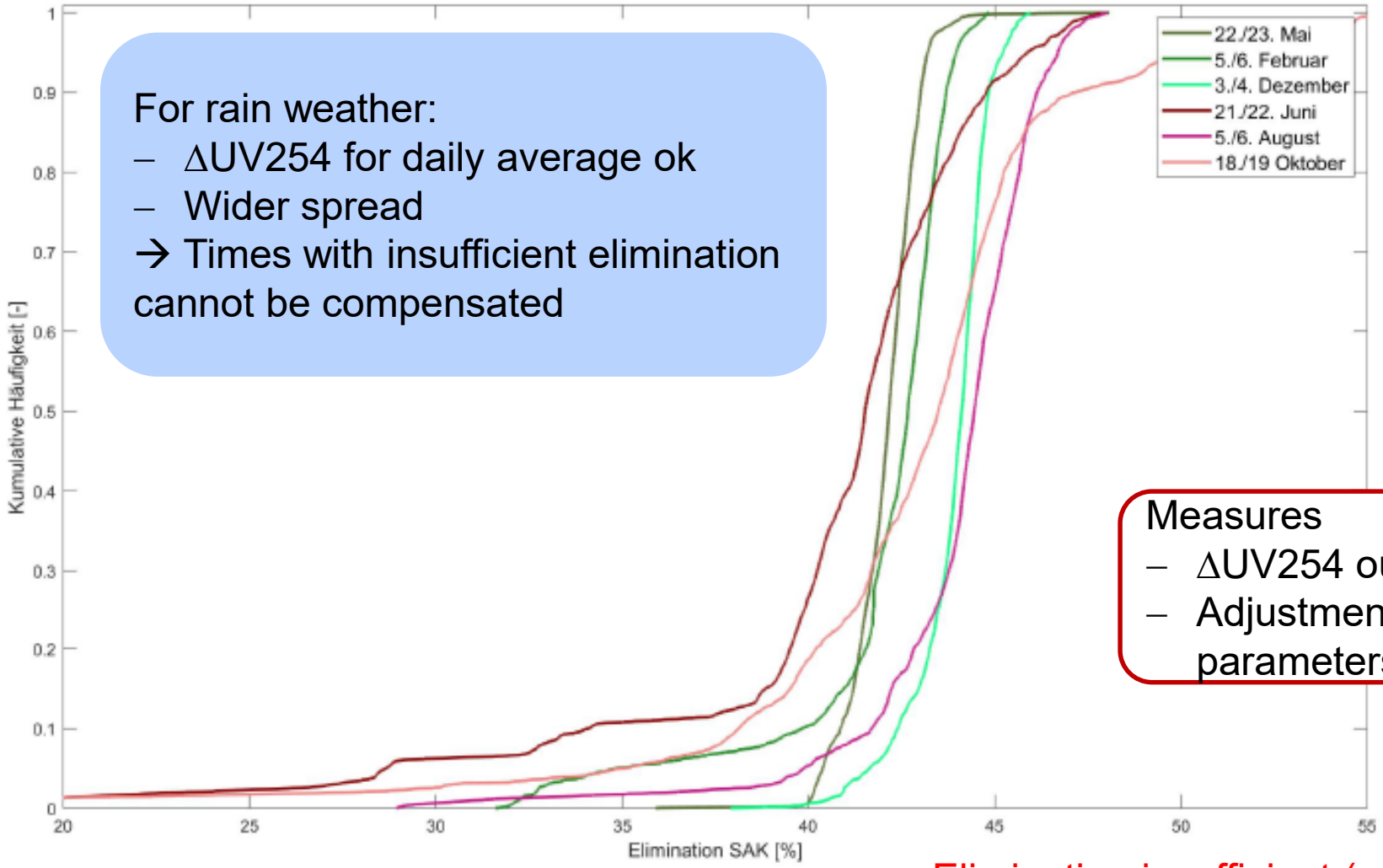

DOC, UV254
8.0
7.8
7.6
7.4
7.2
7.0
6.8
7.00 h
8.12 h
9.24 h
10.36 h
11.48 h
13.00 h
14.12 h
15.24 h
16.36 h
17.48 h
19.00 h


ΔUV254
50
45
40
35
30
25
20
15
10
7.00 h
8.12 h
9.24 h
10.36 h
11.48 h
13.00 h
14.12 h
15.24 h
16.36 h
17.48 h
19.00 h

