# Optimization of a Drone-based System for Instrumental Odour Monitoring using Feature Selection

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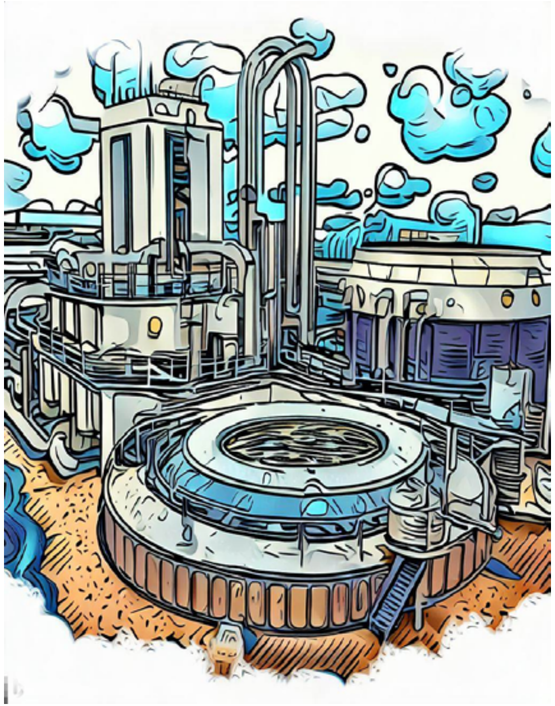
# Environmental Odour Monitoring

- Odour pollution is a major cause of citizen complaints. Waste processing plants often are sources of malodours.
- The reference method to estimate odour concentration is Dynamic Olfactometry (EN13725-2022).
    - Infrequent
    - Limited locations
    - Expensive
- Instrumental Odour Monitoring Systems (IOMS) may be an option to have continuous odour monitoring.



# Odour concentration by IOMS

- Odour is not objective: it is a human perception.
- Malodours are complex mixtures with hundreds of compounds that can contribute to the overall odour perception
- Odours can sometimes be due to minor components in the presence of odourless major components
- Emissions of plants can vary in time due to many factors: e.g. the quality of the water intake.
- The reference method (Dynamic Olfactometry) features  multiplicative errors with a factor of 2 (95% CI)



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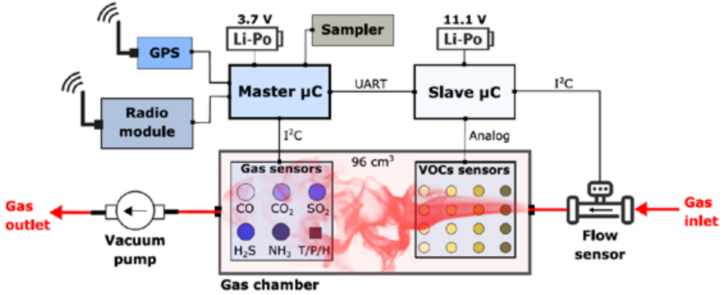
# SNIFFIRDRONE Project

- Usually IOMS are mounted in fixed locations.
- SNIFFIRDRONE GOAL:
  - Real time odour concentration estimation with an IOMS flying on a drone
  - 4 Waste Water Treatment Plants
  - 1 Composting plant
  - **Novelty:**
    - Drone operation
    - Calibration in flight conditions with transient signals.

# RHINOS Electronic nose


J. Burgués et al., Remote Sensing, 2021
J. Burgués et al. iScience, 2021
J. Burgués et al. Sci. Tot. Environ,, 2022

| | Technology | Range | Accuracy | Response time ($T_{90}$) |
|---|---|---|---|---|
| Temperature | Integrated | −40 to +85°C | ±1°C | <2 s |
| Humidity | Integrated | 0 to 100% RH | ±3% RH | <2 s |
| Pressure | Integrated | 30 to 110 kPa | ±0.1 kPa | <2 s |
| Flow rate | Ultrasonic | −33 to +33 L/min | ±3% m.v. | <1 s |
| $CO_2$ | NDIR | 0 to 5000 ppm | ±100 ppm | <60 s |
| CO | Electrochemical | 0 to 100 ppm | ±0.5 ppm | <20 s |
| $H_2S$ | Electrochemical | 0 to 20 ppm | ±0.1 ppm | <20 s |
| $NH_3$ | Electrochemical | 0 to 100 ppm | ±0.5 ppm | <90 s |
| $SO_2$ | Electrochemical | 0 to 20 ppm | ±0.1 ppm | <45 s |

