Supplementary appendix

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Global urban temporal trends in fine particulate matter (PM$_{2.5}$) and attributable health burdens.

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Supplemental methods description

Relative Risk estimates

The Global Burden of Disease (GBD) project conducted a meta-analysis and regression of available epidemiological studies resulting in 1,000 splined meta-regression estimates for 385 integer exposure levels ranging from 0-2,500 µg/m$^3$. To convert these to RR estimates for use in our health impact function (Figure S1), we apply a theoretical minimum risk exposure level (TMREL) as there is uncertainty in the epidemiologic evidence describing the shape of the concentration-response function at these low concentrations. We apply the same TMREL as used in the GBD 2019, assuming a uniform distribution between 2·4 and 5·9 µg/m$^3$ based on the 5$^{th}$ percentile of the epidemiological studies included in the RR estimation.

To create RR estimates for each of the 385 integer exposure levels ($i$), we sample 1,000 times from the 1,000 TMREL estimates. For each iteration ($n=385$), if the integer exposure level is less than the sampled TMREL, then the RR is set to 1. If the integer exposure level is greater than the sampled TMREL, then the RR is set to the RR at the concentration divided by the RR at the TMREL concentration (Equation S1). We do this for each mortality endpoint ($h$) and age-group ($a$), and then average the resulting 1,000 RR estimates per mortality endpoint, age-group, and integer exposure level for use in the health impact function. Estimates of cause specific RR for concentrations relevant to our concentration dataset are shown in Figure S1. Age-specific RR estimates are available for ages 25 to 99 in five-year increments for ischemic heart disease, ischemic and intracerebral hemorrhagic stroke. Figure S1 depicts the average across age groups.

Equation S1.

$$RR_{h,i,a} = \begin{cases} MRBRT(i) & i \leq TMREL \\ \frac{MRBRT(i)}{MRBRT(TMREL)} & i > TMREL \end{cases}$$

Figure S1. Relative risk estimates using the GBD 2019 MR-BRT method and a theoretical minimum risk exposure level of a distribution between 2·4 and 5·9 µg/m$^3$. While MR-BRT estimates are provided from GBD for concentrations up to 2,500 µg/m$^3$, here we depict concentration ranges in line with our concentration dataset. MR-BRT estimates are provided by GBD by age groups for ischemic heart disease, ischemic and intracerebral hemorrhagic stroke, though here we show only the average across all ages. COPD=chronic obstructive pulmonary disease; LRI=lower respiratory infection;
stroke=ischemic and intracerebral hemorrhagic stroke; CVD=ischemic heart disease; GBD=global Burden of Disease study; MR-BRT=splined meta-regression estimates.

**Population datasets and urban extents**
We use two population datasets to estimate population-weighted PM$_{2.5}$ concentrations and city-specific PM$_{2.5}$-attributable mortality: Worldpop for our core results and the Gridded Population of the World (GPW v4) in the sensitivity analysis where we use GBD datasets. GPW population estimates are commonly used in air pollution health impact assessments including the GBD. Worldpop has also been used in air pollution health impact assessments, including to estimate health impacts attributable to NO$_2$ pollution and PM$_{2.5}$-related infant mortality in Africa. The Worldpop dataset has several advantages over GPW for estimating air pollution-attributable health impacts in urban areas. WorldPop population estimates use the same inputs as the Gridded Population of the World (GPW v4) and incorporates additional top-down satellite-derived estimates of population. Studies have found that WorldPop employs a more accurate method of disaggregation, as compared to GPW’s aerial weighting technique, by applying a dasymetric technique re-projecting census population counts onto land areas shown by satellites as inhabitable. WorldPop is also available for all years between 2000 and 2018, whereas GPW v4 is only available in five-year increments.

For urban area definitions, we use urban center boundary definitions as defined by the Global Human Settlement Grid (GHS-SMOD) for ~13,000 urban areas, also available at a 1km$^2$ gridded resolution (version: GHSPOP_GPW42015_GLOBE_R2015A_54009_1k_v1_0, accessed October 19, 2019). The GHS-SMOD dataset creates a globally harmonized definition of urban centers by measuring the degree of urbanization, defined by density, continuity of grid cells, and total population size. Using gridded population estimates from the 2015 Global Human Settlement Population (GHS-POP), the GHS-SMOD dataset designates urban centers as those contiguous grid cells with a population density of $\geq$1,500 inhabitants per grid cell (~1km$^2$), and a total population of $\geq$50,000. We use WHO regional definitions to categorize urban areas. While the GHS-SMOD dataset is one of several urban boundary definition datasets (i.e. Angel and colleagues), the GHS-SMOD includes the largest number of cities, as well as the gridded dataset provided by GHS-SMOD lends itself to ease of analysis when overlaying with the gridded datasets for the other inputs in our health impact assess (i.e. gridded estimates of population and concentrations).

**Parameter contribution analysis**
We assess the influence of each of four factors (population growth ($p$), population aging ($a$), baseline disease rates ($m$), concentrations ($c$)) by estimating PM$_{2.5}$-attributable mortality for five scenarios using methods adapted from Anenberg and colleagues. We first estimate PM$_{2.5}$-attributable mortality for a “baseline” scenario in which we use year-specific data for all four factors for 2019 (Equation S2), where Control denotes the baseline scenario for the year 2019 (Control$_t$). We then estimate PM$_{2.5}$-attributable mortality for four sensitivity scenarios (Simulation$_{m,t}$, Simulation$_{p,t}$, Simulation$_{a,t}$, Simulation$_{c,t}$) in which one the four factors are set to its 2000 value ($c_0$, $m_0$, $p_0$, $a_0$) while all other factors are held at 2019 values ($c_t$, $m_t$, $p_t$, $a_t$) shown in Equations S2-6. The ratios of estimated PM$_{2.5}$-attributable mortality between the baseline and each of the sensitivity scenarios, is the impact of the selected factor (Equation S7) where Simulation$_{m,t}$ is the attributable deaths for the year 2019 ($t$) and where one parameter has been set to the year 2000 (0). We assume that the product of the four ratios is equivalent to the difference between the deaths calculated in 2000 ($Deaths_0$) and 2019 ($Deaths_t$) (Equation S8). To normalize the contribution of each parameter, we log-transform Equation S8. The ratio of deaths in 2019 and deaths in 2000 ($Deaths_t/Deaths_0$) on the left-hand side of Equation S8 is equal to 1. The logarithm of every number in its own base equals 1, therefore we log-transform Equation S8 equal to Equation S9. To calculate the proportional impact of each factor to the percent change in PM$_{2.5}$-attributable mortality between 2000 and 2019, we then multiply the log-transformed parameter for each by the change in deaths between years 2000 and 2019 to calculate the percent contribution of each parameter to that total change (Equation S10).

