Bern University of Applied Sciences
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Quantification of methane emissions from wastewater treatment plants

Open-path concentration measurements in combination with an inverse dispersion technique with a backward Lagrangian Stochastic model to quantify methane emissions from a wastewater treatment plant

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06.05.2020 EGU2020: Sharing Geoscience Online

Introduction

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Inverse dispersion technique provides a promising tool for measurements under real world conditions.

Widely used in Canada and the US for emission measurements from whole farms (Flesch et al., 2009; Flesch et al., 2005; VanderZaag et al., 2014) and animal production buildings (Harper et al., 2010).

Inverse dispersion technique is not frequently used in Europe for emission measurements but e.g. for biogas plants (Reinelt et al., 2017).

So far, no published studies to quantification of methane emissions with inverse dispersion technique of wastewater treatment plants (WWTPs) are available.

Inverse dispersion technique for gaseous emissions

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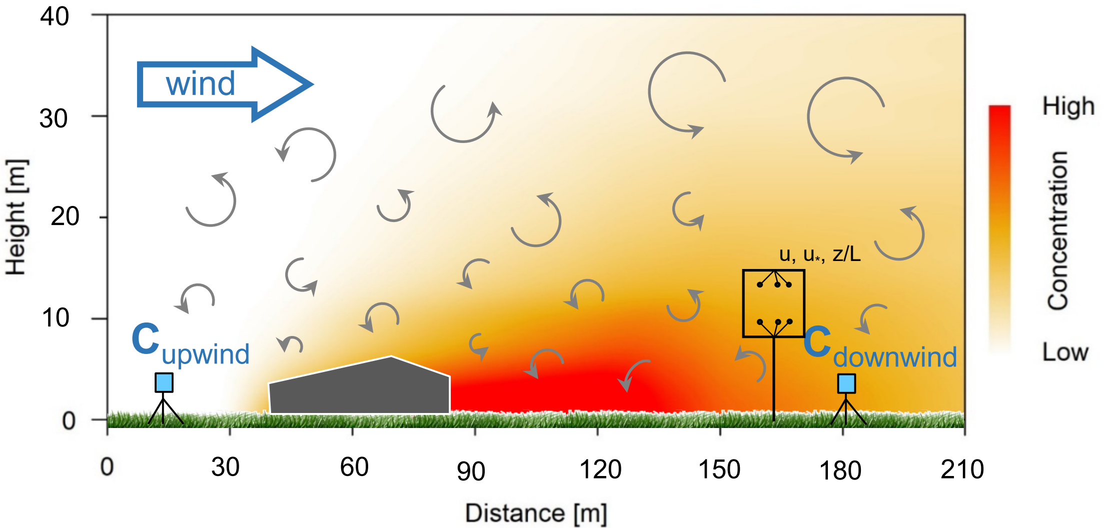
Requires a spatially limited source area of known extension e.g. WWTP, biogas plant, animal housing

Measurement of

- turbulence characteristics ($u, u_*, z/L$) with sonic anemometer
- concentrations up- and downwind of the source

Emission flux:

$$Q = \frac{C_{\text{downwind}} - C_{\text{upwind}}}{D}$$



The "dispersion factor" $D = \Delta C/Q$ is determined by backward Lagrangian Stochastic (bLS) modelling as function of the turbulence parameters and the source/sensor geometry

