## APPENDIX AVAILABLE ON THE HEI WEBSITE

**Research Report 194**

# A Dynamic Three-Dimensional Air Pollution Exposure Model for Hong Kong

**Barratt et al.**

## Appendix A. WP1–WP4 Tables and Figures

This Appendix was reviewed solely for spelling, grammar, and cross-references to the main text. It has not been formatted or fully edited by HEI. This document was reviewed by the HEI Review Committee.

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# Appendix A. WP1–WP4 Tables and Figures

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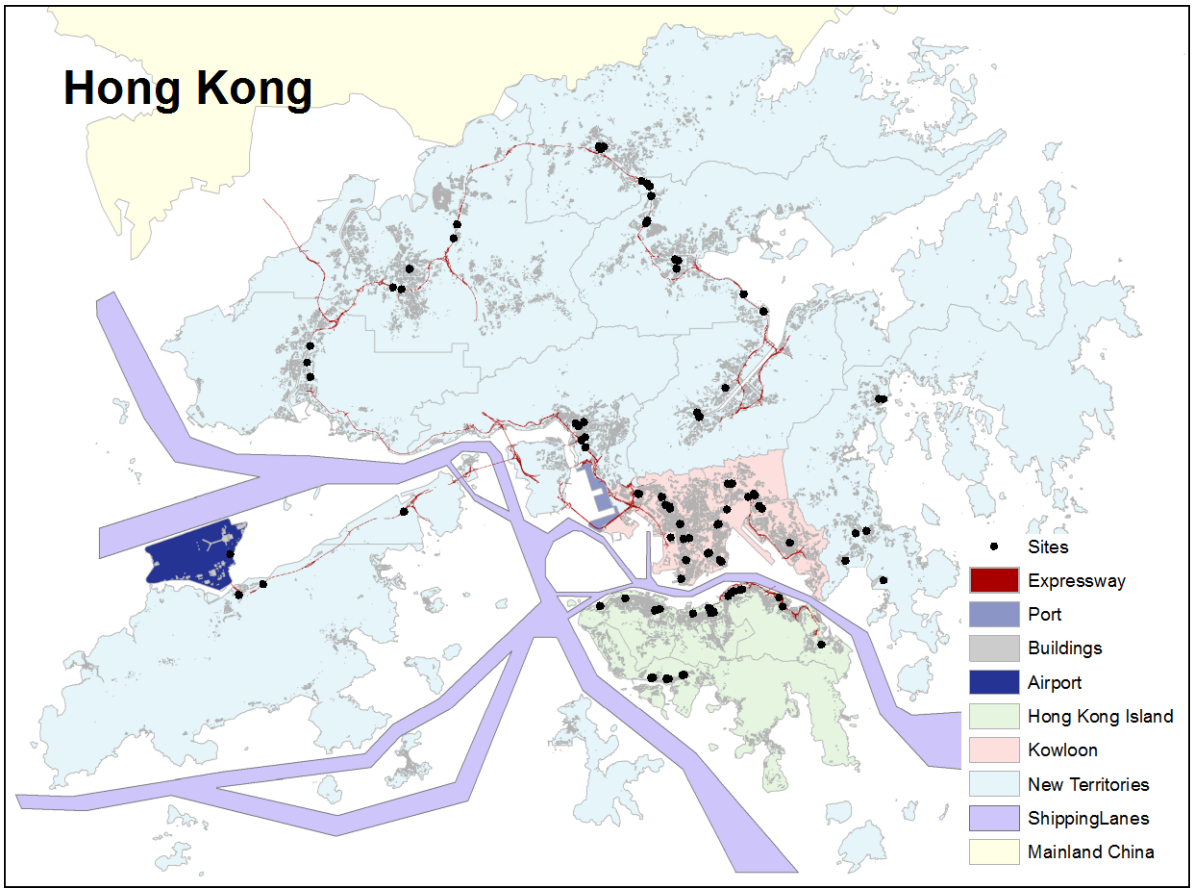



**Figure A.1. Map of spatial campaign sampling sites in Hong Kong**

**Table A.1. Spatial campaign sampling site details**

| Site ID | Latitude | Longitude | Region | District | Planned Collection[a] |
|---|---|---|---|---|---|
| CW-A-1 | 22.28178 | 114.15812 | Hong Kong Island | Central and Western | $NO_2$, NO, PM (2w) |
| CW-B-2 | 22.28103 | 114.15556 | Hong Kong Island | Central and Western | $NO_2$, PM |
| CW-C-3 | 22.28135 | 114.15610 | Hong Kong Island | Central and Western | $NO_2$, NO, PM (2w) |
| EN-A-1 | 22.28226 | 114.18340 | Hong Kong Island | Wan Chai | $NO_2$, PM |
| EN-A-2 | 22.28207 | 114.18372 | Hong Kong Island | Wan Chai | $NO_2$, NO, PM |
| EN-B-5 | 22.29105 | 114.20040 | Hong Kong Island | Eastern | $NO_2$, PM |
| EN-B-7 | 22.28804 | 114.19340 | Hong Kong Island | Eastern | $NO_2$, NO (SC2 only), PM |
| EN-B-8 | 22.28931 | 114.19460 | Hong Kong Island | Eastern | $NO_2$, NO (SC2 only), PM |
| EN-C-10 | 22.29088 | 114.19957 | Hong Kong Island | Eastern | $NO_2$, NO, PM |
| EN-C-9 | 22.29034 | 114.19627 | Hong Kong Island | Eastern | $NO_2$, NO, PM (2w) |
| IS-A-2 | 22.30768 | 113.93743 | New Territories | Islands | $NO_2$, NO (SC2 only), PM |
| IS-A-3 | 22.32826 | 114.02649 | New Territories | Islands | $NO_2$, PM |
| IS-A-4 | 22.29365 | 113.95429 | New Territories | Islands | $NO_2$, NO, PM (2w) |
| IS-B-6 | 22.28851 | 113.94170 | New Territories | Islands | $NO_2$, PM |
| KC-A-1 | 22.32926 | 114.19281 | Kowloon Peninsula | Kowloon City | $NO_2$, NO, PM |
| KC-A-3 | 22.30871 | 114.18347 | Kowloon Peninsula | Kowloon City | $NO_2$, NO (SC2 only), PM |
| KC-A-4 | 22.30822 | 114.18261 | Kowloon Peninsula | Kowloon City | $NO_2$, NO (SC2 only), PM |
| KC-B-5 | 22.30531 | 114.18902 | Kowloon Peninsula | Kowloon City | $NO_2$, NO, PM |
| KC-B-6 | 22.30431 | 114.18978 | Kowloon Peninsula | Kowloon City | $NO_2$, NO (SC2 only), PM |
| KC-B-7 | 22.32227 | 114.18778 | Kowloon Peninsula | Kowloon City | $NO_2$, NO (SC2 only), PM |
| KC-B-8 | 22.32252 | 114.18849 | Kowloon Peninsula | Kowloon City | $NO_2$, PM |
| KT-A-1 | 22.33100 | 114.20925 | Kowloon Peninsula | Kwun Tong | $NO_2$, PM |
| KT-A-2 | 22.32981 | 114.21057 | Kowloon Peninsula | Kwun Tong | $NO_2$, NO, PM |
| KT-B-6 | 22.31347 | 114.22508 | Kowloon Peninsula | Kwun Tong | $NO_2$, NO, PM (2w) |
| KW-A-3 | 22.35916 | 114.12008 | New Territories | Kwai Tsing | $NO_2$, NO, PM (2w) |
| MK-A-1 | 22.32244 | 114.16849 | Kowloon Peninsula | Yau Tsim Mong | $NO_2$, NO, PM (2w) |
| NT-A-1 | 22.47931 | 114.15367 | New Territories | North | $NO_2$, PM |
| NT-A-2 | 22.48393 | 114.15294 | New Territories | North | $NO_2$, NO (SC2 only), PM |
| NT-A-3 | 22.48523 | 114.15163 | New Territories | North | $NO_2$, NO (SC2 only), PM |
| NT-A-4 | 22.48642 | 114.14893 | New Territories | North | $NO_2$, PM |
| NT-B-5 | 22.50270 | 114.12674 | New Territories | North | $NO_2$, PM |
| NT-B-6 | 22.50184 | 114.12775 | New Territories | North | $NO_2$, NO, PM |
| NT-B-7 | 22.50315 | 114.12671 | New Territories | North | $NO_2$, NO (SC2 only), PM |

[a] $NO_2$ refers to Ogawa badge, diffusion tube, or both. PM refers to 24-hour $PM_{2.5}$ and black carbon collection, while PM (2w) refers to 2 week collection.

*Continued on next 2 pages.*

**Table A.1 *continued*.** Spatial campaign sampling site details

| Site ID | Latitude | Longitude | Region | District | Planned Collection[a] |
|---|---|---|---|---|---|
| NT-B-8 | 22.50291 | 114.12920 | New Territories | North | $NO_2$, NO (SC2 only), PM |
| NT-B-9 | 22.50276 | 114.12901 | New Territories | North | $NO_2$, PM |
| P1 | 22.28321 | 114.12749 | Hong Kong Island | Central and Western | $NO_2$, NO, PM |
| P10 | 22.29624 | 114.16919 | Kowloon Peninsula | Yau Tsim Mong | $NO_2$, NO, PM |
| P11 | 22.37122 | 114.11923 | New Territories | Tsuen Wan | $NO_2$, NO, PM |
| P12 | 22.28729 | 114.21942 | Hong Kong Island | Eastern | PM |
| P2 | 22.28697 | 114.14045 | Hong Kong Island | Central and Western | $NO_2$, NO, PM |
| P3 | 22.27956 | 114.17536 | Hong Kong Island | Wan Chai | $NO_2$, NO, PM |
| P4 | 22.28289 | 114.22140 | Hong Kong Island | Eastern | $NO_2$, NO, PM |
| P5 | 22.26472 | 114.24122 | Hong Kong Island | Eastern | $NO_2$, NO, PM |
| P6 | 22.31605 | 114.16383 | Kowloon Peninsula | Yau Tsim Mong | $NO_2$, NO, PM |
| P7 | 22.31536 | 114.17038 | Kowloon Peninsula | Yau Tsim Mong | PM |
| P8 | 22.31582 | 114.17333 | Kowloon Peninsula | Yau Tsim Mong | $NO_2$, NO, PM (2w) |
| P9 | 22.30532 | 114.17164 | Kowloon Peninsula | Yau Tsim Mong | $NO_2$, NO, PM (2w) |
| SK-A-2 | 22.31920 | 114.26438 | New Territories | Sai Kung | $NO_2$, NO, PM (2w) |
| SK-A-3 | 22.30481 | 114.25361 | New Territories | Sai Kung | $NO_2$, NO, PM |
| SK-A-6 | 22.29540 | 114.27331 | New Territories | Sai Kung | $NO_2$, PM |
| SK-A-7 | 22.31810 | 114.25892 | New Territories | Sai Kung | $NO_2$, PM |
| SK-A-9 | 22.38220 | 114.27097 | New Territories | Sai Kung | $NO_2$, PM |
| SK-B-11 | 22.38203 | 114.27342 | New Territories | Sai Kung | $NO_2$, NO, PM |
| SO-A-1 | 22.25036 | 114.17056 | Hong Kong Island | Southern | $NO_2$, NO, PM |
| SO-A-2 | 22.25024 | 114.16969 | Hong Kong Island | Southern | $NO_2$, PM |
| SO-A-3 | 22.24850 | 114.16159 | Hong Kong Island | Southern | $NO_2$, PM |
| SO-A-4 | 22.24844 | 114.16287 | Hong Kong Island | Southern | $NO_2$, NO, PM (2w) |
| SO-B-5 | 22.24896 | 114.15454 | Hong Kong Island | Southern | $NO_2$, NO, PM |
| SO-B-6 | 22.24886 | 114.15366 | Hong Kong Island | Southern | $NO_2$, PM |
| SSP-A-4 | 22.33551 | 114.15913 | Kowloon Peninsula | Sham Shui Po | $NO_2$, NO (SC2 only), PM |
| SSP-B-5 | 22.32982 | 114.16348 | Kowloon Peninsula | Sham Shui Po | $NO_2$, PM |
| SSP-B-6 | 22.33171 | 114.16102 | Kowloon Peninsula | Sham Shui Po | $NO_2$, NO (SC2 only), PM |
| SSP-B-7 | 22.33087 | 114.16315 | Kowloon Peninsula | Sham Shui Po | $NO_2$, NO, PM (2w) |
| SSP-C-10 | 22.33699 | 114.14700 | Kowloon Peninsula | Sham Shui Po | $NO_2$, NO, PM |
| SSP-C-9 | 22.33701 | 114.14764 | Kowloon Peninsula | Sham Shui Po | $NO_2$, PM |
| ST-A-1 | 22.38753 | 114.19191 | New Territories | Sha Tin | $NO_2$, NO (SC2 only), PM |

[a] $NO_2$ refers to Ogawa badge, diffusion tube, or both. PM refers to 24-hour $PM_{2.5}$ and black carbon collection, while PM (2w) refers to 2 week collection.

*Continued on next page.*

**Table A.1 *continued*.** Spatial campaign sampling site details

| District | District | District | District | District | District |
|---|---|---|---|---|---|
| ST-B-5 | 22.37579 | 114.17734 | New Territories | Sha Tin | $NO_2$, NO, PM (2w) |
| ST-B-6 | 22.37391 | 114.17856 | New Territories | Sha Tin | $NO_2$, PM |
| ST-B-7 | 22.37374 | 114.17873 | New Territories | Sha Tin | $NO_2$, PM |
| ST-B-8 | 22.37349 | 114.17843 | New Territories | Sha Tin | $NO_2$, NO (SC2 only), PM |
| TM-A-1 | 22.39960 | 113.97668 | New Territories | Tuen Mun | $NO_2$, NO, PM |
| TM-A-4 | 22.40735 | 113.97831 | New Territories | Tuen Mun | $NO_2$, PM |
| TM-B-6 | 22.39261 | 113.97841 | New Territories | Tuen Mun | $NO_2$, NO, PM (2w) |
| TP-A-1 | 22.42411 | 114.21151 | New Territories | Tai Po | $NO_2$, NO, PM |
| TP-A-2 | 22.43240 | 114.20111 | New Territories | Tai Po | $NO_2$, NO (SC2 only), PM |
| TP-A-3 | 22.46646 | 114.15106 | New Territories | Tai Po | $NO_2$, NO, PM (2w) |
| TP-A-4 | 22.46747 | 114.15176 | New Territories | Tai Po | $NO_2$, PM |
| TP-B-5 | 22.44859 | 114.16702 | New Territories | Tai Po | $NO_2$, PM |
| TP-B-6 | 22.44465 | 114.16666 | New Territories | Tai Po | $NO_2$, PM |
| TP-C-10 | 22.44841 | 114.16740 | New Territories | Tai Po | $NO_2$, NO, PM (2w) |
| TP-C-9 | 22.44903 | 114.16604 | New Territories | Tai Po | $NO_2$, PM |
| TW-A-3 | 22.36251 | 114.11794 | New Territories | Tsuen Wan | $NO_2$, NO (SC2 only), PM |
| TW-A-4 | 22.36397 | 114.11977 | New Territories | Tsuen Wan | $NO_2$, NO, PM |
| TW-B-5 | 22.37062 | 114.11487 | New Territories | Tsuen Wan | $NO_2$, NO (SC2 only), PM |
| TW-B-6 | 22.37004 | 114.11598 | New Territories | Tsuen Wan | $NO_2$, PM |
| TW-B-7 | 22.36908 | 114.11636 | New Territories | Tsuen Wan | $NO_2$, NO (SC2 only), PM |
| WC-A-1 | 22.28006 | 114.18436 | Hong Kong Island | Wan Chai | $NO_2$, NO, PM (2w) |
| WC-B-2 | 22.28014 | 114.18578 | Hong Kong Island | Wan Chai | $NO_2$, PM |
| WC-C-3 | 22.28080 | 114.18551 | Hong Kong Island | Wan Chai | $NO_2$, NO (SC2 only), PM |
| WTS-A-1 | 22.33540 | 114.20355 | Kowloon Peninsula | Wong Tai Sin | $NO_2$, PM |
| WTS-A-3 | 22.33620 | 114.20721 | Kowloon Peninsula | Wong Tai Sin | $NO_2$, NO, PM (2w) |
| WTS-A-4 | 22.33705 | 114.20657 | Kowloon Peninsula | Wong Tai Sin | $NO_2$, PM |
| WTS-B-5 | 22.34175 | 114.19530 | Kowloon Peninsula | Wong Tai Sin | $NO_2$, PM |
| WTS-B-6 | 22.34175 | 114.19315 | Kowloon Peninsula | Wong Tai Sin | $NO_2$, NO, PM (2w) |
| YL-A-1 | 22.46584 | 114.05380 | New Territories | Yuen Long | $NO_2$, NO, PM |
| YL-A-2 | 22.45906 | 114.05216 | New Territories | Yuen Long | $NO_2$, PM |
| YL-A-3 | 22.43547 | 114.02089 | New Territories | Yuen Long | $NO_2$, NO, PM (2w) |
| YL-A-4 | 22.43460 | 114.02527 | New Territories | Yuen Long | $NO_2$, PM |
| YL-B-5 | 22.44463 | 114.02935 | New Territories | Yuen Long | $NO_2$, PM |
| YL-B-6 | 22.44432 | 114.02934 | New Territories | Yuen Long | $NO_2$, PM |

[a] $NO_2$ refers to Ogawa badge, diffusion tube, or both. PM refers to 24-hour $PM_{2.5}$ and black carbon collection, while PM (2w) refers to 2 week collection.

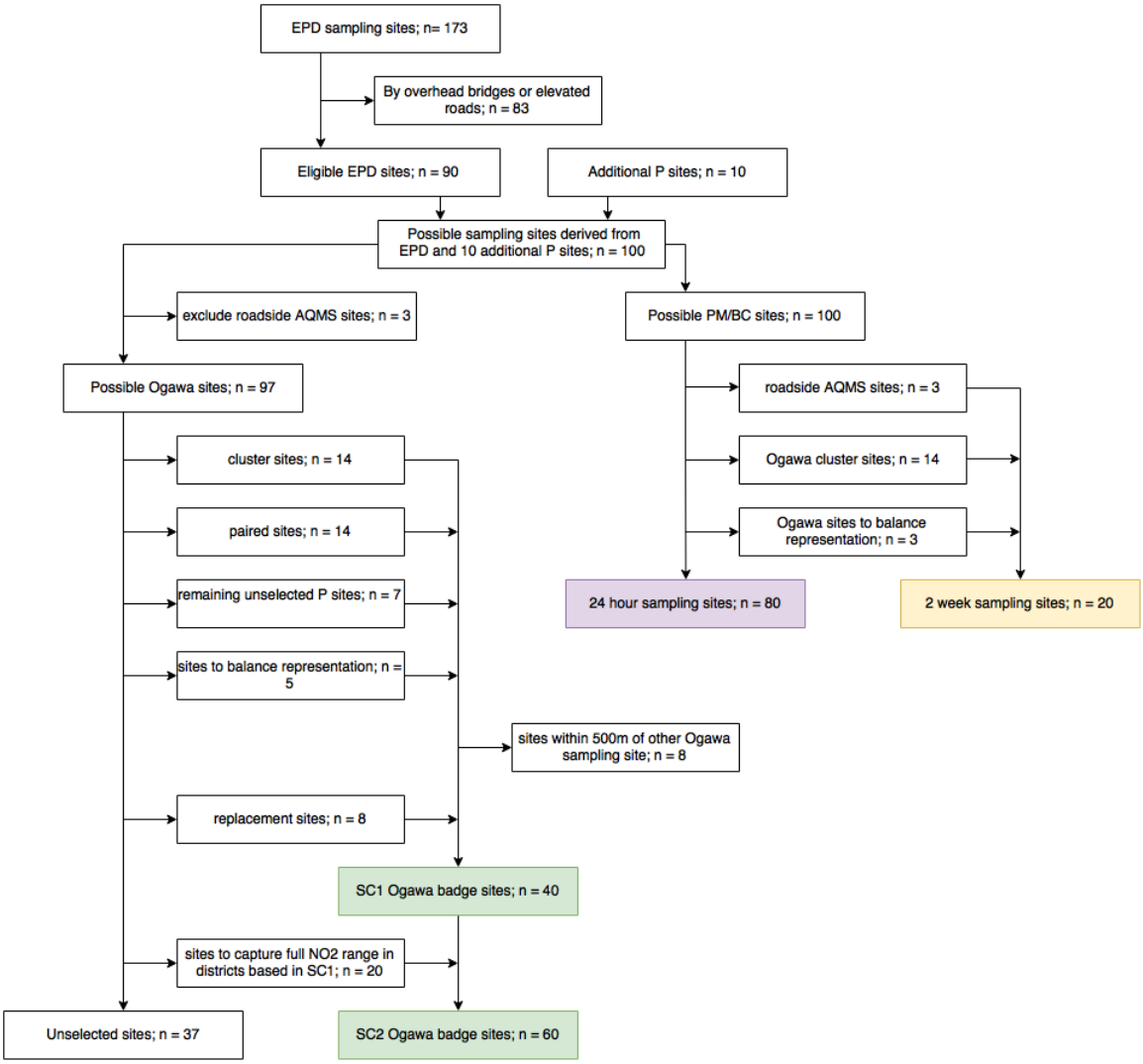



**Figure A.2. Spatial sampling campaign site selection flowchart**

Table A.2. Possible prediction variables offered to variable selection procedures for 2D LUR modeling

| **Buffer value variables (buffer radii 25 m, 50 m, 100 m, 200 m, 300 m, 500 m, 1000 m, 1500 m, 2000 m, 3000 m, 4000 m, 5000 m)** | | |
|---|---|---|
| *Annual Average Traffic Density (AADT)* ***(sum in buffer)*** | Expressway | AADTExp |
| | Main roads | AADTMain |
| | Secondary roads | AADTSec |
| *Road Length* ***(sum [m] in buffer)*** | Expressway | ExpRL |
| | Main roads | MainRL |
| | Secondary roads | SecRL |
| | Elevated roads | ElvRL |
| *Traffic Loading* ***(AADT * road length [m] in buffer)*** | Expressway | ExpTrL |
| | Main roads | MainTrL |
| | Secondary roads | SecTrrL |
| *Urban Build-up* ***(area [$m^2$] or volume [$m^3$] /buffer area)*** | Building volume density | BldVolD |
| | Building area density | BldArD |
| | Population density | WPopDen |
| | On street parking density | PrkArD |
| *Land Use* ***(total area [$m^2$] in buffer)*** | Commercial | ComT |
| | Government | GovT |
| | Park | ParkT |
| | Mixed | MixT |
| | Residential | ResT |
| | Open area | OpArT |
| | Industrial | IndT |
| | Undeveloped lands | Lands |
| | *Point value variables* | |
| *Point feature* ***(count/buffer area)*** | Street intersections | InterD |
| | Bus terminus density | BusTD |
| | Car park density | CarPD |
| | Mini bus terminus density | MiniBusD |
| | Temple density | TmplD |
| | Food stall density | FoodStD |
| *Value Extracted at Point* | In aircraft flight path | FlightRouteBuf |
| | Aspect ratio | AspRatio |
| ***[m above sea-level]*** | Elevation | Elevation |
| ***[decimal degrees]*** | Longitude | Long |
| ***[decimal degrees]*** | Latitude | Lat |
| ***[µg/$m^3$]*** | Predicted $NO_2$ (NO model only) | $NO_2$ |

*Continued on next page.*

Table A.2 continued. Possible prediction variables offered to variable selection procedures for 2D LUR modeling

| | | |
|---|---|---|
| *Distance* ***(Euclidean and natural log [m])*** | Ferry | (Ln)Dist_FerryTerm |
| | Cross boundary vehicle terminus | (Ln)Dist_CrossBrdVehTm |
| | Toll gates | (Ln)Dist_TollGate |
| | Incinerator | (Ln)Dist_Incin |
| | Crematorium | (Ln)Dist_Crematorium |
| | Mass transit rail line | (Ln)Dist_MTRLines |
| | Mass transit rail stations | (Ln)Dist_MTRstnts |
| | Coastline | (Ln)Dist_Coast |
| | Shipping lanes | (Ln)Dist_ShippingLanes |
| | High volume unrestricted shipping lanes | (Ln)DistUnRHighVol |
| | Airport | (Ln)Dist_Airport |
| | Port | (Ln)Dist_Port |
| | Shenzhen | (Ln)Dist_ShenzhenP |
| | Power stations | (Ln)Dist_PSntswoPenny |

Table A.3. LUR modelling for other Asian cities

| *Location* | **Reference** | **Sampling Sites (n)** | **Predictors ($R^2$; no. of predictors)** |
|---|---|---|---|
| *Changsha, China* | Li et al. 2015 | Field campaign (n = 80) $NO_2$ (n = 40 $PM_{10}$) | $NO_2$ (0.41-0.51) $PM_{10}$ (0.32-0.39) [a] |
| *Jinan, China* | Li et al. 2010 | Regulatory air quality monitoring sites (n = 14) | $SO_2$ (0.62; 3) $NO_2$ (0.64; 3) $PM_{10}$ (0.60; 3) |
| *Shanghai, China* | Meng et al. 2015 | Ambient air quality monitoring sites (n = 38) | $NO_2$ (0.82; 4) |
| *Shanghai, China* | Meng et al. 2016 | Ground level air pollution monitoring sites (n = 28) | $PM_{10}$ (0.80; 4) |
| *Tianjin, China* | Chen et al. 2010 | Ambient air quality monitoring sites (n = 20; another 10 used to validate) | $NO_2$ $PM_{2.5}$ (0.74; 5, heating season) (0.61; 4, non-heating season) $PM_{10}$ (0.72; 4, heating season) (0.49; 3, non-heating season) |
| *Metropolitan area of Seoul, Kyunggi, and Incheon, Korea* | Lee et al. 2012 [Conference paper] | Regulatory air quality monitoring sites (n = 102) | $NO_2$ (0.59; 5) |
| *New Delhi, India* | Saraswat et al. 2013 | Field campaign (n = 18, morning; n = 37, afternoon) | Ultrafine particle number concentrations (0.28; 1 morning) (0.23; 2, afternoon) [b] |
| *Shizuoka prefecture, Japan* | Kashima et al. 2009 | Regulatory air quality monitoring sites (n = 83) | $NO_2$ (0.54; 5) SPM (0.11; 1) |
| *Ulaanbaatar, Mongolia* | Allen et al. 2013 | Field campaign deployment (n =37) | Wintertime $NO_2$ (0.74; 5) $SO_2$ (0.78; 2) |

[a] For Li et al. 2015 only the circular buffer models were included as they are directly comparable.

[b] Only models without rooftop concentrations as a predictor are shown.

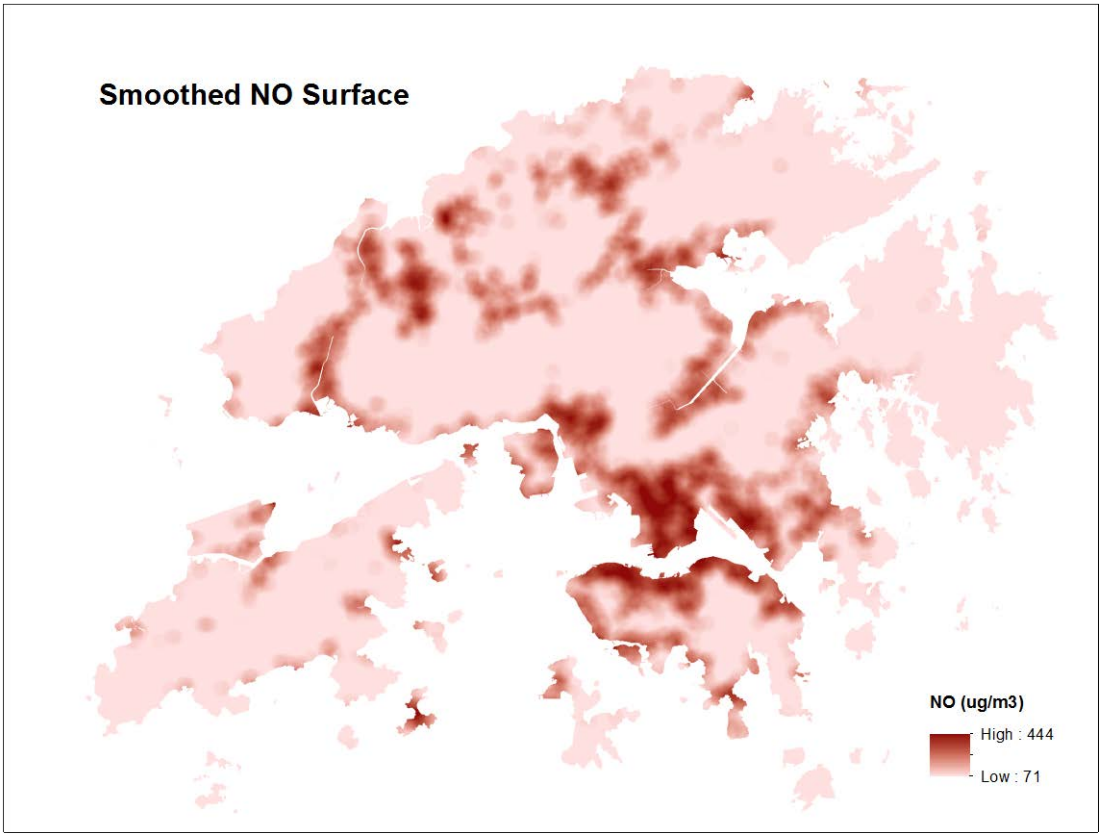



**Figure A.3. 2D LUR model surface for NO with 500 m smoothing applied for use in the cohort.**

# WP2

Prevailing wind direction obtained from Professor Jimmy Fung in the Division of Environment at Hong Kong University of Science and Technology. Two prevailing wind directional maps of Hong Kong at 60m above ground were generated by taking the dominant mode of the wind rose at each 100 m x 100 m grid aggregated over June to August and November to January for the years 2004 to 2006 (Figure A.4).