| Sensor | Model | Target gases | Heater voltage |
|---|---|---|---|
| M1 | TGS 2600 | $H_2$, CO, Ethanol | 1.6 V |
| M2 | TGS 2600 | $H_2$, CO, Ethanol | 3.2 V |
| M3 | TGS 2600 | $H_2$, CO, Ethanol | 4.0 V |
| M4 | TGS 2600 | $H_2$, CO, Ethanol | 4.9 V |
| M5 | TGS 2602 | $H_2S$, $NH_3$, Toluene | 1.6 V |
| M6 | TGS 2602 | $H_2S$, $NH_3$, Toluene | 3.2 V |
| M7 | TGS 2602 | $H_2S$, $NH_3$, Toluene | 4.0 V |
| M8 | TGS 2602 | $H_2S$, $NH_3$, Toluene | 4.9 V |
| M9 | TGS 2611 | $CH_4$, Hydrocarbons | 1.6 V |
| M10 | TGS 2611 | $CH_4$, Hydrocarbons | 3.2 V |
| M11 | TGS 2611 | $CH_4$, Hydrocarbons | 4.0 V |
| M12 | TGS 2611 | $CH_4$, Hydrocarbons | 4.9 V |
| M13 | TGS 2620 | Alcohols, ketones | 1.6 V |
| M14 | TGS 2620 | Alcohols, ketones | 3.2 V |
| M15 | TGS 2620 | Alcohols, ketones | 4.0 V |
| M16 | TGS 2620 | Alcohols, ketones | 4.9 V |

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# Outline

- Methods
  - The waste-water treatment plant (WWTP) & 2020 measurement campaign
  - Signal and data processing workflow
  - Model training & Validation: Array optimization by Feature Selection
- Results
  - Raw signals
  - PLS full model and Variable Importance in Projection
  - Array optimization by Feature Selection
  - Model Comparison
- Summary

# Wastewater treatment plant & Meas. campaign

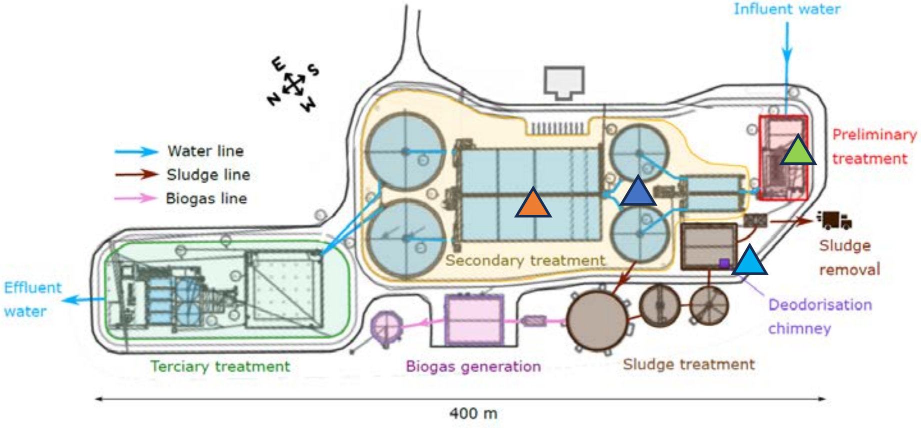
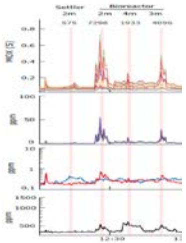



**Table 2.** Number of samples collected in each source during the four measurement days.

| Day | Date | Settler ▲ | Bioreactor ▲ | Pretreatment ▲ | Chimney ▲ | Total (odour) | Blanks | Total |
|---|---|---|---|---|---|---|---|---|
| 1 | 24/06/2020 | 3 | 3 | 2 | 2 | 10 | 7 | 17 |
| 2 | 25/06/2020 | 2 | 2 | 2 | 2 | 8 | 6 | 14 |
| 3 | 14/07/2020 | 3 | 3 | 3 | 3 | 12 | 11 | 23 |
| 4 | 15/07/2020 | 3 | 3 | 3 | 3 | 12 | 7 | 19 |
| | **Total** | 11 | 11 | 10 | 10 | 42 | 31 | 73 |

