

Multi-Parameter Characterization of Indoor Air Quality in a Medical Marijuana Cultivation Facility in Oklahoma: A Pilot Study of Occupational Exposure Determinants

Hongwan Li^{1*}, Yao Yang¹, Anni Yang², Wenwen Cheng³

¹Department of Occupational and Environmental Health, Hudson College of Public Health, The University of Oklahoma Health Campus, Oklahoma City, OK, 73104, USA

²Department of Geography and Environmental Sustainability, College of Atmospheric and Geographic Sciences, University of Oklahoma, Norman, OK, 73019, USA

³Department of Planning and Landscape Architecture, University of Wisconsin-Madison, Madison, WI 53706, USA

*Corresponding author: Hongwan Li, Department of Occupational and Environmental Health, Hudson College of Public Health, The University of Oklahoma Health Campus, Oklahoma City, OK, 73104, USA, hongwan-li@ou.edu

Supplementary Information

Table S1. Facility-provided crop-stage and operational timeline

Period	Crop Stage / Activity
July 10 to July 15	Early flowering
July 15 to July 27	Early-to-mid flowering transition
July 27	Trimming, defoliation, or canopy-maintenance event during flowering
July 27 to August 1	Continued mid-flowering, with established bud development

Table S2. Extended descriptive statistics for gaseous pollutants and particulate matter size fractions measured by TSI BlueSky and PurpleAir sensors, including skewness and kurtosis.

Sensor	Parameter	Unit	N	Mean	SD	Median	P5	P25	P75	P95	Min	Max	Skewness	Kurtosis
TSI-01	CO	ppm	20896	1.6	1.49	1.4	0.3	1	1.8	3.3	0.2	17.6	6.32	53.71
TSI-01	NO2	ppb	20896	48.91	37.2	41	0	22	73	114	0	288	1.21	2.53
TSI-01	O3	ppb	20896	0.09	1.14	0	0	0	0	0	0	30	16.29	310.3
TSI-01	SO2	ppb	20896	14.47	30.4	10	1	6	15	40	0	665	14.5	259.3
TSI-01	tVOC	mg/m ³	20896	1.42	1.21	1.02	0.02	0.67	2.17	3.72	0	8.2	1.32	2.3
TSI-01	EtOH	ppb	20896	757.03	646.15	543	10	359	1156	8.25	0	4359	1.32	2.3
TSI-01	PM1	µg/m ³	20896	65.47	701.97	2	1	2	3	5	0	10869	12.32	158.44
