INTERNATIONAL WATER RESOURCES ASSOCIATION'S
1st ISLANDS WATER CONGRESS
FAROE ISLANDS - SEPTEMBER 4-6, 2024
IWRA International Water Resources Association
JARÐFEINGI Faroese Geological Survey

Infrared sensor for analysis of nitrogen-based contaminants in wastewater

Katy Rodenko
Max-IR Labs

K. Roodenko, Trey B. Daunis, Matthew Molyneux,
Jennifer C. Dussor, Kevin P. Clark, Dennis I. Robbins

kroodenko@max-ir-labs.com

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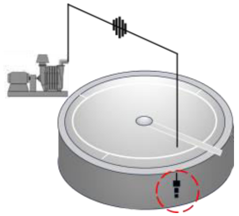
- Overview
- Infrared sensor development
- Pilot studies
- Summary

Monitoring chemical compounds in water



- Wastewater treatment optimization

Monitoring nitrogen compounds

- Remediation

PFAS

- Research

Biological & Environmental monitoring

- Sequestration

Inorganic carbon

Water reuse in Texas

- **Agricultural reuse / irrigation**
- **Industrial reuse (Cooling, Boiler feed)**
- **Direct potable reuse**

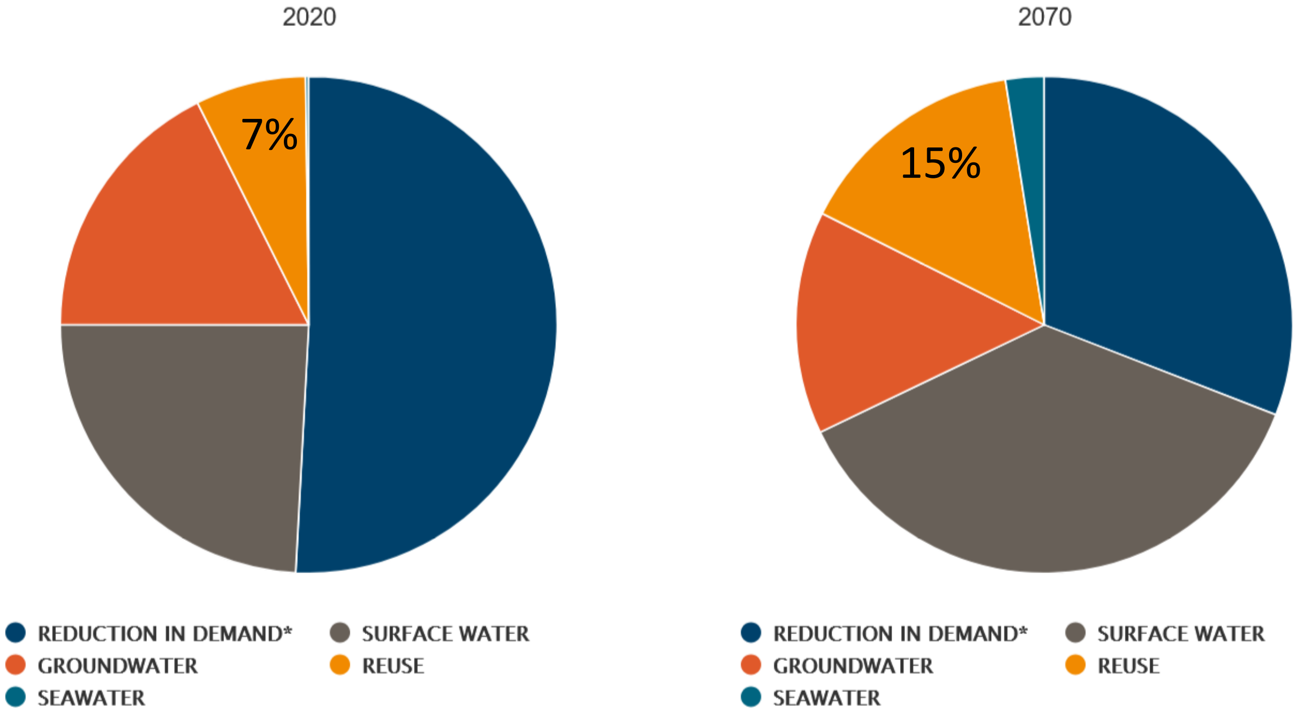
El Paso: Direct Potable Reuse Project. Target 13% DPR by 2030.
Austin: OSCAR(onsite collection &reuse) / CLARA (Closed-loop Advanced Reclaimed Assembly)
- Collect Rainwater and air-conditioning condensate
- Wastewater collection / membrane treatment/ reuse in flushing

