# Supplementary Materials

# Intercomparison of PurpleAir Sensor Performance over Three Years Indoors and Outdoors at a Home: Bias, Precision, and Limit of Detection Using an Improved Algorithm for Calculating PM$_{2.5}$

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**Figure S1.** Indoor PurpleAir monitors 1, 3, & 4. These are mounted on a cart and are 1.0 m high. Behind them are three SidePak monitors used as reference instruments during 47 experiments during the 3-year study.

**Figure S2.** Outdoor PurpleAir monitor attached to bracket mounted 2.0 m from the ground.

**Figure S3.** Miniature pans used to heat various foods. Coated pan at top, cast iron at bottom, stainless steel at right.

Figure S4 is the basis for the determination of the calibration factor (CF3) for indoor PA-II PurpleAir monitors. The value of 3.0 for the CF is based on a side-by-side comparison with a research monitor (SidePak) over 47 experiments with an indoor aerosol mixture of PM2.5 created by normal indoor activities together with exhaled breath PM2.5 from vaping liquid marijuana. The SidePak CF of 0.44 was based on 8 gravimetric analyses using a pump-filter combination and a microbalance to weigh the filter. Data shown has been calculated from the original data underlying the peer-reviewed publication: Wallace, L., Ott, W., Zhao, T., Cheng, K-C, and Hildemann, L. (2020). Secondhand exposure from vaping marijuana: Concentrations, emissions, and exposures determined using both research-grade and low-cost monitors, *Atmospheric Environment X*. Volume 8, December 2020, 100093.
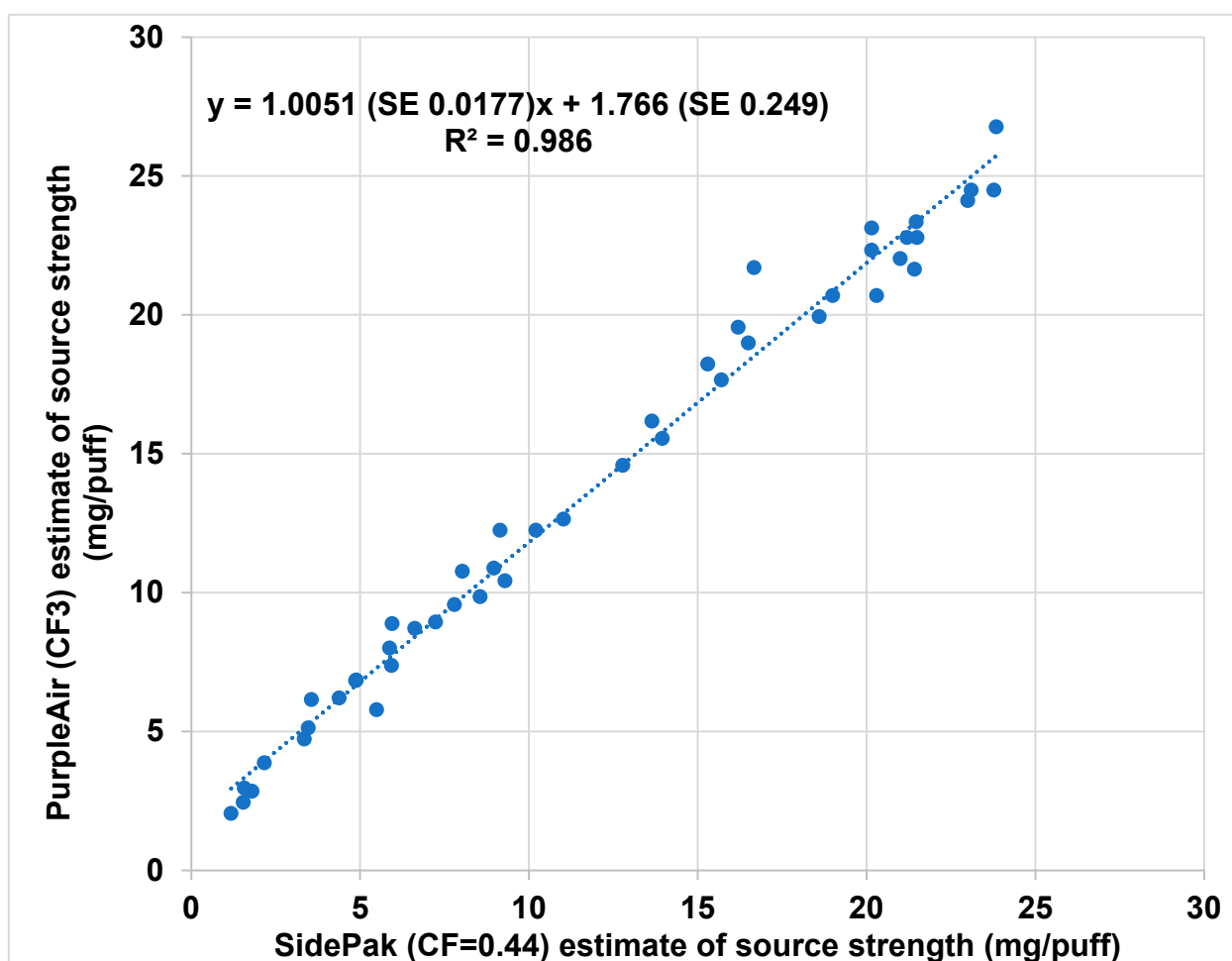


