Efficient N_2O monitoring in wastewater treatment plants

GAS SENSORS – Sewage treatment plants can emit significant amounts of greenhouse gases. Emissions of methane (CH_4) and nitrous oxide (N_2O) are often the most important sources of greenhouse gases. CH_4 is mainly emitted through leaks, while N_2O is produced during biological treatment.

N_2O emissions usually fluctuate greatly from day to day and season to season. Therefore, continuous online monitoring concepts are required to record the emissions and implement reduction strategies. The use of NDIR gas sensors of the type INFRA.sens from Wi.Tec-Sensorik GmbH has been successfully tested for this application and was able to meet all requirements.

The monitoring system

The monitoring system consists of floating gas hoods for taking exhaust gas samples, which are equipped with a flow meter (Figure 01), and a central monitoring unit for measuring the concentration of the individual greenhouse gases (Figure 02). The total emission is calculated on the basis of the gas analysis and the volume flows and is used for balancing.

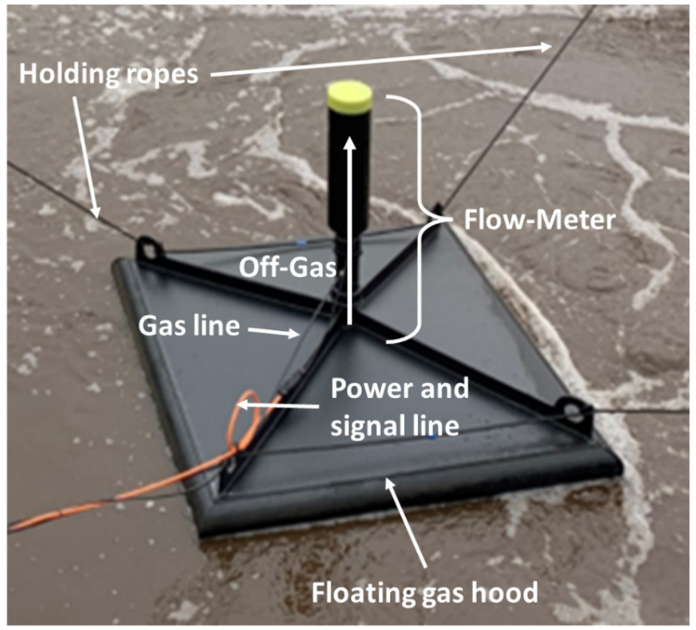
For the concentration measurement, an NDIR gas analyzer is used for several sampling points. A fast response time, multi-component analysis and low drift are important features of the sensor used. The N_2O concentrations are normally between 0 and 300 ppm. However, during the high-emission phases, concentrations of up to 3,000 ppm can be detected. A fully automated multiplexing system with three-way valves connected to up to 14 exhaust hoods enables high spatial resolution and automatic calibration of the system. The central monitoring station is equipped with gas conditioning to protect the gas sensors. Continuous purging of the sample lines enables short measurement intervals (< 1 min).