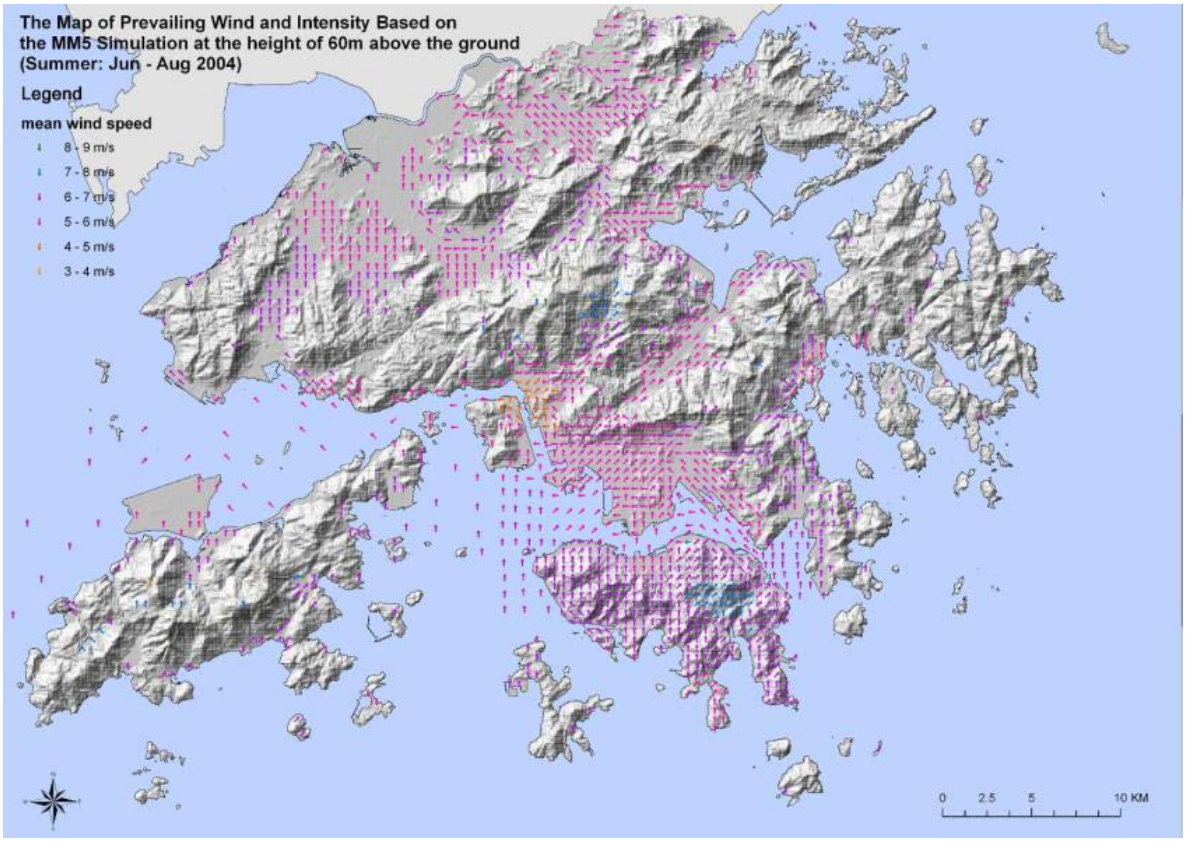



**Figure A.4. Simulated prevailing wind and intensity at 60m AGL for the summer season.**

**Table A.4.** Major factors and selection criteria for street canyons

| *Major Factors* | Selection Criteria | Data Sources |
|---|---|---|
| *Canyon Orientation* | Perpendicular to the prevailing wind direction, preferably opposite prevailing wind direction for summer and winter | Road centerline (Lands Department); Prevailing wind direction (Hong Kong Observatory and Hong Kong University of Science & Technology) |
| *Aspect Ratio* | Medium to high | Building height (Lands Department); Road width (Lands Department) |
| *Canyon Length* | Medium to long | Roads (Lands Department) |
| *Road Type* | Major and minor | Roads (Lands Department) |
| *Annual Average Daily Traffic (AADT)* | Low to high | 2014 Traffic data (Transport Department) |
| *Population Density* | High | 2011 Census (Census & Statistics Department) |
| *Building Type* | Residential (preferable) | Buildings (Census & Statistics Department) |

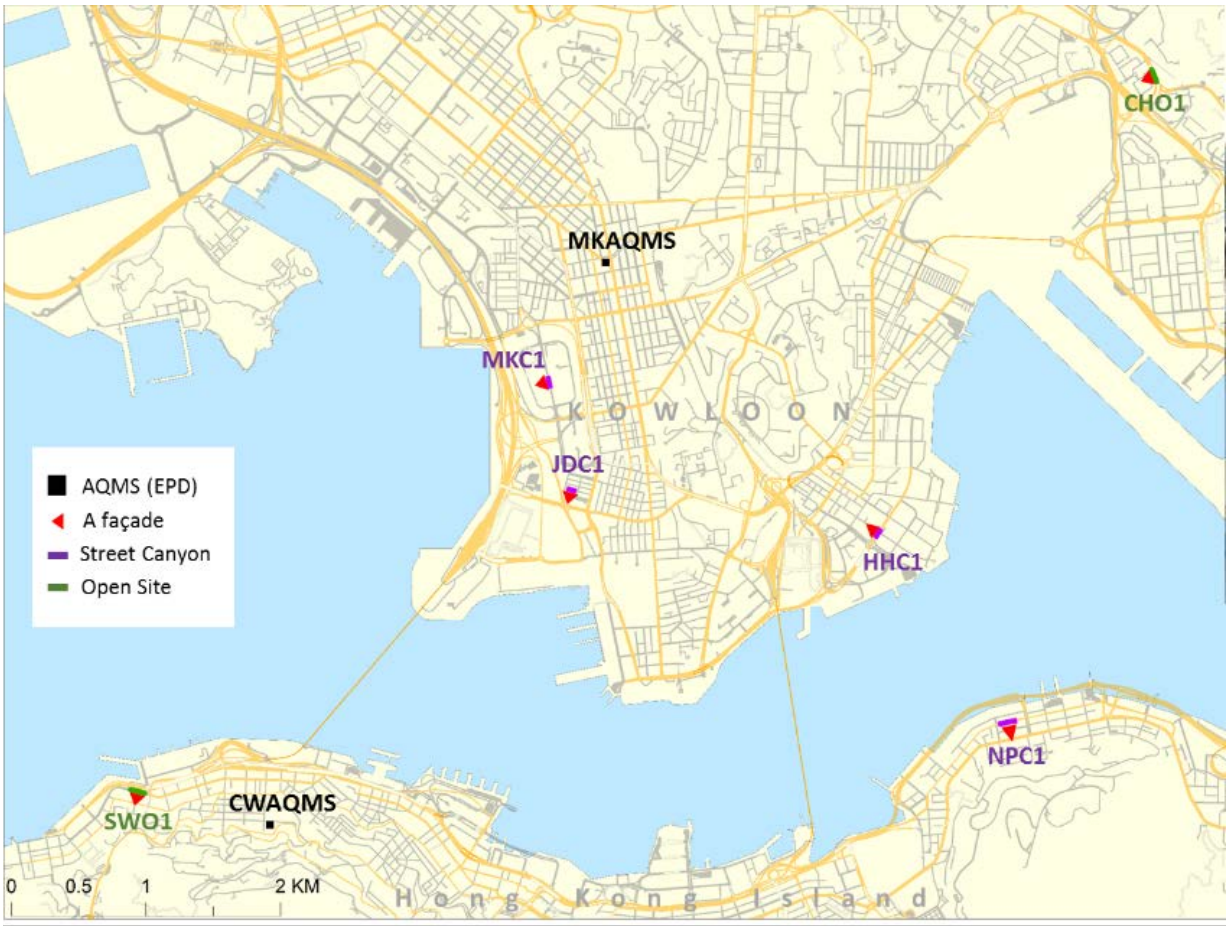
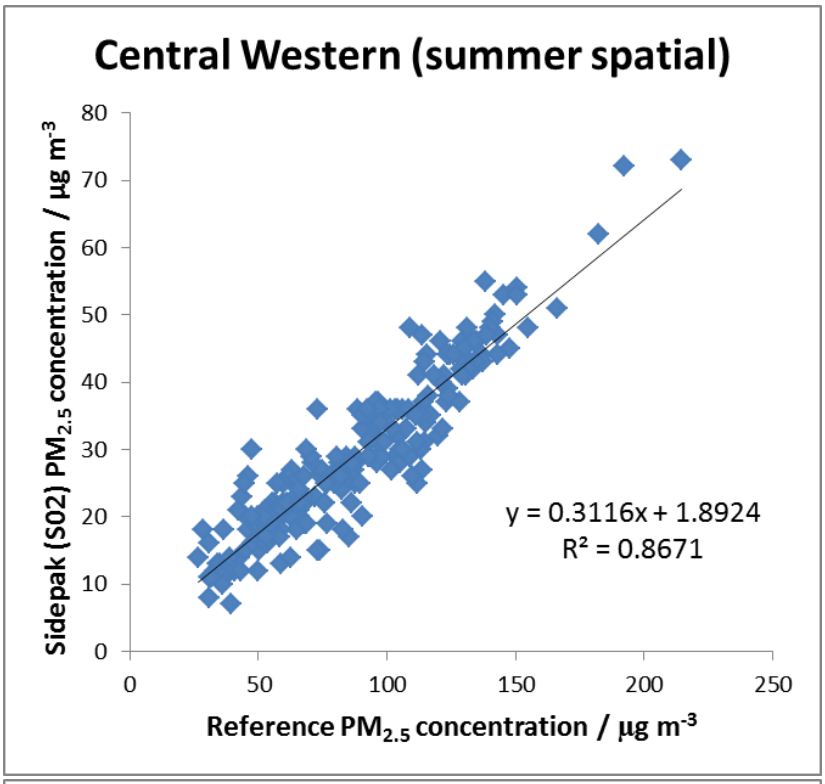


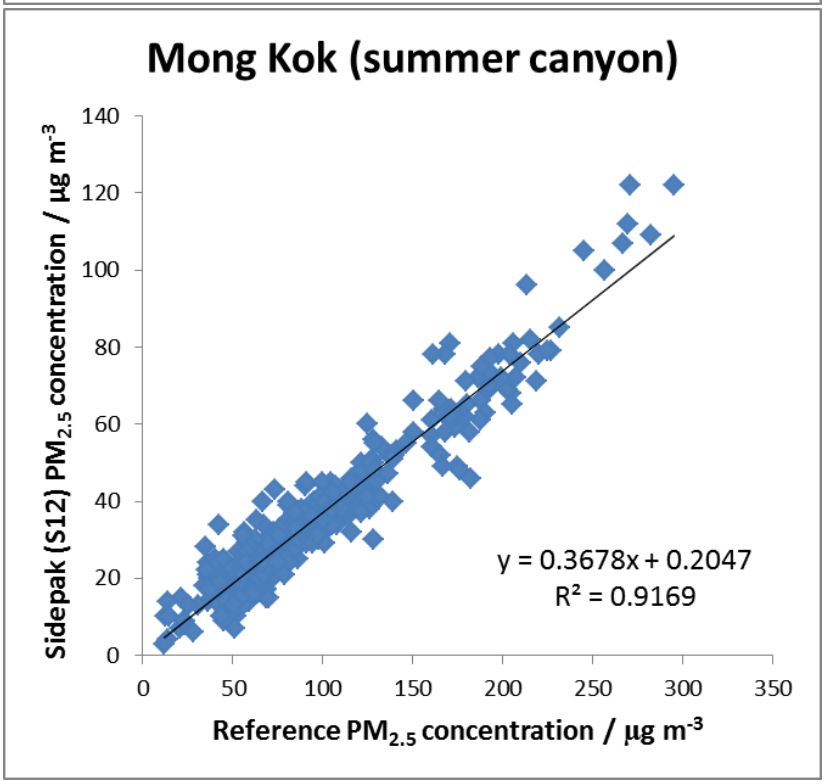

**Figure A.5. Map of the monitoring sites** (Purple = street canyons; green = open streets; red triangles show side A).

## SidePak vs reference monitor scaling

During each spatial and canyon monitoring campaign, SidePak $PM_{2.5}$ monitors were placed alongside an AQMS reference monitoring site for at least two weeks. These co-location periods were used to calculate a reference scaling factor and offset for the "reference" SidePak.

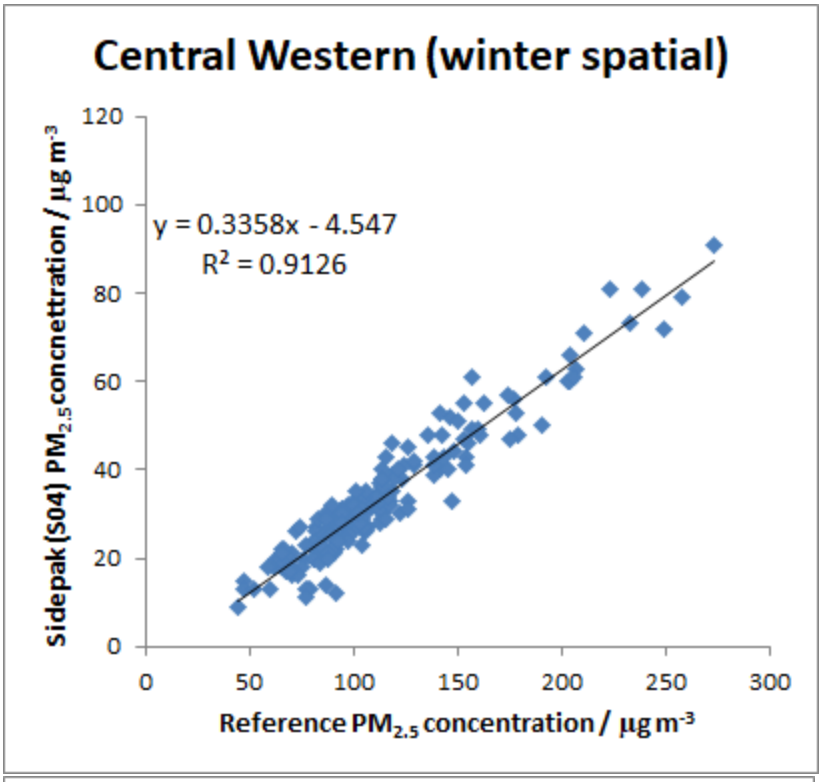



Co-location period: 24-Apr-2014 to 06-May-2014
SidePak unit: S02
Calibration factor: 0.31
Offset: 2

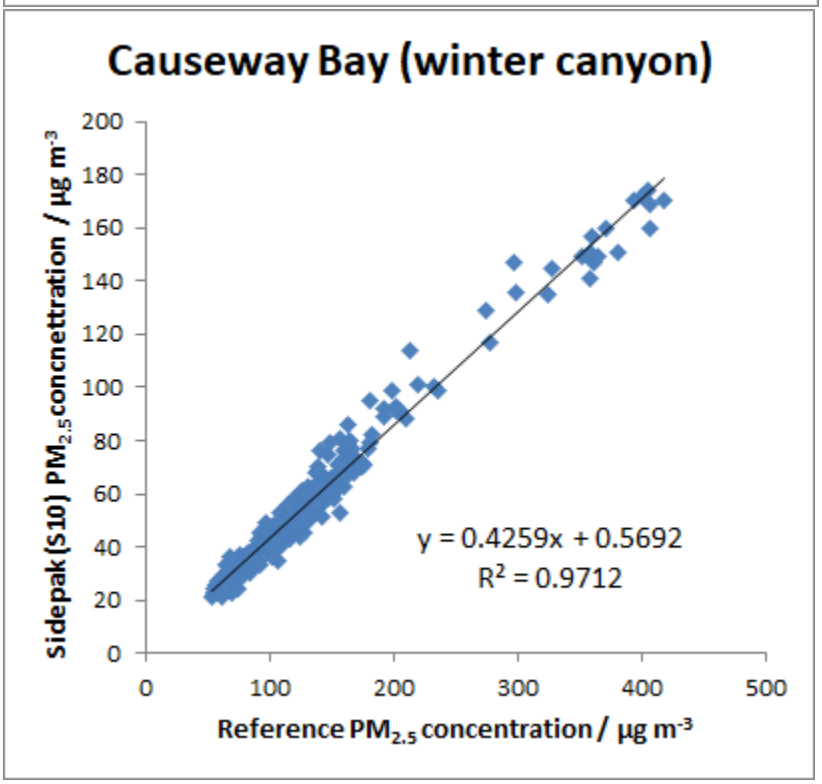



Co-location period: 04-Sept-2014 to 30-Sept-2014
SidePak unit: S12
Calibration factor: 0.37
Offset: 0

**Figure A.6. Summer (warm) season results of co-location of SidePak unit with AQMS reference monitor (FDMS TEOM).**




Co-location period:
18-Nov-2014 to 02-Dec-2015
SidePak unit: S04
Calibration factor: 0.34
Offset: -4.5




Co-location period: 30-Jan-2015 to 30-Feb-2015
SidePak unit: S10
Calibration factor: 0.43
Offset: 0.5

**Figure A.7. Winter (cool) season results of co-location of SidePak unit with AQMS reference monitor (FDMS TEOM).**

## SidePak unit correction factors (derived from precision experiments)

Following reference scaling, each SidePak unit in use during each campaign was scaled according to pre- and post-co-location monitoring results. A linear correlation matrix first identified units not responding in a unified way due to drift or early onset of a fault. In Table A.5 below, unit S03 was been identified as an outlier and subsequently sent for repair. Precision scaling factors and offsets were calculated by applying linear regression analysis to each unit against the 'reference' unit. After precision scaling, all units were reference scaled.

**Table A.5.** Correlation matrix plus offset and gradient scaling factors for the winter canyon pre-campaign precision test. Fill colours indicate degree of correlation, from dark green ($R^2$ = 1.00) through to dark red ($R^2$ < 0.2). *S10 was the reference unit during this test.

| Unit \ $R^2$ | S01 | S02 | S03 | S04 | S07 | S09 | S10* | S11 | S12 | CAN06 |
|---|---|---|---|---|---|---|---|---|---|---|
| S01 | | 1.00 | 0.21 | 0.97 | 0.98 | 0.99 | 1.00 | 0.96 | 1.00 | 1.00 |
| S02 | 1.00 | | 0.21 | 0.97 | 0.98 | 0.99 | 1.00 | 0.97 | 1.00 | 1.00 |
| S03 | 0.21 | 0.21 | | 0.12 | 0.27 | 0.24 | 0.25 | 0.28 | 0.25 | 0.19 |
| S04 | 0.97 | 0.97 | 0.12 | | 0.94 | 0.96 | 0.95 | 0.92 | 0.96 | 0.98 |
| S07 | 0.98 | 0.98 | 0.27 | 0.94 | | 0.96 | 0.98 | 0.99 | 0.99 | 0.98 |
| S09 | 0.99 | 0.99 | 0.24 | 0.96 | 0.96 | | 0.99 | 0.96 | 0.99 | 0.99 |
| S10 | 1.00 | 1.00 | 0.25 | 0.95 | 0.98 | 0.99 | | 0.98 | 1.00 | 0.99 |
| S11 | 0.96 | 0.97 | 0.28 | 0.92 | 0.99 | 0.96 | 0.98 | | 0.98 | 0.97 |
| S12 | 1.00 | 1.00 | 0.25 | 0.96 | 0.99 | 0.99 | 1.00 | 0.98 | | 0.99 |
| CAN06 | 1.00 | 1.00 | 0.19 | 0.98 | 0.98 | 0.99 | 0.99 | 0.97 | 0.99 | |
| Offset | 1 | 5 | | 41 | 29 | 2 | 0 | 3 | 1 | 5 |
| Scale | 1.01 | 1.02 | - | 0.95 | 0.91 | 1.14 | 1.00 | 1.89 | 0.96 | 1.28 |

A comparison of unscaled and precision+reference scaled $PM_{2.5}$ measurements from all SidePak units is shown in Figure A.8 and Figure A.9.

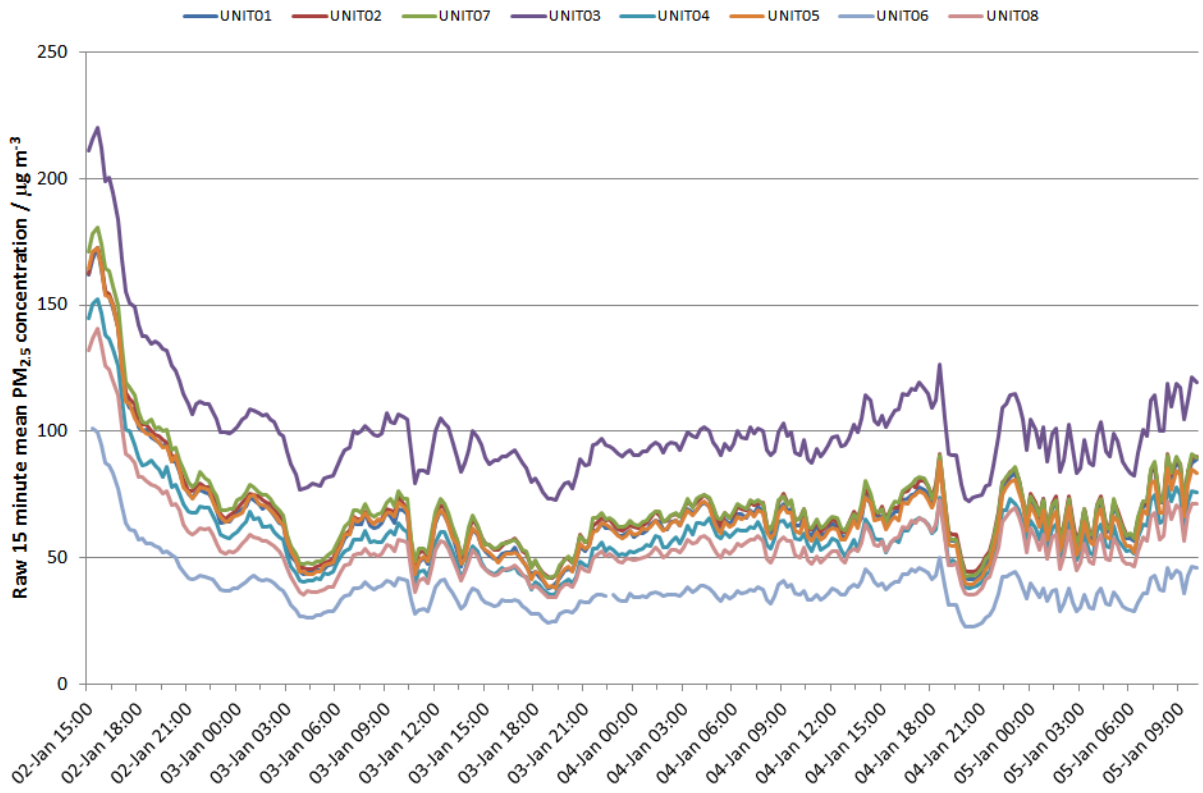



**Figure A.8. Comparison of co-located SidePak units prior to application of the ratification process.**

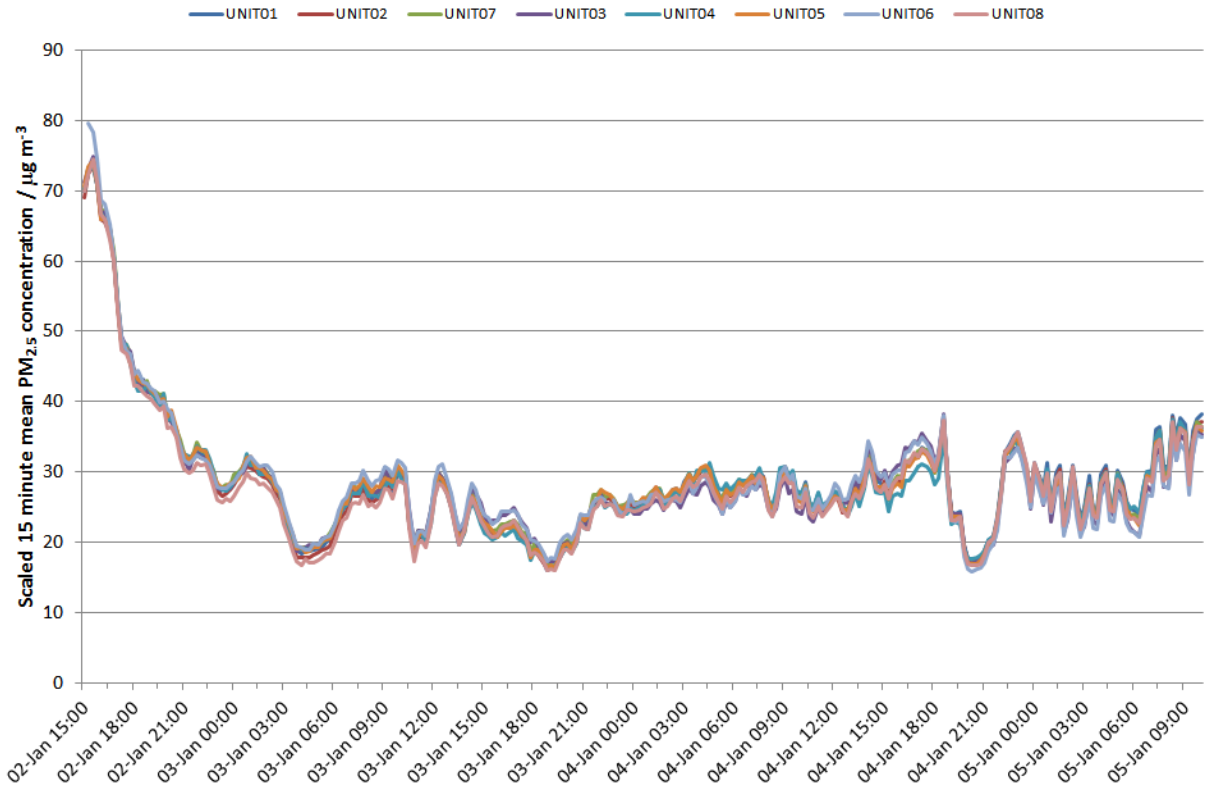



**Figure A.9. Comparison of co-located SidePak units following ratification.**

**Table A.6.** Offset and scale factors for SidePak unit precision correction

| Unit | Offset | Scale | Comments |
|---|---|---|---|
| Summer spatial campaign | | | |
| S01 | -7 | 0.91 | |
| *S02* | *0* | *1.00* | *Reference Unit* |
| S03 | -10 | 1.12 | |
| S04 | 29 | 0.90 | |
| S05 | 16 | 1.10 | |
| S06 | | | Fault |
| S07 | -10 | 1.00 | |
| S08 | -7 | 0.84 | |
| S09 | | | Fault |
| S10 | -8 | 0.87 | |
| S11 | -5 | 1.14 | |
| S12 | -5 | 0.92 | |
| Summer canyon campaign a | | | |
| S01 | -2 | 0.97 | |
| S02 | 5 | 1.12 | |
| S03 | -6 | 1.22 | |
| S04 | 39 | 1.00 | |
| S05 | 21 | 1.30 | |
| S06 | | | Fault |
| S07 | -6 | 1.00 | |
| S08 | -2 | 0.91 | |
| S09 | | | Fault |
| S10 | -3 | 0.93 | |
| S11 | -1 | 1.27 | |
| *S12* | *0* | *1.00* | *Reference Unit* |
| Winter canyon campaign a | | | |
| S01 | 1 | 1.01 | |
| S02 | 5 | 1.02 | |
| S03 | | | Fault |
| S04 | 41 | 0.95 | |
| S05 | | | Fault |
| S06 | | | Fault |
| S07 | 29 | 0.91 | |
| S08 | | | Fault |
| S09 | 2 | 1.14 | |
| *S10* | *0* | *1.00* | *Reference Unit* |
| S11 | 3 | 1.89 | |
| S12 | 1 | 0.96 | |
| CAN06 | 5 | 1.28 | |
| CAN11 | 5 | 1.08 | |

*Continued on next page.*

**Table A.6 *continued*.** Offset and scale factors for SidePak unit precision correction

| | | | |
|---|---|---|---|
| Winter spatial campaign | | | |
| S01 | -35 | 1.08 | |
| S02 | -31 | 1.10 | |
| S03 | | | Fault |
| *S04* | *0* | *1.00* | *Reference Unit* |
| S05 | | | Fault |
| S06 | | | Fault |
| S07 | -15 | 0.95 | |
| S08 | | | Fault |
| S09 | -30 | 1.22 | |
| S10 | -38 | 1.06 | |
| S11 | -17 | 2.04 | |
| S12 | -38 | 1.02 | |
| CAN06 | -26 | 1.35 | |
| CAN11 | 0 | 1.09 | |
| Winter canyon campaign b | | | |
| S01 | 1 | 1.01 | |
| S02 | 5 | 1.02 | |
| S03 | 257 | 1.27 | |
| S04 | 41 | 0.95 | |
| S05 | 3 | 0.94 | |
| S06 | | | Fault |
| S07 | 29 | 0.91 | |
| S08 | 6 | 0.85 | |
| S09 | 2 | 1.14 | |
| *S10* | *0* | *1.00* | *Reference unit* |
| S11 | 3 | 1.89 | |
| S12 | 1 | 0.96 | |
| CAN06 | 5 | 1.28 | |
| CAN11 | 5 | 1.08 | |
| Summer canyon campaign b and AQMS canyons | | | |
| S01 | -4 | 0.82 | |
| S02 | 3 | 0.96 | |
| S03 | | | Fault |
| S04 | 79 | 0.92 | |
| S05 | 11 | 0.90 | |
| S06 | | | Fault |
| S07 | | | Fault |
| S08 | 4 | 0.79 | |
| S09 | 7 | 0.97 | |
| *S10* | *0* | *1.00* | *Reference unit* |
| S11 | | | Fault |
| S12 | 11 | 0.98 | |
| CAN06 | | | Not used |
| CAN07 | 2 | 0.82 | |
| CAN08 | 5 | 1.16 | |

## MicroAeth attenuation correction factors

A number of different methods were tested to correct the microAeth filter loading attenuation effect, including Kirchstetter and Novakov (2007) and Virkkula and colleagues (2007). We found that the Kirchstetter method under-corrected at high filter loadings. We also found that Virkkula attenuation correction factors calculated during the precision tests (by changing filters on half of the units after 24 hours and analyzing the difference in response between fresh and exposed filters) did not remain valid throughout the campaigns due to changes in atmospheric conditions. We therefore calculated factors for each canyon for each season using the following method adapted from Virkkula:

1. Extract 20 minute mean BC concentration prior to and following each filter change for each unit in operation within the canyon (8 units), excluding a 15 minute buffer to allow the instrument to settle.
2. Calculate k factors for each filter change using the formula:

$$\beta = (BC_l - BC_f)/(AT_f*BC_f - AT_l*BC_l)$$

Where $BC_l$ is the last BC concentration before filter change, $BC_f$ is the first following filter change, $AT_l$ and $AT_f$ are the last and first attenuation values before and after filter change.

