Electrooxidation of the pyrolysis aqueous phase on boron-doped diamond electrodes

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AGENDA

1. Thermo-catalytic reforming technology – formation of the aqueous phase
2. Quantity and composition of the aqueous phase from sewage sludge
3. Wastewater parameters
4. Theory of electrooxidation
5. Electrooxidation results
6. Summary & Conclusion
7. Outlook

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Thermo-catalytic reforming (TCR®)

Formation of the aqueous phase

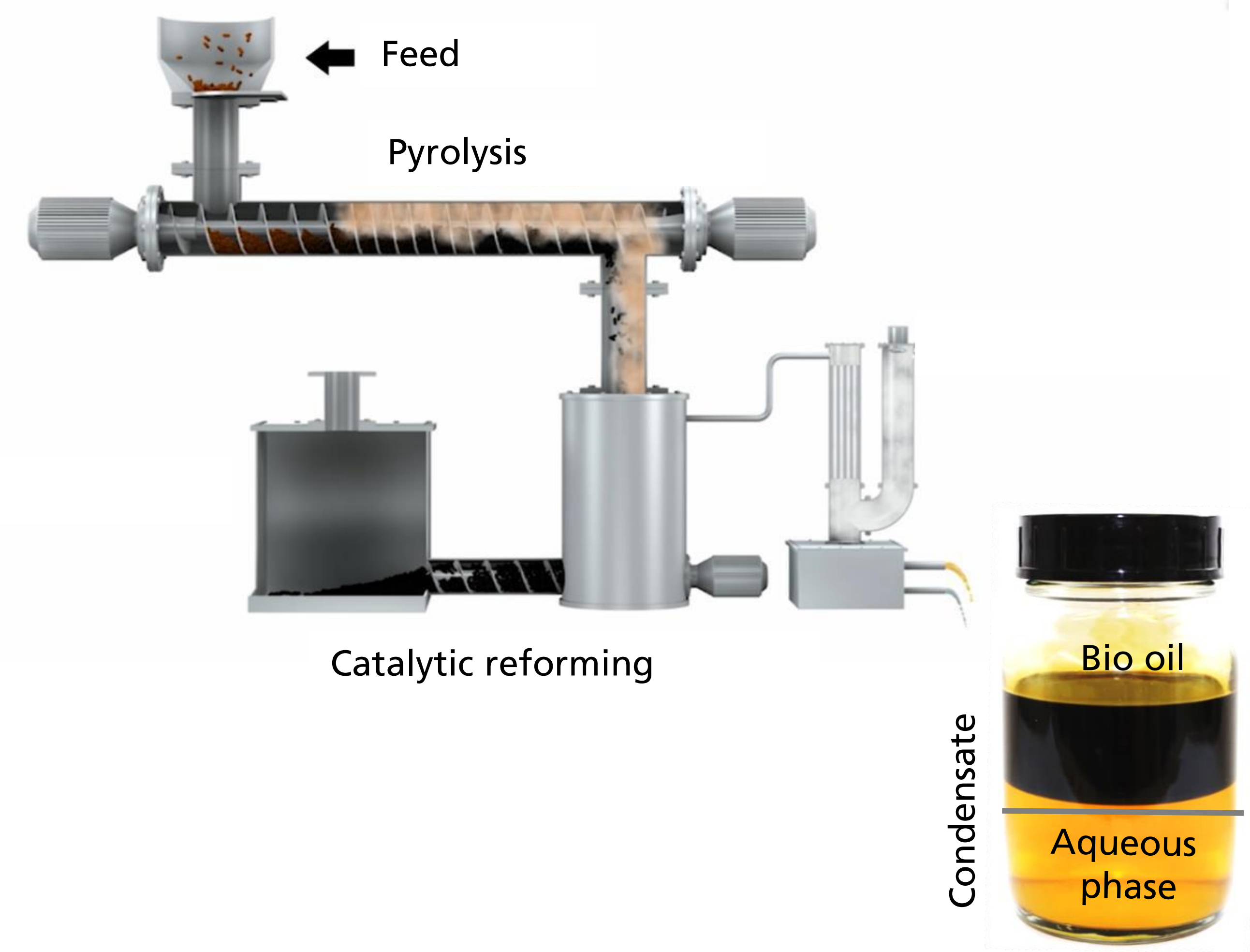
Formation due to:

- Initial moisture of feedstock
- Chemical reactions during conversion

Composition and quantity depend on:

- Initial moisture of feedstock
- Chemical composition of feedstock

For this study: Feedstock sewage sludge



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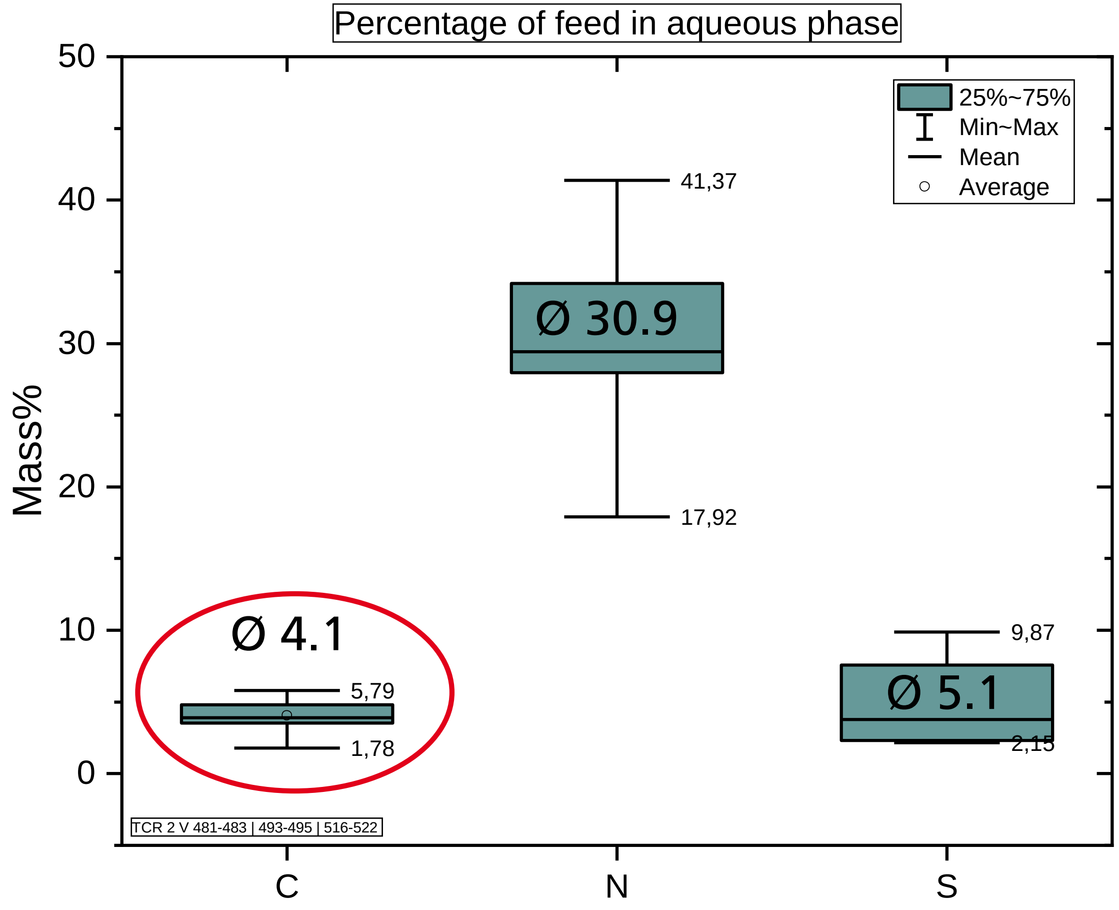
Aqueous phase from sewage sludge

Composition and quantity

Elemental analysis of TCR® aqueous phase

	C in m%	H in m%	N in m%	O in m%	S in m%	H_2O in m%
Average	6.41	2.55	8.55	9.73	0.23	72.54
Median	5.87	2.51	8.18	8.95	0.14	73.68
Standard deviation	1.30	0.51	1.46	2.15	0.12	4.08



Further characteristics of the aqueous phase

- Quantity: ~20 – 30 m% of feedstock
- Lower heating value: < 0.2 MJ/kg

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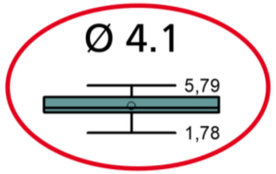
Aqueous phase from sewage sludge

Wastewater parameters and carbon distribution

Wastewater parameter:

- Total organic carbon (TOC)
- Chemical oxygen demand (COD)

Total Carbon (TC)



~50 m%

~50 m%

Inorganic Carbon (TIC)

Total Organic Carbon (TOC)

→ 2 m% of aqueous phase as TOC
≙ 80.000 mg/l COD

~80x municipial wastewater

Typical organic compounds found in the aqueous phase:

Chemical group	Typical representative
Carboxylic acids:	Acetic acid
Nitriles:	Acetonitrile
Azines:	Pyridine, Pyrazine
Azoles:	Pyrrole
Phenols	Phenol

→No solemn biological treatment possible

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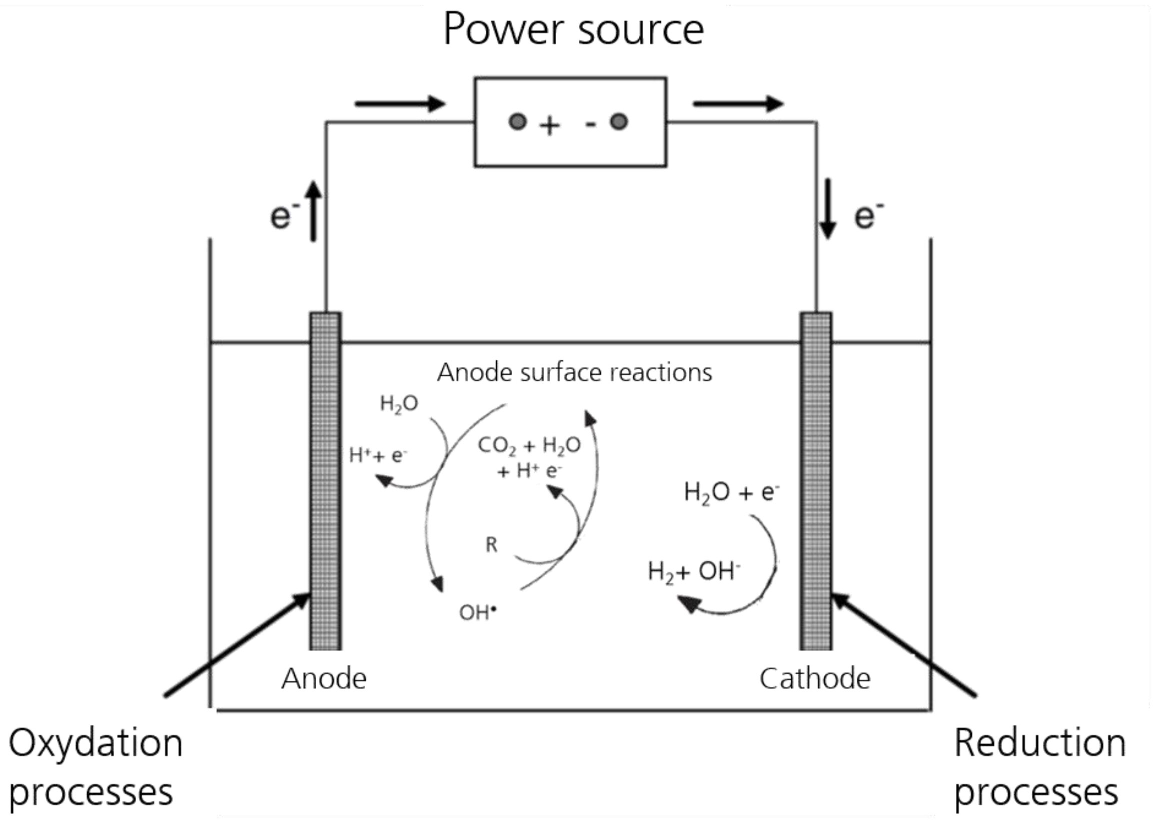
Electrooxidation
Theory and advantages

<u>Theory</u>

- Electrooxidation class of advanced oxidation processes (AOP's)
- In-situ production of oxidants through electricity
- Non selective in regards to organics



<u>Advantages of boron-doped diamond electrodes:</u>

- Chemical stable
- Highest overpotential towards oxygen
- Highest production yield of hydroxyl radicals

