**Appendix A. Supplementary Material**

**The Effects of Ventilation and Filtration on Indoor PM2.5 in Office Buildings in Four Countries**

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**Table S1.** CO2 sensor specifications for environmental sensor packages used in buildings from the Global CogFx Study included in this analysis.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Package Name** | **CO2 Sensor Name** | **Type of CO2 Sensor** | **Range (ppm)** | **Resolution (ppm)** | **Accuracy** | **Third Party Evaluation** |
| Harvard Healthy Buildings | SenseAir S8a | NDIRb | 400-50,000b | NR | ±200 ppm and ±10%b | NR |
| Tsinghua IBEM | NR | NDIRc | 0-5,000c | 1c | ±75 ppmc | Examined by China National Institute of Metrologyc |
| Awair Omni | Amphenol Telaire T6703-5 Kd | NDIRe | 0-5,000e | 1e | ±3% and ±50 ppme | Interior RESET Air Accredited Grade B monitore,f |
| ChemiSense CS-001 | NR | NDIRg | 400-5,000g | 1g | 400 - 2,000 ppm: ±50 ppm and ±3%2,000 - 5,000 ppm: ±50 ppm and ±5%g | Interior RESET Air Accredited Grade B monitorf |
| Tongdy MSD-16 | Amphenol Telaire T67X3h | NDIRi | 0-5,000i | 1i | ±40 ppm and ±3%i | Interior RESET Air Accredited Grade B monitorf |

NDIR: Non-dispersive infrared

NR: Not reported

aHarvard Healthy Buildings sensors were constructed by the authors and their colleagues using SenseAir S8 miniature infrared CO2 sensors.

bSenseAir S8 Specification Sheet: “Data sheet and manual: SenseAir S8 Alarm 5% Miniature infrared CO2 sensor module” by CO2meter.com.

cY. Geng, B. Lin, J. Yu, H. Zhou, W. Ji, H. Chen, Z. Zhang, Y. Zhu, Indoor Environmental Quality of Green Office Buildings in China: Large-Scale and Long-Term Measurement, Build. Environ. 150 (2019) 266–280. https://doi.org/10.1016/j.buildenv.2019.01.014.

dI. Demanega, I. Mujan, B.C. Singer, A.S. Andelković, F. Babich, D. Licina, Performance assessment of low-cost environmental monitors and single sensors under variable indoor air quality and thermal conditions, Build. Environ. 187 (2021) 107415. https://doi.org/10.1016/j.buildenv.2020.107415.

eRESETTM Specification Sheet for AWAIR Omni Indoor Air Quality Monitor.

fRESET Accredited Monitors webpage (<https://www.reset.build/monitors>).

gRESETTM Air Accredited Monitor Testing Report for ChemiSense CS-001.

hTongdy MSD-16 sensors are presumed to use Amphenol Telaire T6703 or T6713 based on observation of deconstructed sensors.

iMSD Sensors Specification Sheet: “MSD IAQ Detector – User Manual V.1707” by Tongdy Sensing Technology Corporation.