backward Lagrangian stochastic (bLS) model

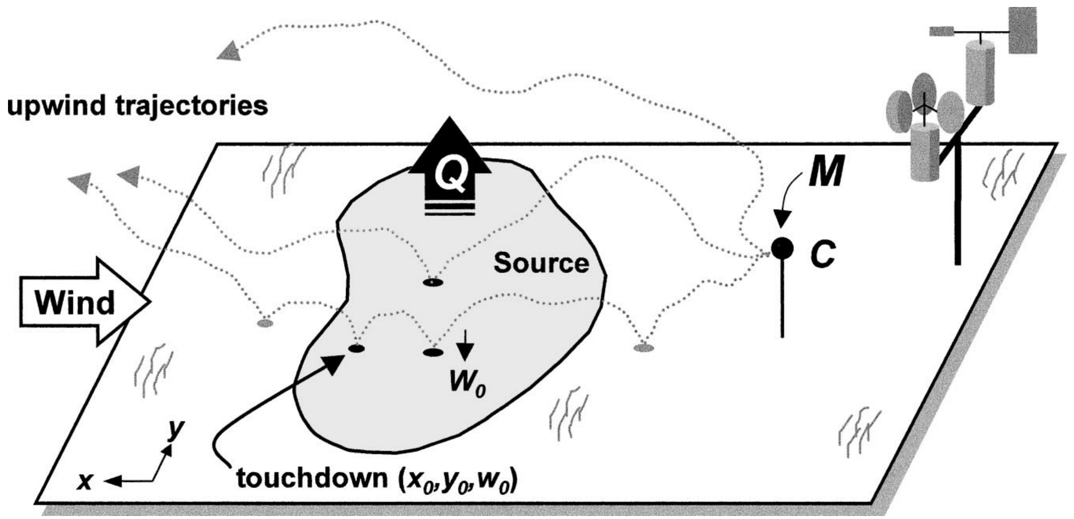
Surface layer model for distances < 1000 m, based on Flesch et al. (2004)

Calculates from the total of backward trajectories the ratio of the concentration (*C*) to the emission rate (*Q*) at the sensor **M**

With the modelled $(C/Q)_{sim}$ values and the measured concentration downwind (C_{DW}) and upwind (C_{UW}) of the source the emission rate *Q* can be calculated:

$$Q = \frac{C_{\text{downwind}} - C_{\text{upwind}}}{(C/Q)_{sim}}$$

Instead of point sensors as shown in the plot from Flesch et al., 2004, we used line integrated devices.



Source: Flesch et al., 2004

Requirements for measuring site

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Stability criteria (Monin-Obukhov similarity theory)

Flat surface

Homogeneous surface

- No major obstacles in the close surroundings (~400 m) around the source that could influence turbulence and wind direction

Enough space to set up line integrated devices

- path length 50 – 250 m depending on setting

Enough distance between sensors and source (~10 times building height of the source)

No additional sources of the same gas species nearby, especially upwind of the WWTP

