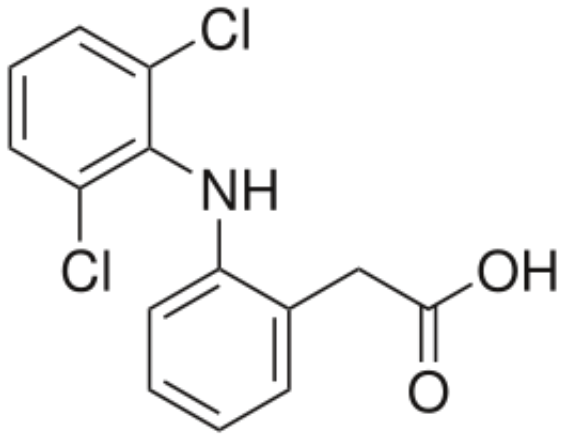
Organic micropollutant (oMP) treatment VI: CO_2-Footprint

Applied wastewater engineering

Michael Jon MATTLE



Field visit to WWTP of VOG

How was the field visit (several answers possible)?

A) it was interesting

B) it was rather boring

C) it helps me to better understand the topics of the course

D) it gives me a better picture of wastewater treatment

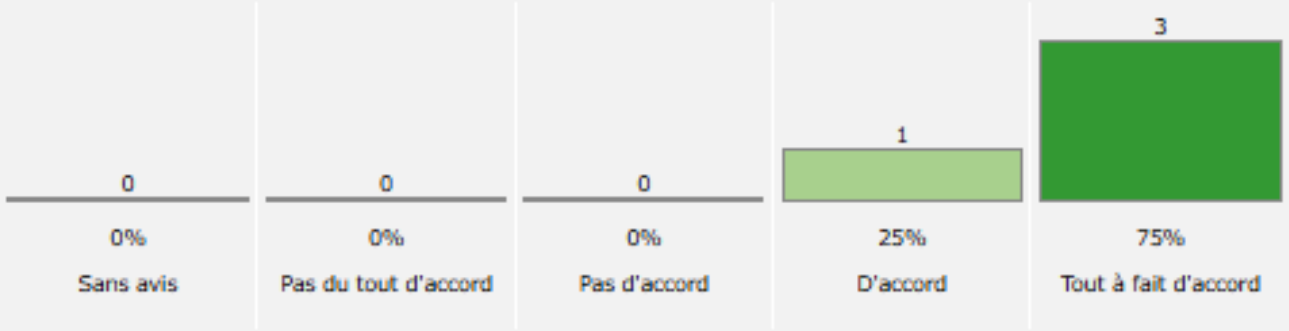
E) I consider it an important part of the course

https://web.speakup.info/room/join/11535

Feedback

Année	2025-2026
Matière	Applied wastewater engineering
Questionnaire	Retour indicatif des enseignements (dès 2022-2023)
Nb Inscrit	15
Nb Répondu	4

Le déroulement du cours permet mon apprentissage et un climat de classe approprié



Remarques
[3 remarque(s)]

- Great class, with a lot of possibilities to ask questions. The corrections are posted a bit late. I am not sure though what is going to be expected in the midterm.
- The answer to exercises could be put earlier
- The course is good! However, it could be great to lighten/simplify the slides presented during the course

Feedback

- Thanks for the feedback!
- It would be great to have more answers (I did not remind you, my fault).
- I greatly appreciate any comments (both negative or positive)!
- My conclusions:
  - I will make an effort to put the solutions earlier: 2 days after the exercise session. Good for you?
  - I will work over the slides (to lighten/simplify) but will not be able to do all the remaining slides during the semester. Can you indicate the slides that are overloaded, please?
  - Exams: I will indicate for future students that the exams are similar to the exercises, enough?