**Equation S2:** \[
Control_0(c_t, m_t, p_t, a_t) = c_0 \times m_0 \times p_0 \times a_0
\]

**Equation S3:** \[
Simulation_{c,t}(c_0, m_t, p_t, a_t) = c_t \times m_0 \times p_0 \times a_t
\]

**Equation S4:** \[
Simulation_{m,t}(c_t, m_0, p_t, a_t) = c_t \times m_t \times p_0 \times a_t
\]

**Equation S5:** \[
Simulation_{p,t}(c_t, m_t, p_0, a_t) = c_t \times m_t \times p_0 \times a_t
\]
Equation S6: \[ \text{Simulation}_{t} (c_t, m_t, p_t, a_0) = c_t \times m_t \times p_t \times a_0 \]

Equation S7: \[ \text{Ratio}_{t} = \frac{\text{Simulation}_{t}}{\text{Control}_{t}} \]

Equation S8: \[ \frac{\text{Deaths}}{\text{Deaths}_0} = \text{Ratio}_{c,t} \times \text{Ratio}_{m,t} \times \text{Ratio}_{p,t} \times \text{Ratio}_{a,t} \]

Equation S9: \[ 1 = \log \left( \text{Ratio}_{c,t} \right) + \log \left( \text{Ratio}_{m,t} \right) + \log \left( \text{Ratio}_{p,t} \right) + \log \left( \text{Ratio}_{a,t} \right) \]

Equation S10: \[ \text{Contribution}_{t} = \frac{\text{Deaths}}{\text{Deaths}_0} \times \log \left( \text{Ratio}_{t} \right) \]

**Sensitivity analysis comparing GBD and Hammer et al. 2020 PM$_{2.5}$ concentrations**

To understand the influence of spatial resolution and generate results that are consistent with the GBD, we compare estimated PM$_{2.5}$-attributable mortality in each urban center using the fine resolution (0.00833°) concentration estimates to results using the GBD’s relatively more coarse resolution (0·1°) data. We obtained GBD PM$_{2.5}$ concentration estimates at a 0·1° × 0·1° (~100 km$^2$) gridded resolution. Comparing differences in magnitude and trends between the application of coarse and fine resolution datasets can indicate whether coarse resolution datasets offering improved computational efficiency are sufficient to describe urban trends in PM$_{2.5}$ and PM$_{2.5}$-attributable mortality or whether they mask trends by diluting urban area extents. Differences between the application of GBD datasets versus our core results are not solely driven by spatial resolution differences, as the GBD PM$_{2.5}$ dataset uses a different modeling approach for incorporating ground monitor data to produce their final surface PM$_{2.5}$ concentration estimates.$^{10,11}$

GBD provides PM$_{2.5}$ concentration data for the years 2000, 2005, and 2010 through 2019. We compare ratios of regionally averaged urban PM$_{2.5}$ concentrations using the fine resolution concentration estimates (~1 km$^2$) from our core analysis, over GBD estimates disaggregated from ~100 km$^2$ to ~1 km$^2$ resolution. We find that the coarse resolution datasets, on average, resulted in both higher regional urban estimates of PM$_{2.5}$ concentrations and attributable mortality rates (Figure S2, A.) compared to fine resolution concentrations. Figure S2 B. compares Hammer and colleagues’$^{12}$ PM$_{2.5}$ averaged to the same resolution of GBD PM$_{2.5}$ (~100 km$^2$). The difference between Figure S2 A. and B. demonstrates the impact of resolution. We find that regionally averaged urban PM$_{2.5}$ concentrations are 16% lower between 2000 and 2019 when using high resolution datasets as compared to more coarsely resolved concentrations. Jointly, our sensitivity analysis comparing coarse resolution GBD datasets to fine resolution datasets for our core results suggests that spatial resolution may be important in defining urban boundaries.

Although coarse resolution estimates may offer improved computational efficiency when producing the risk estimates created as part of this analysis, both the fine and coarse resolution PM$_{2.5}$ concentration estimates can be viewed easily viewed with basic GIS-knowledge on a standard computer operating system, making them informative and useful in low-resource public health settings. Further, the dataset produced as a result of this analysis is an effort to provide estimates in areas that may be low resource public health settings and reduce the need for city-level decision makers to replicate using their own analyses.
Figure S2.
(A.) Ratio of population-weighted annual average PM2.5 concentrations from the core analysis fine resolution (~1km², Hammer et al. 2020) over GBD population-weighted PM2.5 concentration estimates (~100 km²).
B.) Ratio of PM2.5-attributable mortality per 100,000 using PM2.5 concentrations from the core analysis fine resolution (~1 km² averaged to ~100km²) over PM2.5-attributable mortality per 100,000 using GBD PM2.5 concentration estimates (~100km²).

PM2.5 concentration estimates dataset
For surface-level PM2.5 concentrations for 2000 to 2019, we use a dataset that integrates information from satellite-retrieved aerosol optical depth (AOD), chemical transport modeling, and ground monitor data from Hammer and colleagues12, which improved upon prior estimates13. Hammer and colleagues combined multiple AOD retrievals from three satellite instruments (the Moderate Resolution Imaging Spectroradiometer (MODIS), SeaWiFs, and the Multiangle Imaging Spectroradiometer (MISR)). They then used the simulated relationship of total column AOD to surface PM2.5 from the GEOS-Chem chemical transport model to estimate ground-level PM2.5 concentrations. Finally, they incorporated ground-based observations of PM2.5 from the WHO Global Ambient Air Quality Database using a geographically weighted regression (GWR). Several predictor variables were included in the geographically weighted regression to account for the residual bias with ground monitors, including inverse distance to nearest urban land surface, subgrid topographical variation and simulated aerosol types.

A strength of this PM2.5 concentration dataset is that it relies primarily on geophysical information (remote sensing retrievals and chemical transport modelling) that is independent of ground monitor observations, with the statistical fusion used as a refinement. Without including the GWR, Hammer and colleagues were able to achieve an R² of 0.81, with the statistical fusion explaining only 11% of the variance (cross-validated R²=0.90-0.92), providing promise for capturing PM2.5 even in regions with sparse monitoring. Estimated annual average concentrations were highly consistent with out-of-sample cross-validated ground monitoring measurements, with negligible variation in the root mean square error of the GWR-adjusted hybrid model (employed here in the main analysis) and the out-of-sample cross-validated measurements (6.89 µg/m³ versus 6.80 µg/m³). However, the authors concluded that despite the increased ground monitors through the study time period, monitoring locations were insufficient to allow cross-
validation in a number of global sub-regions, including South America and Africa (see Hammer et al. 2020 supplemental information, Table S6).

**Comparison urban and country level baseline mortality rates**

We note in the discussion that urban baseline disease rates may differ from country level baseline disease rates; the latter of which we apply to urban areas using estimates from the GBD 2019 study. Although we may introduce additional uncertainty using this method, we conducted a sensitivity analysis to assess potential bias. The GBD does provide some urban-area level baseline mortality rates. Using estimates from the year 2018, we compare available cause-specific baseline mortality rates for 97 unique urban areas to corresponding country level estimates. Though we find that using national rates may introduce some error in estimated urban PM$_{2.5}$ mortality, doing so does not systematically bias results, as evidenced by no discernable pattern when comparing urban area baseline mortality rates (x-axis Figure S3) and country level baseline disease rates (y-axis Figure S3).

