

Laboratory Evaluation

PurpleAir – PA-II-FLEX



Outline

1. Background
2. $PM_{1.0}$
3. $PM_{2.5}$

DRAFT

Background

Three **PurpleAir PA-II-FLEX** (hereinafter **PA-II-FLEX**) sensors were field-tested at the South Coast AQMD Rubidoux fixed ambient monitoring station (03/17/2022 to 05/24/2022) under ambient environmental conditions. Following field-testing, the same units (except for Unit 7f6d, unit damaged during transport) were evaluated in the South Coast AQMD Sensor Environmental Testing Chamber 2 (SENTEC-2) under controlled artificial aerosol concentration/size range, temperature, and relative humidity.

PA-II-FLEX (2 units tested in the lab):

- Particle sensor: **optical; non-FEM (dual Plantower PMS6003)**
- Each unit reports: $PM_{1.0}$, $PM_{2.5}$ and PM_{10} ($\mu\text{g}/\text{m}^3$)
- Also measures: internal temperature ($^{\circ}\text{F}$) and internal relative humidity (%)
- **Unit cost: \$299**
- Time resolution: 1-min
- Units IDs: Unit #1 (7fd9-a, 7fd9-b); Unit #3 (2bf1-a, 2bf1-b)

Note: each unit has two PM sensors and reports two PM values (Channel A and Channel B. Sensors are named Unit ID-a and Unit ID-b for Channel A and Channel B values, respectively.)

Reference instruments:

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



PurpleAir PA-II-FLEX

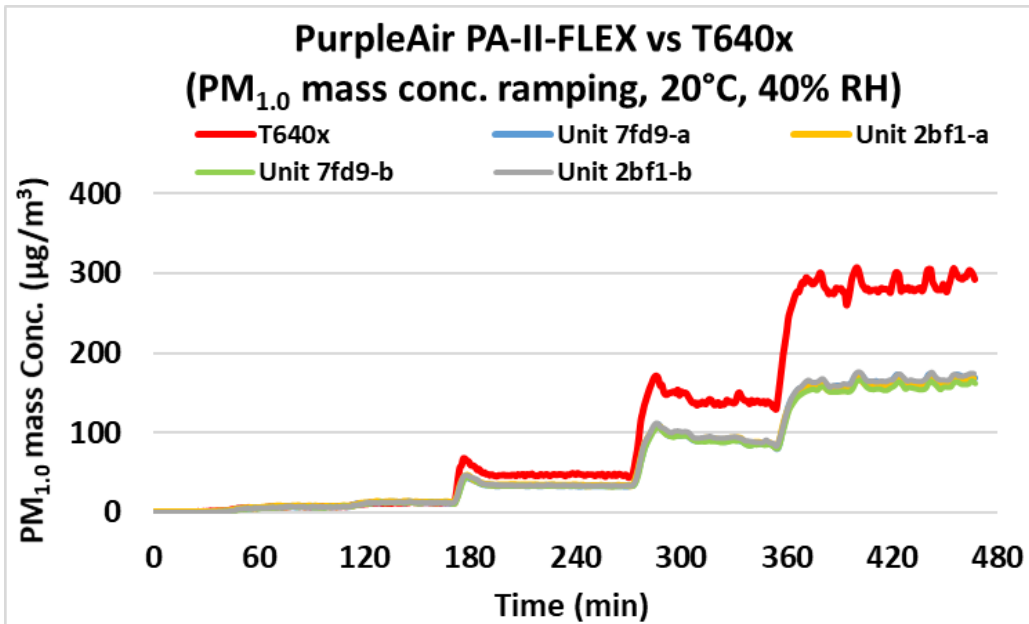


FEM T640x

PM_{1.0}

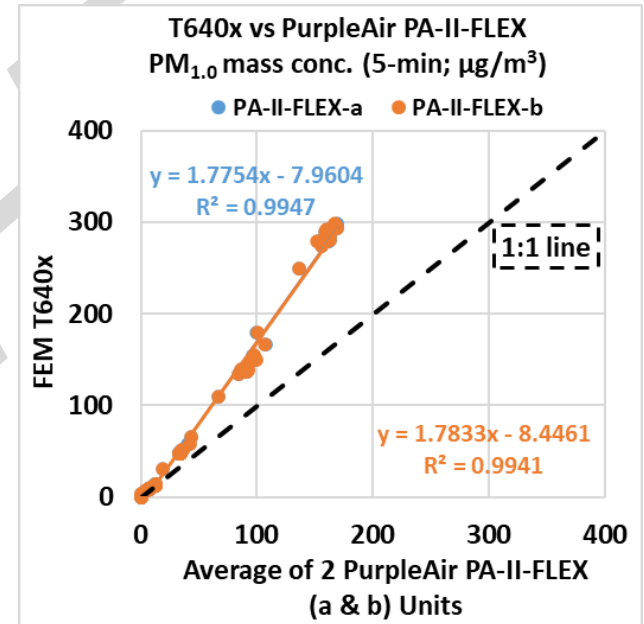
1. **T640x vs PA-II-FLEX**
2. **Accuracy, data recovery and intra-model variability**
3. **Precision**
4. **Climate susceptibility**
5. **Discussion**

PA-II-FLEX vs T640x (PM_{1.0})



- The PA-II-FLEX sensors tracked well with the concentration variation but underestimated PM_{1.0}, compared to the T640x in the concentration range of 0 - 300 µg/m³.

Coefficient of Determination



- The PA-II-FLEX sensors showed very strong correlations with the T640x PM_{1.0} mass conc. ($R^2 > 0.99$)

PA-II-FLEX vs T640x PM_{1.0} Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	a-Sensor Mean (µg/m ³)	T640x (µg/m ³)	Accuracy (%)	Steady State #	b-Sensor Mean (µg/m ³)	T640x (µg/m ³)	Accuracy (%)
1	7.0	8.4	82.7	1	7.2	8.4	84.9
2	12.2	13.1	92.6	2	12.4	13.1	94.5
3	33.2	47.5	70.0	3	33.5	47.5	70.7
4	86.4	138.0	62.6	4	86.6	138.0	62.7
5	166.4	293.3	56.7	5	166.0	293.3	56.6

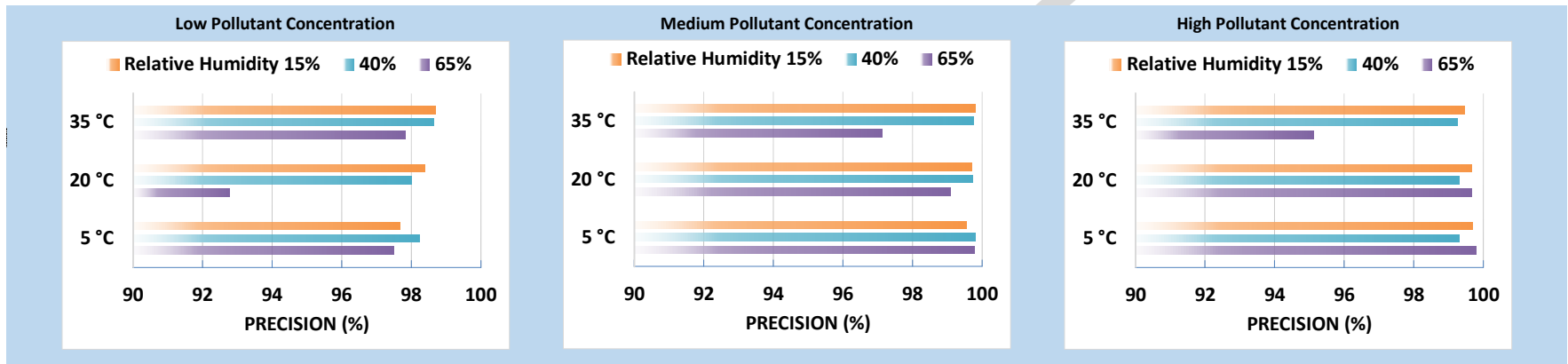
- Overall, the PA-II-FLEX sensors underestimated PM_{1.0} concentration values compared to the T640x PM_{1.0} mass concentration at 20°C and 40% RH. The PA-II-FLEX sensors' accuracy initially increased from 10 to 15 µg/m³ then decreased as concentrations increased from 15 to 300 µg/m³ as compared to the reference T640x. The PA-II-FLEX sensors' accuracy ranged from 56.6% to 94.5% in the range of 10 to 300 µg/m³ as compared to the reference T640x.