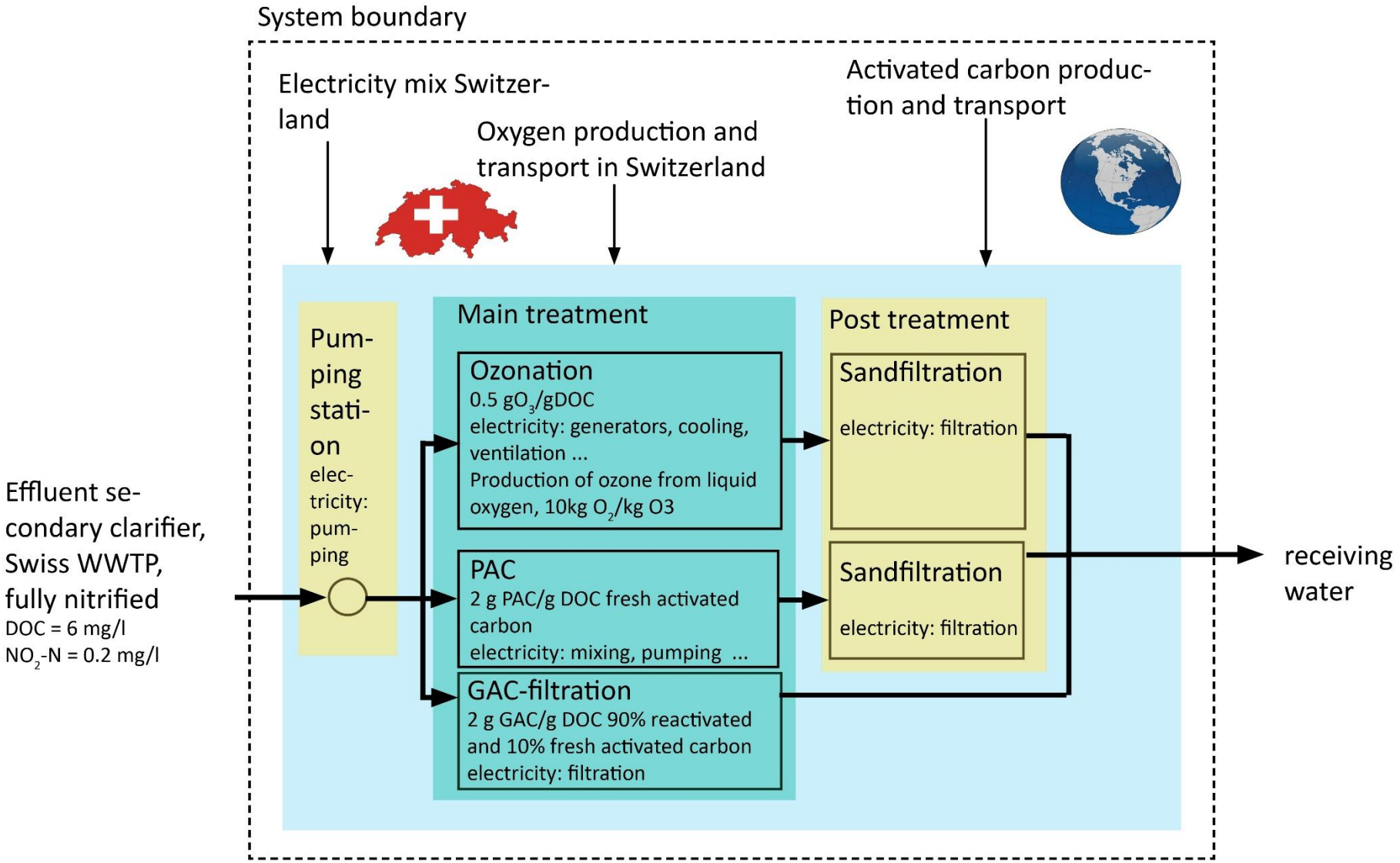
What are the negative impacts of oMP-treatment?

- different technologies can be chosen to remove oMP and achieve the required 80 % elimination rates
- However, what is the ecological impact of
  - constructing these infrastructures?
  - producing and transporting the consumables (PAC, GAC, O_2, O_3)?
  - additional pumping of the wastewater?
- Do all processes have the same ecological impact or have certain processes a lower impact than others?
- What is the impact of the electricity mix including imported electricity (e.g. Switzerland has mainly 'renewable' electricity)?

What are the negative impacts of oMP treatment?

- We will not conduct a full life-cycle analysis but only focus on the CO_2-footprint (impact on global warming) of the different processes
  - because we assume that all processes have a comparable positive effect on the environment (removal of oMP)
  - these positive effects are rather hard to evaluate and difficult (arbitrary) to compare with CO_2-emissions
  - other effects like e.g. land use and primary energy use are also difficult (arbitrary) to compare with CO_2-emission

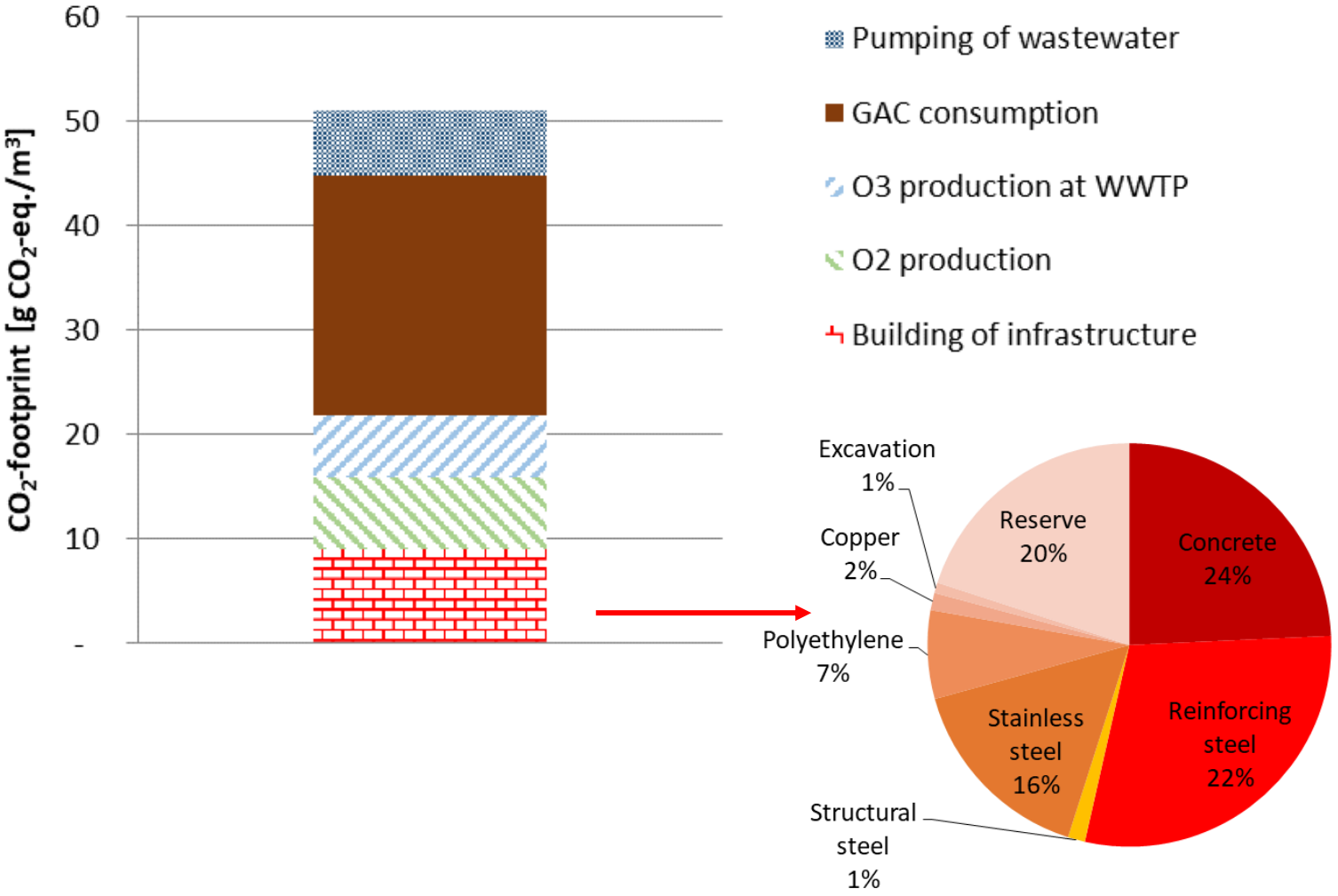
CO_2-footprint model (Meier et al.)