gas sensor technology

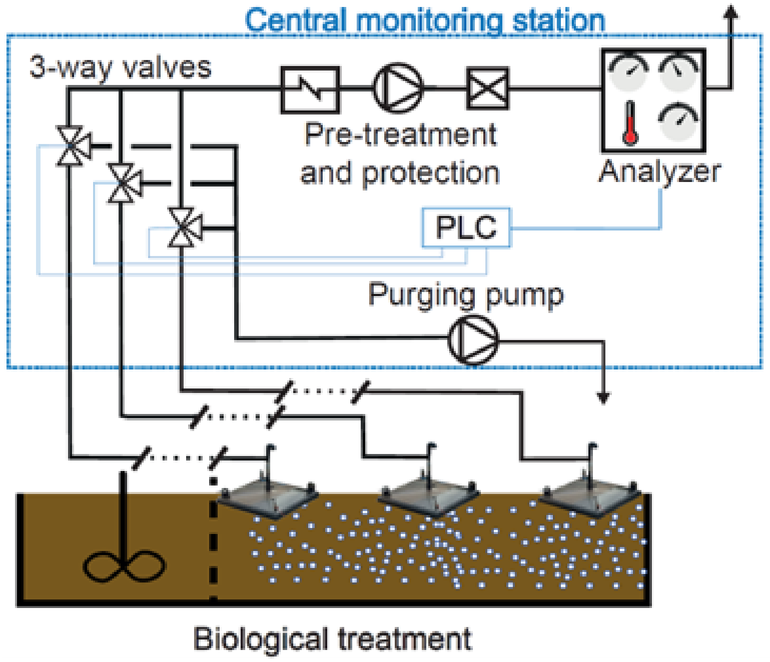
The gas analysis is carried out using NDIR technology (INFRA.sens) in the spectral range of 3–5 µm. The INFRA.sens uses the absorption bands for methane at 3.4 µm, for carbon dioxide at 4.3 µm and for nitrous oxide at 4.5 µm. The radiation source is a black-body emitter (IR source) that can be electrically modulated in the frequency range of 1–10 Hz. To achieve the highest possible resolution, a 250 mm long sample cell is used, which is coated with a special gold layer. The gold layer has a high reflectivity and leads to a high signal level on the detector side. The IR detector is located on the opposite side and consists of 4 elements. Interference filters are used to filter out the gas-specific spectral components for the respective detectors. The interference filters have a very narrow bandwidth and an efficient blocking degree. This results in very high selectivity and negligible cross-sensitivity to other gas components. A reference measurement in a spectral range without absorption ensures long-term stable measurement results.

All signal processing is performed in an electronic evaluation unit (base board) located below the optical bench. Data transfer is via an RS232 interface. CAN interface and MODBUS (option) are also available.

The sample cell is thermostatted to 50 °C to prevent condensation inside the sample cell. Since the emitter and the detector are also heated by this thermostat, the temperature error of these components is also eliminated. The entire structure is integrated into a sheet metal housing that is insulated from the inside to shield against external temperature influences. The gas analyzer is specified for an ambient temperature of 5–45°C. The warm-up time is less than 45 minutes.



01 Exhaust gas collection and flow measurements at a large-scale wastewater treatment plant (Gruber, 2021)



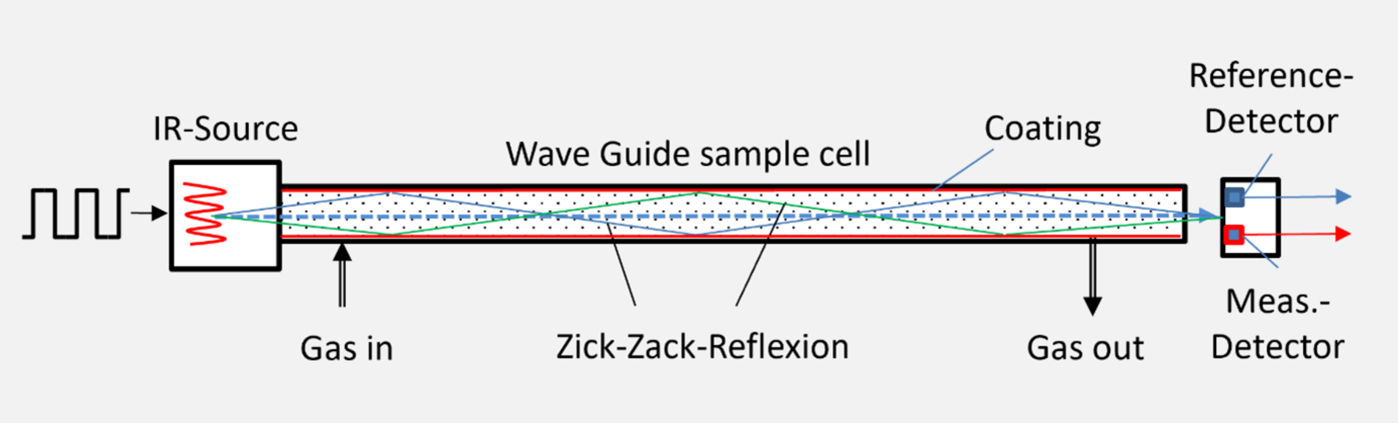
02 Complete measuring system (Gruber 2021)

Oxygen measurement

In addition, this design includes an electrochemical (EC) oxygen sensor (galvanic fuel cell) to measure the oxygen concentration in the gas mixture as O_2. The O2.sens has a measuring range of 0 - 100 vol.% O_2 and is very selective for oxygen, even in the presence of other gases in high concentrations. Compared to physical gas sensors, the lifetime of electrochemical gas sensors is limited due to the chemical reactions in the sensor. The lifetime is measured in vol.%-h. The typical sensor lifetime is > 500 000 vol.%-h. In the presence of 10 - 20 vol.% oxygen, the calculated lifetime is approx. 3 - 6 years. The O2.sens can communicate with the INFRA.sens electronics (baseboard) via an I2C interface. Compared to standard millivolt data transmission, the I2C interface is very robust and less sensitive to electromagnetic interference (EMI).