PA-II-FLEX Data Recovery and Intra-model Variability

- Data recovery for PM_{1.0} measurements was 100% for all units.
- Low PM_{1.0} concentration variations were observed between the units at 20°C and 40% RH, at low, medium, and high PM_{1.0} as measured by the T640x.

PA-II-FLEX vs T640x (PM_{1.0})

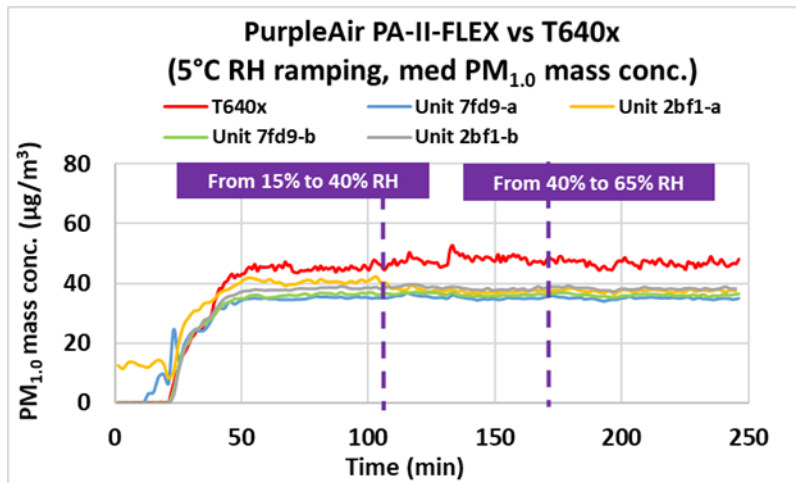
- Precision results from Channel A (effect of PM_{1.0} conc., temperature and relative humidity)



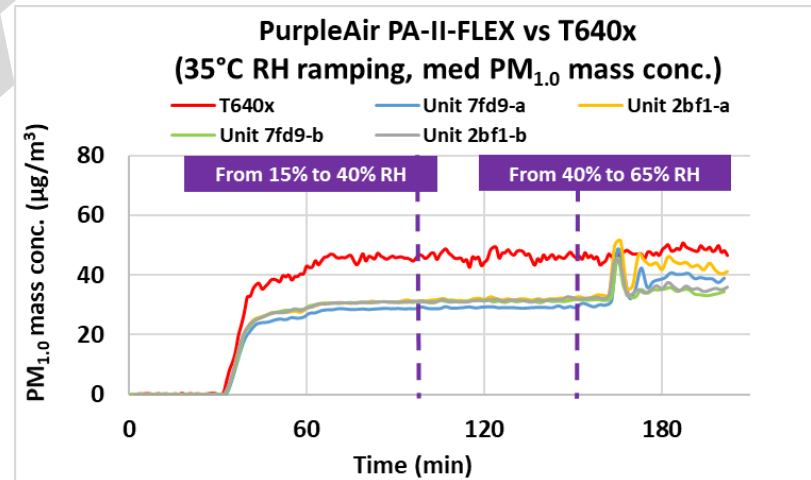
- Overall, PA-II-FLEX sensors showed high precision for all the combinations of low, medium, and high PM_{1.0} conc., T, and RH.

Climate Susceptibility: PA-II-FLEX (PM_{1.0})

Low Temp - RH ramping
(medium conc.)



High Temp - RH ramping
(medium conc.)



Discussion: PM_{1.0}

- **Accuracy:** Overall, the PA-II-FLEX sensors underestimated PM_{1.0} concentration values compared to the T640x PM_{1.0} mass concentration at 20°C and 40% RH. The PA-II-FLEX sensors' accuracy initially increased from 10 to 15 µg/m³ then decreased as concentrations increased from 15 to 300 µg/m³ as compared to the reference T640x. The PA-II-FLEX sensors' accuracy ranged from 56.6% to 94.5% in the range of 10 to 300 µg/m³ as compared to the reference T640x.
- **Precision:** The two PA-II-FLEX sensors exhibited high precision during all tested PM_{1.0} conc., T, and RH conditions.
- **Intra-model variability:** Low PM_{1.0} measurement variations were observed among the two PA-II-FLEX sensors at 20°C and 40% RH.
- **Data Recovery:** Data recovery for PM_{1.0} measurements was 100% for all units.
- **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 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 two PA-II-FLEX sensors showed very strong correlation/linear response with the corresponding T640x PM_{1.0} measurement data ($R^2 > 0.99$).
- **Selectivity:** N/A for PM sensors test
- **Interferences:** N/A for PM sensors test