CO_2-Footprint of combined process

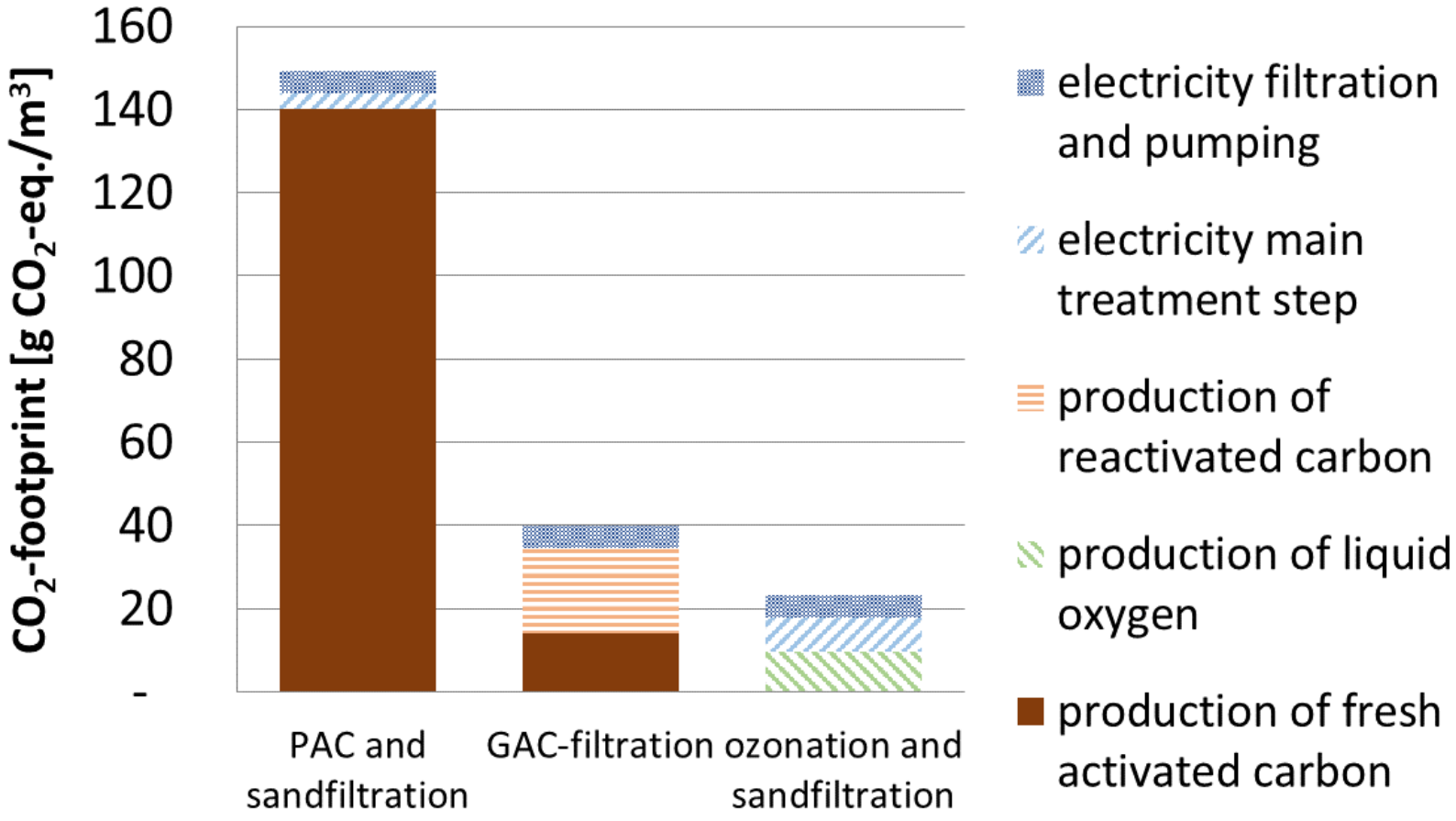
- example of WWTP Altenrhein (ozonation followed by GAC-filtration)
- main CO_2-contributor is GAC production/regeneration
- second major CO_2-contributor is ozonation (O_2- and O_3-production)
- construction of infrastructure (mainly steel and concrete) is less than 20 % (percentage higher in Switzerland than in the European union because of electricity mix)
- pumping generates roughly 10 % of the CO_2-emissions

→ main emissions are due to consumables (GAC, O_2, O_3)