3. Take the mean $\beta$ value from all filter changes (up to 18 per canyon) to derive a canyon specific factor.

The attenuation correction factors calculated for each canyon and season are shown in *Table A.7*.

**Table A.7.** Filter attenuation correction factors calculated for microAeth units for each campaign

| *Site* | Summer 2014 | Winter | Summer 2015 |
|---|---|---|---|
| *Spatial* | 0.008 | 0.007 | |
| *CHO1* | 0.006 | 0.009 | |
| *JDC1* | 0.011 | 0.007 | |
| *MKC1* | 0.019 | 0.004 | |
| *SWO1* | 0.009 | 0.006 | |
| *HHC1* | | 0.009 | 0.008 |
| *NPC1* | | 0.005 | 0.007 |
| *AQMS canyons* | | | 0.008 |

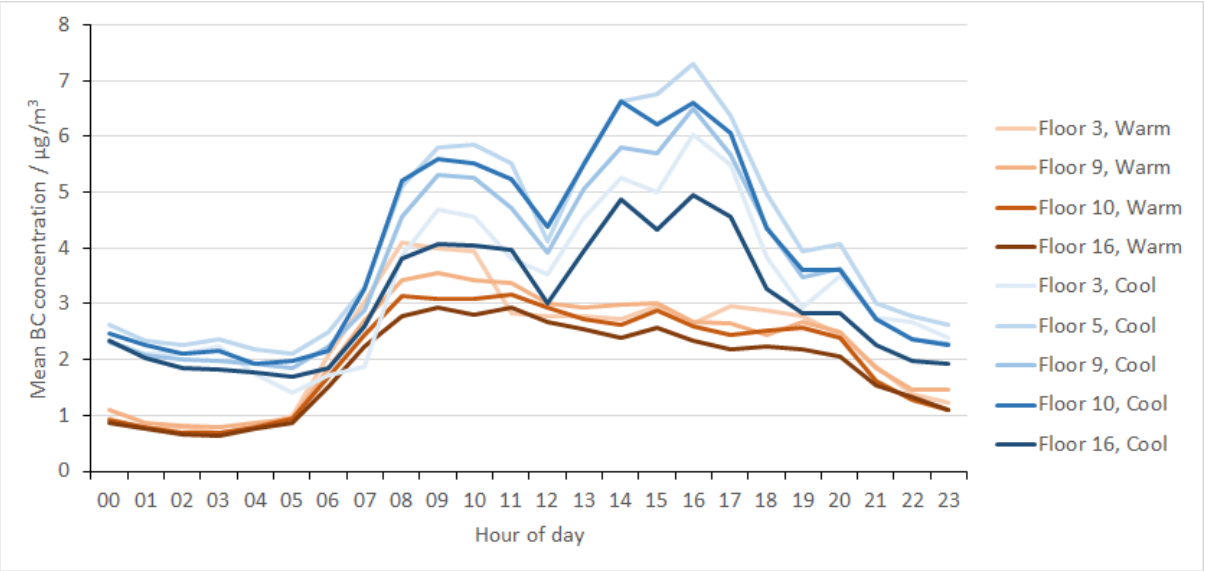
## AQMesh correlation matrices from colocation tests

Five precision tests were carried out on the AQMesh units between August and November 2014, each lasting between two and ten days. After a six hour stabilisation period had been excluded, results from each unit were compared to a single 'reference' AQMesh unit and linear regression used to derive correlation coefficients, scaling factors and offsets.

Table A.8. Precision test results for the eight AQMesh electrochemical units. R2 values ≥95% are shown in bold. Scale and offset values are removed ('-') where associated $R^2$ values were less than 0.2.

| | $R^2$ | | | | | Scale | | | | | Offset | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Unit*** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** | **1** | **2** | **3** | **4** | **5** |
| ***CO (ppb)*** | | | | | | | | | | | | | | | |
| *UNIT01* | Reference unit | | | | | | | | | | | | | | |
| *UNIT02* | 0.93 | 0.83 | 0.05 | 0.92 | 0.93 | 0.76 | 0.99 | - | 0.92 | 0.84 | -157 | -208 | - | -225 | -160 |
| *UNIT03* | **0.97** | 0.93 | 0.90 | **0.97** | **0.99** | 0.9 | 0.85 | 0.83 | 0.94 | 1.08 | 20 | 17 | 32 | 6 | -23 |
| *UNIT04* | 0.87 | 0.75 | 0.01 | **0.95** | 0.12 | 0.76 | 1.18 | - | 0.87 | 1.74 | -155 | -234 | - | -235 | -227 |
| *UNIT05* | 0.91 | 0.81 | **0.95** | **0.96** | **0.98** | 0.85 | 1.19 | 1.05 | 0.86 | 1 | 39 | -43 | -6 | 3 | 4 |
| *UNIT06* | 0.83 | 0.88 | **0.95** | 0.58 | **0.96** | 0.89 | 1.06 | 1.09 | 0.86 | 1.06 | 29 | 6 | -12 | -14 | -3 |
| *UNIT07* | 0.85 | 0.71 | 0.00 | 0.85 | **0.97** | 0.84 | 1.43 | - | 0.98 | 0.95 | 20 | -88 | - | -24 | 12 |
| *UNIT08* | 0.71 | 0.77 | 0.02 | **0.97** | **0.97** | 0.84 | 0.97 | - | 0.91 | 0.98 | 47 | -16 | - | -35 | 4 |
| ***NO (ppb)*** | | | | | | | | | | | | | | | |
| *UNIT01* | Reference unit | | | | | | | | | | | | | | |
| *UNIT02* | 0.69 | 0.11 | 0.71 | 0.09 | 0.58 | 1.03 | - | 0.44 | - | 0.46 | 2 | - | -25 | - | 4 |
| *UNIT03* | **0.98** | **0.99** | **0.98** | 0.76 | 0.83 | 1.17 | 1.28 | 1.69 | 0.79 | 0.88 | -33 | -4 | -2 | -31 | -9 |
| *UNIT04* | **0.99** | **0.99** | 0.87 | 0.00 | 0.29 | 1.25 | 1.48 | 1.16 | - | 0.58 | -16 | 7 | -62 | - | -46 |
| *UNIT05* | **0.96** | **0.97** | 0.94 | 0.78 | 0.93 | 1.5 | 1.27 | 1.06 | 1.04 | 0.97 | 8 | 19 | -12 | 6 | 11 |
| *UNIT06* | 0.33 | 0.16 | **0.98** | 0.36 | 0.88 | 0.74 | - | 1.51 | 0.62 | 1.09 | -27 | - | -34 | -57 | -11 |
| *UNIT07* | **0.95** | n.a. | 0.09 | 0.14 | 0.85 | 1.07 | n.a. | - | - | 1.08 | -43 | n.a. | - | - | 17 |
| *UNIT08* | 0.25 | 0.02 | 0.07 | 0.03 | 0.04 | 0.75 | - | - | - | - | -39 | - | - | - | - |
| ***$NO_2$ (ppb)*** | | | | | | | | | | | | | | | |
| *UNIT01* | 0.29 | 0.04 | 0.10 | 0.07 | 0.35 | 1.49 | - | - | - | 1.27 | 88 | - | - | - | 19 |
| *UNIT02* | Reference unit | | | | | | | | | | | | | | |
| *UNIT03* | 0.72 | 0.91 | 0.86 | 0.51 | 0.74 | 0.78 | 0.9 | 0.82 | 0.71 | 0.88 | -5 | -11 | -9 | -2 | -6 |
| *UNIT04* | 0.74 | 0.90 | 0.90 | 0.76 | 0.93 | 0.77 | 0.88 | 0.77 | 0.73 | 0.85 | -14 | -18 | -16 | -13 | -13 |
| *UNIT05* | 0.90 | 0.94 | 0.91 | 0.45 | **0.96** | 1.06 | 1.02 | 1.26 | 0.86 | 1.06 | 4 | 2 | -4 | 10 | 3 |
| *UNIT06* | 0.73 | 0.91 | 0.94 | 0.56 | **0.97** | 0.89 | 0.94 | 1.02 | 0.81 | 0.99 | -14 | -18 | -21 | -11 | -15 |
| *UNIT07* | 0.87 | **0.95** | 0.15 | 0.35 | 0.90 | 0.92 | 1.02 | - | 0.99 | 0.99 | 9 | 1 | - | 3 | -3 |
| *UNIT08* | 0.67 | 0.64 | 0.08 | 0.54 | 0.90 | 0.78 | 0.96 | - | 1.1 | 0.94 | -18 | -26 | - | -18 | -9 |
| ***Relative humidity (%)*** | | | | | | | | | | | | | | | |
| *UNIT01* | Reference unit | | | | | | | | | | | | | | |
| *UNIT02* | **0.98** | **0.99** | **0.99** | **0.99** | **1.00** | 1.08 | 1.10 | 1.11 | 1.3 | 1.02 | -8 | -10 | -10 | -27 | -2 |
| *UNIT03* | **0.98** | **1.00** | **1.00** | **1.00** | **0.99** | 1.08 | 1.12 | 1.13 | 1.08 | 1.14 | -8 | -11 | -11 | -7 | -13 |
| *UNIT04* | **0.96** | **1.00** | **1.00** | **0.99** | 0.04 | 1.05 | 1.12 | 1.09 | 1.30 | - | -6 | -11 | -9 | -27 | - |
| *UNIT05* | **0.96** | **0.99** | **0.99** | **0.99** | **1.00** | 1.08 | 1.07 | 1.08 | 1.15 | 0.99 | -8 | -8 | -8 | -14 | -1 |
| *UNIT06* | **0.95** | **0.98** | **0.99** | **0.98** | **1.00** | 1.06 | 1.07 | 1.01 | 1.12 | 0.98 | -8 | -9 | -4 | -13 | -1 |
| *UNIT07* | **0.96** | **0.99** | 0.22 | **0.99** | **1.00** | 1.04 | 1.06 | 0.34 | 1.27 | 1.01 | -6 | -7 | 32 | -25 | -2 |
| *UNIT08* | **0.96** | 0.02 | 0.01 | **0.99** | **1.00** | 1.04 | - | - | 1.20 | 0.97 | -6 | - | - | -20 | 0 |
| ***Temperature ($^oC$)*** | | | | | | | | | | | | | | | |
| *UNIT01* | Reference unit | | | | | | | | | | | | | | |
| *UNIT02* | **0.98** | **0.99** | **0.99** | **0.99** | **0.99** | 0.93 | 0.98 | 1.05 | 1.02 | 0.94 | 2 | 1 | -1 | -1 | 2 |
| *UNIT03* | **0.98** | **0.99** | **0.99** | **0.99** | **0.99** | 0.92 | 0.97 | 1.05 | 1.00 | 1.01 | 2 | 1 | -1 | 0 | 0 |
| *UNIT04* | **0.96** | **0.99** | **0.99** | **0.99** | 0.31 | 0.93 | 1.01 | 1.03 | 1.03 | 11.4 | 2 | 0 | -1 | -1 | 305 |
| *UNIT05* | **0.99** | **0.99** | **0.99** | **0.99** | **1.00** | 0.94 | 0.99 | 1.03 | 1.01 | 0.99 | 2 | 0 | -1 | 0 | 0 |
| *UNIT06* | **0.98** | **0.99** | **1.00** | **1.00** | **0.99** | 0.92 | 0.98 | 1.01 | 0.98 | 0.97 | 3 | 1 | 0 | 1 | 1 |
| *UNIT07* | **0.97** | **0.99** | 0.15 | **0.99** | **0.99** | 0.93 | 1 | 0.21 | 1.01 | 1.04 | 2 | 0 | 28 | -1 | -1 |
| *UNIT08* | **0.98** | **0.99** | 0.29 | **0.99** | **0.99** | 0.91 | 1.02 | 2.27 | 1 | 0.94 | 3 | -1 | -35 | 0 | 2 |

## Mean diurnal variations in BC and $PM_{2.5}$ recorded during the canyon campaigns



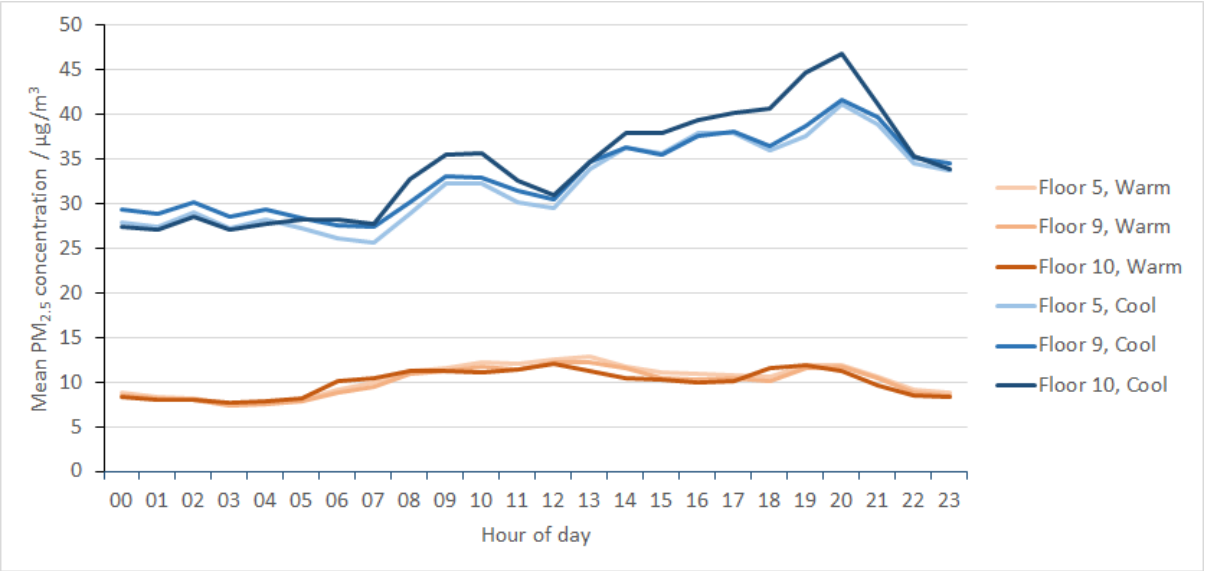
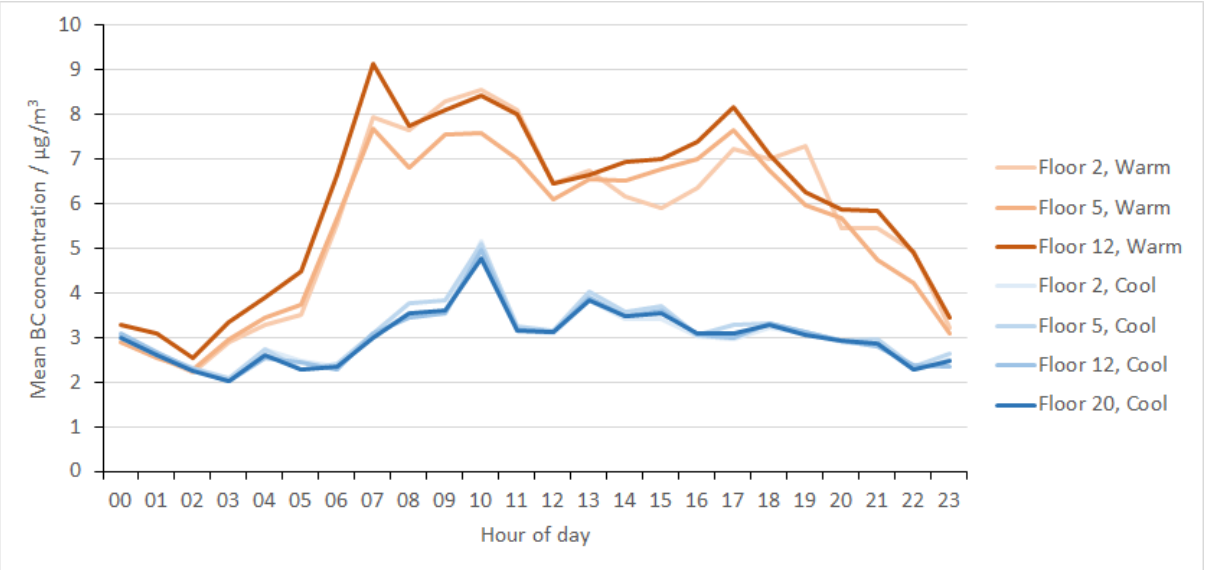




**Figure A.10. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at NPC1.**



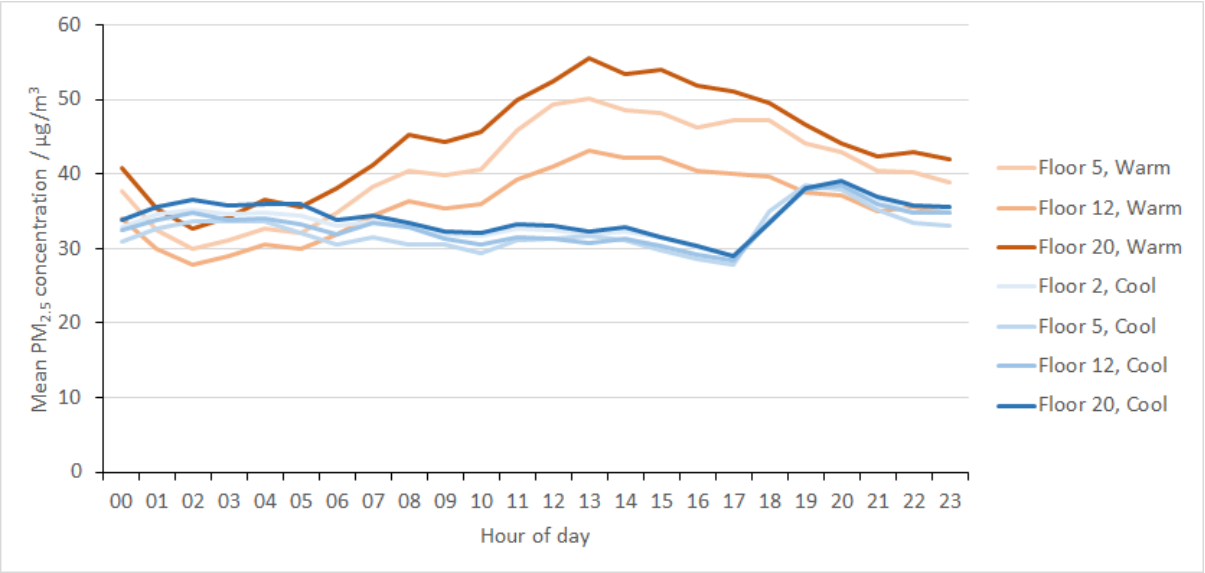
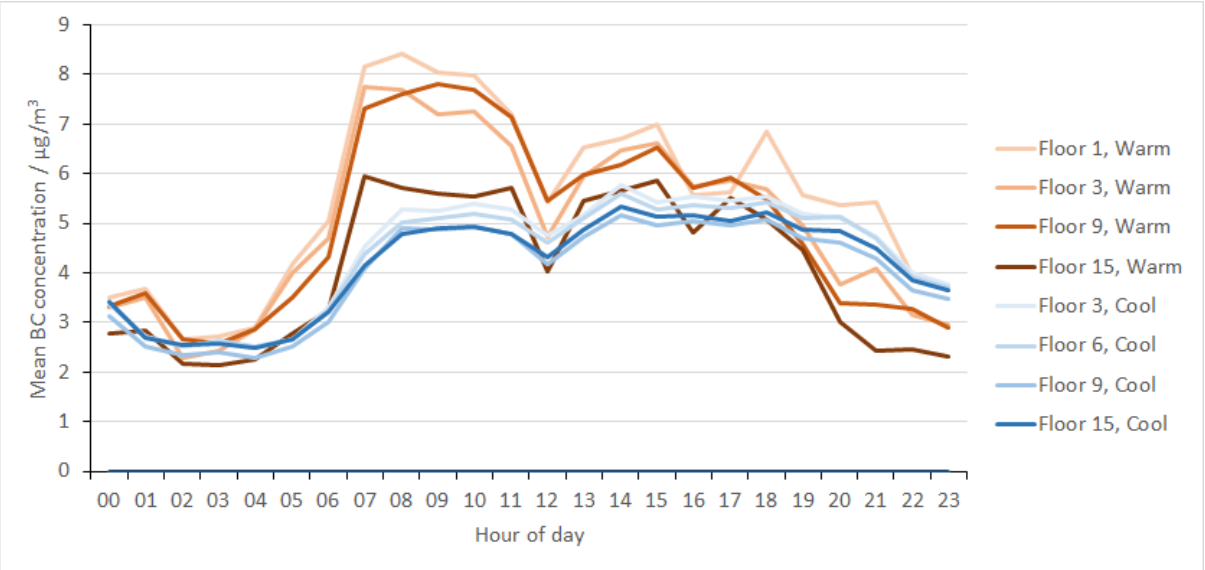




**Figure A.11. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at MKC1.**



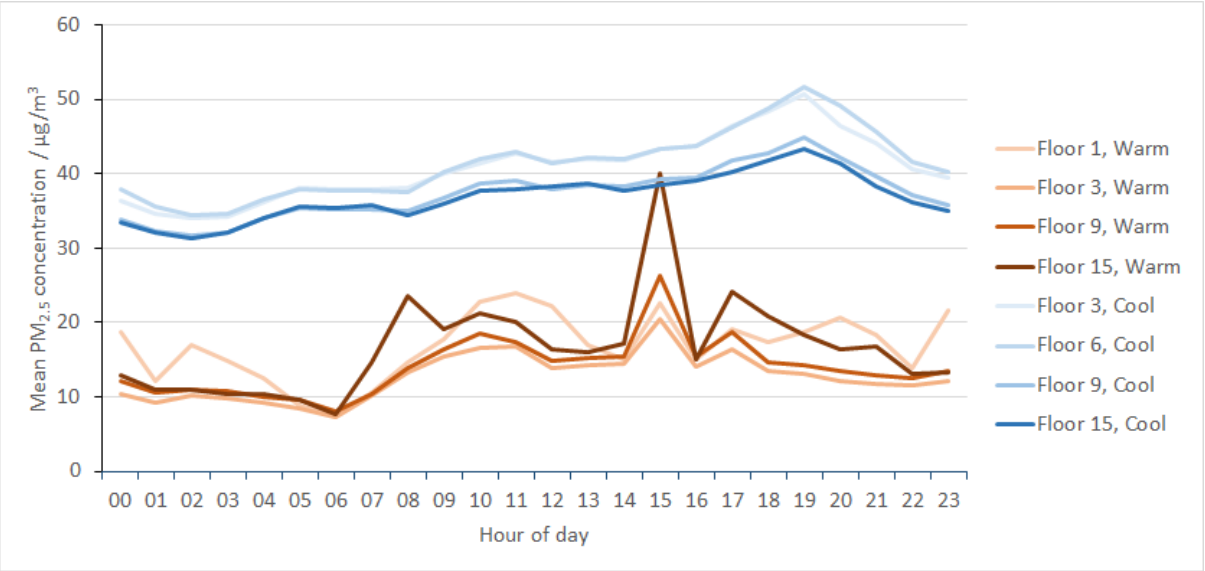
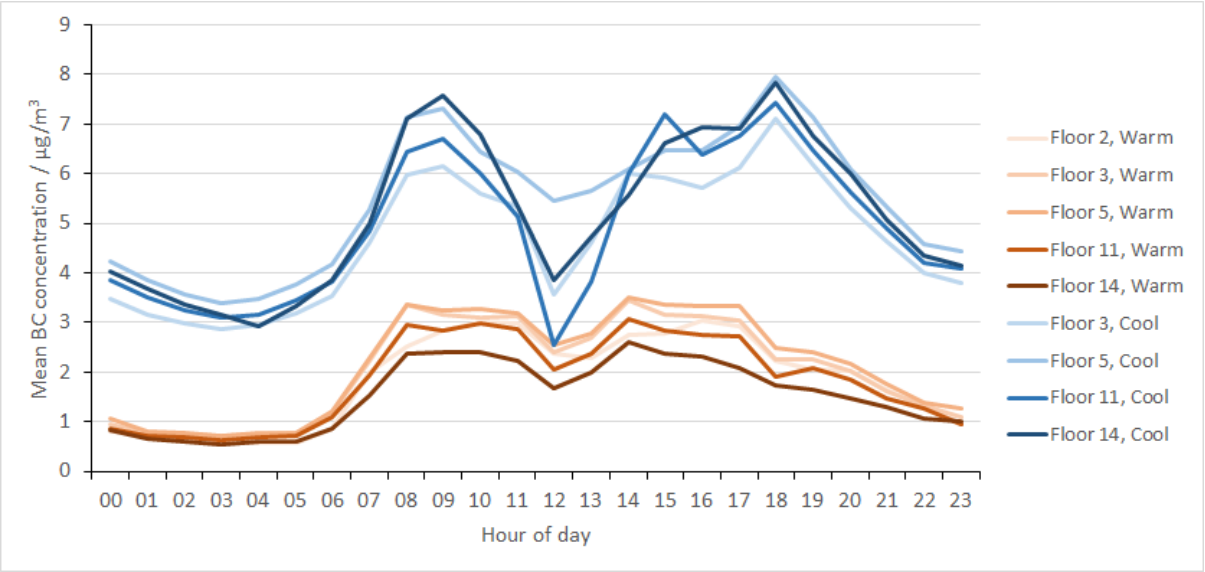




**Figure A.12. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at JDC1.**



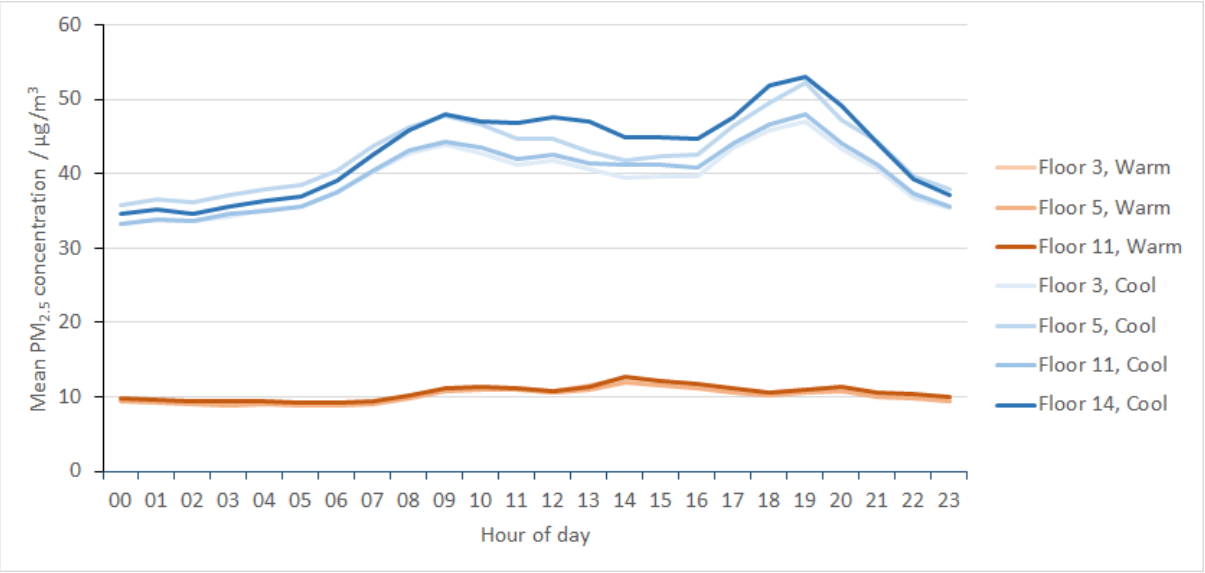
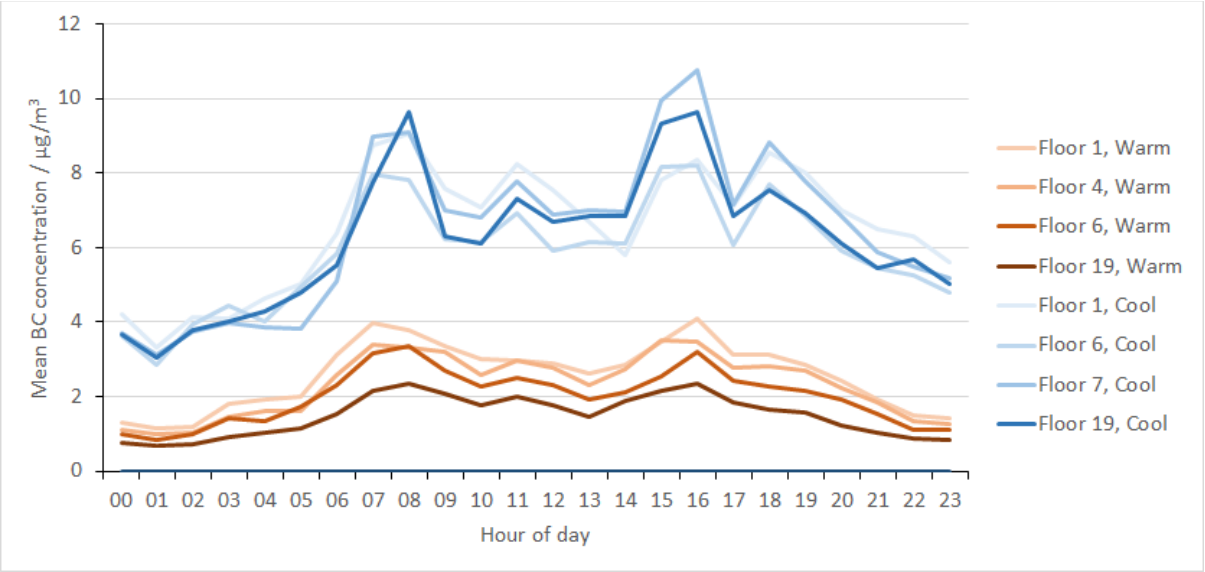