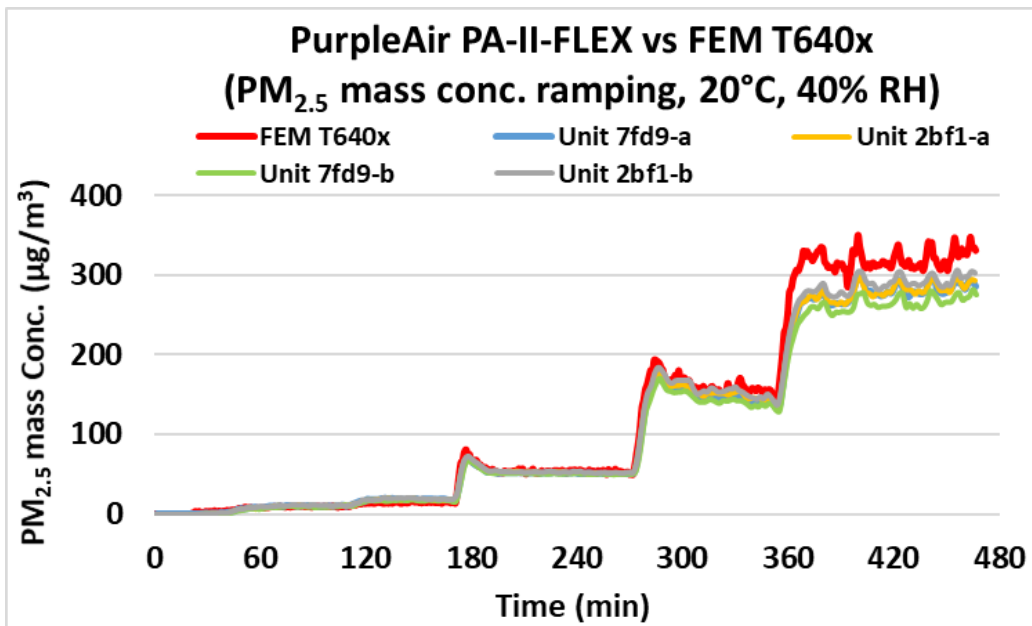
Discussion: PM_{1.0}

- **Measurement duration:** PA-II-FLEX sensors report 2-min averaged values.
- **Measurement frequency:** PA-II-FLEX sensors report 2-min averaged values. The obtained data was used for calculation of statistics (e.g. data recovery, intra-model variability, mean, accuracy, precision), and condensed to 5-minute averages for linear correlation studies against the T640x.
- **Sensor contamination and expiration:** Prior to the laboratory evaluation, the PA-II-FLEX sensors were tested in the field for two months. The PM_{1.0} laboratory studies lasted for about three weeks with intermittent non-operating periods and a storage period of ~12 months.
- **Concentration range:** 0 to 500 µg/m³ as suggested by the manufacturer. During the laboratory evaluation, the PA-II-FLEX sensors were challenged with PM_{1.0} concentrations up to 300 µg/m³.
- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact sensors' precision. Spiked concentrations were observed at the RH change points, especially at the 65% RH change point. The sensors underestimated the PM_{1.0} concentrations at 65% RH at 20°C and 35°C compared to the T640x.
- **Response to loss of power:** PA-II-FLEX sensors were powered through the entirety of the lab tests.