Texas islands: the focus on preserving natural environment

Purple-coded pipes for reuse

Source: https://en.wikipedia.org/wiki/Reclaimed_water

NEW WATER IN STATE WATER PLAN – PERCENT SHARE BY WATER RESOURCE

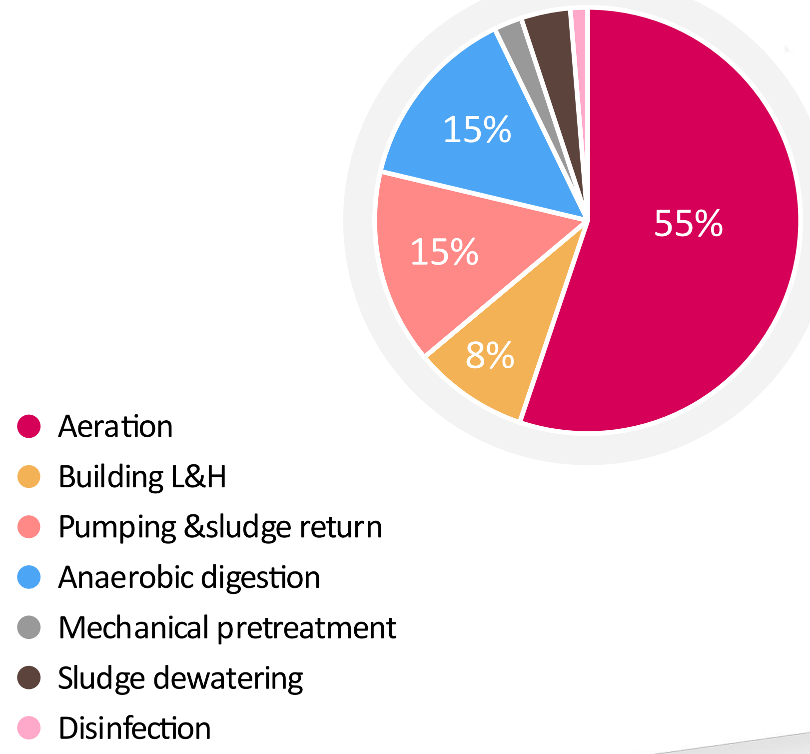


Source: https://comptroller.texas.gov/economy/fiscal-notes/archive/2022/jul/water-systems.php

