

Supplementary data

Multi-pollutant indoor air quality, ventilation, and cognitive status among nursing home residents with dementia: a pilot cross-sectional environmental assessment in Oklahoma, USA

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1. Supplementary tables

Table S1. Specifications of the TSI AirAssure IAQ monitor (model 8144-6).

Parameter	Range	Accuracy/Resolution	Sampling Interval	Units	Regulatory Reference
Temperature	−20 to 60 °C	± 0.5 °C	15 min/1 min	°C	ASHRAE 55
Relative Humidity	5%–95% RH	± 3% RH	15 min/1 min	%	ASHRAE 55
Barometric Pressure	8.5–11 psia	± 0.015 psia	15 min/1 min	inHg	–
PM ₁ , PM _{2.5} , PM ₄ , PM ₁₀	0–1000 µg m ^{−3}	–	15 min/1 min	µg m ^{−3}	EPA NAAQS; WHO
CO ₂	0–5000 ppm	± 50 ppm or ± 3%	15 min/1 min	ppm	ASHRAE 62.1; NIOSH
CO	0–500 ppm	± 2 ppm (0–50)	15 min/1 min	ppm	EPA 8-hr NAAQS
NO ₂	0–5 ppm	± 20 ppb	15 min/1 min	ppb	EPA 1-hr; WHO 24-hr
O ₃	0–1 ppm	± 20 ppb	15 min/1 min	ppb	WHO 8-hr; EPA 8-hr
tVOC	0–50 ppm (isobutylene)	–	15 min/1 min	mg m ^{−3}	CE action ~0.4 mg m ^{−3}

Table S2. Complete descriptive statistics of IAQ parameters for all 13 monitoring locations.

Location	Parameter	n	Mean	SD	Min	P25	Median	P75	P95	Max	% > Guideline	Guideline	Reference
A CR 1	Temperature	128	23.10	0.57	21.40	22.90	23.15	23.40	23.70	26.00	0.0%	26	ASHRAE 55
	Relative Humidity	128	46.99	2.51	42.00	45.00	46.50	49.00	52.00	53.00	0.0%	60	ASHRAE 55
	CO ₂	128	779.09	71.88	614.00	744.50	788.00	818.25	880.30	1009.00	0.8%	1000	ASHRAE 62.1
	PM _{2.5}	128	2.76	0.72	1.00	2.00	3.00	3.00	4.00	4.00	0.0%	35	EPA NAAQS
	PM ₁₀	128	2.76	0.72	1.00	2.00	3.00	3.00	4.00	4.00	0.0%	150	EPA NAAQS
	tVOC	128	4.75	5.45	0.52	1.75	2.23	5.42	17.97	27.15	100.0%	0.4	CE action
	CO	128	1.12	0.17	0.80	1.00	1.10	1.20	1.40	1.80	0.0%	9	EPA NAAQS
	NO ₂	128	6.05	6.61	0.00	0.00	5.00	10.00	19.65	25.00	0.0%	100	EPA NAAQS
	O ₃	128	7.43	9.57	0.00	0.00	2.00	15.00	23.00	38.00	0.0%	60	WHO 8-hr
A CR 2	Temperature	130	24.46	0.74	23.20	23.80	24.45	25.10	25.60	25.90	0.0%	26	ASHRAE 55
	Relative Humidity	130	45.20	3.80	39.00	42.00	46.00	48.00	50.00	56.00	0.0%	60	ASHRAE 55
	CO ₂	130	598.52	53.35	528.00	559.25	599.50	618.75	700.05	903.00	0.0%	1000	ASHRAE 62.1