Measuring period and used devices

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Measuring period

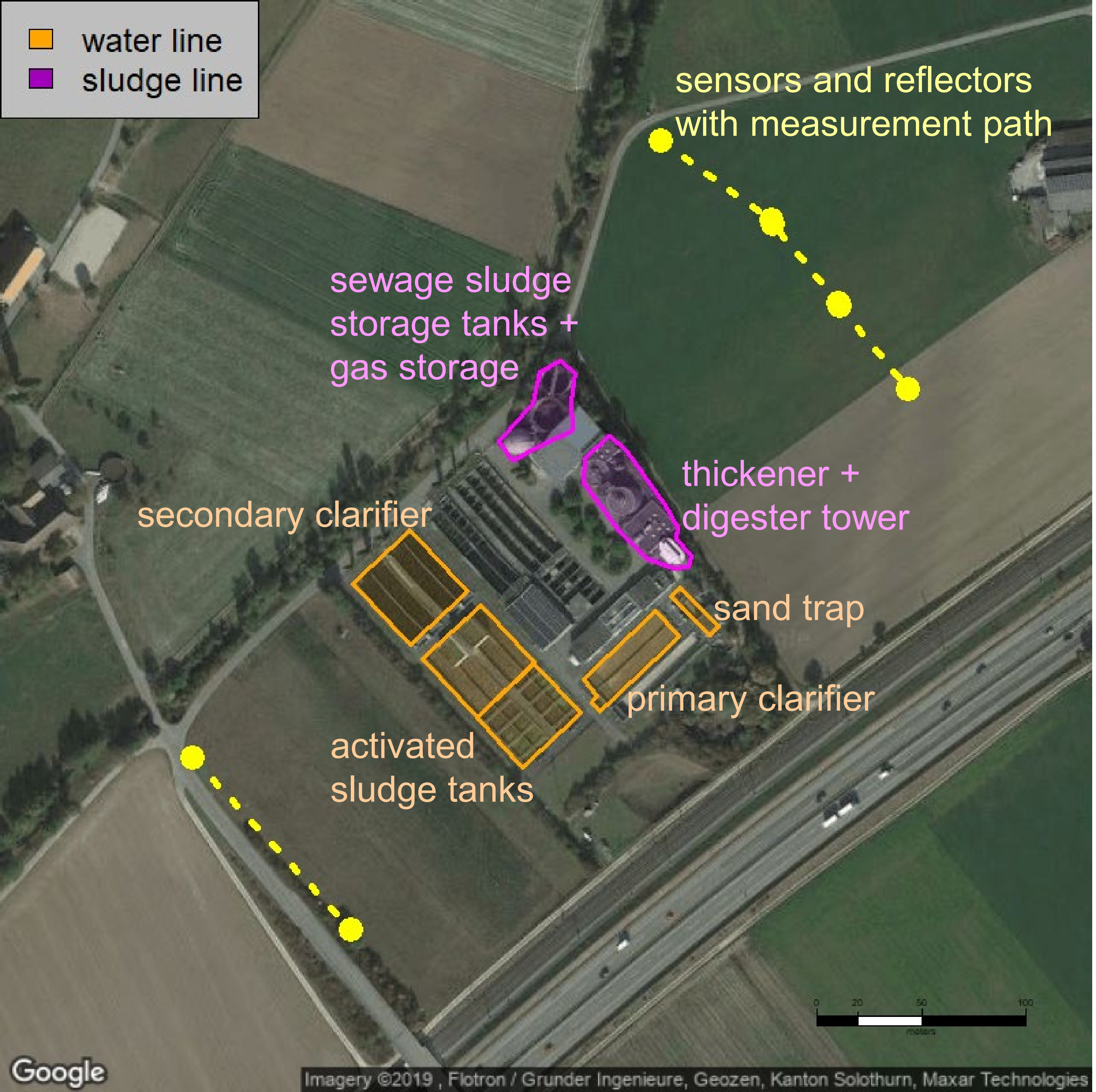
23.09.2019 – 14.10.2019

Our measuring devices

4 Open-path tunable diode laser spectrometers (GasFinder3.0, Boreal Laser, Inc., Edmonton, Alberta, Canada)

2 WindMaster Sonic 3D Anemometer (Gill Instruments, UK)

1 Weather stations OTT WS700 (OTT Hydromet GmbH, Germany)



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Placement of devices to determine methane emissions

- In orange and magenta are the source areas used to determine the methane emissions of the WWTP.
- Yellow dots indicate sensor and reflectors of the GasFinders and dotted lines the measuring path of the GasFinder

The sensors in the north-east were combined to one larger/longer sensor

WWTP: treatment capacity of 35'000 population equivalents; conventional activated sludge system with anaerobic digestion of sludge and on site storage of the liquid sewage sludge