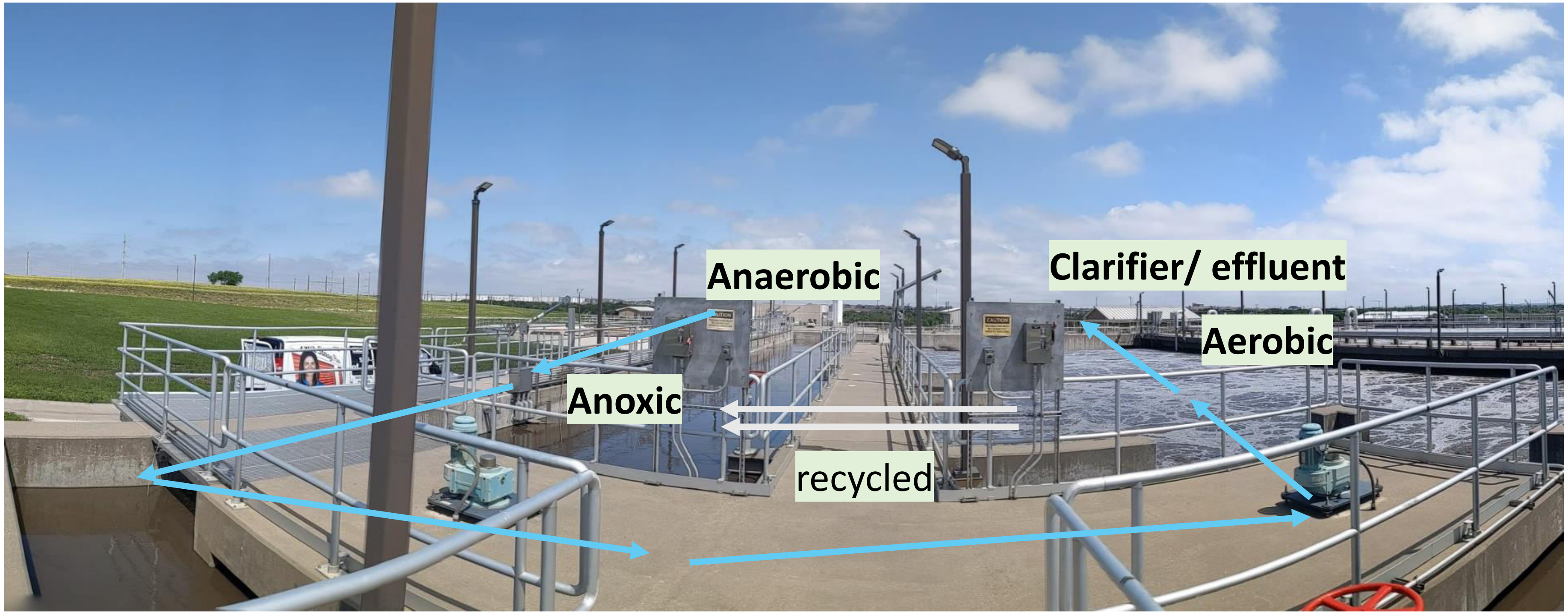
Municipal wastewater treatment

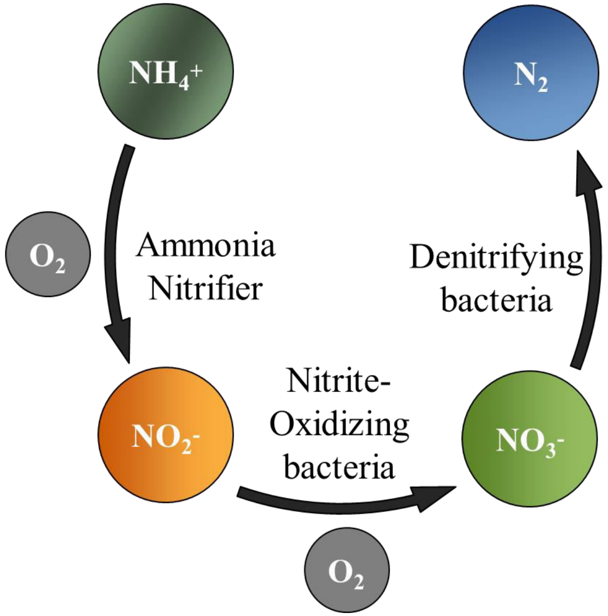
- **2%** of the total electric energy in developed countries is spent on wastewater treatment
- **55%** of this power goes **to aeration** - the process of biodegrading pollutants in water
- 20M metric tons CO_2 per year

Implementing inline analysis of nitrogen compounds will help reduce electric energy required for wastewater treatment

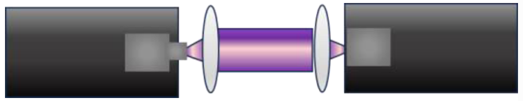


Municipal wastewater treatment

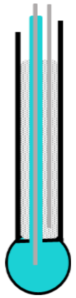




Methods for monitoring nitrogen compounds



- UV sensors
  - Organic interferences
  - Limited to nitrate (no ammonia detection)
  - Frequent calibration requirements



- Ion selective electrodes (ISE) sensors
  - Ionic interferences
  - Frequent calibration required
  - Degradation and fouling

- Grab-sampling
  - Lack of continuous data
  - Potential for sample degradation
  - Long turnaround time for results

Methods for monitoring nitrogen compounds

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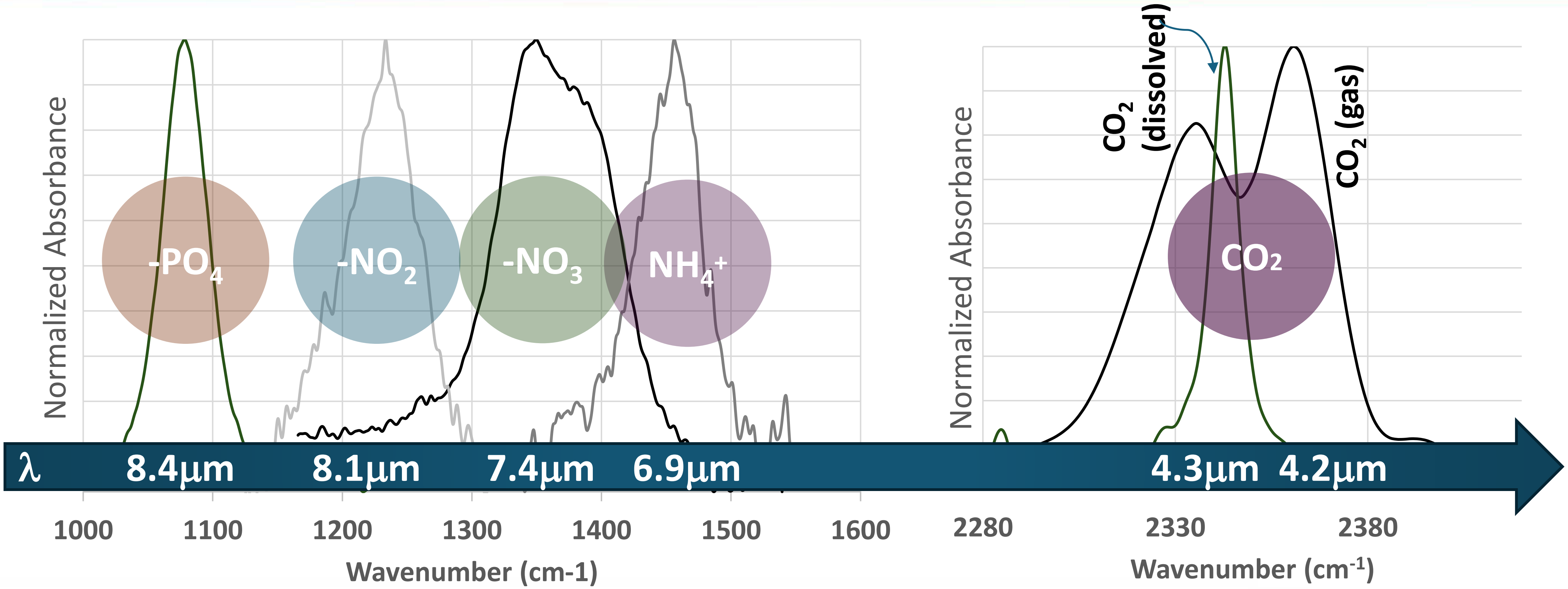
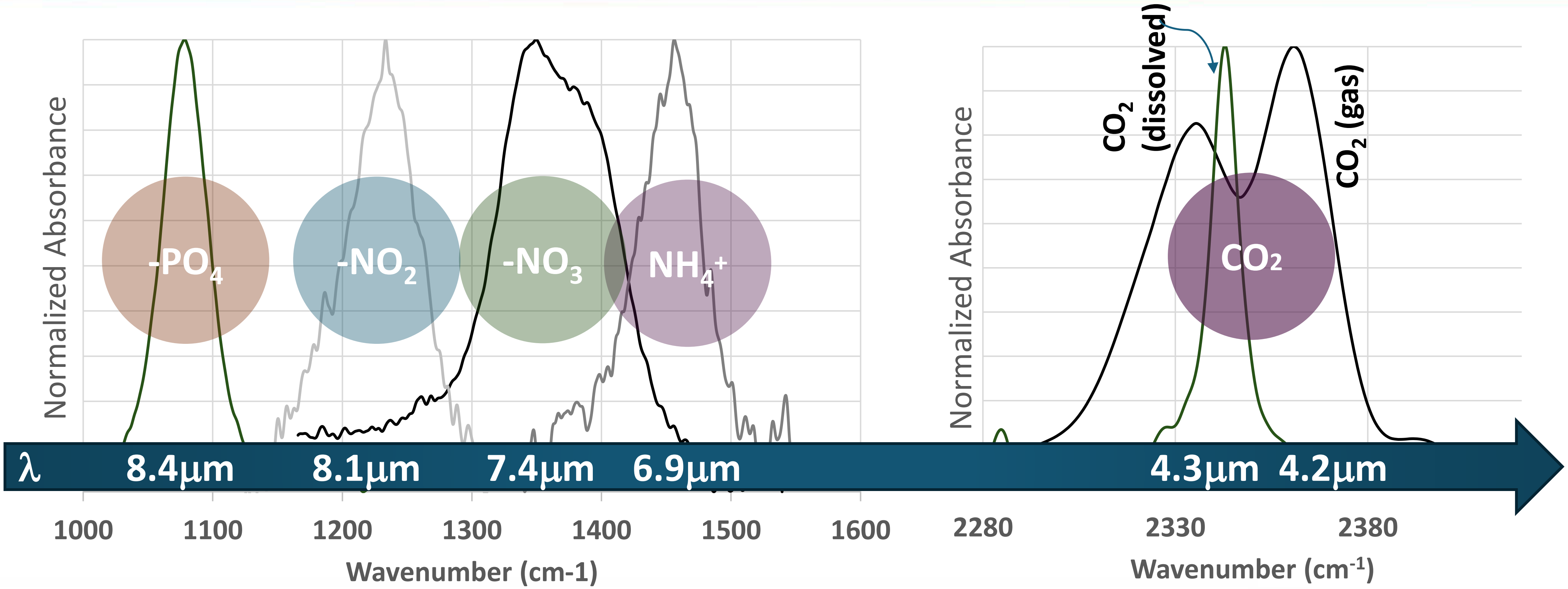


