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Childhood exposure to PM_{10}: relation between personal, classroom, and outdoor concentrations

Nicole A H Janssen, Gerard Hoek, Hendrik Harssema, Bert Brunekreef

Abstract

***Objectives*—To investigate the validity of outdoor concentrations of particulate matter <10 µm diameter (PM_{10}) as a measure of exposure in time series studies, and to study the extent to which differences between personal and outdoor PM_{10} concentrations can be explained.**

***Methods*—Four to eight repeated measurements of personal and outdoor PM_{10} concentrations were conducted for 45 children, aged 10–12 years, from four schools in Wageningen and Amsterdam, The Netherlands. Repeated PM_{10} measurements in the classrooms were conducted in three of the schools. Averaging time was 24 hours for the personal and outdoor measurements, and eight hours (daytime) and 24 hours for the classroom measurements. For each child separately, personal exposures were related to outdoor concentrations in a regression analysis. The distribution of the individual correlation and regression coefficients was investigated. Information about factors that might influence personal exposures was obtained by questionnaire.**

***Results*—Median Pearson's correlations between personal and outdoor concentrations were 0.63 for children with parents who did not smoke and 0.59 for children with parents who smoked. For children with parents who did not smoke, excluding days with exposure to environmental tobacco smoke (ETS) improved the correlation to a median *R* of 0.73. The mean personal PM_{10} concentration was 105 µg/m^3; on average 67 µg/m^3 higher than the corresponding outdoor concentrations. The main part of this difference could be attributed to exposure to ETS, to high PM_{10} concentrations in the classrooms, and to (indoor) physical activity.**

***Conclusions*—The results show a reasonably high correlation between repeated personal and outdoor PM_{10} measurements within children, providing support for the use of fixed site measurements as a measure of exposure to PM_{10} in epidemiological time series studies. The large differences between personal and outdoor PM_{10} concentrations probably result from a child's proximity to particle generating sources and particles resuspended by personal activities.**

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Several recent studies have documented associations between the day to day variation of air pollution by particulate matter and acute health effects on children, including increased respiratory symptoms and decreased lung function.[1–5] In these studies, exposure assessment was based on fixed site measurements in ambient air. Measurements of personal exposure are considered to be a more accurate estimate of the subject's true exposure.[6] Children's personal exposures to particles have rarely been studied. Studies among adults suggest that outdoor concentrations of particle mass correlate poorly with personal exposures.[7] If the variation in outdoor concentrations of particulate matter is not tightly linked to variation in personal exposures, use of outdoor concentrations as a surrogate for personal exposures would tend to misclassify personal exposures and exposure-response relations could be attentuated.[8] However, in most personal exposure studies the correlation between personal and outdoor concentrations was calculated cross sectionally: personal exposure data were collected from a group of subjects by measuring different subsets of subjects on different days (different ambient concentrations) and measuring each subject once or only a limited number of times. Next, one correlation coefficient was calculated, with all measurements from all subjects and days. This correlation is influenced by the variation in personal exposure between subjects. As time series studies relate day to day variations in outdoor concentrations to day to day variations of health end points, the correlation between personal and ambient concentrations within a person, over time, is more relevant than the variation between people. This correlation may be better because factors that can cause variation between subjects, such as exposure to environmental tobacco smoke (ETS), are less variable in time within subjects, and therefore mainly cause variation between subjects. At present, only limited information is available about the correlation within a subject between personal and outdoor concentrations of particulate matter <10 µm diameter (PM_{10}).[9 10]

To investigate the validity of outdoor concentrations as a measure of exposure to PM_{10} in time series studies, we conducted a personal exposure study in which repeated measurements of personal and outdoor PM_{10} were conducted to allow calculation of the correlation between outdoor and personal measurements

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of PM_{10}, within subjects, over time. This paper describes the relation between personal and outdoor PM_{10} concentrations in a group of 10–12 year old children.

Methods

STUDY DESIGN

Children aged 10–12 were recruited through schools; two in Wageningen, a non-industrial town of about 35 000 inhabitants, and two in Amsterdam, the capital of The Netherlands. All children in one class were asked to participate by means of a presentation in their classroom, which included a demonstration of the sampling equipment. The children received a written description and informed consent form for their parents. Out of 57 children in Wageningen 33 (58%) and out of 56 children in Amsterdam 15 (27%) participated. Of those 48 children 45 successfully completed the study.