**Figure S4.** Regression of PurpleAir monitor (CF3) against SidePak monitor (CF0.44). Source: data from Wallace, L., Ott, W., Zhao, T., Cheng, K-C, and Hildemann, L. (2020). Secondhand exposure from vaping marijuana: Concentrations, emissions, and exposures determined using both research-grade and low-cost monitors, *Atmospheric Environment X*, https://doi.org/10.1016/j.aeaoa.2020.100093 (accessd on 2 February 2022).

**Table S1.** Estimates of PM2.5 concentration ($\mu g/m^3$) comparing the ALT-CF3 algorithm to the Plantower CF1 algorithm. Time period: 10 January 2019 to 14 January 2022. Monitors 1 & 2.

| | Valid N | Mean | Std. Err. | Lower Quartile | Median | Upper Quartile | 90th %tile | Max |
|---|---|---|---|---|---|---|---|---|
| **PurpleAir ALT-CF3 algorithm** | | | | | | | | |
| *Monitor 1 indoors* | | | | | | | | |
| 1a PM2.5 | 763102 | 3.9 | 0.02 | 0.64 | 1.4 | 2.7 | 6 | 1061 |
| 1b PM2.5 | 763102 | 3.8 | 0.02 | 0.63 | 1.3 | 2.7 | 5 | 1048 |
| Mean 1 PM2.5 | 763102 | 3.9 | 0.02 | 0.63 | 1.3 | 2.7 | 6 | 1043 |
| *Monitor 2 indoors* | | | | | | | | |
| 2a PM2.5 | 499296 | 4.6 | 0.03 | 0.83 | 1.6 | 3.0 | 6 | 1055 |
| 2b PM2.5 | 499296 | 4.5 | 0.02 | 0.87 | 1.7 | 3.0 | 6 | 908 |
| Mean 2 PM2.5 | 499296 | 4.5 | 0.02 | 0.86 | 1.7 | 3.0 | 6 | 981 |
| *Monitor 2 outdoors* | | | | | | | | |
| 2a PM2.5 | 242663 | 4.8 | 0.02 | 1.2 | 2.4 | 4.4 | 9 | 465 |
| 2b PM2.5 | 242663 | 4.9 | 0.02 | 1.1 | 2.3 | 4.3 | 10 | 473 |
| Mean 2 PM2.5 | 242663 | 4.8 | 0.02 | 1.2 | 2.4 | 4.4 | 9 | 469 |
| **Plantower CF1 algorithm** | | | | | | | | |
| *Monitor 1 indoors* | | | | | | | | |
| 1a PM2.5 | 758867 | 5.9 | 0.03 | 0.2 | 1.4 | 3.8 | 8.6 | 2312 |
| 1b PM2.5 | 763018 | 6.0 | 0.03 | 0.2 | 1.4 | 3.8 | 8.6 | 2582 |
| Mean 1 PM2.5 | 763070 | 6.0 | 0.03 | 0.21 | 1.4 | 3.8 | 8.6 | 2582 |
| *Monitor 2 indoors* | | | | | | | | |
| 2a PM2.5 | 493918 | 7.3 | 0.05 | 0.5 | 1.9 | 4.3 | 9.3 | 2806 |
| 2b PM2.5 | 499251 | 6.6 | 0.04 | 0.1 | 1.1 | 3.5 | 8.6 | 2300 |
| Mean 2 PM2.5 | 499275 | 7.0 | 0.05 | 0.31 | 1.5 | 3.9 | 8.9 | 2521 |
| *Monitor 2 outdoors* | | | | | | | | |
| 2a PM2.5 | 242541 | 8.4 | 0.04 | 1.3 | 3.5 | 7.5 | 17 | 791 |
| 2b PM2.5 | 242656 | 7.4 | 0.04 | 0.45 | 2.5 | 6.2 | 16 | 817 |
| Mean 2 PM2.5 | 242662 | 7.9 | 0.04 | 0.87 | 3.0 | 6.9 | 17 | 804 |