Table S2. *Cont.*

Location	Parameter	n	Mean	SD	Min	P25	Median	P75	P95	Max	% > Guideline	Guideline	Reference
A CR 2	PM _{2.5}	130	2.99	4.72	1	2	2	3	4	55	0.8%	35	EPA NAAQS
	PM ₁₀	130	2.99	4.72	1	2	2	3	4	55	0.0%	150	EPA NAAQS
	tVOC	130	1.12	0.47	0.17	0.8	0.97	1.38	2.17	2.9	99.2%	0.4	CE action
	CO	130	0.44	0.26	0.1	0.2	0.4	0.5	0.95	1.3	0.0%	9	EPA NAAQS
	NO ₂	130	17.71	10.68	0	9	20	26	31	52	0.0%	100	EPA NAAQS
	O ₃	130	3.78	7.43	0	0	0	3	23.65	33	0.0%	60	WHO 8-hr
A NH 1	Temperature	57	21.67	1.12	20.3	20.8	21.4	22.2	23.62	25	0.0%	26	ASHRAE 55
	Relative Humidity	57	49.21	2.58	43	47	49	52	53	53	0.0%	60	ASHRAE 55
	CO ₂	119	500.09	88.93	392	444	475	539	594.3	1032	0.8%	1000	ASHRAE 62.1
	PM _{2.5}	119	2.65	0.6	2	2	3	3	3.1	5	0.0%	35	EPA NAAQS
	PM ₁₀	119	2.65	0.6	2	2	3	3	3.1	5	0.0%	150	EPA NAAQS
	tVOC	52	0.23	0.45	0	0	0.01	0.29	0.83	2.79	19.2%	0.4	CE action
	CO	52	0.08	0.16	0	0	0	0	0.4	0.6	0.0%	9	EPA NAAQS
	NO ₂	52	20.6	11.83	0	15.75	20	24	44.9	62	0.0%	100	EPA NAAQS
A NH 2	O ₃	52	0.73	2.98	0	0	0	0	4.8	18	0.0%	60	WHO 8-hr
	Temperature	128	24.24	0.71	22.4	23.8	24.4	24.72	25	26	0.0%	26	ASHRAE 55
	Relative Humidity	128	42.85	1.66	39	42	43	44	45.65	47	0.0%	60	ASHRAE 55
	CO ₂	128	684.58	88.54	572	616.75	663	719	874.9	1033	0.8%	1000	ASHRAE 62.1
	PM _{2.5}	128	2.71	0.67	1	2	3	3	3	5	0.0%	35	EPA NAAQS
	PM ₁₀	128	2.72	0.68	1	2	3	3	3.65	5	0.0%	150	EPA NAAQS
	tVOC	128	0.29	0.42	0	0.01	0.09	0.42	1.17	2.03	26.6%	0.4	CE action
	CO	128	0.45	0.16	0.1	0.4	0.5	0.5	0.7	1.2	0.0%	9	EPA NAAQS
	NO ₂	128	1.17	4.65	0	0	0	0	6.65	35	0.0%	100	EPA NAAQS
	O ₃	128	7.51	2.66	0	6	8	9	11	13	0.0%	60	WHO 8-hr
	Temperature	5346	24.44	0.43	23	24.2	24.4	24.6	25.3	25.5	0.0%	26	ASHRAE 55
	Relative Humidity	5346	28.67	2.55	25	26	29	30	34	36	0.0%	60	ASHRAE 55
B CR 1	CO ₂	5346	449.53	36.44	379	422	442	474	517	571	0.0%	1000	ASHRAE 62.1
	PM _{2.5}	5346	4.69	4.56	0	2	4	6	10	79	0.3%	35	EPA NAAQS
	PM ₁₀	5346	5.09	5.63	0	2	4	6	11	82	0.0%	150	EPA NAAQS
	tVOC	5346	0.37	0.31	0	0.08	0.27	0.67	0.88	1.21	40.7%	0.4	CE action
	CO	5346	0	0	0	0	0	0	0	0	0.0%	9	EPA NAAQS
	NO ₂	5346	3.33	5.22	0	0	0	6	13.75	35	0.0%	100	EPA NAAQS
	O ₃	5346	0.09	0.63	0	0	0	0	1	28	0.0%	60	WHO 8-hr
	Temperature	5363	24.17	0.49	22.2	23.8	24.3	24.5	24.9	25	0.0%	26	ASHRAE 55
B NH 1	Relative Humidity	5363	29.72	2.63	26	28	30	31	36	39	0.0%	60	ASHRAE 55
	CO ₂	5363	554.64	66.24	433	506	544	591	668	939	0.0%	1000	ASHRAE 62.1
	PM _{2.5}	5363	1.24	3.43	0	0	1	2	2	120	0.1%	35	EPA NAAQS
	PM ₁₀	5363	1.37	5.27	0	0	1	2	2	188	0.0%	150	EPA NAAQS
	tVOC	5363	0.26	0.32	0	0.02	0.09	0.44	0.92	1.31	26.3%	0.4	CE action
	CO	5363	2.74	0.55	1.5	2.4	2.7	3.1	3.7	4.1	0.0%	9	EPA NAAQS
	NO ₂	5363	16.21	19.12	0	3	8	21	53	72	0.0%	100	EPA NAAQS
	O ₃	5363	19.95	11.79	0	10	25	29	32	38	0.0%	60	WHO 8-hr
B NH 2	Temperature	5371	25.16	1.84	22.4	23.8	24.7	27	28.3	28.6	28.5%	26	ASHRAE 55
	Relative Humidity	5371	28	4.75	20	23	29	31	36	39	0.0%	60	ASHRAE 55
	CO ₂	5371	703.98	71.25	597	647	696	736	844	1109	0.4%	1000	ASHRAE 62.1
	PM _{2.5}	5371	2.97	2.38	0	1	2	5	7	16	0.0%	35	EPA NAAQS