**Figure A.13. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at HHC1.**



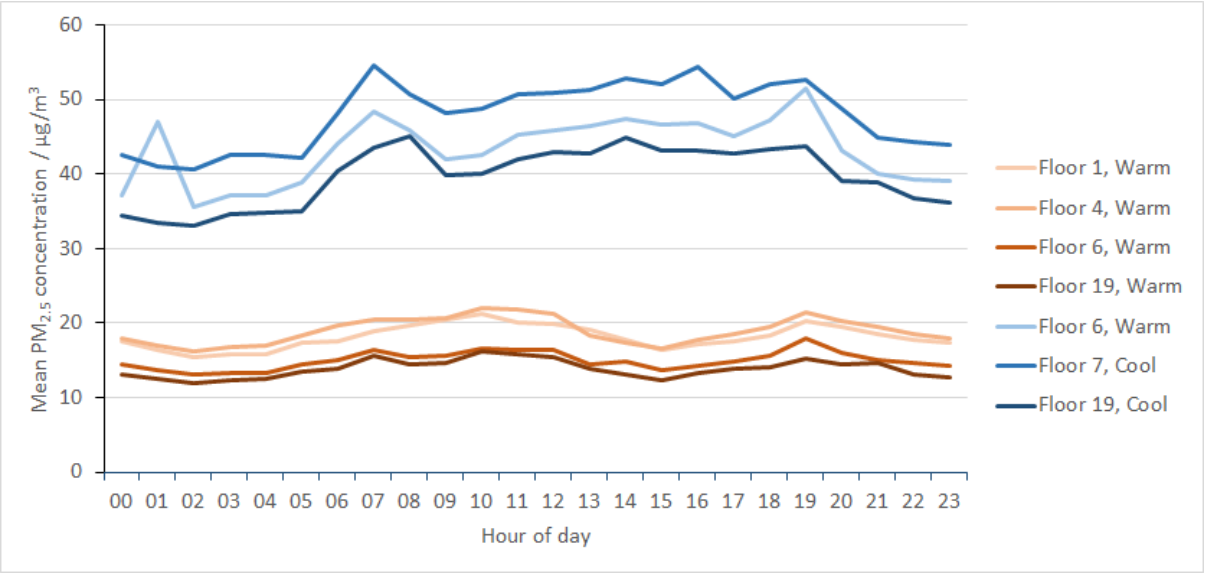




**Figure A.14. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at CHO1.**

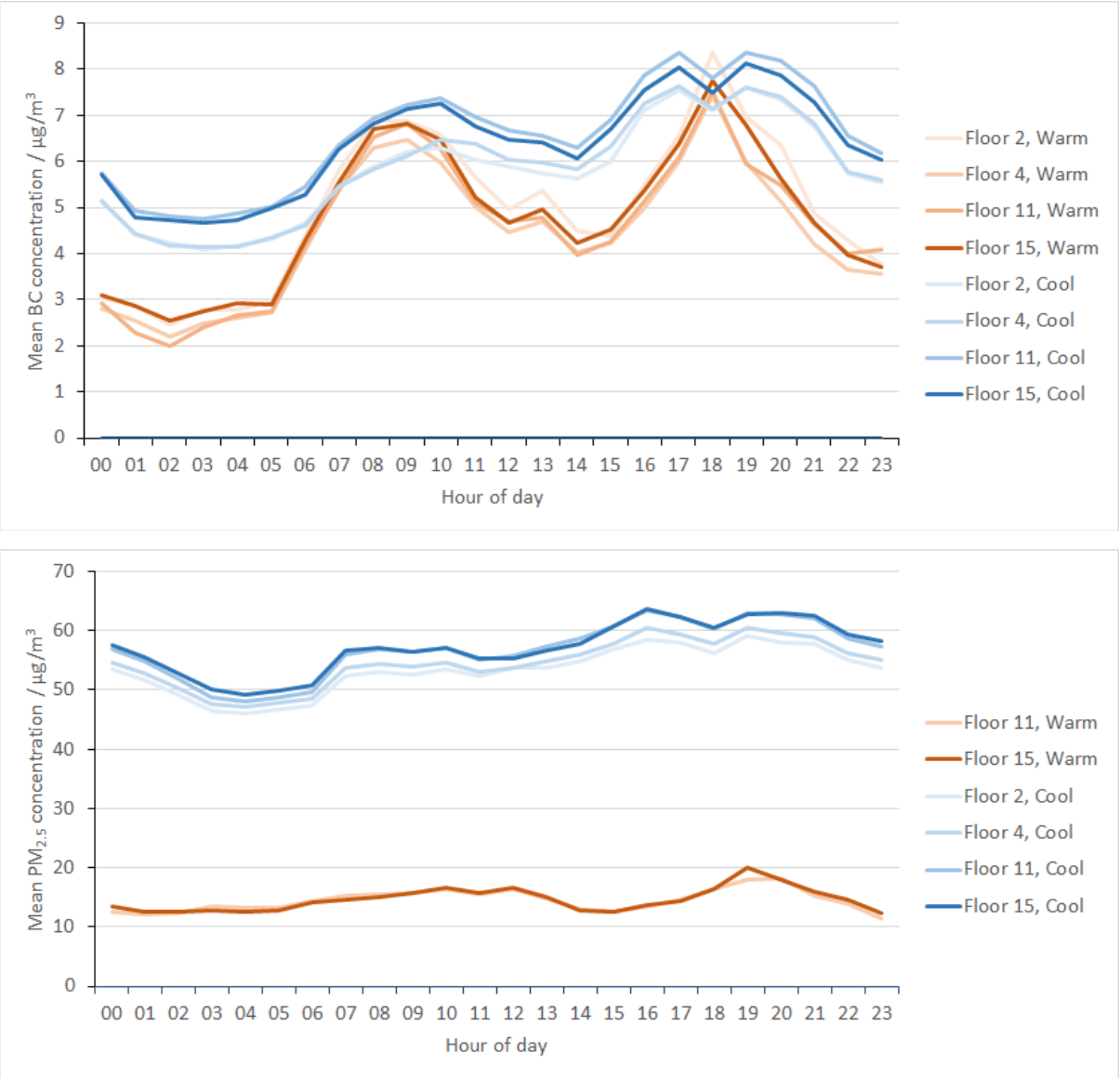
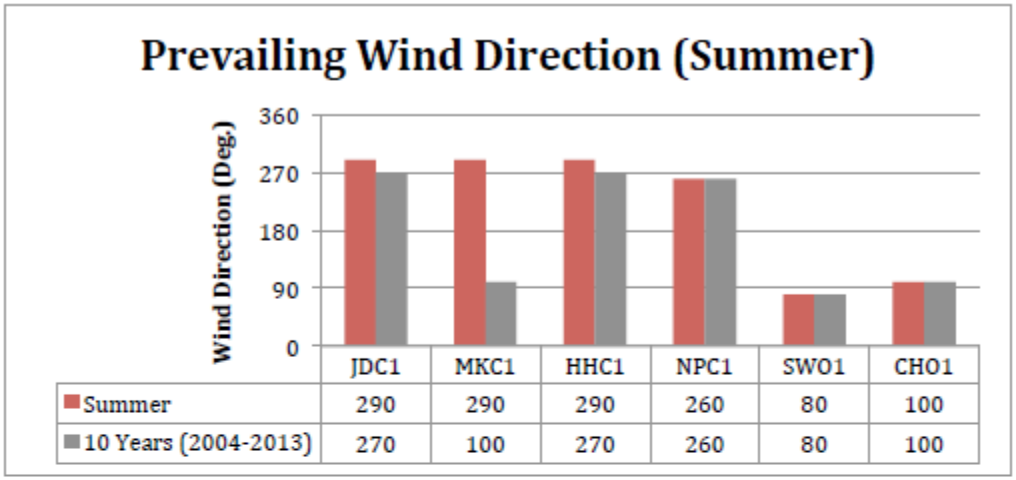



**Figure A.15. Mean diurnal variation in BC (top) and $PM_{2.5}$ (bottom) at SWO1.**

## Comparison of wind direction during canyon campaigns in comparison with 10 year mean

These figures show wind direction recorded at the Hong Kong Observatory site during the summer (warm season) and winter (cool season) canyon monitoring campaigns in comparison with the same site's 10 year mean.



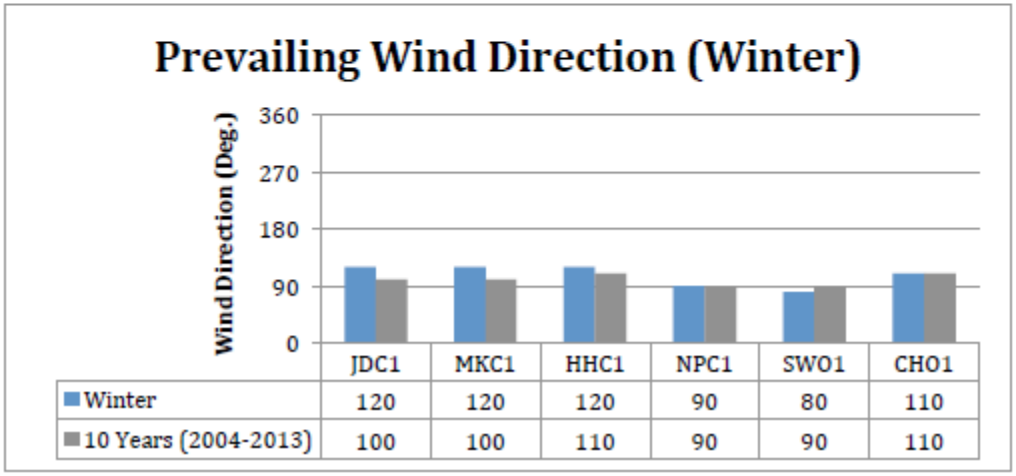




**Figure A.16. Prevailing wind direction recorded at the HK Observatory over the previous 10 years in comparison with the canyon campaign period.**

## Mean vertical concentrations of $PM_{2.5}$ and BC at the CHO1 site

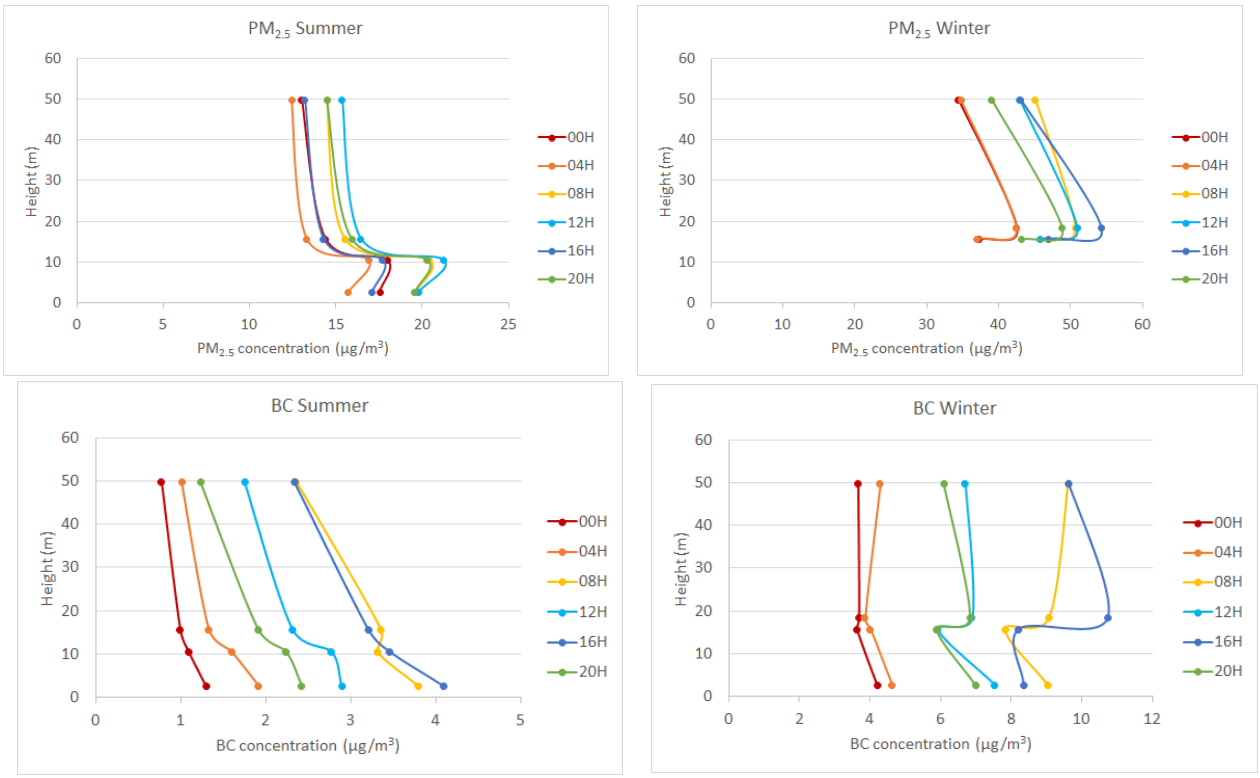



**Figure A.17. Mean vertical concentrations of $PM_{2.5}$ and BC at the CHO1 site at six time points, illustrating the consistency of the decay curve throughout the day.** Note that modeled street level estimates are not included.

## Comparison of measured and modeled $PM_{2.5}$ and BC concentrations

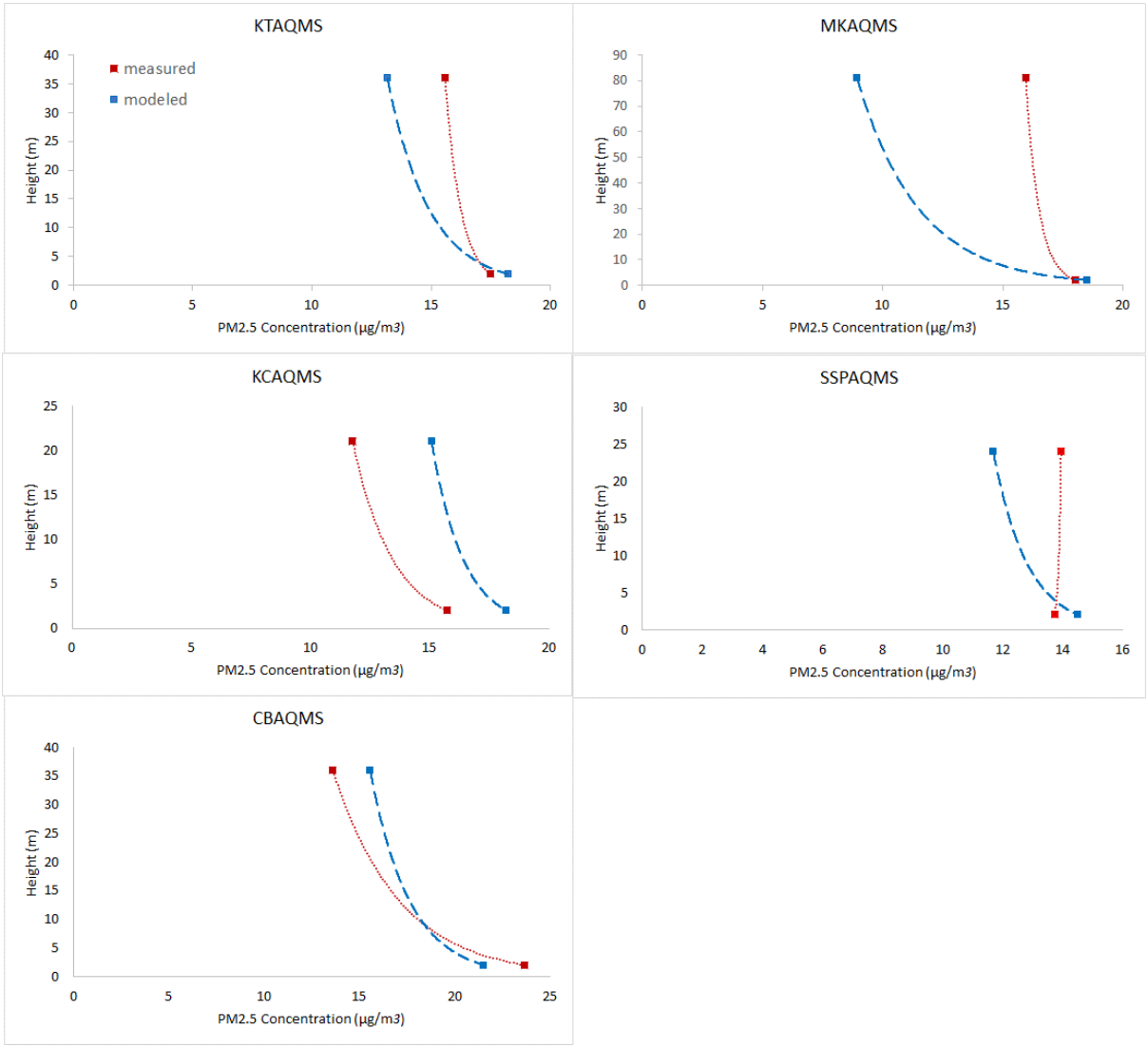



**Figure A.18. Comparison of measured and modeled $PM_{2.5}$ concentrations at five government network canyon monitoring sites.**

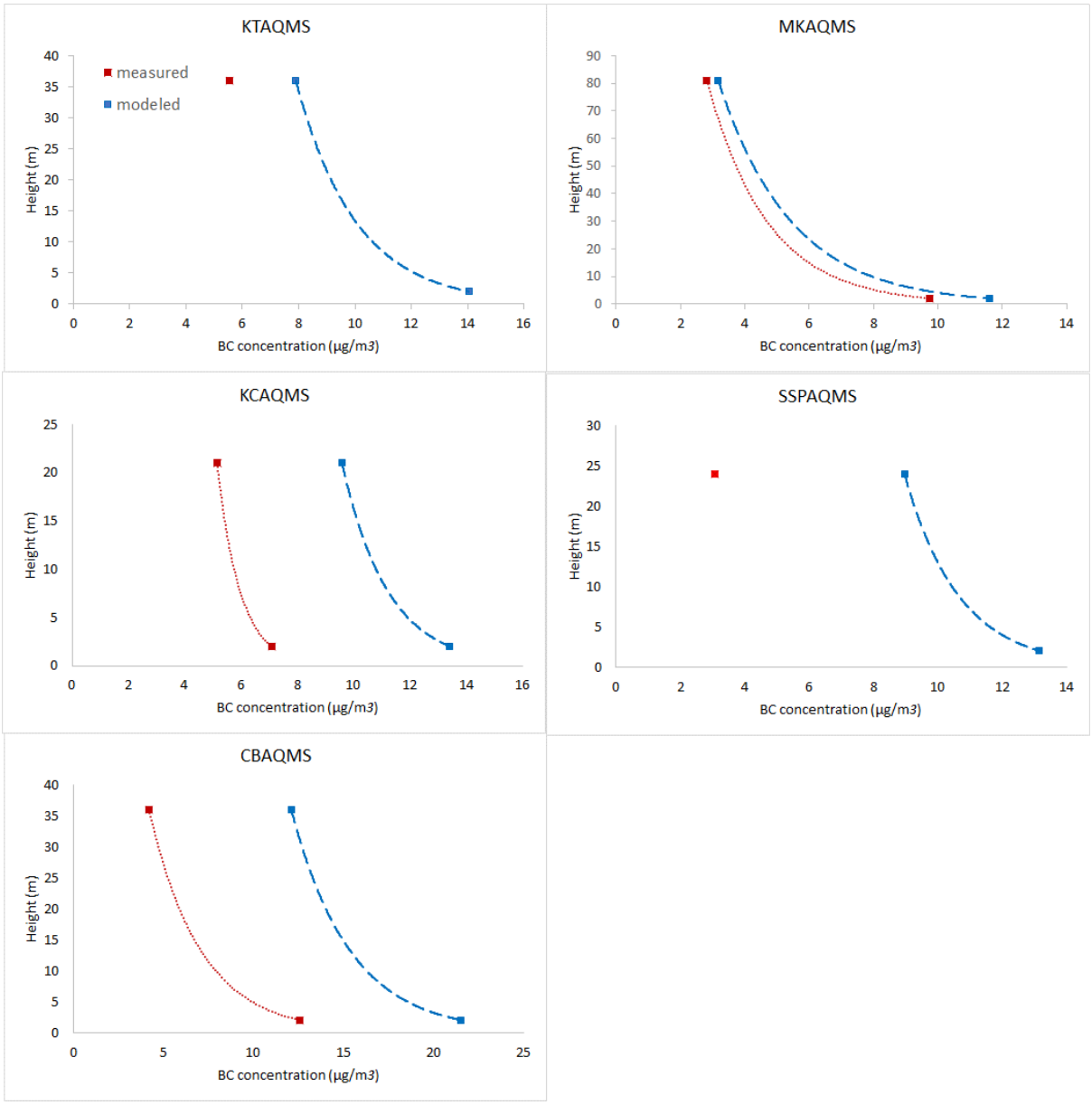



**Figure A.19. Comparison of measured and modeled black carbon concentrations at five government network canyon monitoring sites.**

## Results of $F_{inf}$ calculations from residential sampling

Table A.9. Infiltration efficiencies for all homes derived from the infiltration analysis of paired indoor/outdoor sampling. Median values were used in the dynamic model.

| *Home* | $PM_{2.5}$ warm | $PM_{2.5}$ cool | BC warm | BC cool |
|---|---|---|---|---|
| *CHO1A1* | 0.84 | 0.78 | 1.37 | 0.76 |
| *CHO1A19* | 1.03 | 0.94 | 0.91 | 0.46 |
| *CHO1A4* | 0.48 | | 0.93 | |
| *CHO1A6* | 0.72 | 0.92 | 1.07 | 0.56 |
| *CHO1A7* | | 0.85 | | 0.50 |
| *HHC1A11* | 0.64 | 1.13 | | 0.91 |
| *HHC1A14* | | 0.81 | | 1.02 |
| *HHC1A2* | 0.84 | | | 0.42 |
| *HHC1A3* | 0.39 | 0.79 | 0.97 | 0.96 |
| *HHC1A5* | 1.15 | 1.04 | 1.00 | 0.88 |
| *JDC1A1* | 0.93 | | 1.04 | |
| *JDC1A15* | | 0.93 | 0.86 | 1.30 |
| *JDC1A3* | 0.57 | 0.72 | 0.78 | 1.15 |
| *JDC1A6* | | 0.91 | | 1.20 |
| *JDC1A9* | 0.84 | 0.91 | 0.88 | 0.99 |
| *MKC1A12* | 0.83 | 1.18 | 0.87 | 1.05 |
| *MKC1A2* | 0.61 | 1.12 | 0.78 | 1.02 |
| *MKC1A20* | | 1.01 | 0.89 | 0.89 |
| *MKC1A5* | 0.59 | 0.90 | 0.82 | 1.14 |
| *NPC1A10* | 0.63 | | 0.86 | 0.84 |
| *NPC1A16* | 0.63 | 0.85 | 0.72 | 0.68 |
| *NPC1A5* | 0.81 | 0.85 | 0.93 | 0.91 |
| *NPC1A9* | | 0.82 | 0.64 | 0.77 |
| *SWO1A11* | 1.13 | 0.82 | 0.88 | 0.99 |
| *SWO1A15* | 1.08 | 0.99 | 0.91 | 1.01 |
| *SWO1A2* | 1.04 | 0.86 | 0.75 | 0.73 |
| *SWO1A4* | 0.41 | 0.98 | 0.84 | 0.95 |
| *Mean* | 0.77 | 0.92 | 0.89 | 0.88 |
| *Median* | 0.81 | 0.91 | 0.88 | 0.91 |
| *SD* | 0.23 | 0.12 | 0.15 | 0.23 |

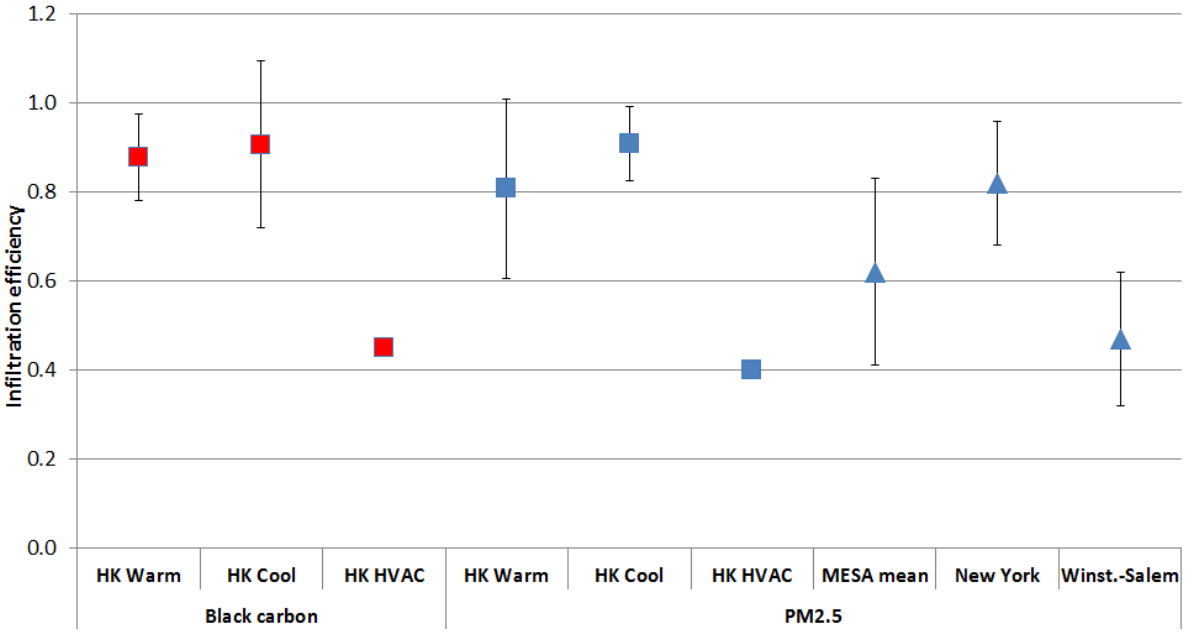



**Table A.10. Summary chart of median $F_{inf}$ values in comparison with U.S. values calculated using a similar methodology in the MESA-Air study (Allen et al. 2012).**

## Correlation analysis of $F_{inf}$ against occupant behavior

BC and $PM_{2.5}$ $F_{inf}$ values derived from paired in/out monitoring during each season were compared against resident questionnaire and daily log responses. For each of cooking, window-opening and in-window air conditioner use (referred to as C, W, and AC respectively), a score was calculated. These scores were defined to be the number of times the residents said they used each of these divided by the total number of opportunities (21 for each). For example, if a resident cooked every evening for all seven days, but not at any other time, then for this resident we would assign C = 7/21 = 1/3. The *R* function lm() was used to perform regression analysis, using single-variable tests (Pearson, Spearman and Kendall).

During the warm season, significant negative correlation ($P$ <0.05) was found between the $F_{inf}$ of both pollutants and AC. During the cool season none of the residents used air conditioning, so an AC correlation test was not possible. No significant correlations were found.

