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## Supplemental Material

# Disparities in Air Pollution Exposure in the United States by Race/Ethnicity and Income, 1990–2010

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Minor differences arise from rounding in tables.

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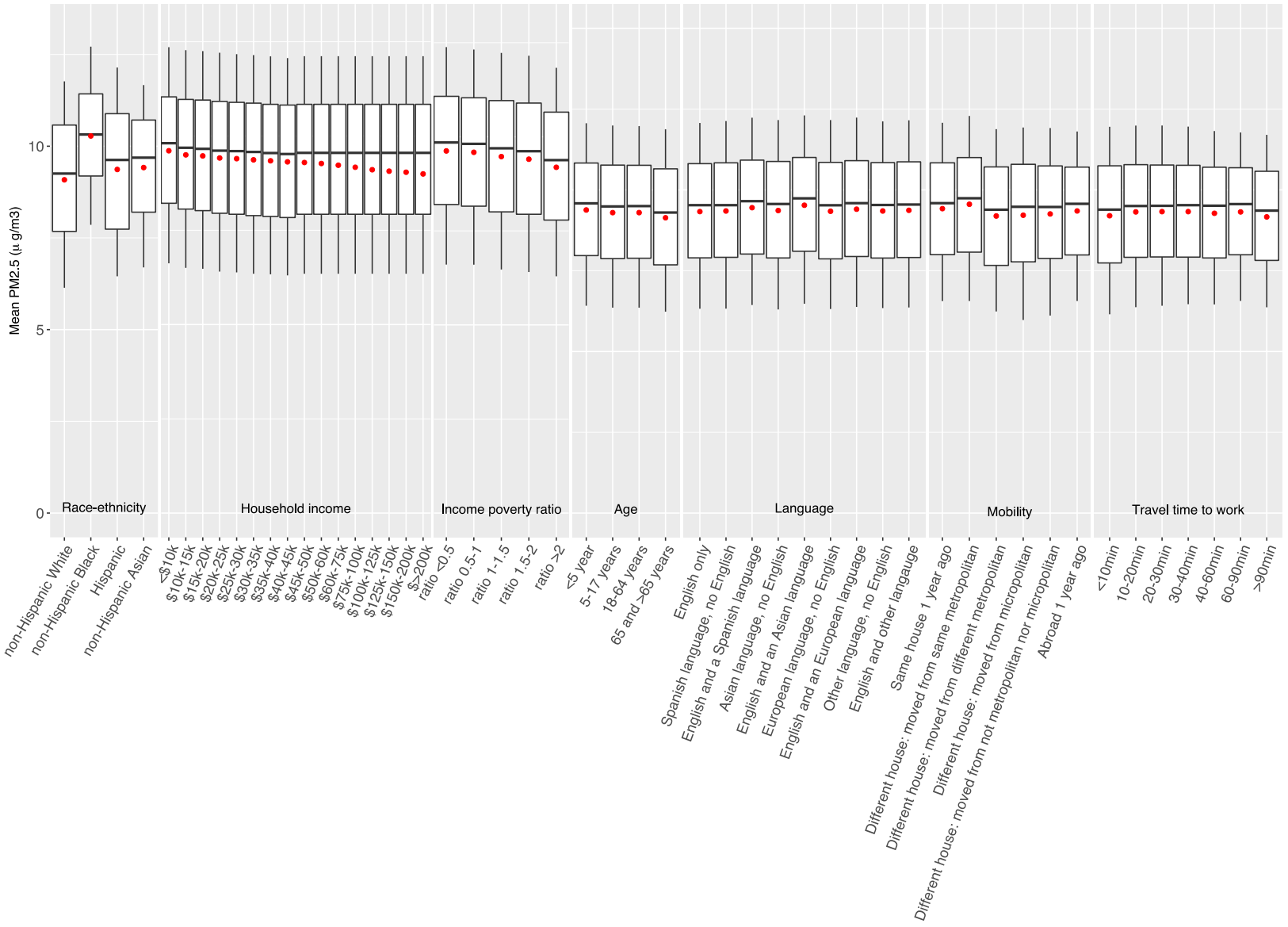


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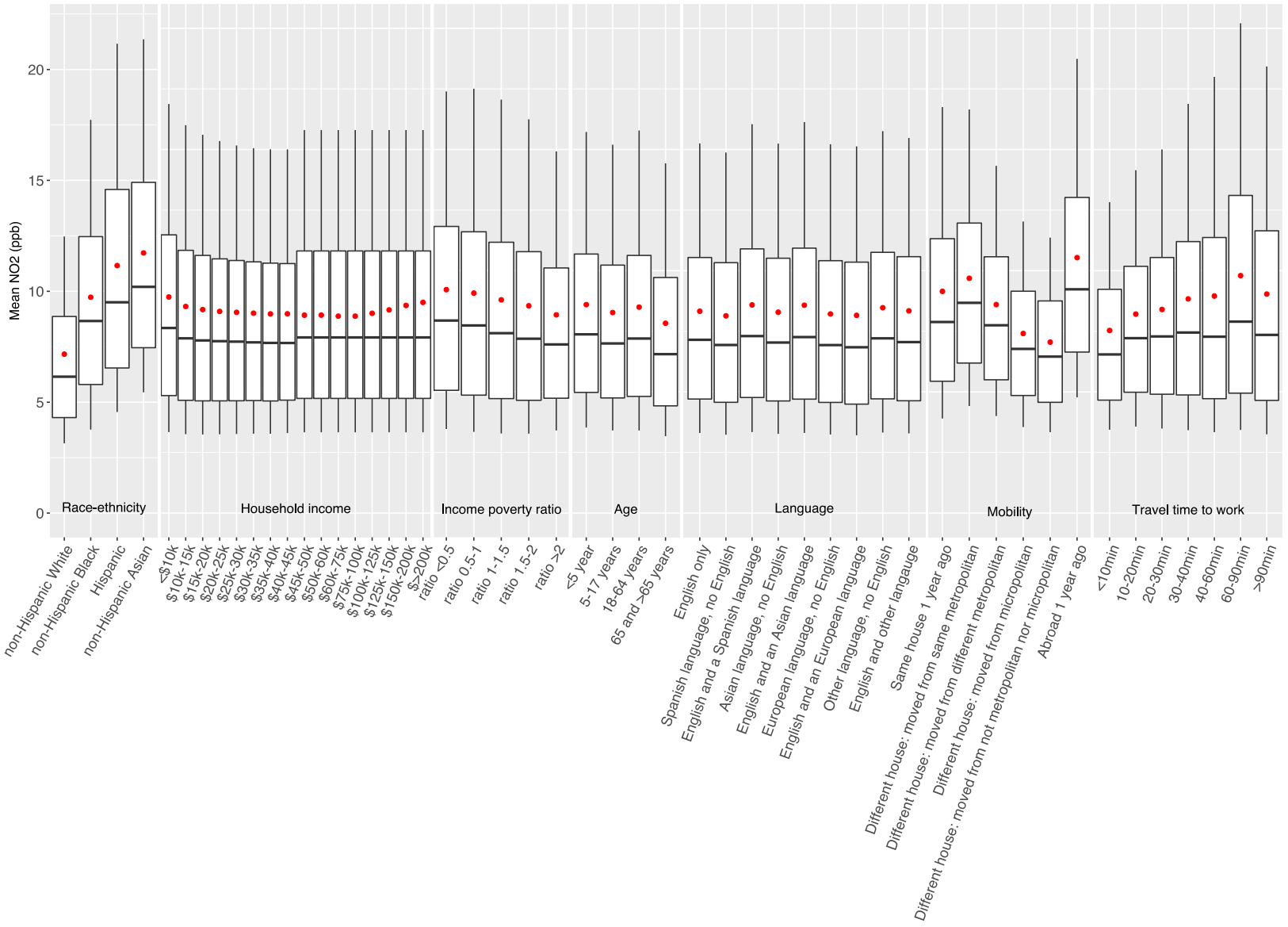


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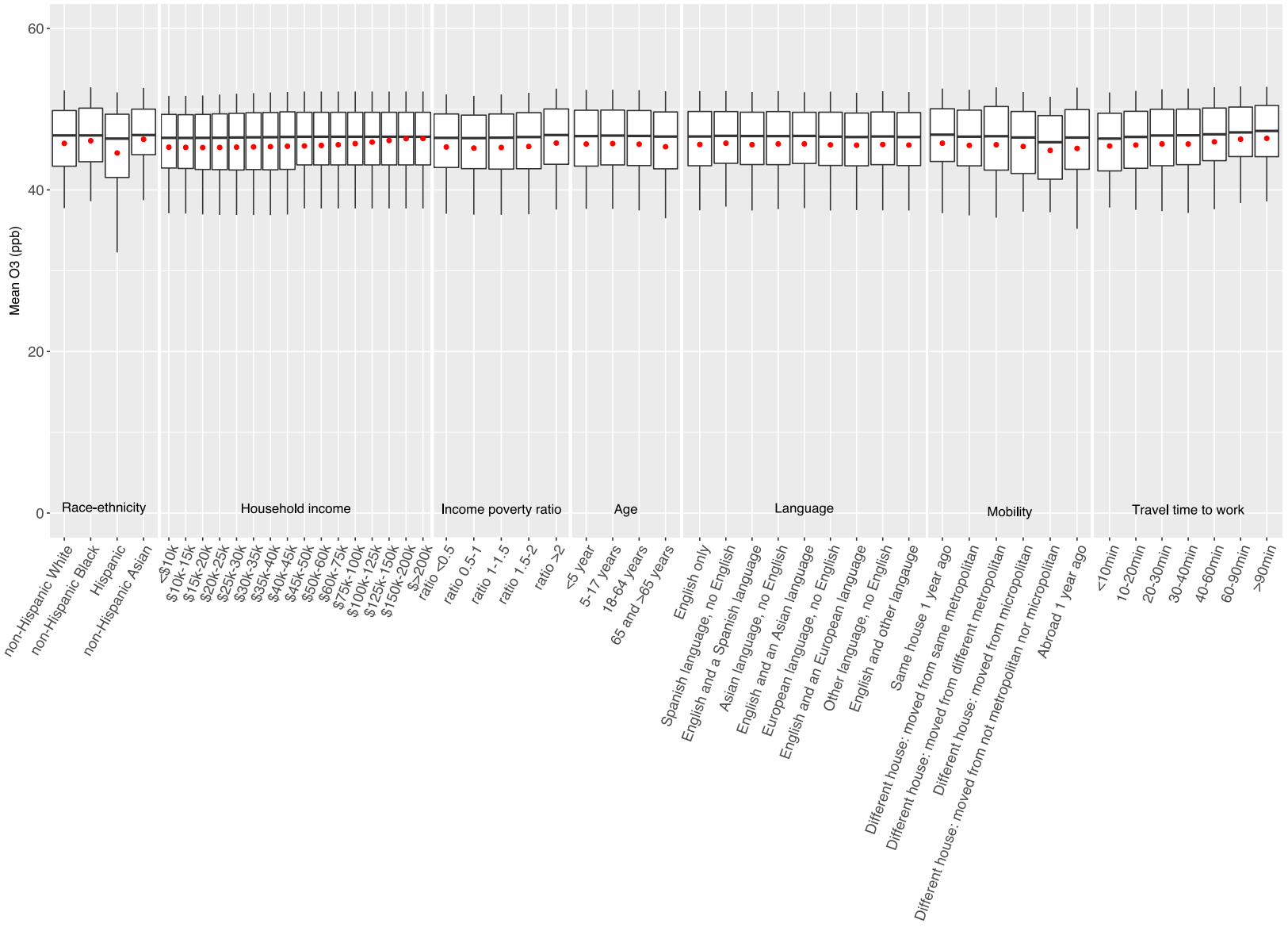


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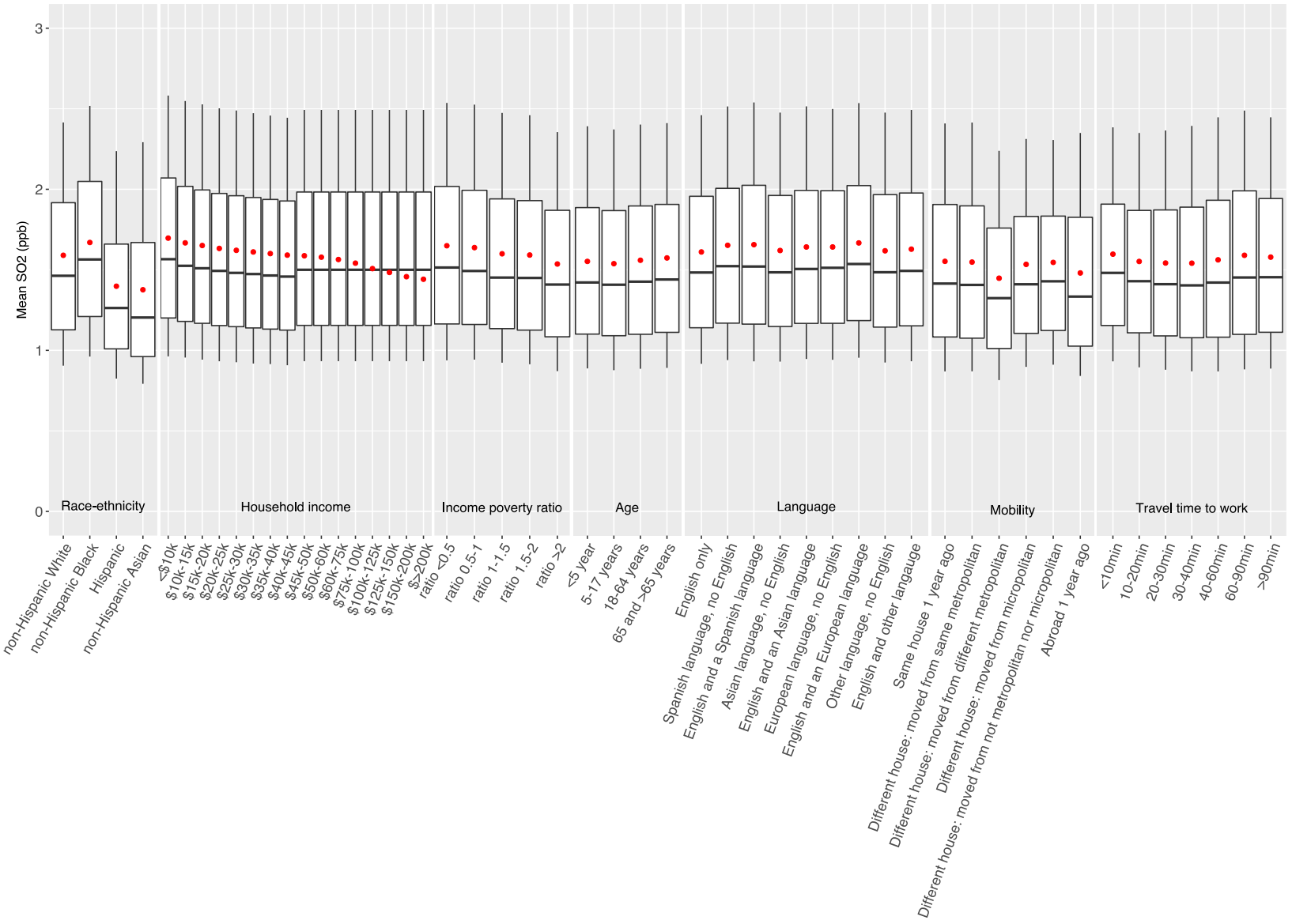


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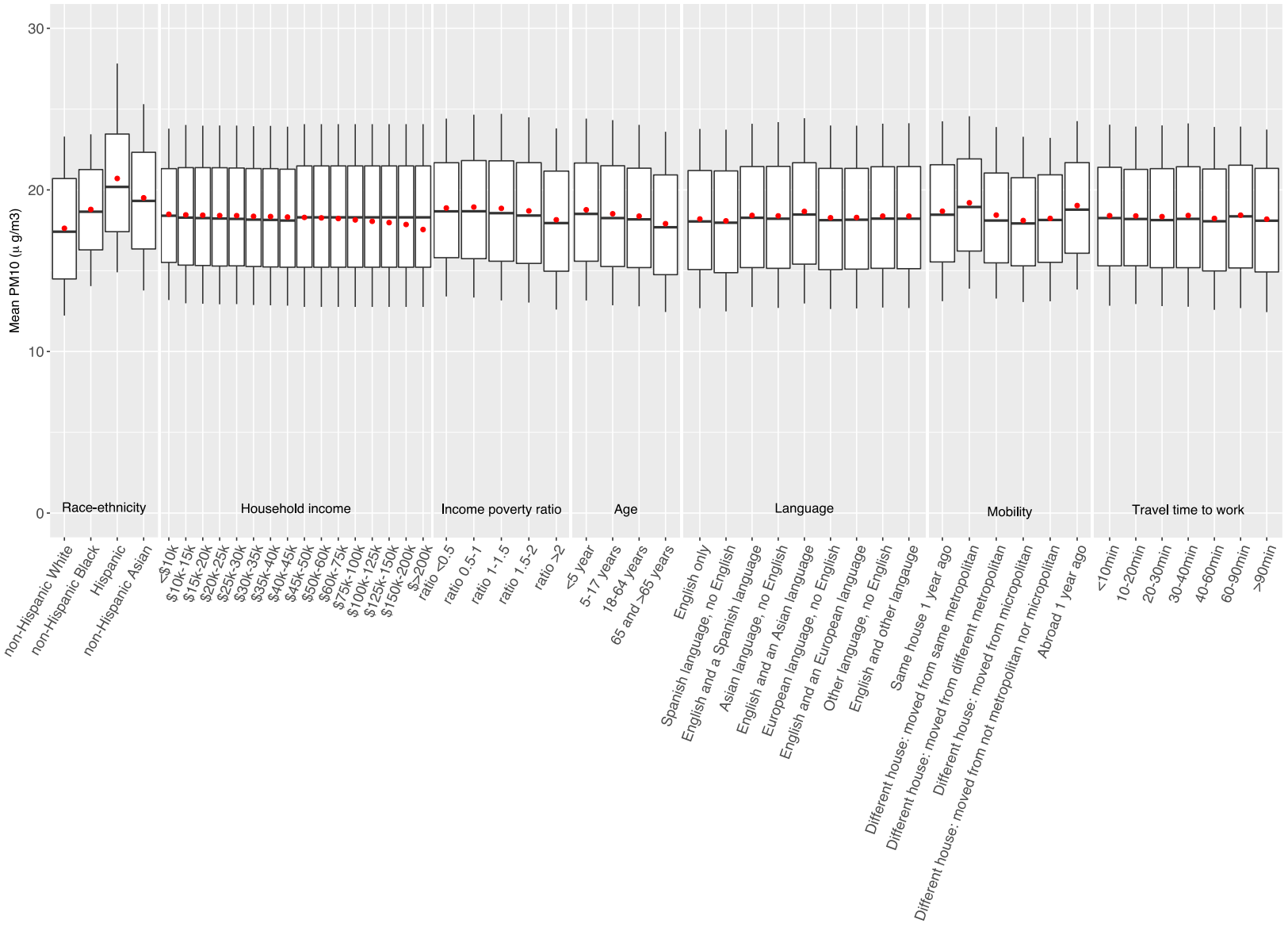