Weighting of sources within the WWTP

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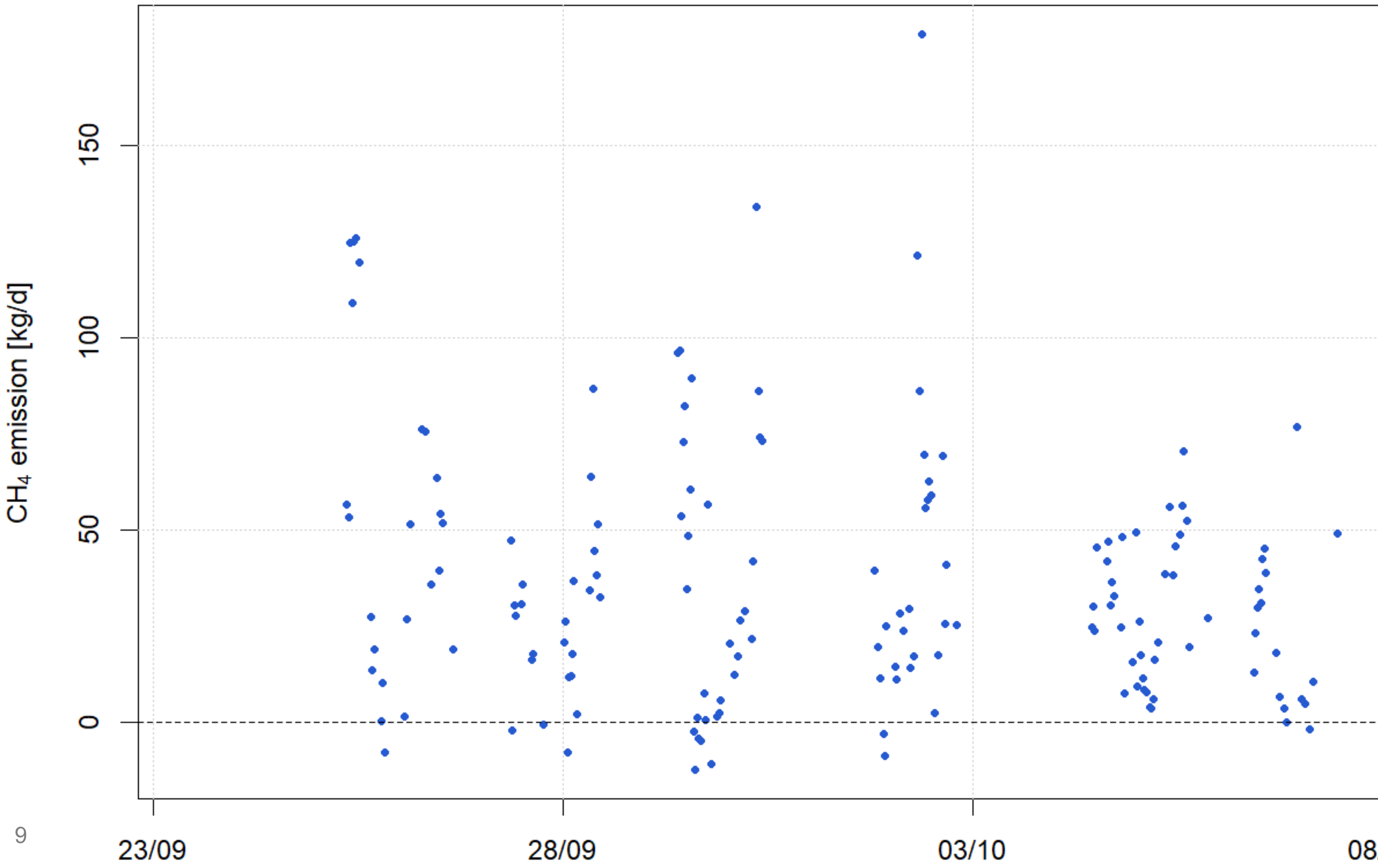
As emissions are not homogeneously spread over the WWTP the individual sources needed to be weighted to each other.

This was done based on available literature data.

Source	**Relative weights**
Sand trap	0.22
Primary clarifier	0.08
Activated sludge tanks	0.14
Secondary clarifier	0.06
Thickener + digester tower	0.74
Sewage sludge storage tanks + gas storage	1.00
Water line	*0.29*
Sludge line	*1.00*

Time series with filtered 30 min emission intervals



- Data gaps are due to applied filtering (u*, L, z0, etc. (not shown in this presentation))
- Negative emissions are due to low concentration differences between the up- and downwind concentration measurements

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Boxplot and diurnal cycle of CH_4 emissions