**Figure S3.** Comparison of urban area (n=97) cause-specific baseline mortality rates per 100,000 (x-axis) and country level baseline mortality rates per 100,000 (y-axis) for the year 2018 by World Health Organization (WHO) region.
Table S1. Population-weighted annual average fine particulate matter (PM$_{2.5}$) concentrations and attributable mortality for the top 250 most populated urban areas, based on 2019 WorldPop population estimates. Results presented for years 2000 and 2019. Confidence intervals are provided in the Supplemental Data File.

| GHS-SMOD ID | City               | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|-------------|--------------------|-----------------|-----------------|-------------------------------|-------------------------------|----------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 12141       | Guangzhou          | 27,699,156      | 45,283,210      | 37.4                          | 32.3                          | 22770                            | 40840                            | 90                             | 90                             |
| 11920       | Jakarta            | 22,668,660      | 37,600,502      | 86.9                          | 67.3                          | 19800                            | 39980                            | 90                             | 110                            |
| 6998        | Delhi [New Delhi]  | 18,045,531      | 28,151,373      | 99.2                          | 110.4                         | 16990                            | 29900                            | 100                            | 110                            |
| 12456       | Shanghai           | 15,024,321      | 28,458,216      | 35.2                          | 40.1                          | 11890                            | 29750                            | 80                             | 110                            |
| 10745       | Beijing            | 10,554,051      | 21,258,225      | 50.7                          | 55.0                          | 10460                            | 26270                            | 100                            | 130                            |
| 9933        | Dhaka              | 13,542,008      | 25,747,195      | 53.3                          | 71.4                          | 8460                             | 22090                            | 70                             | 90                             |
| 9752        | Kolkata            | 18,193,847      | 21,620,848      | 64.4                          | 84.0                          | 14570                            | 21380                            | 80                             | 100                            |
| 6887        | Mumbai             | 16,701,212      | 21,328,649      | 25.8                          | 45.1                          | 7370                             | 16020                            | 50                             | 80                             |
| 3915        | Cairo              | 14,556,344      | 20,158,389      | 36.6                          | 34.2                          | 9300                             | 13470                            | 70                             | 70                             |
| 10354       | Chengdu            | 6,615,753       | 10,376,011      | 171.2                         | 49.9                          | 9780                             | 12190                            | 150                            | 120                            |
| 13017       | Tokyo              | 30,616,278      | 34,988,526      | 21.9                          | 14.3                          | 12520                            | 11480                            | 50                             | 40                             |
| 3686        | Moscow             | 11,673,862      | 14,754,793      | 24.3                          | 16.5                          | 17530                            | 11400                            | 150                            | 80                             |
| 12356       | Suzhou             | 6,531,624       | 9,637,805       | 44.0                          | 47.0                          | 6000                             | 10940                            | 100                            | 120                            |
| 12442       | Hangzhou           | 5,668,834       | 8,517,102       | 57.6                          | 49.6                          | 6030                             | 10010                            | 110                            | 120                            |
| 6203        | Karachi            | 9,313,404       | 14,497,914      | 59.7                          | 63.6                          | 7370                             | 9940                             | 80                             | 70                             |
| 11608       | Wuhan              | 5,800,576       | 7,882,792       | 56.6                          | 54.1                          | 6110                             | 9740                             | 110                            | 130                            |
| 12486       | Jieyang            | 8,550,877       | 11,037,006      | 31.5                          | 30.1                          | 6200                             | 9500                             | 80                             | 90                             |
| 10982       | Tianjin            | 4,483,188       | 7,528,791       | 46.6                          | 55.5                          | 4230                             | 9390                             | 100                            | 130                            |
| 12882       | Quezon City [Manila]| 17,418,360     | 23,149,054      | 38.3                          | 21.6                          | 7910                             | 9370                             | 50                             | 40                             |
| 12445       | Seoul              | 19,208,839      | 22,543,192      | 32.1                          | 27.2                          | 8430                             | 9060                             | 50                             | 40                             |
| 12102       | Bandung            | 5,361,022       | 7,732,915       | 91.5                          | 78.6                          | 4740                             | 8640                             | 90                             | 120                            |
| 10774       | Bangkok            | 8,676,980       | 17,590,756      | 28.6                          | 25.9                          | 3560                             | 8020                             | 50                             | 50                             |
| 12131       | Nanjing            | 3,641,620       | 6,070,441       | 49.0                          | 55.4                          | 3530                             | 7570                             | 100                            | 130                            |
| GHS - SMOD ID | City               | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|---------------|--------------------|-----------------|-----------------|-------------------------------|-------------------------------|----------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 8099          | Bengaluru         | 5,499,094       | 10,724,085      | 21.6                          | 39.3                          | 2090                             | 7410                             | 40                             | 70                             |
| 8733          | Chennai            | 7,130,766       | 10,100,885      | 28.0                          | 41.7                          | 3350                             | 7190                             | 50                             | 80                             |
| 11070         | Zhengzhou          | 3,024,821       | 4,955,589       | 65.9                          | 71.1                          | 3430                             | 6910                             | 120                            | 140                            |
| 11856         | Ho Chi Minh City   | 6,276,079       | 12,961,206      | 16.8                          | 22.4                          | 1750                             | 6790                             | 30                             | 60                             |
| 11392         | Shenyang           | 4,680,058       | 5,814,079       | 48.0                          | 48.4                          | 4480                             | 6760                             | 100                            | 120                            |
| 155           | Mexico City        | 17,171,979      | 19,809,273      | 65.8                          | 21.4                          | 7450                             | 6730                             | 50                             | 40                             |
| 10536         | Xi'an              | 4,193,908       | 5,544,110       | 65.8                          | 50.4                          | 4750                             | 6590                             | 120                            | 120                            |
| 8052          | Hyderabad          | 5,988,588       | 8,400,445       | 27.9                          | 47.8                          | 2810                             | 6460                             | 50                             | 80                             |
| 2133          | Lagos              | 7,092,227       | 12,848,272      | 83.7                          | 66.9                          | 6980                             | 6310                             | 100                            | 50                             |
| 9998          | Comilla            | 5,173,515       | 6,844,814       | 48.8                          | 65.8                          | 3570                             | 6170                             | 70                             | 90                             |
| 6515          | Lahore             | 6,288,827       | 9,923,188       | 45.8                          | 50.2                          | 4310                             | 6120                             | 70                             | 70                             |
| 6693          | Ahmedabad          | 4,808,747       | 7,028,724       | 48.6                          | 57.7                          | 3230                             | 5970                             | 70                             | 90                             |
| 12663         | Surabaya           | 6,533,594       | 8,091,043       | 28.7                          | 31.9                          | 3230                             | 5790                             | 50                             | 80                             |
| 3574          | Istanbul           | 11,318,016      | 14,751,206      | 20.2                          | 19.2                          | 3700                             | 5760                             | 40                             | 40                             |
| 12911         | Osaka [Kyoto]      | 15,580,180      | 16,017,423      | 23.3                          | 15.6                          | 6910                             | 5700                             | 50                             | 40                             |
| 7086          | Pune               | 3,996,547       | 6,771,520       | 24.7                          | 53.3                          | 1710                             | 5550                             | 50                             | 90                             |