# Signal and Data processing workflow

ATTRACT



Model training and optimization
based on double-nested k-fold
External validation: 4-fold one day out

Raw Signals

Filtering

Baseline correction

Time **window**

Log Transform

Autoscale

PLS Regression

De autoscale

Exp

EN13725

Olfactometries

Figure of merit: Relative Error

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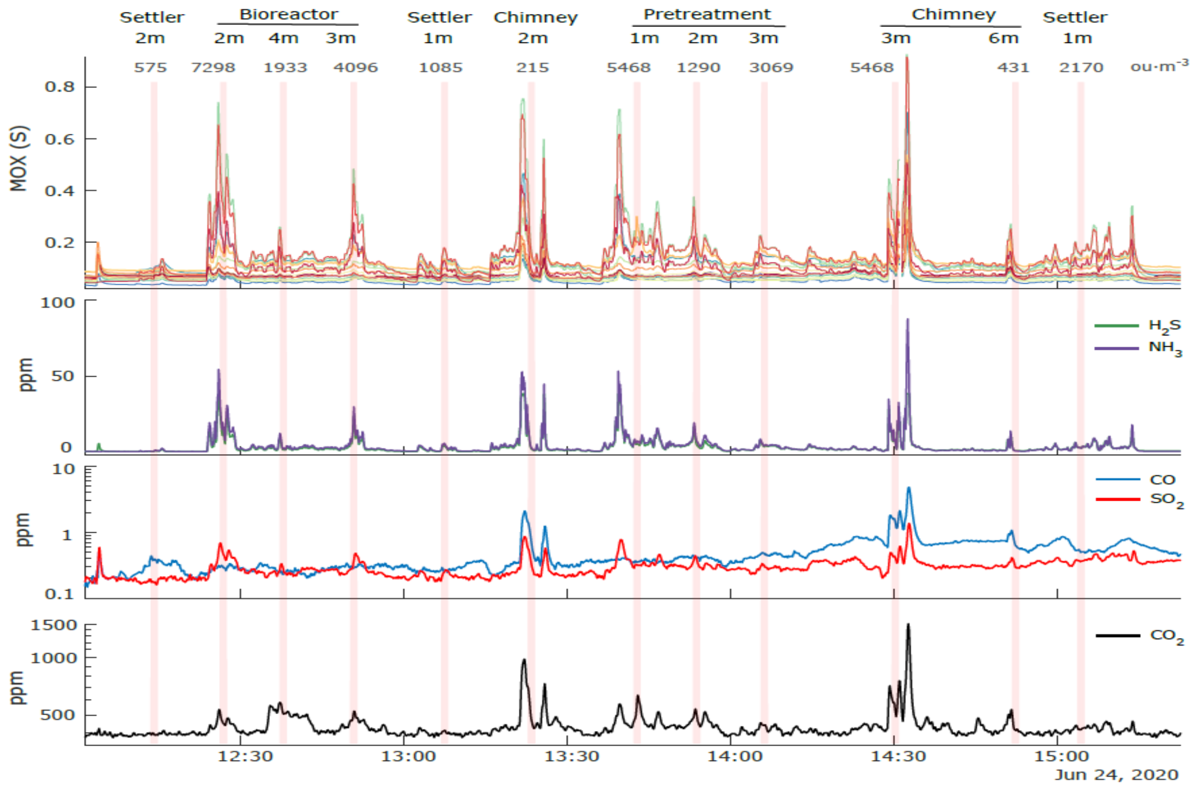
# Example to raw signals

