Photoacoustic spectroscopy based nitrous oxide measurement for field application

Csilla Gombi[1*], Anna Szabó[1,2], Csaba Király[1], Vineet Srivastava[1,3], László Horváth[1,2], Edit Mikó[3], Gábor Szabó[1], Zoltán Bozóki[1,2]

University of Szeged
Institute of Physics

[1]Department of Optics and Quantum Electronics, University of Szeged, Szeged, H-6720, Hungary
[2]HUN-REN-SZTE Research Group for Photoacoustic Monitoring of Environmental Processes, H-6720, Hungary
[3]Faculty of Agriculture, University of Szeged, Andrássy út 15., H-6800 Hódmezővásárhely, Hungary

*corresponding author e-mail: **gombi.csilla@szte.hu**

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Introduction

Nitrogenous molecules are released from fertilisers and from animal manure. The first step to reduce emission is monitoring.
For the monitoring we need:

- Reliable system
- Ppb level detection
- Selective measurement

Monitoring instruments have to meet highly challenging requirements, either their accuracy and time resolution is not sufficient, or they require frequent maintenance, which cannot be provided at most environmental monitoring sites. Laser spectroscopy based instruments can be promising tools.

Experimental setup

The presented system is based on photoacoustic (PA) spectroscopy, which is a subclass of optical absorption spectroscopy, and it is based on the conversion of absorbed light energy into acoustic waves.
The main parts of the system are:

- Quantum cascade laser (7.72 µm, 70 mW)
- Longitudinal PA cell with detecting microphone
- Gas handling:
  - PTFE tubes
  - pump suction ~200 sccm

Minimum detectable concentration of 9 ppb with an averaging time of 10 seconds (3σ).

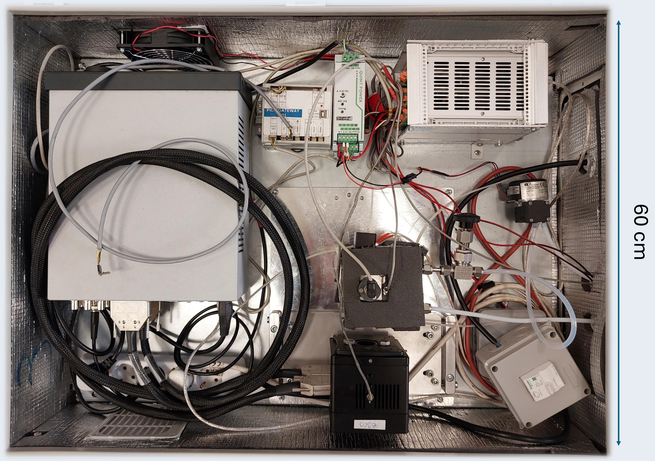

Figure 1. Presented system

Acknowledgement

The work was supported by the Sustainable Development and Technologies National Programme of the Hungarian Academy of Sciences (FFT NP FTA).

Cross-sensitivity study

Components that are possible in field or barn applications were checked in HITRAN database.

After considering the possible concentration of the components, it was concluded that only water vapour and methane can cause problems. Laboratory tests were taken for these two components (Fig. 2.).

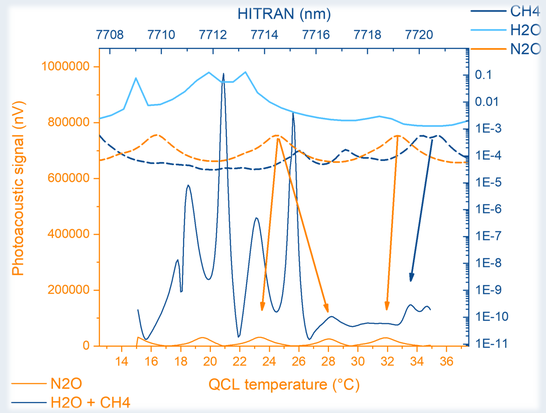

Figure 2. Comparison of measured- and HITRAN database spectra

Test measurement

A one-day test measurement was performed in a naturally ventilated free-stall dairy barn.

During the test

- Continuous measurements of N2O were performed at 6 sampling points
  - 2 background points outside of the stall
  - 4 points inside the stall, different distances from the animals

Spectral scans were also performed to check cross sensitivities (Fig. 6).

Figure 3. Naturally ventilated free-stall dairy barn

Figure 4. Field experiment setup

Results

At the background spots the measured concentration was 388 ppb ± 11 ppb, and inside the barn it was 499 ppb ± 191 ppb.

During the test measurement we found that the methane concentration was higher than expected, and an absorption line slightly overlaps with the N2O line.
A calibration for methane could solve this problem, but in the future, it be more effective to switch to another absorption line.

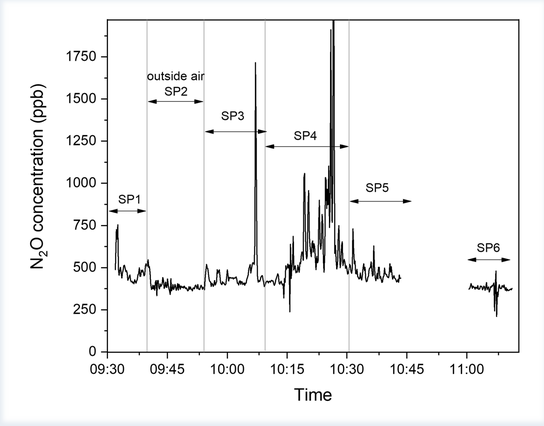

Figure 5. Measured N_2O concentration on different sampling point (SP)

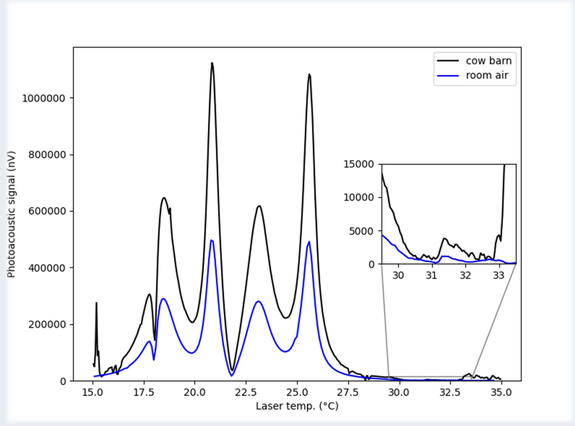

Figure 6. Investigation of spectral interferences. Spectra of cow barn (black line) and of room air (blue line)