TSI-01	PM2.5	µg/m ³	20896	159.05	192.143	2	1	2	3	5	0	34953	14.17	212.39
TSI-01	PM4	µg/m ³	20896	233.08	290.616	2	1	2	3	5	0	54290	14.57	224.52
TSI-01	PM10	µg/m ³	20896	269.93	339.716	2	1	2	3	5	0	63913	14.68	227.91
TSI-02	CO	ppm	31074	2.86	2.55	2.2	0.6	1.3	3.3	8.1	0.2	19.4	2.63	9.31
TSI-02	NO2	ppb	31074	7.34	20.95	0	0	0	1	45	0	250	5.05	35.51
TSI-02	O3	ppb	31074	15.63	16.78	11	0	7	21	42	0	111	2.55	8.42
TSI-02	SO2	ppb	31074	22.98	26.61	20	2	10	29	58	0	596	9.43	139.72
TSI-02	tVOC	mg/m ³	31074	3.61	4.69	1.34	0.02	0.73	4.3	15.19	0	30.23	1.78	2.34
TSI-02	EtOH	ppb	31074	1917.99	249.398	711	10	387	2289.75	808.135	0	16079	1.78	2.34
TSI-02	PM1	µg/m ³	31074	69.66	580.52	2	0	1	2	4	0	6894	9.37	89.56
TSI-02	PM2.5	µg/m ³	31074	184.69	183.51	2	0	1	3	4	0	30070	11.73	145.2
TSI-02	PM4	µg/m ³	31074	275	285.674	2	0	1	3	4	0	48597	12.19	156.52
TSI-02	PM10	µg/m ³	31074	320.31	337.094	2	0	1	3	4	0	57891	12.31	159.56
PA-01	PM1 (Ch.A)	µg/m ³	14613	11.23	78.97	2.57	0.04	1.22	4.07	8.08	0	4557.28	30.43	1402.96
PA-01	PM2.5 (Ch.A)	µg/m ³	14613	36.51	240.69	3.12	0.17	1.54	4.87	9.68	0	4655.51	8.25	74.36
PA-01	PM10 (Ch.A)	µg/m ³	14613	136.84	119.668	3.42	0.22	1.73	5.17	9.92	0	1613.012	10.52	116.48
PA-01	PM1 (Ch.B)	µg/m ³	14613	17.13	194.79	2.07	0	0.78	3.52	7.42	0	4715.19	21.65	493.42
PA-01	PM2.5 (Ch.B)	µg/m ³	14613	36.78	269.06	2.64	0	1.08	4.32	8.51	0	4715.19	11.05	150.48
PA-01	PM10 (Ch.B)	µg/m ³	14613	124.33	107.706	2.98	0	1.31	4.69	8.94	0	1496.775	10.6	119.48
PA-02	PM1 (Ch.A)	µg/m ³	16157	15.31	216.8	0.97	0	0.09	2.14	4.56	0	5007.85	21.64	479.74
PA-02	PM2.5 (Ch.A)	µg/m ³	16157	30.98	263.98	1.39	0	0.34	2.75	5.71	0	5007.85	13.65	224.7
PA-02	PM10 (Ch.A)	µg/m ³	16157	112.05	101.168	1.91	0	0.65	3.3	6.69	0	1484.714	10.9	126.92
PA-02	PM1 (Ch.B)	µg/m ³	16157	14.99	181.47	2.43	0	1.21	3.79	7	0	5009.02	25.29	675.7
PA-02	PM2.5 (Ch.B)	µg/m ³	16157	33.71	254.21	3.05	0	1.6	4.73	8.76	0	5009.02	12.26	192.76
PA-02	PM10 (Ch.B)	µg/m ³	16157	123.66	111.055	3.39	0.03	1.81	5.12	9.48	0	1563.616	10.9	125.72