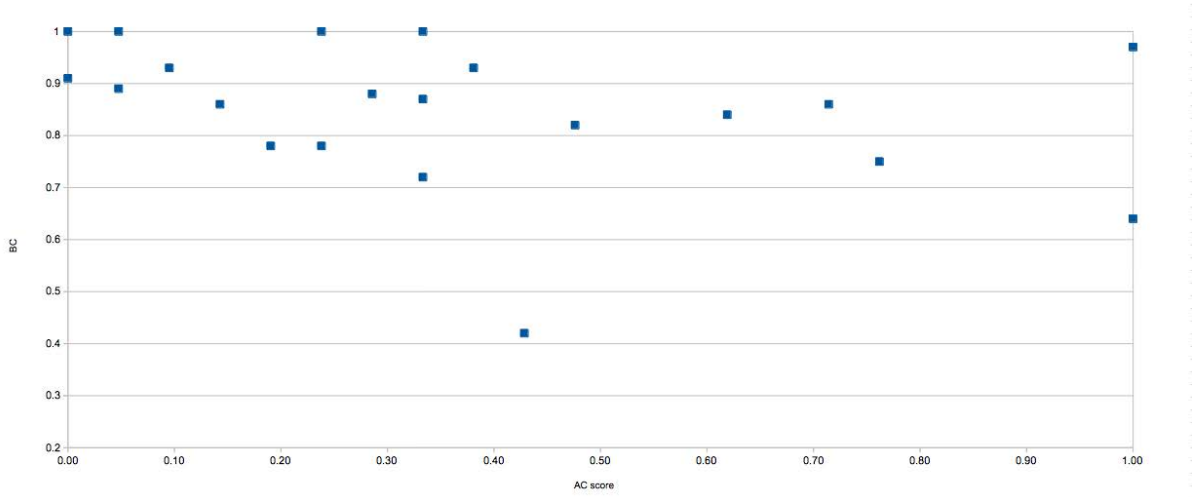



**Figure A.20. Scatter plot of AC score against BC $F_{inf}$ showing evidence of a decreasing monotonic relationship, as supported by the Spearman and Kendall tests.**

Table A.11. Number of survey subjects (TCS) included in analysis

| Original Number of subjects: 101,385 | | |
|---|---|---|
| *Exclusion criteria* | Number of subjects | % in original number of subjects |
| *Subject is driver or worker on van* | 2,380 | 2.4 |
| *Subject works in "Transportation, storage, postal & courier services" industry* | 2,498 | 2.5 |
| *Subject is domestic helper* | 3,510 | 3.5 |
| *Subject is mobile resident* | 199 | 0.2 |
| *Subject's trip involving boundary control points or anywhere outside Hong Kong* | 3,218 | 3.2 |
| *Subject with missing working industry information* | 197 | 0.2 |
| *Time data is incorrectly typed in the original TCS dataset (e.g. $n^{th}$ trip arrival time is later than $(n+1)^{th}$ trip departure time* | 25 | 0.02 |
| *Total subjects excluded* | 12,027 | 11.9% |
| *Number of subjects remaining:* | 89,358 | 88.1% |

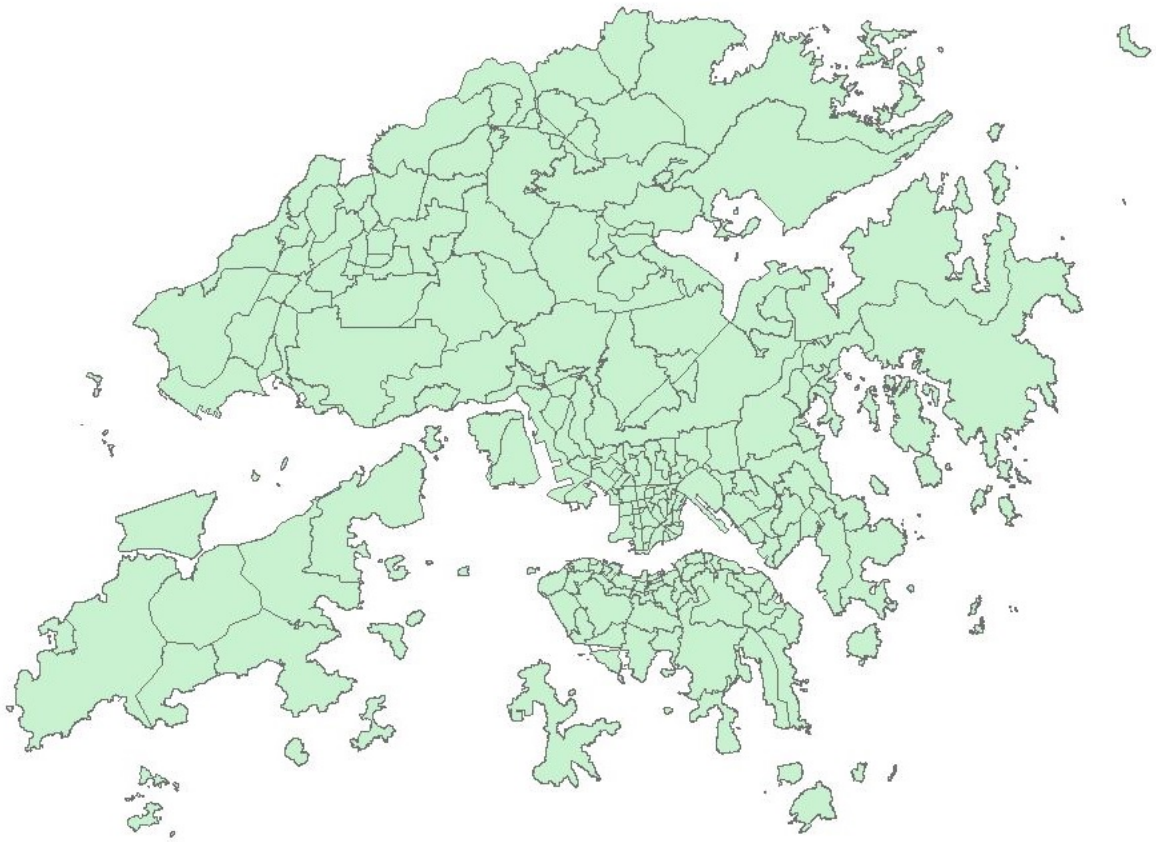


**Figure A.21. Tertiary planning units (TPU) in Hong Kong.**

Table A.12. Classifications of microenvironments

| Microenvironment | Building type |
|---|---|
| *Home indoor* | Residential building |
| *Commercial indoor* | Commercial and industrial building (including shopping plaza and hotel) |
| *School indoor* | School, including Kindergarten/nursery, Primary School, Secondary School, Tertiary Institution and University |
| *Other indoor* | Building other than the above |
| *Outdoor* | non-building area |
| *In-transit* | Bus, train, minibus (23 classifications) |

## Hourly diurnal factors applied in the dynamic model for each pollutant

**Table A.13.** Hourly diurnal factors applied in the dynamic model for each pollutant

| Hour | $PM_{2.5}$ | BC | $NO_2$ |
|---|---|---|---|
| **0** | 0.97 | 0.92 | 0.92 |
| **1** | 0.93 | 0.68 | 0.73 |
| **2** | 0.89 | 0.57 | 0.63 |
| **3** | 0.87 | 0.48 | 0.56 |
| **4** | 0.86 | 0.46 | 0.55 |
| **5** | 0.86 | 0.53 | 0.60 |
| **6** | 0.88 | 0.85 | 0.83 |
| **7** | 0.92 | 1.21 | 1.03 |
| **8** | 0.98 | 1.37 | 1.11 |
| **9** | 1.01 | 1.27 | 1.08 |
| **10** | 1.01 | 1.13 | 1.02 |
| **11** | 1.01 | 1.04 | 1.00 |
| **12** | 1.01 | 0.98 | 0.98 |
| **13** | 1.03 | 0.99 | 1.02 |
| **14** | 1.06 | 1.02 | 1.08 |
| **15** | 1.07 | 1.06 | 1.14 |
| **16** | 1.07 | 1.13 | 1.22 |
| **17** | 1.08 | 1.22 | 1.31 |
| **18** | 1.09 | 1.30 | 1.37 |
| **19** | 1.12 | 1.26 | 1.31 |
| **20** | 1.13 | 1.17 | 1.21 |
| **21** | 1.09 | 1.13 | 1.14 |
| **22** | 1.05 | 1.13 | 1.11 |
| **23** | 1.01 | 1.08 | 1.05 |

**Table A.14.** Mean ambient concentrations for TPUs (N = 289)

| | Mean | Min | Max | S.D. |
|---|---|---|---|---|
| $PM_{2.5}$ | 31.11 | 23.3 | 40.8 | 3.3 |
| *BC* | 8.66 | 2.8 | 18.5 | 3.6 |
| $NO_2$ | 92.42 | 56.2 | 141.1 | 17.6 |

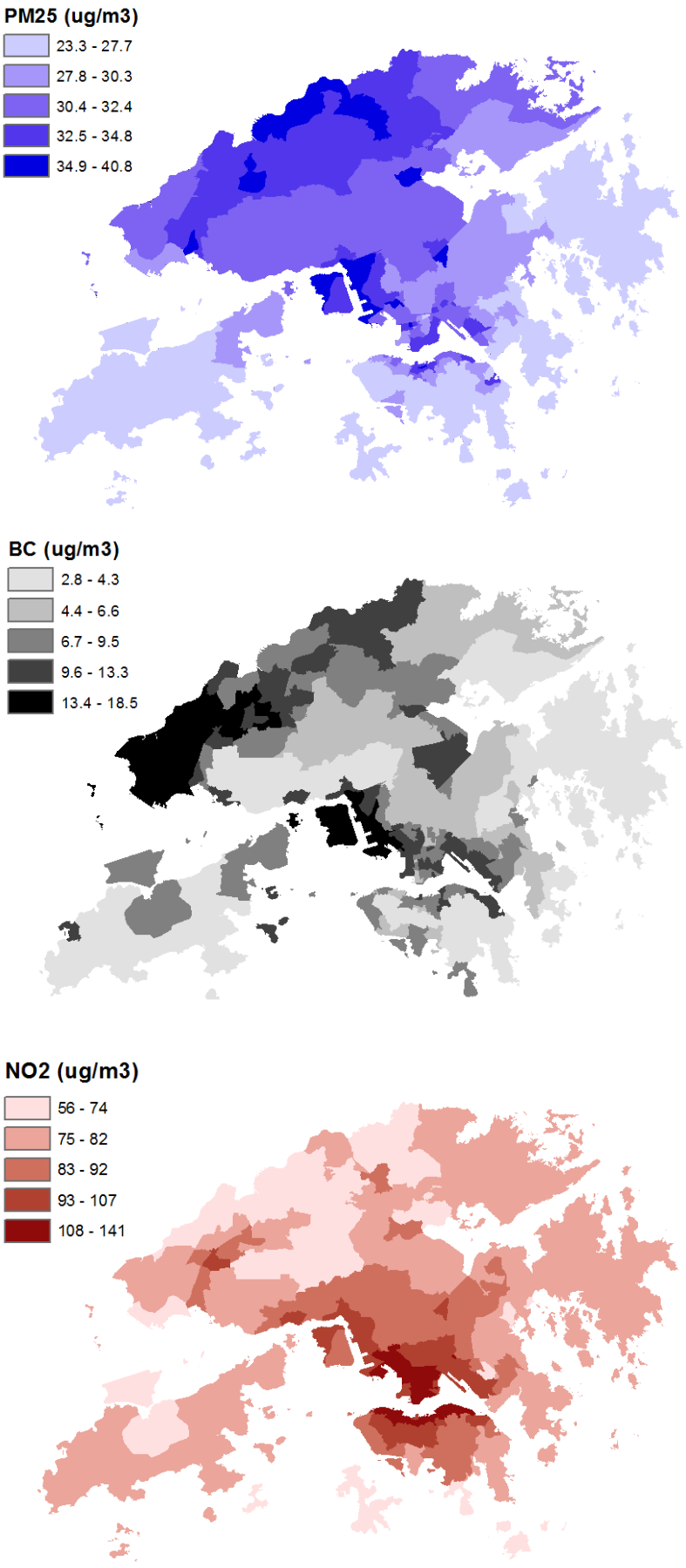



**Figure A.22. TPU-averaged $PM_{2.5}$, BC and $NO_2$ concentrations created from 2D land use regression models.**

## Time-weighted exposures

**Table A.15.** Time-weighted exposure of all modeling stages

| *Stage* | Microenvironment | Time-weighted Exposure (μg/m$^3$) (N = 89,358) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $PM_{2.5}$ | | | | BC | | | | $NO_2$ | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| *1* | Static outdoor | 32.0 | 23.3 | 40.8 | 3.4 | 9.4 | 2.8 | 18.5 | 3.5 | 92.9 | 56.2 | 141.1 | 15.1 |
| *2* | Static indoor | 27.0 | 19.7 | 34.5 | 2.8 | 8.3 | 2.5 | 16.4 | 3.1 | 73.4 | 44.4 | 111.4 | 12.0 |
| *3* | Dynamic indoor | 25.0 | 11.2 | 38.7 | 3.9 | 7.6 | 1.9 | 17.0 | 2.7 | 73.4 | 42.9 | 116.7 | 10.9 |
| *4* | Dynamic indoor + transit | 27.5 | 13.1 | 46.5 | 4.1 | 8.4 | 2.3 | 18.0 | 2.6 | 74.8 | 44.4 | 116.7 | 10.5 |
| *5* | Dynamic indoor + transit + diurnal | 27.1 | 11.9 | 46.8 | 4.2 | 7.8 | 1.2 | 21.5 | 2.8 | 71.3 | 24.9 | 122.7 | 14.3 |
| *6* | Dynamic indoor + transit + diurnal (movement) | 33.8 | 20.3 | 50.2 | 3.9 | 9.6 | 1.3 | 22.0 | 3.4 | 90.9 | 31.5 | 147.7 | 18.1 |

Table A.16. Time-weighted exposure stratified by age group

| Stage | ME | Time-weighted Exposure (µg/m$^3$) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $PM_{2.5}$ | | | | | | | | | | | |
| | | <18 (N = 14,279) | | | | 18-64 (N = 61,882) | | | | 65+ (N = 13,197) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 31.9 | 23.3 | 40.8 | 3.4 | 32.0 | 23.3 | 40.8 | 3.4 | 32.0 | 23.3 | 40.8 | 3.3 |
| 2 | *Static indoor* | 27.0 | 19.7 | 34.5 | 2.9 | 27.0 | 19.7 | 34.5 | 2.8 | 27.0 | 19.7 | 34.5 | 2.8 |
| 3 | *Dynamic indoor* | 27.7 | 16.2 | 37.0 | 2.9 | 24.2 | 11.2 | 38.7 | 4.0 | 26.0 | 14.9 | 35.8 | 2.9 |
| 4 | *Dynamic indoor + transit* | 29.5 | 17.3 | 41.8 | 3.2 | 27.1 | 13.1 | 46.5 | 4.3 | 27.1 | 16.8 | 42.6 | 3.4 |
| 5 | *Dynamic indoor + transit + diurnal* | 29.5 | 16.6 | 42.1 | 3.4 | 26.8 | 11.9 | 46.8 | 4.4 | 26.1 | 16.2 | 42.9 | 3.6 |
| 6 | *Dynamic outdoor + transit + diurnal* | 33.5 | 20.3 | 46.3 | 3.6 | 34.3 | 20.3 | 50.2 | 3.9 | 31.8 | 20.3 | 47.4 | 3.9 |

| Stage | ME | *Time-weighted Exposure (µg/m$^3$)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BC | | | | | | | | | | | |
| | | <18 (N = 14,279) | | | | 18-64 (N = 61,882) | | | | 65+ (N = 13,197) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 9.4 | 2.8 | 18.5 | 3.5 | 9.4 | 2.8 | 18.5 | 3.5 | 9.2 | 2.8 | 18.5 | 3.5 |
| 2 | *Static indoor* | 8.3 | 2.5 | 16.4 | 3.1 | 8.3 | 2.5 | 16.4 | 3.1 | 8.2 | 2.5 | 16.4 | 3.1 |
| 3 | *Dynamic indoor* | 8.3 | 2.3 | 16.4 | 2.8 | 7.4 | 1.9 | 17.0 | 2.6 | 7.8 | 2.3 | 16.4 | 2.9 |
| 4 | *Dynamic indoor + transit* | 8.8 | 2.6 | 17.5 | 2.7 | 8.3 | 2.3 | 18.0 | 2.5 | 8.2 | 2.5 | 17.5 | 2.9 |
| 5 | *Dynamic indoor + transit + diurnal* | 9.2 | 1.3 | 19.2 | 3.1 | 7.8 | 1.2 | 21.5 | 2.7 | 6.6 | 1.2 | 18.9 | 2.8 |
| 6 | *Dynamic outdoor + transit + diurnal* | 10.3 | 1.4 | 21.7 | 3.4 | 9.8 | 1.3 | 22.0 | 3.2 | 7.9 | 1.3 | 21.2 | 3.3 |

| Stage | ME | *Time-weighted Exposure (µg/m$^3$)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $NO_2$ | | | | | | | | | | | |
| | | <18 (N = 14,279) | | | | 18-64 (N = 61,882) | | | | 65+ (N = 13,197) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 91.6 | 56.2 | 141.1 | 14.7 | 92.6 | 56.2 | 141.1 | 15.1 | 95.5 | 56.2 | 141.1 | 15.5 |
| 2 | *Static indoor* | 72.4 | 44.4 | 111.4 | 11.6 | 73.1 | 44.4 | 111.4 | 11.9 | 75.5 | 44.4 | 111.4 | 12.3 |
| 3 | *Dynamic indoor* | 70.5 | 42.9 | 111.4 | 10.6 | 73.8 | 43.1 | 116.3 | 10.6 | 75.0 | 43.9 | 116.7 | 11.9 |
| 4 | *Dynamic indoor + transit* | 72.1 | 44.4 | 111.4 | 10.4 | 75.2 | 44.4 | 116.7 | 10.2 | 76.2 | 44.4 | 113.0 | 11.7 |
| 5 | *Dynamic indoor + transit + diurnal* | 73.9 | 24.9 | 113.2 | 12.7 | 72.1 | 24.9 | 122.7 | 13.9 | 64.7 | 24.9 | 111.2 | 15.6 |
| 6 | *Dynamic outdoor + transit + diurnal* | 95.7 | 31.5 | 147.7 | 16.6 | 91.7 | 31.5 | 147.7 | 17.4 | 82.0 | 31.5 | 143.1 | 19.9 |

Table A.17. Time-weighted exposure stratified by sex

| Stage | ME | Time-weighted Exposure (µg/m$^3$) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $PM_{2.5}$ | | | | | | | |
| | | Male (N = 41,240) | | | | Female (N = 48,148) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 32.0 | 23.3 | 40.8 | 3.4 | 32.0 | 23.3 | 40.8 | 3.4 |
| 2 | *Static indoor* | 27.0 | 19.7 | 34.5 | 2.8 | 27.0 | 19.7 | 34.5 | 2.8 |
| 3 | *Dynamic indoor* | 25.0 | 11.2 | 38.7 | 4.1 | 25.0 | 12.6 | 37.0 | 3.7 |
| 4 | *Dynamic indoor + transit* | 27.7 | 13.1 | 44.4 | 4.3 | 27.3 | 14.7 | 46.5 | 3.8 |
| 5 | *Dynamic indoor + transit + diurnal* | 27.4 | 11.9 | 45.0 | 4.5 | 26.9 | 13.6 | 46.8 | 4.0 |
| 6 | *Dynamic outdoor + transit + diurnal* | 34.1 | 20.3 | 48.9 | 3.9 | 33.6 | 20.3 | 50.2 | 3.9 |

| Stage | ME | *Time-weighted Exposure (µg/m$^3$)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | BC | | | | | | | |
| | | Male (N = 41,240) | | | | Female (N = 48,148) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 9.4 | 2.8 | 18.5 | 3.5 | 9.3 | 2.8 | 18.5 | 3.5 |
| 2 | *Static indoor* | 8.3 | 2.5 | 16.4 | 3.1 | 8.3 | 2.5 | 16.4 | 3.1 |
| 3 | *Dynamic indoor* | 7.6 | 1.9 | 17.0 | 2.7 | 7.6 | 2.0 | 16.6 | 2.7 |
| 4 | *Dynamic indoor + transit* | 8.4 | 2.3 | 17.6 | 2.6 | 8.3 | 2.3 | 18.0 | 2.6 |
| 5 | *Dynamic indoor + transit + diurnal* | 8.1 | 1.2 | 21.5 | 2.9 | 7.7 | 1.2 | 19.6 | 2.8 |
| 6 | *Dynamic outdoor + transit + diurnal* | 9.8 | 1.3 | 22.0 | 3.4 | 9.4 | 1.3 | 21.8 | 3.4 |

| Stage | ME | *Time-weighted Exposure (µg/m$^3$)* | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | $NO_2$ | | | | | | | |
| | | Male (N = 41,240) | | | | Female (N = 48,148) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 93.0 | 56.2 | 141.1 | 15.2 | 92.7 | 56.2 | 141.1 | 15.1 |
| 2 | *Static indoor* | 73.5 | 44.4 | 111.4 | 12.0 | 73.3 | 44.4 | 111.4 | 11.9 |
| 3 | *Dynamic indoor* | 74.0 | 42.9 | 116.3 | 11.0 | 72.9 | 43.1 | 116.7 | 10.8 |
| 4 | *Dynamic indoor + transit* | 75.4 | 44.4 | 116.7 | 10.6 | 74.3 | 44.4 | 112.7 | 10.5 |
| 5 | *Dynamic indoor + transit + diurnal* | 72.8 | 24.9 | 122.7 | 14.4 | 70.1 | 24.9 | 117.3 | 14.0 |
| 6 | *Dynamic outdoor + transit + diurnal* | 92.3 | 31.5 | 147.7 | 17.9 | 89.8 | 31.5 | 147.7 | 18.2 |

Table A.18. Time-weighted exposure stratified by population group

| Stage | ME | Time-weighted Exposure (µg/m³) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $PM_{2.5}$ | | | | | | | | | | | |
| | | Working adults (N = 41,972) | | | | Students (N = 17,871) | | | | Others (N = 29,515) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 31.9 | 23.3 | 40.8 | 3.4 | 31.9 | 23.3 | 40.8 | 3.4 | 32.0 | 23.3 | 40.8 | 3.4 |
| 2 | *Static indoor* | 27.0 | 19.7 | 34.5 | 2.8 | 27.0 | 19.7 | 34.5 | 2.9 | 27.1 | 19.7 | 34.5 | 2.8 |
| 3 | *Dynamic indoor* | 23.0 | 11.2 | 38.7 | 3.9 | 27.8 | 16.7 | 37.0 | 2.8 | 26.2 | 14.4 | 36.2 | 2.8 |
| 4 | *Dynamic indoor + transit* | 26.6 | 13.1 | 46.5 | 4.4 | 29.8 | 18.1 | 44.7 | 3.2 | 27.4 | 15.8 | 42.6 | 3.4 |
| 5 | *Dynamic indoor + transit + diurnal* | 26.5 | 11.9 | 46.8 | 4.5 | 29.7 | 17.2 | 45.4 | 3.4 | 26.4 | 14.4 | 42.9 | 3.6 |
| 6 | *Dynamic outdoor + transit + diurnal* | 35.1 | 20.3 | 50.2 | 3.6 | 33.7 | 20.3 | 48.8 | 3.6 | 32.0 | 20.3 | 48.0 | 3.9 |

| Stage | ME | *Time-weighted Exposure (µg/m³)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | BC | | | | | | | | | | | |
| | | Working adults (N = 41,972) | | | | Students (N = 17,871) | | | | Others (N = 29,515) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 9.3 | 2.8 | 18.5 | 3.5 | 9.4 | 2.8 | 18.5 | 3.4 | 9.4 | 2.8 | 18.5 | 3.5 |
| 2 | *Static indoor* | 8.3 | 2.5 | 16.4 | 3.1 | 8.3 | 2.5 | 16.4 | 3.0 | 8.3 | 2.5 | 16.4 | 3.1 |
| 3 | *Dynamic indoor* | 7.1 | 1.9 | 17.0 | 2.4 | 8.3 | 2.5 | 16.4 | 2.7 | 8.0 | 2.3 | 16.4 | 2.9 |
| 4 | *Dynamic indoor + transit* | 8.1 | 2.3 | 17.6 | 2.4 | 8.9 | 2.7 | 17.5 | 2.7 | 8.4 | 2.5 | 18.0 | 2.9 |
| 5 | *Dynamic indoor + transit + diurnal* | 8.0 | 1.2 | 21.5 | 2.6 | 9.2 | 1.3 | 19.2 | 3.0 | 6.8 | 1.2 | 18.9 | 2.8 |
| 6 | *Dynamic outdoor + transit + diurnal* | 9.3 | 2.8 | 18.5 | 3.5 | 9.4 | 2.8 | 18.5 | 3.4 | 9.4 | 2.8 | 18.5 | 3.5 |

| Stage | ME | *Time-weighted Exposure (µg/m³)* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $NO_2$ | | | | | | | | | | | |
| | | Working adults (N = 41,972) | | | | Students (N = 17,871) | | | | Others (N = 29,515) | | | |
| | | mean | min | max | S.D. | mean | min | max | S.D. | mean | min | max | S.D. |
| 1 | *Static outdoor* | 92.9 | 56.2 | 141.1 | 15.1 | 91.7 | 56.2 | 141.1 | 14.7 | 93.5 | 56.2 | 141.1 | 15.4 |
| 2 | *Static indoor* | 73.4 | 44.4 | 111.4 | 11.9 | 72.4 | 44.4 | 111.4 | 11.6 | 73.9 | 44.4 | 111.4 | 12.2 |
| 3 | *Dynamic indoor* | 74.6 | 43.1 | 116.3 | 10.2 | 70.7 | 42.9 | 111.4 | 10.4 | 73.4 | 43.9 | 116.7 | 11.9 |
| 4 | *Dynamic indoor + transit* | 76.1 | 44.4 | 116.7 | 9.7 | 72.2 | 44.4 | 111.4 | 10.1 | 74.6 | 44.4 | 113.0 | 11.6 |
| 5 | *Dynamic indoor + transit + diurnal* | 75.5 | 24.9 | 122.7 | 12.4 | 73.7 | 24.9 | 113.2 | 12.6 | 63.9 | 24.9 | 111.2 | 14.7 |
| 6 | *Dynamic outdoor + transit + diurnal* | 96.1 | 31.5 | 147.7 | 15.3 | 95.4 | 31.5 | 147.7 | 16.5 | 81.0 | 31.5 | 143.1 | 18.7 |