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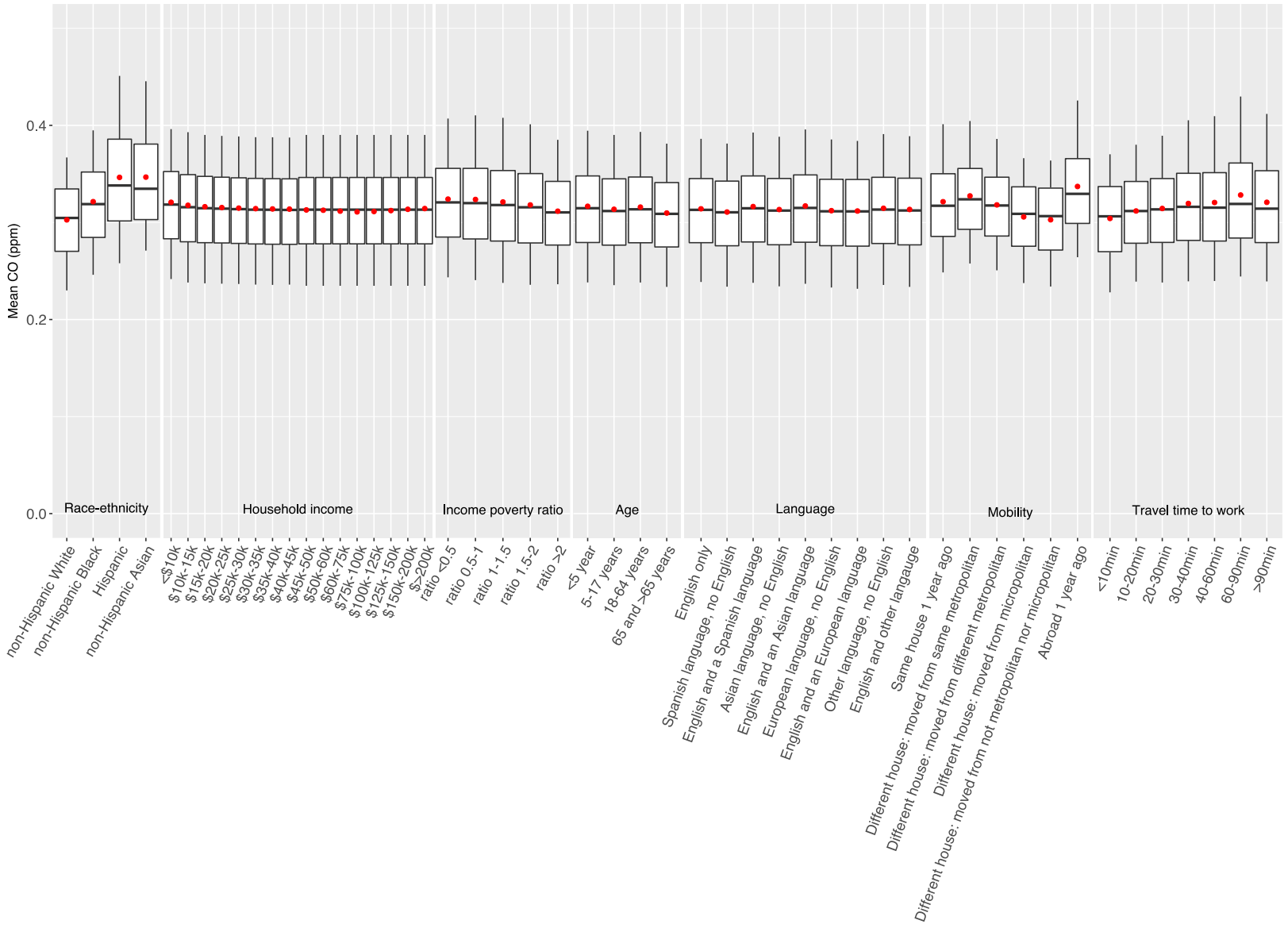
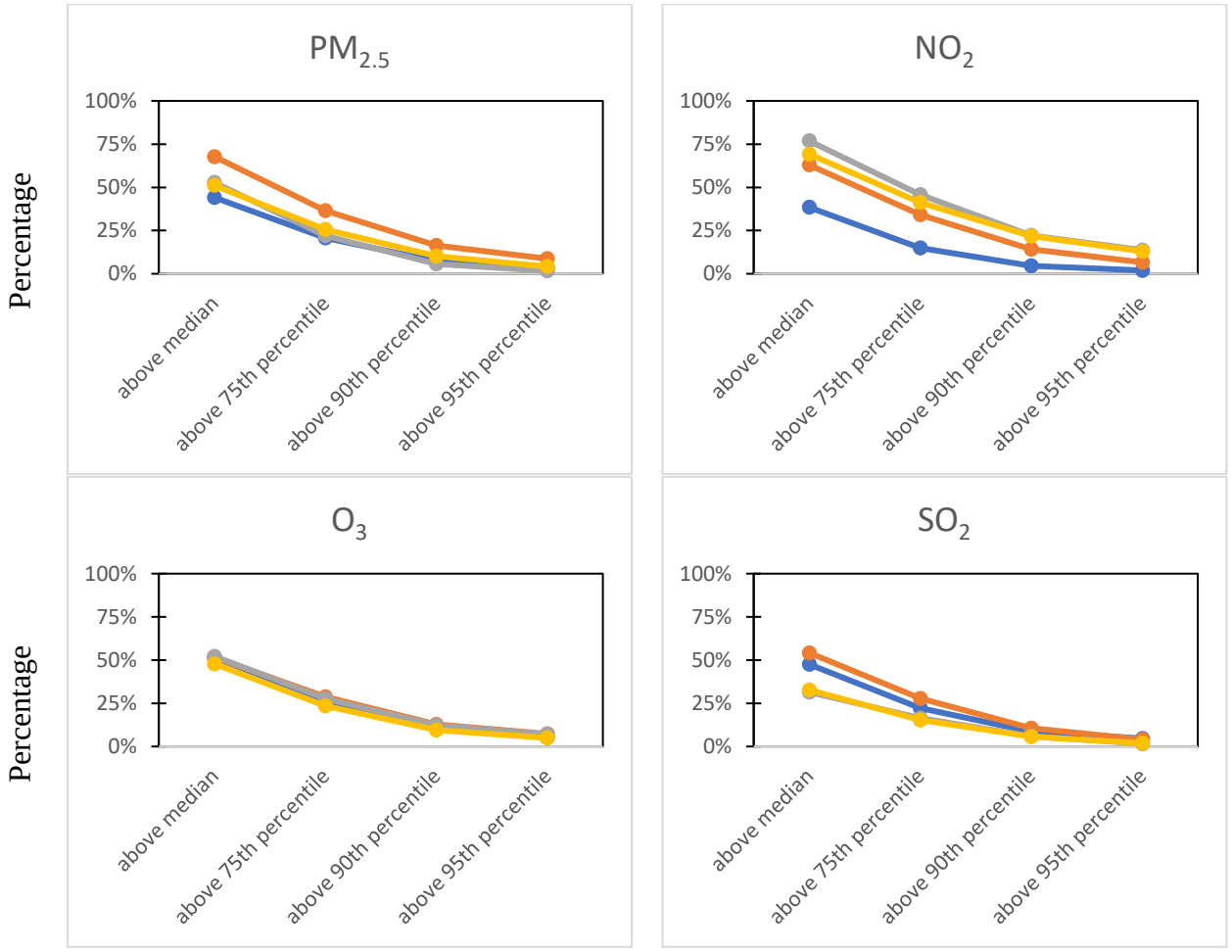
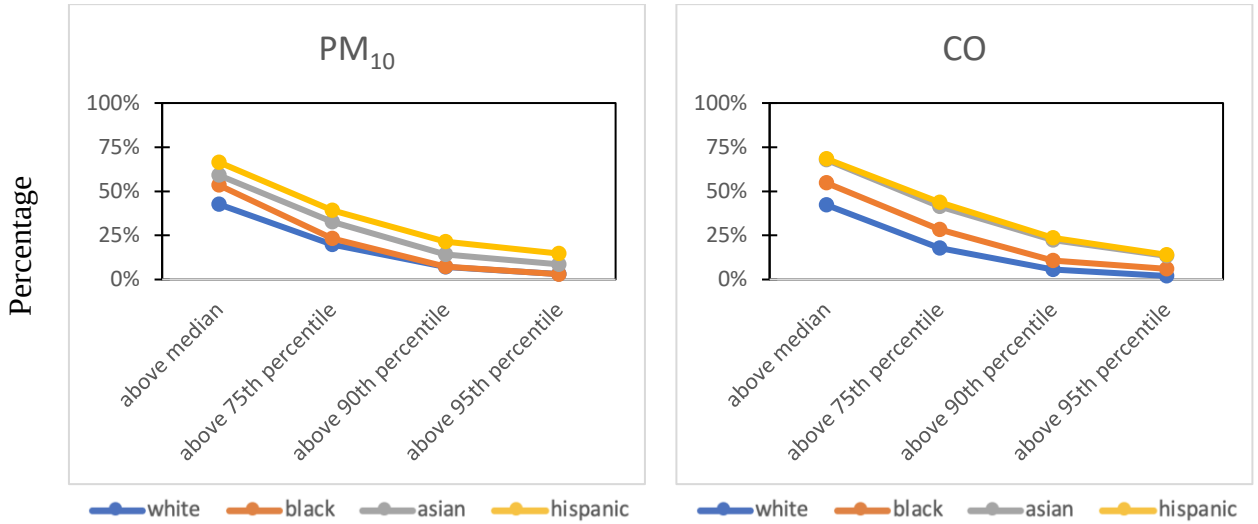

Mean CO (ppm)
0.4
0.2
0.0
Race-ethnicity
Household income
Income poverty ratio
Age
Language
Mobility
Travel time to work
non-Hispanic White
non-Hispanic Black
Hispanic
non-Hispanic Asian
<$10k
$10k-15k
$15k-20k
$20k-25k
$25k-30k
$30k-35k
$35k-40k
$40k-45k
$45k-50k
$50k-60k
$60k-75k
$75k-100k
$100k-125k
$125k-150k
$150k-200k
>$200k
ratio <0.5
ratio 0.5-1
ratio 1-1.5
ratio 1.5-2
ratio >2
<5 year
5-17 years
18-64 years
65 and >65 years
English only
Spanish language, no English
English and a Spanish language
Asian language, no English
English and an Asian language
European language, no English
English and an European language
Other language, no English
English and other langauge
Same house 1 year ago
Different house: moved from same metropolitan
Different house: moved from different metropolitan
Different house: moved from micropolitan
Different house: moved from not metropolitan nor micropolitan
Abroad 1 year ago
<10min
10-20min
20-30min
30-40min
40-60min
60-90min
>90min

**Fig. S1. Population weighted exposure distribution in year-2010 for seven demographic attributes: race-ethnicity, household income, income poverty ratio, age, language, mobility, and travel time to work.** For each boxplot, the lowest bound is the $10^{th}$ percentile value; the box ranges from $25^{th}$ to $75^{th}$ percentile and the middle line in the box is the median value; the highest bound is the $90^{th}$ percentile value. The red point in each boxplot is the population-weighted average for the group. Race-ethnicity includes four groups: non-Hispanic white, non-Hispanic black, Hispanic, and non-Hispanic Asian. Household annual income had 16 categories (in U.S. dollars: <10k, 10k-15k, 15k-20k, 20k-25k, 25k-30k, 30k-35k, 35k-40k, 40k-45k, 45k-50k, 50k-60k, 60k-75k, 75k-100k, 100k-125k, 125k-150k, 150k-200k, >200k). Ratio of income to poverty level were analyzed at five ranges: smaller than 0.5; 0.5-1; 1-1.5; 1.5-2; larger than 2. Age has 4 categories: younger than 5 years old; 5-17 years old; 18-65 years old; older than 65. Language data are by household language for 14-year and over. Total of 9 different household languages were analyzed: English only; Spanish and no 14+ speaks English only or "very well"; Spanish and at least one 14+ speaks English only or "very well"; Other Indo-European language and no 14+ speaks English only or "very well"; Other Indo-European language and at least one 14+ speaks English only or "very well". Asian and Pacific Island language and no 14+ speaks English only or "very well"; Asian and Pacific Island language and at least one 14+ speaks English only or "very well". Other language and no 14+ speaks English only or "very well"; Other language and at least one 14+ speaks English only or "very well". Mobility contained the geographical mobility in the past year for people who currently reside in a Metropolitan Statistical Areas (MSA) data of six different status: same house as 1 year ago; different house but the same MSA; different house and different MSA; different house and moved from micropolitan statistical areas; different house and not moved from MSA or micropolitan statistical areas; abroad 1 year ago. Travel time covers workers 16 year and over in 7 levels: less than 10 minutes; 10-20 minutes; 20-30 minutes; 30-40 minutes; 40-60 minutes; 60-90 minutes; more than 90 minutes; people who work at home are excluded.


Percentage
$PM_{2.5}$
$NO_2$
$O_3$
$SO_2$
100%
75%
50%
25%
0%
above median
above 75th percentile
above 90th percentile
above 95th percentile

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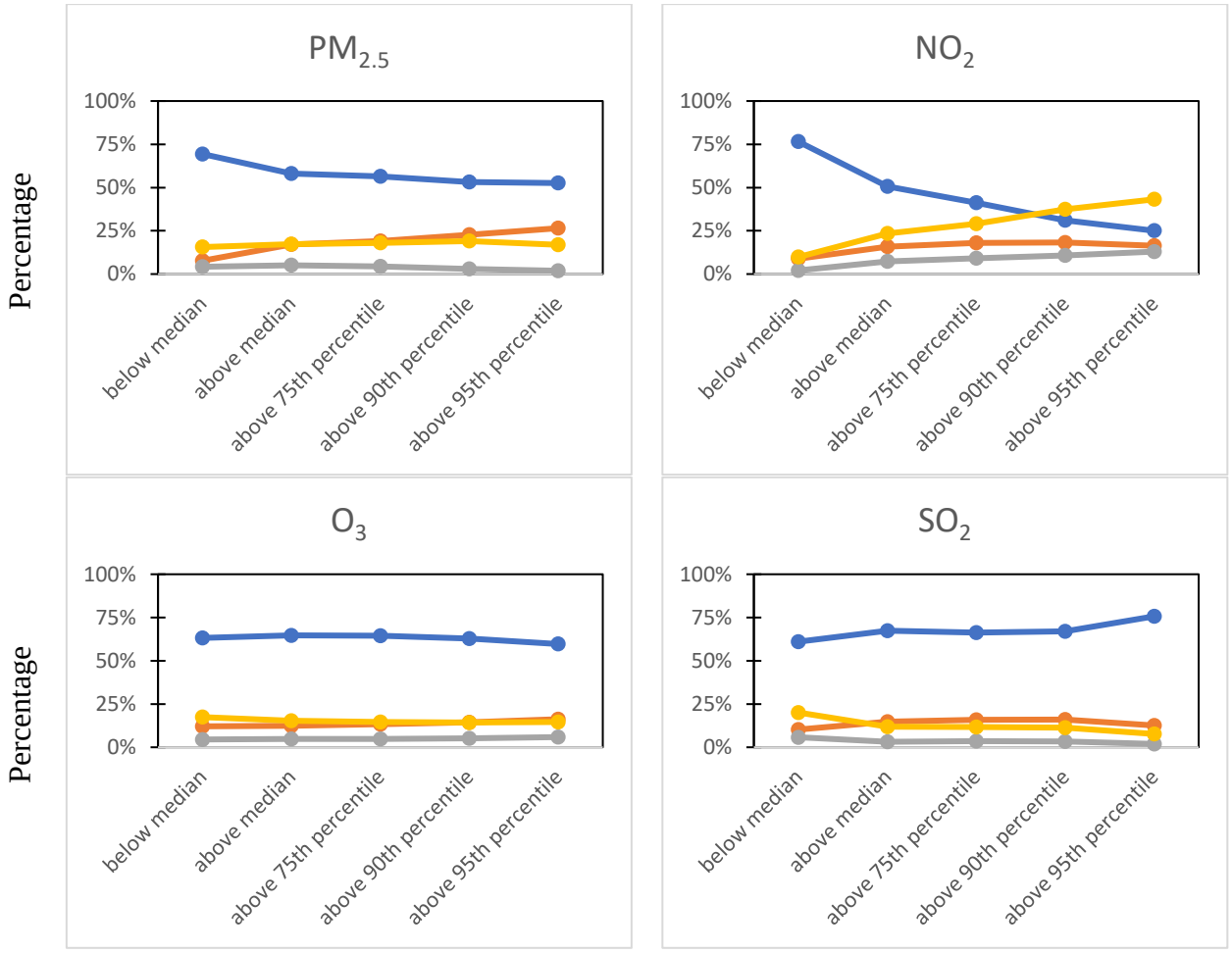
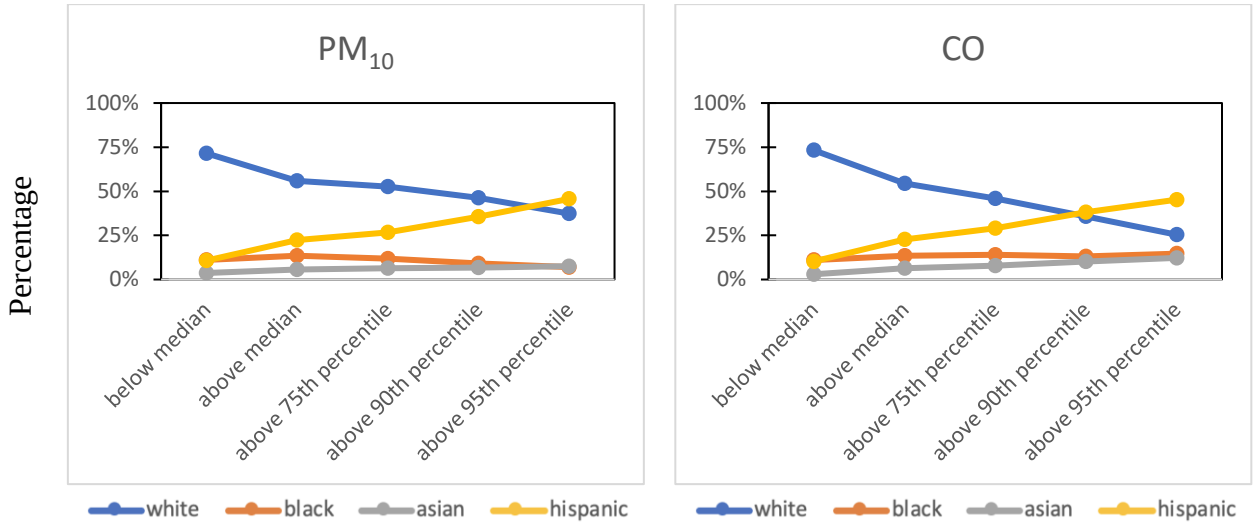

