

Laboratory Evaluation

Oizom – Polludrone Smart



Outline

1. Background
2. CO
3. PM_{2.5}

DRAFT

Background

Three **Oizom Polludrone Smart** (hereinafter **Polludrone Smart**) sensors (units IDs: 0001, 0002, 0003) were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (07/31/2021 to 09/29/2021) under ambient environmental conditions. Following field testing, the units were subjected to further laboratory testing in the South Coast AQMD Sensor Environmental Test Chamber 2 (SENTEC-2) under controlled pollutant concentration, temperature, and relative humidity conditions.

Polludrone Smart (3 units tested):

- Sensors: CO – Electrochemical (**Alphasense B4, non-FEM**)
O₃ – Electrochemical (**Alphasense B4, non-FEM**)
NO – Electrochemical (**Alphasense B4, non-FEM**)
NO₂ – Electrochemical (**Alphasense B4, non-FEM**)
- PM Sensors – Optical Particle Counter (**Wuhan Cubic PM3006S**)
- Each unit measures: CO (ppm), O₃ (ppb), NO and NO₂ (ppb), PM_{1.0}, PM_{2.5} and PM₁₀ (μg/m³), T (°C), RH (%)
- **Unit cost: \$8,000 (PM + Gas sensors)**
- Time resolution: 1-min
- Units IDs: 0001, 0002, 0003

Reference instruments:

- CO instrument (**FRM, T300U, Teledyne, San Diego, CA**); **cost: ~\$15,000**
 - Time resolution: 1-min
- PM_{2.5/10} instrument (**FEM, T640x, Teledyne, San Diego, CA**); **cost: ~\$37,000**
 - Time resolution: 1-min



FEM T640x



FRM T300U

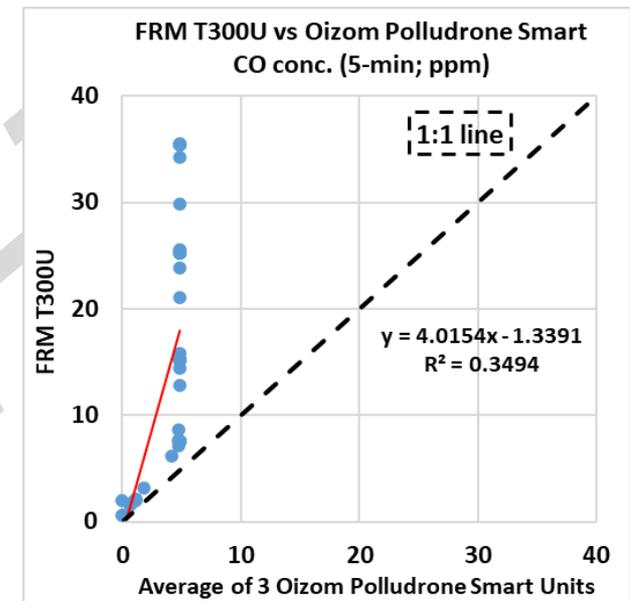
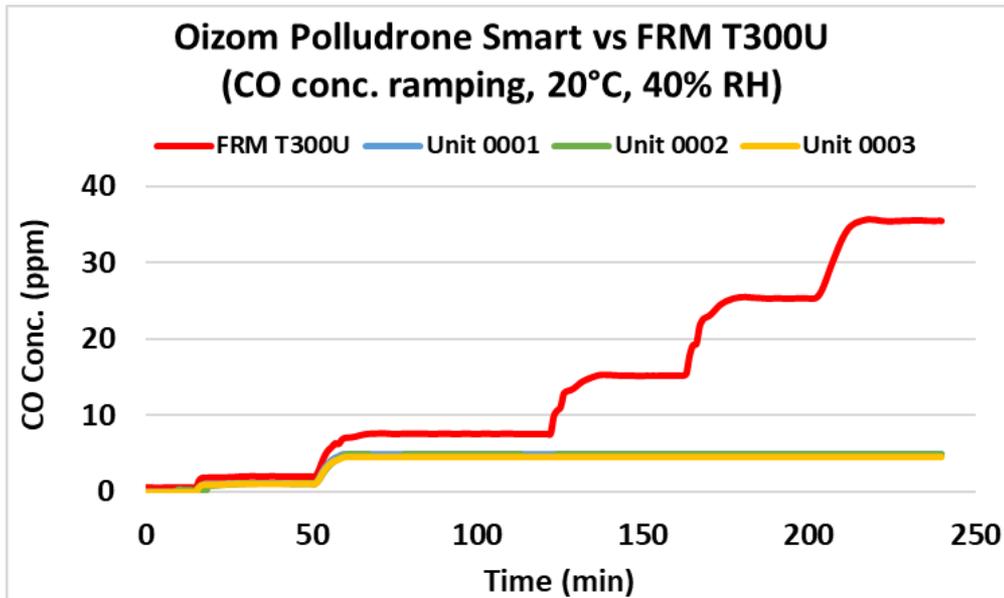