Comparison of different processes

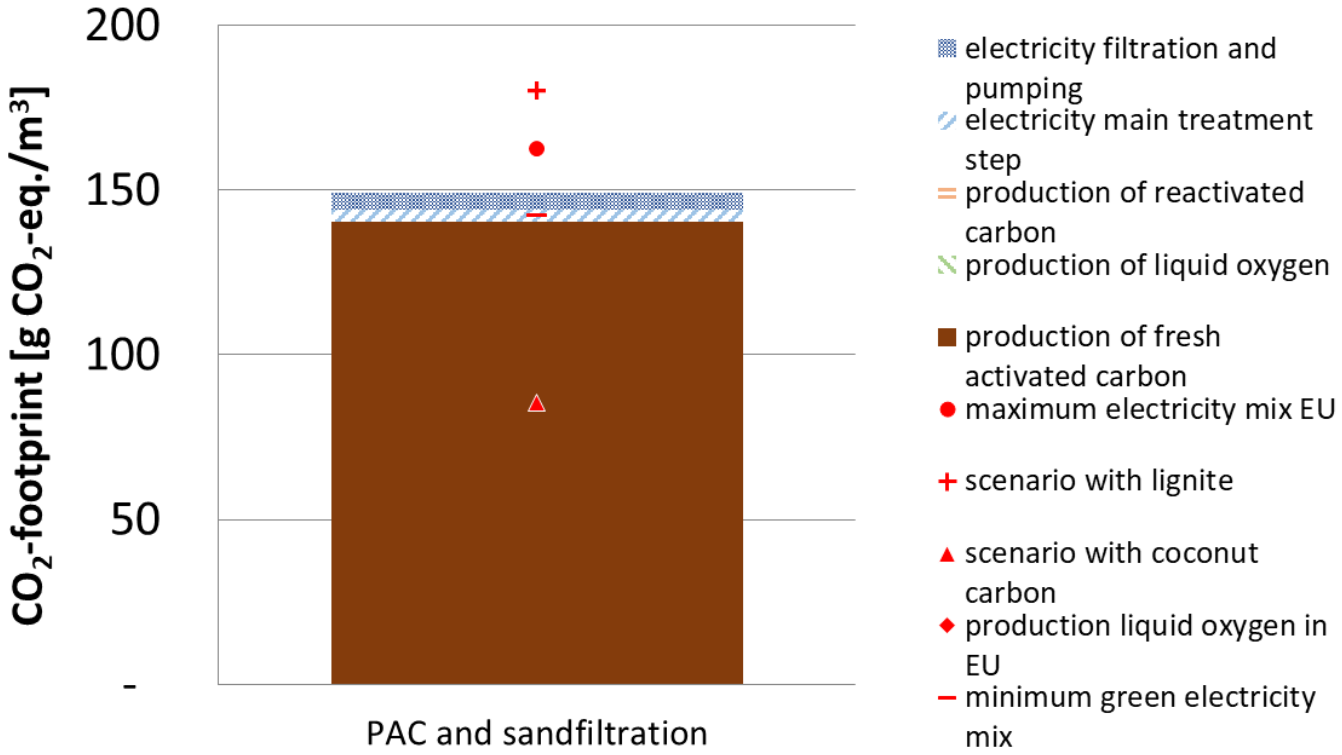
- PAC (produced from coal) has by far the highest CO_2-emissions
  - nearly four times higher than GAC
  - Five times higher than ozonation
- main emission of PAC-treatment comes from coal (mining and incineration) and the activation process (transport is neglectable)



Excluding building of infrastructure

CO_2-footprint of powdered activated carbon (PAC)

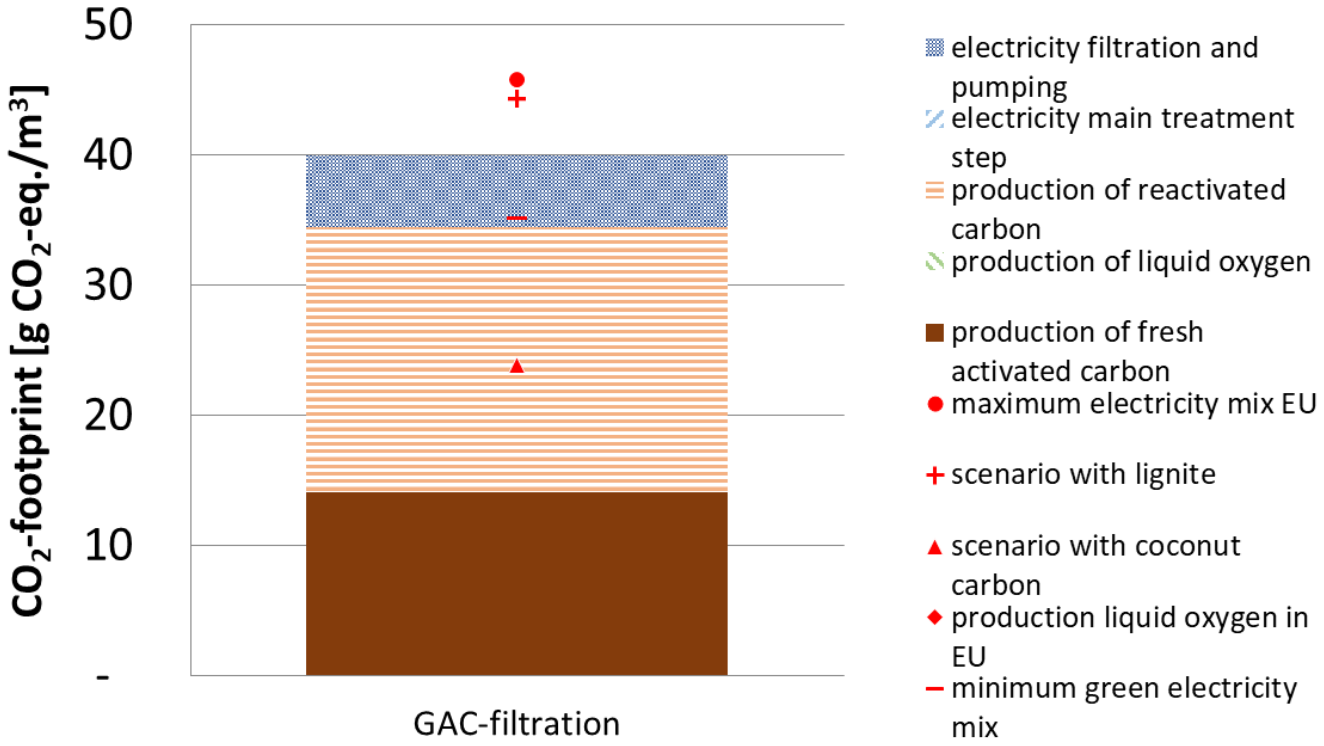
- electricity consumption is comparatively low for PAC
- use of lignite instead of coal would even increase the CO_2-footprint
- use of coconut or wood for PAC-production reduces CO_2-footprint by 40 % (it is often difficult to know from manufacturer which fraction is from renewable sources)
- PAC-consumption is highly variable on COD effluent values (value has an important impact on CO_2-footprint)
- total PAC-consumption equals a car ride of 200 meters per day and per person