Percentage
$PM_{2.5}$
$NO_2$
$O_3$
$SO_2$
100%
75%
50%
25%
0%
below median
above median
above 75th percentile
above 90th percentile
above 95th percentile

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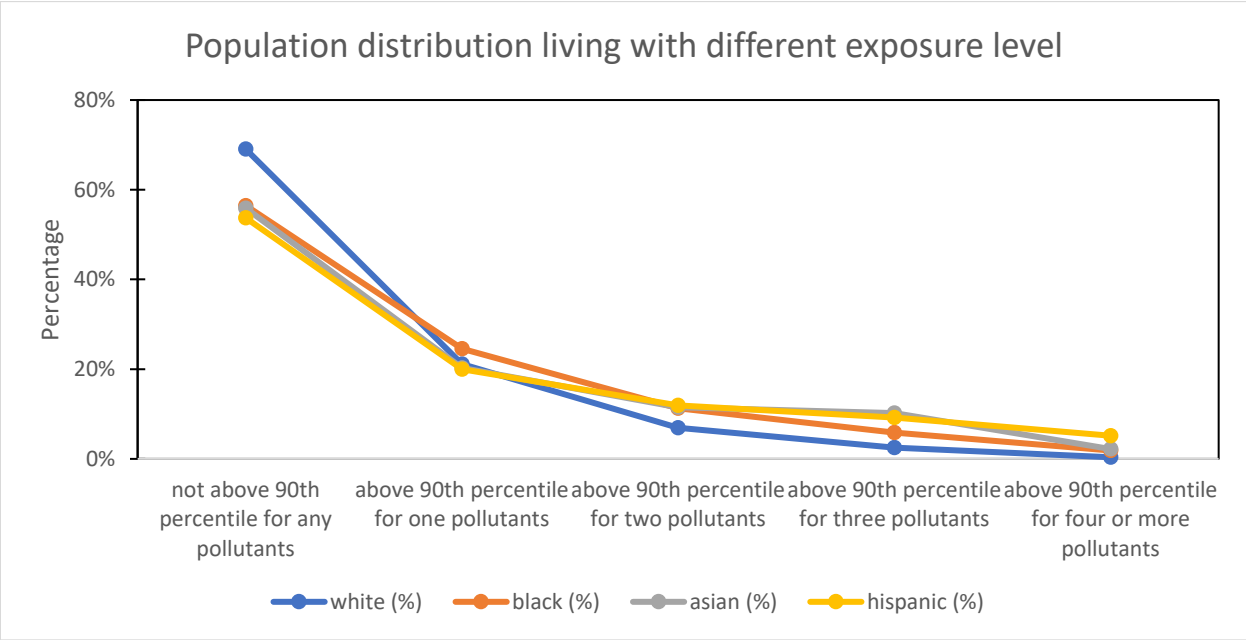


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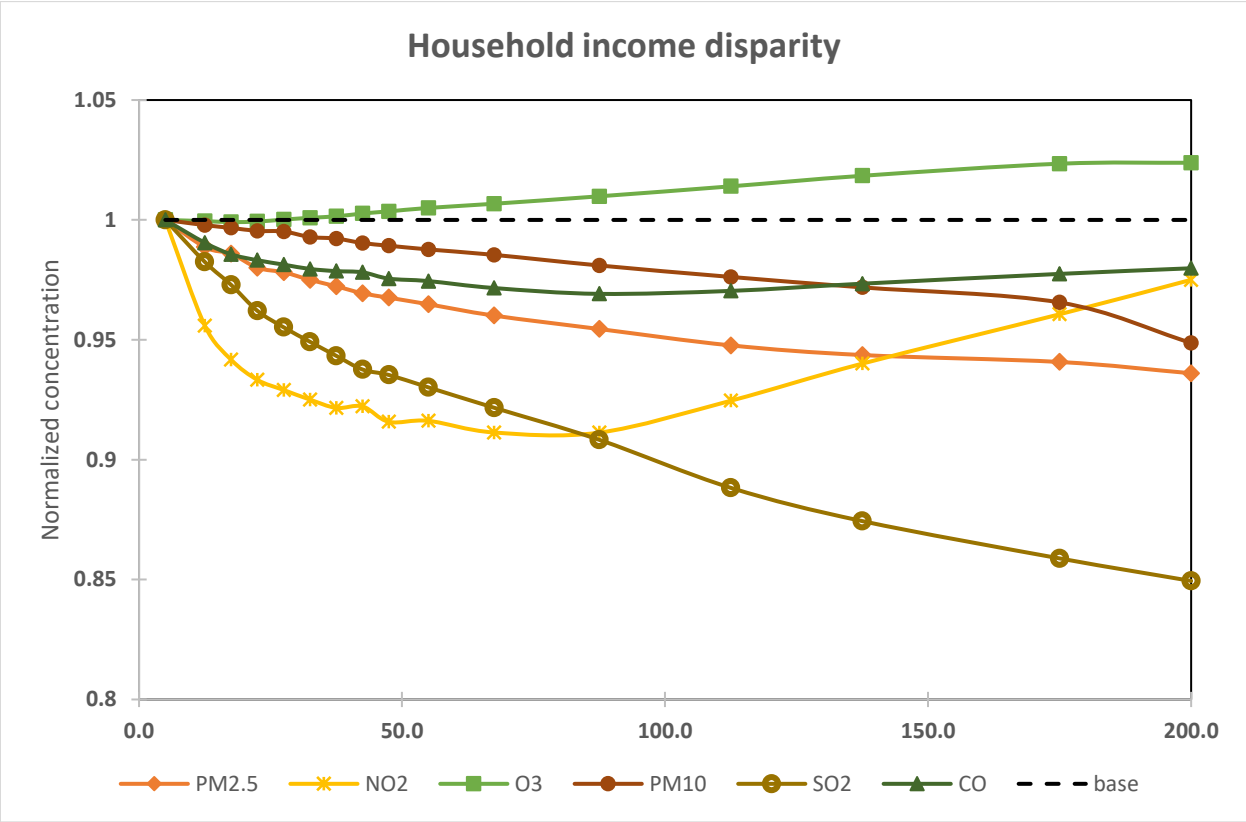


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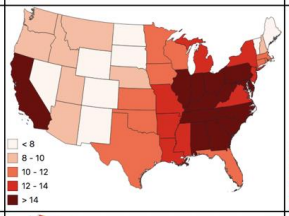
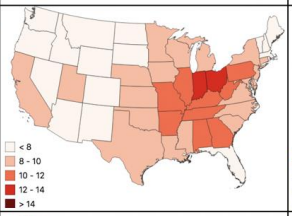
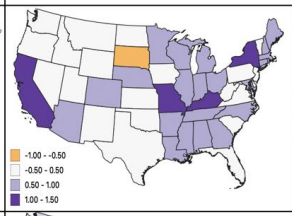
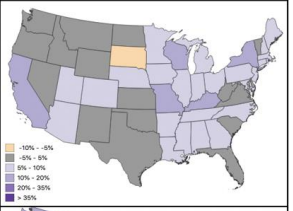
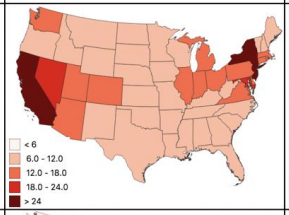
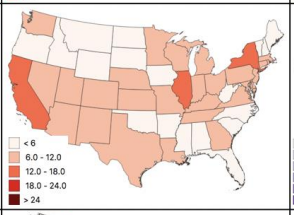
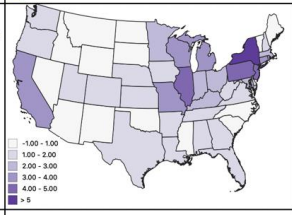
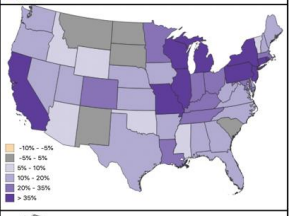
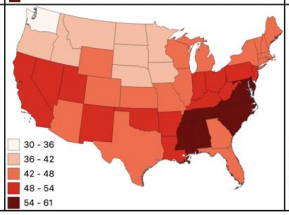
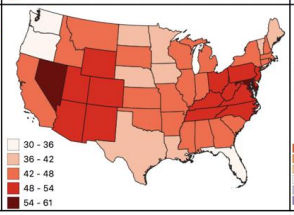
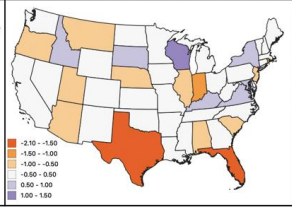
| | 1990 state-level exposure (2000 for $PM_{2.5}$) | 2010 state-level exposure | 2010 Absolute disparity (minority – white) | 2010 Relative disparity % (minority – white)/average |
|---|---|---|---|---|
| $PM_{2.5}$ (ug/m3) |  |  |  |  |
| $NO_2$ (ppb) |  |  |  |  |
| $O_3$ (ppb) |  |  |  |  |

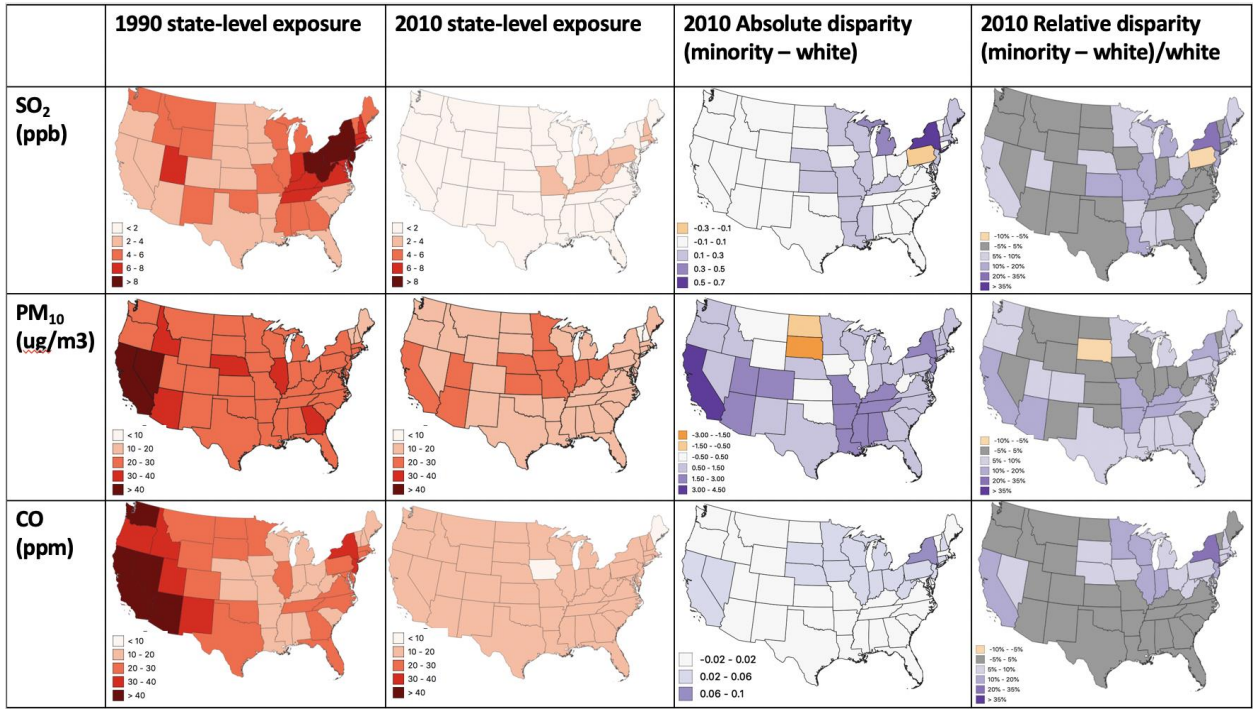
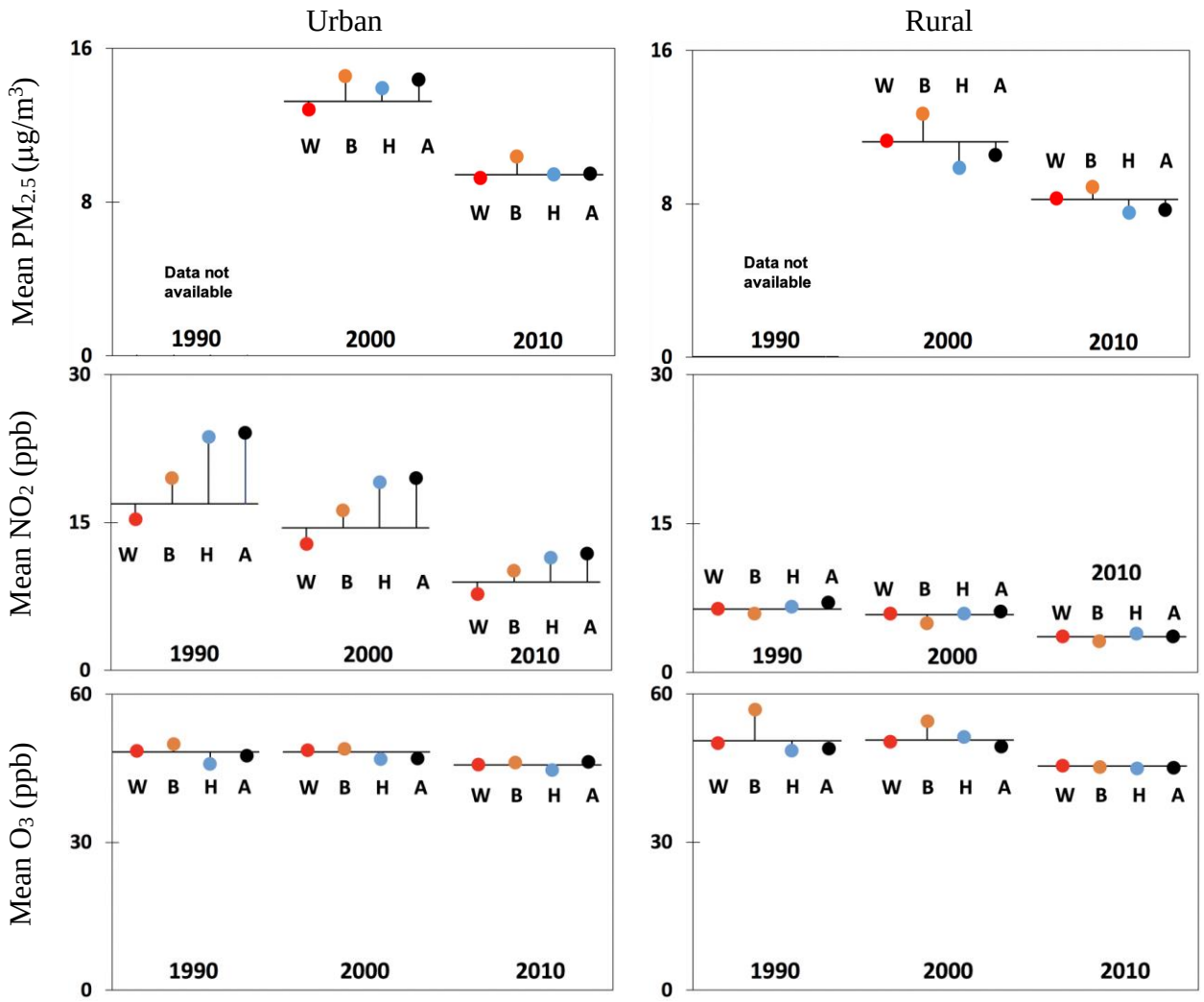



**Fig. S6.** State-level exposure for 1990 and 2010 and absolute/relative disparity between racial-ethnic minorities and non-Hispanic White in 2010. Population-weighted average exposure for all six studied pollutants are calculated for year 1990 and 2010.