CO

1. **FRM T300U vs Polludrone Smart**
2. **Accuracy, data recovery, and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Discussion**

Polludrone Smart vs FRM T300U (CO)

Coefficient of Determination



- The FRM T300U instrument reported a baseline of ~ 0.6 ppm and the Polludrone Smart sensors reported baseline values ~0 ppm
- The three Polludrone Smart sensors did not track the CO concentration variations recorded by FRM T300U instrument; the sensor's readings plateaued at 5 ppm
- The Polludrone Smart sensors underestimated the CO concentration as recorded by the FRM T300U instrument
- The Polludrone Smart sensors showed weak correlations with the corresponding FRM T300U CO conc. ($R^2 \sim 0.35$)

Accuracy: Polludrone Smart vs FRM T300U (CO)

- Accuracy (20 °C and 40% RH)

Steady State (#)	Sensor Mean (ppm)	FRM T300U (ppm)	Accuracy (%)
1	1.1	2.0	54.1
2	4.8	7.6	63.2
3	4.8	15.2	31.7
4	4.8	25.3	19.0
5	4.8	35.4	13.6

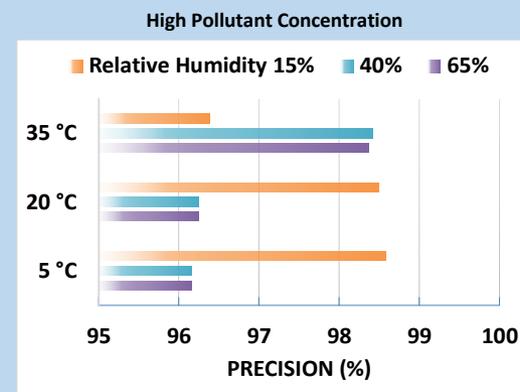
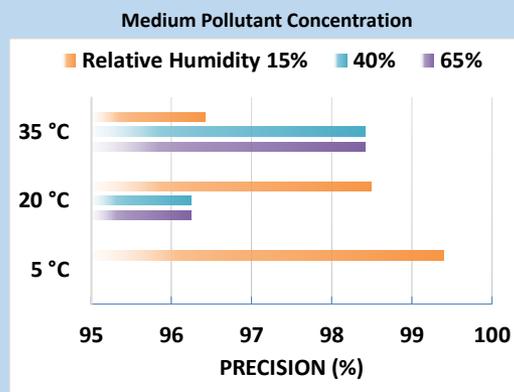
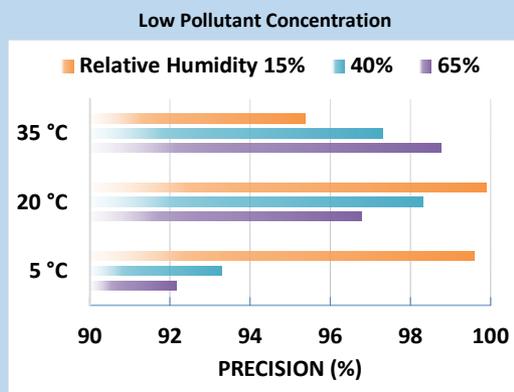
- Accuracy of the three Polludrone Smart sensors ranged from 13.6% to 63.2%. The sensors' accuracy decreased as CO concentration increased and underestimated the FRM T300U measurements at all CO concentrations at 20 °C and 40% RH.

