Energy recovery from antibiotic-contaminated waste sludge

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- Anaerobic stabilization – an efficient technology to treat organic waste, especially sewage sludge
- Circular economy: use of waste sludge from wastewater treatment plants pre-treated with anaerobic stabilization

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- Antibiotics in the animal sludge inhibit biogas production in anaerobic stabilization
- As non-biodegradable, antibiotic are spreading resistance genes in the environment

Levolofxacin
Amoxicillin
Antibiotics
Tiamulin
Toxicity
Biogas
COD
TOC
Biodegradability
OZONE O_3
Wastewater
Anaerobic stabilization
Biological sludge
Contamination

Antibiotics are mostly poorly biodegradable and pass into the environment unchanged

WWTP

- without decomposition - adsorption on sludge
- metabolites are converted back to the parent molecule
- rivers in the EU, <10 ng L^{-1}, without acute toxicity effects

Animal sludge

- Antibiotics represent 80% of all active ingredients found in animal feces
- animal sludge emissions 25% higher than sewage sludge emissions

Anaerobic stabilization

- inhibitory effect
- Anaerobically stabilized animal sludge: risk of developing antibiotic-resistant bacteria and resistance genes

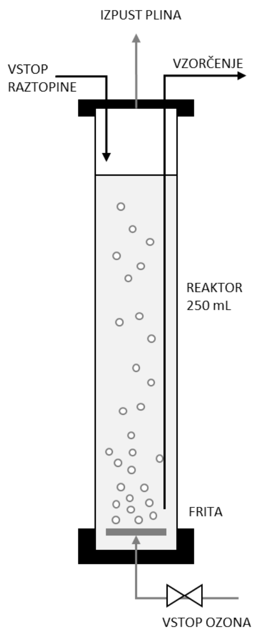
Sludge disposal

- long decomposition time; tetracycline 422 days (-90%)
- fertilization: also present in soil (≈ mg kg^{-1})

development of resistance genes, disturbances of the wider ecosystem

Methods

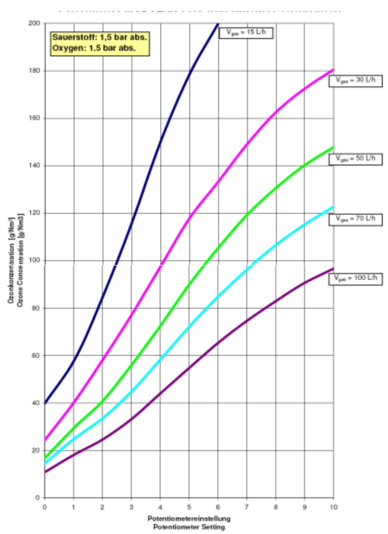
Ozonation system



Semi-batch ozonation

Experiments done

1. Ozonation of sludge
2. Ozonation of contaminated sludge
3. Subsequent measurement of buogas production of non-treated sludge, ozonated, contaminated and contaminated –ozonated sludge



Ozone generation

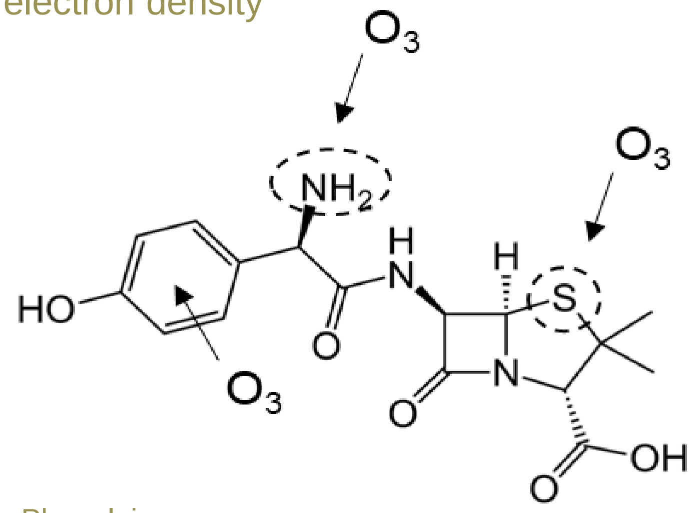
Concetration of ozone in gaseous phase in dependence of generator settings; Xylem Water Solutions GmbH Herford, type OCS Modular 8 HC