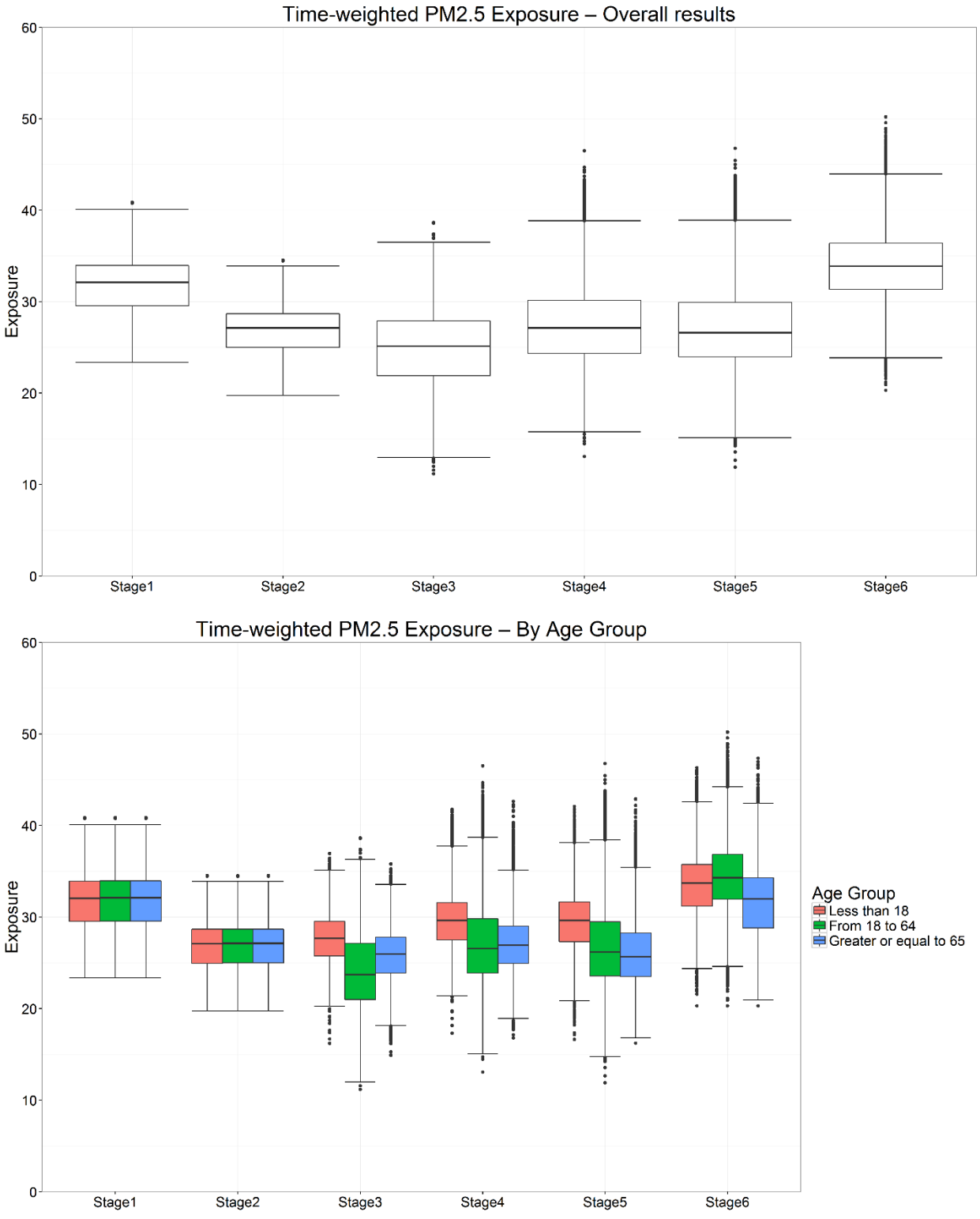



**Figure A.23. Time-weighted $PM_{2.5}$ exposures unstratified (top) and stratified by age group (bottom)**

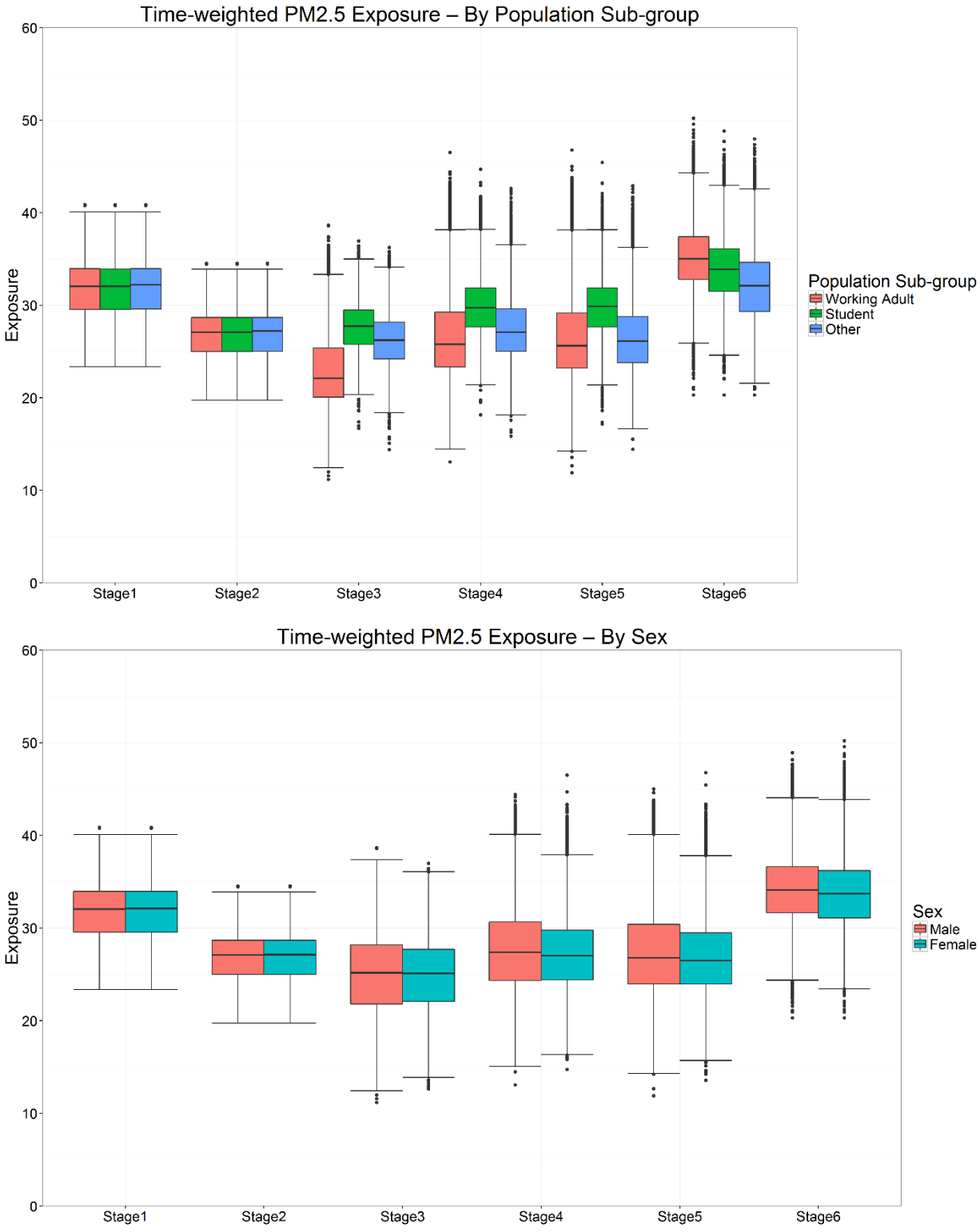



**Figure A.24. Time-weighted $PM_{2.5}$ exposures stratified by population sub-group (top) and sex (bottom).**

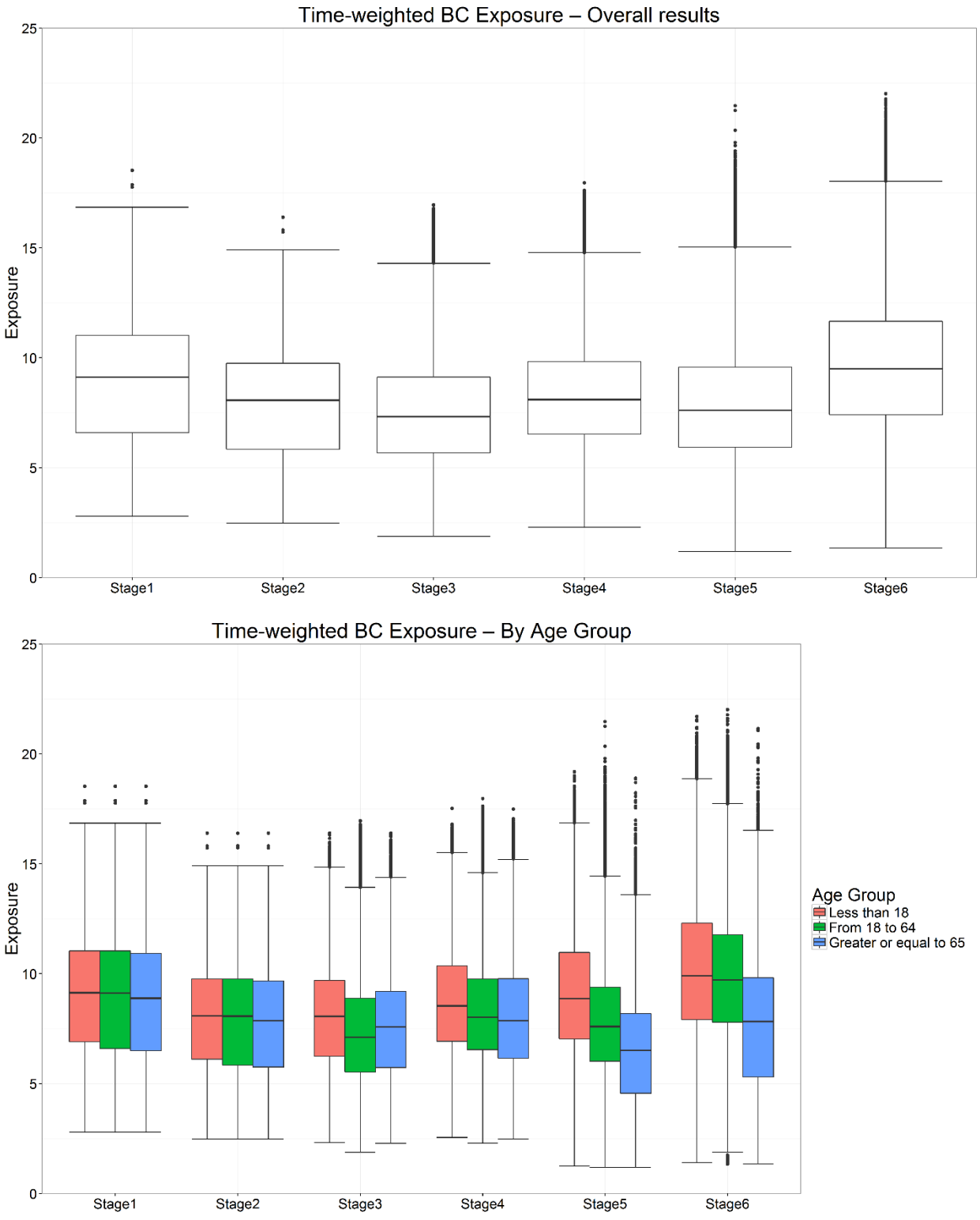



**Figure A.25. Time-weighted BC exposures unstratified (top) and stratified by age group (bottom).**

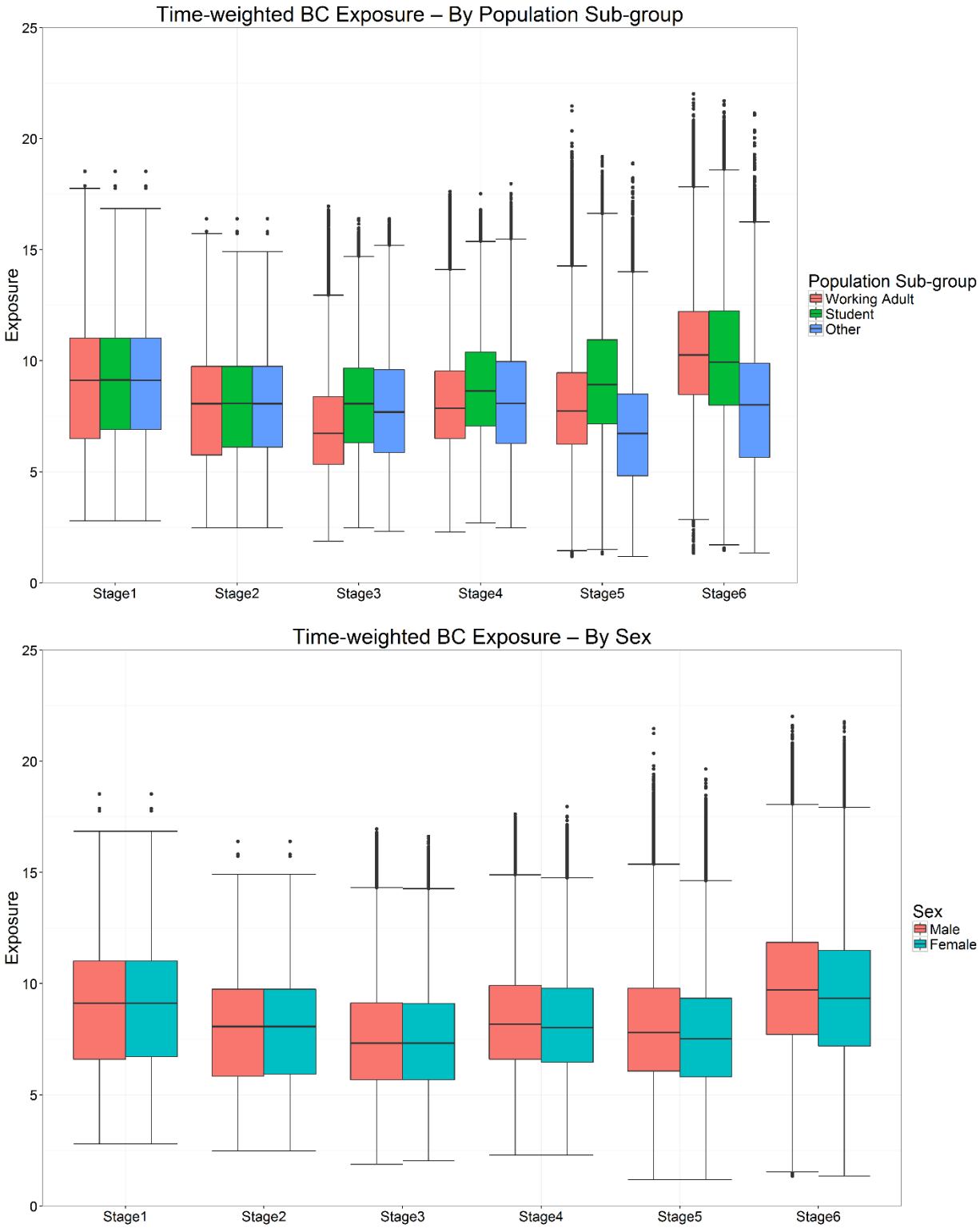



**Figure A.26. Time-weighted BC exposures stratified by population sub-group (top) and sex (bottom).**

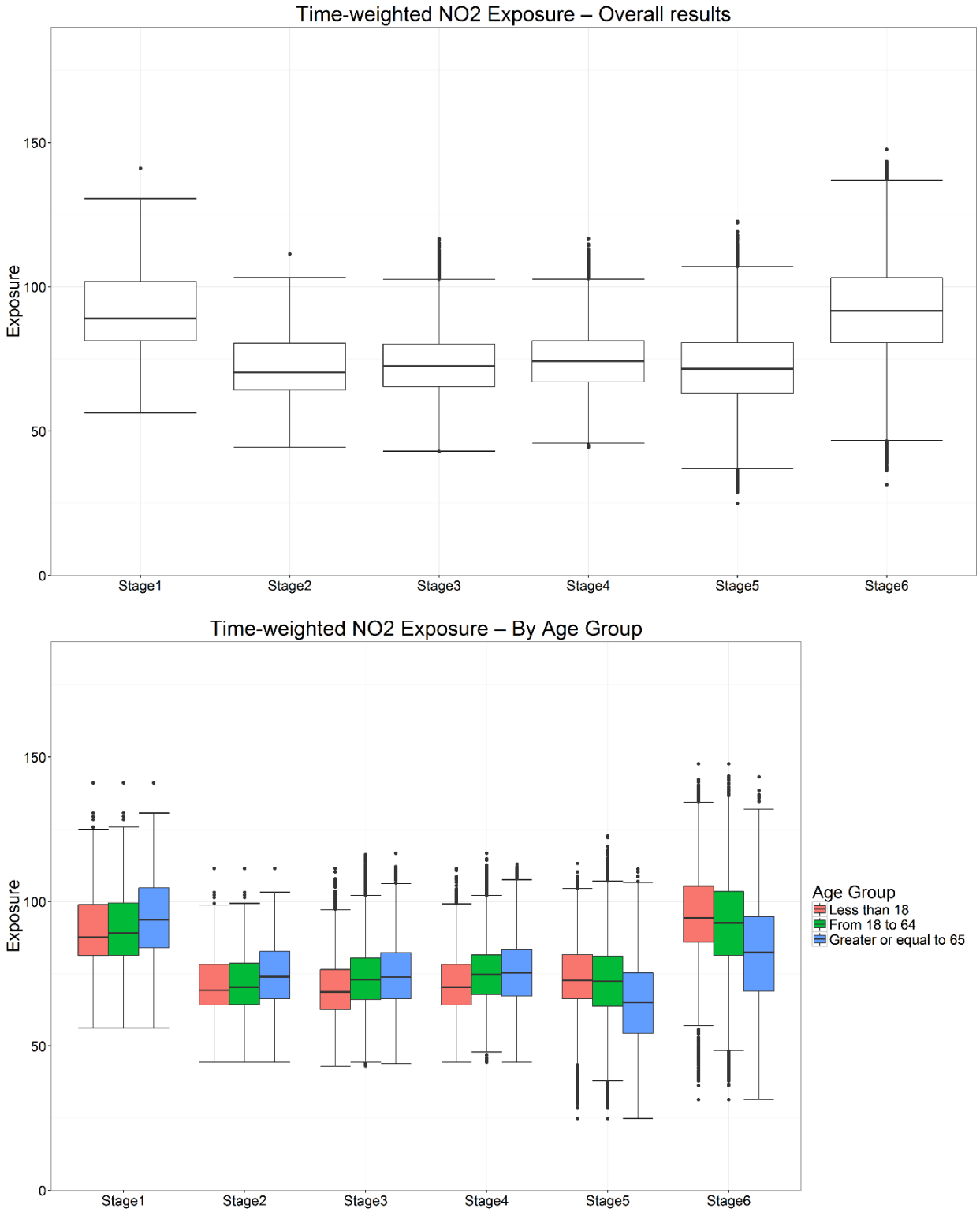



**Figure A.27. Time-weighted $NO_2$ exposures unstratified (top) and stratified by age group (bottom).**

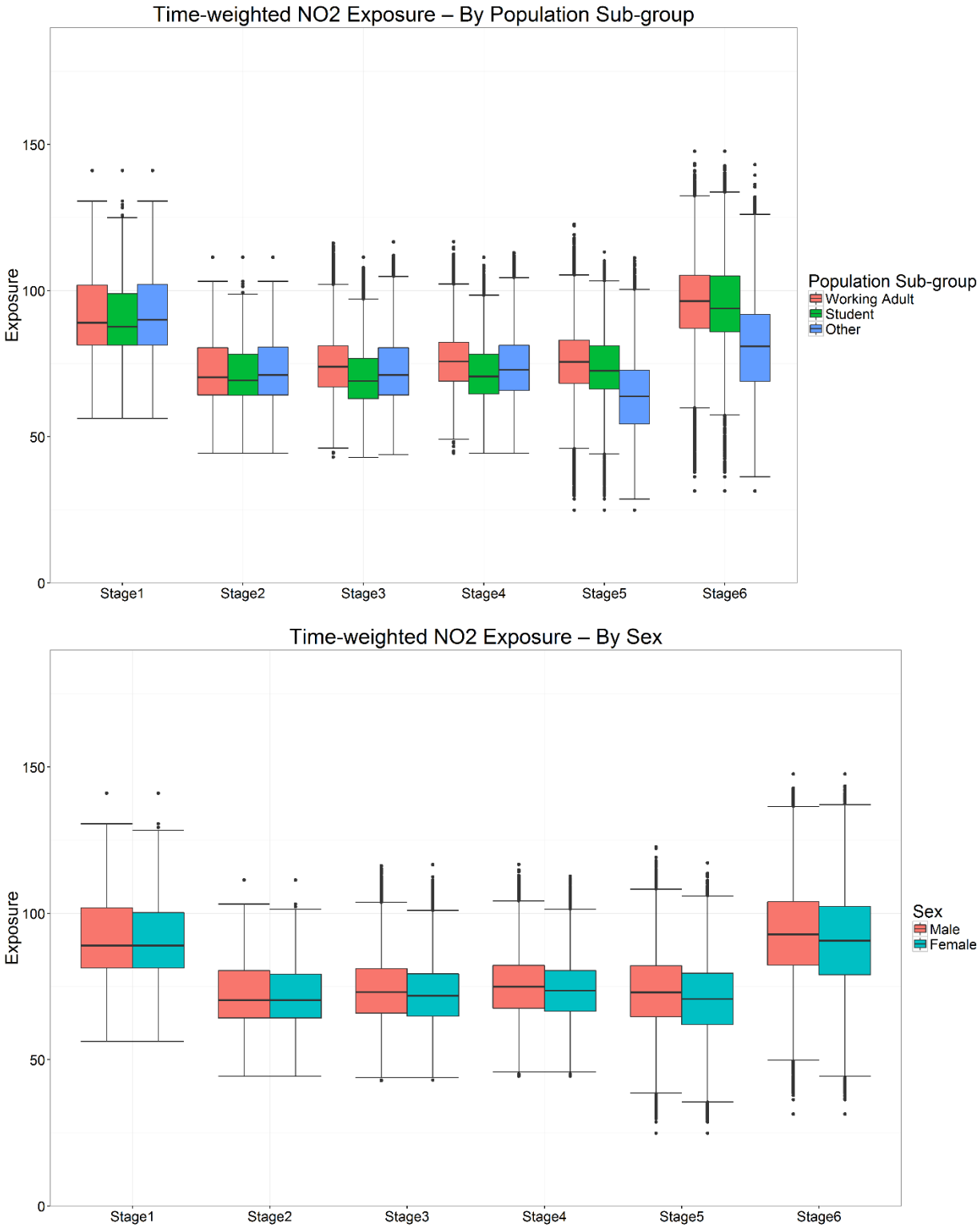



**Figure A.28. Time-weighted $NO_2$ exposures stratified by population sub-group (top) and sex (bottom).**

**Table A.19.** Adjusted individual, ecological and environmental covariates included in the final Cox PH models.

| Level | Variables | Categories |
|---|---|---|
| **Individual** | Age | |
| | Sex | Female, Male |
| | Body mass index (BMI) | Defined as weight/height$^2$ (kg/m$^2$).<br>< 21.6, 21.6–26.3, > 26.3 kg/m$^2$ |
| | Smoking status | (never, ex-smoker, current smoker) |
| | Physical exercise | (days per week) |
| | Education | (< primary, primary, ≥ secondary) |
| | Monthly expenses | (< 128, 128–384, > 384 US$). |
| **TPU** | Proportion of the population ≥ 65 years of age | |
| | Proportion with > secondary education | |
| | Average monthly income | |
| **District** | Proportion of smokers | |

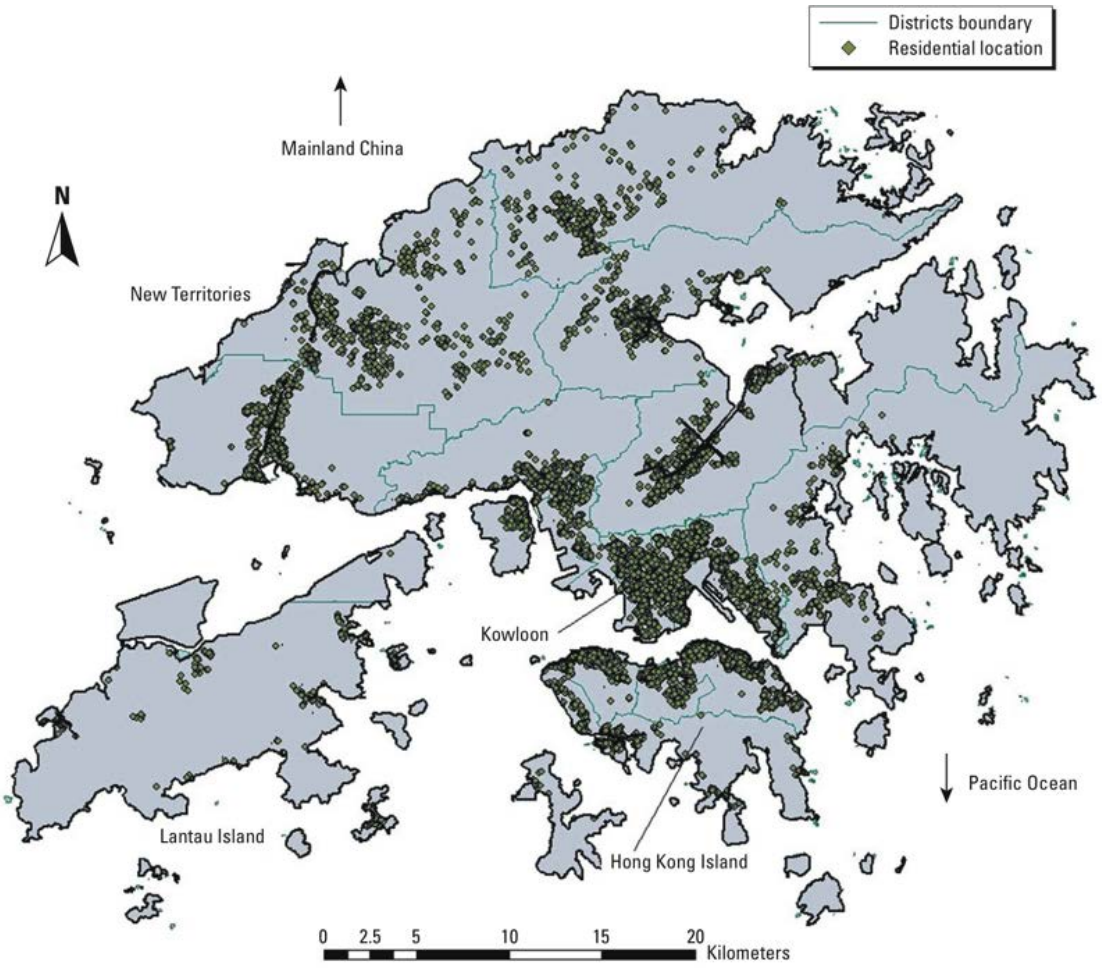



**Figure A.29. Spatial distribution of geocoded addresses of participants and boundaries of the 18 districts (*n* = 60,584).** Each district had one Elderly Health Centre to provide health service for persons ≥65 years of age who have enrolled voluntarily. Those enrolled in 1998–2001 were recruited to this study, and their residential addresses were geocoded into x– and y-coordinates.

## Descriptive statistics of the elderly cohort and exposure estimates

Table A.20. Number of deaths in the elderly cohort after 10–13 years of follow-up in 2011

| ICD10 codes | Cause of death | Number of deaths | % of total death |
|---|---|---|---|
| *A00–R99* | All natural causes | 16,006 | 97.5 |
| *I00–99* | Cardiovascular | 4,656 | 28.4 |
| *I20–I25* | - IHD | 1,810 | 11 |
| *I60–69* | - Cerebrovascular | 1,621 | 9.9 |
| *J00–47, 80–99* | Respiratory | 3,150 | 19.2 |
| *J12–18* | - Pneumonia | 2,057 | 12.5 |
| *J40–44, 47* | - COPD | 940 | 5.7 |
| *S00–T99* | External causes | 409 | 2.5 |
| *All included codes* | All causes | 16,415 | 100 |

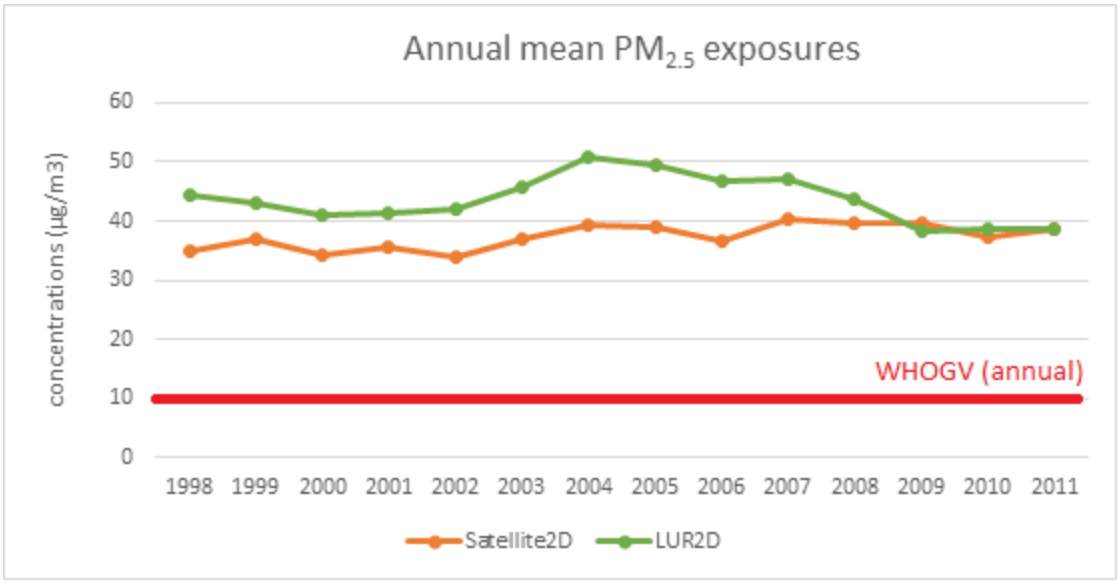
Table A.21. Descriptive statistics of 2D, 3D and D3D LUR modelled and back-extrapolated baseline exposures for all pollutants. *From Wong et al. (2015) **From Wong et al. (2016)

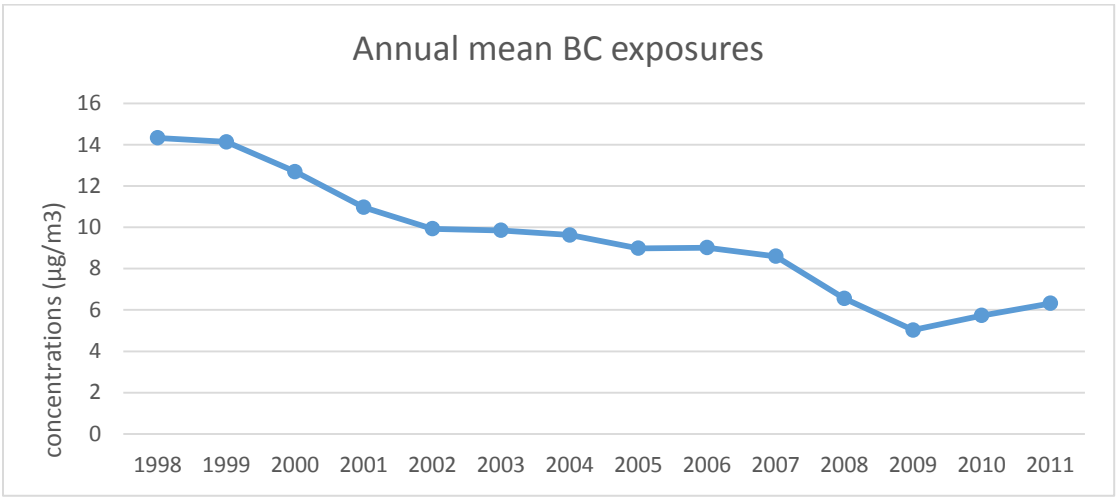
| | | | $PM_{2.5}$ | | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Min** | **IQR** | **Median** | **Max** |
| | | | ***Baseline*** | | | |
| ***2D*** | 42.4 | 4.2 | 27.2 | 5.5 | 42.2 | 73.6 |
| ***3D*** | 36.6 | 5.5 | 18.2 | 7.5 | 36.7 | 66.0 |
| ***D3D*** | 34.0 | 5.1 | 16.8 | 7.0 | 34.1 | 62.1 |
| | | | ***2014*** | | | |
| ***2D*** | 33.1 | 4.0 | 20.0 | 5.0 | 33.0 | 62.0 |
| ***3D*** | 28.6 | 4.7 | 13.3 | 6.3 | 28.6 | 56.8 |
| ***D3D*** | 26.5 | 4.3 | 12.2 | 5.9 | 26.6 | 53.4 |
| | | | ***Baseline (Satellite-based estimates)*** | | | |
| ***2D**** | 35.6 | 2.5 | 26.4 | 3.4 | 35.3 | 44.6 |
| ***3D**** | 33.7 | 3.2 | 26.1 | 3.3 | 33.2 | 92.7 |
| | | | | | | |
| | | | ***BC*** | | | |
| | **Mean** | **SD** | **Min** | **IQR** | **Median** | **Max** |
| | | | ***Baseline*** | | | |
| ***2D*** | 13.1 | 6.7 | 3.9 | 9.6 | 12.1 | 44.7 |
| ***3D*** | 8.8 | 5.4 | 0.9 | 7.2 | 7.7 | 41.1 |
| ***D3D*** | 6.6 | 4.0 | 0.7 | 5.4 | 5.7 | 31.5 |
| | | | ***2014*** | | | |
| ***2D*** | 7.4 | 3.7 | 2.8 | 5.2 | 6.9 | 23.4 |
| ***3D*** | 4.9 | 3.0 | 0.6 | 4.0 | 4.3 | 22.8 |
| ***D3D*** | 3.7 | 2.2 | 0.5 | 3.0 | 3.2 | 17.6 |
| | | | | | | |
| | | | ***NO*** | | | |
| | **Mean** | **SD** | **Min** | **IQR** | **Median** | **Max** |
| | | | ***Baseline*** | | | |
| ***2D*** | 489 | 119 | 120 | 167 | 486 | 785 |
| ***3D*** | 327 | 136 | 39 | 203 | 315 | 776 |
| ***D3D*** | 244 | 102 | 29 | 151 | 235 | 576 |
| | | | ***2014*** | | | |
| ***2D*** | 284 | 69 | 71 | 96 | 282 | 444 |
| ***3D*** | 190 | 79 | 23 | 118 | 183 | 439 |
| ***D3D*** | 141 | 59 | 17 | 88 | 136 | 334 |

| | | | $NO_2$ | | | |
|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Min** | **IQR** | **Median** | **Max** |
| | | | ***Baseline*** | | | |
| ***2D*** | 107 | 19 | 46 | 26 | 104 | 195 |
| ***3D*** | 71 | 26 | 14 | 38 | 72 | 177 |
| ***D3D*** | 58 | 21 | 12 | 31 | 59 | 142 |
| | | | ***2014*** | | | |
| ***2D*** | 96 | 17 | 43 | 23 | 94 | 177 |
| ***3D*** | 64 | 23 | 13 | 34 | 65 | 158 |
| ***D3D*** | 52 | 19 | 10 | 28 | 53 | 127 |

Table A.22. Mean annual exposures from baseline to follow-up period

| *Year* | **Satellite $PM_{2.5}$** | **Satellite $PM_{2.5}$ 3D** | **LUR $PM_{2.5}$** | **LUR BC** | **LUR $NO_2$** | **LUR NO** |
|---|---|---|---|---|---|---|
| *1998* | 34.8 | 33.0 | 44.3 | 14.3 | 107 | 481 |
| *1999* | 36.9 | 34.6 | 43.2 | 14.1 | 108 | 486 |
| *2000* | 34.1 | 32.6 | 41.2 | 12.7 | 106 | 496 |
| *2001* | 35.6 | 33.7 | 41.5 | 11.0 | 106 | 489 |
| *2002* | 34.0 | 32.4 | 42.0 | 9.9 | 104 | 463 |
| *2003* | 37.0 | 34.7 | 45.9 | 9.9 | 106 | 424 |
| *2004* | 39.4 | 36.6 | 50.7 | 9.6 | 109 | 415 |
| *2005* | 38.9 | 36.2 | 49.5 | 9.0 | 105 | 412 |
| *2006* | 36.7 | 34.5 | 46.9 | 9.0 | 103 | 397 |
| *2007* | 40.2 | 37.2 | 47.0 | 8.6 | 104 | 385 |
| *2008* | 39.7 | 36.8 | 43.9 | 6.6 | 102 | 356 |
| *2009* | 39.5 | 36.7 | 38.3 | 5.0 | 99 | 335 |
| *2010* | 37.4 | 35.0 | 38.7 | 5.7 | 102 | 336 |
| *2011* | 38.6 | 35.9 | 38.7 | 6.3 | 103 | 327 |



