Field Evaluation Magnasci SRL uRADMonitor A3 (version HW105) Sensor





Background

- From 10/30/2018 to 01/08/2019, three Magnasci SRL uRADMonitor A3 version HW105 (hereinafter abbreviated as uRADMonitor A3) sensors were deployed at a SCAQMD stationary ambient monitoring site in Rubidoux and were run side-by-side with three reference instruments measuring the same pollutants
- <u>uRADMonitor A3 (3 units tested)</u>:
 - Particle sensor (optical; non-FEM)
 - ➢ PM sensor: Winsen ZH03A
 - Each unit reports: PM_{1.0}, PM_{2.5} and PM₁₀ (µg/m³), Temperature (°F), Relative Humidity (%), barometric pressure (hPa)
 - Each unit also measures: formaldehyde (ppm, electrochemical), carbon dioxide (ppm, nondispersive infrared) and volatile organic compounds (VOC, mg/m³, metal oxide-based)
 - ➤ Unit cost: ~\$500
 - Time resolution: 1- 9 min
 - ➤ Units IDs: 00D3, 00D4, 00D5



- MetOne BAM (reference instrument):
 - Beta-attenuation monitor (FEM PM_{2.5} & PM₁₀)
 - \succ Measures PM_{2.5} & PM₁₀ (µg/m³)
 - ➤ Unit cost: ~\$20,000
 - ➤ Time resolution: 1-hr
- <u>GRIMM (reference instrument)</u>:
 - ➢ Optical particle counter (FEM PM_{2.5})
 - Measures PM_{1.0}, PM_{2.5}, and PM₁₀ (µg/m³)
 - > Cost: ~\$25,000 and up
 - Time resolution: 1-min
 - <u>Teledyne API T640 (reference instrument)</u>:
 - Optical particle counter (FEM PM_{2.5})
 - > Measures $PM_{2.5} \& PM_{10} (\mu g/m^3)$
 - ➤ Unit cost: ~\$21,000
 - Time resolution: 1-min

Data validation & recovery

- Basic QA/QC procedures were used to validate the collected data (i.e. obvious outliers, negative values and invalid data-points were eliminated from the data-set)
- Data recovery from units 00D3, 00D4, and 00D5 is 99.9%, 81.6% and 99.9%, respectively, for all PM fractions. Data recovery is calculated based on the one hour averages due to the fact that the sensors have inconsistent time stamp, limiting comparisons at higher time resolution

uRADMonitor A3; intra-model variability

- Moderate measurement variability (19-25%) was observed between the three uRADMonitor A3 units for $PM_{1.0}$, $PM_{2.5}$ and PM_{10}



Reference Instruments: PM_{2.5} GRIMM, BAM & T640 Data recovery for PM_{2.5} from FEM GRIMM, FEM BAM and FEM T640 is 100 %, 99.6 % and 96.7 %, respectively.

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- Good correlations between the three reference instruments for $PM_{2.5}$ measurements (0.87 < R^2 < 0.95) were observed.



Reference Instruments: PM₁₀ GRIMM, BAM & T640

- Data recovery for PM₁₀ from GRIMM, FEM BAM and T640 is 100 %, 90.4 % and 96.7 %, respectively.
- Good correlations between the three reference instruments for PM₁₀ measurements (0.86 < R² < 0.92) were observed.





uRADMonitor A3 vs GRIMM (PM_{1.0}; 1-hr mean)



- uRADMonitor A3 sensors show good correlations with the corresponding GRIMM data (R² ~ 0.82) when PM_{1.0} mass concentration is > ~10 μg/m³ as recorded by GRIMM.
- Overall, the uRADMonitor A3 sensors underestimate PM_{1.0} mass concentration as measured by GRIMM.
- The uRADMonitor A3 sensors seem to track well the $PM_{1.0}$ diurnal variations when $PM_{1.0}$ mass concentration is > ~10 µg/m³ and report constant values of ~ 2.4 – 3.2 µg/m³ when $PM_{1.0}$ mass concentration is < ~10 µg/m³ as recorded by GRIMM.



uRADMonitor A3 vs FEM GRIMM (PM_{2.5}; 1-hr mean)