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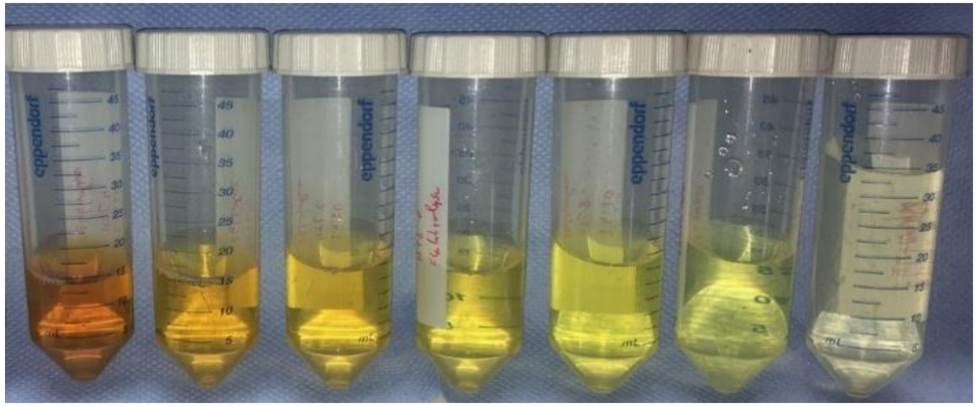
Electrooxidation
Model TCR® aqueous phase and COD results

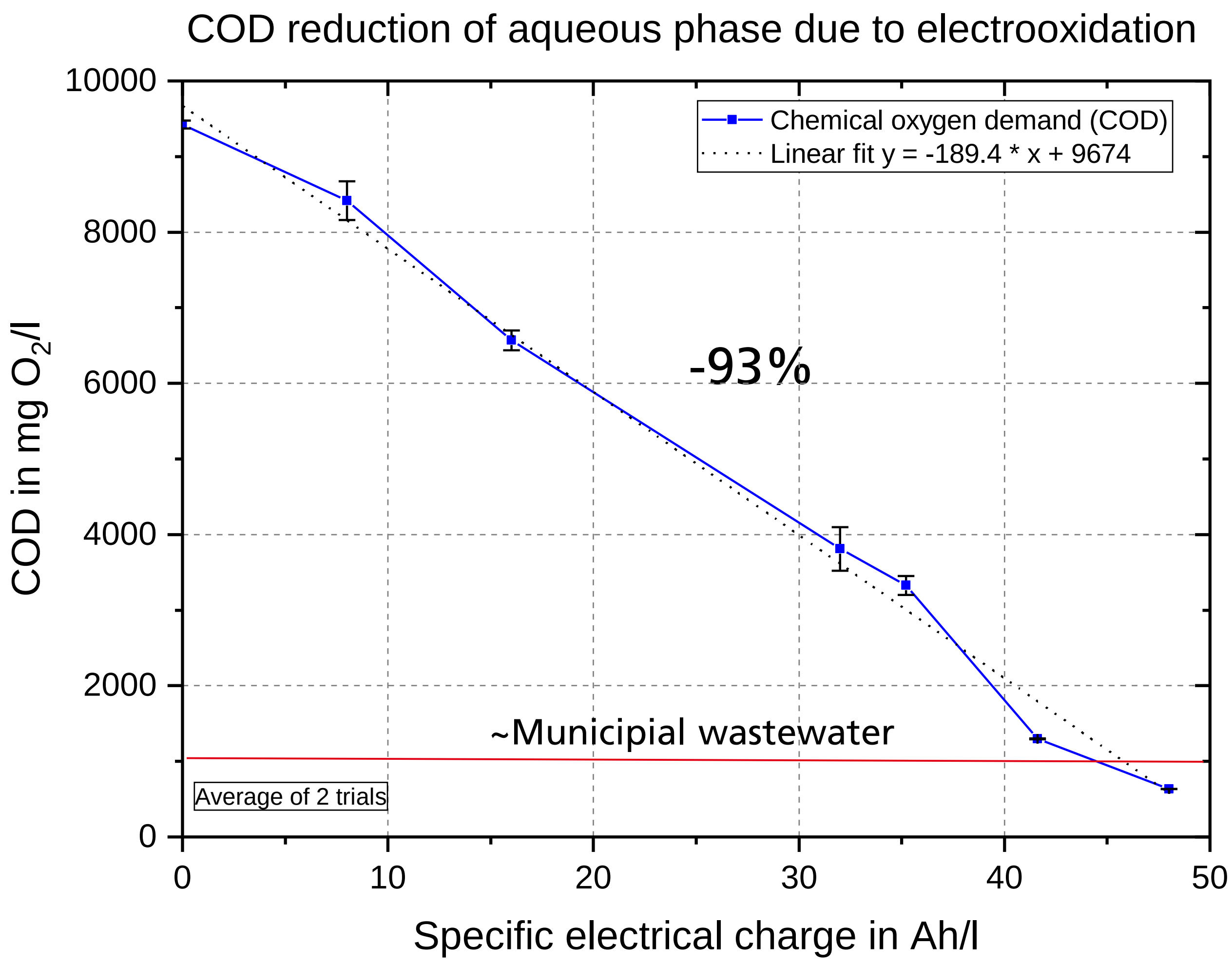
Model TCR® aqueous phase

COD	10.000 mg/l
Added organic compounds	Acetonitrile, Acetic acid, Pyrrole, Pyridine, Phenol