Table S3. Pearson correlation matrix for CO2 measurements across all sensors using hourly-averaged data.

	CO2_01	CO2_02	CO2_03	TSI-01 CO2	TSI-02 CO2
CO2_01	1	0.996	0.996	0.448	0.289
CO2_02	0.996	1	0.999	0.443	0.282
CO2_03	0.996	0.999	1	0.275	0.183
TSI-01 CO2	0.448	0.443	0.275	1	0.994
TSI-02 CO2	0.289	0.282	0.183	0.994	1

Table S4. Complete-case Pearson correlation matrix for hourly CO2 measurements

Sensor	CO2_01	CO2_02	CO2_03	TSI-01 CO2	TSI-02 CO2
CO2_01	1.000	0.998	0.971	-0.496	-0.381
CO2_02	0.998	1.000	0.974	-0.501	-0.387
CO2_03	0.971	0.974	1.000	-0.492	-0.396
TSI-01 CO2	-0.496	-0.501	-0.492	1.000	0.956
TSI-02 CO2	-0.381	-0.387	-0.396	0.956	1.000

Table S5. Largest PM2.5 event hours and coincident TSI CO2.

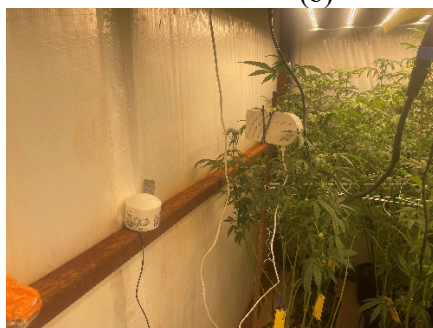
Local hour	Max PM2.5 (ug/m3)	Mean TSI CO2 (ppm)	TSI-01 PM2.5 max	TSI-02 PM2.5 max
2023-07-27 16:00	34953	663	34953	26982
2023-07-27 17:00	25587	824	25587	19420
2023-07-27 18:00	10730	968	10730	7978
2023-07-27 19:00	3650	975	3650	2937



(a)



(b)



(c)

Figure S1. Photo of (a) TSI AirAssure monitor; (b) Aranet4 CO₂ monitor; and (c) PurpleAir PA-II-FLEX monitor.

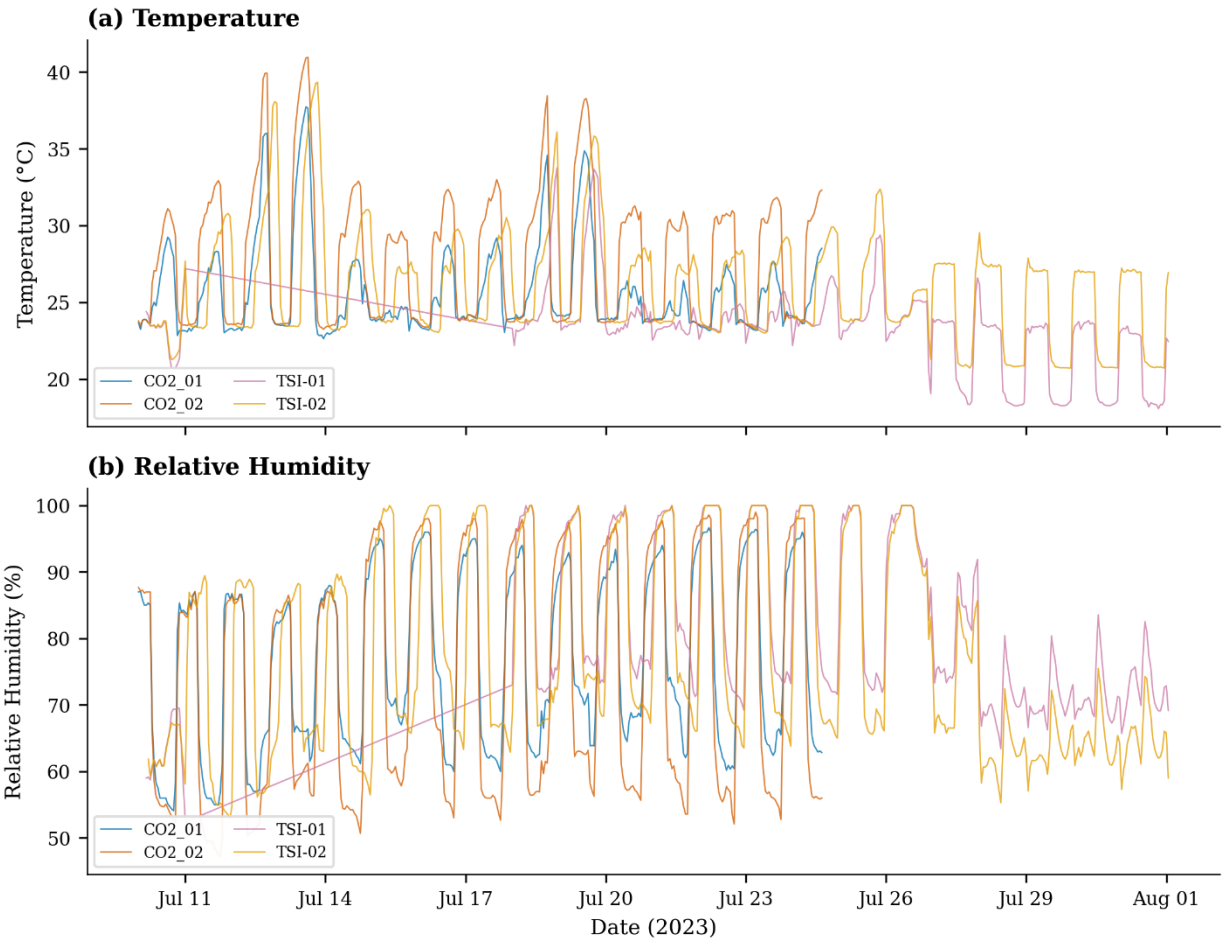


Figure S2. Time series of indoor (a) temperature (degrees C) and (b) relative humidity (%) measured by Aranet4 (CO2_01, CO2_02) and TSI AirAssure (TSI-01, TSI-02) sensors during the monitoring campaign (hourly means, gap-aware).