Measurements took place in two periods: from 16 February to 19 April 1994 (one school in Wageningen) and from 11 January to 18 May 1995 (three schools). Seven to eight measurements per child were planned. Measurements of 24 hour averaged personal PM_{10} values were conducted on weekdays only, spaced about one week apart. Samplers were distributed and collected at school, except for the first measurement when samplers were distributed to the children's homes to provide individual instruction to the children in the presence of a parent. Children were instructed to wear the sampler whenever possible. At night the sampler was placed near the bed. Outdoor PM_{10} measurements were conducted at fixed sites. Classroom PM_{10} measurements were added to the study in 1995 (three schools).

Information on general characteristics such as parental smoking was collected by questionnaire. Also, parents were asked to fill out a questionnaire about each day of personal measurements, including questions on exposure to ETS, time spent in several microenvironments, and cleaning and cooking activities conducted by or in the presence of the child. After each day of measurements these questionnaires were collected from the children's homes and checked for completeness and accuracy of the answers. Exposure to ETS was assessed by the following questions:

Has anybody smoked in your living room during the measurements?

Has your child been in a room, other than your own living room, where people smoked?

In 1995 a question on physical activity was added to the questionnaire:

Has your child done any activities during which he or she was physically active?

If yes, what kind of activities?

Examples of activities were given to clarify this question.

SAMPLING METHODS

Personal measurements were conducted with a personal impactor described by Buckley *et al*,[9] with 25 mm diameter 3 µm pore size Gelman Teflon filters and a flow controlled battery operated pump (Gillian, model Gil-air 5). Details about the sampling method and quality issues are described elsewhere.[11]

Outdoor PM_{10} was measured with the personal sampler at a fixed site. In Amsterdam this site was located in a park in the city centre, about 150 m away from the nearest road; in Wageningen the equipment was placed in a meadow on the outskirts of the town about 500 m away from the nearest road. Both sites were away from local particle sources such as unpaved roads, construction work, or industrial sources. Measurements were conducted at a height of 1.5 m. Co-located operation of the personal sampler with a Harvard impactor and a Sierra Anderson sampler in Amsterdam showed highly correlated outdoor concentrations (R 0.91–0.95) and no significant differences in concentrations obtained with the different methods.[11]

In 1995, PM_{10} measurements in classrooms were conducted with a Harvard impactor (ADE, Harrison, Maine, USA).[12] A flow controlled pump (ADE, model SP-280E) and Anderson 37 mm 2 µm pore size Teflon filters were used. Measurements were conducted at a height of 1.5 m, away from the door and the blackboard. Two averaging times were used: 24 hour measurements at the same time as the personal measurements (1500–1500) and eight hour measurements when the children were at school (0800–1600).

For the personal and classroom measurements, flows were measured at the beginning and end of each sampling period with calibrated rotameters, and elapsed time indicators were used to calculate the sampled volumes. For the outdoor measurements sampled volumes were assessed with calibrated dry gas meters. Measurements that had lasted for less than 20 hours were excluded.

In 1994, filters were weighed on an analytical balance with a 10 µg reading. In 1995 a microbalance was used to weigh the personal and outdoor filters. Classroom filters were weighed on the analytical balance. All filters were weighed twice after equilibrating at 20°C and 44% relative humidity for 24 hours in a desic-

Table 1 Distribution of individual averages of personal and ambient PM_{10}

			Personal (µg/m³)			Ambient (µg/m³)			Difference (µg/m³)		
School	n*	(N)	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Wageningen, 1994	15	(89)	111.0	23.4	83.7–167.0	43.0	7.2	24.5–55.8	68.1	27.3	40.6–142.4
Amsterdam 1995, school 1	6	(41)	105.3	16.6	76.1–121.8	39.2	1.1	37.5–40.8	66.1	17.1	35.3–81.7
Amsterdam 1995, school 2	7	(48)	88.8	31.6	56.9–140.2	36.5	2.6	32.7–39.1	52.3	31.4	22.7–106.6
Wageningen 1995	17	(123)	106.8	34.2	71.3–195.4	35.0	2.3	29.7–39.1	71.8	34.7	35.4–160.1
Total	45	(301)	105.2	28.7	56.9–195.4	38.5	5.6	24.5–55.8	66.8	29.8	22.7–160.1

*Number of children. N=Number of measurements.