Table S2. *Cont.*

Location	Parameter	n	Mean	SD	Min	P25	Median	P75	P95	Max	% > Guideline	Guideline	Reference
B NH 2	PM ₁₀	5371	3.07	2.53	0	1	2	5	7	28	0.0%	150	EPA NAAQS
	tVOC	5371	0.44	0.37	0	0.08	0.37	0.79	1.06	1.6	49.0%	0.4	CE action
	CO	5371	2.77	0.48	2	2.5	2.6	3	3.8	4.1	0.0%	9	EPA NAAQS
	NO ₂	5371	0	0	0	0	0	0	0	0	0.0%	100	EPA NAAQS
	O ₃	5371	58.53	5.29	0	56	58	61	66	75	29.1%	60	WHO 8-hr
B NH 3	Temperature	6123	24.11	1.38	22	23	24.1	24.5	27.5	28.7	9.2%	26	ASHRAE 55
	Relative Humidity	6123	28.34	1.73	25	27	29	30	31	41	0.0%	60	ASHRAE 55
	CO ₂	6123	594.12	93.38	459	525	565	661	769	902	0.0%	1000	ASHRAE 62.1
	PM _{2.5}	6123	3.68	2.38	0	2	4	5	8	19	0.0%	35	EPA NAAQS
	PM ₁₀	6123	3.87	3.07	0	2	4	5	8	29	0.0%	150	EPA NAAQS
B NH 4	tVOC	6123	0.5	0.44	0	0.06	0.36	0.93	1.21	1.54	48.5%	0.4	CE action
	CO	6123	2.03	1.04	0.7	1.4	1.7	2.6	4.6	5	0.0%	9	EPA NAAQS
	NO ₂	6123	19.32	9.17	0	13	20	25	33	147	0.0%	100	EPA NAAQS
	O ₃	6123	2.36	4.37	0	0	0	3	12	55	0.0%	60	WHO 8-hr
	Temperature	5392	24.7	0.56	20.3	24.2	24.7	25.1	25.5	26.2	1.5%	26	ASHRAE 55
B NH 4	Relative Humidity	5392	29.17	3.05	24	26	29	31	35	52	0.0%	60	ASHRAE 55
	CO ₂	5392	617.59	67.38	425	584	625	663.25	709	1080	0.0%	1000	ASHRAE 62.1
	PM _{2.5}	5392	10.34	45.77	0	1	2	4	23	532	4.3%	35	EPA NAAQS
	PM ₁₀	5392	12.53	58.52	0	1	2	4	26	693	2.4%	150	EPA NAAQS
	tVOC	5392	0.39	0.35	0	0.05	0.29	0.77	0.93	1.34	45.3%	0.4	CE action
C CR 1	CO	5392	2.74	0.66	1.3	2.2	2.8	3.3	3.8	4.2	0.0%	9	EPA NAAQS
	NO ₂	5392	0.29	2.24	0	0	0	0	0	102	0.0%	100	EPA NAAQS
	O ₃	5392	7.49	4.67	0	3	7	12	15	20	0.0%	60	WHO 8-hr
	Temperature	380	23.17	0.69	21.6	22.7	23.2	23.6	24.5	24.7	0.0%	26	ASHRAE 55
	Relative Humidity	380	42.57	2.33	37	41	42	44	47	51	0.0%	60	ASHRAE 55
C CR 1	CO ₂	380	770.21	90.86	520	719.75	762	821.25	926.05	1079	2.4%	1000	ASHRAE 62.1
	PM _{2.5}	380	2.76	0.88	1	2	3	3	4	6	0.0%	35	EPA NAAQS
	PM ₁₀	380	2.78	0.9	1	2	3	3	4	6	0.0%	150	EPA NAAQS
	tVOC	380	0.41	0.32	0	0.1	0.41	0.7	0.88	1.32	50.8%	0.4	CE action