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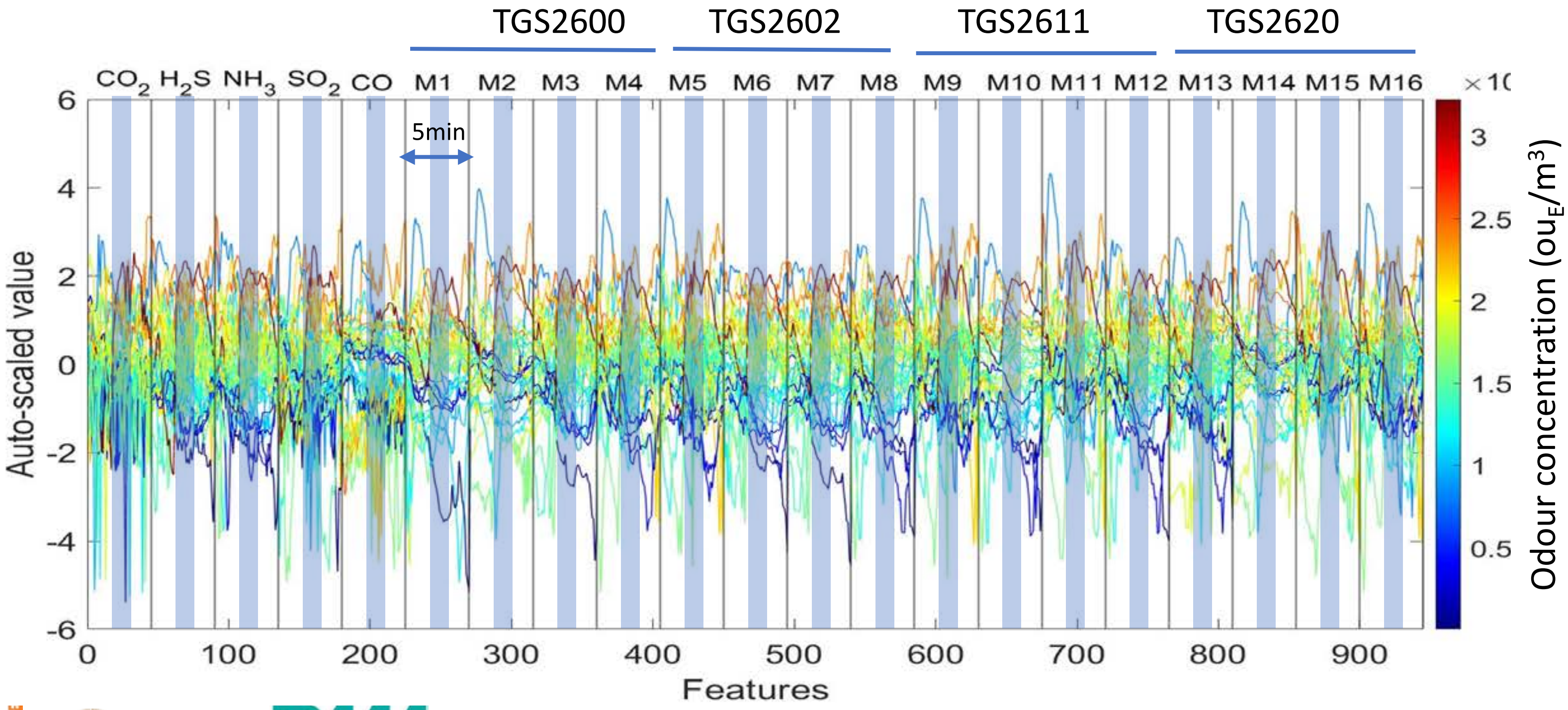
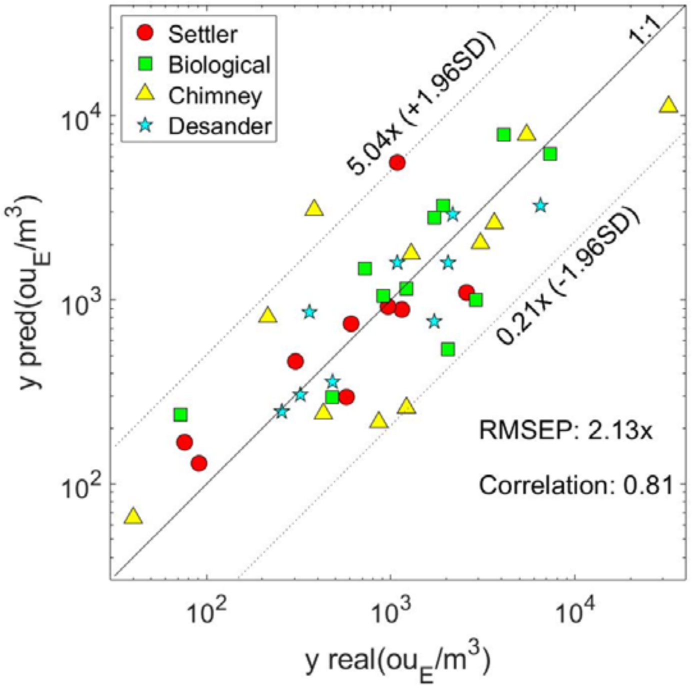
# Pattern formation from preprocessed sensor signals

Pattern is formed by the concatenation of 5 min window centered around the odour sampling period.