Event analysis

For rain weather:
- ΔUV254 for daily average ok
- Wider spread

→ Times with insufficient elimination cannot be compensated

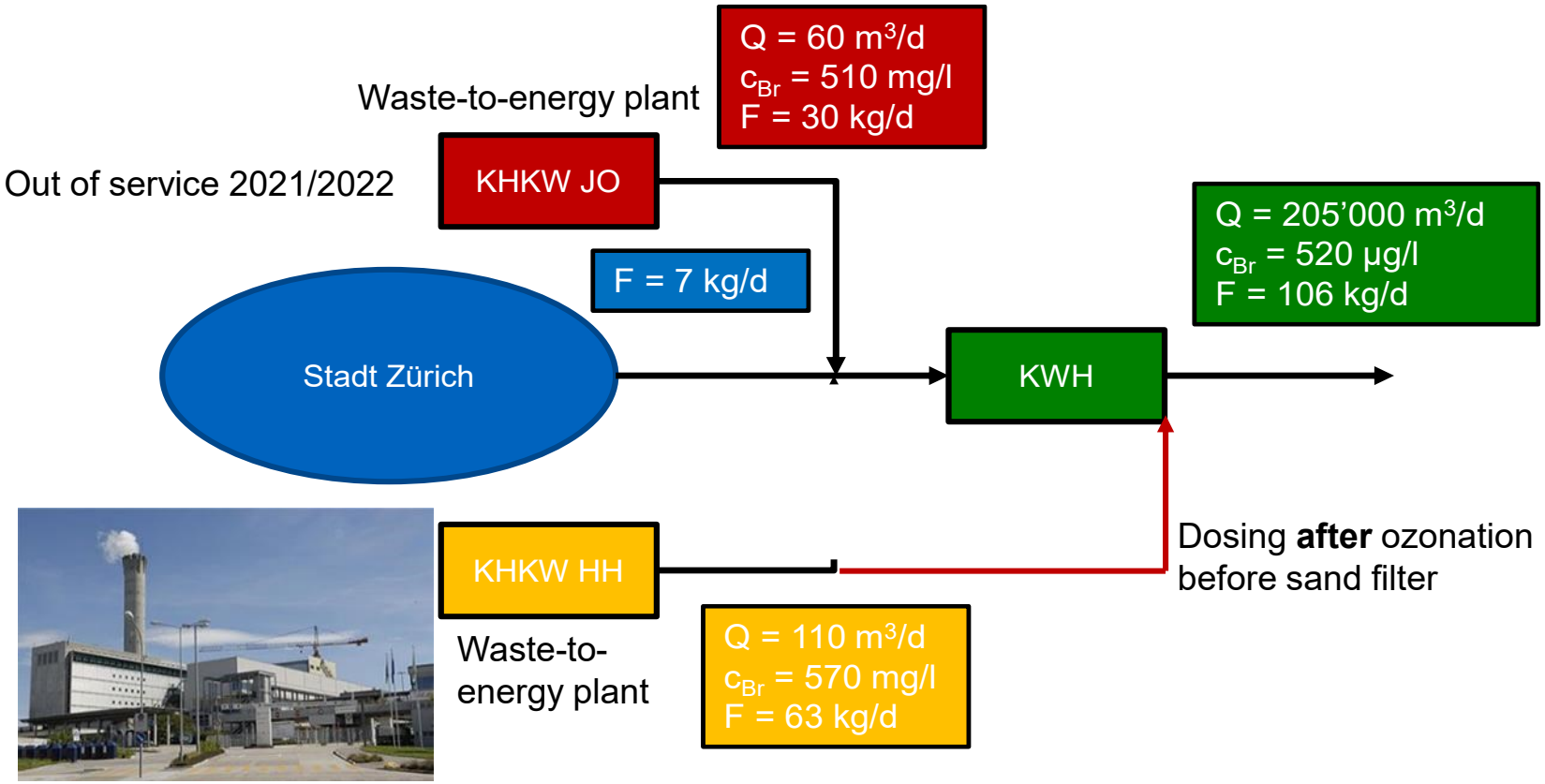


