



Quaternary treatment for WWTPs in light of the proposed new UWWTD

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Overview

- Quaternary treatment in the proposed UWWTD
- Established treatment technologies
- Upgrade estimations for Austria
- Additional considerations
- Conclusions



Introduction to UWWTD¹ Art. 8 (I)

- Quaternary treatment to eliminate “the broadest possible spectrum” of micropollutants
- Which WWTPs to upgrade?
 - **Precautionary** principle combined with **risk-based** approach
 - Precautionary principle ➔ WWTPs $\geq 100,000$ PE (Art. 8.1)
 - Risk-based ➔ WWTPs between 10,000 and 100,000 PE in “micropollutant-sensitive areas” (Art. 8.2+8.4)




Introduction to UWWTD¹ Art. 8 (II)



- Minimum criteria for micropollutant-sensitive water bodies
 - used for drinking water supply
 - bathing waters
 - lakes
 - dilution ratio in rivers below 10
 - aquaculture activities
 - environmental quality standards (EQS) are exceeded
 - ➔ link to water framework directive



Indicator substances ➔ 80% total removal

- Ø removal calculated for at least 6 out of 12 substances*
- Ratio of cat.1/cat.2 substances = 2

* mostly  pharmaceuticals

Category 1 (very good removal)	Amisulprid	Category 2 (good removal)	Benzotriazole 
	Carbamazepine		Candesartan
	Citalopram		Irbesartan
	Clarithromycin		Mix of 4-Methyl- and 6-Methylbenzotriazole
	Diclofenac		
	Hydrochlorothiazid		
	Metoprolol		
	Venlafaxine		



Experience with quaternary treatment at TU Wien

- **POSEIDON** (EU: 2001-2004): Technologies for the Removal of PPCPs from Sewage and Drinking Water
- **KomOzon** (nat.: 2008-2011): Technical implementation of an ozonation step for quaternary treatment
- **KomOzAk I&II** (nat.: 2013-2015 & 2016-2019):
Advanced treatment with ozone and activated carbon –
Micropollutant removal & Toxicology and general applicability



>20 SCI publications on micropollutants

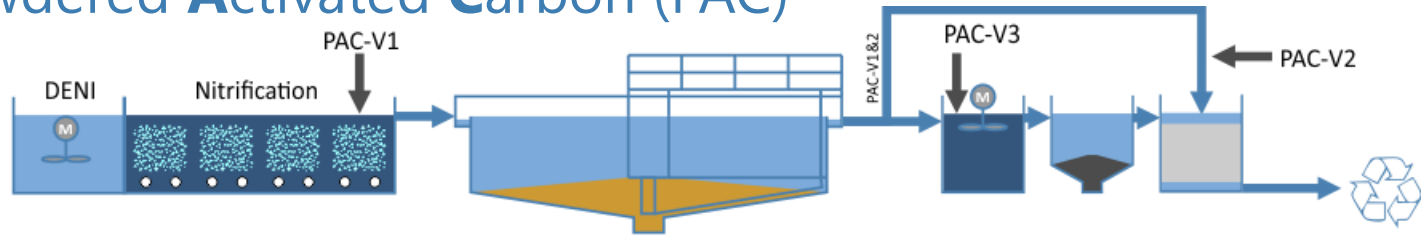
- Micropollutant removal during biological wastewater treatment and a subsequent ozonation step <https://doi.org/10.1016/j.envpol.2009.12.038>
- Effect of ozonation on the biodegradability of urban wastewater treatment plant effluent <https://doi.org/10.1016/j.scitotenv.2021.152466>
- Long-Term Toxicological Monitoring of a Multibarrier Advanced Wastewater Treatment Plant Comprising Ozonation and Granular Activated Carbon with In Vitro Bioassays <https://doi.org/10.3390/w13223245>
- Treatment of micropollutants in wastewater: Balancing effectiveness, costs and implications <https://doi.org/10.1016/j.scitotenv.2022.157593>