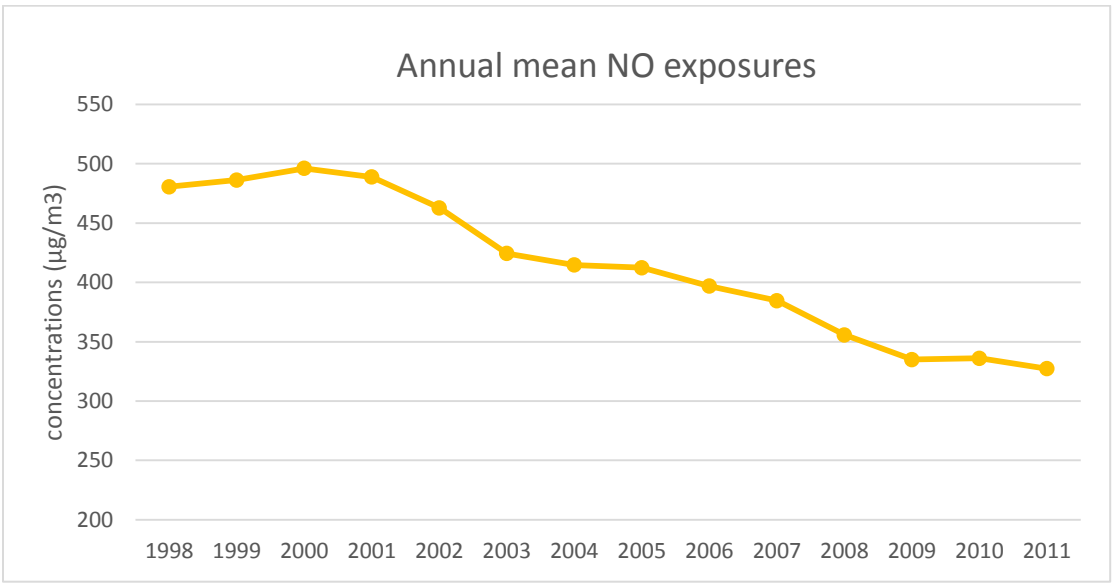




**Figure A.30. Modeled 2D annual mean pollutant exposure trends from baseline to follow-up period. WHOGV = Word Health Organization Guideline Value.**

***Figure continues on next page.***

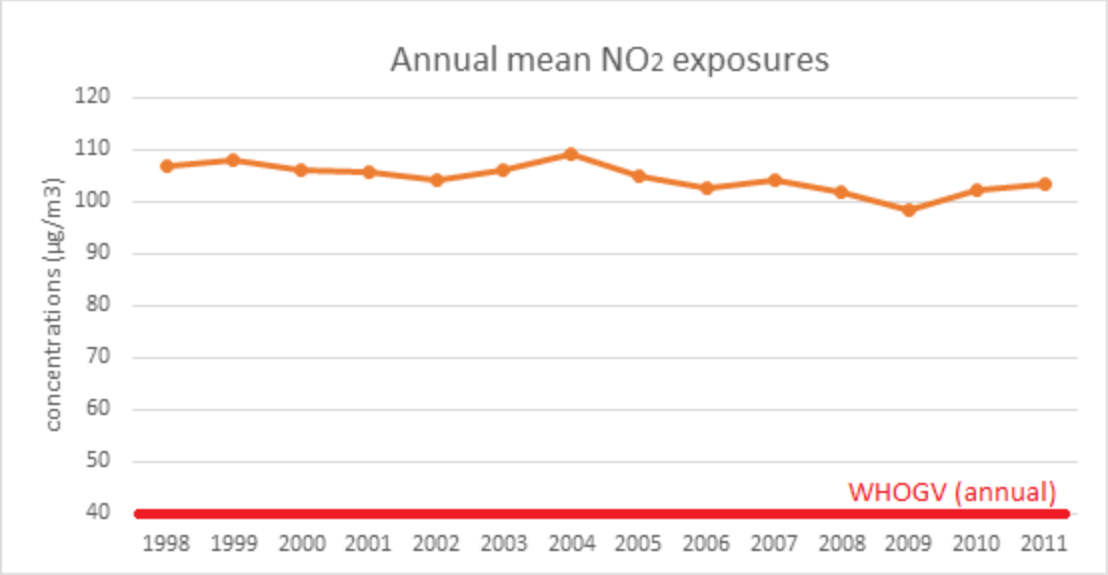



**Figure A.30 *continued*.**

## Sensitivity and stratification analysis results

Hazard ratios

**Table A.23.** Hazard ratio (95% CI) of mortality from all natural causes adjusted for individual covariates only and together with ecological covariates measured at baseline 1998-2001 based on D3D model

| Variables | Individual covariates | Individual and ecological covariates |
|---|---|---|
| Individual Level | | |
| $PM_{2.5}$ concentrations (per 10 μg/$m^3$) | 1.11 (1.08, 1.15) | 1.10 (1.06, 1.13) |
| Age at entry | 1.12 (1.11, 1.12) | 1.12 (1.12, 1.12) |
| Gender: Male (%) | 1 | 1 |
| Female (%) | 0.65 (0.62, 0.68) | 0.65 (0.63, 0.68) |
| BMI quartiles: | | |
| $1^{st}$ [<21.6] (%) | 1.25 (1.21, 1.30) | 1.25 (1.21, 1.30) |
| $2^{nd}$ – $3^{rd}$ [21.6-26.3] (%) | 1 | 1 |
| $4^{th}$ [>26.3] (%) | 1.01 (0.97, 1.05) | 1.01 (0.97, 1.05) |
| Smoking status | | |
| Never (%) | 1 | 1 |
| Former (%) | 1.40 (1.34, 1.45) | 1.39 (1.33, 1.44) |
| Current (%) | 1.72 (1.64, 1.81) | 1.71 (1.62, 1.79) |
| Exercise (days per week) | 0.97 (0.95, 0.98) | 0.97 (0.95, 0.98) |
| Education | | |
| Below primary (%) | 1.23 (1.18, 1.30) | 1.20 (1.14, 1.26) |
| Primary (%) | 1.11 (1.06, 1.16) | 1.08 (1.03, 1.13) |
| Secondary or above (%) | 1 | 1 |
| Expenses/month in US$ | | |
| Low [<128] (%) | 1 | 1 |
| Medium [128-384] (%) | 1.07 (1.01, 1.13) | 1.06 (1.01, 1.12) |
| High [≥385] (%) | 1.02 (0.98, 1.06) | 1.01 (0.96, 1.05) |
| TPU level | | |
| age≥65 | - | 0.99 (0.98, 0.99) |
| tertiary education | - | 0.99 (0.98, 1.00) |
| income≥US$1,923 | - | 1.00 (1.00, 1.00) |
| District level | | |
| Smoking rate | - | 1.07 (1.00, 1.15) |

Sensitivity analysis

**Table A.24.** Hazard ratio (95%CI) per IQR increase of $PM_{2.5}$ in main analysis for average exposure at the baseline period and sensitivity analyses for exposure to average $PM_{2.5}$ yearly and for different inclusion and exclusion criteria

| Cause of Death | Main analysis - baseline exposure[a] | Yearly Exposure | Including deaths within 1 year - baseline exposure | Excluding deaths within 3 years - baseline exposure |
|---|---|---|---|---|
| 2D | | | | |
| All natural causes | **1.03 (1.01, 1.06)*** | 1 (0.98, 1.03) | **1.03 (1.01, 1.05)*** | **1.04 (1.02, 1.07)*** |
| Cardiovascular | **1.06 (1.02, 1.1)*** | 1.02 (0.98, 1.06) | **1.06 (1.02, 1.1)*** | **1.07 (1.03, 1.11)*** |
| IHD | 1.03 (0.97, 1.1) | 0.98 (0.92, 1.05) | 1.04 (0.98, 1.1) | 1.03 (0.97, 1.1) |
| Cerebrovascular | 1.06 (0.99, 1.13) | 1.02 (0.95, 1.09) | 1.05 (0.99, 1.12) | **1.08 (1.01, 1.16)*** |
| Respiratory | 1.02 (0.97, 1.06) | 0.99 (0.94, 1.04) | 1.02 (0.97, 1.06) | 1.02 (0.97, 1.07) |
| Pneumonia | 1 (0.94, 1.06) | 0.98 (0.92, 1.04) | 1 (0.94, 1.06) | 1 (0.95, 1.06) |
| COPD | 1.06 (0.97, 1.15) | 1.02 (0.93, 1.11) | 1.06 (0.97, 1.15) | 1.06 (0.97, 1.16) |
| External causes | 1.02 (0.9, 1.16) | 0.99 (0.86, 1.13) | 1.01 (0.89, 1.15) | 1.02 (0.89, 1.17) |
| 3D | | | | |
| All natural causes | **1.07 (1.04, 1.09)*** | **1.05 (1.02, 1.07)*** | **1.07 (1.04, 1.09)*** | **1.07 (1.05, 1.1)*** |
| Cardiovascular | **1.1 (1.05, 1.14)*** | **1.07 (1.02, 1.11)*** | **1.09 (1.05, 1.14)*** | **1.1 (1.05, 1.14)*** |
| IHD | **1.09 (1.03, 1.17)*** | 1.06 (0.99, 1.13) | **1.09 (1.02, 1.16)*** | **1.09 (1.02, 1.17)*** |
| Cerebrovascular | **1.08 (1.01, 1.16)*** | 1.05 (0.98, 1.12) | 1.08 (1, 1.15) | **1.08 (1.01, 1.16)*** |
| Respiratory | **1.06 (1.01, 1.11)*** | 1.04 (0.99, 1.09) | **1.06 (1.01, 1.11)*** | **1.07 (1.01, 1.12)*** |
| Pneumonia | 1.05 (0.99, 1.12) | 1.03 (0.97, 1.1) | 1.05 (0.99, 1.11) | 1.05 (0.99, 1.12) |
| COPD | 1.09 (1, 1.19) | 1.06 (0.97, 1.16) | 1.09 (1, 1.19) | 1.09 (0.99, 1.2) |
| External causes | 1.03 (0.9, 1.19) | 1.01 (0.88, 1.15) | 1.02 (0.89, 1.17) | 1.02 (0.88, 1.18) |
| D3D | | | | |
| All natural causes | **1.07 (1.04, 1.09)*** | **1.05 (1.02, 1.07)*** | **1.07 (1.04, 1.09)*** | **1.07 (1.05, 1.1)*** |
| Cardiovascular | **1.1 (1.05, 1.14)*** | **1.07 (1.02, 1.11)*** | **1.09 (1.05, 1.14)*** | **1.1 (1.05, 1.14)*** |
| IHD | **1.09 (1.03, 1.17)*** | 1.06 (1, 1.13) | **1.09 (1.02, 1.16)*** | **1.09 (1.02, 1.17)*** |
| Cerebrovascular | **1.08 (1.01, 1.16)*** | 1.05 (0.98, 1.13) | **1.08 (1.01, 1.15)*** | **1.08 (1.01, 1.17)*** |
| Respiratory | **1.06 (1.01, 1.11)*** | 1.04 (0.99, 1.09) | **1.06 (1.01, 1.11)*** | **1.07 (1.01, 1.12)*** |
| Pneumonia | 1.05 (0.99, 1.12) | 1.03 (0.97, 1.1) | 1.05 (0.99, 1.12) | 1.05 (0.99, 1.12) |
| COPD | 1.09 (1, 1.19) | 1.06 (0.97, 1.16) | 1.09 (1, 1.19) | 1.09 (0.99, 1.2) |
| External causes | 1.04 (0.9, 1.19) | 1.01 (0.88, 1.16) | 1.02 (0.89, 1.17) | 1.02 (0.88, 1.18) |

**P < 0.05*; [a] Deaths within 1 year were excluded.

**Table A.25.** Hazard ratio (95%CI) per IQR increase of BC in main analysis for average exposure at the baseline period and sensitivity analyses for exposure to average BC yearly and for different inclusion and exclusion criteria

| Cause of death | Main analysis - baseline exposure[a] | Yearly Exposure | Including deaths within 1 year - baseline exposure | Excluding deaths within 3 years - baseline exposure |
|---|---|---|---|---|
| 2D | | | | |
| All natural causes | **1.03 (1, 1.05)*** | 1.02 (0.99, 1.06) | 1.03 (1, 1.05) | 1.03 (1, 1.05) |
| Cardiovascular | **1.07 (1.03, 1.11)*** | **1.09 (1.02, 1.16)*** | **1.07 (1.03, 1.12)*** | **1.06 (1.02, 1.11)*** |
| IHD | **1.08 (1.01, 1.15)*** | 1.07 (0.96, 1.19) | **1.08 (1.01, 1.15)*** | **1.08 (1.01, 1.15)*** |
| Cerebrovascular | 1.05 (0.98, 1.13) | 1.07 (0.96, 1.2) | 1.06 (0.99, 1.13) | 1.04 (0.97, 1.12) |
| Respiratory | 0.99 (0.94, 1.04) | 0.96 (0.88, 1.04) | 0.99 (0.94, 1.04) | 1 (0.95, 1.05) |
| Pneumonia | 0.99 (0.93, 1.05) | 0.95 (0.86, 1.06) | 0.99 (0.93, 1.05) | 0.99 (0.93, 1.06) |
| COPD | 0.98 (0.9, 1.08) | 0.94 (0.81, 1.09) | 0.98 (0.89, 1.07) | 1 (0.9, 1.1) |
| External causes | **1.18 (1.03, 1.35)*** | **1.27 (1.03, 1.56)*** | **1.17 (1.03, 1.33)*** | 1.16 (1, 1.33) |
| 3D | | | | |
| All natural causes | **1.05 (1.03, 1.07)*** | **1.06 (1.02, 1.09)*** | **1.05 (1.03, 1.07)*** | **1.05 (1.02, 1.07)*** |
| Cardiovascular | **1.09 (1.05, 1.14)*** | **1.14 (1.07, 1.21)*** | **1.1 (1.06, 1.14)*** | **1.09 (1.04, 1.13)*** |
| IHD | **1.1 (1.04, 1.17)*** | **1.14 (1.03, 1.25)*** | **1.11 (1.04, 1.17)*** | **1.11 (1.04, 1.18)*** |
| Cerebrovascular | **1.07 (1.01, 1.14)*** | **1.12 (1.01, 1.24)*** | **1.08 (1.01, 1.15)*** | 1.06 (0.99, 1.13) |
| Respiratory | 1.02 (0.97, 1.06) | 1 (0.93, 1.08) | 1.01 (0.97, 1.06) | 1.02 (0.97, 1.07) |
| Pneumonia | 1.01 (0.96, 1.07) | 1 (0.9, 1.1) | 1.01 (0.96, 1.07) | 1.01 (0.96, 1.08) |
| COPD | 1.01 (0.93, 1.1) | 0.99 (0.86, 1.14) | 1.01 (0.93, 1.1) | 1.02 (0.93, 1.12) |
| External causes | **1.15 (1.01, 1.3)*** | 1.2 (0.99, 1.46) | 1.14 (1, 1.29) | 1.12 (0.97, 1.28) |
| D3D | | | | |
| All natural causes | **1.05 (1.03, 1.07)*** | **1.06 (1.02, 1.09)*** | **1.05 (1.03, 1.07)*** | **1.05 (1.02, 1.07)*** |
| Cardiovascular | **1.1 (1.06, 1.14)*** | **1.14 (1.08, 1.22)*** | **1.1 (1.06, 1.14)*** | **1.09 (1.05, 1.13)*** |
| IHD | **1.11 (1.04, 1.17)*** | **1.14 (1.03, 1.26)*** | **1.11 (1.04, 1.17)*** | **1.11 (1.04, 1.18)*** |
| Cerebrovascular | **1.07 (1.01, 1.15)*** | **1.12 (1.01, 1.24)*** | **1.08 (1.01, 1.15)*** | 1.06 (0.99, 1.14) |
| Respiratory | 1.02 (0.97, 1.06) | 1 (0.93, 1.08) | 1.01 (0.97, 1.06) | 1.02 (0.97, 1.07) |
| Pneumonia | 1.01 (0.96, 1.07) | 1 (0.9, 1.1) | 1.01 (0.96, 1.07) | 1.01 (0.96, 1.08) |
| COPD | 1.01 (0.93, 1.1) | 0.99 (0.86, 1.14) | 1.01 (0.93, 1.1) | 1.02 (0.93, 1.12) |
| External causes | **1.15 (1.01, 1.3)*** | 1.2 (0.99, 1.46) | 1.14 (1, 1.29) | 1.12 (0.98, 1.28) |

*$P < 0.05$; [a] Deaths within 1 year were excluded.

**Table A.26.** Hazard ratio (95%CI) per IQR increase of NO in main analysis for average exposure at the baseline period and sensitivity analyses for exposure to average NO yearly and for different inclusion and exclusion criteria.

| Cause of death | Main analysis - baseline exposure[a] | Yearly Exposure | Including deaths within 1 year - baseline exposure | Excluding deaths within 3 years - baseline exposure |
|---|---|---|---|---|
| 2D | | | | |
| All natural causes | 0.99 (0.97, 1.02) | 1 (0.97, 1.03) | 0.99 (0.97, 1.02) | 0.99 (0.97, 1.02) |
| Cardiovascular | 0.96 (0.91, 1) | 0.95 (0.89, 1) | 0.95 (0.91, 1) | 0.97 (0.92, 1.01) |
| IHD | 0.98 (0.91, 1.05) | 0.97 (0.89, 1.06) | 0.98 (0.91, 1.05) | 1 (0.93, 1.08) |
| Cerebrovascular | 0.96 (0.89, 1.04) | 0.95 (0.86, 1.04) | 0.95 (0.89, 1.03) | 0.97 (0.9, 1.05) |
| Respiratory | 1 (0.94, 1.05) | 1.01 (0.94, 1.08) | 1 (0.94, 1.05) | 0.99 (0.93, 1.05) |
| Pneumonia | 0.99 (0.93, 1.06) | 0.99 (0.9, 1.08) | 0.99 (0.93, 1.06) | 0.98 (0.92, 1.05) |
| COPD | 1.04 (0.94, 1.15) | 1.08 (0.95, 1.22) | 1.04 (0.94, 1.15) | 1.03 (0.92, 1.14) |
| External causes | 1.1 (0.94, 1.28) | 1.13 (0.94, 1.36) | 1.09 (0.93, 1.26) | 1.12 (0.96, 1.32) |
| 3D | | | | |
| All natural causes | **1.05 (1.02, 1.07)*** | **1.06 (1.03, 1.09)*** | **1.05 (1.02, 1.07)*** | **1.05 (1.02, 1.08)*** |
| Cardiovascular | 1.04 (0.99, 1.09) | 1.05 (0.99, 1.11) | 1.03 (0.99, 1.08) | 1.03 (0.99, 1.09) |
| IHD | **1.09 (1.01, 1.17)*** | **1.12 (1.02, 1.23)*** | **1.08 (1.01, 1.16)*** | **1.1 (1.02, 1.19)*** |
| Cerebrovascular | 1.01 (0.94, 1.1) | 1.02 (0.92, 1.13) | 1.01 (0.93, 1.09) | 1 (0.92, 1.09) |
| Respiratory | 1.06 (1, 1.12) | **1.09 (1.01, 1.17)*** | 1.06 (1, 1.12) | 1.06 (1, 1.12) |
| Pneumonia | 1.06 (0.99, 1.13) | 1.07 (0.98, 1.18) | 1.06 (0.99, 1.13) | 1.06 (0.98, 1.13) |
| COPD | 1.1 (0.99, 1.22) | **1.15 (1.01, 1.31)*** | 1.1 (0.99, 1.22) | 1.09 (0.97, 1.21) |
| External causes | 1.07 (0.92, 1.25) | 1.07 (0.89, 1.3) | 1.05 (0.9, 1.23) | 1.07 (0.91, 1.27) |
| D3D | | | | |
| All natural causes | **1.05 (1.02, 1.07)*** | **1.06 (1.03, 1.09)*** | **1.05 (1.02, 1.07)*** | **1.05 (1.02, 1.07)*** |
| Cardiovascular | 1.04 (0.99, 1.09) | 1.05 (0.99, 1.12) | 1.03 (0.99, 1.08) | 1.03 (0.99, 1.09) |
| IHD | **1.09 (1.01, 1.17)*** | 1.12 (1.02, 1.23) | 1.08 (1, 1.16) | **1.1 (1.02, 1.19)*** |
| Cerebrovascular | 1.01 (0.94, 1.1) | 1.02 (0.93, 1.13) | 1.01 (0.93, 1.09) | 1 (0.92, 1.09) |
| Respiratory | 1.06 (1, 1.12) | **1.09 (1.01, 1.17)*** | 1.06 (1, 1.12) | 1.06 (1, 1.12) |
| Pneumonia | 1.06 (0.99, 1.13) | 1.08 (0.98, 1.18) | 1.06 (0.99, 1.13) | 1.06 (0.98, 1.14) |
| COPD | 1.1 (0.99, 1.22) | **1.15 (1.01, 1.31)*** | 1.09 (0.99, 1.21) | 1.08 (0.97, 1.21) |
| External causes | 1.07 (0.92, 1.26) | 1.08 (0.89, 1.3) | 1.05 (0.9, 1.23) | 1.07 (0.91, 1.27) |

**P < 0.05*; [a] Deaths within 1 year were excluded.

**Table A.27.** Hazard ratio (95%CI) per IQR increase of $NO_2$ in main analysis for average exposure at the baseline period and sensitivity analyses for exposure to average $NO_2$ yearly and for different inclusion and exclusion criteria

| Cause of death | Main analysis - baseline exposure[a] | Yearly Exposure | Including deaths within 1 year - baseline exposure | Excluding deaths within 3 years - baseline exposure |
|---|---|---|---|---|
| 2D | | | | |
| All natural causes | 1 (0.97, 1.03) | 0.99 (0.96, 1.02) | 0.99 (0.97, 1.02) | 1 (0.97, 1.03) |
| Cardiovascular | 1 (0.95, 1.05) | 0.99 (0.94, 1.05) | 0.99 (0.94, 1.05) | 1 (0.95, 1.06) |
| IHD | 1.09 (1, 1.18) | 1.08 (0.99, 1.18) | 1.08 (0.99, 1.17) | **1.1 (1.01, 1.2)*** |
| Cerebrovascular | 1 (0.91, 1.09) | 0.99 (0.9, 1.08) | 0.99 (0.91, 1.08) | 0.98 (0.89, 1.08) |
| Respiratory | 0.99 (0.93, 1.06) | 0.99 (0.92, 1.06) | 0.99 (0.93, 1.05) | 0.99 (0.92, 1.06) |
| Pneumonia | 0.98 (0.9, 1.06) | 0.97 (0.9, 1.06) | 0.98 (0.9, 1.06) | 0.98 (0.9, 1.07) |
| COPD | 1.02 (0.9, 1.15) | 1.02 (0.9, 1.16) | 1.02 (0.9, 1.15) | 1.02 (0.9, 1.16) |
| External causes | 1.1 (0.92, 1.31) | 1.09 (0.91, 1.31) | 1.1 (0.92, 1.3) | 1.1 (0.91, 1.33) |
| 3D | | | | |
| All natural causes | **1.06 (1.03, 1.09)*** | **1.06 (1.03, 1.09)*** | **1.06 (1.03, 1.08)*** | **1.06 (1.03, 1.09)*** |
| Cardiovascular | **1.09 (1.04, 1.14)*** | **1.09 (1.04, 1.14)*** | **1.08 (1.03, 1.14)*** | **1.08 (1.02, 1.13)*** |
| IHD | **1.15 (1.06, 1.24)*** | **1.15 (1.07, 1.25)*** | **1.14 (1.06, 1.23)*** | **1.15 (1.06, 1.25)*** |
| Cerebrovascular | 1.06 (0.98, 1.15) | 1.06 (0.98, 1.15) | 1.06 (0.98, 1.15) | 1.04 (0.95, 1.13) |
| Respiratory | 1.06 (1, 1.12) | 1.06 (1, 1.13) | 1.06 (1, 1.12) | **1.07 (1.01, 1.13)*** |
| Pneumonia | 1.06 (0.99, 1.14) | 1.06 (0.98, 1.14) | 1.06 (0.99, 1.14) | 1.06 (0.99, 1.15) |
| COPD | 1.06 (0.96, 1.18) | 1.07 (0.96, 1.19) | 1.07 (0.96, 1.18) | 1.07 (0.96, 1.2) |
| External causes | 1.08 (0.93, 1.27) | 1.08 (0.92, 1.27) | 1.07 (0.91, 1.25) | 1.06 (0.89, 1.25) |
| D3D | | | | |
| All natural causes | **1.06 (1.03, 1.08)*** | **1.06 (1.03, 1.09)*** | **1.06 (1.03, 1.08)*** | **1.06 (1.03, 1.09)*** |
| Cardiovascular | **1.09 (1.04, 1.14)*** | **1.09 (1.04, 1.14)*** | **1.08 (1.03, 1.14)*** | **1.08 (1.02, 1.13)*** |
| IHD | **1.15 (1.06, 1.24)*** | **1.15 (1.07, 1.24)*** | **1.14 (1.06, 1.22)*** | **1.15 (1.06, 1.25)*** |
| Cerebrovascular | 1.06 (0.98, 1.15) | 1.06 (0.98, 1.16) | 1.06 (0.98, 1.15) | 1.04 (0.95, 1.13) |
| Respiratory | 1.06 (1, 1.12) | 1.06 (1, 1.13) | 1.06 (1, 1.12) | **1.07 (1.01, 1.13)*** |
| Pneumonia | 1.06 (0.99, 1.14) | 1.06 (0.98, 1.14) | 1.06 (0.99, 1.14) | 1.07 (0.99, 1.15) |
| COPD | 1.06 (0.96, 1.18) | 1.06 (0.96, 1.19) | 1.06 (0.96, 1.18) | 1.07 (0.96, 1.19) |
| External causes | 1.08 (0.93, 1.27) | 1.08 (0.92, 1.27) | 1.07 (0.91, 1.25) | 1.06 (0.89, 1.25) |

**P<0.05*; [a] Deaths within 1 year were excluded.

**Table A.28.** Hazard ratio (95%CI) per 10 μg/$m^3$ increase of $PM_{2.5}$ in main analysis for average exposure at the baseline period and sensitivity analyses for exposure to average $PM_{2.5}$ yearly and for different inclusion and exclusion criteria

| Cause of Death | Main analysis - baseline exposure[a] | Yearly Exposure | Including deaths within 1 year - baseline exposure | Excluding deaths within 3 years - baseline exposure |
|---|---|---|---|---|
| 2D | | | | |
| All natural causes | **1.06 (1.02, 1.11)*** | 1.01 (0.97, 1.05) | **1.06 (1.02, 1.1)*** | **1.08 (1.04, 1.12)*** |
| Cardiovascular | **1.11 (1.03, 1.19)*** | 1.03 (0.96, 1.11) | **1.1 (1.03, 1.18)*** | **1.13 (1.05, 1.22)*** |
| IHD | 1.06 (0.95, 1.19) | 0.97 (0.86, 1.09) | 1.07 (0.96, 1.19) | 1.06 (0.94, 1.19) |
| Cerebrovascular | 1.11 (0.98, 1.25) | 1.03 (0.91, 1.17) | 1.09 (0.97, 1.23) | **1.16 (1.02, 1.32)*** |
| Respiratory | 1.03 (0.94, 1.12) | 0.98 (0.9, 1.07) | 1.03 (0.95, 1.12) | 1.03 (0.94, 1.13) |
| Pneumonia | 1 (0.9, 1.11) | 0.96 (0.86, 1.07) | 1 (0.9, 1.11) | 1 (0.9, 1.12) |
| COPD | 1.1 (0.95, 1.29) | 1.04 (0.88, 1.22) | 1.11 (0.95, 1.29) | 1.11 (0.94, 1.3) |
| External causes | 1.04 (0.82, 1.32) | 0.98 (0.76, 1.25) | 1.02 (0.81, 1.3) | 1.04 (0.81, 1.34) |
| 3D | | | | |
| All natural causes | **1.09 (1.06, 1.12)*** | **1.06 (1.03, 1.09)*** | **1.09 (1.06, 1.12)*** | **1.1 (1.06, 1.13)*** |
| Cardiovascular | **1.13 (1.07, 1.19)*** | **1.09 (1.03, 1.15)*** | **1.13 (1.07, 1.19)*** | **1.13 (1.07, 1.19)*** |
| IHD | **1.13 (1.03, 1.23)*** | 1.08 (0.99, 1.18) | **1.12 (1.03, 1.22)*** | **1.12 (1.03, 1.23)*** |
| Cerebrovascular | **1.11 (1.01, 1.21)*** | 1.07 (0.97, 1.17) | **1.1 (1.01, 1.21)*** | **1.11 (1.01, 1.22)*** |
| Respiratory | **1.08 (1.01, 1.15)*** | 1.06 (0.99, 1.13) | **1.08 (1.01, 1.15)*** | **1.09 (1.02, 1.16)*** |
| Pneumonia | 1.07 (0.98, 1.16) | 1.05 (0.96, 1.13) | 1.07 (0.98, 1.16) | 1.07 (0.99, 1.17) |
| COPD | 1.12 (1, 1.26) | 1.08 (0.96, 1.22) | 1.12 (1, 1.26) | 1.12 (0.99, 1.27) |
| External causes | 1.05 (0.87, 1.26) | 1.01 (0.84, 1.21) | 1.03 (0.86, 1.23) | 1.02 (0.84, 1.25) |
| D3D | | | | |
| All natural causes | **1.1 (1.06, 1.13)*** | **1.07 (1.03, 1.1)*** | **1.1 (1.06, 1.13)*** | **1.1 (1.07, 1.14)*** |
| Cardiovascular | **1.14 (1.08, 1.21)*** | **1.1 (1.04, 1.16)*** | **1.14 (1.07, 1.2)*** | **1.14 (1.07, 1.21)*** |
| IHD | **1.14 (1.04, 1.25)*** | 1.09 (0.99, 1.2) | **1.13 (1.03, 1.24)*** | **1.14 (1.03, 1.25)*** |
| Cerebrovascular | **1.12 (1.01, 1.23)*** | 1.07 (0.97, 1.18) | **1.11 (1.01, 1.23)*** | **1.12 (1.01, 1.24)*** |
| Respiratory | **1.09 (1.01, 1.17)*** | 1.06 (0.99, 1.14) | **1.09 (1.01, 1.17)*** | **1.1 (1.02, 1.18)*** |
| Pneumonia | 1.07 (0.98, 1.17) | 1.05 (0.96, 1.15) | 1.07 (0.98, 1.17) | 1.08 (0.99, 1.18) |
| COPD | 1.13 (0.99, 1.28) | 1.09 (0.96, 1.24) | 1.13 (1, 1.28) | 1.13 (0.99, 1.29) |
| External causes | 1.05 (0.86, 1.28) | 1.01 (0.83, 1.23) | 1.03 (0.85, 1.25) | 1.03 (0.83, 1.27) |