Polludrone Smart Data Recovery and Intra-model Variability

- Data recovery for CO measurements was 100%, 96%, and 100% for Units 0001, 0002, and 0003, respectively
- Low CO concentration variations were observed between the three units at 20° C and 40% RH, at 2, 7.5, and 15 ppm CO as measured by the FRM T300U.

Precision: Polludrone Smart (CO)

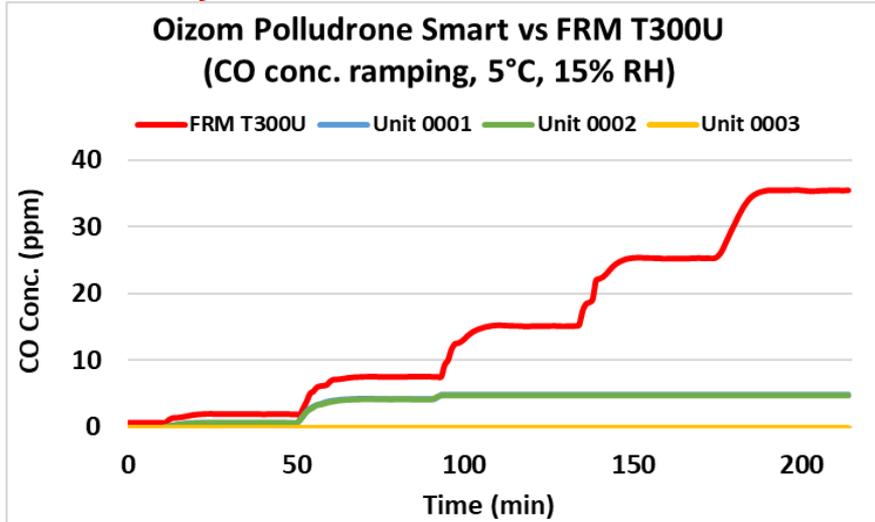
- Precision (Effect of CO conc., temperature and relative humidity)



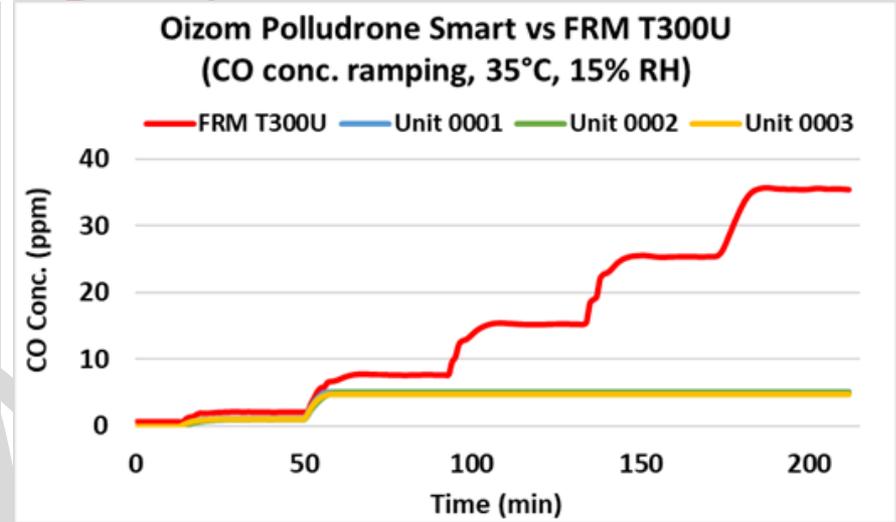
- Overall, the three Polludrone Smart sensors showed high precision for all combinations of low, medium and high CO conc., T, and RH.