Analytical methods

1. COD, TOC, pH, O_3 presence in the solution
2. Molecular structure analysis after ozonation
3. Anaerobic biogas production
4. Toxicity to aerobic sludge

Model antibiotics

Functional groups, susceptible for ozone attack due to electron density

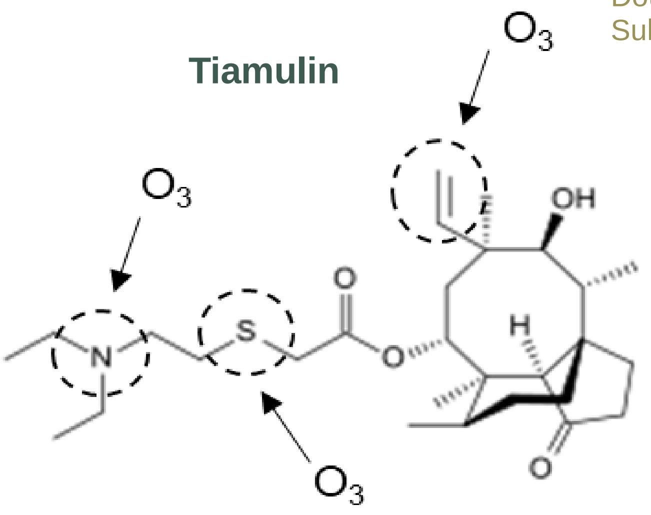


Phenol ring,
-NH2 group
Sulphur atom

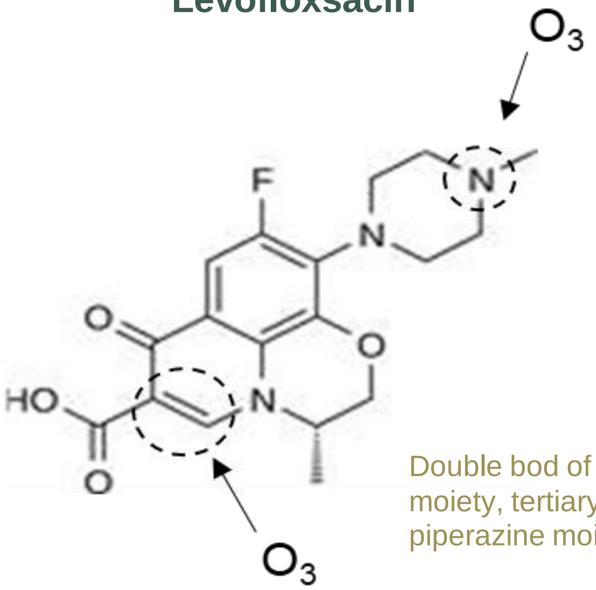
Amoxicilin

Tiamulin

Double bond
Sulphur and nitrogen atom



Levofloxsacin



Double bod of quinolone moiety, tertiary amine of piperazine moiety

100 % ← biodegradability → 0 %

Antibiotics are **mostly environmentally persistent molecules, with low biodegradability**, therefore conventional biological treatment is not sufficient

Aerobic conditions, water solutions of antibiotics

Tiamulin

- Has a low biodegradability (**17 % in 41 days at 400 mg L^{-1}** and **40 % in 41 days at 100 mg L^{-1}**)
- Measured at non-toxic concentration; 30min EC50 : 691 ± 261 mg L^{-1}

Levofloksacin

- Is non-biodegradable (**8 % in 41 days at 100 mg L^{-1}**), structure of the molecule does not have weak points to allow for hydrolysis
- Measured at non-toxic concentration; 30min EC50 : 1.115 ± 298 mg L^{-1}

Amoksicilin

- Is biodegradable (**100 % in 41 days at 100 mg L^{-1}**), β-lactam ring, able to hydrolyze
- Measured at non-toxic concentration; 30min EC50 : 1.026 ± 276 mg L^{-1}.