Table 2 PM_{10} *concentrations in classrooms (µg/m³)*

	Amsterdam 1995, school 1 (n=15)			*Amsterdam 1995, school 2 (n=15)*			*Wageningen 1995 (n=11)*		
	Mean	*SD*	*Range*	*Mean*	*SD*	*Range*	*Mean*	*SD*	*Range*
Averaging 8 h	157.0	38.8	96.2–234.1	80.8	18.7	57.1–127.0	134.1	42.1	66.3–198.6
Averaging 24 h	74.4	19.6	32.1–108.2	45.9	13.9	30.7–79.5	63.1	20.7	37.8–105.6
Outdoor	34.0	14.0	14.7–75.2	34.5	13.8	14.7–75.2	32.0	14.4	16.6–71.5
Estimated 16 h†	37.0	17.4	-1.1–58.7	30.0	14.8	12.9–64.1	33.7	21.8	-0.7–80.3
Difference 8–24‡	82.6***	25.1	34.1–126.0	34.9***	11.9	15.7–64.9	71.0***	29.0	27.9–112.4
Difference 8–outdoor§	123.0***	41.8	57.2–200.8	46.4***	13.1	28.6–76.5	102.1***	36.3	49.7–149.8
Difference 24–outdoor¶	40.4***	21.3	1.0–74.8	11.5**	11.9	-2.2–40.5	31.1***	16.8	11.6–72.4

**P<0.01; ***P<0.001, *t* test mean=0
†Estimated classroom concentration during non-school hours: estimated 16 h=$(C_{24\ hours} \times t_{24\ hours} - C_{8\ hours} \times t_{8\ hours})/(t_{24\ hours} - t_{8\ hours})$.
‡Difference between 8 h averaged and 24 hour averaged concentrations.
§Difference between 8 h averaged and outdoor concentrations.
¶Difference between 24 h averaged and outdoor concentrations.

cator. Mean field blank weight changes were subtracted from all sample weights. Detection limits, defined as three times the SD in field blanks divided by the sampled volume, of personal and outdoor measurements were 10.8 µg/m³ in 1994 and 8.6 µg/m³ in 1995. The detection limits of the classroom measurements were 3.7 µg/m³ for the 24 hour measurements and 11.1 µg/m³ for the eight hour average. All measurements were above the detection limit.

DATA ANALYSIS

Correlation between personal and outdoor concentrations

The correlation between personal and outdoor PM_{10} concentrations was assessed by means of individual regression analysis, with the following model:

$$PM_{10personal,it} = \alpha_i + \beta_i \times PM_{10outdoors,it}$$

where:

i=child i and t=day t.

The distribution of the individual regression results was investigated. Medians are presented because not all regression results were normally distributed for all models. The 95% confidence intervals were calculated with a non-parametric method published by Campbell and Gardner.[13]

All children were non-smokers. No selection on parental smoking was made. Children with parents who did not smoke could be exposed to ETS elsewhere or at home—for example, when a visitor smoked. The influence of exposure to ETS on the relation between personal and outdoor concentrations was investigated by stratifying for parental smoking and by excluding days that children with parents who did not smoke were exposed to ETS.

The influence of time spent outdoors on the relation between personal and outdoor PM_{10} was assessed by adding an interaction term "much time spent outdoors × outdoor concentration" to the regression model. The variable "much time spent outdoors" was assigned 1 for measurement days that a child had spent more time outdoors than the median amount of time spent outdoors and 0 for the other days.

The influence of PM_{10} exposure in the classroom on the relation between personal and outdoor PM_{10} was assessed by regressing the personal exposures against a time weighted concentration C_{tw}:

$$C_{tw} = (C_{classroom,\ 8\ h} \times 6\ h + C_{outdoors,\ 24\ h} \times 18\ h)/24\ h$$

where:

$C_{classroom,\ 8\ h}$ = 8 h averaged concentration in the classroom; $C_{outdoors}$= concentrations outdoors (24 hour averaged); 6 h= number of hours spent at school.