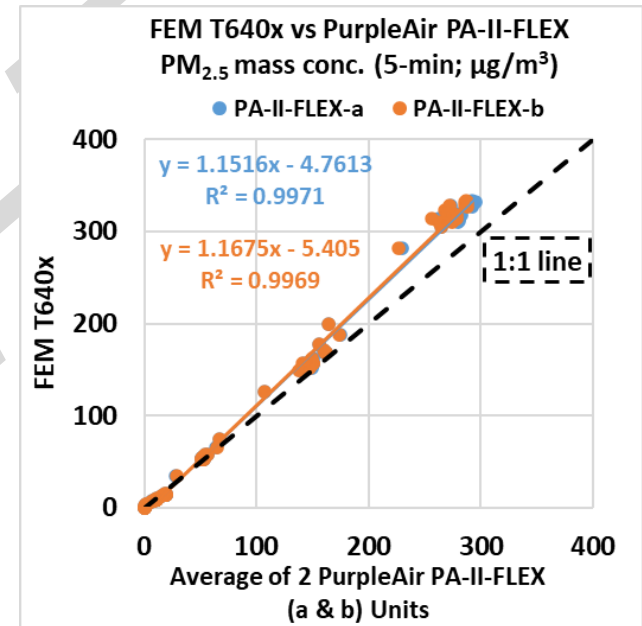
PM_{2.5}

1. **Data recovery and intra-model variability**
2. **FEM T640x vs PA-II-FLEX**
3. **Climate susceptibility**
4. **Accuracy**
5. **Precision**
6. **Discussion**

PA-II-FLEX vs FEM T640x (PM_{2.5})



Coefficient of Determination



- Overall, the PA-II-FLEX sensors overestimated low PM_{2.5} levels (10 to 15 µg/m³) and underestimated high PM_{2.5} levels (50 to 300 µg/m³) compared to the FEM T640x PM_{2.5} mass concentration at 20°C and 40% RH.
- The PA-II-FLEX sensors showed very strong correlations with the FEM T640x PM_{2.5} mass conc. ($R^2 > 0.99$)

PA-II-FLEX vs FEM T640x PM_{2.5} Accuracy

- Accuracy (20 °C and 40% RH)

Steady State #	a-Sensor Mean (µg/m ³)	FEM T640x (µg/m ³)	Accuracy (%)
1	10.5	9.3	87.2
2	18.4	14.3	71.4
3	51.3	52.6	97.6
4	142.1	154.1	92.2
5	287.3	327.1	87.8

Steady State #	b-Sensor Mean (µg/m ³)	FEM T640x (µg/m ³)	Accuracy (%)
1	10.8	9.3	83.4
2	18.4	14.3	71.4
3	51.6	52.6	98.1
4	141.0	154.1	91.4
5	283.8	327.1	86.7

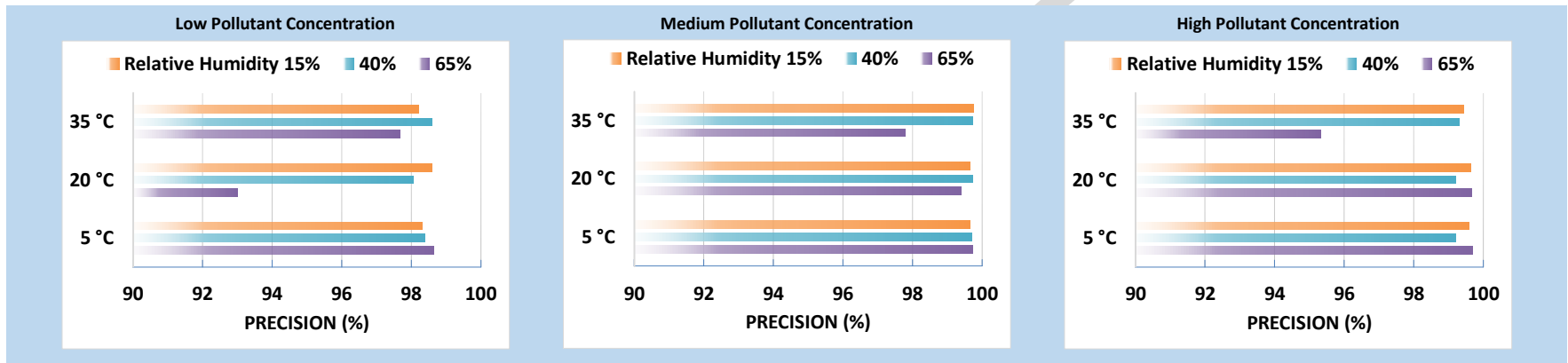
- Overall, the PA-II-FLEX sensors overestimated low PM_{2.5} levels (10 to 15 µg/m³) and underestimated high PM_{2.5} levels (50 to 300 µg/m³) compared to the FEM T640x PM_{2.5} mass concentration at 20°C and 40% RH. The PA-II-FLEX sensors' accuracy ranged from 71.4% to 98.1% in the range of 10 to 300 µg/m³ as compared to the reference FEM T640x.

