Supplemental Information

Refined ambient $PM_{2.5}$ exposure surrogates and the risk of myocardial infarction

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Air Exchange Rates

Calculation Method

Air exchange rates were calculated at the census tract level using the Lawrence Berkeley National Laboratory (LBNL) Infiltration Model (Sherman and Grimsrud, 1980) and an adjustment to account for open windows. The LBNL infiltration model predicts AER for single-family, closed homes (i.e. windows and doors closed) based on the leakage area, certain house characteristics, and meteorological conditions. Although the mechanisms driving airflow across a crack are well defined, the characteristics of cracks in buildings are not well known and are likely to be highly varied within and across buildings (Liu and Nazaroff, 2001). As a result, home leakiness is commonly quantified in terms of overall leakiness of the building shell, or effective leakage area (ELA; Chan et al., 2005). We calculated the distributions of normalized leakage (NL; ELA normalized by floor area) in each census tract using the regression analysis of Chan et al. (2005). Separate models were used depending on household poverty status because these factors affect home leakiness (Chan et al., 2005):

$$NL_{low\,income} = \exp[11.1 - (5.37 \times 10^{-3} \times \text{year built}) - (4.18 \times 10^{-3} \times \text{floor area})] \quad (1)$$

$$NL_{conventional} = \exp[11.1 - (1.07 \times 10^{-2} \times \text{year built}) - (2.20 \times 10^{-3} \times \text{floor area})] \quad (2)$$

Resident poverty status, home-age and year-built distributions of the housing units in each census tract were retrieved from the Census 2000 Summary File 3 (SF3) available at the American Fact Finder website (http://factfinder.census.gov) and American Housing Survey (*www.census.gov/hhes/www/ahs. html)*. In cases where needed parameters were not available separately for single-family and multi-unit residences, housing units that were listed as "owner-occupied" were assumed to be single-family residences. Floor area, which is not directly available through the Census, was estimated from the distribution of number of rooms in each housing unit (available from SF3) and data relating number of rooms to floor area from the American Housing Survey. AER distributions were then calculated from the NL distributions:

$$AER = \frac{NL}{1000 \times h_f}\left(\frac{2.5}{H}\right)^{0.3} s \quad (3)$$

H is the building height and h_f is the height of the building's ceiling. The specific infiltration rate (s) is a function of wind velocity (v), the stack parameter (f_s), the wind parameter (f_w), and the indoor-outdoor temperature difference (ΔT):

$$s = \sqrt{f_s^2 \Delta T + f_w^2 v^2} \quad (4)$$

The stack parameter is defined as

$$f_s = \left(\frac{1 + {}^{R}\!/_{2}}{3}\right)\left(1 - \frac{X^2}{(2-R)^2}\right)^{3/2}\left(\frac{gH}{T_o}\right)^{1/2}. \quad (5)$$

R is the fraction of total leakage area contained within the floor and ceiling areas, X is the difference between floor leakage area and ceiling leakage area. H is the ceiling height, T_o is 298 K (77^{o}F), and g is the acceleration due to gravity. The wind parameter is defined as

$$f_w = C(1-R)^{1/3} A\left(\frac{H}{10}\right)^B. \tag{6}$$

C is a parameter that describes the magnitude of wind shielding resulting from obstructions surrounding the building. A and B are parameters that depend on the terrain and land usage surrounding the building. Parameter values and full derivation of the model are available from Sherman and Grimsrud (1980).

We assumed H was constant at 5 m for all homes, a shielding parameter of 4 (obstructions around most of home perimeter), and that half of the total leakage area in each home was contained within the walls (R=0.5). A and B were 0.67 and 0.25, respectively, and correspond to a terrain parameter of 4 (urban, industrial, or forested area). X was held constant at 0.25. We also assumed a constant indoor temperature of 20^{o}C. Outdoor temperatures were retrieved from the same airports as were used to generate apparent temperature estimates as described above.

When outdoor temperatures exceeded 22.5^{o}C, we assumed that all homes without air conditioning had open windows. The percent of homes without air conditioning in each census tract was estimated from air conditioning prevalence data for sub regions of New Jersey available from the American Housing Survey. For homes with open windows, we assumed that indoor temperature was 90% of the outdoor temperature and that having windows open increased leakage area by 0.5 m^2. Hourly air exchange rates were generated with the LBNL Infiltration model and our adjustment for open windows for each case and control period and were then averaged over the same 24 hours to provide community-average AER for each MI.