Urban
Rural
Mean PM2.5 (µg/m3)
Mean NO2 (ppb)
Mean O3 (ppb)
Data not available
Data not available
1990
2000
2010
W B H A

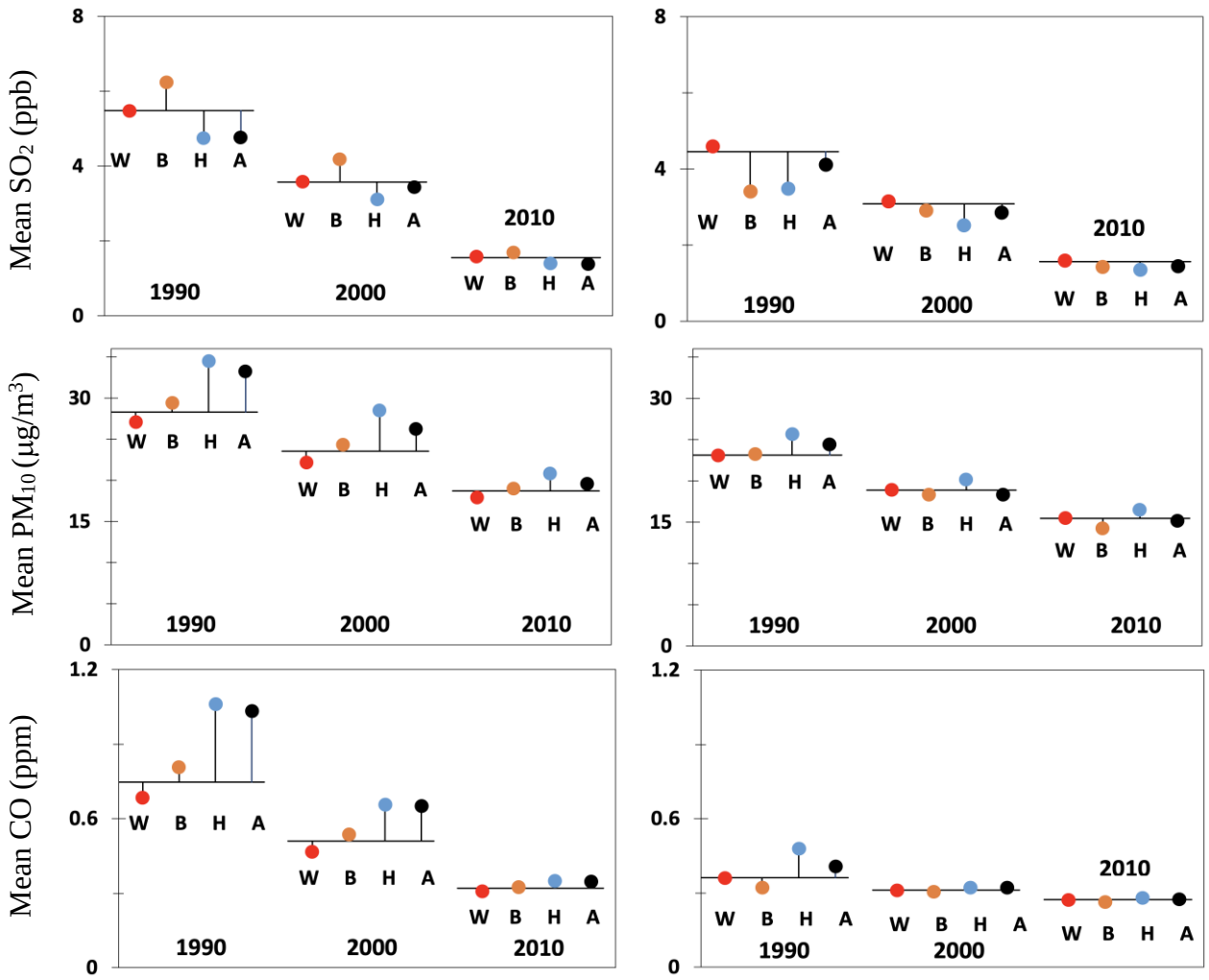



**Fig. S7.** Estimated annual average criteria air pollution concentrations for the four largest race-ethnicity groups (non-Hispanic whites, non-Hispanic blacks, Hispanics of any race(s), and non-Hispanic Asians) for urban and rural populations in years 1990, 2000, and 2010. Horizontal lines indicate the estimated population-weighted mean concentration for each year for the total population (all race-ethnicity groups) and circles indicate the population-weighted mean concentration for each year for each of the four largest race-ethnicity groups.

**Table S1. CACES empirical regression models performance for six criteria pollutants from 1990 to 2010.**

| Pollutant | Year | # of observations | Cross-validated R2 | Root Mean Squared Error (RMSE) [a] | Mean Error (ME) [b] | Mean Bias (MB) (%) [c] |
|---|---|---|---|---|---|---|
| $PM_{2.5}$ (μg $m^{-3}$) | 1990 | 0 | NA | NA | NA | NA |
| $PM_{2.5}$ (μg $m^{-3}$) | 2000 | 950 | 0.85 | 1.59 | -0.05 | 2.1 |
| $PM_{2.5}$ (μg $m^{-3}$) | 2010 | 934 | 0.85 | 1.17 | -0.02 | 2.3 |
| $NO_2$ (ppb) | 1990 | 266 | 0.89 | 3.53 | -0.09 | 5.0 |
| $NO_2$ (ppb) | 2000 | 345 | 0.88 | 2.90 | -0.06 | 5.0 |
| $NO_2$ (ppb) | 2010 | 327 | 0.84 | 2.20 | -0.09 | 8.1 |
| $O_3$ (ppb) | 1990 | 492 | 0.62 | 4.80 | -0.04 | 1.0 |
| $O_3$ (ppb) | 2000 | 768 | 0.78 | 3.46 | -0.04 | 0.5 |
| $O_3$ (ppb) | 2010 | 850 | 0.82 | 2.89 | 0.00 | 0.5 |
| $PM_{10}$ (μg $m^{-3}$) | 1990 | 946 | 0.62 | 6.22 | -0.31 | 3.0 |
| $PM_{10}$ (μg $m^{-3}$) | 2000 | 1021 | 0.61 | 6.45 | -0.26 | 5.5 |
| $PM_{10}$ (μg $m^{-3}$) | 2010 | 829 | 0.56 | 5.50 | -0.26 | 6.2 |
| $SO_2$ (ppb) | 1990 | 619 | 0.66 | 2.80 | -0.17 | 13.2 |
| $SO_2$ (ppb) | 2000 | 496 | 0.63 | 1.76 | -0.14 | 14.0 |
| $SO_2$ (ppb) | 2010 | 370 | 0.32 | 1.36 | -0.13 | 22.2 |
| CO (ppm) | 1990 | 277 | 0.57 | 0.31 | -0.02 | 6.3 |
| CO (ppm) | 2000 | 293 | 0.52 | 0.19 | -0.01 | 5.9 |
| CO (ppm) | 2010 | 218 | 0.34 | 0.08 | 0.00 | 3.3 |

[a] $\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(c_m - c_o)^2}$

[b] $\text{ME} = \frac{1}{n}\sum_{i=1}^{n}(c_m - c_o)$

[c] $\text{MB} = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{c_m - c_o}{c_o}\right) \times 100\%$

where $c_m$ is the modeled average level for census block group *i*, $c_o$ is the observed average level for EPA monitors within census block group *i*, and *n* is the number of census block groups with monitors

This paper is adopted from Kim et al. (2020)

**Table S2. Population-weighted exposure distribution for six criteria pollutants for four main racial-ethnic groups [a] from 1990 to 2010.**

| **$PM_{2.5}$** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W 2010 | NH-B | H | NH-A |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $10^{th}$ percentile | NA | NA [b] | NA | NA | NA | 8.9 | 8.5 | 11 | 8.7 | 10 | 6.3 | 6.1 | 7.9 | 6.5 | 6.7 |
| $25^{th}$ percentile | NA | NA | NA | NA | NA | 11 | 11 | 13 | 11 | 12 | 7.9 | 7.7 | 9.2 | 7.7 | 8.2 |
| $50^{th}$ percentile | NA | NA | NA | NA | NA | 13 | 13 | 15 | 13 | 14 | 9.5 | 9.3 | 10 | 9.6 | 9.7 |
| Mean | NA | NA | NA | NA | NA | 13 | 13 | 14 | 14 | 14 | 9.3 | 9.1 | 10 | 9.4 | 9.4 |
| $75^{th}$ percentile | NA | NA | NA | NA | NA | 15 | 15 | 16 | 16 | 16 | 11 | 11 | 11 | 11 | 11 |
| $90^{th}$ percentile | NA | NA | NA | NA | NA | 17 | 16 | 17 | 21 | 20 | 12 | 12 | 13 | 12 | 12 |
| **$NO_2$** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W | NH-B | H | NH-A |
| $10^{th}$ percentile | 6.3 | 6.1 | 6.8 | 8.5 | 11.4 | 5.8 | 5.5 | 5.9 | 7.6 | 10 | 3.4 | 3.1 | 3.8 | 4.6 | 5.4 |
| $25^{th}$ percentile | 8.8 | 8.3 | 11.2 | 13.1 | 15.6 | 8.0 | 7.4 | 9.9 | 11 | 13 | 4.9 | 4.3 | 5.8 | 6.6 | 7.5 |
| $50^{th}$ percentile | 13 | 12 | 17 | 19 | 21 | 12 | 11 | 14 | 16 | 17 | 7.4 | 6.2 | 8.7 | 9.5 | 10 |
| Mean | 16 | 14 | 19 | 23 | 24 | 13 | 12 | 16 | 19 | 19 | 8.4 | 7.2 | 9.7 | 11 | 12 |
| $75^{th}$ percentile | 20 | 18 | 24 | 35 | 32 | 17 | 15 | 20 | 25 | 25 | 11 | 8.9 | 12 | 15 | 15 |
| $90^{th}$ percentile | 28 | 24 | 35 | 44 | 42 | 24 | 19 | 27 | 34 | 33 | 16 | 12.5 | 18 | 21 | 21 |
| **$O_3$** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W | NH-B | H | NH-A |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10th percentile | 40 | 40 | 43 | 39 | 41 | 40 | 41 | 41 | 37 | 40 | 38 | 38 | 39 | 33 | 39 |
| 25th percentile | 45 | 45 | 46 | 43 | 45 | 44 | 44 | 44 | 42 | 43 | 43 | 43 | 43 | 42 | 44 |
| 50th percentile | 49 | 49 | 50 | 46 | 48 | 49 | 49 | 50 | 48 | 48 | 47 | 47 | 47 | 46 | 47 |
| Mean | 49 | 49 | 50 | 46 | 48 | 49 | 49 | 49 | 47 | 47 | 46 | 46 | 46 | 45 | 46 |
| 75th percentile | 52 | 53 | 55 | 50 | 51 | 53 | 54 | 55 | 52 | 51 | 50 | 50 | 50 | 49 | 50 |
| 90th percentile | 57 | 57 | 59 | 52 | 53 | 57 | 57 | 58 | 56 | 55 | 52 | 52 | 53 | 52 | 53 |
| **$SO_2$** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W | NH-B | H | NH-A |
| 10th percentile | 2.0 | 2.1 | 2.3 | 1.7 | 1.4 | 1.8 | 1.8 | 2.0 | 1.5 | 1.5 | 0.95 | 0.91 | 1.0 | 0.83 | 0.79 |
| 25th percentile | 3.0 | 3.2 | 3.3 | 2.4 | 2.0 | 2.2 | 2.3 | 2.7 | 1.9 | 1.9 | 1.2 | 1.1 | 1.2 | 1.0 | 1.0 |
| 50th percentile | 4.7 | 4.8 | 5.4 | 3.4 | 3.5 | 3.1 | 3.1 | 3.7 | 2.4 | 2.6 | 1.5 | 1.5 | 1.6 | 1.3 | 1.2 |
| Mean | 5.4 | 5.4 | 6.1 | 4.7 | 4.8 | 3.5 | 3.5 | 4.1 | 3.1 | 3.5 | 1.6 | 1.6 | 1.7 | 1.4 | 1.4 |
| 75th percentile | 7.1 | 7.1 | 8.2 | 6.0 | 6.9 | 4.5 | 4.4 | 5.3 | 3.5 | 4.5 | 2.0 | 1.9 | 2.1 | 1.7 | 1.7 |
| 90th percentile | 9.3 | 8.9 | 11 | 10 | 9.9 | 6.1 | 5.7 | 7.0 | 6.2 | 7.0 | 2.5 | 2.4 | 2.5 | 2.2 | 2.3 |
| **$PM_{10}$** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W | NH-B | H | NH-A |
| 10th percentile | 20 | 19 | 22 | 22 | 23 | 16 | 15 | 18 | 18 | 17 | 13 | 12 | 14 | 15 | 14 |
| 25th percentile | 23 | 22 | 25 | 25 | 26 | 19 | 18 | 20 | 22 | 21 | 15 | 14 | 16 | 17 | 16 |
| 50th percentile | 26 | 25 | 28 | 31 | 30 | 22 | 21 | 23 | 25 | 24 | 18 | 17 | 19 | 20 | 19 |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 28 | 27 | 29 | 33 | 33 | 23 | 22 | 24 | 28 | 26 | 18 | 18 | 19 | 21 | 20 |
| 75th percentile | 30 | 29 | 31 | 42 | 38 | 25 | 24 | 27 | 33 | 31 | 22 | 21 | 21 | 23 | 22 |
| 90th percentile | 37 | 35 | 37 | 54 | 54 | 31 | 28 | 31 | 44 | 40 | 24 | 23 | 23 | 28 | 25 |
| **CO** | National 1990 | NH-W | NH-B | H | NH-A | National 2000 | NH-W | NH-B | H | NH-A | National 2010 | NH-W | NH-B | H | NH-A |
| 10th percentile | 0.34 | 0.33 | 0.37 | 0.53 | 0.51 | 0.29 | 0.28 | 0.32 | 0.35 | 0.38 | 0.24 | 0.23 | 0.25 | 0.26 | 0.27 |
| 25th percentile | 0.44 | 0.41 | 0.53 | 0.71 | 0.68 | 0.35 | 0.33 | 0.38 | 0.43 | 0.46 | 0.28 | 0.27 | 0.29 | 0.30 | 0.30 |
| 50th percentile | 0.62 | 0.57 | 0.70 | 0.96 | 0.99 | 0.44 | 0.41 | 0.47 | 0.56 | 0.58 | 0.31 | 0.31 | 0.32 | 0.34 | 0.34 |
| Mean | 0.70 | 0.64 | 0.78 | 1.04 | 1.03 | 0.49 | 0.44 | 0.52 | 0.65 | 0.65 | 0.31 | 0.30 | 0.32 | 0.35 | 0.35 |
| 75th percentile | 0.87 | 0.79 | 0.92 | 1.37 | 1.35 | 0.56 | 0.51 | 0.60 | 0.84 | 0.80 | 0.35 | 0.33 | 0.35 | 0.39 | 0.38 |
| 90th percentile | 1.22 | 1.08 | 1.33 | 1.70 | 1.63 | 0.77 | 0.64 | 0.84 | 1.08 | 1.04 | 0.39 | 0.37 | 0.40 | 0.45 | 0.45 |

[a] For the four racial-ethnic groups, NH-W stands for non-Hispanic White; NH-B stands for non-Hispanic Black; H stands for Hispanic of any race; NH-A stands for non-Hispanic Asian

[b] $PM_{2.5}$ didn't have data in year 1990

**Table S3. Population-weighted average exposure for six criteria pollutants for total population and four main racial-ethnic groups [a] in 2010 based on empirical model prediction.**

| Pollutants | Total population | NH-W | NH-B | H | NH-A |
|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 9.28 | 9.08 | 10.3 | 9.36 | 9.42 |
| $NO_2$ (ppb) | 8.38 | 7.17 | 9.73 | 11.2 | 11.7 |
| $O_3$ (ppb) | 45.6 | 45.7 | 46.1 | 44.6 | 46.3 |
| $SO_2$ (ppb) | 1.56 | 1.59 | 1.67 | 1.40 | 1.38 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 18.4 | 17.6 | 18.8 | 20.7 | 19.5 |
| CO (ppm) | 0.315 | 0.303 | 0.321 | 0.346 | 0.347 |

[a] For the four racial-ethnic groups, NH-W stands for non-Hispanic White; NH-B stands for non-Hispanic Black; H stands for Hispanic of any race; NH-A stands for non-Hispanic Asian