- IR spectroscopy is a very powerful tool for water analysis
- Multiple challenges operating in field conditions
  - Low IR signal ➔ cooled detectors required
  - Cross-Interferences of multiple analytes ➔ separation is required

Methods for monitoring nitrogen compounds



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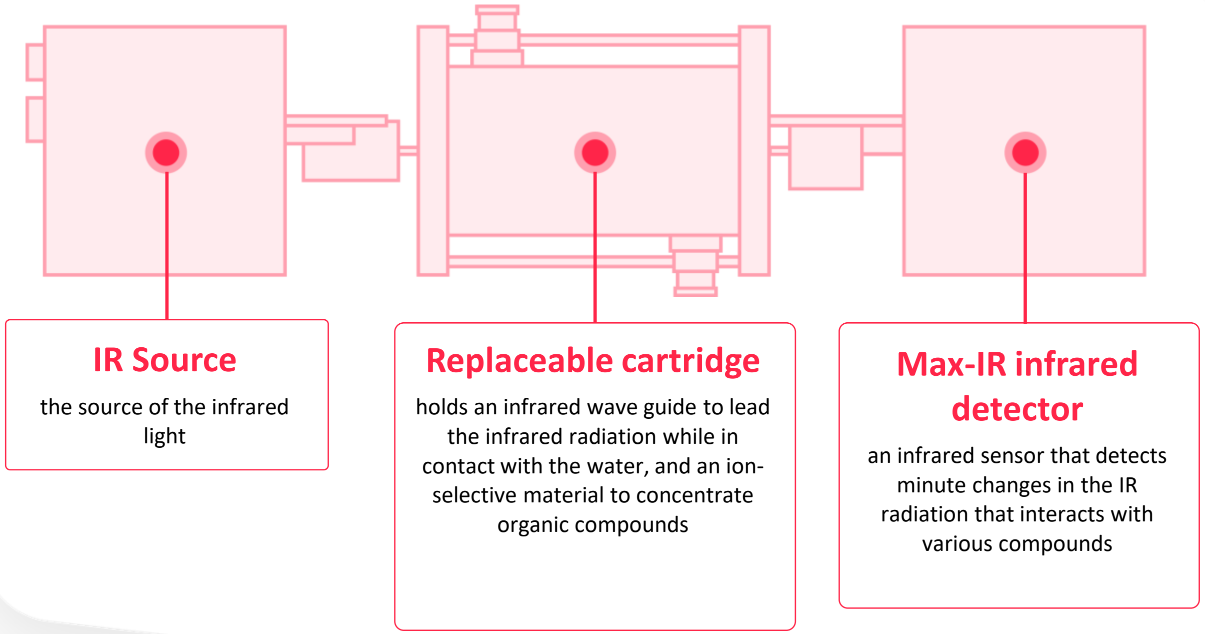
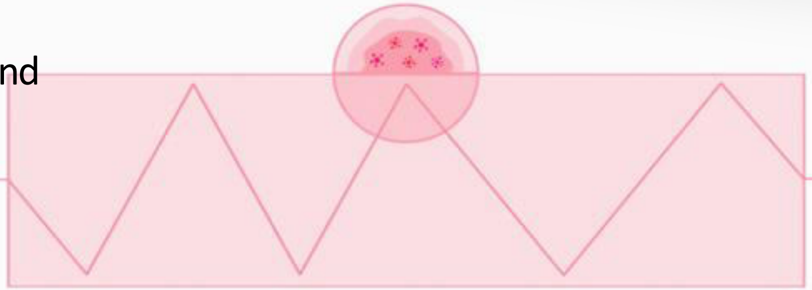
❯ **CARTIDGE DESIGN**