**Table S2.** Detailed summary of hourly measurements of indoor PM2.5 by country and month, shown separately for standard work hours (weekdays 9:00 – 17:00 local time) and non-work hours (weekends and weekdays before 7:00 or after 19:00 local time).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **Month** | **Standard Work Hours or Non-Work Hours** | **Indoor PM2.5 (**$μ$**g/m3)** | **# of PM2.5 Datapoints** |
| **Minimum** | **1st %ile** | **5th %ile** | **25th %ile** | **Median** | **Mean** | **75th %ile** | **95th %ile** | **99th %ile** | **Maximum** |
| China | Mar - May | Standard work hours | 1.0 | 1.0 | 1.0 | 10.5 | 18.3 | 19.4 | 24.9 | 40.2 | 72.6 | 426.4 | 11,194 |
| Non-work hours | 1.0 | 2.5 | 4.8 | 11.1 | 17.2 | 17.9 | 23.3 | 34.0 | 48.0 | 120.1 | 29,234 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 1.0 | 5.3 | 11.8 | 14.4 | 19.4 | 33.7 | 71.5 | 334.0 | 10,747 |
| Non-work hours | 0.0 | 0.0 | 2.0 | 5.1 | 9.9 | 11.3 | 16.0 | 25.4 | 35.2 | 110.2 | 29,230 |
| Sep - Nov | Standard work hours | 0.0 | 1.0 | 1.6 | 10.5 | 20.0 | 20.7 | 27.3 | 44.0 | 72.6 | 176.6 | 10,314 |
| Non-work hours | 0.0 | 2.2 | 4.8 | 10.5 | 18.3 | 18.8 | 24.5 | 37.8 | 53.3 | 189.7 | 25,573 |
| Dec - Feb | Standard work hours | 1.0 | 1.0 | 2.5 | 12.2 | 21.7 | 23.0 | 28.5 | 52.5 | 83.8 | 203.4 | 10,714 |
| Non-work hours | 0.8 | 2.2 | 5.5 | 13.0 | 20.8 | 21.7 | 27.5 | 44.5 | 60.0 | 169.7 | 26,923 |
| India | Mar - May | Standard work hours | 0.0 | 0.0 | 0.0 | 11.2 | 17.5 | 19.0 | 25.7 | 40.8 | 49.7 | 57.0 | 485 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 16.2 | 23.2 | 24.4 | 34.7 | 42.8 | 51.1 | 82.8 | 1,055 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 0.0 | 4.0 | 6.0 | 6.6 | 8.5 | 15.0 | 21.0 | 34.8 | 3,012 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 5.7 | 8.8 | 9.7 | 12.5 | 21.7 | 34.2 | 155.8 | 8,033 |
| Sep - Nov | Standard work hours | 0.0 | 0.0 | 0.0 | 5.6 | 9.2 | 12.2 | 15.7 | 36.0 | 47.0 | 71.3 | 2,502 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 7.0 | 12.0 | 16.2 | 21.0 | 44.8 | 55.8 | 157.0 | 6,199 |
| Dec - Feb | Standard work hours | 0.0 | 0.0 | 7.5 | 19.2 | 28.6 | 39.4 | 42.2 | 136.3 | 220.5 | 249.6 | 534 |
| Non-work hours | 0.0 | 0.0 | 10.3 | 29.3 | 45.2 | 46.8 | 58.3 | 95.9 | 137.2 | 197.6 | 956 |
| UK | Mar - May | Standard work hours | 0.0 | 0.0 | 0.0 | 0.4 | 1.0 | 2.1 | 2.2 | 6.5 | 11.7 | 500.0 | 13,282 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 1.0 | 1.5 | 2.3 | 2.8 | 7.5 | 13.3 | 216.7 | 36,759 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 1.1 | 1.5 | 3.5 | 5.8 | 77.2 | 9,404 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 0.0 | 1.0 | 1.6 | 2.0 | 4.5 | 8.8 | 431.0 | 24,574 |
| Sep - Nov | Standard work hours | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8 | 0.4 | 3.8 | 12.3 | 27.6 | 1,320 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 1.3 | 1.3 | 5.8 | 17.1 | 31.5 | 3,543 |
| Dec - Feb | Standard work hours | 0.0 | 0.0 | 0.0 | 0.7 | 1.8 | 3.0 | 3.2 | 8.3 | 14.2 | 311.7 | 4,674 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 1.6 | 3.4 | 4.6 | 6.0 | 14.0 | 20.0 | 85.0 | 11,311 |
| USA | Mar - May | Standard work hours | 0.0 | 0.0 | 0.0 | 0.5 | 1.2 | 2.9 | 4.6 | 10.0 | 13.9 | 166.5 | 21,788 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 0.7 | 1.8 | 3.3 | 5.3 | 10.5 | 14.4 | 81.2 | 54,226 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 0.0 | 0.8 | 2.3 | 3.6 | 6.2 | 10.3 | 12.9 | 62.7 | 22,906 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 1.0 | 2.9 | 3.8 | 5.8 | 10.8 | 13.0 | 396.0 | 61,230 |
| Sep - Nov | Standard work hours | 0.0 | 0.0 | 0.0 | 0.2 | 1.7 | 3.4 | 5.8 | 11.3 | 14.4 | 104.2 | 15,213 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 0.3 | 2.7 | 3.9 | 6.2 | 12.1 | 14.5 | 116.6 | 38,298 |
| Dec - Feb | Standard work hours | 0.0 | 0.0 | 0.0 | 0.1 | 1.4 | 3.5 | 6.0 | 11.8 | 18.7 | 120.2 | 17,810 |
| Non-work hours | 0.0 | 0.0 | 0.0 | 0.2 | 1.7 | 3.6 | 6.3 | 12.1 | 14.4 | 90.0 | 45,223 |