[b] $PM_{2.5}$ didn't have data in year 1990

**Table S4. Difference between exposure for the most-exposed racial-ethnic group versus the least-exposed racial-ethnic group [a] for criteria pollutants in 2010 based on empirical model prediction**

| Pollutant | The most-exposed group | The least-exposed group | Absolute Disparity [b] | Percentage Difference (%) [c] | Relative Disparity [d] |
|---|---|---|---|---|---|
| $PM_{2.5}$ | NH-B | NH-W | 1.2 μg $m^{-3}$ | 13 | 1.1 |
| $NO_2$ | NH-A | NH-W | 4.6 ppb | 54 | 1.6 |
| $O_3$ | NH-A | H | 1.6 ppb | 3.6 | 1.0 |
| $SO_2$ | NH-B | NH-A | 0.29 ppb | 19 | 1.2 |
| $PM_{10}$ | H | NH-W | 3.0 μg $m^{-3}$ | 17 | 1.2 |
| CO | NH-A | NH-W | 0.044 ppm | 14 | 1.1 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] Absolute Disparity = exposure for the most-exposed racial-ethnic group – exposure for the least-exposed racial-ethnic group

[c] Percent difference $= \frac{Population-weighted\ mean\ concentration\ for\ the\ most\ exposed\ group - the\ least\ exposed\ group}{pollutant's\ national\ mean\ based\ on\ empirical\ model\ prediction\ in\ year\ 2010} \times 100\%$

[d] Relative Disparity = exposure for the most-exposed racial-ethnic group / exposure for the least-exposed racial-ethnic group

**Table S5. Difference between exposure for the most-exposed demographic group versus the least-exposed demographic group for criteria pollutants in 2010**

| Absolute disparity [a] | Income poverty ratio | Age | Language | Mobility | Travel time to work |
|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 0.43 | 0.24 | 0.20 | 0.36 | 0.16 |
| $NO_2$ (ppb) | 1.0 | 0.77 | 0.45 | 3.5 | 2.3 |
| $O_3$ (ppb) | 0.63 | 0.39 | 0.25 | 0.90 | 0.95 |
| $SO_2$ (ppb) | 0.11 | 0.036 | 0.056 | 0.10 | 0.056 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 0.79 | 0.86 | 0.59 | 1.1 | 0.24 |
| CO (ppm) | 0.012 | 0.0069 | 0.0062 | 0.034 | 0.024 |

| Normalized disparity [b] (%) | Income poverty ratio | Age | Language | Mobility | Travel time to work |
|---|---|---|---|---|---|
| $PM_{2.5}$ | 4.7 | 2.6 | 2.1 | 3.9 | 1.8 |
| $NO_2$ | 12 | 9.2 | 5.4 | 42 | 27 |
| $O_3$ | 1.4 | 0.85 | 0.55 | 2.0 | 2.1 |
| $SO_2$ | 7.3 | 2.3 | 3.6 | 6.7 | 3.6 |
| $PM_{10}$ | 4.3 | 4.7 | 3.2 | 6.0 | 1.3 |
| CO | 4.0 | 2.2 | 2.0 | 11 | 7.7 |

[a] Absolute disparity = exposure for the most-exposed demographic group – exposure for the least-exposed demographic group

[b] Normalized disparity $= \frac{absolute\ disparity}{pollutant's\ national\ mean\ based\ on\ empirical\ model\ prediction\ in\ year\ 2010} \times 100\%$

**Table S6. Weighted Gini coefficients by racial-ethnic group and pollutant, 1990 - 2010**

| Pollutants | Total population | NH-W | NH-B | H | NH-A |
|---|---|---|---|---|---|
| **1990** | | | | | |
| $PM_{2.5}$ | NA [b] | NA | NA | NA | NA |
| $NO_2$ | 0.32 | 0.30 | 0.30 | 0.32 | 0.26 |
| $O_3$ | 0.073 | 0.074 | 0.073 | 0.075 | 0.061 |
| $SO_2$ | 0.31 | 0.30 | 0.31 | 0.31 | 0.40 |
| $PM_{10}$ | 0.15 | 0.14 | 0.12 | 0.15 | 0.17 |
| CO | 0.27 | 0.26 | 0.25 | 0.27 | 0.23 |
| **2000** | | | | | |
| $PM_{2.5}$ | 0.14 | 0.14 | 0.10 | 0.15 | 0.14 |
| $NO_2$ | 0.30 | 0.27 | 0.28 | 0.30 | 0.25 |
| $O_3$ | 0.078 | 0.076 | 0.077 | 0.078 | 0.072 |
| $SO_2$ | 0.27 | 0.25 | 0.25 | 0.27 | 0.32 |
| $PM_{10}$ | 0.16 | 0.14 | 0.13 | 0.16 | 0.17 |
| CO | 0.22 | 0.19 | 0.20 | 0.22 | 0.21 |
| **2010** | | | | | |
| $PM_{2.5}$ | 0.13 | 0.13 | 0.10 | 0.13 | 0.11 |
| $NO_2$ | 0.32 | 0.30 | 0.30 | 0.30 | 0.28 |
| $O_3$ | 0.073 | 0.071 | 0.071 | 0.086 | 0.067 |
| $SO_2$ | 0.22 | 0.22 | 0.21 | 0.21 | 0.23 |
| $PM_{10}$ | 0.14 | 0.14 | 0.11 | 0.13 | 0.13 |
| CO | 0.11 | 0.10 | 0.11 | 0.12 | 0.11 |

Table S6 shows the weighted Gini coefficients for each racial-ethnic group (and, the overall population), pollutant, and year. One coefficient is calculated for each racial-ethnic group (and, for the overall population), pollutant, and year (e.g., in the table above, for NO2 in 1990, the weighted Gini coefficient is 0.32 for the overall population and 0.30 for non-Hispanic White people). The calculation reflects the population of that group in each Census block group and the air pollution concentration for that Census block group. For a given racial-ethnic group, pollutant, and year, the weighted Gini coefficient is calculated using weighted.gini function in package acid under R version 4.0.2. The input to the weighted.gini function is the air pollution concentration and the population for the racial-ethnic group (or, the total population) for each Census block group.

Reference:

1. Acid: Analysing conditional income distributions. Weighted. Gini: Gini coefficient. https://rdrr.io/cran/acid/man/weighted.gini.html [assessed 04 Nov, 2021].

**Table S7. Between-group Atkinson Index (AI) by racial-ethnic group and pollutant, 1990 - 2010**

| | 1990 | 2000 | 2010 |
|---|---|---|---|
| $PM_{2.5}$ | NA | 1.1e-3 | 6.3e-4 |
| $NO_2$ | 0.013 | 0.013 | 0.015 |
| $O_3$ | 1.6e-4 | 8.7e-5 | 4.1e-5 |
| $SO_2$ | 1.3e-3 | 2.0e-3 | 1.3e-3 |
| $PM_{10}$ | 2.6e-3 | 3.3e-3 | 1.4e-3 |
| CO | 0.011 | 7.9e-3 | 1.2e-3 |

Table S7 shows the between-group Atkinson Index (AI) by pollutant and year. The four racial-ethnic groups are non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic Asian. One coefficient is calculated for each pollutant and year (e.g., in the table above, for NO2 in 1990, the between-group AI is 0.013). The calculation reflects the inequality of air pollution between the four racial-ethnic groups. Between-group AI is calculated using the decomAktinson function in package IC2 under R version 4.0.2, using Das and Parikh (1982) decomposition. The input to the decompAtkinson function is the air pollution concentration, the racial-ethnic group (factors that determine subgroups for between-group AI calculation), and the population for the racial-ethnic group for each Census block group.

Reference:


1. IC2: Inequality and concentration indices and curves. DecompAtkinson: Decomposition by groups for Atkinson Index. https://rdrr.io/cran/IC2/man/decompAtkinson.html [accessed 07 Feb, 2021].
2. Das T, Parikh A. 1982. Decomposition of inequality measures and a comparative analysis. Empirical Economics 7(1-2): 23-48; doi:10.1007/BF02506823.

**Table S8. Population-weighted average exposure for six criteria pollutants for total population [a] and four main racial-ethnic groups [a] in 2010 based on U.S. EPA monitoring data.**

| Pollutants | Total population | NH-W | NH-B | H | NH-A |
|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 9.03 | 8.72 | 10.5 | 9.24 | 9.27 |
| $NO_2$ (ppb) | 9.28 | 7.87 | 10.5 | 11.5 | 11.0 |
| $O_3$ (ppb) | 46.3 | 46.1 | 46.2 | 46.4 | 46.9 |
| $SO_2$ (ppb) | 2.11 | 2.30 | 1.96 | 1.69 | 1.64 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 19.2 | 17.3 | 20.8 | 23.5 | 19.3 |
| CO (ppm) | 0.809 | 0.782 | 0.793 | 0.905 | 0.828 |

[a] For the four racial-ethnic groups, NH-W stands for non-Hispanic White; NH-B stands for non-Hispanic Black; H stands for Hispanic of any race; NH-A stands for non-Hispanic Asian

[b] $PM_{2.5}$ didn't have data in year 1990

[c] CO didn't have data in year 1990

**Table S9. Difference between exposure for the most-exposed racial-ethnic group versus the least-exposed racial-ethnic groups [a] for criteria pollutants in 2010 based on U.S. EPA monitoring data**

| Pollutant | The most-exposed group | The least-exposed group | Absolute disparity [b] | Percentage difference (%) [c] | Relative disparity [d] |
|---|---|---|---|---|---|
| $PM_{2.5}$ | NH-B | NH-W | 1.8 mg m-3 | 20 | 1.2 |
| $NO_2$ | H | NH-W | 3.6 ppb | 39 | 1.5 |
| $O_3$ | NH-A | NH-W | 0.8 ppb | 1.7 | 1.0 |
| $SO_2$ | NH-W | NH-A | 0.66 ppb | 31 | 1.4 |
| $PM_{10}$ | H | NH-W | 6.2 mg m-3 | 32 | 1.4 |
| CO | H | NH-W | 0.123 ppm | 15 | 1.2 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] Absolute disparity = exposure for the most-exposed racial-ethnic group – exposure for the least-exposed racial-ethnic group

[c] Percent difference $= \frac{Population\text{-}weighted\ mean\ concentration\ for\ the\ most\ exposed\ group\ -the\ least\ exposed\ group}{pollutant's\ national\ mean\ based\ on\ empirical\ model\ prediction} \times 100\%$

[d] Relative disparity = exposure for the most-exposed racial-ethnic group / exposure for the least-exposed racial-ethnic group

**Table S10. Population-weighted mean error (ME [a]) for total population and racial-ethnic groups [b] by pollutants and by year**

| Pollutants | Year | Total ME | NH-W ME | NH-B ME | H ME | NH-A ME | Max-min [c] |
|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 1990 | NA [d] | NA | NA | NA | NA | NA |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 2000 | -0.12 | -0.08 | -0.08 | 0.01 | -0.05 | 0.09 |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 2010 | -0.09 | -0.11 | 0.04 | -0.12 | -0.06 | 0.16 |
| $NO_2$ (ppb) | 1990 | -0.11 | -0.06 | -0.19 | -0.87 | -0.1 | 0.81 |
| $NO_2$ (ppb) | 2000 | -0.22 | -0.1 | -0.44 | -0.32 | -0.12 | 0.34 |
| $NO_2$ (ppb) | 2010 | -0.18 | -0.09 | -0.41 | 0.13 | -0.07 | 0.54 |
| $O_3$ (ppb) | 1990 | -0.19 | -0.18 | 0.05 | -0.43 | -0.12 | 0.48 |
| $O_3$ (ppb) | 2000 | -0.07 | -0.11 | 0.16 | -0.24 | -0.07 | 0.4 |
| $O_3$ (ppb) | 2010 | -0.07 | -0.1 | -0.07 | -0.35 | -0.06 | 0.29 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 1990 | -0.24 | -0.1 | 0.03 | -0.45 | 0.09 | 0.54 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 2000 | -0.26 | -0.12 | -0.34 | 1.29 | 0.11 | 1.63 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 2010 | -0.38 | -0.21 | -0.66 | 0.55 | -0.14 | 1.21 |
| $SO_2$ (ppb) | 1990 | -0.15 | -0.17 | -0.09 | -0.23 | -0.16 | 0.14 |
| $SO_2$ (ppb) | 2000 | -0.12 | -0.13 | -0.06 | -0.25 | -0.14 | 0.19 |
| $SO_2$ (ppb) | 2010 | -0.08 | -0.11 | 0.06 | 0.07 | -0.08 | 0.18 |
| CO (ppm) | 1990 | -0.01 | 0 | -0.03 | 0.01 | -0.01 | 0.04 |
| CO (ppm) | 2000 | -0.01 | -0.01 | -0.02 | 0 | 0 | 0.02 |
| CO (ppm) | 2010 | 0 | 0 | 0 | 0 | 0.01 | 0.01 |
| Average [e] | 1990 | -0.14 | -0.10 | -0.05 | -0.39 | -0.06 | 0.35 |
| Average [f] | 2000 | -0.13 | -0.09 | -0.13 | 0.08 | -0.05 | 0.21 |
| Average [f] | 2010 | -0.13 | -0.10 | -0.17 | 0.05 | -0.07 | 0.22 |
| Overall | - | -0.14 | -0.10 | -0.12 | -0.07 | -0.06 | 0.42 |

[a] population-weighted ME $\frac{\sum_{i=1}^{n}(c_{im}-c_{io})p_{ik}}{\sum_{i=1}^{n}p_{ik}}$

where $c_{im}$ is the model-predicted concentration for block group *i*, $c_{io}$ is the observed concentration for block group *i*, $p_{ik}$ is the population of demographic group *k* in block group *i*

[b] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[c] Max-Min ME = max(Total ME, White ME, Black ME, Hispanic ME, Asian ME) for pollutant *i* in year *j* - min(Total ME, White ME, Black ME, Hispanic ME, Asian ME) for pollutant *i* in year *j*

[d] $PM_{2.5}$ didn't have data in 1990

[e] Average in year 1990 = $\frac{NO_2\ ME + O_3\ ME + SO_2\ ME + PM_{10}\ ME + CO\ ME}{5}$ for each demographic group

[f] Average in year 2000/2010 = $\frac{PM_{2.5}\ ME + NO_2\ ME + O_3\ ME + SO_2\ ME + PM_{10}\ ME + CO\ ME}{6}$ for each demographic group

**Table S11. Disparity between the most- and least-exposed racial-ethnic groups [a] and difference between population-weighted average error for the most- and least-exposed racial-ethnic groups by pollutants and by year**

| Pollutants | Year | Highest exposure [b] | Lowest exposure [c] | Disparity [d] | Mean error difference [e] | Ratio [f] |
|---|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 1990 | NA [g] | NA | NA | NA | NA |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 2000 | 14 (NH-B) | 13 (NH-W) | 1.9 | 0.0052 | 0.0028 |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 2010 | 10 (NH-B) | 9.1 (NH-W) | 1.2 | 0.15 | 0.13 |
| $NO_2$ (ppb) | 1990 | 24 (NH-A) | 14 (NH-W) | 9.8 | -0.81 | -0.082 |
| $NO_2$ (ppb) | 2000 | 19 (NH-A) | 12 (NH-W) | 7.5 | -0.22 | -0.029 |
| $NO_2$ (ppb) | 2010 | 12 (NH-A) | 7.2 (NH-W) | 4.6 | 0.22 | 0.048 |
| $O_3$ (ppb) | 1990 | 50 (NH-B) | 46 (H) | 4.4 | 0.17 | 0.039 |
| $O_3$ (ppb) | 2000 | 49 (NH-B) | 47 (H) | 2.3 | 0.23 | 0.098 |
| $O_3$ (ppb) | 2010 | 46 (NH-A) | 45 (H) | 1.6 | -0.28 | -0.17 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 1990 | 6.0 (NH-B) | 4.7 (H) | 1.3 | 0.0069 | 0.0052 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 2000 | 4.1 (NH-B) | 3.1 (H) | 1.0 | 0.0083 | 0.0081 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 2010 | 1.7 (NH-B) | 1.4 (NH-A) | 0.29 | -0.017 | -0.058 |
| $SO_2$ (ppb) | 1990 | 33 (NH-A) | 27 (NH-W) | 6.6 | -0.35 | -0.053 |
| $SO_2$ (ppb) | 2000 | 28 (H) | 22 (NH-W) | 6.5 | 0.23 | 0.035 |
| $SO_2$ (ppb) | 2010 | 21 (H) | 18 (NH-W) | 3.0 | 0.067 | 0.022 |
| CO (ppm) | 1990 | 1.0 (H) | 0.64 (NH-W) | 0.40 | -0.0035 | -0.0089 |
| CO (ppm) | 2000 | 0.65 (NH-A) | 0.44 (NH-W) | 0.20 | 0.0062 | 0.031 |
| CO (ppm) | 2010 | 0.35 (NH-A) | 0.30 (NH-W) | 0.044 | 0.0031 | 0.072 |
| Average | 1990 | - | - | - | - | -0.020 |
| Average | 2000 | - | - | - | - | 0.024 |
| Average | 2010 | - | - | - | - | 0.0073 |
| Absolute average | 1990 | - | - | - | - | 0.038 |
| Absolute average | 2000 | - | - | - | - | 0.034 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Absolute average | 2010 | - | - | - | - | 0.083 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] Population-weighted average exposure for the most-exposed racial-ethnic group

[c] Population-weighted average exposure for the least-exposed racial-ethnic group

[d] Disparity = highest exposure – lowest exposure

[e] Mean error difference $= \frac{\sum_{i=1}^{n}(c_{im}-c_{io})p_{hi}}{\sum_{i=1}^{n}p_{hi}} - \frac{\sum_{i=1}^{n}(c_{im}-c_{io})p_{li}}{\sum_{i=1}^{n}p_{li}}$,

where $c_{im}$ is the modeled average concentration for block group i, $c_{io}$ is the observed average concentration for block group i, $p_{hi}$ is the population of the most-exposed demographic group h in block group i, $p_{li}$ is the population of the least-exposed demographic group l in block group i, and n is the total number of block groups with monitor data