ISMIR: Ion-selective Measurement using Infrared

1. An infrared signal is passed down a special optical fiber in contact with the liquid.
2. The electromagnetic field associated with the infrared signal penetrates a short distance into the water where it is absorbed by target compounds.
3. This effect generates small changes in the IR signal, which are detected by the sensor.

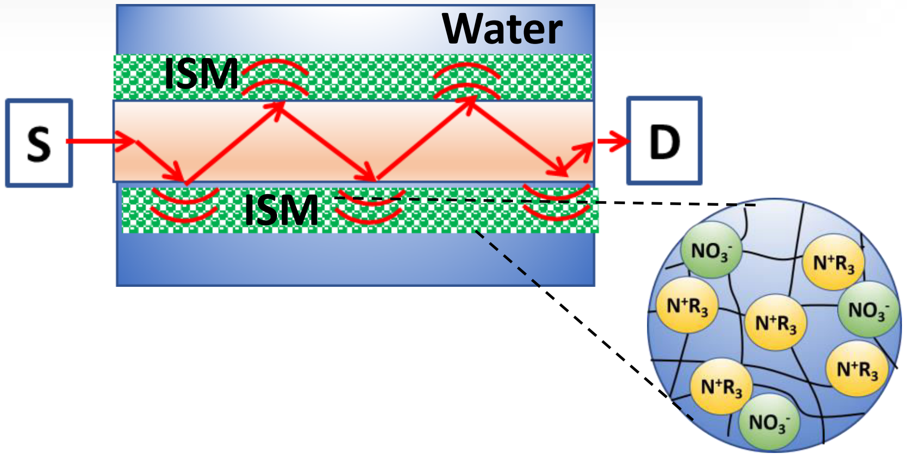


US. Patents #10,890,525, #10,883,930, #10,613,025, and #10,458,907

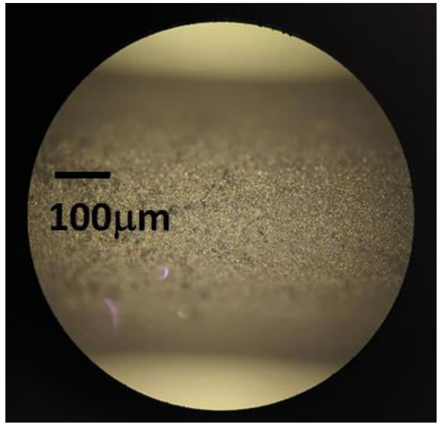


Cartridge Design

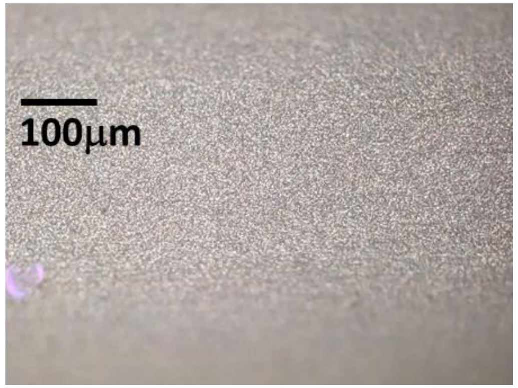
Operation principles: infrared absorption