Climate Susceptibility: Polludrone Smart (CO)

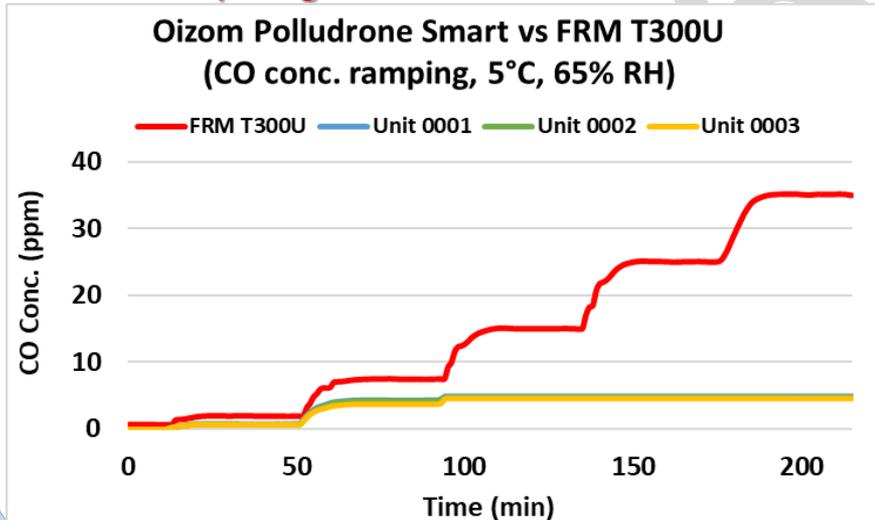
Low Temp-Low RH



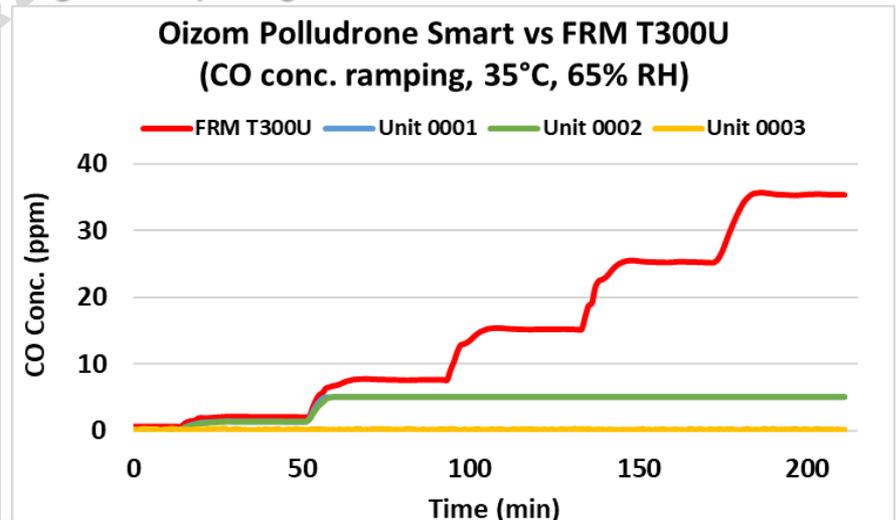
High Temp-Low RH



Low Temp-High RH



High Temp-High RH



Discussion: CO

- **Accuracy:** The three Polludrone Smart sensors showed accuracy ranged from 13.6% to 63.2%.
- **Precision:** The three Polludrone Smart sensors exhibited high precision during all tested conditions (CO concentration, T and RH).
- **Intra-model variability:** Low CO measurement variations were observed among the three Polludrone Smart sensors at 20 °C and 40% RH.
- **Data recovery:** Data recovery for CO measurements was 100%, 96%, and 100% for Units 0001, 0002, and 0003, respectively.
- **Baseline:** At all conditions, FRM T300U CO instrument baseline was ~ 0.6 ppm, while the sensors' baseline was ~ 0 ppm.
- **Response time:** Response time could not be studied due to the system design of the chamber system. With a 1.6 m³ chamber volume and the max gas flow of 20 LPM, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** Polludrone Smart sensors showed weak correlation/linear response with the corresponding FRM T300U CO measurement data ($R^2 > 0.35$).
- **Interferent:** Sensors were not tested against an interfering gas species.