Excluding building of infrastructure

CO_2-footprint granular activated carbon (GAC)

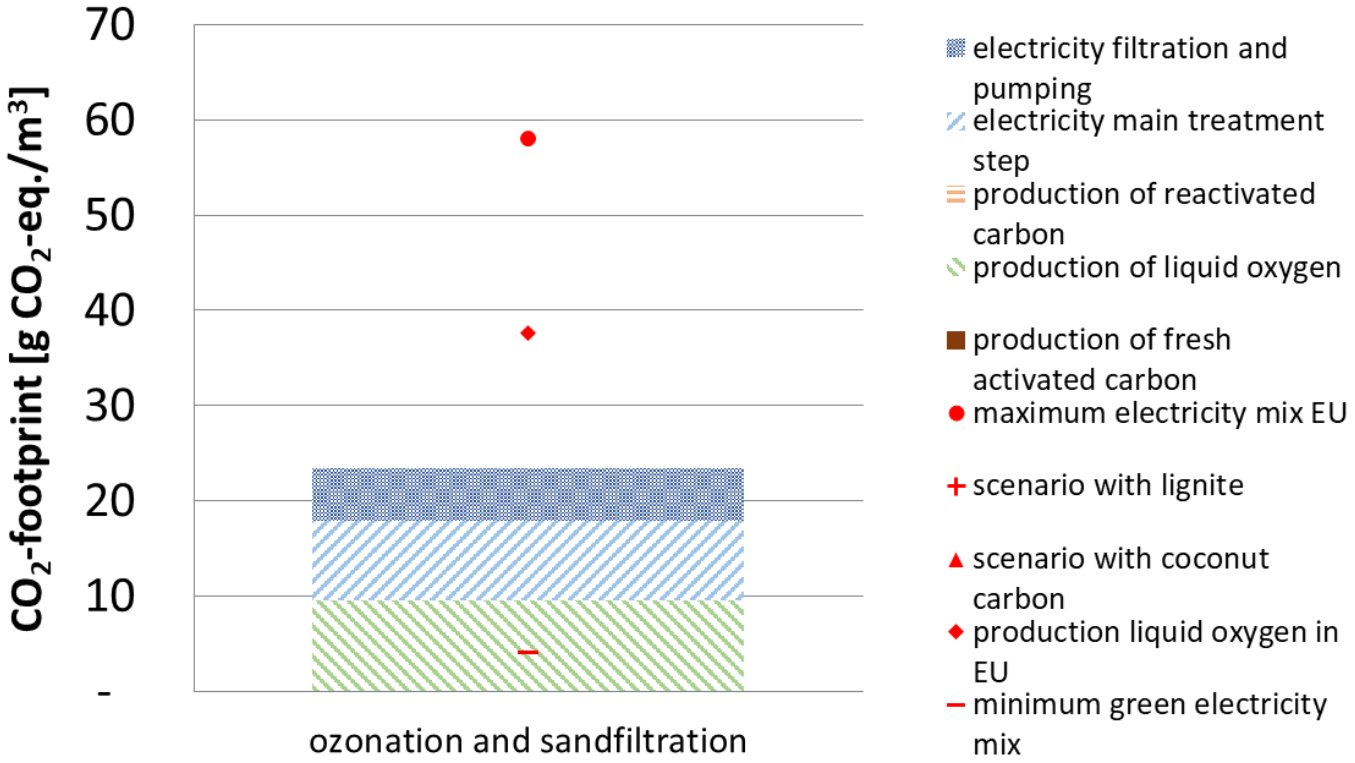
- reactivation process has the largest CO_2-footprint (about 50 %) for GAC
- production of new GAC (only about 10 % to compensate loss of GAC during reactivation process) corresponds to about 40 % of the CO_2-footprint
- electricity consumption is comparatively low (about 10 %)
- Currently, there is no GAC produced from renewable sources available on the market (wood-based GAC is too fragile and does therefore not work)