[f] Ratio = $\frac{Mean\ error\ difference}{Disparity}$

[g] $PM_{2.5}$ didn't have data in 1990

**Table S12. 10% block group bins with highest and lowest racial-ethnic minority residents' exposure for six studied pollutants in year 2010**

| Pollutants | $1^{st}$ - $10^{th}$ percentile | $90^{th}$ – $100^{th}$ percentile | Absolute disparity [a] | Relative disparity (Ratio) [b] |
|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 9.2 | 10.5 | 1.3(14% [c]) | 1.1 |
| $NO_2$ (ppb) | 4.5 | 14 | 9.4 (113%) | 3.1 |
| $O_3$ (ppb) | 46 | 45 | -1.3 (-2.2%) | 0.98 |
| $SO_2$ (ppb) | 2.0 | 1.6 | -0.32 (-26%) | 0.8 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 17 | 21 | 4.6 (22%) | 1.2 |
| CO (ppm) | 0.27 | 0.37 | 0.097 (32%) | 1.4 |

[a] Absolute disparity between the $1^{st}$ - $10^{th}$ percentile (which are 10% block group bins with least racial-ethnic minority residents) and the $90^{th}$ – $100^{th}$ percentile (above which are 10% block group bins with highest racial-ethnic minority residents) in year 2010

[b] relative disparity = $\frac{\text{90th – 100th percentile exposure}}{\text{1st – 10th percentile exposure}}$

[c] Percentage difference = $\frac{absolute\ disparity}{Pollutant's\ national\ mean} \times 100\%$

**Table S13. The proportion of the population living in Block Groups with high-end exposures (i.e., above the 90th and 95th percentiles) for the four racial-ethnic groups in year 2010 [a]**

| **$PM_{2.5}$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio [b] | National (%) |
|---|---|---|---|---|---|---|---|
| above the 90th percentile | 7.3 | 16 | 10 | 5.6 | 12 | 1.6 | 8.8 |
| above the 95th percentile | 3.3 | 8.7 | 4.2 | 1.7 | 5.5 | 1.7 | 4.1 |
| **$NO_2$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio | National (%) |
| above the 90th percentile | 4.6 | 14 | 22 | 22 | 19 | 4.1 | 9.6 |
| above the 95th percentile | 1.9 | 6.6 | 13 | 14 | 11 | 5.6 | 5.1 |
| **$O_3$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio | National (%) |
| above the 90th percentile | 11 | 13 | 9.5 | 12 | 11 | 1.0 | 11 |
| above the 95th percentile | 5.2 | 7.3 | 5.0 | 7.0 | 6.1 | 1.2 | 5.7 |
| **$SO_2$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio | National (%) |
| above the 90th percentile | 8.6 | 11 | 5.7 | 5.9 | 7.6 | 0.88 | 8.2 |
| above the 95th percentile | 4.7 | 4.1 | 1.9 | 1.6 | 2.6 | 0.57 | 4.1 |

| **$PM_{10}$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio | National (%) |
|---|---|---|---|---|---|---|---|
| above the $90^{th}$ percentile | 7.2 | 7.3 | 21 | 14 | 15 | 2.1 | 9.9 |
| above the $95^{th}$ percentile | 3.1 | 3.0 | 15 | 8.6 | 9.5 | 3.1 | 5.4 |
| **CO** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) | RE-M (%) | Ratio | National (%) |
| above the $90^{th}$ percentile | 5.7 | 11 | 24 | 22 | 19 | 3.3 | 10 |
| above the $95^{th}$ percentile | 2.0 | 6.1 | 14 | 13 | 11 | 5.5 | 5.2 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A), Hispanic of any race(s) (H), and racial-ethnic minority (RE-M)

**Table S14. The distribution of the population living in Block Groups with high-end exposures (i.e., above the 90th and 95th percentiles) for the four racial-ethnic groups [a]**

| **National [b]** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
|---|---|---|---|---|
| | 66 | 13 | 17 | 4.8 |
| **$PM_{2.5}$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 54 | 23 | 19 | 3.0 |
| above the 95th percentile | 54 | 27 | 17 | 1.9 |
| **$NO_2$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 32 | 19 | 38 | 11 |
| above the 95th percentile | 26 | 17 | 44 | 13 |
| **$O_3$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 65 | 15 | 15 | 5.4 |
| above the 95th percentile | 62 | 17 | 15 | 6.1 |
| **$SO_2$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 69 | 16 | 12 | 3.4 |
| above the 95th percentile | 77 | 13 | 7.9 | 2.0 |
| **$PM_{10}$** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 47 | 9.3 | 36 | 6.9 |
| above the 95th percentile | 38 | 7.2 | 47 | 7.8 |
| **CO** | NH-W (%) | NH-B (%) | H (%) | NH-A (%) |
| above the 90th percentile | 37 | 13 | 39 | 11 |
| above the 95th percentile | 26 | 15 | 46 | 13 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] National total population only include the four racial-ethnic groups

**Table S15. Risk of living in block groups above the 90th percentile for multiple pollutants for the four racial-ethnic groups in year 2010 [a]**

| Criteria | National [b] (%) | NH-W (%) [ratio [c]] | NH-B (%) [ratio] | H (%) [ratio] | NH-A (%) [ratio] |
|---|---|---|---|---|---|
| Above 90th percentile for 0 pollutants | 64 | 69 [1.1] | 56 [0.88] | 54 [0.84] | 56 [0.87] |
| Above 90th percentile for 1 pollutant | 21 | 21 [0.99] | 25 [1.2] | 20 [0.94] | 20 [0.95] |
| Above 90th percentile for 2 pollutants | 8.5 | 7.0 [0.81] | 11 [1.3] | 12 [1.4] | 11 [1.3] |
| Above 90th percentile for 3 pollutants | 4.4 | 2.5 [0.57] | 5.8 [1.3] | 9.2 [2.1] | 10 [2.3] |
| Above 90th percentile for 4+ pollutants | 1.4 | 0.36 [0.25] | 1.9 [1.3] | 5.2 [3.6] | 2.2 [1.5] |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] National total population only include the four racial-ethnic groups

[c] ratio = $\frac{racial-ethnic\ group's\ percentage}{National\ percentage}$

**Table S16. Exposure disparity by household income: most- and least exposed-income categories exposures in 2010**

| Pollutants | Most-exposed income category exposure | Least-exposed income category exposure | Absolute difference [a] | Percentage difference (%) [b] | Relative difference [c] |
|---|---|---|---|---|---|
| $PM_{2.5}$ | 9.6 μg $m^{-3}$ | 9.0 μg $m^{-3}$ | 0.61 μg $m^{-3}$ | 6.6 | 1.1 |
| $NO_2$ | 8.9 ppb | 8.1 ppb | 0.79 ppb | 9.4 | 1.1 |
| $O_3$ | 46 ppb | 45 ppb | 1.1 ppb | 2.5 | 1.0 |
| $SO_2$ | 1.7 ppb | 1.4 ppb | 0.26 ppb | 16 | 1.2 |
| $PM_{10}$ | 18 μg $m^{-3}$ | 18 μg $m^{-3}$ | 0.95 μg $m^{-3}$ | 5.2 | 1.1 |
| CO | 0.32 ppm | 0.31 ppm | 0.0099 ppm | 3.1 | 1.0 |

[a] Absolute difference = population-weighted concentration for the most-exposed household income group – population-weighted concentration for the least-exposed household income group

[b] Percentage difference $= \frac{Pollutant's\ difference\ between\ the\ most-and\ least-exposed\ income\ groups}{pollutant's\ national\ mean}$

[c] Relative difference = population-weighted concentration for the most-exposed household income group/population-weighted concentration for the least-exposed household income group

[d] Percentage difference $= \frac{Pollutant's\ difference\ between\ highest\ and\ lowest\ income\ groups}{pollutant's\ national\ mean}$

[e] Relative difference = population-weighted concentration for the lowest household income group/population-weighted concentration for the highest household income group

**Table S17. Exposure disparity by household income: highest- and lowest-income categories exposures in 2010**

| Pollutants | Lowest-income category [a] exposure | Highest-income category [b] exposure | Absolute difference [c] | Percentage difference (%) [d] | Relative difference [e] |
|---|---|---|---|---|---|
| $PM_{2.5}$ | 9.6 μg $m^{-3}$ | 9.0 μg $m^{-3}$ | 0.61 μg $m^{-3}$ | 6.6 | 1.1 |
| $NO_2$ | 8.9 ppb | 8.7 ppb | 0.22 ppb | 2.6 | 1.0 |
| $O_3$ | 45 ppb | 46 ppb | -1.1 ppb | -2.4 | 0.98 |
| $SO_2$ | 1.7 ppb | 1.4 ppb | 0.26 ppb | 16 | 1.1 |
| $PM_{10}$ | 18 μg $m^{-3}$ | 18 μg $m^{-3}$ | 0.95 μg $m^{-3}$ | 5.2 | 1.2 |
| CO | 0.32 ppm | 0.31 ppm | 0.0065 ppm | 2.0 | 1.0 |

[a] Lowest income category is household with less than $10k income

[b] Highest income category is household with more than $200k income

[c] Absolute difference = population-weighted concentration for the lowest household income group – population-weighted concentration for the highest household income group

**Table S18. Exposure disparity by 25th, 50th and 75th percentile of household income in 2010 and average change**

| Pollutants | 25th income [a] exposure | 50th income [b] exposure | 75th income [c] exposure | 25th – 50th Difference [d] | Average change I per $10,000 [e] | 50th – 75th Difference [f] | Average change II per $10,000 [g] | 25th – 75th Difference [h] | Average change III per $10,000 [i] |
|---|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ (μg $m^{-3}$) | 9.4 | 9.3 | 9.2 | 0.10 | 0.051 (0.55% [j]) | 0.14 | 0.032 (0.34%) | 0.25 | 0.038 (0.41%) |
| $NO_2$ (ppb) | 8.3 | 8.2 | 8.1 | 0.010 | 0.049 (0.59%) | 0.097 | 0.022 (0.26%) | 0.20 | 0.030 (0.36%) |
| $O_3$ (ppb) | 45 | 45 | 46 | -0.15 | -0.076 (-0.17%) | -0.32 | -0.072 (-0.16%) | -0.48 | -0.073 (-0.16%) |
| $SO_2$ (ppb) | 1.6 | 1.6 | 1.5 | 0.042 | 0.021 (1.3%) | 0.050 | 0.011 (0.71%) | 0.091 | 0.014 (0.90%) |
| $PM_{10}$ (μg $m^{-3}$) | 18 | 18 | 18 | 0.094 | 0.047 (0.26%) | 0.17 | 0.038 (0.21%) | 0.27 | 0.014 (0.22%) |
| CO (ppm) | 0.32 | 0.31 | 0.31 | 1.6e-3 | 8.1e-4 (0.26%) | 2.9e-3 | 6.4e-4 (0.20%) | 4.5e-3 | 6.9e-4 (0.22%) |

[a] Midpoint of 25th percentile household income category ($20,000-25,000), i.e., $22,500
[b] Midpoint of 50th percentile household income category ($40,000-45,000), i.e., $42,500
[c] Midpoint of 75th percentile household income category ($75,000-100,000), i.e., $87,500
[d] 25th – 50th Difference = 25th income exposure – 50th income exposure
[e] Average change I per $10,000 = 25th – 50th Difference/(42,500-22,500) ×10,000
[f] 50th – 75th Difference = 50th income exposure – 75th income exposure
[g] Average change II per $10,000 = 50th – 75th Difference/(87,500-42,500) ×10,000
[h] 25th – 75th Difference = 25th income exposure – 75th income exposure
[i] Average change II per $10,000 = 25th – 75th Difference/(87,500-22,500) ×10,000
[j] percentage = average change/pollutant's national mean*100%

**Table S19. The absolute exposure disparity between the most- and least-exposed racial-ethnic groups and the absolute exposure disparity between the most- and least-exposed income categories in 2010**

| Pollutants | Absolute racial-ethnic disparities [a] | Absolute income disparities [b] | Ratio [c] |
|---|---|---|---|
| $PM_{2.5}$ | 1.2 μg $m^{-3}$ | 0.61 μg $m^{-3}$ | 2.0 |
| $NO_2$ | 4.6 ppb | 0.22 ppb | 21 |
| $O_3$ | 1.6 ppb | -1.1 ppb | 1.4 |
| $SO_2$ | 0.29 ppb | 0.26 ppb | 1.1 |
| $PM_{10}$ | 3.0 μg $m^{-3}$ | 0.95 μg $m^{-3}$ | 3.2 |
| CO | 0.044 ppm | 0.0065 ppm | 6.8 |

| Pollutants | Absolute racial-ethnic disparities [a] | Absolute alternative income disparities [d] | Ratio [c] |
|---|---|---|---|
| $PM_{2.5}$ | 1.2 μg $m^{-3}$ | 0.61 μg $m^{-3}$ | 2.0 |
| $NO_2$ | 4.6 ppb | 0.79 ppb | 5.8 |
| $O_3$ | 1.6 ppb | 1.1 ppb | 1.4 |
| $SO_2$ | 0.29 ppb | 0.26 ppb | 1.1 |
| $PM_{10}$ | 3.0 μg $m^{-3}$ | 0.95 μg $m^{-3}$ | 3.2 |
| CO | 0.044 ppm | 0.0099 ppm | 4.4 |

[a] Absolute racial-ethnic disparities = population-weighted concentration for the most-exposed racial-ethnic group – population-weighted concentration for the least-exposed racial-ethnic group

[b] Absolute income disparities = population-weighted concentration for the lowest household income group (<$10k) – population-weighted concentration for the highest household income group (>$200k)

[c] ratio = |absolute racial-ethnic disparities/absolute income disparities|

[d] Absolute alternative income disparities = population-weighted concentration for the most-exposed household income group – population-weighted concentration for the least-exposed household income group

**Table S20. National mean exposure for the four racial-ethnic groups in 2010**

| $PM_{2.5}$ | NH White | Black [a] | Hispanic | Asian [a] |
|---|---|---|---|---|
| <10k ($) | 9.3 | 10.6 | 9.3 | 9.7 |
| 10k-15k | 9.2 | 10.5 | 9.4 | 9.7 |
| 15k-20k | 9.2 | 10.5 | 9.4 | 9.7 |
| 20k-25k | 9.2 | 10.4 | 9.4 | 9.6 |
| 25k-30k | 9.2 | 10.4 | 9.4 | 9.6 |
| 30k-35k | 9.2 | 10.4 | 9.4 | 9.6 |
| 35k-40k | 9.2 | 10.4 | 9.4 | 9.6 |
| 40k-45k | 9.1 | 10.3 | 9.3 | 9.6 |
| 45k-50k | 9.1 | 10.3 | 9.3 | 9.6 |
| 50k-60k | 9.1 | 10.3 | 9.3 | 9.5 |
| 60k-75k | 9.1 | 10.2 | 9.3 | 9.5 |
| 75k-100k | 9.1 | 10.2 | 9.3 | 9.4 |
| 100k-125k | 9.0 | 10.1 | 9.2 | 9.4 |
| 125k-150k | 9.0 | 10.0 | 9.2 | 9.4 |
| 150k-200k | 9.0 | 9.9 | 9.1 | 9.3 |
| >200k | 9.0 | 9.8 | 9.0 | 9.2 |
| $NO_2$ | NH White | Black | Asian | Hispanic |
| <10k | 7.4 | 10.2 | 12.9 | 11.8 |
| 10k-15k | 7.2 | 10.0 | 13.5 | 11.6 |
| 15k-20k | 7.2 | 9.8 | 13.1 | 11.4 |
| 20k-25k | 7.1 | 9.8 | 12.7 | 11.2 |
| 25k-30k | 7.1 | 9.8 | 12.6 | 11.2 |
| 30k-35k | 7.1 | 9.9 | 12.5 | 11.2 |
| 35k-40k | 7.1 | 10.0 | 12.4 | 11.2 |
| 40k-45k | 7.2 | 10.0 | 12.3 | 11.3 |
| 45k-50k | 7.1 | 10.0 | 12.3 | 11.2 |

| | | | | |
|---|---|---|---|---|
| 50k-60k | 7.2 | 10.0 | 12.1 | 11.3 |
| 60k-75k | 7.2 | 10.0 | 12.0 | 11.3 |
| 75k-100k | 7.3 | 10.1 | 11.8 | 11.3 |
| 100k-125k | 7.6 | 10.3 | 11.6 | 11.3 |
| 125k-150k | 7.8 | 10.3 | 11.5 | 11.4 |
| 150k-200k | 8.1 | 10.4 | 11.3 | 11.1 |
| >200k | 8.4 | 10.4 | 10.9 | 10.4 |
| $O_3$ | NH White | Black | Asian | Hispanic |
| <10k | 45.4 | 45.9 | 45.7 | 43.5 |
| 10k-15k | 45.4 | 45.8 | 45.8 | 43.7 |
| 15k-20k | 45.4 | 45.8 | 45.8 | 43.9 |
| 20k-25k | 45.4 | 45.8 | 45.9 | 44.1 |
| 25k-30k | 45.4 | 45.9 | 45.8 | 44.1 |
| 30k-35k | 45.4 | 46.1 | 45.9 | 44.2 |
| 35k-40k | 45.4 | 46.1 | 45.9 | 44.3 |
| 40k-45k | 45.4 | 46.2 | 46.0 | 44.4 |
| 45k-50k | 45.5 | 46.1 | 45.9 | 44.5 |
| 50k-60k | 45.5 | 46.4 | 46.0 | 44.5 |
| 60k-75k | 45.6 | 46.5 | 46.2 | 44.7 |
| 75k-100k | 45.7 | 46.8 | 46.3 | 44.8 |
| 100k-125k | 45.9 | 47.1 | 46.5 | 45.0 |
| 125k-150k | 46.1 | 47.4 | 46.6 | 45.2 |
| 150k-200k | 46.3 | 47.8 | 46.9 | 45.1 |
| >200k | 46.3 | 48.0 | 46.9 | 44.6 |
| $SO_2$ | NH White | Black | Asian | Hispanic |
| <10k | 1.7 | 1.8 | 1.5 | 1.6 |
| 10k-15k | 1.7 | 1.8 | 1.5 | 1.5 |
| 15k-20k | 1.7 | 1.7 | 1.5 | 1.5 |