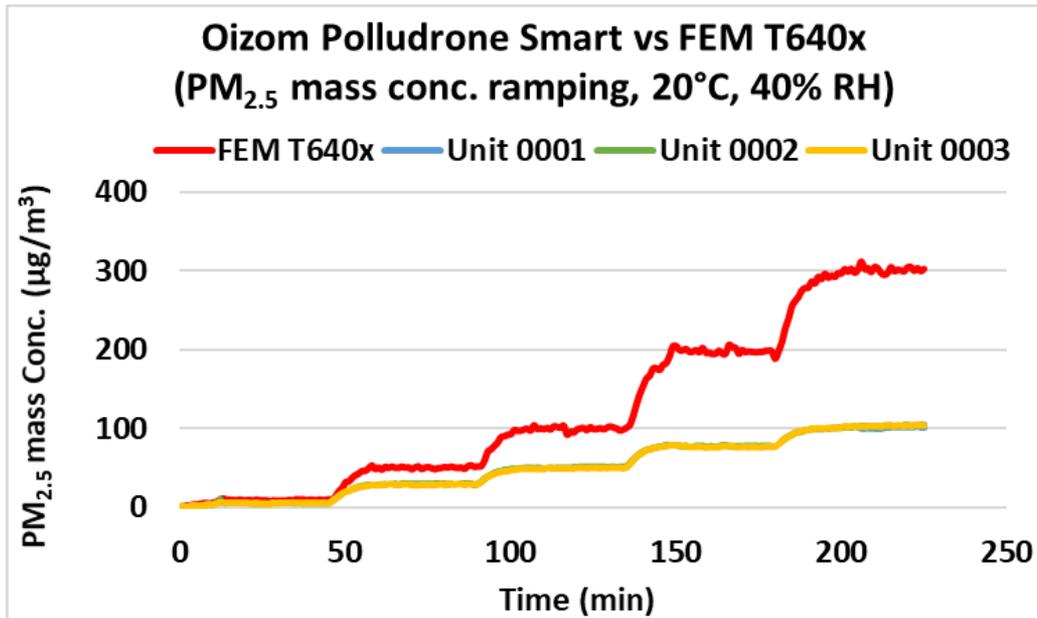
Discussion: CO

- **Measurement duration:** Polludrone Smart sensors report 1-min averaged values.
- **Measurement frequency:** Polludrone Smart sensors report 1-min averaged values. The obtained data was used as-is for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), but condensed into 5-minute averages for linear correlation studies against the FRM T300U.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Polludrone Smart sensors were tested in the field for two months. The CO laboratory studies lasted for about 10 days with intermittent non-operating periods and a storage period of ~ 3 months. For CO measurements, all three Polludrone Smart sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** 0-1,000 ppm CO concentration as suggested by the manufacturer. During the laboratory evaluation, the Polludrone Smart sensors were challenged with CO concentrations up to 35 ppm.
- **Climate susceptibility:** During the lab studies, temperature and relative humidity had little effect on the precision of CO concentrations as recorded by the Polludrone Smart sensors. However, the sensor's readings plateaued at 5 ppm in all conditions tested.
- **Response to loss of power:** Polludrone Smart sensors were powered through the entirety of the lab tests.