Model Validation

We validated the distribution of AERs generated with the LBNL infiltration model and our adjustment for open windows against AER measurements performed in Elizabeth, NJ as part of the Relationships of Indoor, Outdoor, and, Personal Air (RIOPA) Study (Weisel et al., 2005). Supplemental Information, Table 1 shows the summary statistics of the distribution of measured AERs for Elizabeth, NJ RIOPA homes and the distribution of AERs predicted using home-specific data gathered as part of the RIOPA study and zip-code level data from the U.S. Census and American Housing Survey. Distributions of measured AERs and AERs modeled with home-specific data are in good agreement (Table 1). There was lesser agreement between measured AERs and those calculated using zip-code level data; however, it should be noted that RIOPA participants were selected to over-represent homes in close proximity to sources and do not reflect a random sampling of the population.

References

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	N	Mean	Median	Standard Deviation
Measured AER	155	1.19	0.88	0.93
Modeled AER (home-specific level)	94	1.17	0.93	0.77
Modeled AER (zip-code-level)	160	0.93	0.61	0.82

Supplemental Information, Table 1. Summary statistics for the distribution of measured air exchange rates (AERs) for Elizabeth, NJ RIOPA homes and for AERs modeled with the LBNL Infiltration Model using home-specific data from the RIOPA questionnaires and zip-code level data gathered from the Census and American Housing Survey for RIOPA home zip codes. The zip-code level calculations are more relevant to the calculated AERs used as inputs for the Tier 2b exposure estimates. However, it should be noted that RIOPA homes were not a representative sample of the housing stock in each Elizabeth zip code.

	Air Exchange Rates (h^{-1})						
Tertile	**Minimum**	**5th**	**25th**	**Median**	**75th**	**95th**	**Maximum**
COOL SEASON							
Low	0.24	0.28	0.36	0.41	0.44	0.46	0.47
Middle	0.47	0.48	0.50	0.54	0.57	0.60	0.60
High	0.60	0.61	0.63	0.67	0.72	0.81	1.11
WARM SEASON							
Low	0.19	0.28	0.35	0.40	0.44	0.46	0.47
Middle	0.47	0.47	0.50	0.53	0.57	0.60	0.60
High	0.60	0.62	0.67	0.75	0.87	1.05	1.35

Supplemental Information, Table 2. Air exchange rate distributions for the cool season (November – April) and the warm season (May – October). Similarities between AER distributions for the warm and cool seasons can be attributed to the fact that indoor-outdoor temperature differences and human activities such as opening windows are major drivers of AER. The warm and cold seasons explored here included the transitional seasons spring and fall, respectively, which tend to have similar distributions of indoor-outdoor temperature difference. At the colder extremes of outdoor temperature, homes with heating in use have large differences in indoor and outdoor temperatures, resulting in higher AERs. This is also true for homes with air conditioning in use during warm days. While air conditioning prevalence is relatively low in the region studied, higher AERs can also occur during the warmer months because open windows allow greater air exchange.

	Mass Fraction	
$PM_{2.5}$ Species	**Cool Season**	**Warm Season**
Sulfate	0.43 ± 0.13	0.50 ± 0.14
Nitrate	0.25 ± 0.11	0.10 ± 0.06
Elemental Carbon	0.07 ± 0.03	0.07 ± 0.04
Organic Carbon	0.25 ± 0.12	0.33 ± 0.14
	Mass Concentration (μg/m^3)	
Total $PM_{2.5}$	10.2 ± 6.1	11.4 ± 8.4

Supplemental Information, Table 3. Study-period average species mass fractions of the major $PM_{2.5}$ species and total $PM_{2.5}$ concentrations ± standard deviations in the cool (November to April) and warm (May to October) seasons measured at the New Brunswick central-site monitor.

Central Site $PM_{2.5}$ Monitor	AER tertile	# of MI	Percent of tertile- specific MI assigned to monitor
Camden	Low	110	21.9%
Elizabeth	Low	78	15.5%
Flemington	Low	17	3.4%
Jersey City	Low	20	4.0%
Millville	Low	20	4.0%
New Brunswick	Low	222	44.1%
Rahway	Low	36	7.2%
Camden	Medium	164	32.3%
Elizabeth	Medium	183	36.0%
Jersey City	Medium	34	6.7%
Flemington	Medium	0	0.0%
Millville	Medium	28	5.5%
New Brunswick	Medium	69	13.6%
Rahway	Medium	30	5.9%
Camden	High	44	8.6%
Elizabeth	High	320	62.4%
Flemington	High	0	0.0%
Jersey City	High	98	19.1%
Millville	High	5	1.0%
New Brunswick	High	1	0.2%
Rahway	High	45	8.8%

Supplemental Information, Table 4. Number and percent of MIs assigned to each PM2.5-monitoring-site-community by AER tertile