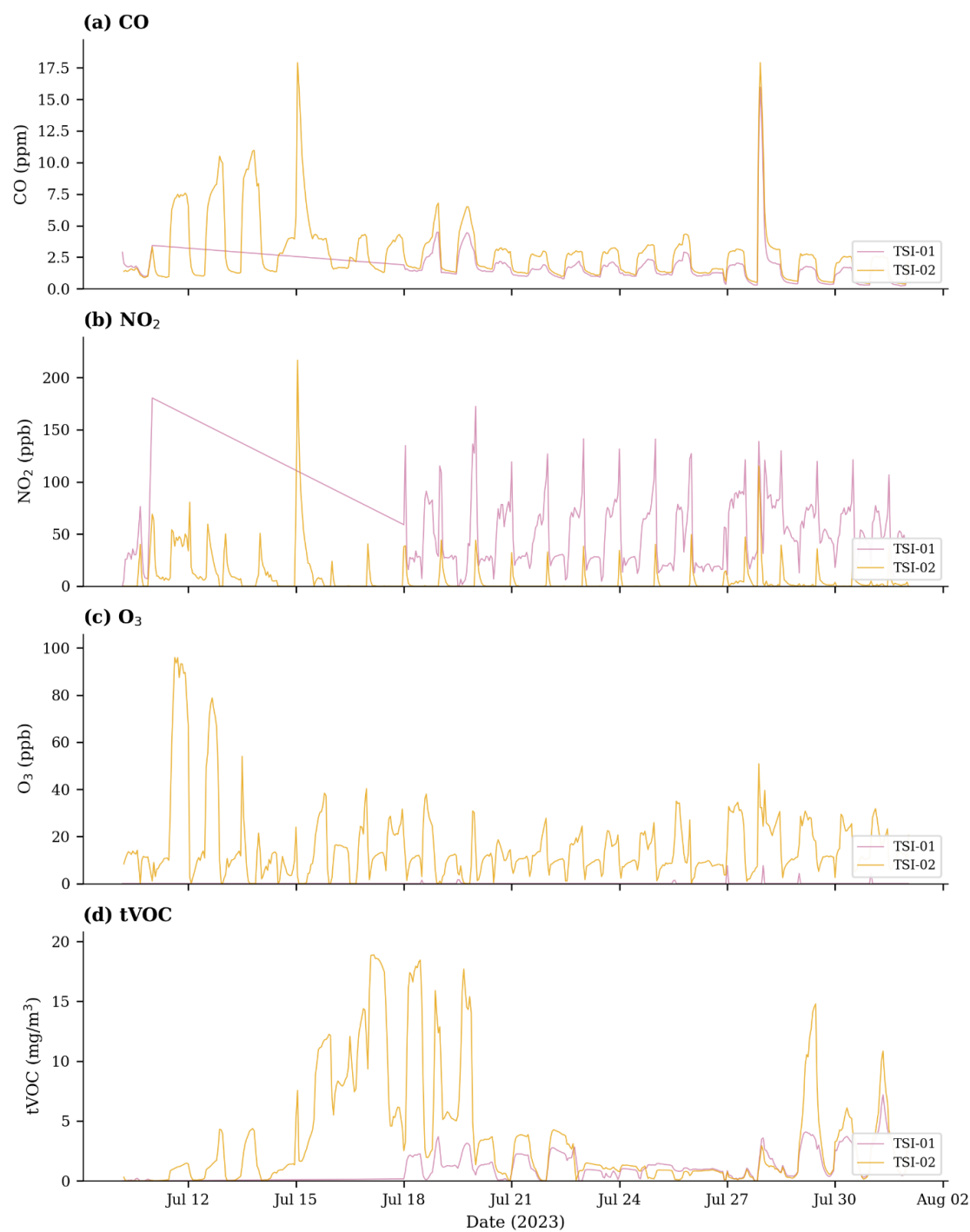


Figure S3. Time series of gaseous pollutant concentrations measured by TSI AirAssure sensors (hourly means, gap-aware): (a) carbon monoxide (CO, ppm), (b) nitrogen dioxide (NO₂, ppb), (c) ozone (O₃, ppb), and (d) total volatile organic compounds (tVOC, mg/m³).

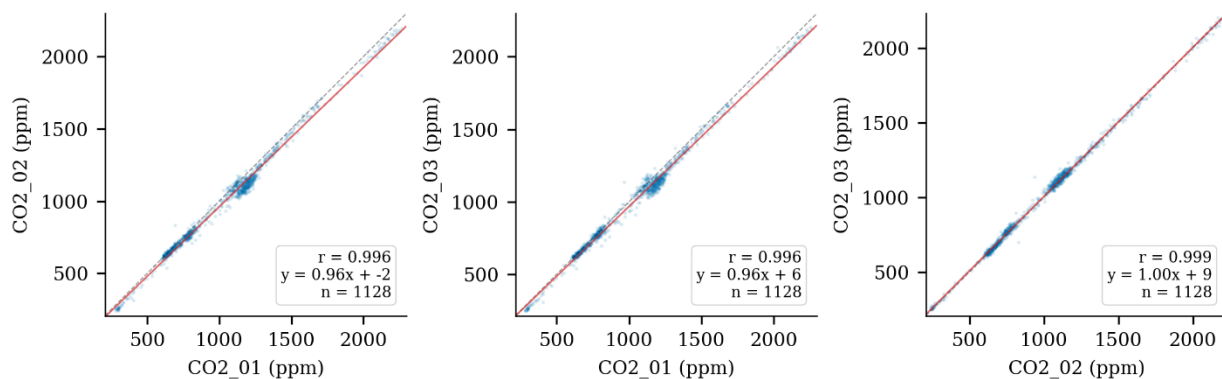


Figure S4. Inter-sensor agreement scatter plots for CO₂ concentrations among the three Aranet4 sensors (10-minute resampled means).