- uRADMonitor A3 sensors show good correlations with the corresponding FEM GRIMM data (R² ~ 0.76) when PM_{2.5} mass concentration is > ~15 μg/m³ as recorded by FEM GRIMM
- Overall, the uRADMonitor A3 sensors underestimate the PM_{2.5} mass concentrations measured by FEM GRIMM
- The uRADMonitor A3 sensors seem to track well the $PM_{2.5}$ diurnal variations when $PM_{2.5}$ mass concentration is > ~15 µg/m³ as recorded by FEM GRIMM but report constant values of ~ 2.4-4.4 µg/m³ when mass concentration is < ~15 µg/m³



uRADMonitor A3 vs GRIMM (PM₁₀; 1-hr mean)



uRADMonitor A3 vs GRIMM (PM_{1.0}; 24-hr mean)



- uRADMonitor A3 sensors correlate well with the corresponding GRIMM data ($R^2 \sim 0.85$) when $PM_{1.0}$ mass concentration is > ~ 6 µg/m³ as recorded by GRIMM
- Overall, the uRADMonitor A3 sensors underestimate PM_{1.0} mass concentration as measured by GRIMM
- The uRADMonitor A3 seem to track well the $PM_{1.0}$ concentration variations when $PM_{1.0}$ mass concentration is > ~ 6 µg/m³ as recorded by GRIMM



uRADMonitor A3 vs FEM GRIMM (PM_{2.5}; 24-hr mean)



uRADMonitor A3 vs GRIMM (PM₁₀; 24-hr mean)



- uRADMonitor A3 sensors do not correlate with the corresponding GRIMM data (R² ~ 0.24)
- Overall, the uRADMonitor A3 sensors underestimate the PM₁₀ mass concentrations measured by GRIMM
- The uRADMonitor A3 sensors do not seem to track the PM₁₀ concentration variations as recorded by GRIMM



uRADMonitor A3 vs FEM BAM (PM_{2.5}; 1-hr mean)



- uRADMonitor A3 sensors show good correlations with the corresponding FEM BAM data (R² ~ 0.72) when PM_{2.5} mass concentration is > ~10 µg/m³ as recorded by FEM BAM
- Overall, the uRADMonitor A3 sensors underestimate the PM_{2.5} mass concentrations measured by FEM BAM
- The uRADMonitor A3 seem to track the $PM_{2.5}$ diurnal variations when $PM_{2.5}$ mass concentration is > 10 µg/m³ and report constant values of ~ 2.4 – 3.2 µg/m³ as recorded by FEM BAM.



uRADMonitor A3 vs FEM BAM (PM₁₀; 1-hr mean)



- uRADMonitor A3 sensors do not correlate with the corresponding FEM BAM data (R² ~ 0.20)
- Overall, the uRADMonitor A3 sensors underestimate the PM₁₀ mass concentrations measured by FEM BAM
- The uRADMonitor A3 sensors seem to modestly track the PM_{10} diurnal variations as recorded by FEM BAM when not randomly reporting constant values of ~ $6.9 8.4 \mu g/m^3$



uRADMonitor A3 vs FEM BAM (PM_{2.5}; 24-hr mean)



- uRADMonitor A3 sensors show good correlations with the corresponding FEM BAM data (R² ~ 0.81) when PM_{2.5} mass concentration is > ~10 µg/m³ as recorded by FEM BAM
- Overall, the uRADMonitor A3 sensors slightly underestimate the PM_{2.5} mass concentrations measured by FEM BAM
- The uRADMonitor A3 seem to track the $PM_{2.5}$ concentration variations when $PM_{2.5}$ mass concentration is > ~10 µg/m³ and report constant values of ~2.6 – 4 µg/m³ as recorded by FEM BAM



uRADMonitor A3 vs FEM BAM (PM₁₀; 24-hr mean)



- uRADMonitor A3 sensors do not correlate with the corresponding FEM BAM data (R² ~ 0.34)
- Overall, the uRADMonitor A3 sensors underestimate the PM₁₀ mass concentrations measured by FEM BAM
- The uRADMonitor A3 sensors do not seem to track the PM₁₀ concentration variations as recorded by FEM BAM

 PM_{10} (24-hr mean, $\mu g/m^3$)

y = 1.1716x + 26.594

 $R^2 = 0.3157$

80

Unit 00D5

40

0



uRADMonitor A3 vs FEM T640 (PM_{2.5}; 1-hr mean)



uRADMonitor A3 vs T640 (PM₁₀; 1-hr mean)



- uRADMonitor A3 sensors do not correlate with the corresponding T640 data ($R^2 \sim 0.38$)
- Overall, the uRADMonitor A3 sensors underestimate the PM₁₀ mass concentrations measured by T640
- The uRADMonitor A3 sensors seem to modestly track the PM₁₀ diurnal variations when not reporting constant values of ~ $5.1 - 6.9 \mu g/m^3$