Use of animal sludge, pre-treated with anaerobic stabilization

- **Inhibitory effect on anaerobic digestion;** tertacyclines and sulfonamides up to -93% (Spielmeyer et al. 2018).
- Anaerobic stabilized sludge - **presence of resistance genes.**
- Ozonation - **skip the level of hydrolysis, improve biogas production**.

BIODEGRADATION IS INHIBITED – molecules are passing biological treatment unchanged and /or biogas production is inhibited

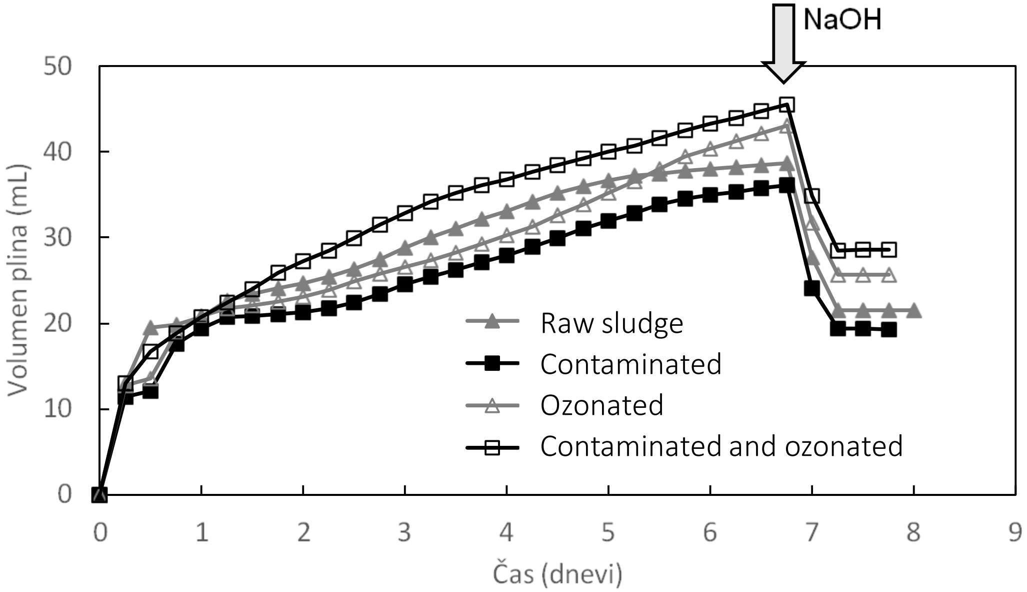
Anaerobic conditions

400 mg L^{-1}, inhibitions of biogas production:

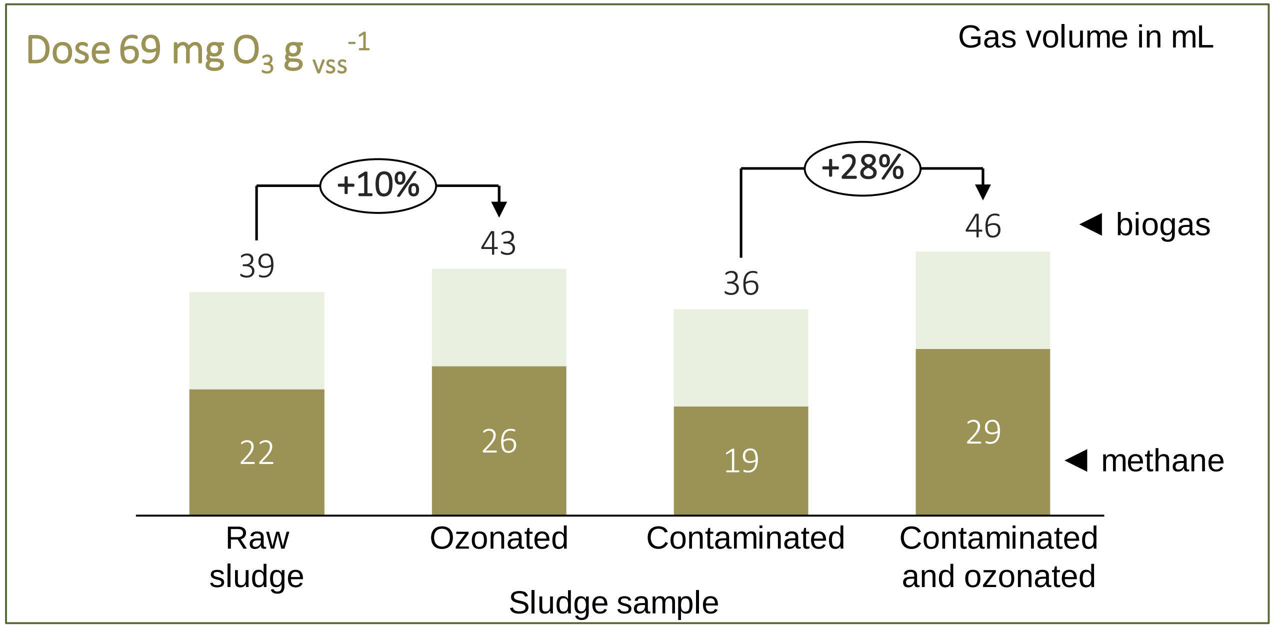
- tiamulin 8 % (14 % CH_4)
- levofloxacin 27 % (44 % CH_4)
- amoxicillin 30 % (45 % CH_4)

TIAMULIN

Ozonation of contaminated sludge



Biogas production for a raw sludge and ozonated sludge, sludge contaminated with 400 mg L^{-1} tiamulin and ozonated contaminated sludge, dose 69 mg O_3 g_{vss}^{-1}



The impact of single step ozonation of antibiotics-contaminated waste sludge to biogas production. Chemosphere. 2021, 271, 1-8.

Ozone a… antibioti… and sludge. *Ozone: science & engineering*. 2020, 42 (2), 128-135.