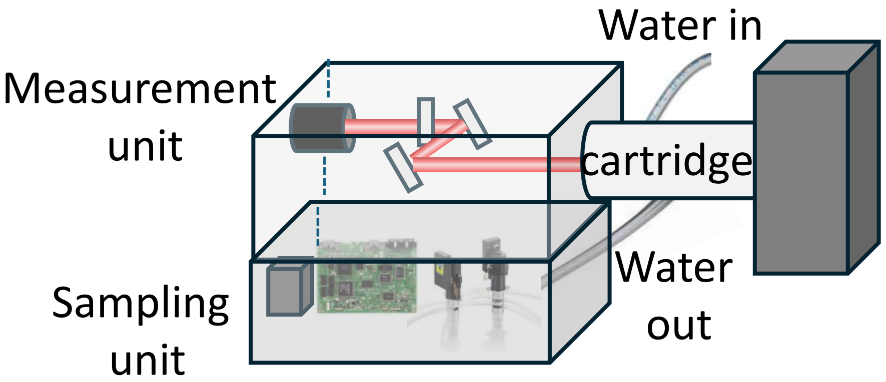
Activated Carbon



ISM (ion-selective material)

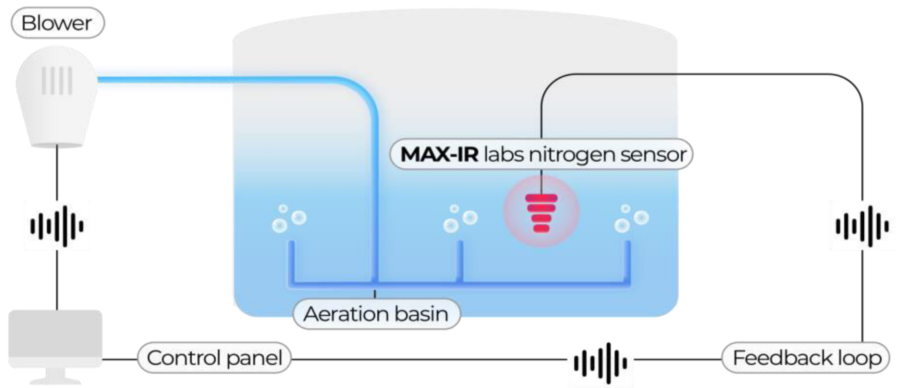


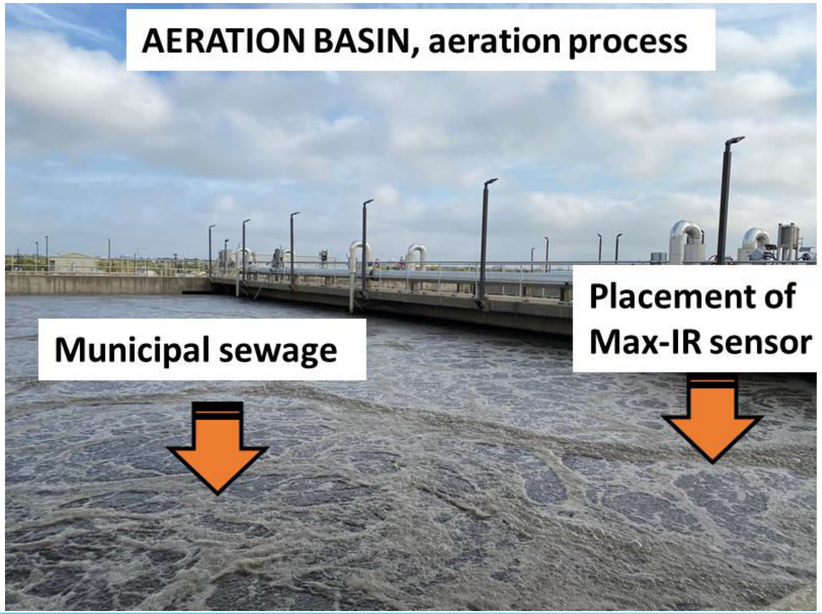
Max-IR Mobile Lab



Max-IR Mobile Lab

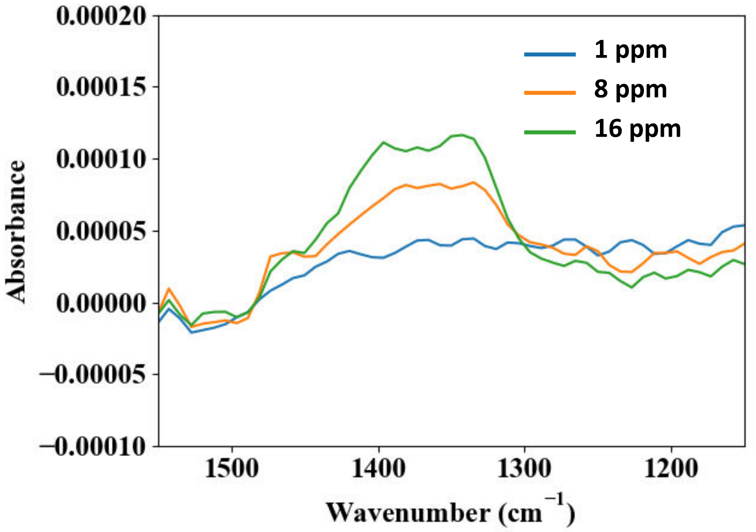
We target process control and energy efficiency of wastewater treatment