**Table S3.** Detailed summary of hourly measurements of outdoor PM2.5 by country and month, shown separately for standard work hours (weekdays 9:00 – 17:00 local time) and non-work hours (weekends and weekdays before 7:00 or after 19:00 local time).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **Month** | **Standard Work Hours or Non-Work Hours** | **Outdoor PM2.5 (**$μ$**g/m3)** | **# of PM2.5 Datapoints** |
| **Minimum** | **1st %ile** | **5th %ile** | **25th %ile** | **Median** | **Mean** | **75th %ile** | **95th %ile** | **99th %ile** | **Maximum** |
| China | Mar - May | Standard work hours | 0.0 | 2.0 | 8.0 | 16.0 | 27.0 | 34.4 | 46.0 | 85.0 | 112.0 | 154.0 | 11,194 |
| Non-work hours | 0.0 | 4.0 | 8.0 | 17.0 | 28.0 | 34.3 | 44.0 | 84.0 | 123.0 | 192.0 | 29,234 |
| Jun - Aug | Standard work hours | 0.0 | 2.0 | 5.0 | 12.0 | 20.0 | 23.8 | 32.0 | 56.0 | 75.1 | 106.0 | 10,747 |
| Non-work hours | 0.0 | 1.4 | 3.0 | 10.0 | 19.0 | 22.2 | 31.0 | 51.0 | 69.7 | 144.0 | 29,230 |
| Sep - Nov | Standard work hours | 0.0 | 6.0 | 10.0 | 19.0 | 28.0 | 34.6 | 44.0 | 81.0 | 137.0 | 173.0 | 10,314 |
| Non-work hours | 0.0 | 5.0 | 9.0 | 18.6 | 28.0 | 34.5 | 41.0 | 88.0 | 123.0 | 183.0 | 25,573 |
| Dec - Feb | Standard work hours | 0.0 | 5.0 | 10.0 | 22.0 | 35.0 | 44.1 | 58.0 | 105.0 | 152.0 | 228.0 | 10,714 |
| Non-work hours | 0.0 | 6.0 | 10.0 | 21.0 | 35.0 | 43.7 | 59.0 | 103.0 | 147.0 | 186.0 | 26,923 |
| India | Mar - May | Standard work hours | 0.0 | 0.0 | 11.3 | 26.2 | 32.2 | 39.1 | 39.0 | 122.7 | 161.9 | 182.2 | 485 |
| Non-work hours | 0.0 | 4.4 | 14.0 | 28.9 | 37.0 | 47.0 | 50.3 | 126.2 | 179.7 | 308.8 | 1,055 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 2.0 | 8.0 | 13.0 | 16.4 | 21.0 | 34.4 | 64.9 | 845.8 | 3,012 |
| Non-work hours | 0.0 | 0.0 | 1.7 | 7.5 | 12.2 | 16.4 | 19.5 | 40.5 | 73.8 | 844.1 | 8,033 |
| Sep - Nov | Standard work hours | 0.0 | 0.0 | 4.0 | 11.2 | 16.9 | 21.7 | 27.4 | 51.5 | 79.5 | 320.0 | 2,502 |