Excluding building of infrastructure

CO_2-footprint of ozonation

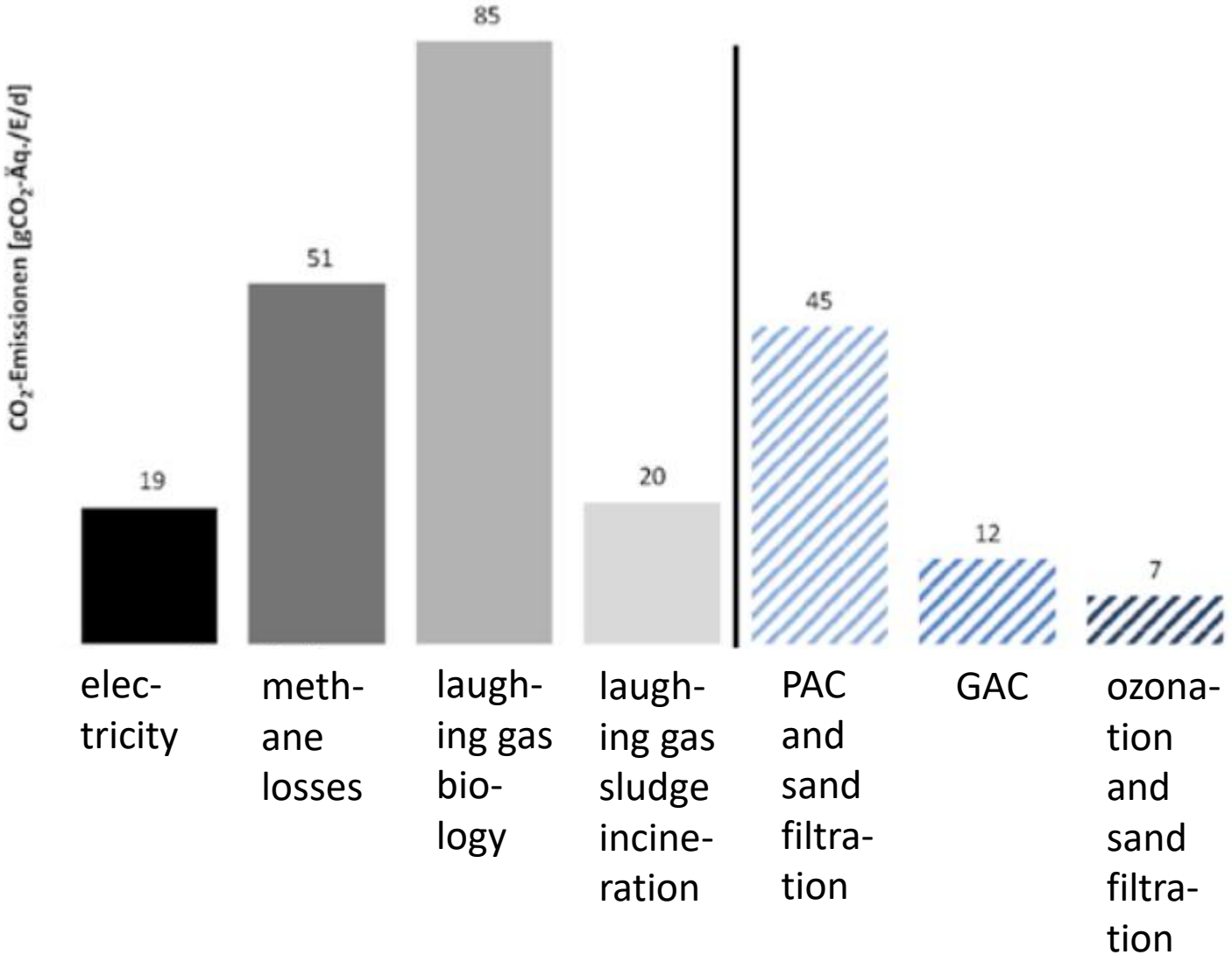
- electricity consumption is clearly the major contributor to CO_2-footprint
  - about 45 % due to liquid oxygen production
  - about 35 % for ozone production (real data have shown clearly lower consumption)
  - about 20 % for pumping
- with European electricity mix, the CO_2-footprint would increase by more than 250 %! GAC would then have a lower CO_2-footprint than ozonation
- a hypothetical green electricity mix with no imports from the EU would reduce the CO_2-footprint by a factor of 6



Excluding building of infrastructure

Comparison with other emissions of WWTP

- emissions of oMP-treatment are low compared to emissions from WWTP in general (see air emissions control chapter)
  - 4 % for ozonation
  - 5.5 % for GAC
  - 20 % for PAC