Measures
- ΔUV254 outlet ozonation
- Adjustment of control parameters

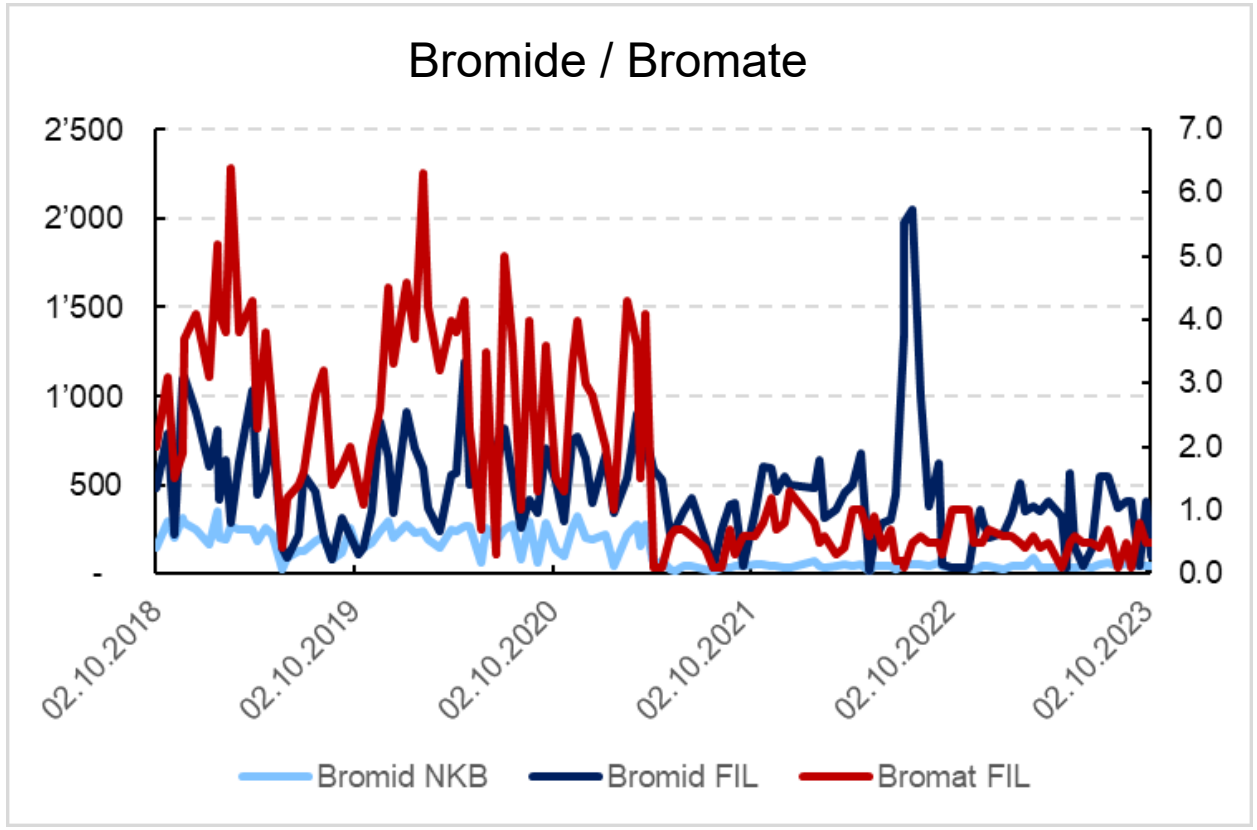
Elimination insufficient (< 80%)
Elimination ok (> 80%)