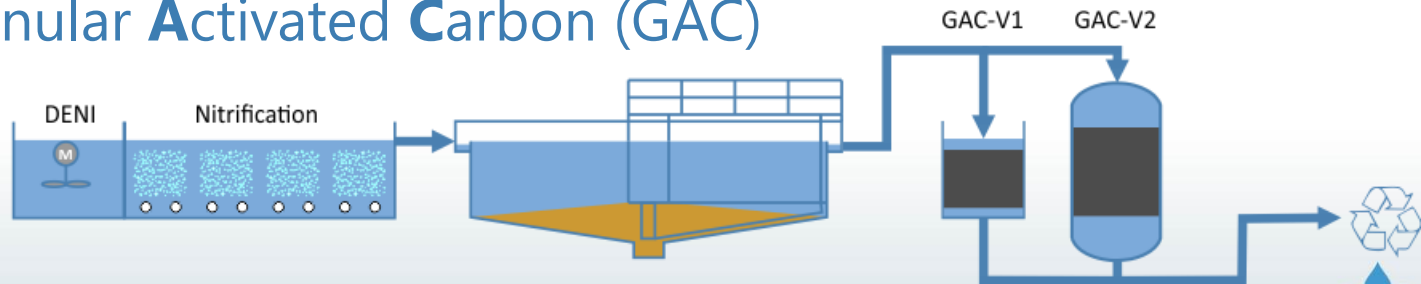


Established technologies

- Activated carbon treatment
 - **Powdered Activated Carbon (PAC)**



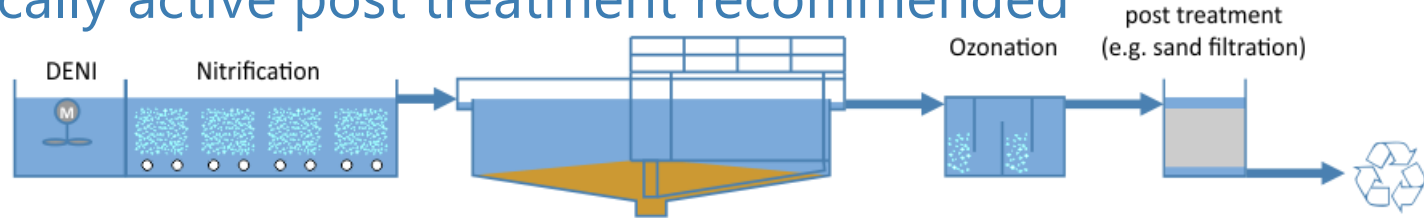
- **Granular Activated Carbon (GAC)**



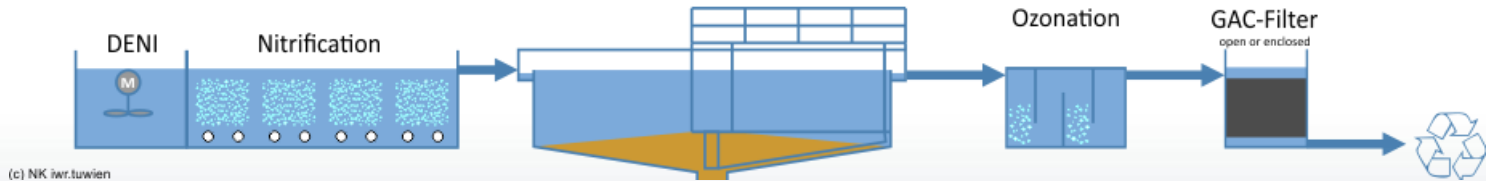


Established technologies

- Ozonation (O_3)
 - Biologically active post treatment recommended



- Combination of O_3 + GAC



(c) NK iwr.tuwien



Category	Indicator substance	Elimination AC	Elimination O ₃
1 (very well adsorbable/ oxidizable)	Amisulpride		
	Carbamazepine		
	Citalopram		
	Clarithromycin		
	Diclofenac		
	Hydrochlorothiazide		
	Metoprolol		
2 (well adsorbable/ oxidizable)	Venlafaxine		
	Benzotriazole		
	Candesartan		
	Irbesartan		
Mix of 4-Methyl- and 6-Methylbenzotriazole			