| 11939         | Hefei              | 3,212,298       | 4,289,535       | 53.4                          | 54.4                          | 3290                             | 5300                             | 110                            | 130                            |
| 11194         | Hanoi              | 3,775,942       | 5,872,764       | 46.1                          | 47.3                          | 2410                             | 5170                             | 70                             | 90                             |
| 10777         | Shijiazhuang       | 2,963,151       | 3,553,053       | 52.7                          | 77.6                          | 3000                             | 5100                             | 110                            | 150                            |
| 8819          | Kathmandu          | 763,069         | 6,417,430       | 35.6                          | 51.5                          | 400                              | 5080                             | 60                             | 80                             |
| 11280         | Jinan              | 2,894,198       | 3,772,514       | 49.7                          | 65.1                          | 2840                             | 5080                             | 100                            | 140                            |
| 11171         | Harbin             | 3,511,002       | 4,410,980       | 28.6                          | 47.9                          | 2350                             | 5070                             | 70                             | 120                            |
| 11197         | Kuala Lumpur       | 4,141,754       | 7,258,444       | 30.1                          | 40.1                          | 1780                             | 5040                             | 50                             | 70                             |
| 10664         | Chongqing          | 5,138,728       | 4,616,409       | 89.7                          | 44.0                          | 6570                             | 5040                             | 130                            | 110                            |
| 10589         | Taiyuan            | 2,494,251       | 3,857,184       | 37.5                          | 58.0                          | 2050                             | 4890                             | 90                             | 130                            |
| 12632         | Wenzhou            | 3,544,565       | 5,123,080       | 43.3                          | 33.0                          | 3210                             | 4720                             | 100                            | 100                            |
| 7089          | Ürümqi             | 1,934,668       | 3,545,246       | 56.4                          | 63.4                          | 2040                             | 4710                             | 110                            | 140                            |
| GHS - SMOD ID | City         | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|--------------|--------------|-----------------|-----------------|-------------------------------|-------------------------------|----------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 530          | Lima         | 6,464,807       | 10,108,650      | 81.0                          | 73.2                          | 3160                             | 4680                             | 50                             | 50                             |
| 6770         | Surat        | 3,021,819       | 5,981,082       | 30.8                          | 48.3                          | 1540                             | 4650                             | 60                             | 80                             |
| 5767         | Tehran       | 8,573,766       | 10,844,851      | 24.7                          | 28.3                          | 2850                             | 4540                             | 40                             | 50                             |
| 1308         | São Paulo    | 16,387,667      | 19,456,006      | 17.1                          | 13.1                          | 4630                             | 4500                             | 30                             | 30                             |
| 12584        | Xiamen       | 1,906,913       | 5,145,829       | 34.0                          | 29.4                          | 1450                             | 4320                             | 80                             | 90                             |
| 11685        | Changsha     | 2,707,678       | 3,521,500       | 57.0                          | 50.2                          | 2880                             | 4180                             | 110                            | 120                            |
| 11828        | Qingdao      | 2,940,000       | 3,899,965       | 34.8                          | 38.4                          | 2280                             | 3950                             | 80                             | 110                            |
| 1919         | London       | 8,081,641       | 10,257,319      | 21.4                          | 15.3                          | 5950                             | 3940                             | 80                             | 40                             |
| 12451        | Yogyakarta   | 4,262,764       | 4,856,306       | 39.3                          | 37.7                          | 2620                             | 3890                             | 70                             | 80                             |
| 11305        | Changchun    | 3,062,565       | 3,497,865       | 36.7                          | 44.2                          | 2470                             | 3870                             | 90                             | 120                            |
| 7899         | Lucknow      | 2,332,861       | 3,463,583       | 111.0                         | 125.4                         | 2260                             | 3750                             | 100                            | 110                            |
| 10306        | Yangon       | 3,822,415       | 5,375,917       | 14.1                          | 25.1                          | 1640                             | 3680                             | 50                             | 70                             |
| 12748        | New Taipei [Taipei] | 7,717,256      | 9,213,826       | 27.4                          | 18.2                          | 3310                             | 3650                             | 50                             | 40                             |
| 624          | Bogota       | 5,517,952       | 10,354,679      | 36.8                          | 30.0                          | 1900                             | 3650                             | 40                             | 40                             |
| 12333        | Hong Kong    | 5,253,823       | 5,832,679       | 24.3                          | 20.5                          | 3100                             | 3590                             | 60                             | 70                             |
| 10094        | Chattogram   | 3,796,783       | 5,067,074       | 30.5                          | 46.0                          | 1640                             | 3560                             | 50                             | 70                             |
| 12067        | Nanchang     | 2,379,999       | 3,181,871       | 43.8                          | 44.2                          | 2160                             | 3520                             | 100                            | 120                            |
| 12623        | Quanzhou     | 3,443,265       | 4,269,426       | 34.8                          | 29.0                          | 2670                             | 3490                             | 80                             | 90                             |
| 12309        | Changzhou    | 1,985,348       | 2,898,725       | 45.4                          | 51.0                          | 1850                             | 3480                             | 100                            | 120                            |
| 14           | Los Angeles  | 13,232,430      | 14,981,454      | 17.6                          | 10.5                          | 6430                             | 3450                             | 50                             | 30                             |
| 8516         | Varanasi     | 2,329,445       | 3,147,004       | 75.6                          | 120.7                         | 2000                             | 3410                             | 90                             | 110                            |
| 7802         | Kanpur       | 2,534,107       | 2,994,367       | 108.7                         | 121.5                         | 2390                             | 3240                             | 100                            | 110                            |
| 10750        | Medan        | 2,881,033       | 3,792,291       | 26.9                          | 41.8                          | 1350                             | 3220                             | 50                             | 90                             |
| 12582        | Ningbo       | 1,915,962       | 3,017,045       | 40.4                          | 38.1                          | 1660                             | 3050                             | 90                             | 110                            |
| 3528         | Kyiv         | 2,351,583       | 2,603,963       | 19.4                          | 16.2                          | 3090                             | 2980                             | 140                            | 120                            |
| 6935         | Jaipur       | 2,175,391       | 3,088,810       | 60.2                          | 74.0                          | 1690                             | 2930                             | 80                             | 100                            |
| 11554        | Singapore    | 4,048,151       | 5,948,131       | 78.3                          | 49.4                          | 2630                             | 2930                             | 70                             | 50                             |
| GHS - SMOD ID | City      | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|---------------|-----------|-----------------|-----------------|-------------------------------|-------------------------------|----------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 9459          | Asansol   | 2,380,378       | 2,864,919       | 64.5                          | 92.0                          | 1910                             | 2910                             | 80                             | 110                             |
| 11597         | Dalian    | 2,856,376       | 3,618,563       | 30.8                          | 28.0                          | 2020                             | 2880                             | 80                             | 80                             |
| 12967         | Nagoya    | 7,422,183       | 8,045,825       | 24.7                          | 15.3                          | 3420                             | 2860                             | 50                             | 40                             |
| 10181         | Lanzhou   | 1,939,337       | 2,548,575       | 87.9                          | 41.3                          | 2460                             | 2700                             | 130                            | 110                            |