| Non-work hours | 0.0 | 0.0 | 4.0 | 11.0 | 17.1 | 23.1 | 28.0 | 58.8 | 109.0 | 470.3 | 6,199 |
| Dec - Feb | Standard work hours | 24.3 | 30.0 | 34.1 | 56.0 | 77.3 | 92.8 | 117.0 | 192.0 | 273.5 | 494.9 | 534 |
| Non-work hours | 10.8 | 23.6 | 32.0 | 53.5 | 75.0 | 90.7 | 118.0 | 198.0 | 259.0 | 583.8 | 956 |
| UK | Mar - May | Standard work hours | 2.0 | 3.0 | 4.0 | 7.0 | 10.0 | 13.3 | 15.0 | 38.0 | 49.0 | 83.0 | 13,282 |
| Non-work hours | 3.0 | 3.0 | 5.0 | 7.0 | 10.0 | 13.9 | 16.0 | 37.0 | 49.0 | 61.0 | 36,759 |
| Jun - Aug | Standard work hours | 1.0 | 3.0 | 4.0 | 5.0 | 7.0 | 7.5 | 9.0 | 14.0 | 24.9 | 30.0 | 9,404 |
| Non-work hours | 1.0 | 3.0 | 4.0 | 5.0 | 7.0 | 7.4 | 9.0 | 14.0 | 21.0 | 27.0 | 24,574 |
| Sep - Nov | Standard work hours | 2.0 | 3.2 | 5.0 | 6.0 | 7.0 | 9.8 | 10.0 | 23.0 | 37.0 | 105.0 | 1,320 |
| Non-work hours | 2.0 | 3.0 | 4.0 | 6.0 | 7.0 | 9.6 | 11.0 | 22.0 | 37.6 | 90.0 | 3,543 |
| Dec - Feb | Standard work hours | 3.0 | 4.0 | 6.0 | 9.0 | 14.0 | 20.5 | 31.8 | 47.0 | 61.0 | 74.0 | 4,674 |
| Non-work hours | 0.0 | 5.0 | 6.0 | 10.0 | 20.0 | 21.9 | 30.0 | 47.0 | 53.0 | 63.0 | 11,311 |
| USA | Mar - May | Standard work hours | 0.0 | 0.0 | 1.0 | 4.5 | 7.0 | 7.6 | 10.0 | 16.0 | 21.0 | 156.9 | 21,788 |
| Non-work hours | 0.0 | 0.0 | 1.6 | 4.6 | 7.5 | 8.4 | 11.0 | 19.0 | 27.0 | 560.6 | 54,226 |
| Jun - Aug | Standard work hours | 0.0 | 0.0 | 1.3 | 5.0 | 8.0 | 8.8 | 11.8 | 18.0 | 27.2 | 146.4 | 22,906 |
| Non-work hours | 0.0 | 0.0 | 2.0 | 5.2 | 8.3 | 9.6 | 13.0 | 20.8 | 27.0 | 111.0 | 61,230 |
| Sep - Nov | Standard work hours | 0.0 | 0.0 | 1.0 | 4.1 | 7.0 | 8.1 | 10.8 | 18.0 | 26.5 | 86.0 | 15,213 |
| Non-work hours | 0.0 | 0.0 | 1.3 | 4.2 | 7.0 | 8.1 | 10.5 | 18.0 | 27.0 | 62.0 | 38,298 |
| Dec - Feb | Standard work hours | 0.0 | 0.0 | 1.2 | 4.9 | 7.0 | 8.6 | 11.0 | 20.0 | 31.1 | 86.2 | 17,810 |
| Non-work hours | 0.0 | 0.0 | 1.4 | 4.8 | 7.2 | 8.7 | 11.0 | 20.2 | 31.3 | 82.7 | 45,223 |