**Removal -
quaternary**

> 80%

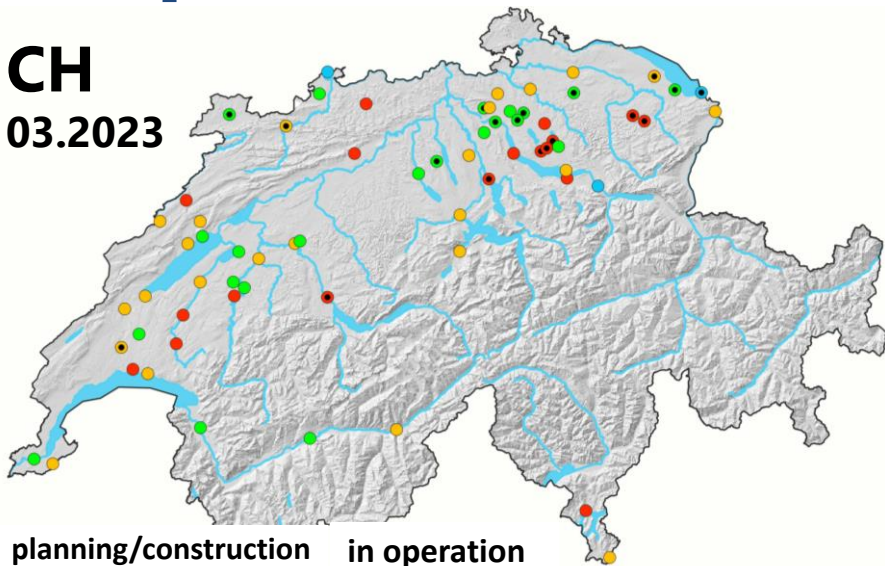
50 – 80%





Implementation – current status (CH|Ger)

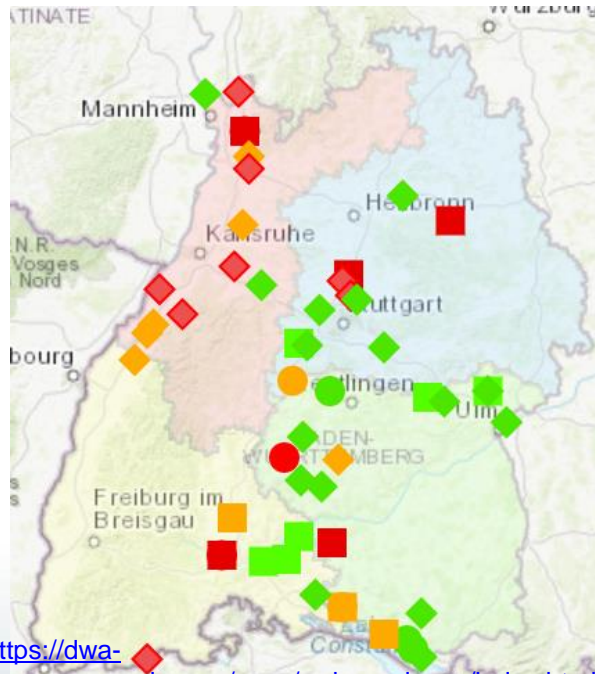
CH
03.2023



- | | |
|---|--|
| planning/construction | in operation |
| ● O3 | ● O3 |
| ● PAC | ● PAC |
| ● GAC | ● GAC |
| ● combination | |