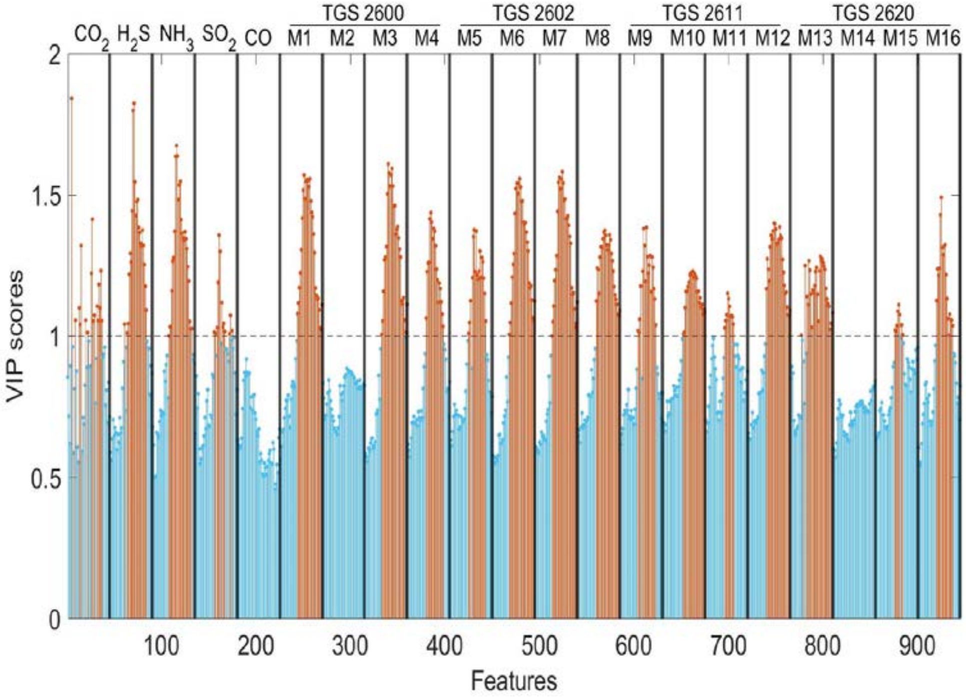


# PLS Regression – Variable Importance

- PLS LV=2, Model External Validation (N=40)




- Variable Importance

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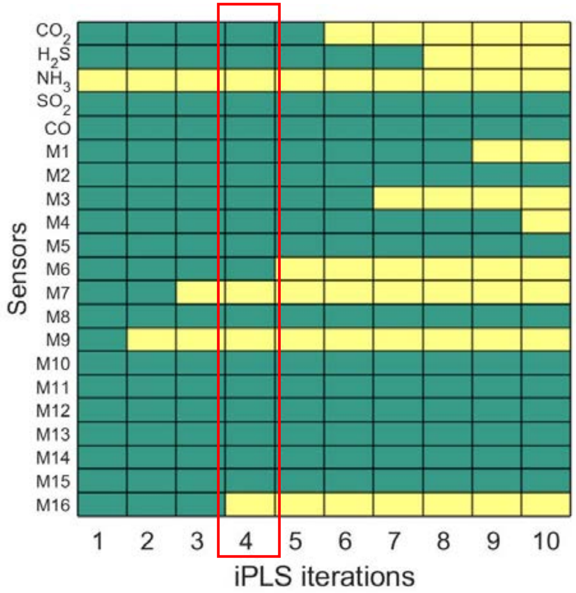
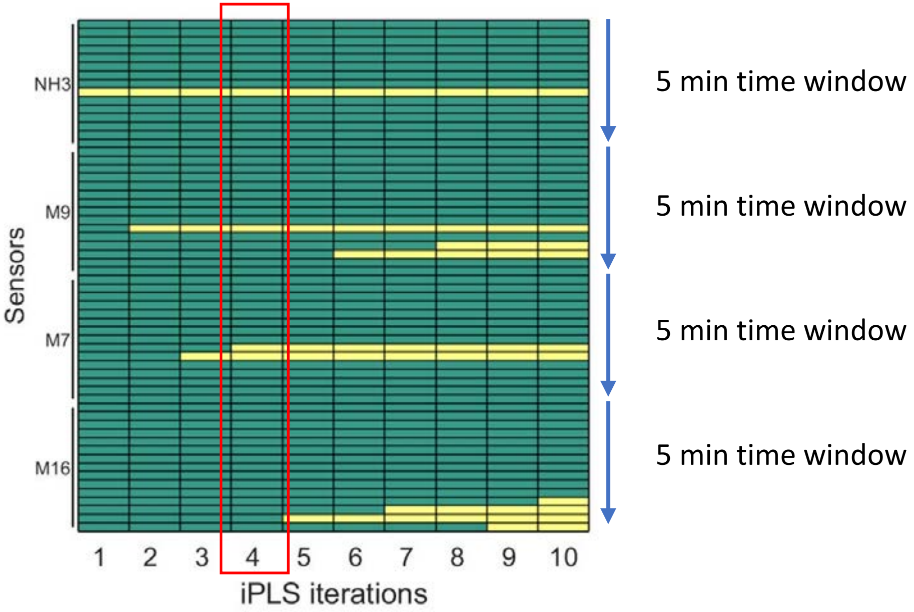
# Array Optimization: Sensors and Time Intervals