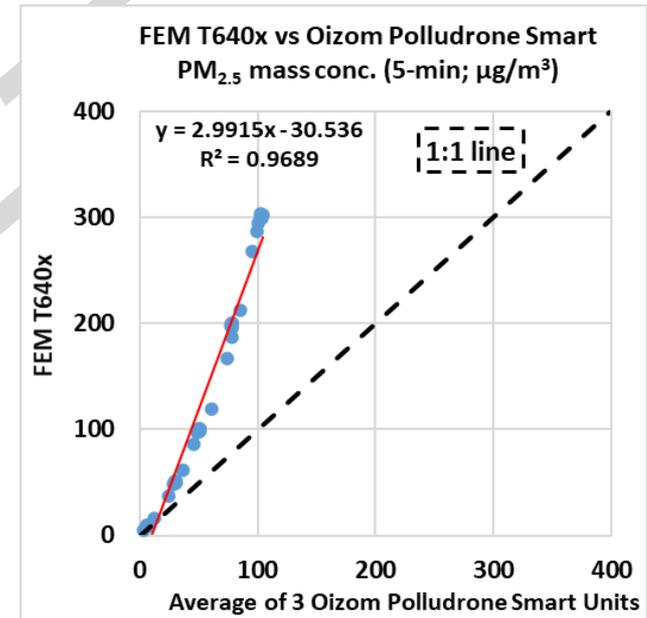
PM_{2.5}

1. **FEM T640x vs Polludrone Smart**
2. **Accuracy, data recovery, and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Discussion**

Polludrone Smart vs FEM T640x (PM_{2.5})



Coefficient of Determination



- The Polludrone Smart sensors tracked well with the concentration variation but underestimated PM_{2.5} concentration values compared to the FEM T640x in the concentration range of 0 - 300 $\mu\text{g}/\text{m}^3$.

- The Polludrone Smart sensors showed very strong correlations with the FEM T640x PM_{2.5} mass conc. ($R^2 > 0.96$)

Polludrone Smart vs FEM T640x PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	Sensor Mean (µg/m ³)	FEM T640x (µg/m ³)	Accuracy (%)
1	6.1	9.1	67.3
2	30.1	50.4	59.7
3	51.0	99.3	51.4
4	77.8	197.5	39.4
5	103.4	301.6	34.3

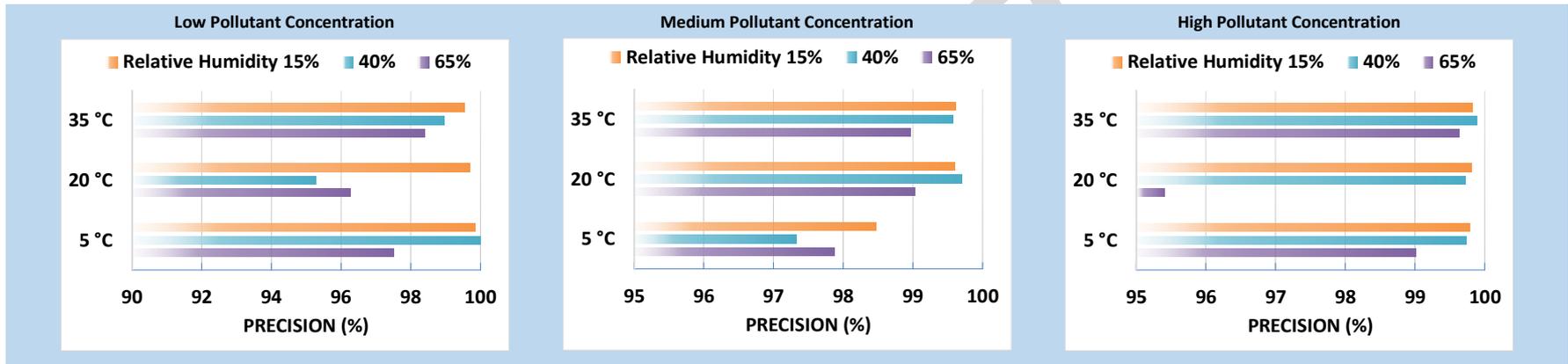
- The Polludrone Smart sensors underestimated the measured concentration compared to the FEM T640x PM_{2.5} mass concentration at 20 °C and 40% RH. The Polludrone Smart sensors' accuracy decreased from 67.3% to 34.3% as PM concentrations increased when compared to the reference FEM T640x.