<https://micropoll.ch/Mediathek/karte-der-ara-mit-mv-stufe/>

Ger (BW)
12.2022



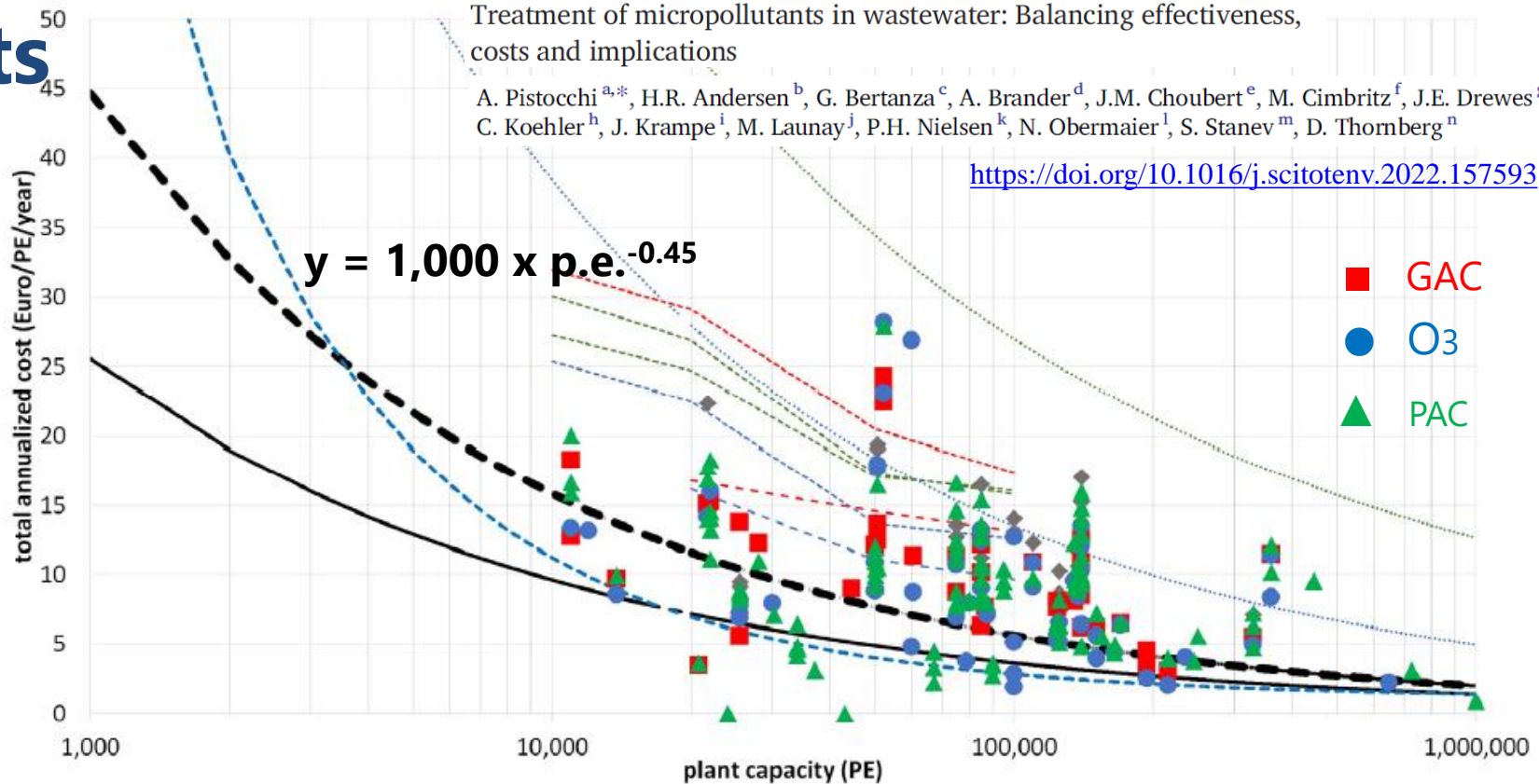
- ◆ PAC
- GAC
- O3

- in operation
- planning
- construction

<https://dwa-bw.maps.arcgis.com/apps/webappviewer/index.html?id=2428880b396f4a21a6123b3fb87feb8b>



Costs





WWTPs upgrade – estimates for Austria

large WWTPs \geq 100,000 PE-design (Art. 8.1)	37	= 57% of WWTP capacity
WWTP \geq 10,000 – 99,999 EW-design (Art. 8.2a-f)	= 56 241(f1 f2)*	= 8 35% of WWTP capacity
a) drinking water supply	0 – 8	→ River Rhine catchment, but no river bank filtration
b) bathing waters	19	
c) lakes	5	
d) dilution ratio < 10	37	
e) aquaculture activities	no data	
f1)* areas with EQS -exceedance (current directive)	0	
f2)* areas with EQS -exceedance (proposal 2022)	241	
Σ Art. 8.1 + 8.2 (scenario f1)	93	= 65% of WWTP capacity
Σ Art. 8.1 + 8.2 (scenario f2)	278	= 92% of WWTP capacity