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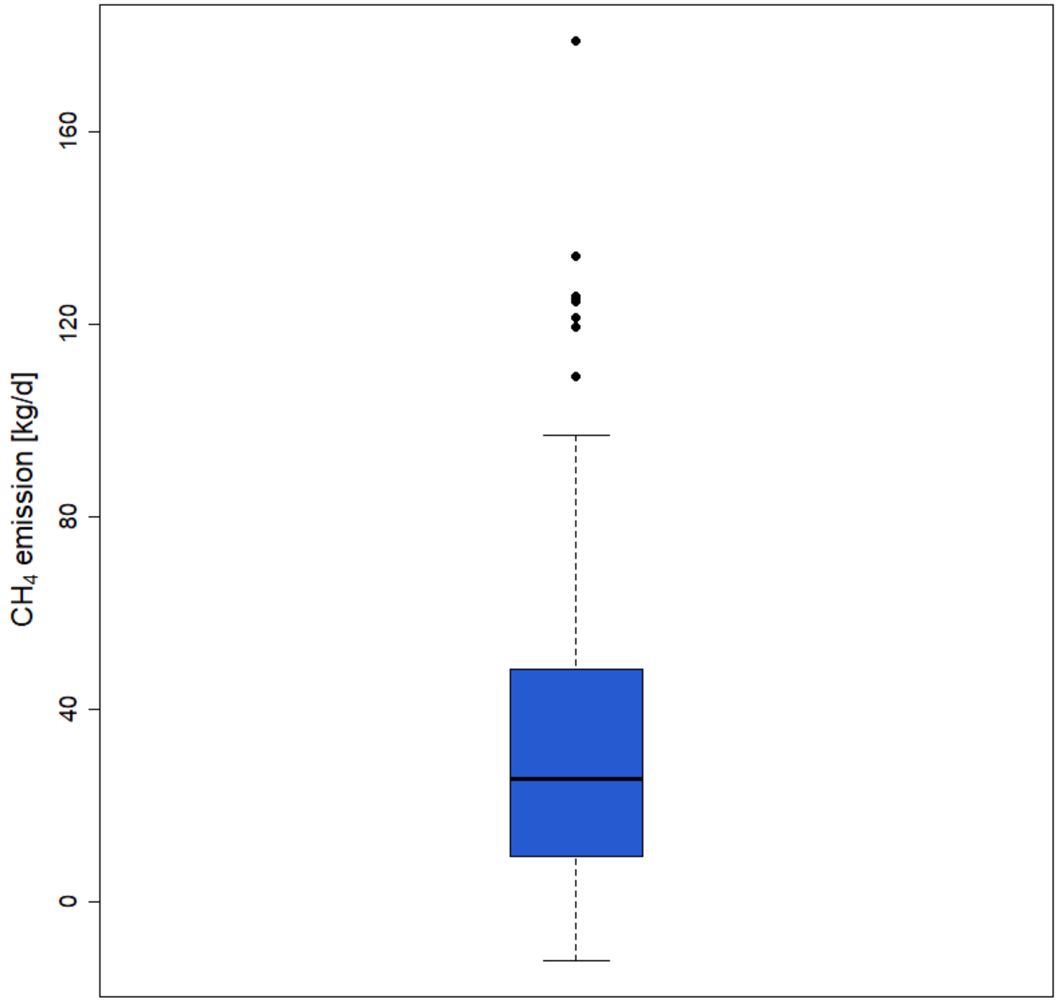