**Table S2.** Estimates of PM2.5 concentration ($\mu g/m^3$) comparing the ALT-CF3 algorithm to the Plantower CF1 algorithm. Time period: 18 June 2020 to 14 January 2022. Monitors 3 & 4.

| | N obs. | Mean | SE | Lower Quartile | Median | Upper Quartile | 90th %tile | Max |
|---|---|---|---|---|---|---|---|---|
| **ALT-CF3 algorithm** | | | | | | | | |
| *Monitor 3 outdoors* | | | | | | | | |
| 3a PM2.5 | 356484 | 5.5 | 0.02 | 1.2 | 2.5 | 4.8 | 10 | 421 |
| 3b PM2.5 | 356484 | 5.9 | 0.02 | 1.3 | 2.6 | 5.2 | 10 | 472 |
| Mean 3 PM2.5 | 356484 | 5.7 | 0.02 | 1.3 | 2.6 | 5.0 | 10 | 444 |
| *Monitor 3 indoors* | | | | | | | | |
| 3a PM2.5 | 42204 | 7.5 | 0.08 | 2.3 | 3.8 | 7.9 | 15 | 322 |
| 3b PM2.5 | 42204 | 7.8 | 0.08 | 2.3 | 4.0 | 8.4 | 16 | 316 |
| Mean 3 PM2.5 | 42204 | 7.6 | 0.08 | 2.3 | 3.9 | 8.2 | 15 | 319 |
| *Monitor 4 indoors* | | | | | | | | |
| 4a PM2.5 | 370906 | 3.5 | 0.02 | 0.70 | 1.5 | 3.0 | 6 | 558 |
| 4b PM2.5 | 370906 | 3.7 | 0.02 | 0.74 | 1.6 | 3.3 | 7 | 508 |
| Mean 4 PM2.5 | 370906 | 3.6 | 0.02 | 0.73 | 1.6 | 3.1 | 6 | 526 |
| **Plantower CF1 algorithm** | | | | | | | | |
| *Monitor 3 outdoors* | | | | | | | | |
| 3a PM2.5 | 356473 | 8.4 | 0.04 | 1.3 | 3.3 | 7.2 | 16 | 718 |
| 3b PM2.5 | 356473 | 9.9 | 0.04 | 1.4 | 3.9 | 8.5 | 18 | 759 |
| Mean 3 | 356483 | 9.1 | 0.04 | 1.3 | 3.6 | 7.8 | 17 | 738 |
| *Monitor 3 indoors* | | | | | | | | |
| 3a PM2.5 | 42184 | 11.2 | 0.12 | 2.7 | 5.2 | 12.1 | 23 | 506 |
| 3b PM2.5 | 42202 | 13.1 | 0.14 | 3.2 | 6.1 | 13.9 | 27 | 606 |
| Mean 3 | 42203 | 12.1 | 0.13 | 3.0 | 5.6 | 13.0 | 25 | 556 |
| *Monitor 4 indoors* | | | | | | | | |
| 4a PM2.5 | 370888 | 5.0 | 0.03 | 0.28 | 1.6 | 4.1 | 9 | 921 |
| 4b PM2.5 | 370897 | 5.8 | 0.03 | 0.35 | 1.9 | 4.9 | 11 | 891 |
| Mean 4 | 370904 | 5.6 | 0.03 | 0.33 | 1.8 | 4.6 | 10 | 891 |

**Table S3.** Mean PM2.5 concentrations (ug/m3) and relative bias for the ALT-CF3 algorithm.

| | N obs. | Mean | SE | RSE | Bias |
|---|---|---|---|---|---|
| 1a PM2.5 CF3 IN | 353256 | 3.38 | 0.016 | 0.0049 | 1.031 |
| 1b PM2.5 CF3 IN | 353256 | 3.18 | 0.015 | 0.0049 | 0.969 |
| Mean 1 CF3 IN | 353256 | 3.28 | 0.023 | 0.0069 | |
| 4a PM2.5 CF3 IN | 353256 | 3.65 | 0.018 | 0.0049 | 0.970 |
| 4b PM2.5 CF3 IN | 353256 | 3.88 | 0.019 | 0.0048 | 1.030 |
| Mean 4 CF3 IN | 353256 | 3.77 | 0.026 | 0.0068 | |
| 2a PM2.5  CF3 IN | 117804 | 3.31 | 0.018 | 0.0054 | 0.953 |
| 2b PM2.5 CF3 IN | 117804 | 3.64 | 0.020 | 0.0055 | 1.047 |
| Mean 2 CF3 IN | 117804 | 3.48 | 0.027 | 0.0077 | |
| 2a PM2.5 CF3 OUT | 242663 | 4.82 | 0.020 | 0.0042 | 0.995 |
| 2b PM2.5 CF3 OUT | 242663 | 4.87 | 0.021 | 0.0043 | 1.005 |
| Mean 2 CF3 OUT | 242663 | 4.85 | 0.029 | 0.0060 | |
| 3a PM2.5 CF3 OUT | 356484 | 5.54 | 0.022 | 0.0039 | 0.965 |
| 3b PM2.5 CF3 OUT | 356484 | 5.94 | 0.023 | 0.0039 | 1.035 |
| Mean 3 OUT CF3 | 356484 | 5.74 | 0.032 | 0.0056 | |