| 2054          | Paris     | 8,985,702       | 10,230,286      | 19.5                          | 15.0                          | 3530                             | 2690                             | 40                             | 30                             |
| 12620         | Fuzhou    | 2,565,109       | 3,171,285       | 37.8                          | 29.9                          | 2110                             | 2660                             | 90                             | 90                             |
| 1912          | Accra     | 2,477,927       | 4,893,531       | 77.0                          | 51.9                          | 1630                             | 2600                             | 70                             | 60                             |
| 11440         | Nanning   | 2,104,006       | 2,557,832       | 38.9                          | 38.3                          | 1760                             | 2590                             | 90                             | 110                            |
| 11440         | New York  | 15,733,283      | 16,518,285      | 13.4                          | 8.0                           | 5690                             | 2560                             | 40                             | 20                             |
| 10920         | Luoyang   | 1,715,778       | 1,893,840       | 60.0                          | 64.8                          | 1860                             | 2530                             | 110                            | 140                            |
| 4426          | Damascus  | 2,446,163       | 3,849,622       | 19.7                          | 26.5                          | 750                              | 2490                             | 40                             | 70                             |
| 2723          | Kano      | 2,482,889       | 4,511,166       | 94.9                          | 83.6                          | 2570                             | 2460                             | 110                            | 60                             |
| 7973          | Nagpur    | 2,168,756       | 2,815,127       | 34.7                          | 59.1                          | 1210                             | 2430                             | 60                             | 90                             |
| 7235          | Indore    | 1,651,763       | 2,785,461       | 31.5                          | 60.4                          | 860                              | 2420                             | 60                             | 90                             |
| 6041          | Tashkent  | 2,154,439       | 2,681,603       | 50.8                          | 38.0                          | 2560                             | 2420                             | 120                            | 90                             |
| 6041          | Tashkent  | 2,154,439       | 2,681,603       | 50.8                          | 38.0                          | 2560                             | 2420                             | 120                            | 90                             |
| 10914         | Guiyang   | 1,992,264       | 2,675,252       | 48.6                          | 32.6                          | 1930                             | 2410                             | 100                            | 90                             |
| 6445          | Faisalabad| 2,696,230       | 4,283,515       | 39.8                          | 42.4                          | 1700                             | 2410                             | 70                             | 60                             |
| 12535         | Cixi      | 1,364,324       | 2,162,526       | 46.6                          | 44.3                          | 1290                             | 2390                             | 100                            | 120                            |
| 8973          | Patna     | 1,577,376       | 2,295,431       | 71.5                          | 109.6                         | 1320                             | 2390                             | 90                             | 110                            |
| 10244         | Baotou    | 1,611,598       | 2,168,700       | 43.2                          | 42.2                          | 1460                             | 2340                             | 100                            | 110                            |
| 11412         | Zibo      | 1,540,380       | 1,810,509       | 45.8                          | 59.4                          | 1440                             | 2340                             | 100                            | 130                            |
| 6152          | Kabul     | 2,327,587       | 3,844,855       | 47.7                          | 50.8                          | 2700                             | 2330                             | 120                            | 70                             |
| 3221          | Kinshasa  | 4,443,480       | 6,725,426       | 40.8                          | 35.8                          | 2480                             | 2320                             | 60                             | 40                             |
| 12440         | Semarang  | 2,199,727       | 2,857,423       | 46.2                          | 37.5                          | 1490                             | 2290                             | 70                             | 80                             |
| 7308          | Agra      | 1,567,719       | 2,080,942       | 84.4                          | 105.5                         | 1400                             | 2160                             | 90                             | 110                            |
| 10323         | Hohhot    | 1,467,449       | 2,046,945       | 33.8                          | 40.4                          | 1110                             | 2140                             | 80                             | 110                            |
| 1682          | Abidjan   | 3,026,204       | 5,066,070       | 63.5                          | 47.4                          | 2050                             | 2110                             | 70                             | 50                             |
| GHS - SMOD ID | City         | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|--------------|--------------|-----------------|-----------------|-------------------------------|-------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 10533        | Kunming      | 2,636,143       | 3,249,997       | 31.1                          | 21.2                          | 1910                            | 2090                            | 80                              | 70                              |
| 1367         | Rio de Janeiro | 8,636,095     | 9,922,350       | 18.2                          | 12.7                          | 2580                            | 2080                            | 30                              | 30                              |
| 1791         | Kumasi       | 1,380,714       | 3,600,919       | 84.0                          | 58.6                          | 930                             | 2040                            | 70                              | 60                              |
| 6376         | Multan       | 1,756,132       | 2,901,086       | 57.4                          | 59.0                          | 1370                            | 1930                            | 80                              | 70                              |
| 3407         | Saint Petersburg | 4,016,078   | 4,482,570       | 11.4                          | 10.4                          | 2650                            | 1930                            | 70                              | 50                              |
| 3060         | Luanda       | 519,152         | 11,819,698      | 13.0                          | 17.8                          | 100                             | 1920                            | 20                              | 20                              |
| 3684         | Johannesburg | 4,327,932       | 7,503,852       | 18.2                          | 14.6                          | 1610                            | 1870                            | 40                              | 30                              |
| 9341         | Dhanbad      | 1,499,689       | 1,824,697       | 62.4                          | 93.0                          | 1180                            | 1860                            | 80                              | 110                             |
| 3430         | Athens       | 3,353,435       | 3,273,728       | 17.5                          | 14.8                          | 2000                            | 1850                            | 60                              | 60                              |
| 6368         | Rawalpindi [Islamabad] | 1,697,765   | 3,052,259       | 54.1                          | 45.6                          | 1290                            | 1780                            | 80                              | 60                              |
| 5337         | Baghdad      | 3,360,108       | 4,783,270       | 23.0                          | 23.0                          | 1260                            | 1760                            | 40                              | 40                              |
| 3454         | Bucharest    | 1,962,253       | 1,926,459       | 26.3                          | 18.5                          | 2370                            | 1740                            | 130                             | 90                              |
| 6803         | Chandigarh   | 1,273,847       | 1,890,123       | 69.7                          | 68.1                          | 1060                            | 1740                            | 90                              | 100                             |
| 2570         | Milan        | 2,995,168       | 3,173,223       | 42.0                          | 20.7                          | 2960                            | 1730                            | 100                             | 60                              |
| 1110         | Buenos Aires | 10,929,399      | 14,133,052      | 8.3                           | 7.7                           | 1590                            | 1710                            | 20                              | 20                              |
| 8896         | Colombo      | 4,146,643       | 4,706,074       | 16.2                          | 17.7                          | 1160                            | 1710                            | 30                              | 40                              |
| 2494         | Onitsha      | 1,886,939       | 3,169,095       | 94.0                          | 80.5                          | 1950                            | 1700                            | 110                             | 60                              |
| 6779         | Vadodara     | 1,481,732       | 1,982,234       | 42.6                          | 57.0                          | 950                             | 1670                            | 70                              | 90                              |
| 7503         | Bhopal       | 1,186,039       | 1,849,336       | 34.0                          | 64.1                          | 650                             | 1660                            | 60                              | 90                              |
| 936          | Santiago     | 4,970,070       | 6,672,441       | 19.9                          | 17.9                          | 1230                            | 1650                            | 30                              | 30                              |