Colour reduction



Treatment duration



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Electrooxidation
Energy efficiency in regards to the COD

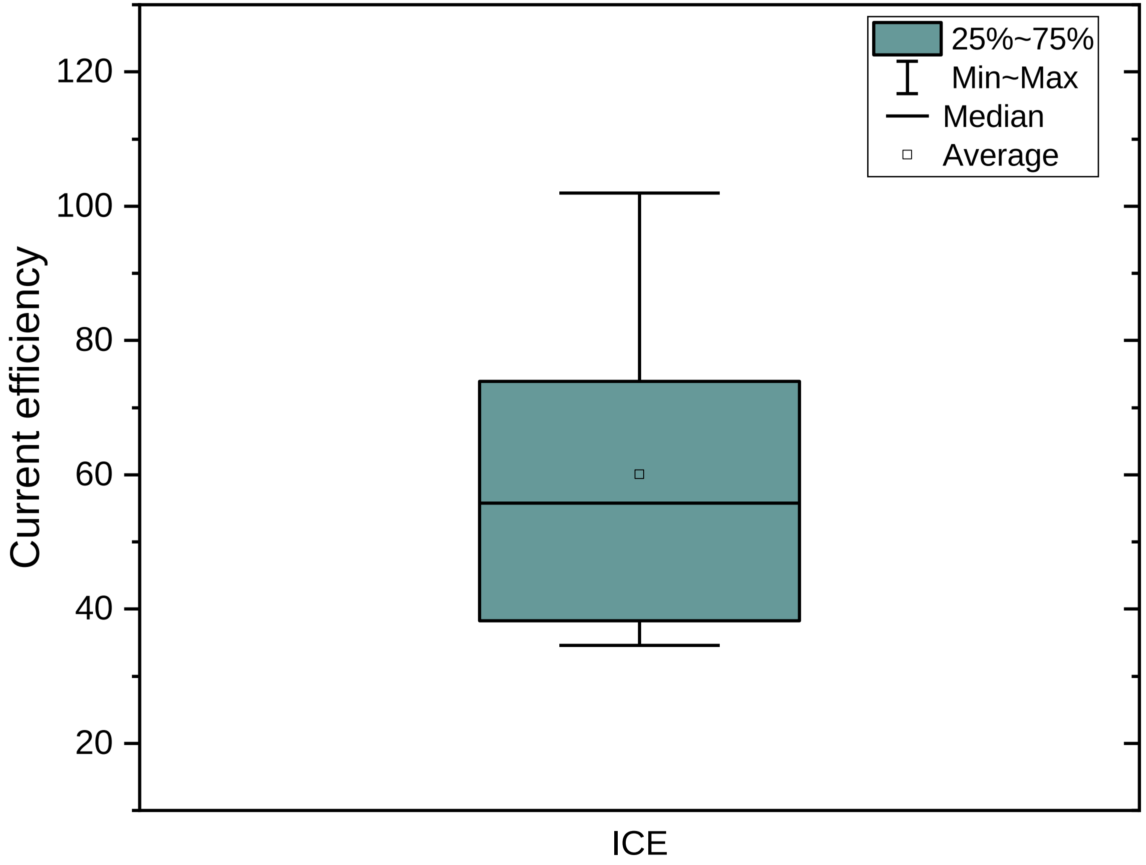
Instantaneous current efficiency (ICE)

$$ICE_{COD} = \frac{FV}{8I}\frac{[(COD)_t - (COD)_{t+\Delta t}]}{\Delta t}$$

Symbols and constants	
Faraday constant	*F*
Volume of electrolyte	*V*
Applied Current	*I*

COD results	
Theoretical maximum spec. COD reduction	0.298 g_{COD}/Ah
Ø Specific COD reduction	0.18 g_{COD}/Ah
Ø ICE	**60 %**