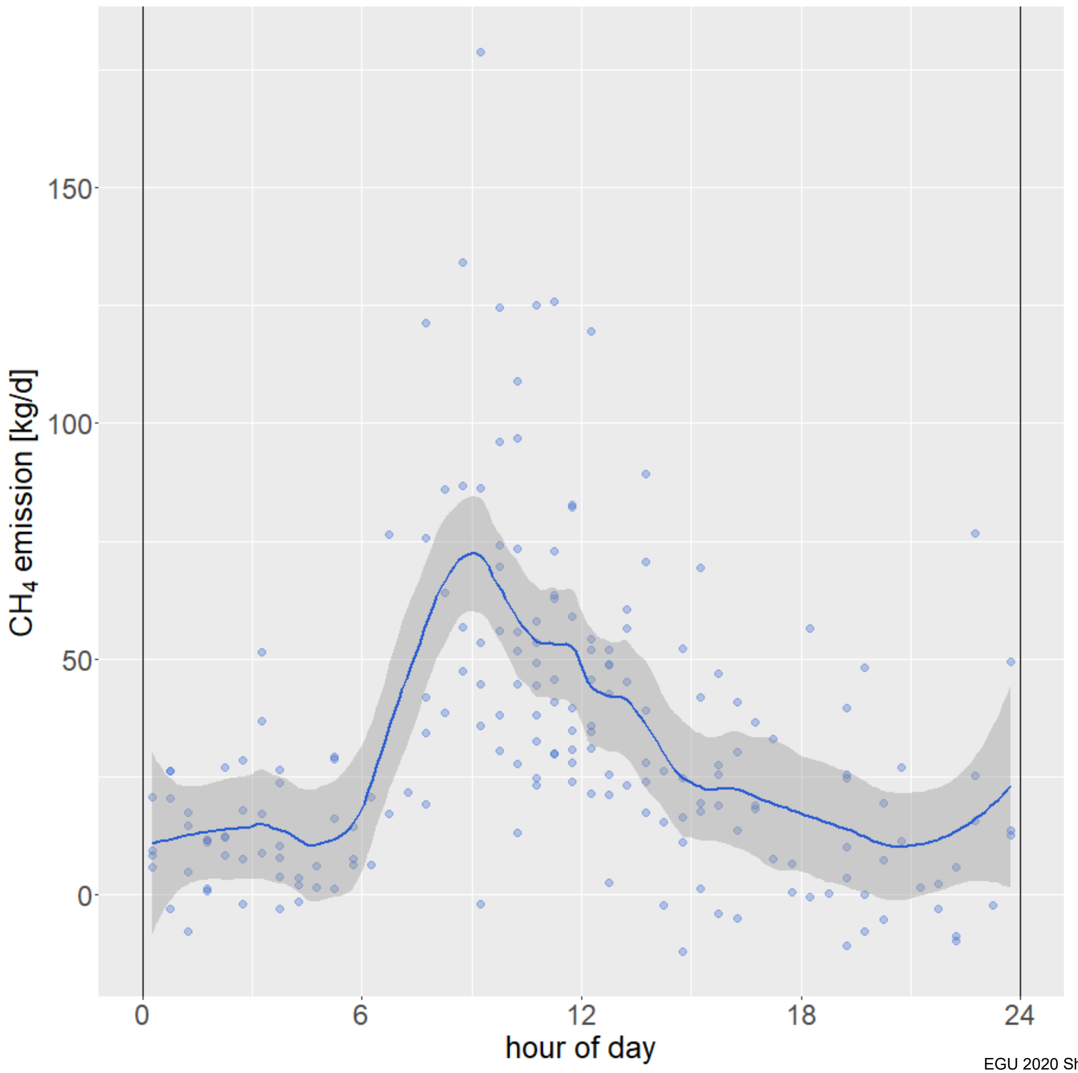

Comparison with literature data

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Boxplot summary [kg CH_4/d]	
N intervals	*194*
Min.	-12.1
1st Qu.	9.7
Median	25.5
Mean	32.6
3rd Qu.	48.0
Max.	178.8

	This study	Data literature	This study	Data literature
	WWTP CH_4 (g PE^{-1} y^{-1})		WWTP CH_4 % COD in influent	
N	-	13	-	12
Avg	266	428	0.8%	0.9%
Med	-	310	-	0.9%
Min	-	140	-	0.3%
Max	-	1339	-	1.7%

Emission factors derived from a literature data and generated within the measurements scaled to PE (Population Equivalent) and COD (Chemical Oxygen Demand). The literature data are mainly based on Samuelsson et al., 2018 and Delre et al., 2017 which conducted measurements based on the release of tracer.

Conclusion

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For the first time, CH_4 emission values from wastewater treatment plants were generated with an inverse dispersion technique.

The emissions are in the range of previously published literature values based on tracer method.

There is a diurnal cycle in the emissions at this wastewater treatment plant.

At the moment we are looking into processes that might be responsible for the diurnal cycle which require further in–depth data-analyses.

We are planning to conduct measurements at another WWTP.

Literature + Acknowledgment

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This project is funded by the Swiss Federal Office for the Environment (Contract 06.0091.PZ / R281-0748)