Multi-Pollutant Exposure Assessment Study of Children, Steubenville, OH

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BACKGROUND

Air pollution exposure studies have consistently shown ambient fine particle ($PM_{2.5}$) concentrations to be strong proxies of corresponding personal exposures. Even stronger ambient-personal relationships have been demonstrated for sulfate (SO_4^{2-}), a major $PM_{2.5}$ component, while weaker, albeit generally significant, ambient-personal associations have been found for elemental carbon (EC), a fine particle component generally associated with traffic. These associations have been demonstrated primarily for healthy adults and for older adults with pre-existing cardiovascular and pulmonary disease. Less is known about the ability of ambient PM to reflect the PM exposures of children, a potentially sensitive and more active subpopulation.

This study was conducted to assess the ability of ambient PM to reflect corresponding exposures for children through the characterization of personal, indoor, and outdoor concentrations of $PM_{2.5}$ and its major components, SO_4^{2-} and EC.

STUDY DESIGN

A study was conducted to characterize the air pollution exposures for a panel of children (9-13 years) living in Steubenville, Ohio, a small city located in the Ohio River Valley. As part of this study, personal, indoor, and outdoor $PM_{2.5}$, EC, SO_4^{2-}, SO_2, NO_2, and O_3 exposures were measured for each child for 24-h on seven days (Figure 2). Air pollutant samples were also collected daily at a central monitoring site located at the Franciscan University of Steubenville.

Sampling was conducted during two seasons: winter (1/20 - 3/4/2001) and summer (6/1 - 7/3/2001). Sixteen (10 girls, 6 boys) children participated in the winter session, while fifteen (10 girls, 5 boys) participated in the summer. Twelve of the children were monitored in both seasons. All children lived in non-smoking households and in single-family dwellings located throughout Steubenville (Figure 1).

All air pollution samples were collected using our multi-pollutant sampler (MPS) (Figure 3). Information on activities and time spent in various microenvironments was also obtained for each child on each monitoring day using activity diaries and housing characteristic questionnaires. This study was conducted as part of the larger Steubenville Comprehensive Air Monitoring Project (SCAMP).

Figure 1. Sampling Locations

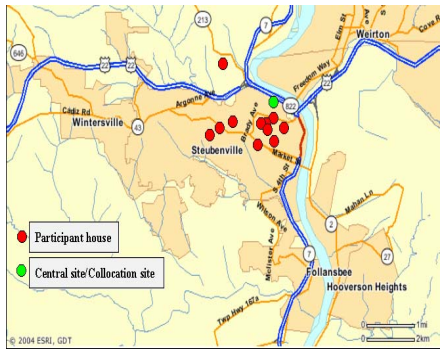


Figure 2. Monitoring Plan

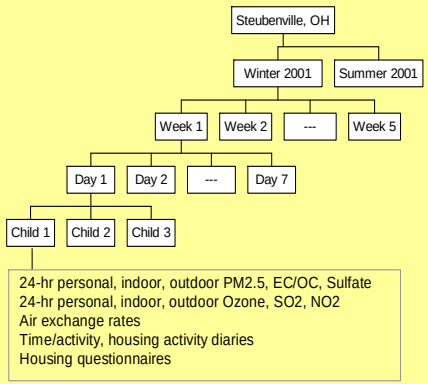


Figure 3. Multi-pollutant Sampler

- Two $PM_{2.5}$ PEMs to measure fine particulate mass and metal concentrations
- Two $PM_{2.5}$ MiniPEMs to measure EC and SO_4^{2-}
- Two Ogawa passive samplers to measure SO_2, NO_2, and O_3

RESULTS AND DISCUSSION

Mean personal $PM_{2.5}$ exposures were generally lower than corresponding mean outdoor concentrations and higher than mean indoor concentrations (Table 1). Similarly, mean personal exposures for SO_4^{2-} and EC were lower than those outdoors, but were comparable to mean indoor concentrations (Table 1). Associations between personal exposures and ambient concentrations differed by particulate measure and by season. Personal-ambient associations were strongest for SO_4^{2-}, a regional pollutant with few indoor sources, with a slope and crude R^2 value higher during the summer as compared to winter months (Table 2). Weaker, although still significant personal-ambient associations were also found for $PM_{2.5}$ and EC in the summer. In the winter, however, associations between personal $PM_{2.5}$ and EC exposures and corresponding ambient concentrations were insignificant, as ambient concentrations explained virtually none of the variability in personal exposures. Stronger associations in the summer as compared to winter is consistent with the fact that the effective penetration efficiency of ambient particles is generally greater during the summer due to increased indoor ventilation. Stronger associations for SO_4^{2-} as compared to PM2.5 and EC may be attributed to its lack of indoor sources and also possibly due to higher effective penetration efficiencies. Both summer and winter slopes and R^2 values in Steubenville are lower than those found in our exposure study of children in Baltimore and in Boston (Table 3).