| | | | | |
|---|---|---|---|---|
| 20k-25k | 1.7 | 1.7 | 1.5 | 1.4 |
| 25k-30k | 1.7 | 1.7 | 1.5 | 1.4 |
| 30k-35k | 1.6 | 1.7 | 1.5 | 1.4 |
| 35k-40k | 1.6 | 1.7 | 1.4 | 1.4 |
| 40k-45k | 1.6 | 1.7 | 1.4 | 1.4 |
| 45k-50k | 1.6 | 1.7 | 1.4 | 1.4 |
| 50k-60k | 1.6 | 1.7 | 1.4 | 1.4 |
| 60k-75k | 1.6 | 1.6 | 1.4 | 1.4 |
| 75k-100k | 1.6 | 1.6 | 1.4 | 1.4 |
| 100k-125k | 1.5 | 1.6 | 1.3 | 1.4 |
| 125k-150k | 1.5 | 1.6 | 1.3 | 1.3 |
| 150k-200k | 1.5 | 1.6 | 1.3 | 1.3 |
| >200k | 1.5 | 1.5 | 1.3 | 1.3 |
| $PM_{10}$ | NH White | Black | Asian | Hispanic |
| <10k | 17.8 | 19.0 | 19.8 | 20.2 |
| 10k-15k | 17.8 | 19.0 | 20.2 | 20.6 |
| 15k-20k | 17.8 | 18.9 | 20.1 | 20.6 |
| 20k-25k | 17.7 | 18.8 | 20.0 | 20.7 |
| 25k-30k | 17.7 | 18.9 | 19.9 | 20.7 |
| 30k-35k | 17.7 | 18.8 | 19.9 | 20.6 |
| 35k-40k | 17.7 | 18.8 | 19.8 | 20.6 |
| 40k-45k | 17.7 | 18.8 | 19.8 | 20.6 |
| 45k-50k | 17.7 | 18.8 | 19.7 | 20.7 |
| 50k-60k | 17.7 | 18.8 | 19.7 | 20.6 |
| 60k-75k | 17.7 | 18.8 | 19.7 | 20.7 |
| 75k-100k | 17.7 | 18.8 | 19.5 | 20.5 |
| 100k-125k | 17.7 | 18.8 | 19.4 | 20.5 |
| 125k-150k | 17.6 | 18.7 | 19.3 | 20.4 |

| | | | | |
|---|---|---|---|---|
| 150k-200k | 17.6 | 18.7 | 19.0 | 19.9 |
| >200k | 17.4 | 18.6 | 18.5 | 19.2 |
| CO | NH White | Black | Asian | Hispanic |
| <10k | 0.31 | 0.32 | 0.36 | 0.35 |
| 10k-15k | 0.31 | 0.32 | 0.37 | 0.35 |
| 15k-20k | 0.31 | 0.32 | 0.36 | 0.35 |
| 20k-25k | 0.30 | 0.32 | 0.36 | 0.35 |
| 25k-30k | 0.30 | 0.32 | 0.36 | 0.35 |
| 30k-35k | 0.30 | 0.32 | 0.36 | 0.35 |
| 35k-40k | 0.30 | 0.33 | 0.36 | 0.35 |
| 40k-45k | 0.30 | 0.33 | 0.35 | 0.35 |
| 45k-50k | 0.30 | 0.33 | 0.35 | 0.35 |
| 50k-60k | 0.30 | 0.33 | 0.35 | 0.35 |
| 60k-75k | 0.30 | 0.33 | 0.35 | 0.35 |
| 75k-100k | 0.30 | 0.33 | 0.35 | 0.35 |
| 100k-125k | 0.30 | 0.33 | 0.34 | 0.34 |
| 125k-150k | 0.31 | 0.33 | 0.34 | 0.35 |
| 150k-200k | 0.31 | 0.33 | 0.34 | 0.34 |
| >200k | 0.31 | 0.33 | 0.33 | 0.33 |

[a] Here and after, in race-ethnicity and income analysis, black and Asian population include both Hispanic and non-Hispanic

**Table S21. Population distribution of four studied racial-ethnic groups [a] in 16 household income categories in 2010**

| Income Category ($) | Midpoint [b] | NH-W | B | A | H |
|---|---|---|---|---|---|
| <10k | 5k | 61% | 23% | 3.5% | 13% |
| 10k-15k | 12.5k | 68% | 17% | 2.5% | 12% |
| 15k-20k | 17.5k | 69% | 15% | 2.5% | 14% |
| 20k-25k | 22.5k | 69% | 14% | 2.5% | 14% |
| 25k-30k | 27.5k | 70% | 14% | 2.5% | 14% |
| 30k-35k | 32.5k | 71% | 13% | 2.6% | 13% |
| 35k-40k | 37.5k | 72% | 12% | 2.6% | 13% |
| 40k-45k | 42.5k | 73% | 12% | 2.9% | 12% |
| 45k-50k | 47.5k | 74% | 11% | 2.8% | 12% |
| 50k-60k | 55k | 75% | 10% | 3.0% | 11% |
| 60k-75k | 67.5k | 77% | 9.5% | 3.5% | 10% |
| 75k-100k | 87.5k | 79% | 8.2% | 3.9% | 9.0% |
| 100k-125k | 112.5k | 80% | 7.1% | 4.9% | 7.8% |
| 125k-150k | 137.5k | 81% | 6.4% | 5.5% | 7.0% |
| 150k-200k | 175k | 82% | 5.5% | 6.7% | 6.0% |
| >200k | 200k | 85% | 3.5% | 6.9% | 4.3% |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), black (both Hispanic and non-Hispanic) (B), Asian (both Hispanic and non-Hispanic) (A) and Hispanic of any race(s) (H)

[b] Midpoint for each category is the average of lower and higher bound of the category besides >200k income category

**Table S22. Average racial-ethnic disparities in the same household categories and average household income disparities in the same racial-ethnic group in 2010**

| Pollutants | Average racial-ethnic absolute disparities [a] | Average racial-ethnic relative disparities [b] | Percentage difference (%) [c] | Average income absolute disparities [d] | Average income relative disparities [e] | Percentage difference (%) |
|---|---|---|---|---|---|---|
| $PM_{2.5}$ | 1.1 μg $m^{-3}$ | 1.1 | 12 | 0.46 μg $m^{-3}$ | 1.0 | 5.0 |
| $NO_2$ | 4.8 ppb | 1.7 | 58 | 0.53 ppb | 1.0 | 6.3 |
| $O_3$ | 2.1 ppb | 1.0 | 4.5 | -1.3 ppb | 0.97 | -2.9 |
| $SO_2$ | 0.27 ppb | 1.2 | 17 | 0.24 ppb | 1.2 | 15 |
| $PM_{10}$ | 2.7 μg $m^{-3}$ | 1.2 | 15 | 0.74 μg $m^{-3}$ | 1.0 | 4.1 |
| CO | 0.047 ppm | 1.2 | 15 | 0.0085 ppm | 1.0 | 2.7 |

[a] Average racial-ethnic absolute disparities = average(most-exposed racial-ethnic group – least-exposed racial-ethnic group) in household income category *i*, where *i*=1,…, 16

[b] Average racial-ethnic relative disparities = average(most-exposed racial-ethnic group / least-exposed racial-ethnic group) in household income category *i*, where *i*=1,…, 16

[c] percentage difference = $\frac{disparities}{pollutant's\ national\ mean}$

[d] Average income absolute disparities = average(lowest household income category – highest household income category) in racial-ethnic group *i*, where *i*=1,…, 4

[e] Average income relative disparities = average(lowest household income category / highest household income category) in racial-ethnic group *i*, where *i*=1,…, 4

**Table S23. Urban/rural exposures in 2010**

| | Urban [a] | Rural [b] | Absolute disparity [c] | Percentage diff (%) [d] | Relative disparity [e] |
|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 9.4 | 8.2 | 1.2 | 13 | 1.1 |
| $NO_2$ (ppb) | 8.9 | 3.6 | 5.4 | 64 | 2.5 |
| $O_3$ (ppb) | 46 | 45 | 0.26 | 0.57 | 1.0 |
| $SO_2$ (ppb) | 1.6 | 1.6 | 0.00 | 0.00 | 1.0 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 19 | 15 | 3.2 | 18 | 1.2 |
| CO (ppm) | 0.32 | 0.27 | 0.049 | 16 | 1.2 |

[a] Urban stands for population-weighted average exposure level for block groups defined as urban

[b] Rural stands for population-weighted average exposure level for block groups defined as rural

[c] Absolute disparity $=$ urban $-$ rural

[d] Percentage diff $= \frac{urban-rural}{pollutant's\ national\ mean}$

[e] Relative disparity $= \frac{urban}{rural}$

**Table S24. Difference between exposure for the most exposed racial-ethnic group versus the most exposed racial-ethnic groups [a] for criteria pollutants for urban block groups and rural block groups in 2010**

| | Race-ethnicity disparities in urban block groups | | | | | Race-ethnicity disparities in rural block groups | | | | | Race-ethnicity disparities between urban and rural block groups | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Most exposed | Least exposed | Absolute disparity [b] | Percentage Diff (%) [c] | Relative disparity [d] | Most exposed | Least exposed | Absolute disparity | Percentage Diff (%) | Relative disparity | Absolute disparity ratio [e] | Relative disparity ratio [f] |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | NH-B | NH-W | 1.1 | 12 | 1.1 | NH-B | H | 1.3 | 14 | 1.2 | 0.85 | 0.95 |
| $NO_2$ | NH-A | NH-W | 4.1 | 49 | 1.5 | H | NH-B | 0.73 | 8.8 | 1.2 | 5.5 | 1.2 |
| $O_3$ | NH-A | H | 1.6 | 3.6 | 1 | NH-W | H | 0.51 | 1.1 | 1 | 3.1 | 1.0 |
| $SO_2$ | NH-B | NH-A | 0.31 | 20 | 1.2 | NH-W | H | 0.24 | 15 | 1.2 | 1.3 | 1.0 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | H | NH-W | 2.8 | 15 | 1.2 | H | NH-B | 2.3 | 12 | 1.2 | 1.2 | 1.0 |
| CO | H | NH-W | 0.041 | 13 | 1.1 | H | NH-B | 0.017 | 5.4 | 1.1 | 2.4 | 1.1 |

[a] Racial-ethnic groups are non-Hispanic white (NH-W), non-Hispanic black (NH-B), non-Hispanic Asian (NH-A) and Hispanic of any race(s) (H)

[b] Absolute disparity = exposure for the most-exposed racial-ethnic group – exposure for the least-exposed racial-ethnic group

[c] Percentage diff $= \frac{exposure\ for\ the\ most\ exposed\ group - exposure\ the\ least\ exposed\ group}{pollutant's\ national\ mean}$

[d] Relative disparity $= \frac{\text{exposure for the most-exposed racial-ethnic group}}{\text{exposure for the least-exposed racial-ethnic group}}$

[e] Absolute disparity ratio$= \frac{\text{absolute disparity for the urban block groups}}{\text{absolute disparity for the rural block groups}}$

[f] Relative disparity ratio$= \frac{\text{relative disparity for the urban block groups}}{\text{relative disparity for the rural block groups}}$

**Table S25. Exposure disparity by household income: highest- and lowest-income categories exposures in 2010 for urban and rural block groups**

| Urban | Lowest-income category [a] exposure | Highest-income category [b] exposure | Absolute disparity [c] | Percentage difference (%) [d] | Relative disparity [e] |
|---|---|---|---|---|---|
| $PM_{2.5}$ | 9.8 μg $m^{-3}$ | 9.1 μg $m^{-3}$ | 0.71 μg $m^{-3}$ | 7.7 | 1.1 |
| $NO_2$ | 9.6 ppb | 8.9 ppb | 0.69 ppb | 8.3 | 1.1 |
| $O_3$ | 45 ppb | 46 ppb | -1.1 ppb | -2.5 | 0.98 |
| $SO_2$ | 1.7 ppb | 1.4 ppb | 0.27 ppb | 17 | 1.2 |
| $PM_{10}$ | 19 μg $m^{-3}$ | 18 μg $m^{-3}$ | 1.3 μg $m^{-3}$ | 6.8 | 1.1 |
| CO | 0.33 ppm | 0.32 ppm | 0.011 ppm | 3.3 | 1.0 |
| Rural | Lowest-income category [a] exposure | Highest-income category [b] exposure | Absolute disparity [c] | Percentage difference (%) [d] | Relative disparity [e] |
| $PM_{2.5}$ | 8.4 μg $m^{-3}$ | 7.7 μg $m^{-3}$ | 0.64 μg $m^{-3}$ | 6.9 | 1.1 |
| $NO_2$ | 3.5 ppb | 3.6 ppb | -0.13 ppb | -1.5 | 0.96 |
| $O_3$ | 45 ppb | 45 ppb | 0.039 ppb | 0.087 | 1.0 |
| $SO_2$ | 1.6 ppb | 1.5 ppb | 0.14 ppb | 9.1 | 1.1 |
| $PM_{10}$ | 15 μg $m^{-3}$ | 15 μg $m^{-3}$ | 0.48 μg $m^{-3}$ | 2.6 | 1.0 |
| CO | 0.27 ppm | 0.27 ppm | 0.0020 ppm | 0.65 | 1.0 |

| Urban vs. rural | Abs(Urban absolute disparity : rural absolute disparity) | Abs(Urban relative disparity : rural relative disparity) |
|---|---|---|
| $PM_{2.5}$ | 1.1 | 1.0 |
| $NO_2$ | 5.6 | 1.1 |
| $O_3$ | 25 | 0.98 |
| $SO_2$ | 2.1 | 1.1 |
| $PM_{10}$ | 2.1 | 1.0 |
| CO | 4.9 | 1.0 |

[a] Lowest income category is household with less than $10,000 income

[b] Highest income category is household with more than $200,000 income

[c] Absolute disparity = population-weighted concentration for the lowest household income group – population-weighted concentration for the highest household income group

[d] Percentage difference $= \frac{Pollutant's\ difference\ between\ highest\ and\ lowest\ income\ groups}{pollutant's\ national\ mean}$

[e] Relative disparity = population-weighted concentration for the lowest household income group / population-weighted concentration for the highest household income group

**Table S26. Population-weighted average exposure for six criteria pollutants for total population and four main racial-ethnic groups [a] from 1990 to 2010.**

| Pollutants | Total population | NH-W | NH-B | H | NH-A |
|---|---|---|---|---|---|
| **1990** | | | | | |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | NA [b] | NA | NA | NA | NA |
| $NO_2$ (ppb) | 15.7 | 14.1 | 18.6 | 23.2 | 24.0 |
| $O_3$ (ppb) | 48.6 | 48.7 | 50.4 | 46.0 | 47.5 |
| $SO_2$ (ppb) | 5.36 | 5.36 | 6.05 | 4.71 | 4.78 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 27.7 | 26.6 | 29.0 | 32.7 | 33.2 |
| CO (ppm) | 0.703 | 0.640 | 0.775 | 1.04 | 1.03 |
| **2000** | | | | | |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 13.0 | 12.6 | 14.4 | 13.8 | 14.4 |
| $NO_2$ (ppb) | 13.5 | 11.9 | 15.6 | 18.7 | 19.4 |
| $O_3$ (ppb) | 48.6 | 48.9 | 49.3 | 47.0 | 47.0 |
| $SO_2$ (ppb) | 3.53 | 3.52 | 4.12 | 3.09 | 3.45 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 23.0 | 21.7 | 24.0 | 28.2 | 26.2 |
| CO (ppm) | 0.488 | 0.444 | 0.522 | 0.645 | 0.648 |
| **2010** | | | | | |
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | 9.28 | 9.08 | 10.3 | 9.36 | 9.42 |
| $NO_2$ (ppb) | 8.38 | 7.17 | 9.73 | 11.2 | 11.7 |
| $O_3$ (ppb) | 45.6 | 45.7 | 46.1 | 44.6 | 46.3 |
| $SO_2$ (ppb) | 1.56 | 1.59 | 1.67 | 1.40 | 1.38 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 18.4 | 17.6 | 18.8 | 20.7 | 19.5 |
| CO (ppm) | 0.315 | 0.303 | 0.321 | 0.346 | 0.347 |

[a] For the four racial-ethnic groups, NH-W stands for non-Hispanic White; NH-B stands for non-Hispanic Black; H stands for Hispanic of any race; NH-A stands for non-Hispanic Asian

[b] $PM_{2.5}$ didn't have data in year 1990

**Table S27. National annual population-weighted average change for six studied pollutants from 1990 to 2010 (2000 to 2010 for $PM_{2.5}$)**

| Pollutants | Exposure in 1990 | Exposure in 2010 | Absolute [a] | Percentage [b] |
|---|---|---|---|---|
| $PM_{2.5}$ | In 2000: 13 μg $m^{-3}$ | 9.3 μg $m^{-3}$ | -3.7 μg $m^{-3}$ | -29% |
| $NO_2$ | 16 ppb | 8.3 ppb | -7.3 ppb | -47% |
| $O_3$ | 49 ppb | 46 ppb | -3.0 ppb | -6% |
| $SO_2$ | 5.4 ppb | 1.6 ppb | -3.8 ppb | -71% |
| $PM_{10}$ | 28 μg $m^{-3}$ | 18 μg $m^{-3}$ | -9.3 μg $m^{-3}$ | -34% |
| CO | 0.70 ppm | 0.31 ppm | -0.39 ppm | -55% |