Instantaneous current efficiency



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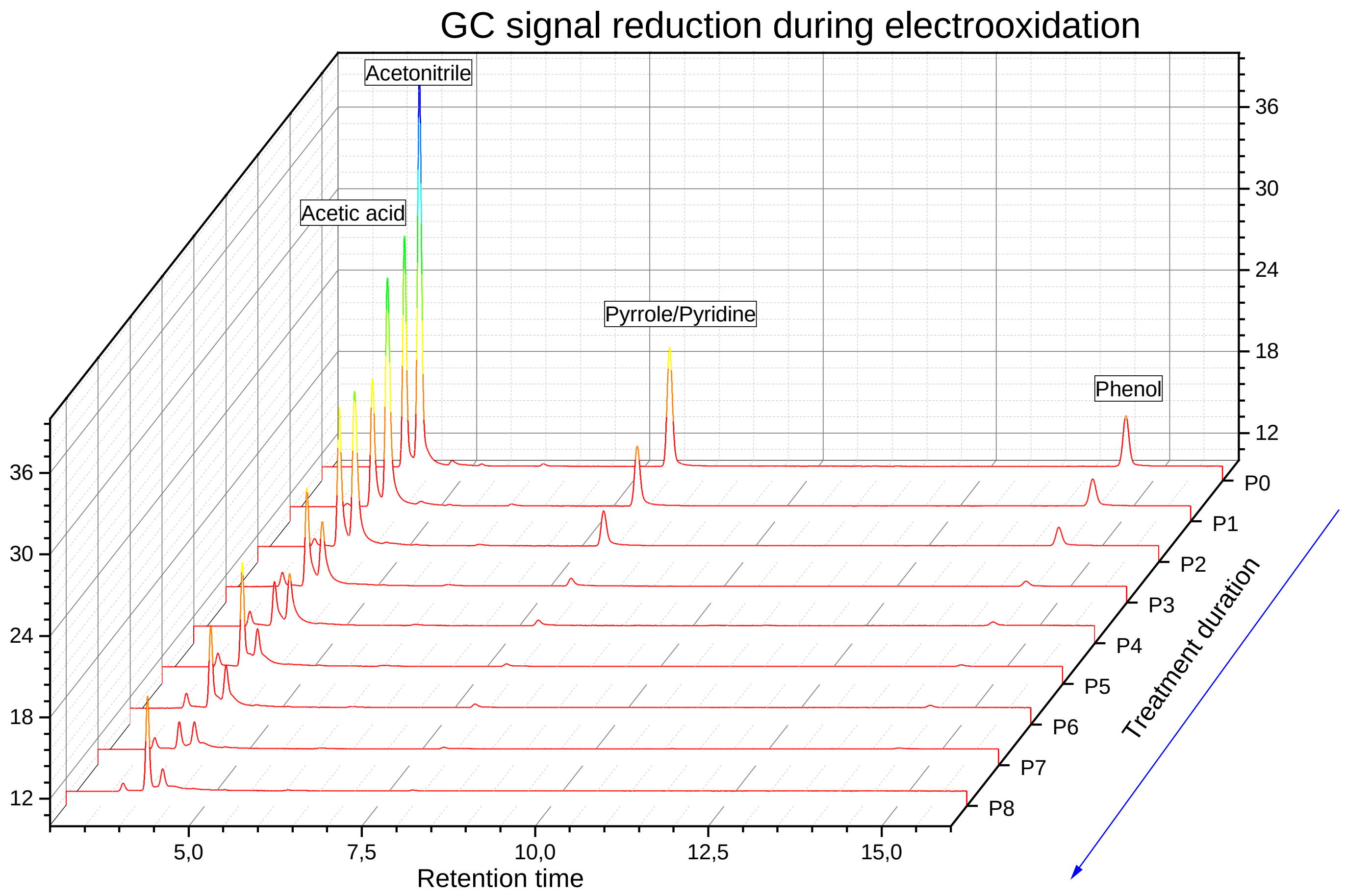
Electrooxidation

Gas chromatography results

Compound	Achieved area reduction
Acetic acid	84%
Acetonitrile	88%
Pyrrole/Pyridine	>98%
Phenol	>96%



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Summary and Conclusion

- Thermo-catalytical reforming of biomass produces an aqueous phase
- In case of sewage sludge it has a low energy content and consists out of ~72 m% H_2O, 6.4 m% C
- About 50 % of this carbon is of organic nature consisting of various organic compounds
- The persistance of some of those compounds make a solemn biological treatment not possible
- Electrooxidation is suitable for reduction of those organic compounds (COD -93%, non-selective)
- The current efficiency for the model aqueous phase was ~ 0.18 g_{COD}/Ah equally to an ICE of 60%

Outlook
Whats next

- Testing of a real TCR® aqueous phase from sewage sludge
- Parameter variation in order to further increase the current efficiency
- Separation tests for evolving hydrogen