Measurements in a wastewater treatment plant

The strong seasonal and daytime fluctuations of N_2O emissions were determined in a one-year measurement phase in a wastewater treatment plant and are shown in Figure 06. The short-term dynamics are strongly influen-

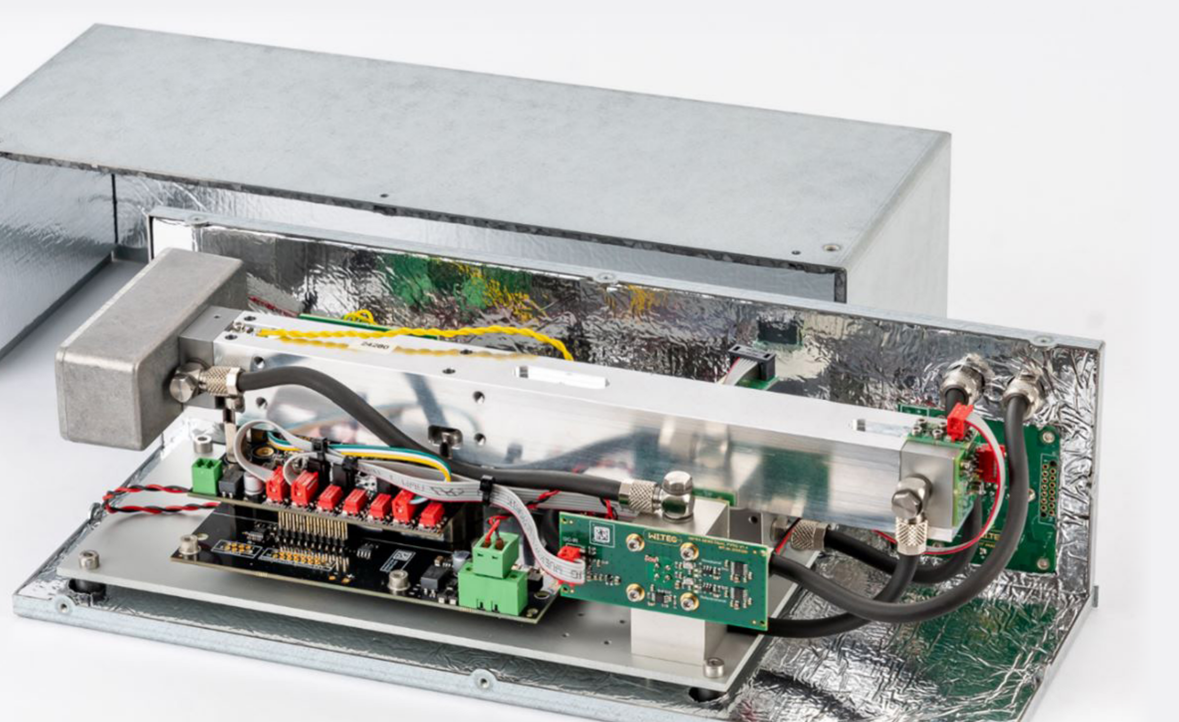


03 **Basic structure of the INFRA.sens gas sensor module**

ced by rain events, which are characterized by temperature drops. Typically, rain events significantly reduce N_2O emissions due to the dilution of the wastewater. Emissions reach their maximum during the sharp temperature rise of the wastewater between spring and summer. The maximum concentration in this plant was 350 ppm N_2O. The phase of maximum emissions can be associated with a change in the composition of the microbial community, which has a strong effect on the accumulation of nitrogen compounds that lead to N_2O formation. The mitigation strategies in this plant mainly include reducing the airflow in the biological treatment and optimizing denitrification. Thanks to measurement-based monitoring and control, significant energy savings have been achieved by monitoring oxygen transfer and adjusting the aeration system and strategy accordingly.