	CO	380	1.23	0.46	0	0.9	1.2	1.4	2.1	2.2	0.0%	9	EPA NAAQS
C CR 2	NO ₂	380	5.91	7.98	0	0	4	9	19	68	0.0%	100	EPA NAAQS
	O ₃	380	16.02	4.22	0	14	16	19	22	39	0.0%	60	WHO 8-hr
	Temperature	388	23.66	0.5	21.8	23.4	23.55	24	24.5	25.4	0.0%	26	ASHRAE 55
	Relative Humidity	388	42.51	2.67	37	41	42.5	44	48	50	0.0%	60	ASHRAE 55
	CO ₂	388	874.53	90.44	706	811	863.5	918	1041.65	1299	8.5%	1000	ASHRAE 62.1
C CR 2	PM _{2.5}	388	2.45	1.91	1	2	2	3	4	25	0.0%	35	EPA NAAQS
	PM ₁₀	388	2.51	2.46	1	2	2	3	4	35	0.0%	150	EPA NAAQS
	tVOC	388	0.26	0.29	0	0.04	0.13	0.42	0.87	1.49	25.8%	0.4	CE action
	CO	388	1.52	0.19	0.8	1.4	1.5	1.6	1.8	2	0.0%	9	EPA NAAQS
	NO ₂	388	0	0.05	0	0	0	0	0	1	0.0%	100	EPA NAAQS
C NH 1	O ₃	388	39.8	22.8	0	20.75	43	59	70	89	21.4%	60	WHO 8-hr
	Temperature	97	22.5	1.14	20.6	21.5	22.4	23.6	24.22	24.3	0.0%	26	ASHRAE 55
	Relative Humidity	97	44.44	2.31	41	42	45	46	48	49	0.0%	60	ASHRAE 55
	CO ₂	97	898	133.99	692	801	862	1043	1098.4	1163	29.9%	1000	ASHRAE 62.1
	PM _{2.5}	97	8.63	22.06	2	2	3	4	34.2	188	4.1%	35	EPA NAAQS
C NH 1	PM ₁₀	97	9.34	24.77	2	2	3	4	37.2	211	1.0%	150	EPA NAAQS

Table S2. Cont.

Location	Parameter	n	Mean	SD	Min	P25	Median	P75	P95	Max	% > Guideline	Guideline	Reference
C NH 1	tVOC	97	0.24	0.36	0	0	0.03	0.33	1	1.45	21.6%	0.4	CE action
	CO	97	0.56	0.22	0.1	0.4	0.6	0.7	0.8	1.4	0.0%	9	EPA NAAQS
	NO ₂	97	30.33	12.68	0	23	32	39	46	62	0.0%	100	EPA NAAQS
	O ₃	97	1.46	5.24	0	0	0	0	14.2	32	0.0%	60	WHO 8-hr
	Temperature	384	22.22	1.07	20.7	21.4	21.8	23	24.4	24.9	0.0%	26	ASHRAE 55
C NH 2	Relative Humidity	384	48.68	2.99	42	46	49	50	54	59	0.0%	60	ASHRAE 55
	CO ₂	384	836.49	131.95	546	725	818	948	1041.7	1193	15.1%	1000	ASHRAE 62.1
	PM _{2.5}	384	1.07	0.28	1	1	1	1	2	4	0.0%	35	EPA NAAQS
	PM ₁₀	384	1.07	0.31	1	1	1	1	2	5	0.0%	150	EPA NAAQS
	tVOC	384	0.39	0.33	0	0.09	0.31	0.66	0.91	2.02	45.6%	0.4	CE action
	CO	384	0.76	0.29	0.3	0.5	0.7	1	1.3	1.7	0.0%	9	EPA NAAQS
	NO ₂	384	57.01	20.89	0	46.75	60	70	88	109	1.6%	100	EPA NAAQS
	O ₃	384	0.21	1.34	0	0	0	0	0	13	0.0%	60	WHO 8-hr