Regression analyses with the outdoor and classroom concentrations as two separate independent variables was not conducted because one school's daytime classroom concentrations were highly correlated with outdoor concentrations (*R* 0.91).

For comparison purposes we calculated what the correlation would have been if it had been calculated cross sectionally. In this analysis, we randomly selected one measurement per subject and next calculated the cross sectional correlation between personal and outdoor concentrations. This procedure was repeated 1000 times and the mean of those 1000 correlation coefficients was calculated to get a more reliable estimate of the cross sectional correlation.

Difference between personal and ambient concentrations

The questionnaire data were used to examine to what extent differences between personal and ambient concentrations could be explained by certain activities—such as exposure to ETS. The difference between personal exposures and time weighted concentrations was used as the dependent variable in a regression analysis. The SAS (statistical analysis system) procedure "PROC MIXED" was used to adjust regression results for correla-

Table 3 *Distribution of individual averages of personal and time weighted* PM_{10} *concentrations (µg/m³)*

	All children (n=30)			*Children with non-smoking parents (n=16)*			*Children with smoking parents (n=14)*		
	Mean	*SD*	*Range*	*Mean*	*SD*	*Range*	*Mean*	*SD*	*Range*
Personal	102.3	30.9	56.9–195.4	84.0	17.3	56.9–126.4	123.3	30.0	80.1–195.4
C_{tw}*	58.9	7.5	42.5–67.2	58.9	8.0	42.6–67.2	58.9	7.3	42.5–65.8
Difference	43.4	30.8	8.7–134.2	25.1	14.8	8.7–64.4	64.4	31.2	31.8–134.2

*Time weighted average of outdoor and classroom PM_{10} concentrations.

Table 4 Distribution of individual regression result: regression of $PM_{10\ personal}$ *(Y variable) on* $PM_{10\ outdoors}$ *(X variable)*

	All children (n=45)		*Children with non-smoking parents (n=25)*		*Children with smoking parents (n=20)*	
	Median	*95% CI*	*Median*	*95% CI*	*Median*	*95% CI*
Intercept	75.4	68.4 to 86.9	69.5	53.2 to 75.5	97.3	75.9 to 114.0
Slope	0.57	0.43 to 0.75	0.57	0.40 to 0.77	0.60	0.28 to 1.00
Pearson's *R*	0.63	0.50 to 0.72	0.63	0.50 to 0.80	0.59	0.36 to 0.80

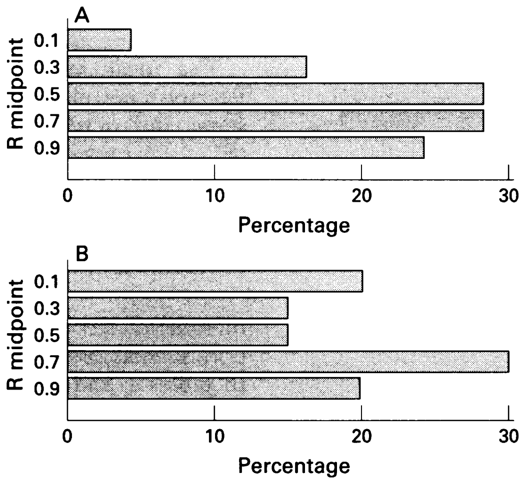

Figure 1 Distribution of individual Pearson's correlation coefficients between personal and outdoor concentrations for children with parents who (A) did not smoke (n=25) and (B) who smoked (n=20).

tions between repeated measurements. A random intercept model was used. Different questions on cleaning activities (dusting, vacuum cleaning, sweeping, and cleaning a pet's cage) were combined into one variable "cleaning activities". Physical activities were divided into four categories: active indoors, pump nearby or carried; active outdoors, pump carried; active outdoors, pump nearby; active, pump elsewhere, which included activities during which the pump had not been at the same site as the child. Active indoors, pump nearby or carried was not divided into two variables because for all but five occasions that indoor physical activities were reported, subjects also reported not to having carried the pump.