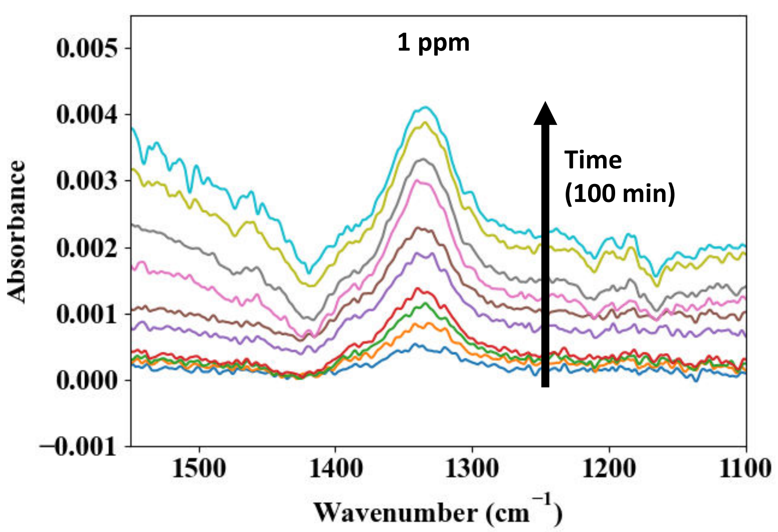


What's behind data evaluation

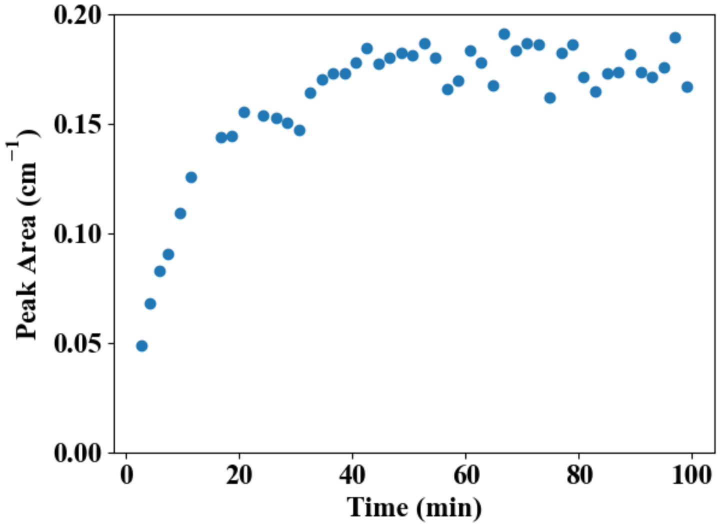
Nitrate absorbance uncoated fiber
LN2-MCT detector



Nitrate absorbance
coated fiber
DTGS detector



Peak area vs. time – coated fiber



- **Fiber coating enables room temperature measurement using DTGS detector**
  - Signal enhanced by >300x
  - But what about the longer measurement time?

What's behind data evaluation

Data is fit to a pseudo-second order kinetic model

Pseudo-second order kinetics

$$\frac{dC_t}{dt} = \pm k_2 (C_t - C_e)^2$$

Solve for concentration in fiber coating (q_t)