**Table S4.** Mean PM2.5 concentrations and relative bias for the Plantower CF1 algorithm.

| | N obs | Mean | SE | RSE | Bias |
|---|---|---|---|---|---|
| 1a PM2.5_CF1 IN | 242553 | 7.07 | 0.040 | 0.0056 | 1.012 |
| 1b PM2.5_CF1 IN | 242553 | 6.90 | 0.040 | 0.0058 | 0.988 |
| Mean 1 CF1 IN | 242553 | 6.98 | 0.057 | 0.0081 | |
| 4a PM2.5_CF1 IN | 240097 | 7.54 | 0.043 | 0.0057 | 0.937 |
| 4b PM2.5 CF1 IN | 240097 | 8.55 | 0.049 | 0.0057 | 1.063 |
| Mean 4 CF1 IN | 240097 | 8.05 | 0.065 | 0.0080 | |
| 2a PM2.5_CF1 IN | 64344 | 8.59 | 0.056 | 0.0066 | 0.994 |
| 2b PM2.5_CF1 IN | 64344 | 8.70 | 0.060 | 0.0069 | 1.006 |
| Mean 2 CF1 IN | 64344 | 8.65 | 0.082 | 0.0095 | |
| 2a PM2.5_CF1 OUT | 129081 | 14.00 | 0.067 | 0.0048 | 1.038 |
| 2b PM2.5_CF1 OUT | 129081 | 12.98 | 0.068 | 0.0053 | 0.962 |
| Mean 2 CF1 OUT | 129081 | 13.49 | 0.096 | 0.0071 | |
| 3a PM2.5_CF1 OUT | 278256 | 10.48 | 0.045 | 0.0043 | 0.918 |
| 3b PM2.5_CF1 OUT | 278256 | 12.35 | 0.054 | 0.0044 | 1.082 |
| Mean 3 CF1 OUT | 278256 | 11.41 | 0.070 | 0.0061 | |

**Table S5.** Precision comparing the ALT-CF3 algorithm to the Plantower CF1 algorithm. Time period: 18 June 2020 to 14 January 2022. Monitors 3 & 4.

| | N obs. | Mean | SE | Lower Quartile | Median | Upper Quartile | 90th %tile | Max |
|---|---|---|---|---|---|---|---|---|
| **ALT-CF3 algorithm using precision cutoff at 0.2** | | | | | | | | |
| Monitor 3 outdoors | 356484 | 0.06 | 7.E−05 | 0.02 | 0.05 | 0.08 | 0.12 | 0.20 |
| Monitor 3 indoors | 42204 | 0.04 | 2.E−04 | 0.02 | 0.04 | 0.06 | 0.09 | 0.20 |
| Monitor 4 indoors | 370906 | 0.07 | 8.E−05 | 0.03 | 0.06 | 0.10 | 0.14 | 0.20 |
| **Plantower CF1 algorithm using the ALT-CF3 precision cutoff at 0.2** | | | | | | | | |
| Monitor 3 outdoors | 343593 | 0.16 | 3.E−04 | 0.06 | 0.10 | 0.17 | 0.31 | 1 |
| Monitor 3 indoors | 42041 | 0.10 | 4.E−04 | 0.05 | 0.08 | 0.12 | 0.17 | 1 |
| Monitor 4 indoors | 324460 | 0.20 | 5.E−04 | 0.05 | 0.10 | 0.21 | 1 | 1 |
| **Plantower CF1 algorithm using the CF1 precision cutoff at 0.2** | | | | | | | | |
| Monitor 3 outdoors | 278256 | 0.09 | 9.E−05 | 0.05 | 0.08 | 0.12 | 0.16 | 0.20 |
| Monitor 3 indoors | 39011 | 0.08 | 2.E−04 | 0.05 | 0.08 | 0.11 | 0.14 | 0.20 |
| Monitor 4 indoors | 240097 | 0.08 | 1.E−04 | 0.04 | 0.08 | 0.12 | 0.16 | 0.20 |