Precise N_2O monitoring

N_2O is an important source of greenhouse gases from wastewater treatment. Due to the significant spatial and temporal variations in emissions, long-term online monitoring approaches with a high spatial resolution are required for emission quantification and mitigation strategies. The system is based on an accurate multi-channel NDIR gas analyzer (INFRA.sens), which has been integrated into a fully automated monitoring system. The stability and accuracy of the NDIR technology used has been impressively demonstrated in various measurement series. Continuous use over a maintenance period of several months/years is thus possible without any problems. It is expected that in the future, WWTPs will monitor N_2O emissions to reduce their carbon footprint (NetZero) and promote the full potential of exhaust gas monitoring systems for energy conservation.



04 **INFRA.sens modules (CH_4, CO_2, N_2O and O_2) integrated into a steel plate casing (thermobox) with thermostat (50 °C)**

05 **Electrochemical oxygen gas sensor (O2.sens) integrated into an INFRA.sens module**

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Images: *Wi.Tec-Sensorik GmbH*

www.witec-sensorik.com

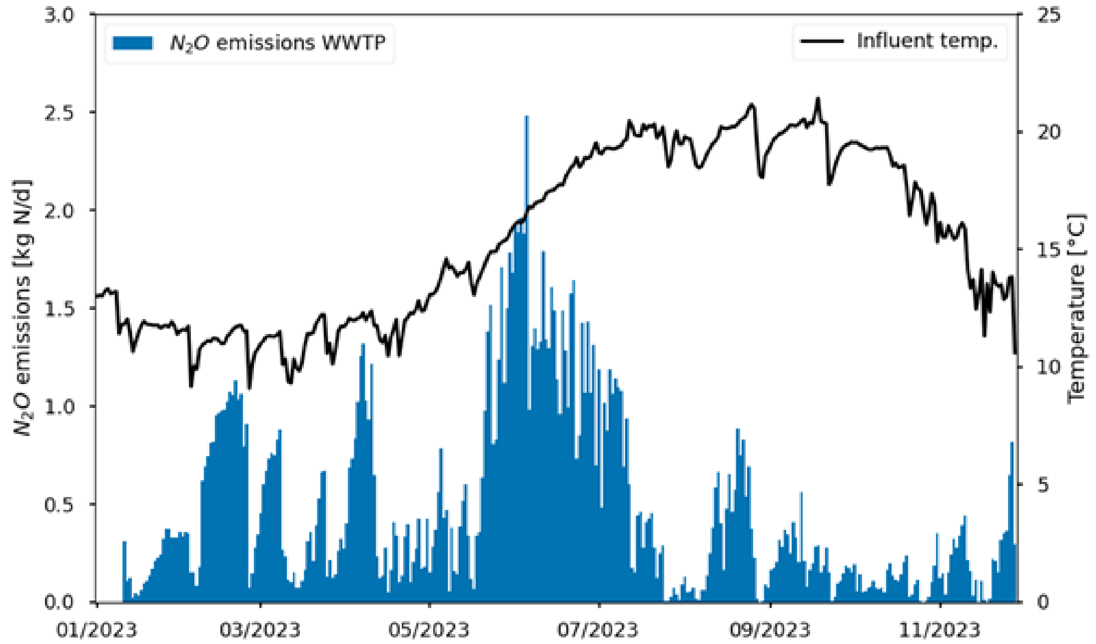
Recommended reading:

Wiegleb, G.: Gas Measurement Technology in Theory and Practice, Springer publishing house, Wiesbaden 2023

Gruber, W.: Long-term N_2O emission monitoring in biological wastewater treatment: methods, applications and relevance, Dissertation in Institute for Environmental Engineering. 2021, ETH Zürich: Zürich. p. 292.

Gruber, W., Wiegleb, G., Piasny M.: Measurement of greenhouse gases (CH_4, N_2O, CO_2) in municipal wastewater treatment plants. International Environmental Technology, IET June 2024 p.4-6

Produktinformationen Wi.Tec-Sensorik GmbH (2022)



06 **N_2O emissions during a one-year measurement period at a Swiss wastewater treatment plant (upwater 2024)**