$$q_t = \frac{k_2 q_e^2 t}{k_2 q_e t + 1}$$

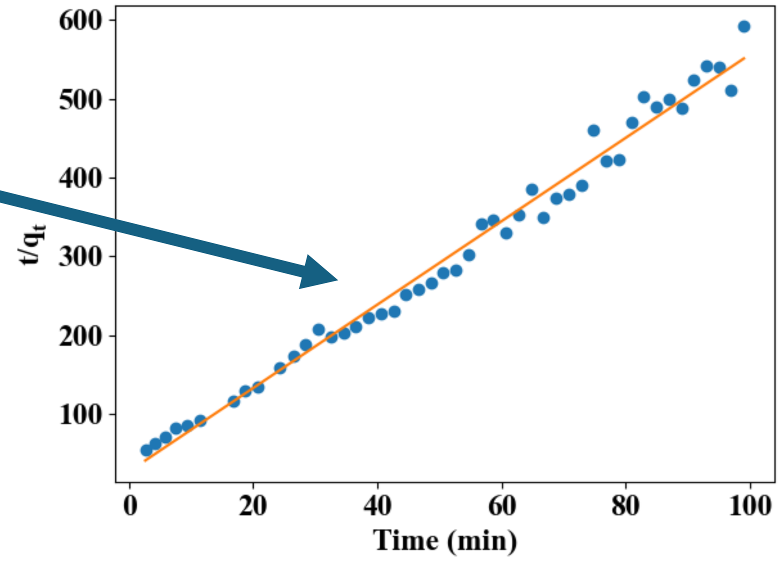
Linearized equation

$$\frac{t}{q_t} = \frac{1}{q_e^2 k_2} + \frac{1}{q_e} t$$

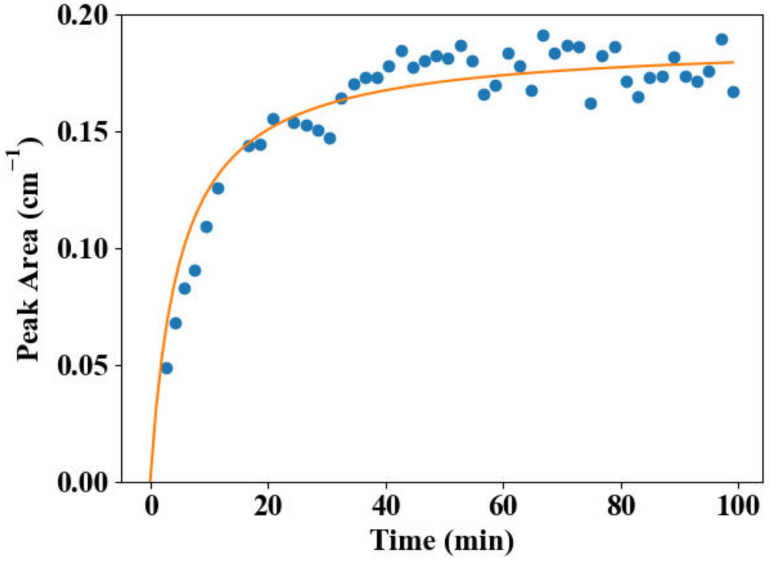
Linear equation – constant change in output with time

We can use this to predict the final value at any time

Psuedo-second order linearization

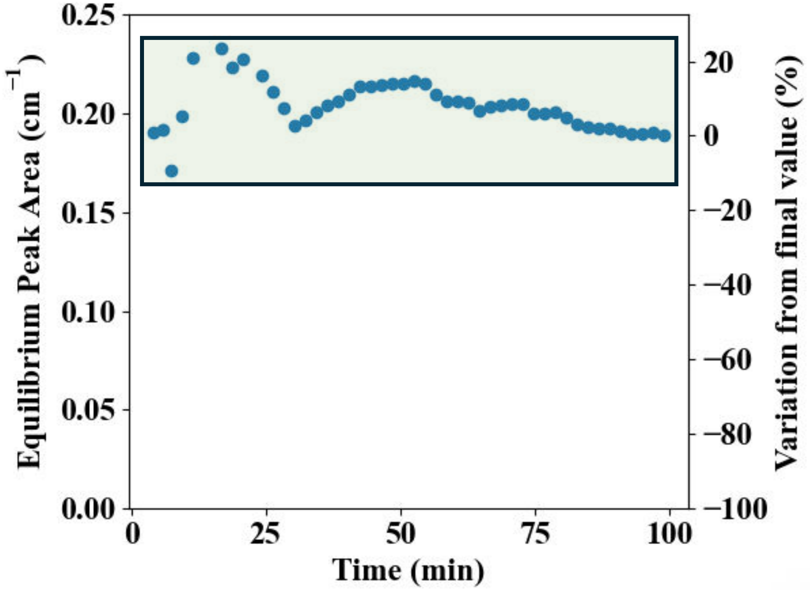


Psuedo-second order data fit

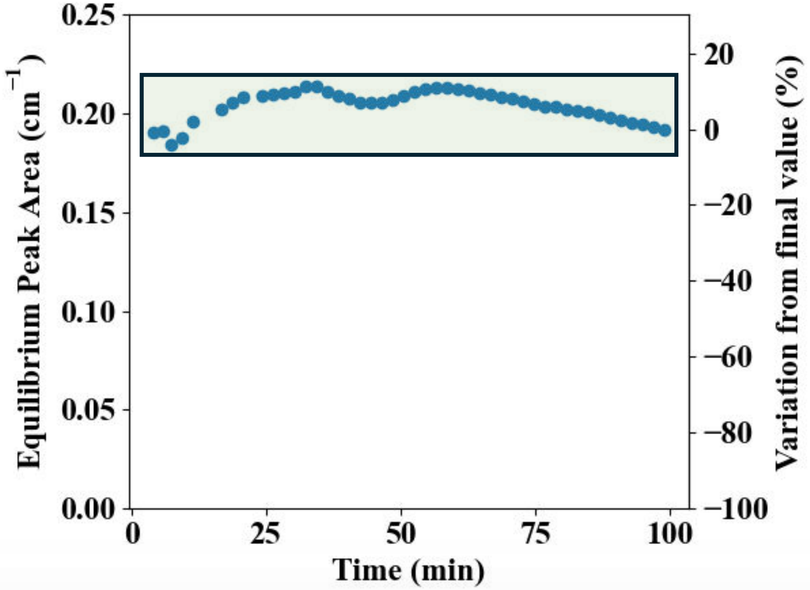


What's behind data evaluation

Predictive saturation peak area



Predictive saturation peak area with moving average



Predicted value is within 12% of final value beginning **4 minutes** after measurements begin

Predicted value is within 25% of final value beginning **4 minutes** after measurements begin

- **Trap-and-measure to enhance signal**
  - Enables use of room temperature detector
- **Predictive modelling to estimate concentration**
  - Allows for fast measurement even with slow kinetics
  - **Prior knowledge of kinetics is not necessary**

Summary

- **Mid-IR detector selection is constrained by application**
  - Beyond wavelength, cooling and S/N are primary considerations
- **Baseline absorbance vs. time are the most practical detector comparison metric**
- **Trap-and-measure signal enhancement expands detector and application options**
- **Analysis of nitrogen-based compounds is enabled at room temperature**
- **Working on implementing Inorganic Carbon, PFAS, Orthophosphates measurements**

Team