Table S3. Percentage of monitoring time exceeding major indoor/outdoor air quality guidelines.

Parameter	Guideline	A CR 1	A CR 2	A NH 1	A NH 2	B CR 1	B NH 1	B NH 2	B NH 3	B NH 4	C CR 1	C CR 2	C NH 1	C NH 2
CO ₂	ASHRAE 62.1 (1000 ppm)	0.8%	0.0%	0.8%	0.8%	0.0%	0.0%	0.4%	0.0%	0.0%	2.4%	8.5%	29.9%	15.1%
PM _{2.5}	EPA 24-hr NAAQS (35 µg/m ³)	0.0%	0.8%	0.0%	0.0%	0.3%	0.1%	0.0%	0.0%	4.3%	0.0%	0.0%	4.1%	0.0%
PM _{2.5}	WHO AQG (15 µg/m ³)	0.0%	0.8%	0.0%	0.0%	2.2%	0.2%	0.0%	0.3%	5.5%	0.0%	0.5%	10.3%	0.0%
Temperature	ASHRAE 55 upper (26 °C)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	28.5%	9.2%	1.5%	0.0%	0.0%	0.0%	0.0%
Temperature	ASHRAE 55 lower (< 20 °C)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Relative Humidity	ASHRAE 55 upper (60% RH)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Relative Humidity	ASHRAE 55 lower (< 30% RH)	0.0%	0.0%	0.0%	0.0%	65.2%	47.8%	53.2%	73.8%	51.8%	0.0%	0.0%	0.0%	0.0%
O ₃	WHO 8-hr (60 ppb)	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	29.1%	0.0%	0.0%	0.0%	21.4%	0.0%	0.0%
NO ₂	WHO 24-hr (25 ppb)	0.0%	27.7%	11.5%	1.6%	0.5%	23.4%	0.0%	22.4%	0.1%	1.3%	0.0%	69.1%	91.7%
tVOC	CE action level (0.4 mg/m ³)	100.0%	99.2%	19.2%	26.6%	40.7%	26.3%	49.0%	48.5%	45.3%	50.8%	25.8%	21.6%	45.6%

Bold cells: > 20% of monitoring time exceeding threshold. Lower-bound rows (ASHRAE 55 temperature < 20 °C and RH < 30%) reflect time BELOW the threshold. A_NH_2 now based on full recovered dataset (n = 128). WHO = World Health Organization (2021 AQGs); EPA = U.S. Environmental Protection Agency; CE = Comité Européen.

Table S4. Air change rate in the residents rooms.

Room	Room function	Volume (m ³)	Number of occupants	Ventilation rates (h ⁻¹)
A_NH_1	Residential room	35.68	1	2.11
A_NH_2	Residential room	61.16	1	0.84
A_CR_1	Dining room	-	Shared room	-
A_CR_2	Dining room	-	Shared room	-
B_NH_1	Residential room	61.17	2	2.42
B_NH_2	Residential room	47.35	2	2.09
B_NH_3	Residential room	44.85	2	3.08
B_NH_4	Residential room	47.35	2	5.07
B_CR_1	TV room	-	Shared room	-
C_NH_1	Residential room	27.86	1	1.16
C_NH_2	Residential room	51.08	1	1.09
C_CR_1	Front lobby	-	Shared room	-
C_CR_2	Activity room	-	Shared room	-

2. Supplementary figures



Figure S1. Photo of air quality sensor in a resident room.