Bromide, bromate formation

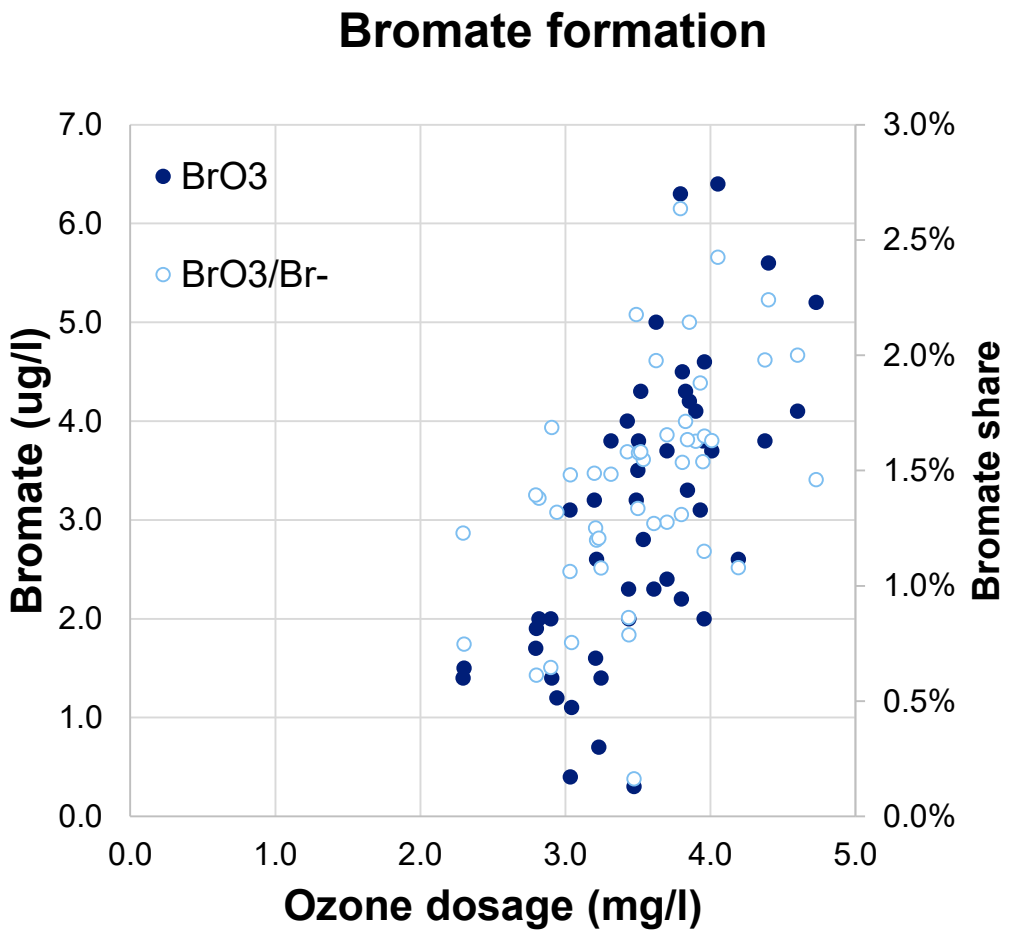
Bromide sources?



Bromide und bromate formation



NKB = Secondary clarifier



Energy and costs

Energy consumption (2019)

Gas, water, waste water Nr. 7 2011



Mikroverunreinigungen

Energieverbrauch und Kosten weitergehender Verfahren auf kommunalen ARA

Micropolluants
Consommation d'énergie et coûts des traitements avancés dans les STEP communales

La mise en place de traitements avancés (comme l'ozonation ou le traitement par charbon actif en poudre) dans environ 100 des 700 STEP de Suisses permettrait de réduire considérablement le rejet de micropolluants dans les cours d'eaux et d'amé-