| 1559         | Bambako      | 1,164,744       | 3,998,775       | 51.5                          | 44.2                          | 720                             | 1610                            | 70                              | 40                              |
| 2198         | Ibadan       | 1,711,206       | 3,148,963       | 94.3                          | 70.7                          | 1770                            | 1590                            | 110                             | 60                              |
| 3493         | Călărași     | 612             | 1,752,380       | 22.8                          | 18.6                          | 0                               | 1590                            | 110                             | 90                              |
| 3412         | Minsk        | 1,733,061       | 2,024,313       | 18.9                          | 14.4                          | 1850                            | 1570                            | 110                             | 80                              |
| 639          | Chicago      | 6,950,901       | 6,970,911       | 12.8                          | 9.8                           | 2280                            | 1530                            | 40                              | 30                              |
| 9984         | Brahmanbaria | 1,396,050       | 1,835,433       | 49.6                          | 65.2                          | 830                             | 1520                            | 60                              | 90                              |
| 7932         | Kochi        | 2,104,919       | 2,263,203       | 36.8                          | 37.9                          | 1220                            | 1510                            | 60                              | 70                              |
| GHS - SMOD ID | City      | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|--------------|-----------|----------------|----------------|-------------------------------|-------------------------------|-----------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 12270        | Zhuhai    | 1,370,351      | 2,011,250      | 31.4                          | 25.2                          | 990                               | 1500                              | 80                             | 80                             |
| 1805         | Ouagadougou | 814,453        | 2,960,026      | 60.4                          | 46.6                          | 610                               | 1500                              | 80                             | 60                             |
| 10046        | Noakhali  | 1,288,145      | 1,809,924      | 44.9                          | 65.3                          | 720                               | 1500                              | 60                             | 90                             |
| 564          | Medellin  | 2,198,583      | 3,717,910      | 57.1                          | 35.3                          | 970                               | 1490                              | 50                             | 40                             |
| 12312        | Tegal     | 1,614,445      | 1,834,915      | 44.1                          | 36.3                          | 1060                              | 1440                              | 70                             | 80                             |
| 3228         | Warsaw    | 1,788,720      | 1,854,761      | 32.5                          | 23.5                          | 1840                              | 1440                              | 110                           | 80                             |
| 4355         | Beirut    | 1,349,821      | 4,211,130      | 9.8                           | 14.2                          | 250                               | 1440                              | 20                             | 40                             |
| 4436         | Aleppo    | 1,674,576      | 2,681,719      | 15.5                          | 20.9                          | 410                               | 1400                              | 30                             | 60                             |
| 2971         | Yaounde   | 1,278,413      | 3,786,664      | 54.6                          | 37.4                          | 770                               | 1400                              | 60                             | 40                             |
| 6237         | Peshawar  | 1,426,041      | 2,360,014      | 54.5                          | 46.2                          | 1080                              | 1400                              | 80                             | 60                             |
| 3203         | Budapest  | 1,654,183      | 1,782,695      | 28.1                          | 17.7                          | 2110                              | 1390                              | 130                           | 80                             |
| 8070         | Coimbatore| 1,281,039      | 1,744,587      | 39.4                          | 47.9                          | 780                               | 1340                              | 70                             | 80                             |
| 6288         | Hyderabad | 1,169,887      | 1,816,918      | 71.7                          | 76.6                          | 1010                              | 1340                              | 90                             | 80                             |
| 2990         | Naples    | 3,212,540      | 3,264,426      | 19.3                          | 15.4                          | 1780                              | 1340                              | 60                             | 50                             |
| 6510         | Gujranwala| 1,565,212      | 2,370,752      | 44.5                          | 42.6                          | 1060                              | 1340                              | 70                             | 60                             |
| 3763         | Alexandria| 4,064,791      | 5,588,195      | 12.3                          | 11.6                          | 980                               | 1330                              | 30                             | 30                             |
| 5728         | Riyadh    | 1,116,899      | 2,753,116      | 33.8                          | 49.1                          | 430                               | 1270                              | 40                             | 50                             |
| 2860         | Berlin    | 3,219,359      | 3,123,881      | 21.9                          | 14.5                          | 2120                              | 1260                              | 70                             | 40                             |
| 3821         | Ankara    | 2,233,464      | 2,911,243      | 21.3                          | 21.4                          | 760                               | 1250                              | 40                             | 50                             |
| 2028         | Lomé      | 1,033,367      | 2,463,090      | 78.5                          | 57.8                          | 650                               | 1240                              | 70                             | 50                             |
| 3539         | Izmir     | 2,738,463      | 2,765,802      | 19.8                          | 22.5                          | 860                               | 1230                              | 40                             | 50                             |
| 5555         | Baku      | 1,453,258      | 1,934,533      | 22.6                          | 19.3                          | 990                               | 1230                              | 70                             | 70                             |
| 2285         | Dortmund  | 3,635,796      | 3,338,652      | 20.3                          | 13.2                          | 2290                              | 1230                              | 70                             | 40                             |
| 1458         | Dakar     | 1,987,928      | 3,430,653      | 40.0                          | 35.0                          | 810                               | 1230                              | 50                             | 40                             |
| 3552         | Mbuji-Mayi| 1,653,276      | 3,790,074      | 45.9                          | 33.0                          | 1000                              | 1230                              | 60                             | 40                             |
| 7769         | Kozhikode | 1,421,542      | 1,956,910      | 28.8                          | 33.9                          | 690                               | 1220                              | 50                             | 70                             |
| 4356         | Khartoum  | 1,600,862      | 2,563,482      | 38.5                          | 38.8                          | 1000                              | 1180                              | 70                             | 50                             |
| GHS - SMOD ID | City     | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|--------------|----------|----------------|----------------|---------------------------------|---------------------------------|---------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 2059         | Barcelona| 3,358,001      | 4,415,666      | 19.5                            | 12.7                            | 1680                            | 1170                              | 50                             | 30                             |
| 1708         | Madrid   | 3,962,449      | 5,634,881      | 15.0                            | 9.9                             | 1440                            | 1120                              | 40                             | 20                             |
| 5664         | Sana'a   | 1,402,873      | 2,442,012      | 30.6                            | 36.5                            | 600                             | 1100                              | 50                             | 50                             |
| 12745        | Taichung | 1,995,124      | 2,330,203      | 27.5                            | 21.7                            | 860                             | 1070                              | 50                             | 50                             |
| 12760        | Denpasar | 1,030,492      | 2,040,455      | 16.1                            | 20.9                            | 310                             | 1040                              | 30                             | 60                             |
| 3601         | Bursa    | 917,282        | 1,862,701      | 29.3                            | 29.5                            | 400                             | 1030                              | 50                             | 60                             |
| 12730        | Busan    | 3,703,049      | 3,446,669      | 24.6                            | 19.3                            | 1320                            | 1030                              | 40                             | 30                             |
| 12761        | Kaohsiung| 2,396,291      | 2,455,455      | 19.5                            | 19.5                            | 770                             | 1030                              | 40                             | 50                             |
| 11983        | Haikou   | 1,015,029      | 1,831,530      | 19.5                            | 18.6                            | 480                             | 1020                              | 50                             | 60                             |