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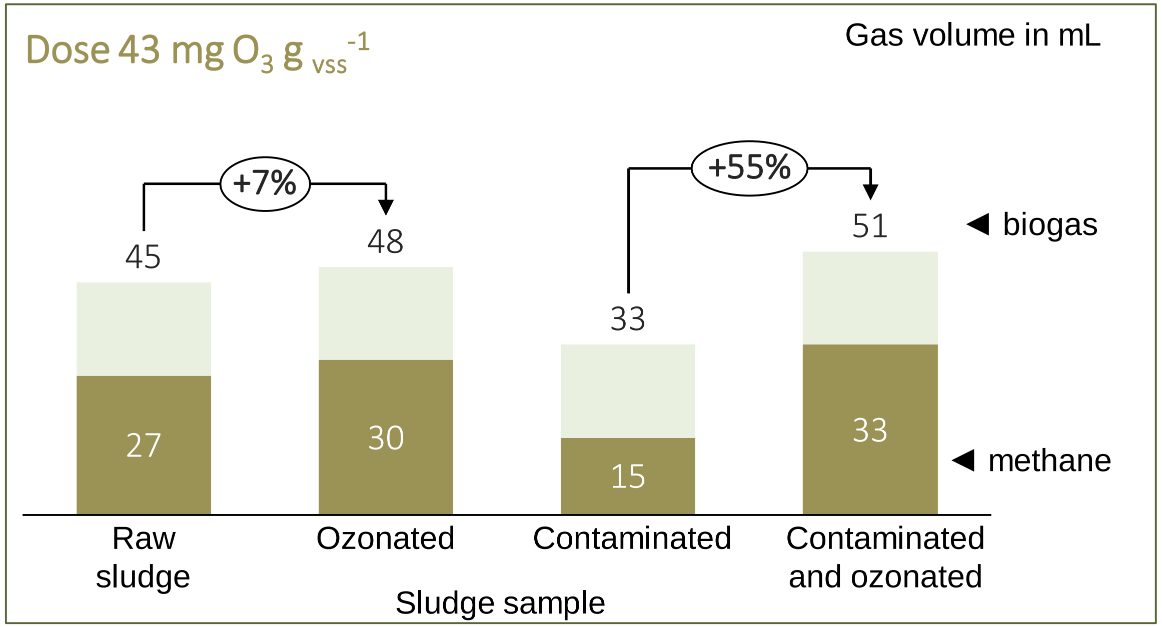
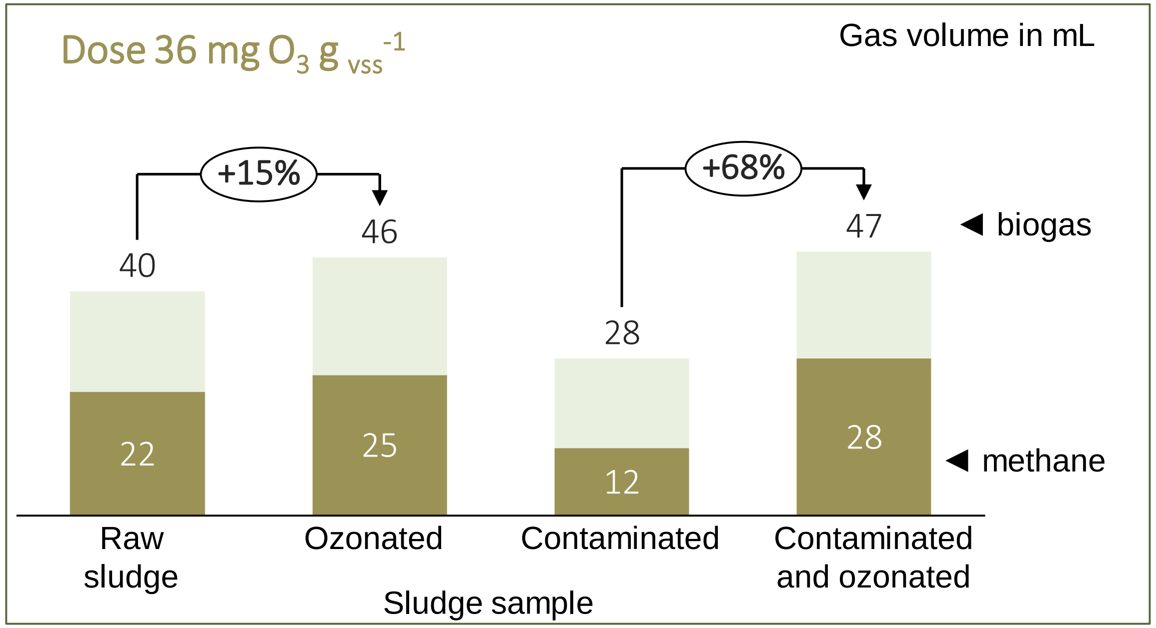
LEVOFLOXACIN in AMOXICILLIN

Ozonation of contaminated sludge





Levofloxacin

Amoxicillin

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Ozone as an element of circular economy: gaining energy from bio-waste, while eliminating spread of antibiotics contamination

- **Ozonation might be a key technique of circular economy** when gaining energy from waste sludge, while simultaneously considering broader environmental sustainability.

- In case of antibiotics contaminated sludge (400 mg L^{-1}), ozonation (dose of 36 mg O3 g vss^{-1}) **not only eliminates any inhibition of biogas production, but also enhances biogas production (by 68%).**

- Gained excess biogas however does not compensate for cost of ozone used.

- In terms of sustainability it is important, **that ozonation eliminates the spread of antibiotic resistance genes in the environment,** when anaerobically stabilized sludge is applied to agriculture soils.