**P < 0.05*; [a] Deaths within 1 year were excluded.

Stratified analysis

**Table A.29.** Hazard ratio (95%CI) per IQR increase of $PM_{2.5}$ in stratified analyses by age and sex with exposure at baseline (deaths within the first year were excluded). (2D and D3D Exposure)

| Cause of death | Age <71 years | Age ≥71 years | Inter-action | Male | Female | Inter-action |
|---|---|---|---|---|---|---|
| 2D | | | | | | |
| All natural causes | **1.07 (1.03, 1.11)*** | 1.02 (0.99, 1.05) | 0.007 | **1.05 (1.01, 1.08)*** | 1.03 (1, 1.06) | 0.442 |
| Cardiovascular | **1.13 (1.05, 1.21)*** | 1.02 (0.98, 1.07) | 0.001 | **1.08 (1.02, 1.15)*** | 1.04 (0.99, 1.09) | 0.235 |
| IHD | **1.13 (1.01, 1.27)*** | 0.99 (0.92, 1.07) | 0.008 | 1.06 (0.96, 1.17) | 1.02 (0.94, 1.1) | 0.578 |
| Cerebrovascular | 1.11 (0.99, 1.24) | 1.04 (0.96, 1.12) | 0.107 | 1.1 (0.99, 1.22) | 1.03 (0.95, 1.12) | 0.179 |
| Respiratory | 1.09 (0.99, 1.2) | 0.99 (0.94, 1.04) | 0.12 | 1 (0.94, 1.07) | 1.04 (0.97, 1.11) | 0.541 |
| Pneumonia | 1.1 (0.97, 1.25) | 0.96 (0.9, 1.03) | 0.077 | 0.97 (0.89, 1.05) | 1.03 (0.95, 1.11) | 0.225 |
| COPD | 1.13 (0.96, 1.32) | 1.04 (0.94, 1.15) | 0.363 | 1.05 (0.95, 1.17) | 1.07 (0.93, 1.24) | 0.784 |
| External causes | 1.01 (0.82, 1.24) | 1.04 (0.88, 1.23) | 0.977 | 1.03 (0.86, 1.24) | 1 (0.83, 1.21) | 1 |
| D3D | | | | | | |
| All natural causes | **1.11 (1.07, 1.16)*** | **1.09 (1.06, 1.12)*** | 0.061 | **1.07 (1.03, 1.1)*** | **1.07 (1.03, 1.1)*** | 0.924 |
| Cardiovascular | **1.15 (1.07, 1.24)*** | **1.13 (1.08, 1.19)*** | 0.097 | **1.11 (1.04, 1.18)*** | **1.09 (1.03, 1.14)*** | 0.406 |
| IHD | 1.13 (1, 1.27) | **1.14 (1.05, 1.23)*** | 0.232 | 1.1 (0.99, 1.22) | 1.09 (1, 1.18) | 0.985 |
| Cerebrovascular | 1.14 (1, 1.28) | **1.12 (1.03, 1.22)*** | 0.672 | **1.17 (1.05, 1.3)*** | 1.03 (0.94, 1.13) | 0.048 |
| Respiratory | **1.16 (1.05, 1.28)*** | **1.1 (1.04, 1.17)*** | 0.279 | 1.05 (0.98, 1.12) | 1.08 (1, 1.16) | 0.497 |
| Pneumonia | **1.21 (1.06, 1.38)*** | **1.09 (1.02, 1.17)*** | 0.115 | 1.05 (0.96, 1.14) | 1.05 (0.97, 1.14) | 0.699 |
| COPD | 1.12 (0.95, 1.31) | **1.13 (1.02, 1.26)*** | 0.944 | 1.06 (0.95, 1.18) | 1.17 (1, 1.37) | 0.531 |
| External causes | 1.03 (0.83, 1.28) | 1.1 (0.92, 1.31) | 0.87 | 1.1 (0.91, 1.33) | 0.97 (0.8, 1.18) | 0.463 |

**P < 0.05.*

**Table A.30.** Hazard ratio (95%CI) per IQR increase of BC in stratified analyses by age and sex with exposure at baseline (deaths within the first year were excluded). 2D and D3D Exposure

| Cause of death | Age <71 years | Age ≥71 years | Inter-action | Male | Female | Inter-action |
|---|---|---|---|---|---|---|
| 2D | | | | | | |
| All natural causes | 1.03 (1, 1.08) | **1.04 (1.02, 1.07)*** | 0.914 | **1.04 (1.01, 1.08)*** | 1.02 (0.99, 1.05) | 0.456 |
| Cardiovascular | **1.11 (1.03, 1.19)*** | **1.08 (1.03, 1.13)*** | 0.231 | **1.12 (1.05, 1.2)*** | 1.04 (0.98, 1.09) | 0.028 |
| IHD | **1.17 (1.04, 1.32)*** | 1.06 (0.98, 1.15) | 0.049 | **1.12 (1.01, 1.23)*** | 1.05 (0.96, 1.14) | 0.379 |
| Cerebrovascular | 1.12 (0.99, 1.27) | 1.05 (0.97, 1.14) | 0.326 | 1.12 (1, 1.26) | 1.01 (0.93, 1.11) | 0.088 |
| Respiratory | 0.96 (0.87, 1.07) | 1.03 (0.97, 1.09) | 0.234 | 1 (0.93, 1.07) | 0.98 (0.92, 1.06) | 0.941 |
| Pneumonia | 0.95 (0.82, 1.09) | 1.04 (0.97, 1.11) | 0.237 | 0.99 (0.91, 1.09) | 0.99 (0.91, 1.07) | 0.773 |
| COPD | 0.96 (0.81, 1.13) | 1.02 (0.91, 1.14) | 0.745 | 0.98 (0.87, 1.1) | 1 (0.86, 1.17) | 0.923 |
| External causes | **1.31 (1.07, 1.61)*** | 1.11 (0.93, 1.33) | 0.17 | **1.25 (1.03, 1.51)*** | 1.12 (0.93, 1.35) | 0.537 |
| D3D | | | | | | |
| All natural causes | **1.08 (1.04, 1.12)*** | **1.08 (1.05, 1.1)*** | 0.541 | **1.05 (1.02, 1.08)*** | **1.04 (1.01, 1.07)*** | 0.945 |
| Cardiovascular | **1.15 (1.07, 1.23)*** | **1.13 (1.08, 1.18)*** | 0.159 | **1.13 (1.07, 1.2)*** | **1.07 (1.02, 1.13)*** | 0.095 |
| IHD | **1.17 (1.05, 1.31)*** | **1.13 (1.05, 1.21)*** | 0.091 | **1.11 (1.01, 1.21)*** | **1.1 (1.02, 1.19)*** | 0.945 |
| Cerebrovascular | **1.16 (1.04, 1.3)*** | **1.1 (1.02, 1.19)*** | 0.393 | **1.16 (1.05, 1.28)*** | 1.03 (0.94, 1.12) | 0.038 |
| Respiratory | 1.02 (0.93, 1.13) | **1.08 (1.03, 1.14)*** | 0.433 | 1.02 (0.96, 1.09) | 1 (0.94, 1.07) | 0.91 |
| Pneumonia | 1.03 (0.91, 1.18) | **1.08 (1.02, 1.15)*** | 0.601 | 1.04 (0.95, 1.13) | 0.99 (0.92, 1.07) | 0.835 |
| COPD | 0.97 (0.82, 1.14) | 1.08 (0.97, 1.19) | 0.453 | 0.98 (0.88, 1.09) | 1.08 (0.94, 1.24) | 0.399 |
| External causes | **1.26 (1.04, 1.52)*** | 1.13 (0.96, 1.33) | 0.27 | **1.2 (1.01, 1.42)*** | 1.11 (0.93, 1.33) | 0.623 |

**P < 0.05*.

**Table A.31.** Hazard ratio (95%CI) per IQR increase of NO in stratified analyses by age and sex with exposure at baseline (deaths within the first year were excluded). 2D and D3D Exposure.

| Cause of death | Age <71 years | Age ≥71 years | Inter-action | Male | Female | Inter-action |
|---|---|---|---|---|---|---|
| 2D | | | | | | |
| All natural causes | 0.98 (0.94, 1.03) | 0.99 (0.96, 1.02) | 0.439 | 1 (0.96, 1.03) | 0.99 (0.96, 1.03) | 0.954 |
| Cardiovascular | 0.97 (0.9, 1.06) | 0.94 (0.89, 0.99) | 0.587 | 0.97 (0.91, 1.04) | 0.94 (0.89, 1) | 0.481 |
| IHD | 1.05 (0.92, 1.2) | 0.95 (0.87, 1.03) | 0.065 | 0.99 (0.88, 1.1) | 0.98 (0.89, 1.07) | 0.812 |
| Cerebrovascular | 1 (0.87, 1.15) | 0.93 (0.85, 1.02) | 0.991 | 1.02 (0.9, 1.15) | 0.93 (0.84, 1.02) | 0.639 |
| Respiratory | 1.04 (0.93, 1.16) | 0.98 (0.92, 1.05) | 0.677 | 1.01 (0.94, 1.09) | 0.99 (0.91, 1.07) | 0.55 |
| Pneumonia | 0.98 (0.85, 1.14) | 0.99 (0.92, 1.07) | 0.813 | 1.02 (0.92, 1.12) | 0.97 (0.89, 1.06) | 0.32 |
| COPD | 1.16 (0.97, 1.39) | 0.99 (0.88, 1.11) | 0.239 | 1.03 (0.91, 1.16) | 1.08 (0.91, 1.28) | 0.675 |
| External causes | 1.24 (0.97, 1.58) | 1.01 (0.83, 1.23) | 0.3 | 1.19 (0.95, 1.49) | 1.02 (0.82, 1.26) | 0.589 |
| D3D | | | | | | |
| All natural causes | **1.06 (1.01, 1.11)*** | **1.09 (1.06, 1.12)*** | 0.492 | **1.04 (1, 1.08)*** | **1.05 (1.02, 1.09)*** | 0.529 |
| Cardiovascular | 1.05 (0.96, 1.14) | **1.09 (1.03, 1.15)*** | 0.815 | 1.04 (0.97, 1.12) | 1.03 (0.97, 1.09) | 0.681 |
| IHD | 1.09 (0.96, 1.25) | **1.15 (1.05, 1.25)*** | 0.564 | 1.08 (0.97, 1.21) | 1.09 (0.98, 1.2) | 0.972 |
| Cerebrovascular | 1.05 (0.91, 1.21) | 1.06 (0.97, 1.17) | 0.508 | 1.1 (0.98, 1.25) | 0.96 (0.87, 1.07) | 0.264 |
| Respiratory | **1.13 (1.01, 1.27)*** | **1.13 (1.06, 1.2)*** | 0.849 | 1.08 (1, 1.16) | 1.04 (0.96, 1.14) | 0.793 |
| Pneumonia | 1.14 (0.98, 1.33) | **1.14 (1.05, 1.23)*** | 0.891 | 1.1 (1, 1.21) | 1.02 (0.92, 1.12) | 0.334 |
| COPD | 1.12 (0.93, 1.35) | **1.14 (1.01, 1.28)*** | 0.96 | 1.06 (0.94, 1.2) | 1.17 (0.98, 1.41) | 0.417 |
| External causes | 1.18 (0.93, 1.51) | 1.06 (0.86, 1.3) | 0.503 | 1.17 (0.94, 1.46) | 0.98 (0.78, 1.23) | 0.419 |

**P < 0.05.*

**Table A.32.** Hazard ratio (95%CI) per IQR increase of $NO_2$ in stratified analyses by age and sex with exposure at baseline (deaths within the first year were excluded). 2D and D3D Exposure.

| Cause of death | Age <71 years | Age>=71 years | Inter-action | Male | Female | Inter-action |
|---|---|---|---|---|---|---|
| 2D | | | | | | |
| All natural causes | 0.99 (0.94, 1.04) | 1 (0.96, 1.03) | 0.133 | 1.01 (0.97, 1.05) | 0.99 (0.95, 1.03) | 0.808 |
| Cardiovascular | 0.98 (0.89, 1.08) | 1.01 (0.95, 1.07) | 0.183 | 1.04 (0.96, 1.13) | 0.97 (0.91, 1.04) | 0.473 |
| IHD | 1.1 (0.95, 1.28) | 1.07 (0.97, 1.18) | 0.792 | 1.12 (0.98, 1.27) | 1.06 (0.95, 1.19) | 0.653 |
| Cerebrovascular | 1.03 (0.88, 1.21) | 0.98 (0.88, 1.1) | 0.287 | 1.1 (0.95, 1.27) | 0.94 (0.84, 1.05) | 0.836 |
| Respiratory | 0.98 (0.87, 1.12) | 0.98 (0.91, 1.05) | 0.664 | 1.02 (0.94, 1.12) | 0.95 (0.87, 1.05) | 0.309 |
| Pneumonia | 0.97 (0.82, 1.16) | 0.96 (0.88, 1.05) | 0.818 | 1.02 (0.91, 1.15) | 0.94 (0.84, 1.05) | 0.13 |
| COPD | 0.97 (0.78, 1.2) | 1.07 (0.92, 1.24) | 0.404 | 1.01 (0.87, 1.18) | 1.04 (0.85, 1.28) | 0.621 |
| External causes | 1.09 (0.83, 1.43) | 1.09 (0.87, 1.37) | 0.709 | 1.05 (0.82, 1.34) | 1.15 (0.9, 1.47) | 0.479 |
| D3D | **1.08 (1.03, 1.13)*** | **1.11 (1.07, 1.14)*** | 0.364 | **1.05 (1.01, 1.09)*** | **1.06 (1.03, 1.1)*** | 0.4 |
| All natural causes | 1.09 (1, 1.19) | 1.17 (1.1, 1.23) | 0.247 | **1.1 (1.02, 1.18)*** | **1.08 (1.02, 1.15)*** | 0.851 |
| Cardiovascular | 1.1 (0.97, 1.26) | **1.25 (1.14, 1.37)*** | 0.58 | **1.14 (1.02, 1.28)*** | **1.14 (1.03, 1.26)*** | 0.87 |
| IHD | 1.11 (0.96, 1.28) | **1.13 (1.03, 1.24)*** | 0.291 | **1.18 (1.04, 1.33)*** | 1 (0.9, 1.11) | 0.259 |
| Cerebrovascular | 1.11 (0.99, 1.24) | **1.15 (1.07, 1.22)*** | 0.68 | 1.08 (1, 1.17) | 1.03 (0.95, 1.13) | 0.718 |
| Respiratory | **1.17 (1.01, 1.36)*** | **1.15 (1.06, 1.24)*** | 0.859 | 1.1 (1, 1.22) | 1.01 (0.92, 1.12) | 0.279 |
| Pneumonia | 0.99 (0.82, 1.19) | **1.18 (1.04, 1.33)*** | 0.207 | 1.04 (0.91, 1.18) | 1.12 (0.93, 1.34) | 0.487 |
| COPD | 1.1 (0.86, 1.41) | 1.14 (0.93, 1.4) | 0.803 | 1.11 (0.89, 1.38) | 1.06 (0.85, 1.33) | 0.928 |
| External causes | **1.08 (1.03, 1.13)*** | **1.11 (1.07, 1.14)*** | 0.364 | **1.05 (1.01, 1.09)*** | **1.06 (1.03, 1.1)*** | 0.4 |

**P < 0.05.*

Table A.33. Hazard ratios (95%CI) per IQR increase of pollutants for baseline exposure using the alternative decay profile capped at 20m[a]

| | | | |
|---|---|---|---|
| | ***$PM_{2.5}$*** | | |
| *Cause of Death* | 2D (IQR: 5.5 μg/m$^3$) | 3D (IQR: 5.3 μg/m$^3$) | D3D (IQR: 4.9 μg/m$^3$) |
| *All natural causes* | **1.03 (1.01, 1.06)*** | **1.04 (1.02, 1.07)*** | **1.04 (1.02, 1.07)*** |
| *Cardiovascular* | **1.06 (1.02, 1.10)*** | **1.08 (1.04, 1.12)*** | **1.08 (1.04, 1.12)*** |
| *IHD* | 1.03 (0.97, 1.10) | **1.06 (1, 1.13)*** | **1.06 (1, 1.13)*** |
| *Cerebrovascular* | 1.06 (0.99, 1.13) | **1.08 (1.01, 1.15)*** | **1.08 (1.01, 1.15)*** |
| *Respiratory* | 1.02 (0.97, 1.06) | 1.02 (0.97, 1.06) | 1.01 (0.97, 1.06) |
| *Pneumonia* | 1.00 (0.94, 1.06) | 1 (0.94, 1.06) | 1 (0.94, 1.06) |
| *COPD* | 1.06 (0.97, 1.15) | 1.06 (0.97, 1.16) | 1.06 (0.97, 1.15) |
| *External causes* | 1.02 (0.90, 1.16) | 1.02 (0.89, 1.16) | 1.02 (0.89, 1.16) |
| | ***BC*** | | |
| *Cause of Death* | 2D (IQR: 9.6 μg/m$^3$) | 3D (IQR: 8.0 μg/m$^3$) | D3D (IQR: 4.9 μg/m$^3$) |
| *All natural causes* | **1.03 (1.00, 1.05)*** | **1.03 (1.01, 1.05)*** | **1.03 (1.01, 1.05)*** |
| *Cardiovascular* | **1.07 (1.03, 1.11)*** | **1.08 (1.04, 1.12)*** | **1.08 (1.04, 1.12)*** |
| *IHD* | **1.08 (1.01, 1.15)*** | **1.09 (1.02, 1.16)*** | **1.09 (1.02, 1.16)*** |
| *Cerebrovascular* | 1.05 (0.98, 1.13) | 1.06 (0.99, 1.13) | 1.06 (0.99, 1.13) |
| *Respiratory* | 0.99 (0.94, 1.04) | 0.99 (0.94, 1.04) | 0.99 (0.94, 1.04) |
| *Pneumonia* | 0.99 (0.93, 1.05) | 0.98 (0.92, 1.05) | 0.98 (0.93, 1.05) |
| *COPD* | 0.98 (0.90, 1.08) | 0.98 (0.9, 1.08) | 0.98 (0.9, 1.08) |
| *External causes* | **1.18 (1.03, 1.35)*** | **1.18 (1.04, 1.35)*** | **1.18 (1.04, 1.35)*** |
| | ***NO*** | | |
| *Cause of Death* | 2D (IQR: 167 μg/m$^3$) | 3D (IQR: 141 μg/m$^3$) | D3D (IQR: 106 μg/m$^3$) |
| *All natural causes* | 0.99 (0.97, 1.02) | 1.01 (0.99, 1.04) | 1.01 (0.99, 1.04) |
| *Cardiovascular* | 0.96 (0.91, 1.00) | 0.99 (0.95, 1.03) | 0.99 (0.95, 1.04) |
| *IHD* | 0.98 (0.91, 1.05) | 1.03 (0.96, 1.1) | 1.03 (0.96, 1.1) |
| *Cerebrovascular* | 0.96 (0.89, 1.04) | 0.99 (0.92, 1.07) | 0.99 (0.92, 1.07) |
| *Respiratory* | 1.00 (0.94, 1.05) | 1.01 (0.96, 1.06) | 1.01 (0.96, 1.06) |
| *Pneumonia* | 0.99 (0.93, 1.06) | 1 (0.94, 1.07) | 1 (0.94, 1.07) |
| *COPD* | 1.04 (0.94, 1.15) | 1.07 (0.97, 1.18) | 1.06 (0.97, 1.17) |
| *External causes* | 1.10 (0.94, 1.28) | 1.09 (0.94, 1.27) | 1.1 (0.94, 1.27) |

[a] *$P < 0.05$, 2D = street level LUR, 3D = 2D + vertical decay, D3D = 3D + infiltration, mobility and transport microenvironments

*Continued on next page*

**Table A.33 continued.** Hazard ratios (95%CI) per IQR increase of pollutants for baseline exposure using the alternative decay profile capped at 20m[a]

| | $NO_2$ | | |
|---|---|---|---|
| *Cause of Death* | 2D (IQR: 26 μg/m$^3$) | 3D (IQR: 22 μg/m$^3$) | D3D (IQR: 18 μg/m$^3$) |
| *All natural causes* | 1.00 (0.97, 1.03) | **1.03 (1, 1.06)*** | **1.03 (1, 1.06)*** |
| *Cardiovascular* | 1.00 (0.95, 1.05) | **1.06 (1.01, 1.12)*** | **1.06 (1.01, 1.12)*** |
| *IHD* | 1.09 (1.00, 1.18) | **1.15 (1.06, 1.24)*** | **1.15 (1.06, 1.24)*** |
| *Cerebrovascular* | 1.00 (0.91, 1.09) | 1.06 (0.97, 1.15) | 1.06 (0.97, 1.15) |
| *Respiratory* | 0.99 (0.93, 1.06) | 1 (0.94, 1.07) | 1 (0.94, 1.07) |
| *Pneumonia* | 0.98 (0.90, 1.06) | 0.99 (0.92, 1.07) | 0.99 (0.92, 1.07) |
| *COPD* | 1.02 (0.90, 1.15) | 1.04 (0.92, 1.16) | 1.03 (0.92, 1.16) |
| *External causes* | 1.10 (0.92, 1.31) | 1.12 (0.95, 1.32) | 1.11 (0.94, 1.31) |

[a] *$P$ < 0.05, 2D = street level LUR, 3D = 2D + vertical decay, D3D = 3D + infiltration, mobility and transport microenvironments

## Sample extracts from 3D visualization animation

These screen captures show three time intervals of animated $PM_{2.5}$ concentrations within the JDC1 canyon. The color scale represents an equally distributed range of $PM_{2.5}$ concentrations in μg/m$^3$ increasing from blue to red. The full sample video can be seen at http://geog.hku.hk/h-city/HKD3D.html.

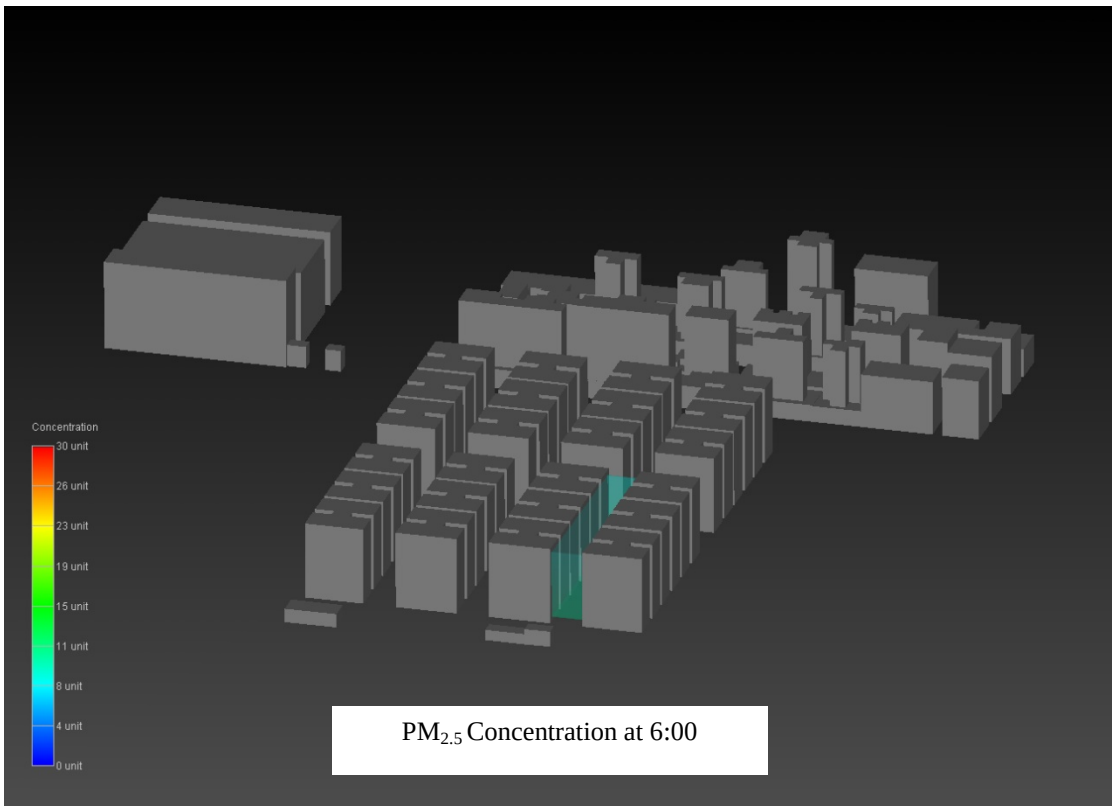
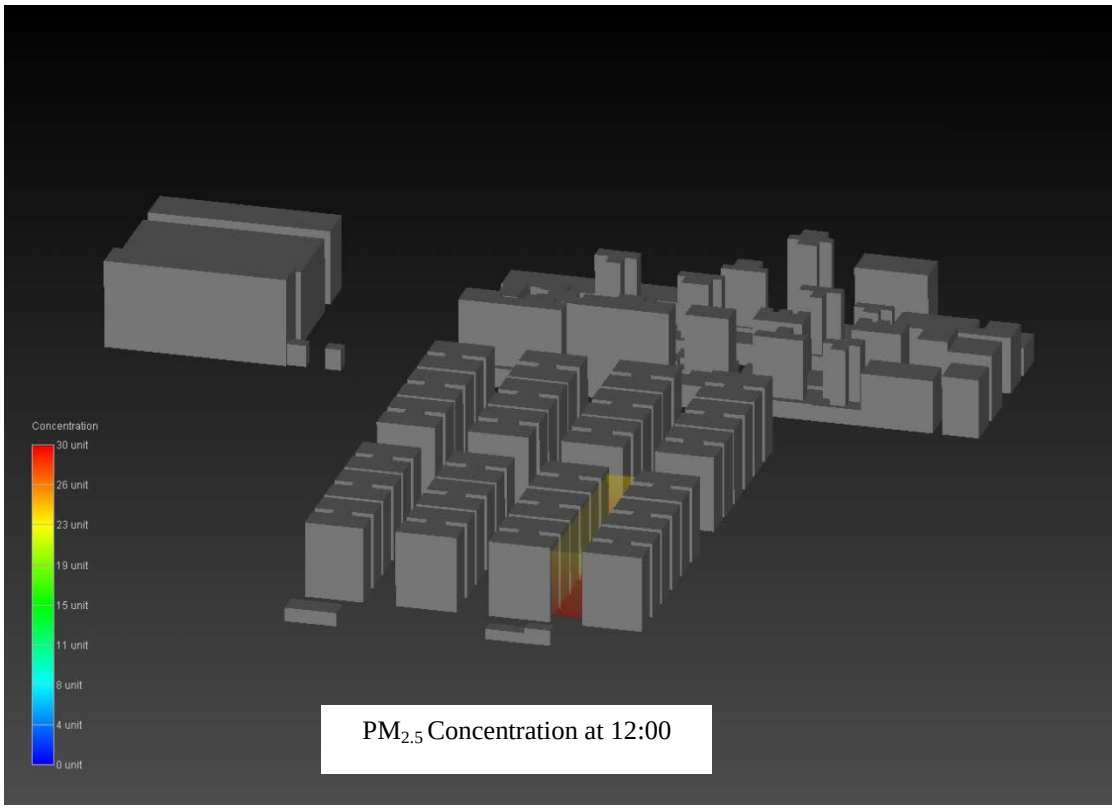



**Figure A.31. Screen captures from an animated 3D visualisation of $PM_{2.5}$ concentrations within the JDC1 canyon.**

*Figure continues on next page.*



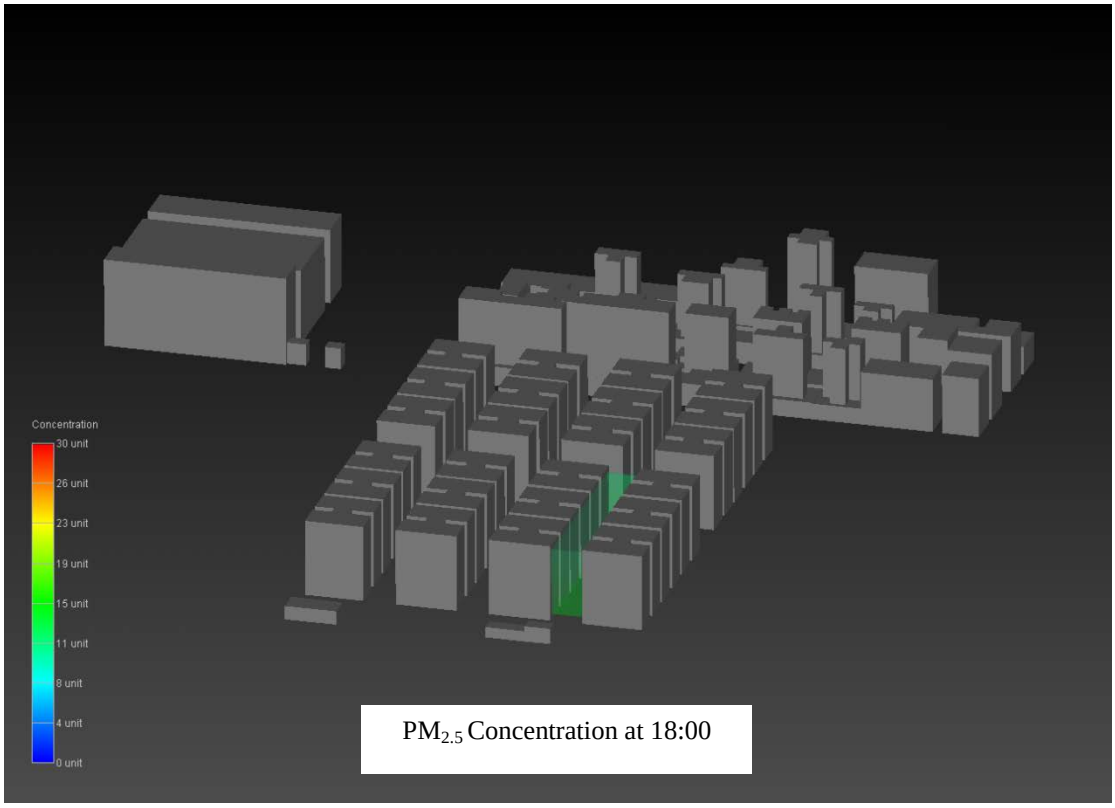




**Figure A.31 *continued*.**

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