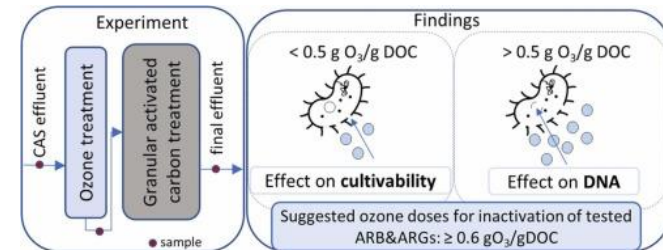
Additional considerations

- Water reuse
- Green hydrogen as future fuel
- Per- and polyfluoroalkyl substances ➔ PFAS challenge
- Emission modelling



Reuse of treated wastewater

- UWWTD Art.15 : "Member States shall systematically promote the reuse of treated wastewater from all UWWTPs."
- EU legislation 2020/741¹ : regulation on minimum requirements for water reuse
- Micropollutant removal not required
- Quaternary treatment is an added benefit in a multibarrier system



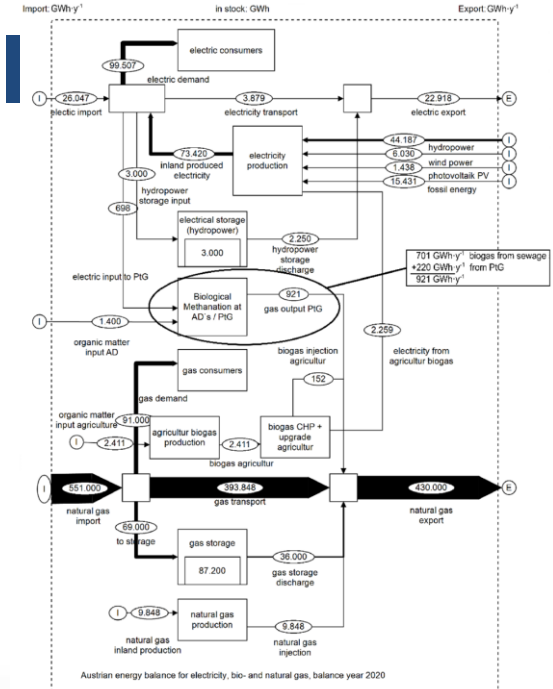
Advanced Wastewater Treatment With Ozonation and Granular Activated Carbon Filtration: Inactivation of Antibiotic Resistance Targets In A Long-Term Pilot Study

<https://doi.org/10.1016/j.jhazmat.2022.129396>



Green hydrogen as future fuel

- H₂ generation by electrolysis
- O₂ as a by-product of electrolysis
- O₂ can be used as a feed gas for ozone generation



<https://doi.org/10.3390/en14206618>

Energetic Potential for Biological Methanation in Anaerobic Sewage Sludge Digesters in Austria



PFAS – forever chemicals

- Currently not removed by conventional WWT
- Newly proposed PFAS-EQS will result in nationwide exceedance of EQS (Art. 8.2f) ➔ quaternary treatment
- Effect of quaternary treatment
 - O₃ does not eliminate PFAS
 - AC adsorbs PFAS (disposal/regeneration of AC to be considered)
- Emission modelling as a tool to assess the measures

See also:

<https://promiscues.eu/>



Emission modelling

- Considerations on the catchment area level are needed
 - e.g., the number and location of WWTPs to be upgraded
- Emission modelling as a tool to
 - assess the effectiveness of measures for the immission situation
 - determine the cumulative effect of upgrading multiple WWTPs
 - distinguish between diffuse and point sources

Coupling a pathway-oriented approach with tailor-made monitoring as key to well-performing regionalized modelling of PFAS emissions and river concentrations

<https://doi.org/10.1016/j.scitotenv.2022.157764>



Recap and conclusions

- Implementation of quaternary treatment based on a precautionary and a risk-based approach ($\geq 10,000$ PE)
- Established treatment technologies exist
- Estimates for AT range between 65 and 92% of the WWTP capacity depending on the considered EQS scenario



Recap and conclusions

- Emission modelling can help to assess the situation on the catchment area level and to identify effective measures
- Don't get distracted by the ambitious goals of the UWWTD, but consider challenges to be tackled as well as potential synergies to be used.





Hvala za vašo pozornost!

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