| 2907         | Rome     | 2,298,478      | 2,447,408      | 19.5                            | 15.4                            | 1280                            | 1000                              | 60                             | 50                             |
| 12703        | Daegu    | 2,420,397      | 2,414,291      | 32.0                            | 28.4                            | 1060                            | 1000                              | 50                             | 50                             |
| 13097        | Sydney   | 3,410,018      | 3,411,233      | 7.7                             | 17.2                            | 390                             | 990                               | 20                             | 30                             |
| 880          | Toronto  | 4,724,416      | 6,352,870      | 11.3                            | 8.7                             | 1130                            | 970                               | 30                             | 20                             |
| 1581         | Casablanca| 3,165,275    | 4,112,750      | 14.1                            | 10.1                            | 890                             | 970                               | 30                             | 30                             |
| 316          | Houston  | 3,644,988      | 5,543,890      | 13.7                            | 8.4                             | 1320                            | 960                               | 40                             | 20                             |
| 324          | Dallas   | 4,003,770      | 5,850,071      | 13.4                            | 8.1                             | 1450                            | 950                               | 40                             | 20                             |
| 11536        | Phnom Penh| 1,117,463    | 2,266,074      | 15.5                            | 20.1                            | 340                             | 940                               | 30                             | 50                             |
| 1507         | Conakry  | 1,113,732      | 2,044,581      | 31.3                            | 31.7                            | 710                             | 900                               | 70                             | 50                             |
| 2859         | Douala   | 832,441        | 2,207,491      | 53.7                            | 41.3                            | 500                             | 870                               | 60                             | 40                             |
| 12793        | Fukuoka  | 2,111,578      | 2,223,591      | 19.1                            | 16.8                            | 790                             | 850                               | 40                             | 40                             |
| 3037         | Vienna   | 1,571,688      | 1,922,492      | 25.7                            | 18.8                            | 1130                            | 820                               | 80                             | 50                             |
| 821          | Santo Domingo| 2,523,184  | 4,296,570      | 11.6                            | 10.0                            | 320                             | 820                               | 20                             | 20                             |
| 2103         | Algiers  | 2,723,204      | 4,441,856      | 13.5                            | 11.8                            | 560                             | 800                               | 20                             | 20                             |
| 12788        | Sapporo  | 1,896,151      | 1,896,978      | 17.6                            | 17.4                            | 630                             | 770                               | 40                             | 50                             |
| 775          | Detroit  | 3,652,565      | 3,334,928      | 13.2                            | 10.6                            | 1320                            | 770                               | 40                             | 30                             |
| 1011         | Manaus   | 1,363,639      | 2,188,749      | 15.3                            | 19.5                            | 340                             | 760                               | 30                             | 40                             |
| 12916        | Makassar | 1,413,119      | 2,059,564      | 11.3                            | 14.2                            | 280                             | 740                               | 20                             | 40                             |
| GHS - SMOD ID | City             | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|---------------|------------------|-----------------|-----------------|-------------------------------|-------------------------------|-----------------------------------|-----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 514           | Cali             | 1,404,525       | 2,404,449       | 31.5                          | 24.0                          | 440                               | 730                               | 40                             | 30                             |
| 289           | Guatemala City   | 2,088,080       | 2,603,382       | 32.8                          | 22.3                          | 830                               | 720                               | 40                             | 30                             |
| 903           | Philadelphia     | 3,206,357       | 3,361,490       | 15.7                          | 9.6                           | 1370                              | 720                               | 50                             | 30                             |
| 2775          | Tunis            | 1,606,951       | 2,179,736       | 17.6                          | 14.9                          | 500                               | 700                               | 40                             | 40                             |
| 178           | Puebla           | 1,825,856       | 2,442,704       | 35.6                          | 17.7                          | 590                               | 690                               | 40                             | 30                             |
| 1786          | Manchester       | 1,979,881       | 2,342,405       | 18.5                          | 12.3                          | 1260                              | 690                               | 70                             | 30                             |
| 200           | Monterrey        | 3,344,551       | 4,679,962       | 16.3                          | 9.7                           | 590                               | 670                               | 20                             | 20                             |
| 5865          | Manama           | 592,112         | 1,990,111       | 36.1                          | 32.9                          | 230                               | 670                               | 40                             | 40                             |
| 5945          | Dubai            | 605,806         | 2,006,292       | 38.6                          | 38.6                          | 160                               | 660                               | 30                             | 40                             |
| 860           | Washington D.C.  | 3,022,325       | 3,710,751       | 14.9                          | 8.5                           | 1190                              | 660                               | 40                             | 20                             |
| 2131          | Rotterdam [The Hague] | 1,818,723 | 1,996,792       | 21.6                          | 14.1                          | 1090                              | 650                               | 60                             | 40                             |
| 3880          | Durban           | 2,515,492       | 3,089,246       | 12.6                          | 13.0                          | 600                               | 640                               | 30                             | 30                             |
| 4427          | Amman            | 2,181,336       | 3,182,397       | 15.9                          | 22.8                          | 390                               | 640                               | 20                             | 20                             |
| 5155          | Addis Ababa      | 2,354,778       | 3,537,184       | 16.2                          | 22.6                          | 570                               | 630                               | 30                             | 20                             |
| 88            | Guadalajara      | 3,670,750       | 4,934,126       | 18.5                          | 9.0                           | 730                               | 630                               | 20                             | 20                             |
| 5894          | Doha             | 291,618         | 4,018,396       | 47.5                          | 45.4                          | 90                                | 610                               | 40                             | 20                             |
| 1806          | Birmingham       | 2,226,863       | 2,548,110       | 17.8                          | 10.7                          | 1340                              | 580                               | 60                             | 30                             |
| 4328          | Tel Aviv         | 1,870,101       | 2,272,641       | 18.2                          | 19.4                          | 460                               | 560                               | 30                             | 30                             |
| 4302          | Gaza             | 1,124,683       | 2,094,018       | 19.4                          | 20.4                          | 380                               | 530                               | 40                             | 30                             |
| 13034         | Cebu City        | 1,633,175       | 3,039,172       | 7.9                           | 9.9                           | 140                               | 530                               | 10                             | 20                             |
| 5734          | Kuwait City      | 1,182,456       | 2,324,975       | 32.2                          | 28.4                          | 320                               | 520                               | 30                             | 30                             |
| 1351          | Belo Horizonte   | 3,452,180       | 4,140,356       | 7.7                           | 8.5                           | 320                               | 520                               | 10                             | 20                             |
| 724           | Maracaibo        | 1,261,496       | 1,951,178       | 12.4                          | 13.9                          | 190                               | 520                               | 20                             | 30                             |
| 4446          | Kampala          | 1,722,189       | 3,571,255       | 17.1                          | 18.1                          | 340                               | 520                               | 20                             | 20                             |