PA-II-FLEX Data Recovery and Intra-model Variability

- Data recovery for PM_{2.5} measurements was 100% for all units.
- Low PM_{2.5} concentration variations were observed between the units at 20°C and 40% RH, at low, medium, and high PM_{2.5} as measured by the T640x.

PA-II-FLEX vs FEM T640x (PM_{2.5})

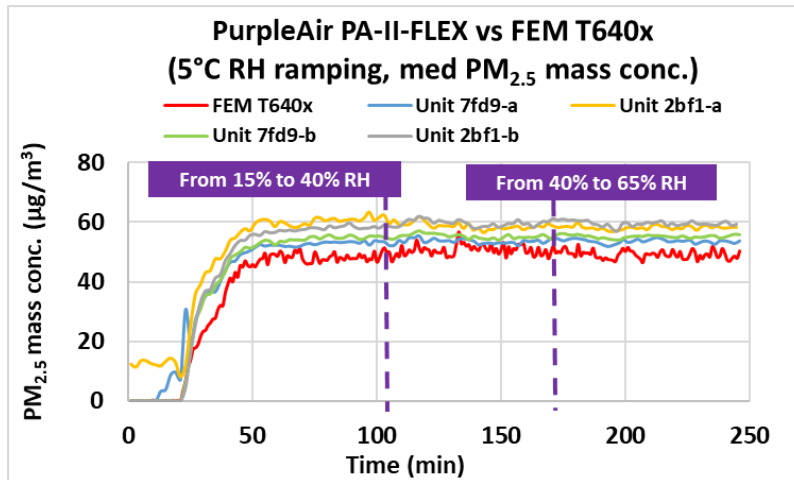
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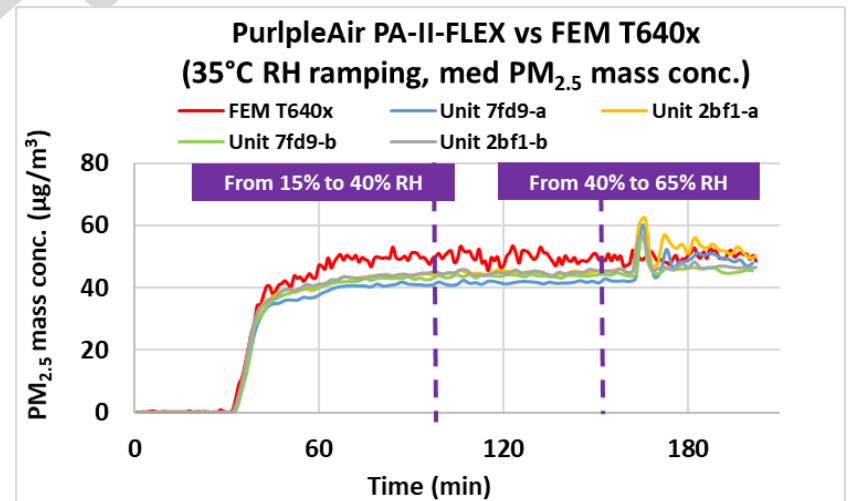
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Climate Susceptibility: PA-II-FLEX (PM_{2.5})

Low Temp - RH ramping
(medium conc.)



High Temp - RH ramping
(medium conc.)



Discussion: PM_{2.5}

- **Accuracy:** Overall, the PA-II-FLEX sensors overestimated low PM_{2.5} levels (10 to 15 µg/m³) and underestimated high PM_{2.5} levels (50 to 300 µg/m³) compared to the FEM T640x PM_{2.5} mass concentration at 20°C and 40% RH. The PA-II-FLEX sensors' accuracy ranged from 71.4% to 98.1% in the range of 10 to 300 µg/m³ as compared to the reference FEM T640x.
- **Precision:** The two PA-II-FLEX 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 two PA-II-FLEX sensors at 20°C and 40% RH.
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- **Linear Correlation:** The two PA-II-FLEX sensors showed very strong correlation/linear response with the corresponding FEM T640x PM_{2.5} measurement data ($R^2 > 0.99$).
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- **Drift:** N/A
- **Climate susceptibility:** During the lab studies, climate did not significantly impact sensors' precision. Spiked concentrations were observed at the RH change points, especially at the 65% RH change point. Increasing RH led to less underestimation compared to the FEM T640x.
- **Response to loss of power:** PA-II-FLEX sensors were powered through the entirety of the lab tests.