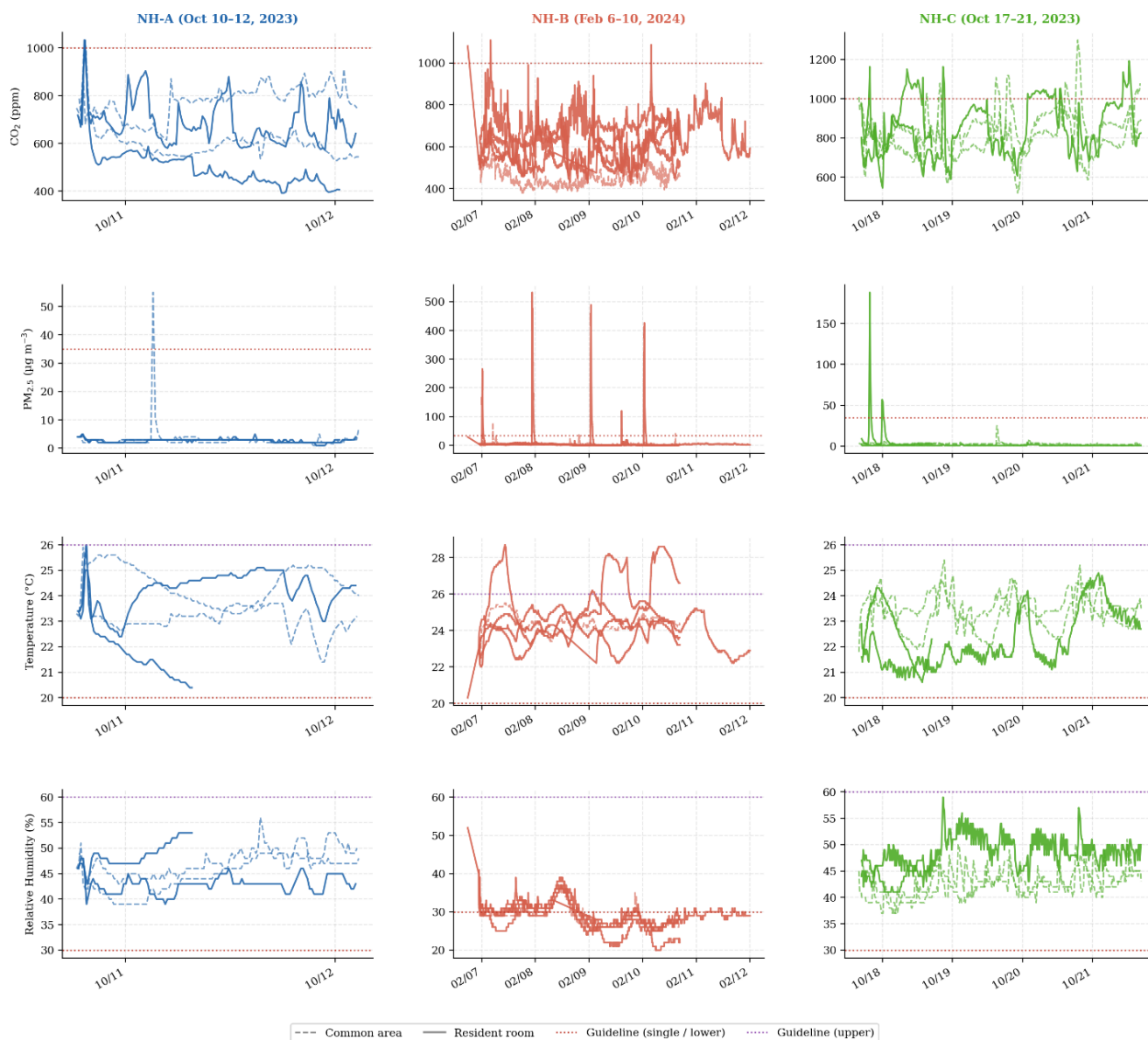


Figure S2. Time series of air quality parameters across three nursing homes. Solid lines = resident rooms, dashed = common areas. Red dotted reference lines mark regulatory thresholds.