Tier	IQR	N	AIC	OR	95% CI	p-value
Tier 1	10.3	1561	4397.4	1.10	1.01, 1.19	0.03
Tier 2A SHEDS	5.4		4397.2	1.10	1.01, 1.20	0.03
Tier 1	10.3	1552*	4367.7	1.09	1.01, 1.19	0.04
Tier 2B APP	5.4		4366.8	1.10	1.10, 1.20	0.02
Tier 1	10.3	1561	4397.4	1.10	1.01, 1.19	0.03
Tier 3 HYBRID	5.4		4396.1	1.10	1.02, 1.20	0.01

Supplemental Information, Table 5. Relative odds of a transmural infarction associated with an IQR increase in $PM_{2.5}$ concentration, by exposure Tier. Refined exposure estimates were calculated at the zip-code level rather than at the one-value-per-monitor level presented in the main analysis. We observed no change in ORs, 95% CIs, nor AIC values for this spatial resolution compared to the main analysis.

* Subjects were excluded if there was a period of more than nine days between STN measurements for the case period or all control periods

	Total Transmural MI (n = 745) n(%)	Low AER Tertile (n = 244) n(%)	Middle AER Tertile (n = 302) n(%)	High AER Tertile (n=199) n(%)
Age (Years)				
18-44	58 (8)	20 (8)	22 (7)	16 (8)
45-54	152 (20)	47 (19)	58 (19)	47 (24)
55-64	184 (25)	64 (26)	69 (23)	51 (26)
65-74	151 (20)	51 (21)	61 (20)	39 (20)
75-84	141 (19)	40 (16)	70 (23)	31 (16)
≥ 85	59 (8)	22 (9)	22 (7)	15 (8)
Sex				
Male	460 (62)	157 (64)	180 (60)	123 (62)
Female	285 (38)	87 (36)	122 (40)	76 (38)
Race				
White	520 (70)	173 (71)	206 (68)	141 (71)
Black	85 (11)	18 (7)	38 (13)	29 (15)
Other	140 (19)	53 (22)	58 (19)	29 (15)
Year				
2004	209 (28)	70 (29)	90 (30)	49 (25)
2005	205 (28)	41 (17)	92 (30)	72 (36)
2006	331 (44)	133 (55)	120 (40)	78 (39)
Comorbidities				
Hypertension	411 (55)	135 (55)	169 (56)	107 (54)
Diabetes Mellitus	195 (26)	63 (26)	78 (26)	54 (27)
Type I Diabetes	4 (1)	0 (0)	3 (1)	1 (1)
Type II Diabetes	141 (19)	45 (18)	58 (19)	38 (19)
COPD	81 (11)	28 (11)	34 (11)	19 (10)
Pneumonia	31 (4)	12 (5)	9 (3)	10 (5)
Heart Disease	636 (85)	210 (86)	258 (85)	168 (84)

Supplemental Information, Table 6. Frequency and percentage of study subjects included in the "AER Effect Modification" analysis and within AER tertiles in the cool season (November - April).

Characteristic	Total Transmural MI (n = 779) n(%)	Low AER Tertile (n = 259) n(%)	Middle AER Tertile (n = 206) n(%)	High AER Tertile (n=314) n(%)
Age (Years)				
18-44	76 (10)	25 (10)	20 (10)	31 (10)
45-54	167 (21)	51 (20)	40 (19)	76 (24)
55-64	207 (27)	71 (27)	60 (29)	76 (24)
65-74	140 (18)	52 (20)	32 (16)	56 (18)
75-84	128 (16)	41 (16)	36 (17)	51 (16)
≥ 85	61 (8)	19 (7)	18 (9)	24 (8)
Sex				
Male	493 (63)	168 (65)	123 (60)	202 (64)
Female	286 (37)	91 (35)	83 (40)	112 (36)
Race				
White	538 (69)	177 (68)	146 (71)	215 (68)
Black	87 (11)	29 (11)	21 (10)	37 (12)
Other	154 (20)	53 (20)	39 (19)	62 (20)
Year				
2004	226 (29)	65 (25)	77 (37)	84 (27)
2005	178 (23)	59 (23)	49 (24)	70 (22)
2006	375 (48)	135 (52)	80 (39)	160 (51)
Comorbidity				
Hypertension	435 (56)	146 (56)	116 (56)	173 (55)
Diabetes Mellitus	220 (28)	82 (32)	51 (25)	87 (28)
Type I Diabetes	9 (1)	3 (1)	4 (2)	1 (0.3)
Type II Diabetes	166 (21)	61 (24)	36 (17)	69 (22)
COPD	82 (10)	20 (8)	29 (14)	33 (11)
Pneumonia	26 (3)	10 (4)	5 (2)	11 (4)
Heart Disease	656 (84)	218 (84)	175 (85)	263 (84)

Supplemental Information, Table 7. Frequency and percentage of study subjects included in the "AER Effect Modification" analysis and within AER tertiles in the warm season (May - October).