Results

POPULATION

Altogether 45 children, 21 boys and 24 girls, participated, 13 children lived in Amsterdam and 32 in Wageningen, and 20 children had a parent who smoked. Of those children 18 were exposed to ETS on all measurement days; two children had one day without exposure to ETS. On days of personal measurements, children spent on average 2.7 hours outdoors, 14.9 hours at home, and 5.7 hours at school.

CONCENTRATIONS

From the 45 participating children 334 personal measurements were conducted, of which 33 samples (9.9%) were lost, mostly due to pump failure.[11] Table 1 shows the distributions of the individual means of personal and outdoor PM_{10}. Personal exposures were on average 67 μg/m^3 higher than outdoor concentrations. The mean coefficients of variation (CV) in personal and outdoor concentrations, and the difference between personal and outdoor concentrations were 22.6%, 56.0%, and 37.6% respectively. Table 2 shows the results of the PM_{10} measurements in the classrooms. In all schools, PM_{10} concentrations during school hours were much higher than during non-school hours. Classroom concentrations, for both 24 and eight hours, were significantly higher than outdoor concentrations. It was striking that in the school with the lowest classroom concentrations (Amsterdam, school 2), the lowest personal concentrations were also measured. Table 3 shows the distribution of the time weighted concentrations. Personal exposures were on average 43 μg/m^3 higher than the time weighted concentrations. This will be discussed in more detail later.

CORRELATION BETWEEN PERSONAL AND OUTDOOR CONCENTRATIONS

Table 4 and figure 1 show the results from the individual regression analyses for the relation between personal and outdoor concentrations. Median Pearson's *R* was 0.63. Median *R* and slope were similar for children with parents who did not smoke and children with parents who smoked. The median intercept was higher for children with parents who smoked. Adding information about time spent outdoors did not improve the correlations: the median slope of the interaction term much time spent outdoors × outdoor concentration was -0.02 and highly non-significant (P=0.82). No consistent differences between Wageningen and Amsterdam were found, in either correlations or in slopes. The mean range (maximum − minimum) in outdoor concentrations on days of personal sampling was 63 μg/m^3 (SD 29; range 13–105 μg/m^3). Excluding children with a range smaller than 25 μg/m^3 (four children), resulted in exclusion of the two highest slopes (>2.5), but did not significantly change the medians.

Table 5 and figure 2 show the results from the regression analyses with the time weighted concentrations instead of the outdoor concentrations. Because measurements in the classrooms were not conducted in 1994, only 30 children are included in table 5. For these 30 children, median Pearson *R* increased from 0.58 to 0.67 for all children, from 0.61 to 0.70 for children with parents who did not smoke and from 0.47 to 0.60 for children with parents who smoked.

Table 6 and figure 3 show the results after excluding days that children with parents who did not smoke were exposed to ETS. Of the 25 children included in table 4 10 were occasionally exposed to ETS and therefore had different regression results in table 6 compared with

Table 5 Distribution of individual regression results: regression of $PM_{10\ personal}$ (Y variable) on $PM_{10\ tw\text{-}model}$ (X variable)

	All children (n=30)		*Children with non-smoking parents (n=16)*		*Children with smoking parents (n=14)*	
	Median	*95% CI*	*Median*	*95% CI*	*Median*	*95% CI*
Intercept	57.2	40.6 to 70.6	42.5	23.2 to 58.4	76.9	53.9 to 147.5
Slope	0.67	0.53 to 0.76	0.65	0.50 to 0.99	0.70	0.03 to 0.81
Pearson's *R*	0.67	0.52 to 0.81	0.70	0.59 to 0.83	0.60	0.02 to 0.81