**Table S4.** Detailed summary of hourly measurements of indoor CO2 by country and month, shown separately for standard work hours (weekdays 9:00 – 17:00 local time) and non-work hours (weekends and weekdays before 7:00 or after 19:00 local time).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Country** | **Month** | **Standard Work Hours or Non-Work Hours** | **Indoor CO2 (ppm)** | **# of CO2 Datapoints** |
| **Minimum** | **1st %ile** | **5th %ile** | **25th %ile** | **Median** | **Mean** | **75th %ile** | **95th %ile** | **99th %ile** | **Maximum** |
| China | Mar - May | Standard work hours | 400 | 400 | 412 | 460 | 511 | 529 | 575 | 696 | 883 | 1849 | 10457 |
| Non-work hours | 400 | 400 | 400 | 406 | 423 | 445 | 457 | 583 | 640 | 880 | 25120 |
| Jun - Aug | Standard work hours | 400 | 406 | 435 | 509 | 567 | 596 | 659 | 840 | 976 | 1453 | 10341 |
| Non-work hours | 400 | 400 | 400 | 403 | 421 | 445 | 458 | 571 | 718 | 1213 | 25826 |
| Sep - Nov | Standard work hours | 400 | 400 | 413 | 475 | 532 | 556 | 608 | 776 | 982 | 1854 | 9802 |
| Non-work hours | 400 | 400 | 400 | 410 | 432 | 460 | 478 | 614 | 756 | 1104 | 22443 |
| Dec - Feb | Standard work hours | 400 | 400 | 415 | 491 | 552 | 603 | 654 | 978 | 1312 | 1971 | 10445 |
| Non-work hours | 400 | 400 | 400 | 409 | 431 | 460 | 475 | 621 | 755 | 1801 | 23560 |
| India | Mar - May | Standard work hours | 400 | 408 | 429 | 524 | 630 | 793 | 920 | 1729 | 2150 | 4714 | 453 |
| Non-work hours | 400 | 402 | 406 | 423 | 473 | 564 | 566 | 1138 | 1655 | 3439 | 1010 |
| Jun - Aug | Standard work hours | 407 | 425 | 476 | 638 | 753 | 816 | 933 | 1254 | 2145 | 4366 | 3012 |
| Non-work hours | 400 | 400 | 404 | 423 | 460 | 524 | 543 | 873 | 1311 | 4162 | 7937 |
| Sep - Nov | Standard work hours | 400 | 401 | 415 | 516 | 711 | 775 | 966 | 1325 | 1900 | 2892 | 2484 |
| Non-work hours | 400 | 401 | 409 | 430 | 470 | 549 | 562 | 996 | 1335 | 2444 | 6076 |
| Dec - Feb | Standard work hours | 441 | 473 | 513 | 667 | 1058 | 1091 | 1467 | 1806 | 2124 | 2250 | 534 |
| Non-work hours | 401 | 405 | 425 | 488 | 560 | 630 | 683 | 1125 | 1453 | 1874 | 944 |
| UK | Mar - May | Standard work hours | 400 | 404 | 448 | 666 | 750 | 780 | 889 | 1107 | 1245 | 1951 | 13282 |
| Non-work hours | 400 | 400 | 401 | 416 | 434 | 457 | 466 | 605 | 751 | 1448 | 36756 |
| Jun - Aug | Standard work hours | 400 | 458 | 565 | 700 | 796 | 817 | 933 | 1114 | 1233 | 2373 | 9184 |
| Non-work hours | 400 | 400 | 404 | 416 | 433 | 467 | 477 | 622 | 1024 | 2190 | 23819 |
| Sep - Nov | Standard work hours | 455 | 480 | 548 | 672 | 790 | 807 | 910 | 1148 | 1350 | 1638 | 1257 |
| Non-work hours | 400 | 401 | 404 | 415 | 447 | 473 | 501 | 638 | 755 | 1080 | 3230 |
| Dec - Feb | Standard work hours | 421 | 442 | 538 | 662 | 740 | 776 | 850 | 1151 | 1313 | 1530 | 4643 |
| Non-work hours | 400 | 400 | 400 | 419 | 456 | 483 | 508 | 681 | 835 | 1024 | 11092 |
| USA | Mar - May | Standard work hours | 400 | 421 | 454 | 514 | 578 | 627 | 681 | 998 | 1316 | 2439 | 21754 |
| Non-work hours | 400 | 400 | 402 | 417 | 444 | 492 | 514 | 733 | 1023 | 2627 | 50220 |
| Jun - Aug | Standard work hours | 400 | 418 | 457 | 533 | 604 | 653 | 709 | 1025 | 1499 | 1857 | 22897 |
| Non-work hours | 400 | 400 | 403 | 420 | 458 | 501 | 530 | 727 | 1184 | 1681 | 58379 |
| Sep - Nov | Standard work hours | 400 | 405 | 435 | 519 | 589 | 643 | 702 | 1087 | 1344 | 1594 | 15040 |
| Non-work hours | 400 | 400 | 402 | 417 | 443 | 492 | 508 | 776 | 1083 | 1475 | 35430 |
| Dec - Feb | Standard work hours | 400 | 402 | 439 | 541 | 617 | 671 | 732 | 1175 | 1362 | 1688 | 17593 |
| Non-work hours | 400 | 400 | 402 | 418 | 441 | 497 | 504 | 814 | 1124 | 1531 | 42414 |