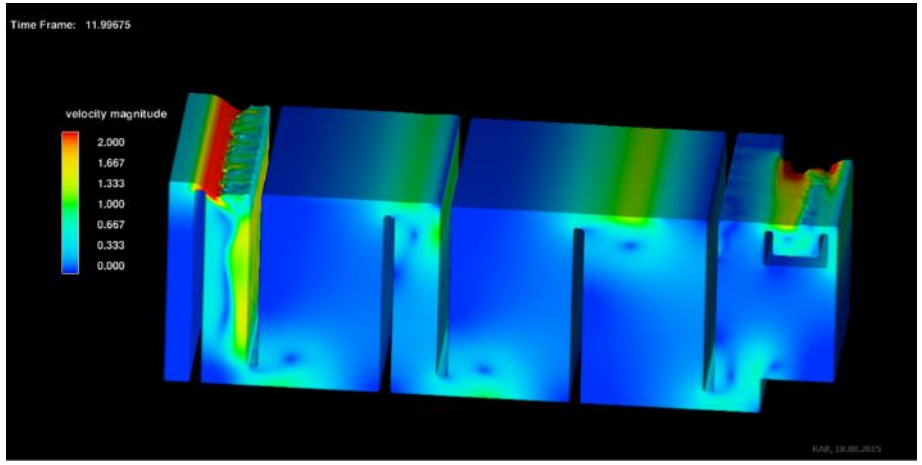
Conclusions and recommendations

- In order to reduce CO_2-emissions
  - choice of treatment process has a major impact
  - optimise dosage of AC and/or ozone which has an important impact on CO_2-emissions
  - use renewable activated carbon (e.g. coconut or wood-based) if available
  - use regenerated activated carbon (PAC and GAC) or already used AC (e.g. for drinking water production) or PAC-waste from GAC production
  - recycle PAC into biological system if possible
  - reduce DOC values if possible (e.g. industrial pre-treatment or higher sludge age)
  - reuse existing infrastructure (e.g. concrete) if possible
  - reduce nitrite concentrations in effluent (only for ozonation), buy liquid oxygen from Swiss production and reuse effluent gas from ozonation for aeration of biology (if feasible)
  - reuse generated heat energy (e.g. ozone production)

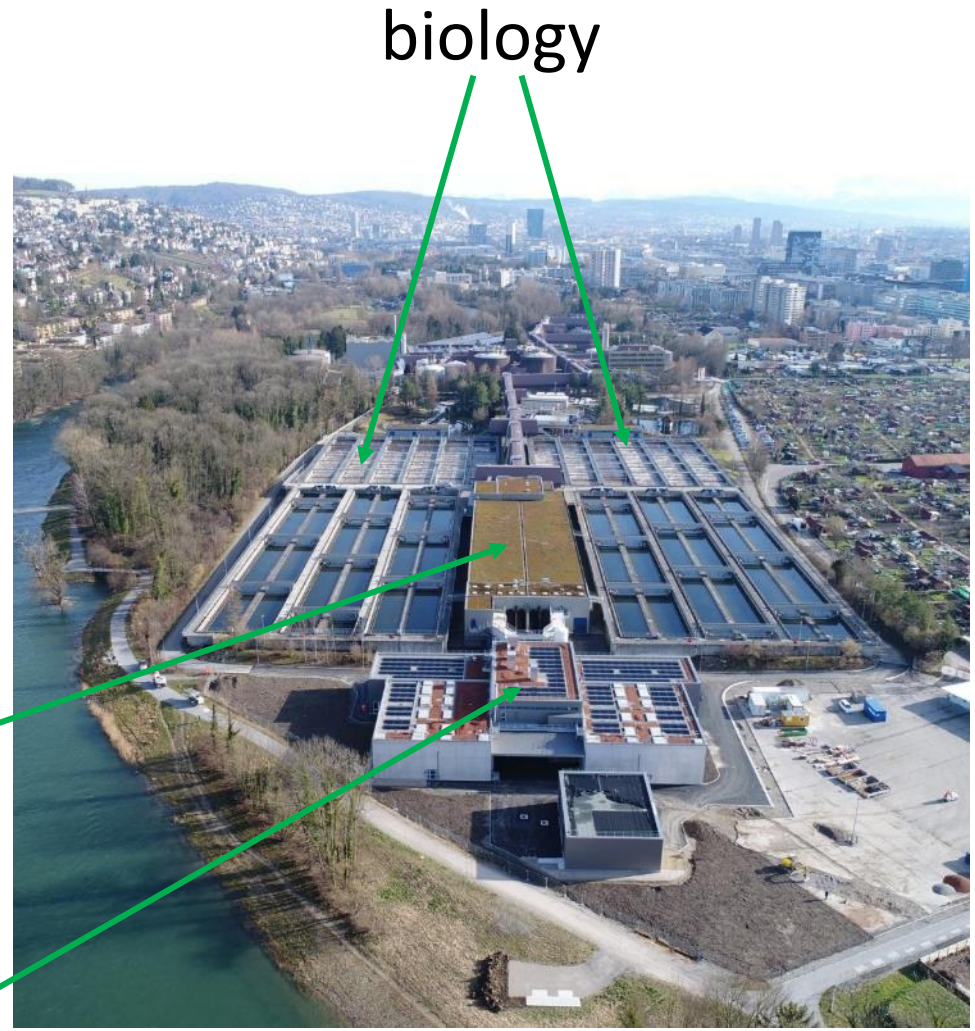
Outlook

- over 100 wastewater treatment plants will be equipped for organic micropollutant removal (construction start by the lasted in 2035)

➡ there is a lot of challenging work for motivated engineers!



CFD-modelling by René Kaufmann/Jörn Heilig



WWTP Werdhölzli, Zurich

Outlook

- Federal council proposed to refuse motion 20.4262 to extent the treatment of oMP to all WWTP
- Both federal chambers adapted motion 20.4262 on 17.12.2020

20.4262 MOTION

Mesures visant à éliminer les micropolluants applicables à toutes les stations d'épuration des eaux usées

Submitted by:	COMMISSION DE L'ÉCONOMIE ET DES REDEVANCES CN
Rapporteur:	REGAZZI FABIO , SCHMID MARTIN , WALTI BEAT
Submission date:	13/10/2020
Submitted:	Conseil national
State of deliberations:	Transmis au Conseil fédéral