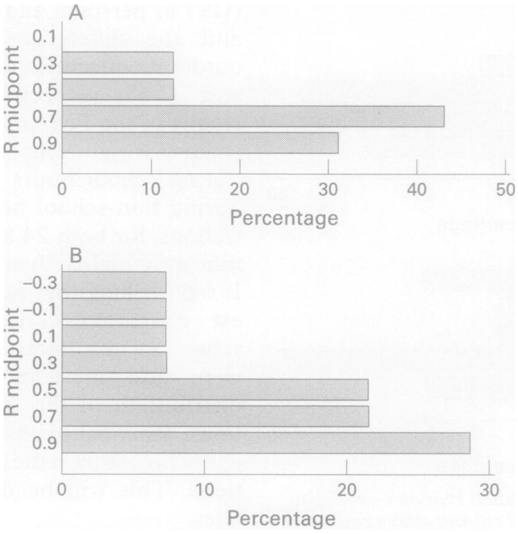

Figure 2 Distribution of individual Pearson correlation coefficients between personal and time weighted concentrations for children with parents who (A) did not smoke (n=16) and (B) who smoked (n=14).

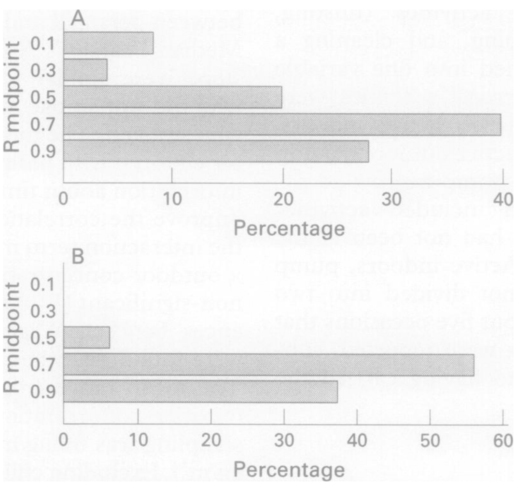

Figure 3 Distribution of individual Pearson's correlation coefficients (A) between personal and outdoor concentration (n=25), and (B) between personal and time weighted concentrations (n=16) for children with parents who did not smoke, after excluding days with exposure to ETS.

table 4. For these 10 children, median Pearson's *R* increased from 0.51 to 0.73. For the correlation between personal and time weighted concentrations, eight children had different regression results in table 6 compared with table 5 and for these eight children median *R* increased from 0.65 to 0.79.

The mean value of 1000 cross sectional Pearson's correlation coefficients between personal and outdoor concentrations was 0.28 (SD 0.12; range -0.11 to 0.60) for all children, 0.45 (SD 0.16; range -0.23 to 0.82) for children with parents who did not smoke and 0.20 (SD 0.19; range -0.46 to 0.82) for children with parents who smoked.

DIFFERENCE BETWEEN PERSONAL AND AMBIENT CONCENTRATIONS

In tables 1 and 3 it was shown that personal exposures were on average 67 $\mu g/m^3$ higher than outdoor concentrations and 43 $\mu g/m^3$ higher than time weighted concentrations. The mean difference between personal and time weighted concentrations was 25 $\mu g/m^3$ for children with parents who did not smoke and 64 $\mu g/m^3$ for children with parents who smoked. The mean difference between personal and time weighted concentrations per school ranged from 39 to 45 $\mu g/m^3$; a much smaller range than that presented in table 1 (52 to 72 $\mu g/m^3$).

Table 7 shows the results from the analyses of the relation between the difference between personal and time weighted concentrations and several personal characteristics or activities. Exposure to ETS and physical activity significantly contributed to the difference between measured personal exposures and the time weighted model predictions. Dividing the physical activities into categories only showed a significant influence of "active indoors". The other activity categories did not have a significant effect. The parameter estimate for active indoors was 12.9 (SE 3.7) $\mu g/m^3$. Time spent outdoors, both as a continuous variable and as a binary variable, did not consistently influence personal exposures and is therefore not included in the model presented in table 7. The intercept of the model is 6.6 $\mu g/m^3$ and not significantly different from zero.

Discussion

CORRELATION BETWEEN PERSONAL AND OUTDOOR CONCENTRATIONS

This study has shown that personal PM_{10} concentrations of children are reasonably well correlated over time with ambient PM_{10} concentrations. The median of the individual correlation coefficients was 0.63 for children with parents who did not smoke and 0.59 for children exposed to parental smoking. The estimated cross sectional correlation coefficients were considerably lower: 0.47 and 0.20 for children with parents who did not smoke and parents who smoked respectively.