Christian Abegglen

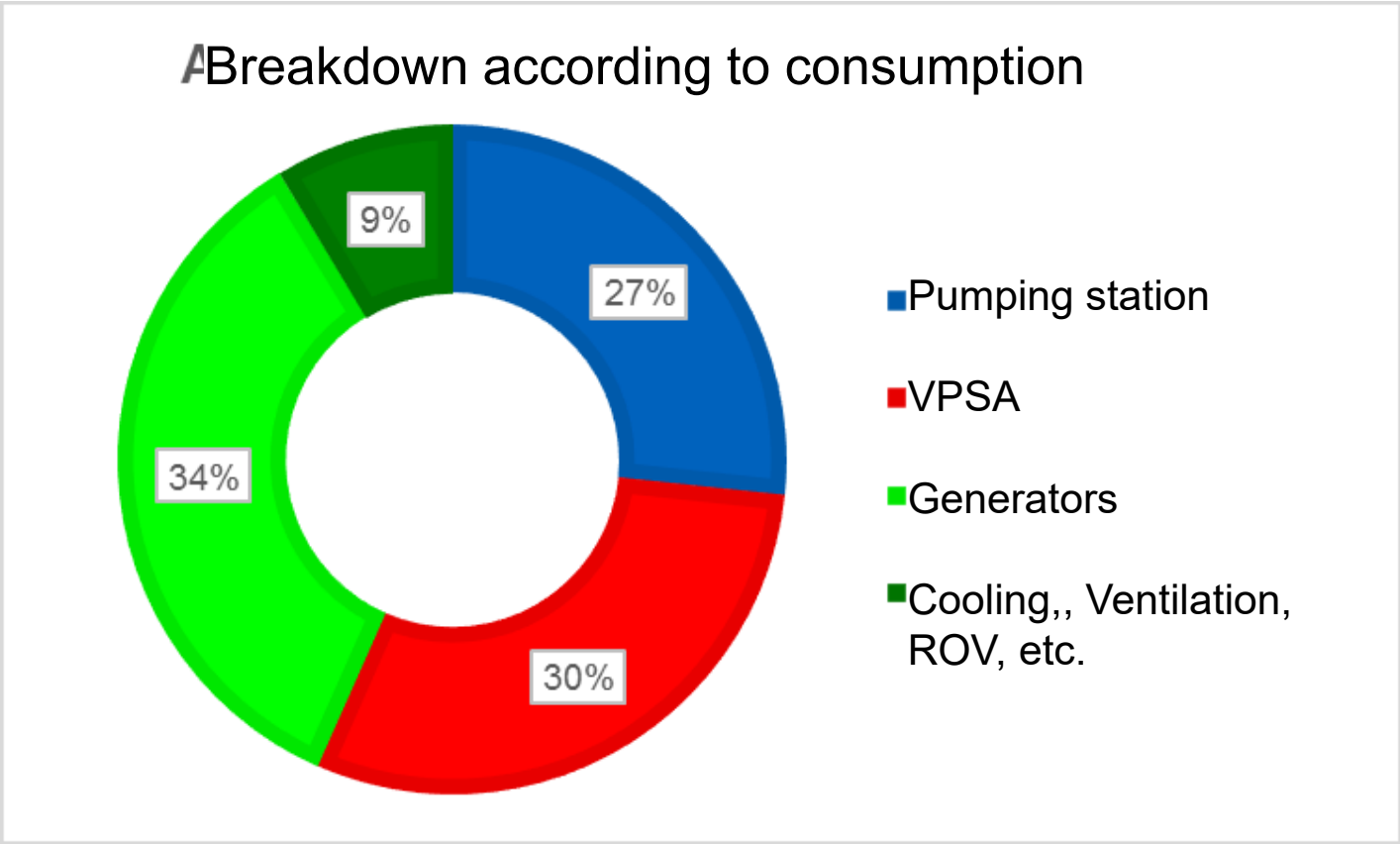
Werdhölzli 2019		Total	Without VPSA	Without VPSA and PW
Dosage	mg/l	3.5	3.5	3.5
Spec. Energy	kWh/m³	0.08	0.054	0.033

Primary energy

		ARA			Primärenergie		
Ozonation							
Dosis / Dosage	mg O_3/ℓ	**5**	4	6	5	4	6
Spez. Energie /Spec. Energy	kWh/m³	**0,06**	0,05	0,08	0,27	0,22	0,33
Spez. Energie /Spec. Energy	kWh/EW/a	**11**	9	13	33	26	40
	kWh/PE/a						

Factor 3

Energy (2019): Distribution, increase in consumption



Total	+ 24%
Without PW	+ 20%
Without VPSA, PW	+ 13%

Costs (2019)

	Total	Compensation
CHF/P	30.-	85.-
CHF/PE	22.50	65.-

	Total	Compensation
CHF/P/a	7.60	4.40
CHF/PE/a	5.70	3.30

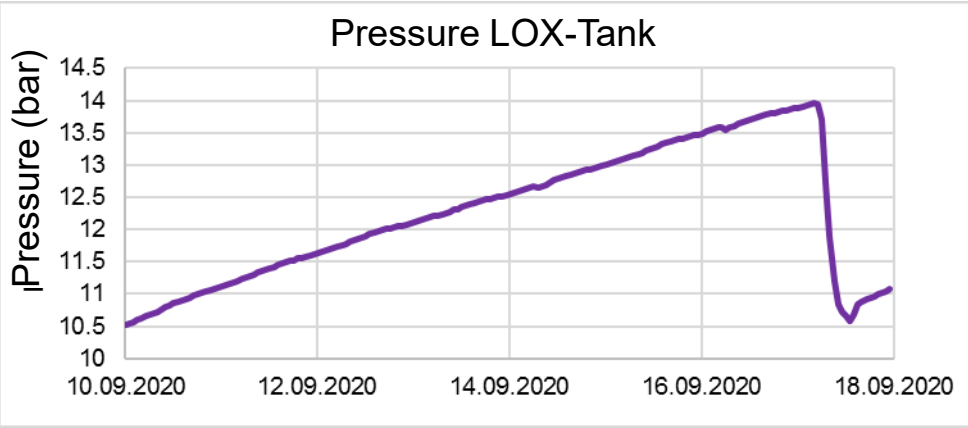
Investments	**Costs in CHF**
Construction of the 4th treatment stage at the WWTP Werdhölzli	38´583´052.88
Compensation fund „Bund“ (75% of the chargeable costs)	24´979´413.00
Investment costs of the 4th treatment stage at the WWTP Werdhölzli	**13´603´639.88**