50

0

0

50

100

Unit 00D5

150

 PM_{10} (1-hr mean, $\mu g/m^3$)

y = 1.1467x + 23.983

 $R^2 = 0.3652$



uRADMonitor A3 vs FEM T640 (PM_{2.5}; 24-hr mean)



- uRADMonitor A3 sensors show good correlations with the corresponding FEM T640 data ($R^2 \sim 0.84$) when $PM_{2.5}$ mass concentration is > ~10 µg/m³ as recorded by T640
- Overall, the uRADMonitor A3 sensors underestimate the PM_{2.5} mass concentrations measured by FEM T640
- The uRADMonitor A3 sensors seem to modestly track the PM_{2.5} concentration variations as recorded by FEM T640



uRADMonitor A3 vs T640 (PM₁₀; 24-hr mean)



 uRADMonitor A3 sensors modestly correlate with the corresponding T640 data (R² ~ 0.52)

- Overall, the uRADMonitor A3 sensors underestimate the PM₁₀ mass concentrations measured by T640
- The uRADMonitor A3 sensors seem to track the PM₁₀ concentration variations when PM_{2.5} mass concentration is > ~40 µg/m³ as recorded by T640

 PM_{10} (24-hr mean, $\mu g/m^3$)

40

0

v = 1.4248x + 20.993

 $R^2 = 0.4976$

80

Unit 00D5



uRADMonitor A3 vs SCAQMD Met Station (Temp; 1-hr mean)



- uRADMonitor A3 temperature measurements correlate very well with the corresponding SCAQMD Met Station data (R² ~ 0.97)
- Overall, the uRADMonitor A3 temperature measurements seem to be quite accurate
- The uRADMonitor A3 sensors seem to track well the temperature diurnal variations as recorded by SCAQMD Met Station



uRADMonitor A3 vs SCAQMD Met Station (RH; 5-min mean)



- The uRADMonitor A3 RH measurements correlate very well with the corresponding SCAQMD Met Station data (R² ~ 0.98)
- Overall, the uRADMonitor A3 RH measurements underestimate at RHs > 40% and overestimate at RHs < 40%, as recorded by the SCAQMD Met Station
- The uRADMonitor A3 sensors seem to track well the RH diurnal variations as recorded by SCAQMD Met Station



Discussion

- The three uRADMonitor A3 sensors' data recovery from units 00D3, 00D4, and 00D5 is 99.9%, 81.6% and 99.9%, respectively, for all PM fractions. Data recovery is calculated based on the one hour averages due to the fact that the sensors have inconsistent time stamp, limiting comparisons at higher time resolution
- The three sensors showed moderate intra-model variability (19% to 25%)
- The reference instruments (GRIMM, BAM and T640) correlate well with each other for both PM_{2.5} (R² ~ 0.91) and PM₁₀ (R² ~ 0.90) mass concentration measurements (1-hr mean)
- PM sensor data is accessed via analog, converting sensor voltage readings to mass concentrations in µg/m³; this represents PM_{2.5} mass concentrations, PM_{1.0} and PM₁₀ mass concentrations are extrapolated from PM_{2.5} values using a linear model. The analog readings will impose some limitation on resolution and limits of detection for PM mass concentrations.
- PM_{1.0} mass concentration measurements measured by uRADMonitor A3 sensors correlate well with the corresponding GRIMM values (R² ~ 0.82, 1-hr mean) when PM_{1.0} mass concentration is > ~10 µg/m³ and underestimate PM_{1.0} mass concentration measured by the GRIMM
- PM_{2.5} mass concentration measurements measured by uRADMonitor A3 sensors show good correlations with the corresponding FEM GRIMM, FEM BAM and FEM T640 (R² ~ 0.76, 0.72 and 0.81, respectively, 1-hr mean) when PM_{2.5} mass concentration is > ~10 20 µg/m³ and underestimate PM_{2.5} mass concentration measured by the FEM GRIMM, FEM BAM and FEM T640
- PM₁₀ mass concentration measurements measured by uRADMonitor A3 sensors do not correlate with the corresponding GRIMM, FEM BAM and T640 (R² ~ 0.15, 0.20 and 0.38, respectively, 1-hr mean) and underestimate PM₁₀ mass concentration measured by the reference instruments
- No sensor calibration was performed by SCAQMD Staff prior to the beginning of this test
- Laboratory chamber testing is necessary to fully evaluate the performance of these sensors under known aerosol concentrations and controlled temperature and relative humidity conditions
- All results are still preliminary