Polludrone Smart Data Recovery and Intra-model Variability

- Data recovery for PM_{2.5} measurements was 100%, 97% and 100% for Units 0001, 0002 and 0003, respectively
- Low PM_{2.5} concentration variations were observed between the three units at 20 °C and 40% RH, at 10, 50, and 150 µg/m³ PM_{2.5} as measured by the FEM T640x.

Precision: Polludrone Smart (PM_{2.5})

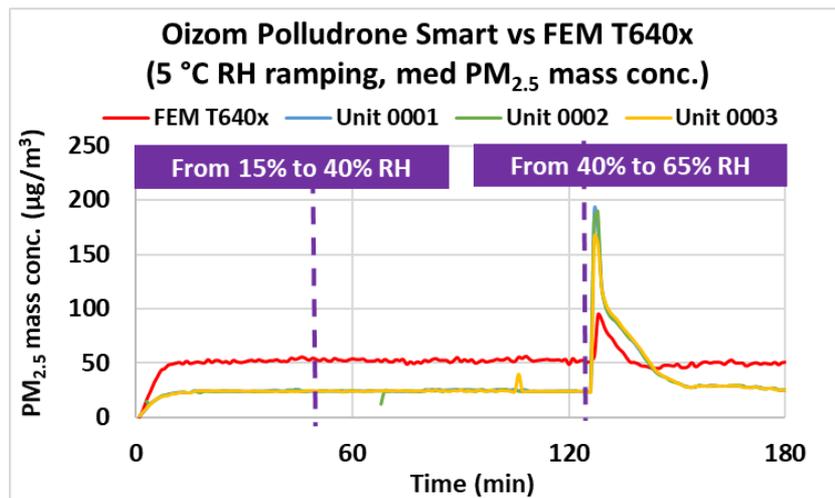
- Precision (Effect of PM_{2.5} conc., temperature and relative humidity)



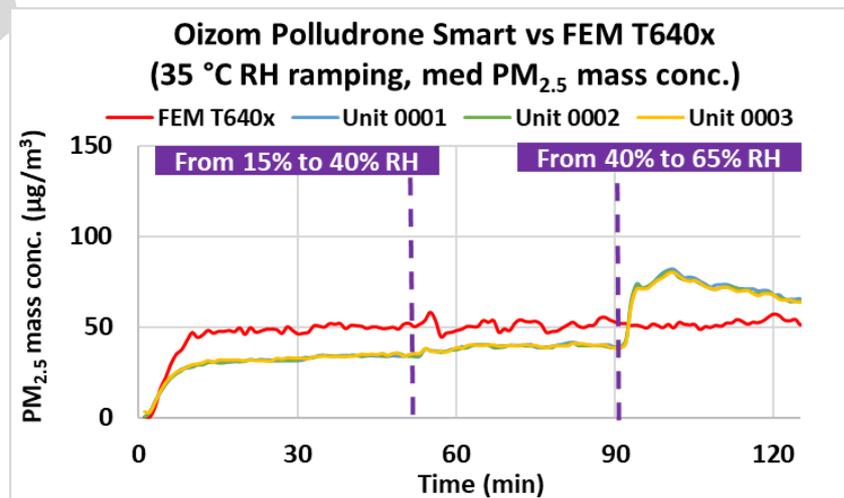
- Overall, the three Polludrone Smart sensors showed high precision for all combinations of PM_{2.5} conc., T, and RH.