| 1022          | Montreal         | 2,757,446       | 3,167,709       | 13.1                          | 9.1                           | 820                               | 510                               | 30                             | 20                             |
| 1170          | Belem            | 1,703,704       | 2,152,337       | 14.6                          | 13.9                          | 390                               | 500                               | 30                             | 30                             |
| 79            | Phoenix          | 2,692,126       | 4,108,806       | 15.1                          | 7.0                           | 1150                              | 500                               | 50                             | 20                             |
| GHS - SMOD ID | City            | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|---------------|-----------------|-----------------|-----------------|-------------------------------|-------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| 1451          | Recife          | 2,963,020       | 3,498,015       | 8.9                           | 9.1                           | 370                             | 490                             | 20                              | 20                              |
| 559           | Miami           | 4,728,666       | 5,773,275       | 10.5                          | 6.1                           | 1210                            | 490                             | 30                              | 10                              |
| 862           | Caracas         | 2,059,521       | 2,601,447       | 8.2                           | 10.0                          | 170                             | 490                             | 10                              | 20                              |
| 429           | Guayaquil       | 1,445,979       | 2,315,848       | 15.6                          | 17.0                          | 220                             | 480                             | 20                              | 30                              |
| 3768          | Lubumbashi      | 513,572         | 2,550,889       | 16.9                          | 17.6                          | 130                             | 480                             | 30                              | 20                              |
| 1247          | Curitiba        | 1,981,378       | 2,444,911       | 12.5                          | 11.5                          | 380                             | 460                             | 20                              | 20                              |
| 5244          | Dar es Salaam   | 2,089,211       | 6,048,191       | 9.0                           | 8.6                           | 210                             | 440                             | 10                              | 10                              |
| 10            | San José        | 4,425,021       | 4,834,100       | 7.09                          | 6.2                           | #VALUE!                         | 430                             | 20                              | 10                              |
| 629           | Barranquilla    | 1,341,310       | 2,336,402       | 17.3                          | 14.5                          | 250                             | 420                             | 20                              | 20                              |
| 13076         | Melbourne       | 3,196,247       | 3,197,688       | 6.8                           | 9.2                           | 280                             | 420                             | 10                              | 20                              |
| 468           | Quito           | 1,386,528       | 2,247,631       | 12.1                          | 15.7                          | 160                             | 410                             | 20                              | 20                              |
| 1602          | Rabat           | 1,495,956       | 1,859,830       | 12.2                          | 8.8                           | 350                             | 360                             | 30                              | 20                              |
| 3278          | Cape Town       | 2,447,336       | 3,988,034       | 7.6                           | 7.2                           | 290                             | 350                             | 20                              | 10                              |
| 21            | Tijuana         | 3,709,053       | 4,767,831       | 10.3                          | 6.8                           | 370                             | 350                             | 10                              | 10                              |
| 562           | Atlanta         | 1,466,247       | 1,941,784       | 15.7                          | 8.7                           | 630                             | 350                             | 50                              | 20                              |
| 74            | Las Vegas       | 1,241,425       | 2,411,854       | 12.8                          | 7.6                           | 410                             | 350                             | 40                              | 20                              |
| 557           | Minneapolis [Saint Paul] | 1,726,850 | 1,864,549 | 9.8                           | 8.4                           | 420                             | 320                             | 30                              | 20                              |
| 1223          | Porto Alegre    | 1,649,337       | 1,781,768       | 9.4                           | 9.7                           | 220                             | 270                             | 20                              | 20                              |
| 1079          | Asuncion        | 1,508,097       | 2,126,506       | 8.5                           | 9.8                           | 120                             | 270                             | 10                              | 20                              |
| 4830          | Nairobi         | 2,352,871       | 4,686,412       | 7.7                           | 8.0                           | 120                             | 270                             | 10                              | 10                              |
| 101           | Portland        | 1,404,772       | 1,846,375       | 10.3                          | 7.5                           | 360                             | 260                             | 30                              | 20                              |
| 211           | San Luis        | 2,751           | 1,835,916       | 15.1                          | 9.2                           | 0                               | 250                             | 20                              | 20                              |
| 4238          | Maputo          | 1,474,180       | 2,511,931       | 12.0                          | 9.5                           | 210                             | 250                             | 20                              | 10                              |
| 273           | Denver          | 1,863,532       | 2,439,154       | 9.6                           | 6.3                           | 450                             | 230                             | 30                              | 10                              |
| 1412          | Fortaleza       | 2,523,215       | 3,346,731       | 5.7                           | 6.4                           | 110                             | 220                             | 10                              | 10                              |
| 3810          | Lusaka          | 905,770         | 2,467,122       | 10.9                          | 9.8                           | 120                             | 220                             | 20                              | 10                              |
| 1182          | Goiania         | 1,359,353       | 2,041,394       | 5.5                           | 7.8                           | 50                              | 210                             | 10                              | 20                              |
| GHS-SMOD ID | City          | Population 2000 | Population 2019 | PM$_{2.5}$ concentrations 2000 | PM$_{2.5}$ concentrations 2019 | PM$_{2.5}$-attributable cases 2000 | PM$_{2.5}$-attributable cases 2019 | PM$_{2.5}$-attributable mortality per 100,000 2000 | PM$_{2.5}$-attributable mortality per 100,000 2019 |
|------------|---------------|-----------------|-----------------|-------------------------------|-------------------------------|----------------------------------|----------------------------------|-----------------------------------------------|-----------------------------------------------|
| 1027       | Boston        | 2,040,081       | 2,171,649       | 9.1                           | 6.5                           | 450                              | 210                              | 30                             | 10                             |
| 1557       | Lisbon        | 1,952,970       | 2,063,921       | 10.6                          | 6.1                           | 610                              | 200                              | 40                             | 10                             |
| 746        | Port-au-Prince| 1,900,017       | 3,592,216       | 6.6                           | 5.6                           | 170                              | 180                              | 10                             | 10                             |
| 187        | Vancouver     | 1,533,493       | 2,149,829       | 10.5                          | 6.3                           | 320                              | 170                              | 30                             | 10                             |
| 139        | Seattle       | 2,353,327       | 2,954,384       | 7.3                           | 5.3                           | 340                              | 160                              | 20                             | 10                             |
| 502        | Vancouver     | 1,754,241       | 2,189,432       | 13.4                          | 5.8                           | 630                              | 150                              | 40                             | 10                             |
| 1426       | Salvador      | 2,536,163       | 3,104,612       | 6.0                           | 5.4                           | 130                              | 120                              | 10                             | 10                             |
| 394        | San José      | 1,556,377       | 1,801,305       | 6.9                           | 7.5                           | 60                               | 110                              | 10                             | 10                             |
| 143        | Ciudad Juarez | 1,618,459       | 1,823,764       | 11.7                          | 6.1                           | 190                              | 100                              | 20                             | 10                             |
| 5823       | Antananarivo  | 967,299         | 2,339,538       | 4.5                           | 5.4                           | 20                               | 70                               | 10                             | 10                             |
| 474        | Havana        | 1,934,652       | 1,746,637       | 7.3                           | 4.6                           | 240                              | 70                               | 20                             | 10                             |
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