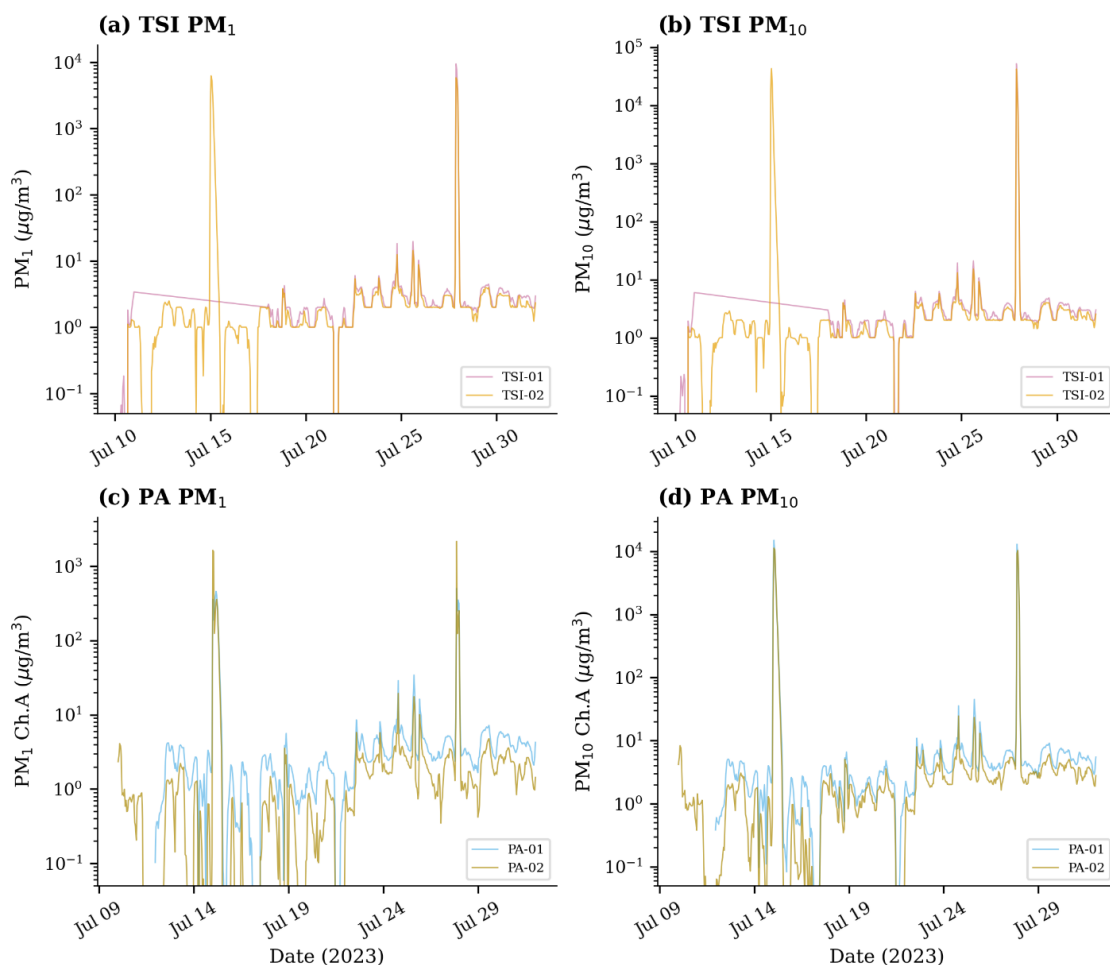


Figure S5. Time series of particulate matter size fractions (hourly means, log scale): (a) TSI AirAssure PM₁, (b) TSI AirAssure PM₁₀, (c) PurpleAir PM₁ (Channel A), and (d) PurpleAir PM₁₀ (Channel A).