EXPAND ALL

SUBMITTED TEXT

Le Conseil fédéral est chargé de modifier les bases légales comme suit, afin que l'ensemble des quelque 740 stations d'épuration des eaux usées (STEP) doivent prendre des mesures visant à éliminer les micropolluants :
1. Pour financer la mise en oeuvre de ces mesures supplémentaires dans les STEP, le montant maximal de la taxe fédérale sur les eaux usées visée à l'art. 60b de la loi fédérale sur la protection des eaux est relevé dans la mesure nécessaire et le délai de perception de la taxe est prolongé.
2. Les prescriptions concernant le déversement des eaux usées dans les eaux figurant à l'annexe 3.1, ch. 2, n° 8, de l'ordonnance sur la protection des eaux sont modifiées de sorte que toutes les STEP centrales doivent prendre des mesures pour éliminer les micropolluants.
3. Les cantons sont tenus de soumettre à la Confédération, dans un délai d'un an à compter de l'entrée en vigueur des prescriptions légales ad hoc, une planification relative à l'optimisation de l'équipement de toutes les STEP, laquelle comprendra des mesures visant à éliminer les micropolluants.

Outlook

CHRONOLOGIE

17.12.2020 CONSEIL NATIONAL

Adoption

15.06.2021 CONSEIL DES ETATS

La motion est adoptée avec la modification suivante:Le Conseil fédéral est chargé ...2. Les prescriptions concernant le déversement des eaux usées dans les eaux figurant à l'annexe 3.1, ch. 2, n° 8, de l'ordonnance sur la protection des eaux (RS 814.201) sont modifiées de sorte que toutes les STEP dont le déversement des eaux usées épurées entraîne des dépassements des valeurs limites doivent prendre des mesures pour éliminer les micropolluants.

30.11.2021 CONSEIL NATIONAL

Adhésion

- Conseil des états modified the text so that all WWTP are concerned that cause overstepping of defined maximal values defined for surface waters in Annex 2

No	Parameter	Requirements
3	Medicinal products	
	Azithromycin (CAS No 83905-01-5)	0.18 µg/l 0.019 µg/l (continuous)[2]
	Clarithromycin (CAS No 81103-11-9)	0.19 µg/l 0.12 µg/l (continuous)[2]
	Diclofenac (CAS No 15307-86-5)	0.05 µg/l (continuous)[2]

Outlook

- Possible consequences of this motion:
  - many additional smaller WWTP will have to treat oMP in the future
  - certain WWTP will have to treat certain parameter to higher elimination rates (> 80 %)
  - diclofenac will be mostly the limiting parameter in surface waters
  - process choice may in future be influenced if higher elimination rates are required: ozonation achieves higher diclofenac removal with common dosages as compared to AC
  - processes must be adapted to smaller WWTP with less operation personal

Outlook

- the Federal Office for the Environment is currently working on this topic to propose a modification of the Water protection ordinance (WPO) to the parliament
  - a modified ordinance may come into force in 2028
  - a new system to finance these additional installations is required
  - construction of new treatment units will have to be started within a defined time period (15 – 20 years?)
  - we are not yet done, there is still a lot of challenging work to come in the field of wastewater engineering!

Outlook

- Proposal for a revised Urban Wastewater Treatment Directive:
  - treatment of oMP: 80 % > 100'000 PE and
    10'000 – 100'000 PE in areas where oMP pose a risk to human health or the environment
  - producers are forced to contribute to the costs
  - regular analysis of antimicrobial restistance (twice a year)
- BUT the samples shall be taken so that they reflect the pollution during dry weather conditions

EUROPEAN
COMMISSION

Brussels, 26.10.2022
COM(2022) 541 final

2022/0345 (COD)

Proposal for a

DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

concerning urban wastewater treatment (recast)

Outlook

- same treatment goal (80 %) as defined in Switzerland
- same substances
- same computation of treatment goal
- …

- we will see whether it will be approved in the current form, but it will have a huge impact on wastewater treatment in Europe

Table 3: Requirements for quaternary treatment of discharges from urban wastewater treatment plants referred to in Article 8(1) and (3).

Indicators	**Minimum percentage of removal**
Substances that can pollute water even at low concentrations (see Note 1)	80 % (see Note 2)

Note 1: The concentration of the organic substances referred to in points (a) and (b) shall be measured.

(a) Category 1 (substances that can be very easily treated):

(i) Amisulprid (CAS No 71675-85-9),

(ii) Carbamazepine (CAS No 298-46-4),

(iii) Citalopram (CAS No 59729-33-8),

(iv) Clarithromycin (CAS No 81103-11-9),

(v) Diclofenac (CAS No 15307-86-5),

(vi)— Hydrochlorothiazide (CAS No 58-93-5),

(vii) Metoprolol (CAS No 37350-58-6),

(viii)— Venlafaxine (CAS No 93413-69-5);

(b) Category 2 (substances that can be easily disposed of):

(i) Benzotriazole (CAS No 95-14-7),

(ii) Candesartan (CAS No 139481-59-7),

(iii) Irbesartan (CAS No 138402-11-6),

(iv) mixture of 4-Methylbenzotriazole (CAS No 29878-31-7) and 6-methyl-benzotriazole (CAS No 136-85-6).

Note 2: The percentage of removal shall be calculated for at least six substances. The number of substances in category 1 shall be twice the number of substances in category 2. If less than six substances can be measured in sufficient concentration, the competent authority shall designate other substances to calculate the minimum percentage of removal when it is necessary. The average of the percentages of removal of all substances used in the calculation shall be used in order to assess whether the required 80 % minimum percentage of removal has been reached.

References

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- *Essais-pilotes – traitement des micropoluants par charbon actif en micrograin*, Horisberger, M. et al., **2017**
- *Wastewater Engineering: Treatment and Resource Recovery*, Metcalf & Eddy \ Aecom, Fifth Edition **2014**
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Thanks for their help

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