- Optimization was based on Nested Sequential Forward Selection using Interval Partial Least Squares (iPLS).

Minimum RMSECV error

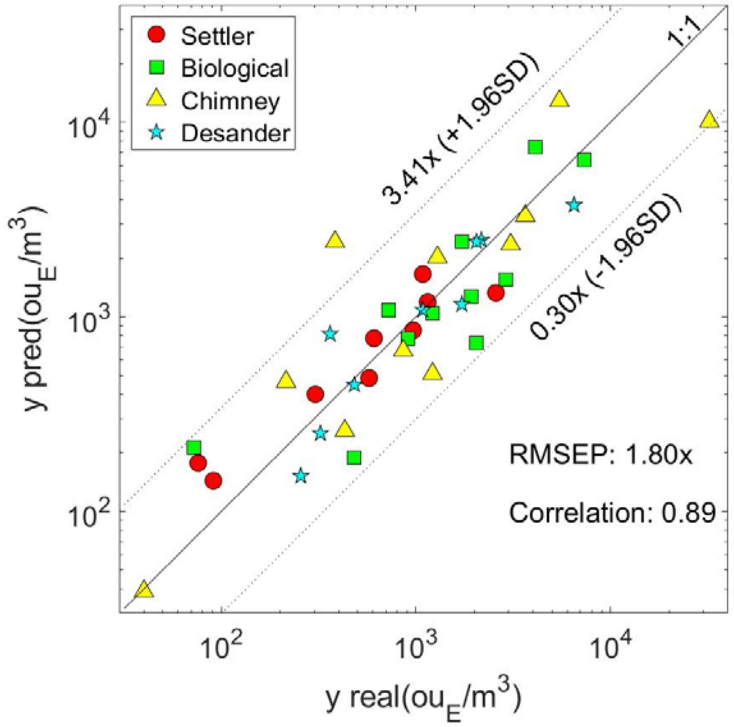



Minimum RMSECV error



# Array Optimization: Sensors and Time intevals

## Optimal Model




## Multiplicative Errors – Correlation Coeff.

| Array Configuation | 95% Conf | R |
|---|---|---|
| Full model | (0.2x-5.0x) | 0.81 |
| $NH_3$<br>TGS2602 @ 4V<br>TGS2611 @ 1.6V | (0.3x -3.4 x) | 0.89 |

N=40 samples

# Summary 1: Conclusions

- IOMS on a flying drone provides odour concentration estimation based on transient sensor signals acquired in flying conditions.
- We have used a single model for all the odour sources.
- Full model provides unbiased predictions with  95% CI errors of a factor of 5x.
- After the optimization, the sensor array uses an EC $NH_3$ sensor and two MOX sensors.
- The reduced system still provides unbiased predictions, and the error has been reduced to a factor 3.4x-
- The validity of these results is limited by the duration of the study and the use of a single WWTP.

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- Examples of technologies based on chemical sensing that became medical devices

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