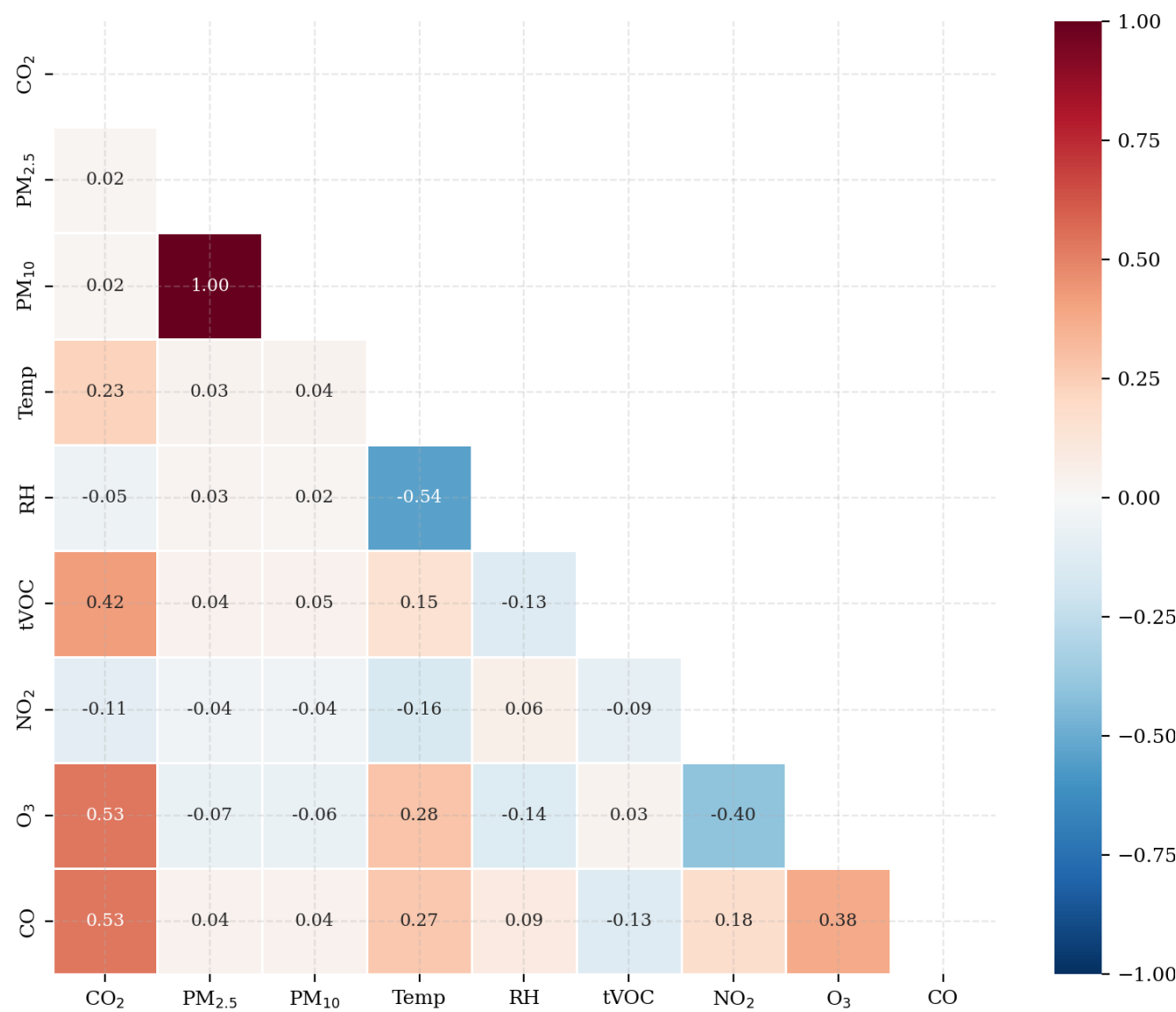


Figure S3. Spearman correlation matrix of IAQ parameters in NH-B.