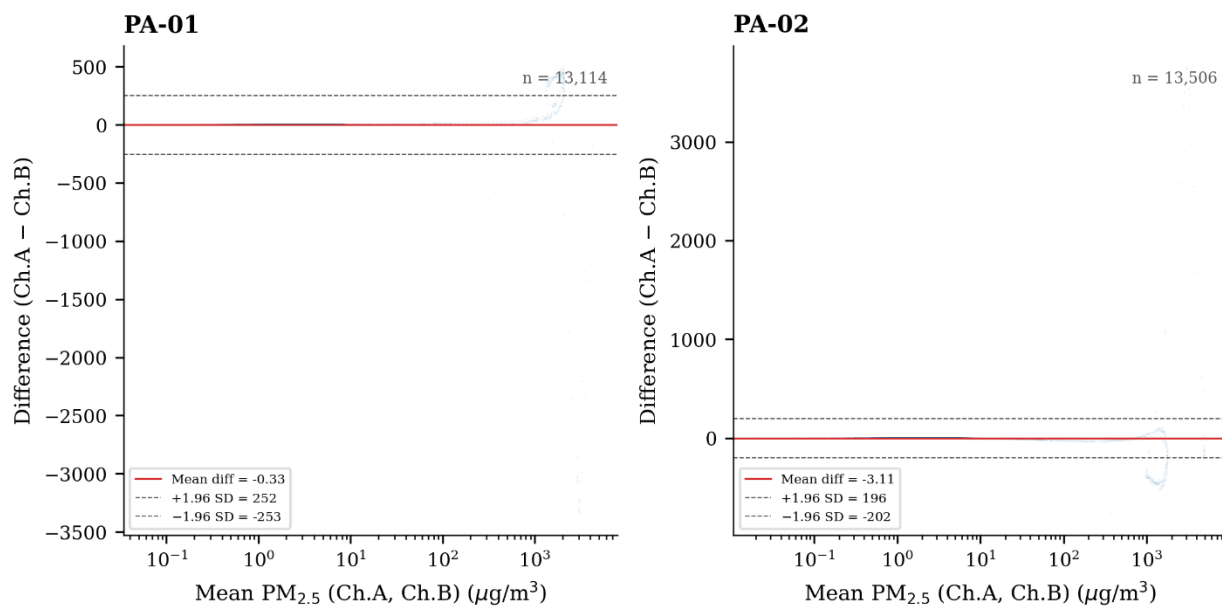


Figure S6. Bland-Altman plots assessing agreement between the dual laser channels (Channel A versus Channel B) within each PurpleAir PA-II-FLEX sensor. The solid red line indicates the mean difference and dashed lines indicate 95% limits of agreement.

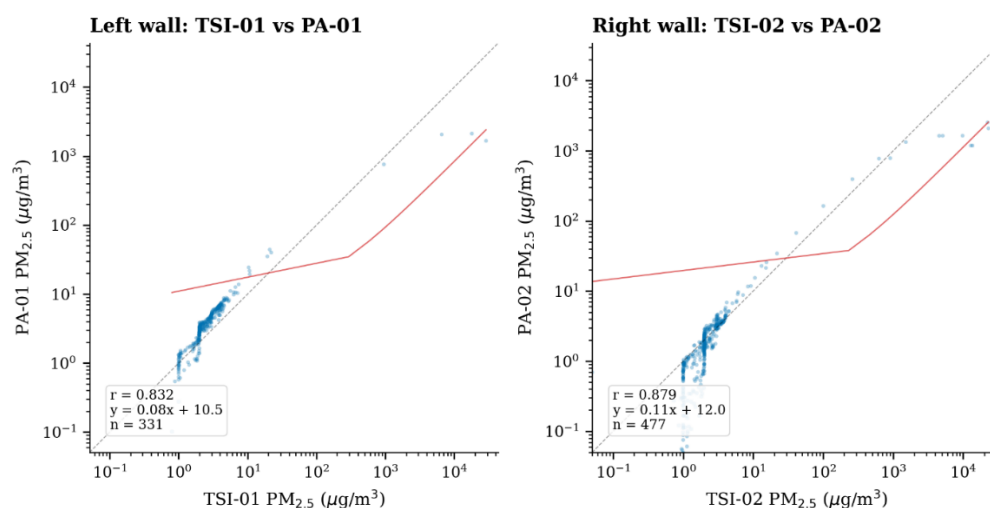


Figure S7. Cross-platform PM_{2.5} comparison between co-located TSI AirAssure and PurpleAir sensors at the (left panel) left wall (TSI-01 versus PA-01) and (right panel) right wall (TSI-02 versus PA-02), using hourly-averaged data on log-log axes. The dashed line indicates the 1:1 reference, and the red line shows the ordinary least-squares regression fit.

CO2_01	1.00	1.00	0.97	-0.50	-0.38
CO2_02	1.00	1.00	0.97	-0.50	-0.39
CO2_03	0.97	0.97	1.00	-0.49	-0.40
TSI-01 CO2	-0.50	-0.50	-0.49	1.00	0.96
TSI-02 CO2	-0.38	-0.39	-0.40	0.96	1.00

Figure S8. Complete-case hourly CO2 correlation matrix under nominal UTC-to-CDT timestamp conversion. Values are Pearson r using only hours when all five CO2 sensors had data.