Table 1. Summary Statistics for Personal, Indoor and Outdoor PM

Pollutant	WINTER			SUMMER		
	N	Mean (SD) (μg/m³)	Max (μg/m³)	N	Mean (SD) (μg/m³)	Max (μg/m³)
$PM_{2.5}$:						
Personal	105	11.7 (6.6)	33.8	102	20.1 (13.0)	62.5
Indoor	107	9.3 (5.8)	30.7	104	18.8 (12.5)	60.5
Outdoor	104	13.5 (6.0)	36.1	103	24.5 (13.5)	57.4
EC:						
Personal	104	0.6 (0.5)	4.3	99	1.1 (4.0)	35.5
Indoor	104	0.6 (0.7)	4.8	103	0.7 (1.6)	16.1
Outdoor	100	0.6 (0.3)	1.4	101	0.7 (0.3)	1.6
SO_4^{2-}:						
Personal	104	1.9 (1.2)	6.5	100	6.2 (4.7)	22.9
Indoor	102	1.9 (1.2)	7.1	101	5.8 (4.7)	23.2
Outdoor	102	3.4 (1.7)	10.7	101	9.0 (5.9)	24.8

Table 2. Relationship between Personal PM Exposures and Ambient Concentrations

Pollutant	Crude R^2	Slope (SE)	Intercept (SE)
$PM_{2.5}$:	0.39	**0.58 (0.05)**	**4.6 (1.3)**
Summer	0.38	**0.62 (0.08)**	4.8 (2.3)
Winter	0.05	**0.24 (0.10)**	**8.1 (1.6)**
EC†:	0.12	**0.40 (0.09)**	**0.36 (0.07)**
Summer	0.32	**0.60 (0.10)**	**0.19 (0.07)**
Winter	0.05	0.22 (15.0)	**0.51 (0.11)**
SO_4^{2-}:	0.77	**0.70 (0.03)**	−0.22 (0.27)
Summer	0.70	**0.70 (0.04)**	0.05 (0.54)
Winter	0.54	**0.55 (0.05)**	0.03 (0.20)

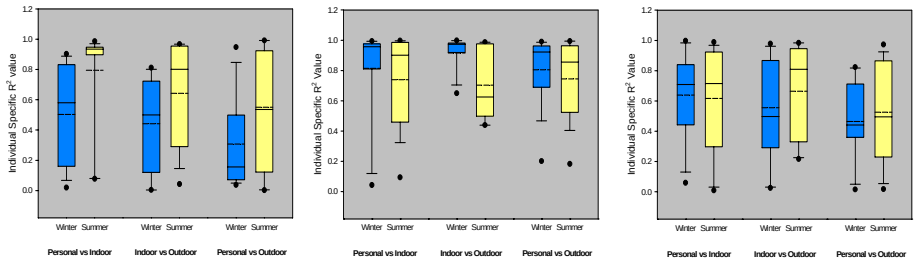
Crude R^2 calculated using simple linear regression models. Slope and std. deviation calculated using mixed models regression analysis. Bold values indicate significance at 0.05 level.
† Four personal samples collected during periods of candle burning were omitted from the EC analysis.

When analyzed by participant, considerable inter-personal variability in the association between personal exposures and ambient concentrations was found for each of the particulate measures, even for SO_4^{2-} and even during the summer when overall associations were strong (Figure 4). Median individual-specific R^2 values ranged widely by participant, with associations significant for some individuals and insignificant for others. Results indicate that the ability of ambient concentrations to reflect personal exposures will vary by child and by particulate component.

Table 3. Personal-Ambient Associations: by Study

City / Season	Slope	Intercept
Steubenville		
Winter	0.24 ± 0.10*	8.1± 1.6
Summer	0.62 ± 0.08	4.8 ± 2.3
Baltimore		
Winter	0.27	18.0
Summer	0.70	5.6
Boston		
Winter	0.39	13.4
Summer	0.89	14.2

Figure 4. Individual-Specific R^2 Values for Personal, Indoor, and Outdoor Comparisons



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