[a] Absolute difference = 2010 national population-weighted average – 1990 national population-weighted average

[b] Percentage difference $= \frac{absolute\ difference}{\text{1990 national population-weighted average}}$

**Table S28. Temporal change of disparity on absolute and relative basis from 1990 to 2010 (2000 to 2010 for $PM_{2.5}$)**

| Pollutants | Most-exposed racial-ethnic group in 1990 | Least-exposed racial-ethnic group in 1990 | Absolute disparity between most and least [a] in 1990 | Most-exposed racial-ethnic group in 2010 | Least-exposed racial-ethnic group in 2010 | Absolute disparity between most and least in 2010 | Temporal change in absolute disparity between most and least [a] | Relative disparity between most and least [b] in 1990 | Relative disparity between most and least in 2010 | Temporal change in relative disparity between most and least [e] |
|---|---|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ [c] | In 2000: NH-B | In 2000: NH-W | In 2000: 1.9 μg $m^{-3}$ | NH-B | NH-W | 1.2 μg m-3 | -0.66 μg $m^{-3}$ (35% [d]) | In 2000: 1.14 | 1.13 | 0.99 (1% [f]) |
| $NO_2$ | NH-A | NH-W | 9.8 ppb | NH-A | NH-W | 4.6 ppb | -5.3 ppb (54%) | 1.70 | 1.60 | 0.94 (6%) |
| $O_3$ | NH-B | H | 4.4 ppb | NH-A | H | 1.6 ppb | -2.7 ppb (61%) | 1.10 | 1.04 | 0.95 (5%) |
| $SO_2$ | NH-B | H | 1.3 ppb | NH-B | NH-A | 0.29 ppb | -1.1 ppb (85%) | 1.28 | 1.21 | 0.95 (5%) |
| $PM_{10}$ | NH-A | NH-W | 6.6 μg $m^{-3}$ | H | NH-W | 3.0 μg m-3 | -3.6 μg $m^{-3}$ (55%) | 1.25 | 1.18 | 0.94 (6%) |
| CO | H | NH-W | 0.40 ppm | NH-A | NH-W | 0.044 ppm | -0.35 ppm (88%) | 1.63 | 1.15 | 0.71 (29%) |

[a] Temporal change in absolute disparity between most and least = absolute disparity between the most and least exposed racial-ethnicity groups in 2010 – absolute disparity between the most and least exposed racial-ethnicity groups in 1990

[b] Relative difference between most and least = relative disparity between the most and least exposed racial-ethnicity groups in 2010 – relative disparity between the most and least exposed racial-ethnicity groups in 1990

relative

[c] For $PM_{2.5}$, no data in year 1990, data was replaced with data in year 2000

[d] Percentage difference $= \frac{temporal\ absolute\ disparity\ difference}{absolute\ disparity\ in\ 1990}$

[e] Temporal change in relative disparity between most and least = $\frac{\text{absolute disparity between the most and least exposed racial−ethnicity groups in 2010}}{\text{absolute disparity between the most and least exposed racial−ethnicity groups in 1990}}$

[f] Percentage difference $= \frac{temporal\ relative\ disparity\ difference}{relative\ disparity\ in\ 1990}$

**Table S29. Temporal change for absolute disparity between lowest and highest deciles block group bins from 1990 to 2010 (2000 to 2010 for $PM_{2.5}$)**

| Pollutants | Difference [a] in 1990 | Difference [a] in 2010 | Temporal change of absolute disparity [b] | Percentage change [c] (%) |
|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) | In 2000: 2.8 | 1.3 | -1.6 | -17 |
| $NO_2$ (ppb) | 16 | 9.4 | -6.2 | -74 |
| $O_3$ (ppb) | -1.7 | -1.3 | 0.34 | 0.74 |
| $SO_2$ (ppb) | -0.16 | -0.32 | -0.16 | -10 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 9.2 | 4.6 | -4.5 | -25 |
| CO (ppm) | 0.61 | 0.097 | -0.52 | -164 |

[a] Difference between lowest and highest deciles block group bins (i.e., with, respectively, the lowest and highest deciles racial-ethnic minorities percentage) in year 1990 (2000 for PM2.5) and in year 2010. Difference is calculated as absolute highest deciles block group bins average exposure – absolute lowest deciles block group bins average exposure.

[b] Temporal change = difference in 2010 - difference in 1990.

[c] Percentage difference $= \frac{temporal\ change\ of\ absolute\ disparity}{pollutant's\ national\ mean\ in\ year\ 2010} \times 100\%$.

**Table S30. Change (from 1990 to 2010) in absolute racial-ethnic exposure disparity for 48 states plus District of Columbia (2000 to 2010 for $PM_{2.5}$)**

| State | $PM_{2.5}$ diff [a] ($\mu g\ m^{-3}$) | $NO_2$ diff (ppb) | $O_3$ diff (ppb) | $SO_2$ diff (ppb) | $PM_{10}$ diff ($\mu g\ m^{-3}$) | CO diff (ppm) |
|---|---|---|---|---|---|---|
| Alabama | 0.07 | -0.79 | 0.82 | -0.32 | -0.17 | -0.06 |
| Arizona | 0.35 | 3.39 | -0.82 | -0.12 | 3.14 | 0.06 |
| Arkansas | -0.03 | -0.52 | -0.27 | -0.21 | -0.25 | -0.08 |
| California | -1.30 | -3.77 | 1.49 | -0.13 | -1.56 | -0.23 |
| Colorado | -0.14 | 0.48 | 0.20 | -0.34 | 0.75 | -0.06 |
| Connecticut | -0.28 | -1.53 | 1.32 | -0.84 | -2.07 | -0.16 |
| Delaware | -0.20 | -0.55 | 0.58 | -0.61 | -1.54 | -0.08 |
| District of Columbia | 0.04 | -0.37 | -1.64 | -0.10 | -0.39 | -0.05 |
| Florida | 0.17 | -0.40 | 1.23 | -0.09 | 0.78 | -0.11 |
| Georgia | 0.05 | -0.59 | 1.21 | 0.39 | 0.07 | -0.08 |
| Idaho | -0.16 | 0.21 | 0.14 | -0.17 | 0.57 | -0.02 |
| Illinois | -0.78 | -1.52 | 1.36 | -0.45 | -3.93 | -0.15 |
| Indiana | -0.11 | -2.17 | 1.06 | -0.06 | -1.75 | -0.07 |
| Iowa | 0.07 | -1.96 | 0.39 | -0.41 | -0.23 | -0.05 |
| Kansas | 0.00 | -0.99 | 0.89 | -0.05 | -0.37 | -0.07 |
| Kentucky | 0.35 | -1.15 | 2.92 | -0.86 | -1.89 | -0.14 |
| Louisiana | 0.12 | -0.24 | 0.58 | -0.08 | 0.23 | -0.07 |
| Maine | 0.24 | 0.10 | 1.20 | -0.08 | 0.36 | -0.04 |
| Maryland | -0.05 | -1.96 | 0.61 | -0.70 | -0.96 | -0.11 |
| Massachusetts | -0.39 | -2.09 | 1.22 | -0.88 | -1.42 | -0.18 |
| Michigan | -1.11 | -3.12 | 2.12 | -1.37 | -2.77 | -0.14 |
| Minnesota | -0.31 | -1.72 | 0.92 | -0.40 | -0.73 | -0.10 |
| Mississippi | 0.23 | 0.25 | 0.88 | 0.16 | 0.33 | -0.04 |
| Missouri | -0.13 | -2.12 | 0.23 | -2.39 | -2.69 | -0.13 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Montana | 0.24 | 0.66 | -0.96 | 0.71 | 0.08 | 0.06 |
| Nebraska | 0.13 | -1.35 | 0.66 | 0.23 | -1.22 | -0.08 |
| Nevada | 0.15 | -2.01 | 0.60 | -0.04 | -1.11 | -0.10 |
| New Hampshire | -0.01 | -0.56 | 0.95 | -0.12 | 0.21 | -0.05 |
| New Jersey | -0.75 | -2.62 | 1.43 | -1.24 | -1.60 | -0.22 |
| New Mexico | 0.04 | 1.04 | 0.13 | -0.10 | 0.83 | 0.04 |
| New York | -1.33 | -5.24 | 2.33 | -2.75 | -3.25 | -0.40 |
| North Carolina | 0.27 | -0.34 | 0.32 | 0.14 | -0.23 | -0.03 |
| North Dakota | 0.17 | 0.83 | -0.79 | 0.02 | 0.83 | 0.07 |
| Ohio | 0.22 | -1.47 | 0.58 | -0.55 | -1.19 | -0.08 |
| Oklahoma | 0.06 | 0.31 | 0.17 | 0.04 | 0.51 | -0.03 |
| Oregon | -0.14 | -1.15 | 0.18 | -0.29 | 1.05 | -0.11 |
| Pennsylvania | -0.64 | -4.56 | 0.19 | -1.70 | -3.10 | -0.29 |
| Rhode Island | -0.46 | -1.35 | 1.78 | -1.02 | -2.19 | -0.19 |
| South Carolina | 0.17 | 0.07 | -0.47 | 0.50 | 0.30 | 0.00 |
| South Dakota | -0.13 | 0.51 | -2.15 | 0.54 | -0.40 | 0.18 |
| Tennessee | 0.43 | -2.34 | 1.67 | -0.67 | 0.47 | -0.16 |
| Texas | 0.22 | -0.44 | 0.61 | -0.52 | -0.44 | -0.12 |
| Utah | -0.06 | 0.58 | 0.24 | -0.21 | 1.37 | -0.02 |
| Vermont | 0.27 | -0.37 | 0.30 | -0.32 | -0.02 | -0.04 |
| Virginia | -0.06 | -0.64 | 0.26 | -0.28 | 0.58 | -0.06 |
| Washington | -0.27 | -0.22 | 0.27 | -0.27 | -0.19 | -0.08 |
| West Virginia | 0.02 | -0.59 | 0.54 | 0.07 | -1.62 | -0.07 |
| Wisconsin | -0.13 | -1.96 | 0.30 | -0.21 | -3.06 | -0.10 |
| Wyoming | 0.13 | -0.68 | 0.35 | 0.02 | 0.20 | -0.01 |
| # states with a decrease (negative value) | 26 | 42 | 37 | 43 | ß29 | 48 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Percentage (%) [b] | 53 | 86 | ß76 | 88 | 59 | 98 |

[a] Difference = disparity for state *i* in 2010 - disparity for state *i* in 1990 (2000 for $PM_{2.5}$). Here, disparity for state *i* in year *j* is the difference between the most-exposed racial-ethnic group in state *i*, year *j*, and the non-Hispanic White in state *i*, year *j*

[b] $\text{Percentage} = \frac{\#\text{ states with a decrease}}{49} \times 100\%$

**Table S31. Temporal change of exposure for urban and rural block groups from 1990 to 2010 (2000 to 2010 for $PM_{2.5}$)**

| Pollutants | Urban difference [a] | Rural difference [b] | Urban absolute disparity difference [c] | Rural absolute disparity difference [d] | Urban versus rural disparity reduction [e] | Urban versus rural disparity reduction ratio [f] |
|---|---|---|---|---|---|---|
| $PM_{2.5}$ ($\mu g\ m^{-3}$) [g] | 3.8 | 3.0 | 0.63 | 1.5 | -0.87 | 0.42 |
| $NO_2$ (ppb) | 7.9 | 2.8 | 4.7 | 0.36 | 4.3 | 13 |
| $O_3$ (ppb) | 2.7 | 5.1 | 2.3 | 7.9 | -5.6 | 0.29 |
| $SO_2$ (ppb) | 3.9 | 2.9 | 1.2 | 1.0 | 0.20 | 1.2 |
| $PM_{10}$ ($\mu g\ m^{-3}$) | 9.6 | 7.7 | 4.6 | 0.36 | 4.2 | 13 |
| CO (ppm) | 0.43 | 0.090 | 0.34 | 0.14 | 0.20 | 2.4 |

[a] Urban difference = urban exposure in 1990 (2000 for $PM_{2.5}$) - urban exposure in 2010

[b] Rural difference = rural exposure in 1990 (2000 for $PM_{2.5}$) - rural exposure in 2010

[c] Urban absolute disparity difference = urban disparity in 1990 - urban disparity in 2010

[d] Rural absolute disparity difference = rural disparity in 1990 - rural disparity in 2010

[e] Urban versus rural disparity reduction = Urban absolute disparity difference - rural absolute disparity difference

[f] Urban versus rural disparity reduction ratio = Urban absolute disparity difference/rural absolute disparity difference

[g] For $PM_{2.5}$, 1990 data is replaced with 2000 data

**Table S32. Population-weighted exposure for counterfactual scenarios of migration**

| A. | $PM_{2.5}$ ($\mu g\ m^{-3}$) | $NO_2$ (ppb) | $O_3$ (ppb) | $SO_2$ (ppb) | $PM_{10}$ ($\mu g\ m^{-3}$) | CO (ppm) |
|---|---|---|---|---|---|---|
| NH-White | NA | 13 | 49 | 5 | 26 | 0.62 |
| NH-Black | NA | 18 | 51 | 6 | 29 | 0.75 |
| Hispanic | NA | 23 | 48 | 5 | 32 | 0.99 |
| NH-Asian | NA | 22 | 47 | 5 | 34 | 0.99 |

| B. | $PM_{2.5}$ ($\mu g\ m^{-3}$) | $NO_2$ (ppb) | $O_3$ (ppb) | $SO_2$ (ppb) | $PM_{10}$ ($\mu g\ m^{-3}$) | CO (ppm) |
|---|---|---|---|---|---|---|
| NH-White | NA | 12 | 49 | 4 | 22 | 0.46 |
| NH-Black | NA | 16 | 49 | 4 | 24 | 0.53 |
| Hispanic | NA | 20 | 47 | 3 | 27 | 0.67 |
| NH-Asian | NA | 20 | 46 | 3 | 29 | 0.68 |

| C. | $PM_{2.5}$ ($\mu g\ m^{-3}$) | $NO_2$ (ppb) | $O_3$ (ppb) | $SO_2$ (ppb) | $PM_{10}$ ($\mu g\ m^{-3}$) | CO (ppm) |
|---|---|---|---|---|---|---|
| NH-White | 12 | 11 | 49 | 3.5 | 22 | 0.44 |
| NH-Black | 14 | 15 | 50 | 4.0 | 24 | 0.51 |
| Hispanic | 14 | 18 | 47 | 3.4 | 26 | 0.62 |
| NH-Asian | 13 | 17 | 48 | 3.0 | 27 | 0.60 |

| D. | $PM_{2.5}$ ($\mu g\ m^{-3}$) | $NO_2$ (ppb) | $O_3$ (ppb) | $SO_2$ (ppb) | $PM_{10}$ ($\mu g\ m^{-3}$) | CO (ppm) |
|---|---|---|---|---|---|---|
| NH-White | 9.2 | 7.4 | 46 | 1.6 | 18 | 0.30 |
| NH-Black | 10 | 10 | 46 | 1.7 | 19 | 0.33 |
| Hispanic | 10 | 12 | 46 | 1.4 | 20 | 0.35 |
| NH-Asian | 10 | 12 | 45 | 1.4 | 21 | 0.36 |

A. Population-weighted exposure for counterfactual scenarios of 1990 air pollution with 2000 demographic
B. Population-weighted exposure for counterfactual scenarios of 2000 air pollution with 1990 demographic
C. Population-weighted exposure for counterfactual scenarios of 2000 air pollution with 2010 demographic
D. Population-weighted exposure for counterfactual scenarios of 2010 air pollution with 2000 demographic

**Table S33. Contribution of air pollution concentration change over time for actual absolute racial-ethnic disparity by using counterfactual scenarios of migration**

| I. (%) | $PM_{2.5}$ | $NO_2$ | $O_3$ | $SO_2$ | $PM_{10}$ | CO |
|---|---|---|---|---|---|---|
| NH-White | NA | 74 | -32 | 97 | 95 | 94 |
| NH-Black | NA | 83 | 125 | 95 | 95 | 96 |
| Hispanic | NA | 86 | 146 | 103 | 93 | 95 |
| NH-Asian | NA | 73 | 35 | 96 | 89 | 92 |
| Average | 87 | | | | | |

| II. (%) | $PM_{2.5}$ | $NO_2$ | $O_3$ | $SO_2$ | $PM_{10}$ | CO |
|---|---|---|---|---|---|---|
| NH-White | 97 | 95 | 100 | 99 | 97 | 99 |
| NH-Black | 97 | 91 | 98 | 97 | 96 | 98 |
| Hispanic | 97 | 91 | 107 | 98 | 97 | 98 |
| NH-Asian | 97 | 86 | 103 | 98 | 94 | 96 |
| Average | 97 | | | | | |

I. (Population-weighted exposure for real-world scenario of 1990 air pollution with 1990 demographic - (Population-weighted exposure for counterfactual scenario of 2000 air pollution with 1990 demographic)/ (Population-weighted exposure for real-world scenario of 1990 air pollution with 1990 demographic - (Population-weighted exposure for real-world scenario of 2000 air pollution with 2000 demographic) ×100%

II. (Population-weighted exposure for real-world scenario of 2000 air pollution with 2000 demographic - (Population-weighted exposure for counterfactual scenario of 2010 air pollution with 2000 demographic)/ (Population-weighted exposure for real-world scenario of 2000 air pollution with 2000 demographic - (Population-weighted exposure for real-world scenario of 2010 air pollution with 2010 demographic) ×100%