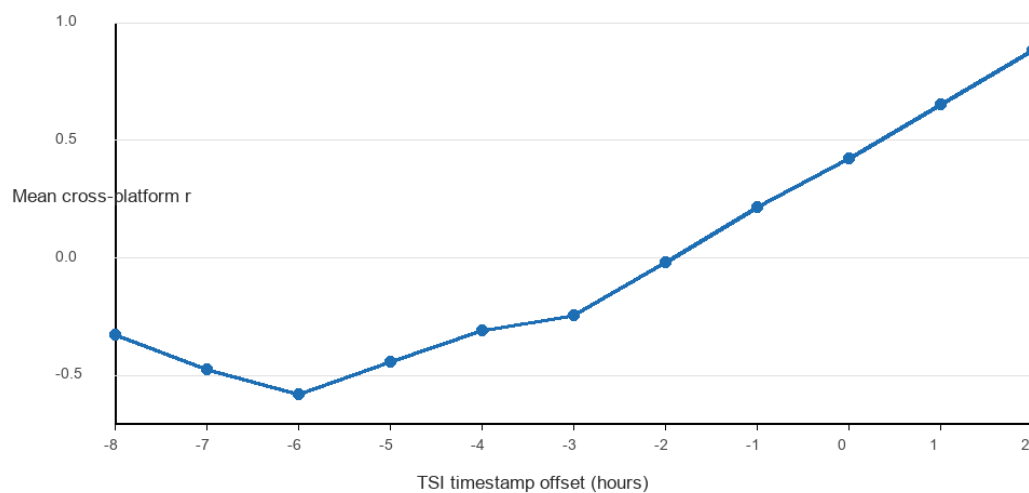


Figure S9. Timestamp-offset sensitivity analysis for complete-case Aranet4-TSI CO2 correlations.

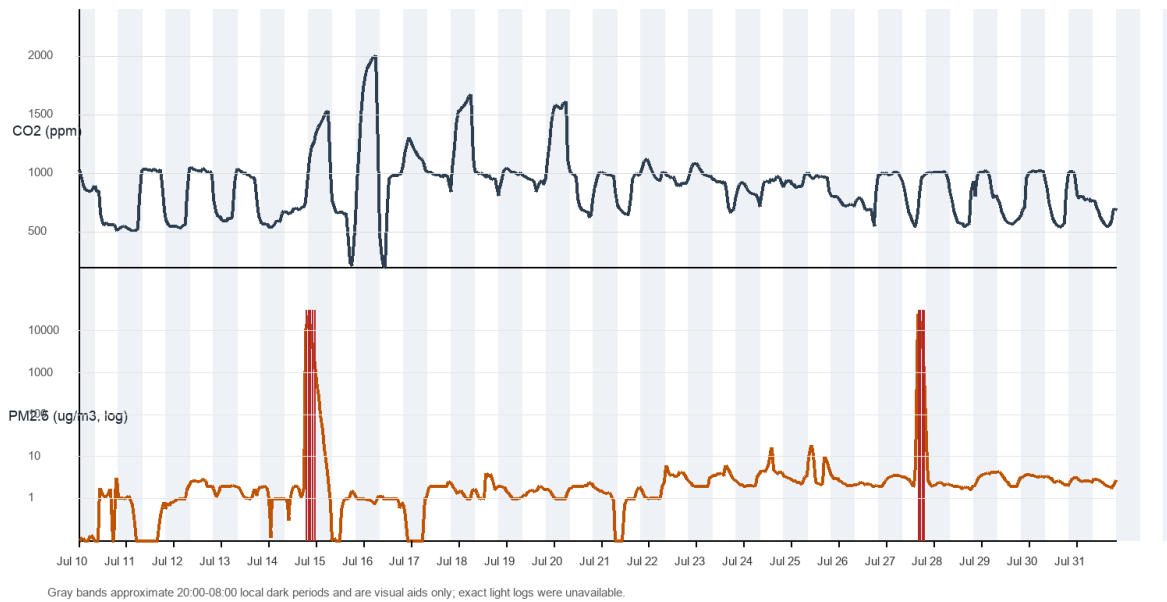


Figure S10. Paired TSI hourly CO2 and PM2.5 time series. Gray bands indicate approximate 20:00-08:00 local dark periods for visual reference only.