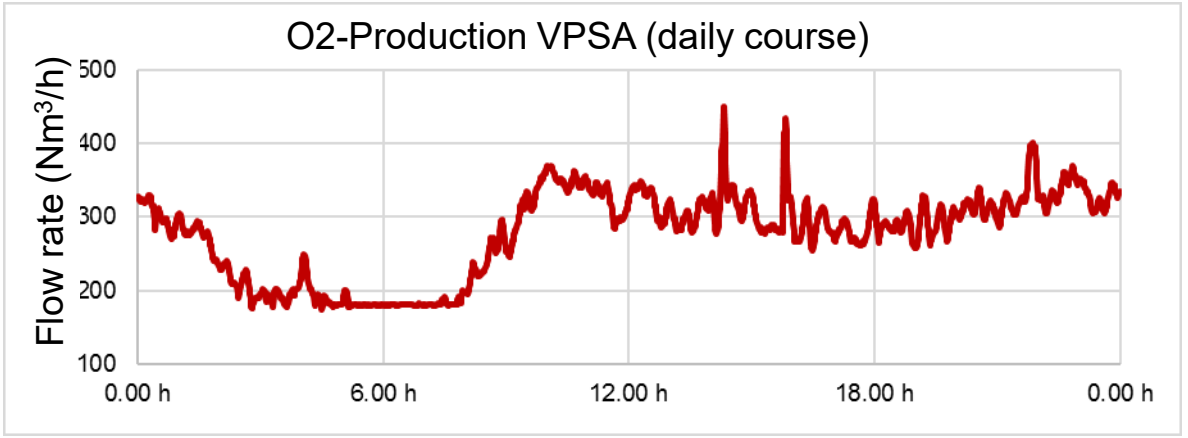
Operating costs of the 4th treatment stage WWTP Werdhölzli	**Costs in CHF**
Financial cost (amortisation, interest)	793´521.42
Material costs	168´042.46
Electricity	710´047.00
Employee cost allocation (CHF 80 per hour)	710´047.00
Total operating costs 2019	**1´959´370.40**