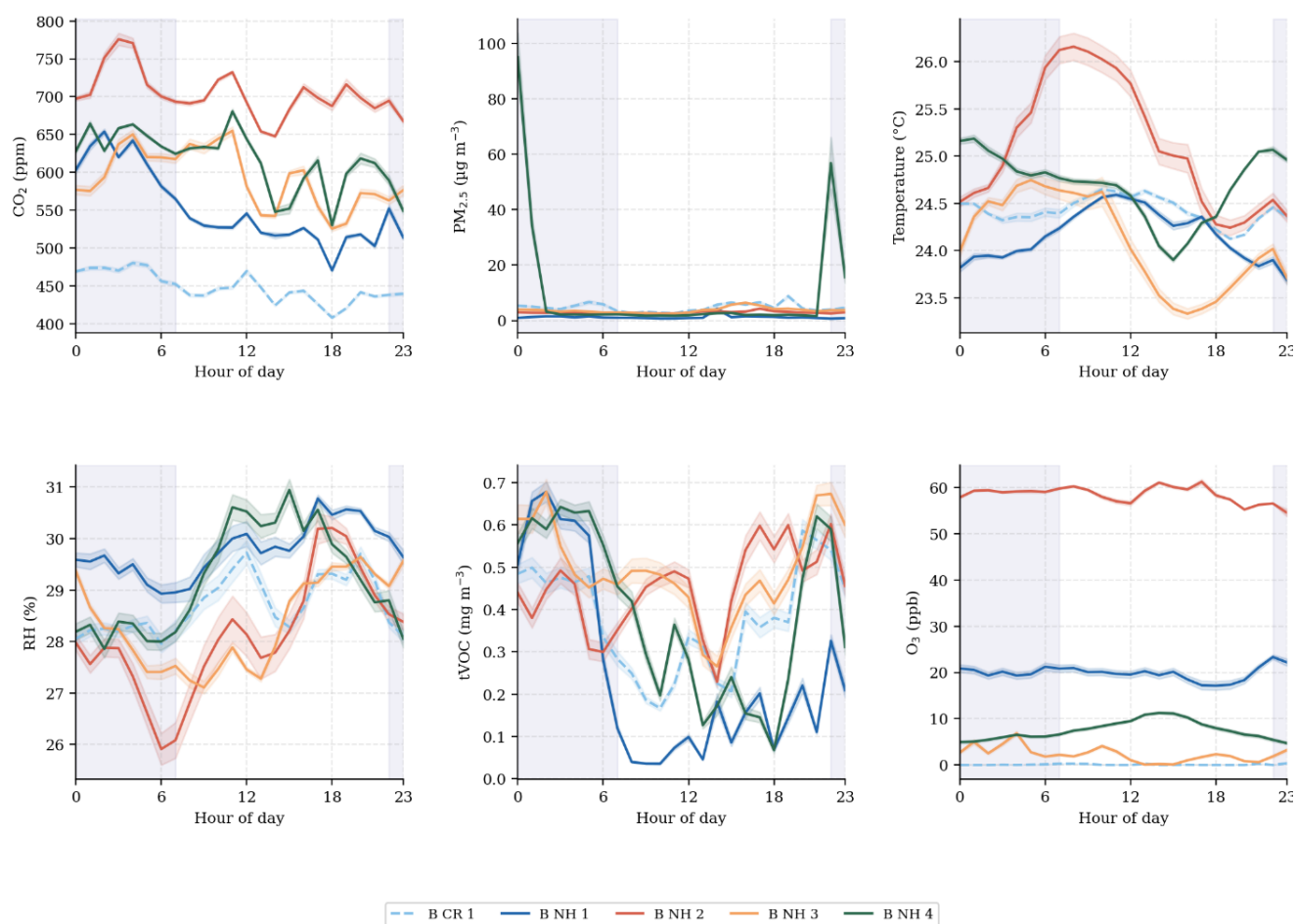


Figure S4. Mean diurnal IAQ parameters in NH-B. Shading = $\pm$ SEM; Grey bands = night hours 22:00–07:00.