Climate Susceptibility: Polludrone Smart (PM_{2.5})

Low Temp - RH ramping
(medium conc.)



High Temp - RH ramping
(medium conc.)



Discussion: PM_{2.5}

- **Accuracy:** The three Polludrone Smart sensors showed accuracy ranged from 34.3% to 67.3%.
- **Precision:** The three Polludrone Smart sensors exhibited high precision during all tested PM_{2.5} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{2.5} measurement variations were observed among the three Polludrone Smart sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM_{2.5} measurements was 100%, 97% and 100% for Units 0001, 0002 and 0003, respectively.
- **Linear Correlation:** The three Polludrone Smart sensors showed very strong correlation/linear response with the corresponding FEM T640x PM_{2.5} measurement data ($R^2 > 0.96$).
- **Climate susceptibility:** During the lab studies, temperature and relative humidity generally had little effect on the precision of PM_{2.5} concentrations as recorded by the Polludrone Smart sensors. The sensors showed spiked concentration change at the 65% RH change point. The sensors showed significant change in concentration at 65% RH at 20 °C and 35 °C.

Discussion: PM_{2.5}

- **Accuracy:** The three Polludrone Smart sensors showed accuracy ranged from 34.3% to 67.3%.
- **Precision:** The three Polludrone Smart sensors exhibited high precision during all tested PM_{2.5} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{2.5} measurement variations were observed among the three Polludrone Smart sensors at 20 °C and 40% RH.
- **Data Recovery:** Data recovery for PM_{2.5} measurements was 100%, 97% and 100% for Units 0001, 0002 and 0003, respectively.
- **Bias:** N/A
- **Detection limit:** The detection limit cannot be estimated due to limitations in the chamber system design.
- **Response time:** Response time could not be studied due to the system design of the chamber system. With a 1.6 m³ chamber volume, it was not possible to reach a high pollutant concentration within a short time.
- **Linear Correlation:** The three Polludrone Smart sensors showed very strong correlation/linear response with the corresponding FEM T640x PM_{2.5} measurement data ($R^2 > 0.96$). (refer to slide 18)
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test
- **Note about PM_{1.0}:** The field evaluation compared the PM_{1.0} values reported from the Polludrone Smart sensors against the field GRIMM and T640 that reported PM_{1.0}. However, PM_{1.0} was not compared in this lab evaluation because at the time of lab testing (before March 2022) the lab T640x firmware upgrade to report PM_{1.0} was not finalized yet.

Discussion: PM_{2.5}

- **Measurement duration:** Polludrone Smart sensors report 1-min averaged values.
- **Measurement frequency:** Polludrone Smart sensors report 1-min averaged values. The obtained data was used as-is for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), but condensed into 5-minute averages for linear correlation studies against the FEM T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the Polludrone Smart sensors were tested in the field for two months. The PM_{2.5} laboratory studies lasted for about 50 days with intermittent non-operating periods and a storage period of ~ 3 months. For PM_{2.5} measurements, all Polludrone Smart sensors maintained their functionalities and operated normally throughout the duration of the testing.
- **Concentration range:** up to 5000 µg/m³ PM_{2.5} concentration as suggested by the manufacturer. During the laboratory evaluation, the Polludrone Smart sensors were challenged with PM_{2.5} concentrations up to 300 µg/m³. (refer to slide 18)
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, temperature and relative humidity generally had little effect on the precision of PM_{2.5} concentrations as recorded by the Polludrone Smart sensors. The sensors showed spiked concentration change at the 65% RH change point. The sensors showed enhancement in PM_{2.5} mass concentration at 65% RH at 20 °C and 35 °C.
- **Response to loss of power:** Polludrone Smart sensors were powered through the entirety of the lab tests.