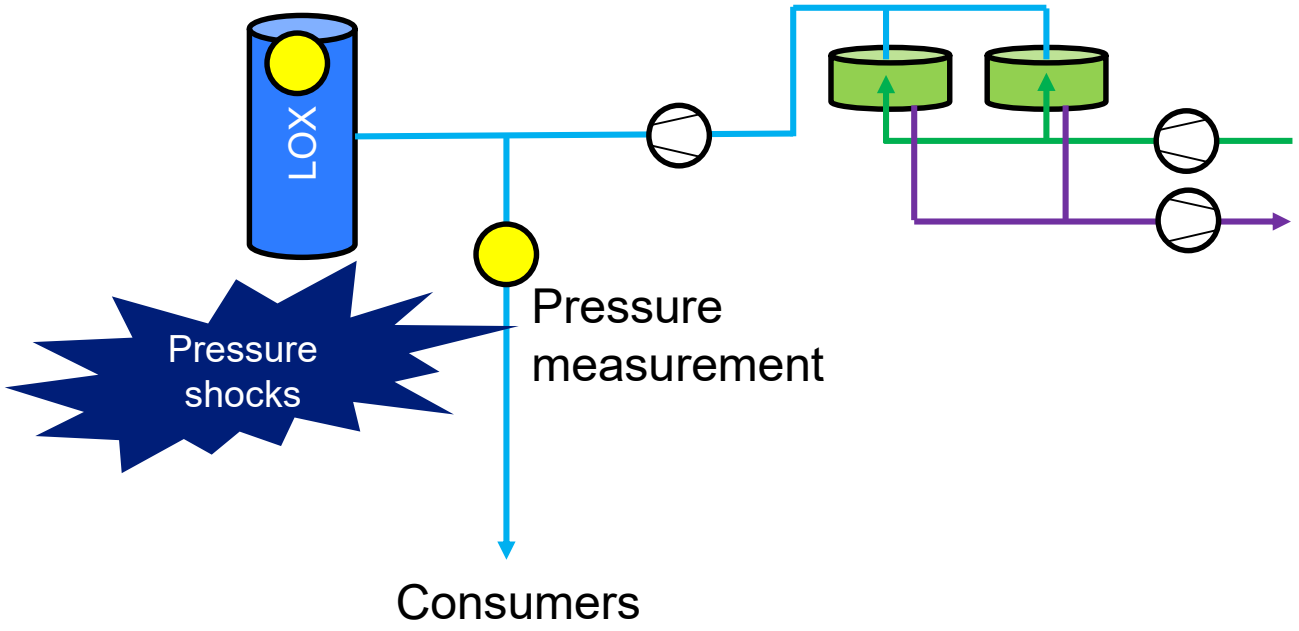
Comparison	**Costs in CHF**
Compensation of WWTP through fund „Bund“ CHF 9.- per resident and year	3´690´000.00
Costs 4th treatment stage WWTP Werdhölzli 2019	1´959´370.40
Savings WWTP in 2019	**1´730´629.60**

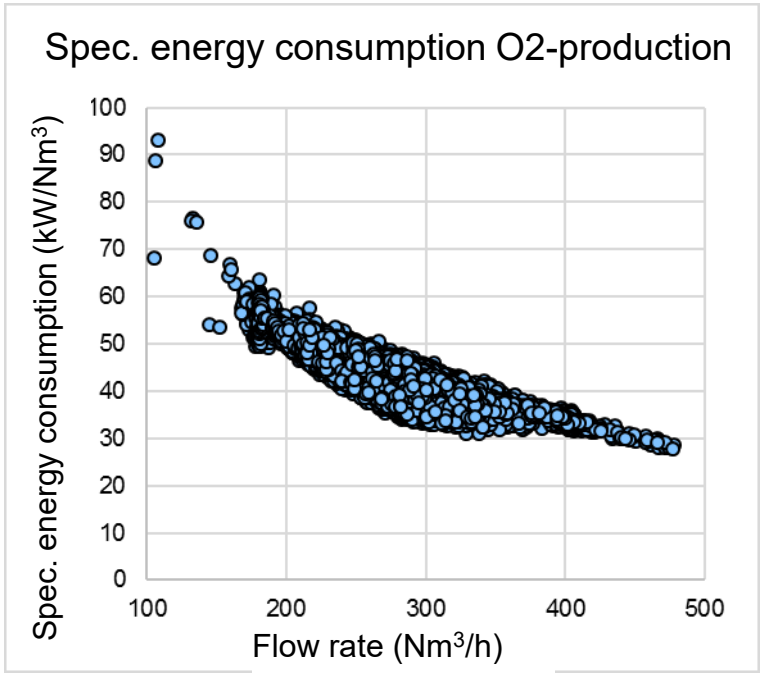
Tips and Tricks ☺

VPSA / Lox


Pressure LOX-Tank
Pressure (bar)
14.5
14
13.5
13
12.5
12
11.5
11
10.5
10
10.09.2020
12.09.2020
14.09.2020
16.09.2020
18.09.2020


O2-Production VPSA (daily course)
Flow rate (Nm³/h)
500
400
300
200
100
0.00 h
6.00 h
12.00 h
18.00 h
0.00 h


LOX
Pressure shocks
Pressure measurement
Consumers


Spec. energy consumption O2-production
Spec. energy consumption (kW/Nm³)
100
90
80
70
60
50
40
30
20
10
0
100
200
300
400
500
Flow rate (Nm³/h)

Facilities

- Ventilation → small rooms, what «simultaneity» must be covered?
- Emergency scenarios (what happens where in the event of «too much ozone»)
- Lids → just as many, as necessary
- ROV: moisture, condensate
- Cooling: short ways, heat production at downtime not negligible
- Networking of individual reactors (pressure ratios, ozone entrainment)
- Accessibility



Questions?