Table 6 Distribution of individual regression results for children with non-smoking parents, after excluding days with exposure to ETS

	$PM_{10\ personal} = PM_{10\ outdoors}$ (n=25)		*$PM_{10\ personal} = PM_{10\ tw\text{-}model}$ (n=16)*	
	Median	*95% CI*	*Median*	*95% CI*
Intercept	61.4	43.6 to 76.1	37.7	22.9 to 50.8
Slope	0.57	0.41 to 0.86	0.72	0.50 to 0.99
Pearson's *R*	0.73	0.56 to 0.83	0.76	0.67 to 0.89

Table 7 Multiple regression analysis of the relation between the difference between personal and time weighted concentrations and several other variables (n=208)

	Parameter estimate	SE	95% CI	Mean of the variable
Intercept	6.64	8.25	−9.53 to 22.81	
Smoking parent(s) (yes/no)	41.28**	8.64	24.34 to 58.22	0.45
Exposure to ETS (yes/no)†	12.29*	5.13	2.24 to 22.33	0.11
Physical activity (yes/no)	11.61**	3.70	4.36 to 18.86	0.63
Sex (girl=0; boy=1)	10.80	8.88	−6.60 to 28.21	0.62
Time spent in a vehicle (yes/no)	3.42	5.49	−7.34 to 14.19	0.15
Cooking (yes/no)‡	1.24	3.54	−5.69 to 8.17	0.59
Cleaning activities (yes/no)‡	3.84	4.34	−4.66 to 12.34	0.30
Living room window opened (yes/no)	0.98	4.82	−8.46 to 10.42	0.20
Slept with bedroom window opened (yes/no)	0.45	4.70	−8.77 to 9.66	0.33

*P< 0.05; **P< 0.01.
†Other than caused by parental smoking.
‡Conducted by or in the presence of the child.

Exposure to ETS significantly increased personal PM_{10} exposures. For children with parents who smoked, smoking in the living room was reported on all but two occasions. The median *R* of 0.59 found for children with parents who smoked shows that, despite the significant influence of parental smoking on the level of exposure, personal PM_{10} exposures of children exposed to ETS on a day to day basis were still reasonably well correlated with outdoor concentrations. Excluding days that children with parents who did not smoke were exposed to ETS improved the correlation to a median *R* of 0.73.

The PM_{10} concentrations in the classrooms were another important cause of excess personal exposures. Correlating the personal exposure with concentrations calculated with a time weighted model that accounted for the daytime concentration in the classroom showed somewhat higher correlations.

A similarly designed study[14] of 37 50–70 year old adults who did not smoke, were not occupationally exposed, and lived in Amsterdam showed a median Pearson's *R* between personal and ambient PM_{10} concentrations of 0.50. Excluding days that subjects were exposed to ETS increased the correlation to a median *R* of 0.71, comparable with the value of 0.73 found in this study for children not exposed to ETS. In the total human environmental exposure study (THEES), the correlation within subjects was calculated, using nine to 14 personal measurements from 13 adults who did not smoke.[9] Individual personal outdoor correlations ranged from 0.14 to 0.90 with a median value of 0.53. Using activity data improved the personal PM_{10} estimates for all people to a median *R* of 0.93 (range 0.58 to 0.999). Exposure to ETS was one of the variables that contributed to this improvement, together with house cleaning activities, cooking, and use of unvented kerosene space heaters. Correlations after accounting for exposure to ETS alone were not described. Wallace[10] presented additional analyses of the PTEAM pilot study, which included repeated measurements of personal, indoor, and outdoor PM_{10} in nine households (two people in each household). Cross sectionally, personal PM_{10} exposures were uncorrelated with outdoor concentrations but for the 10 subjects with six to eight measurements, individual correlations ranged from -0.17 to 0.79, with a median value of 0.26.

Assuming that personal PM_{10} measurements are the most accurate estimate of the subject's true exposure, the correlation between personal and outdoor concentrations can be used to estimate the bias in the relation between exposure and disease caused by the use of outdoor concentrations as a measure of exposure instead of personal exposures. If the measurement error in the exposure is non-differential and is the only source of error in the measure of the association between exposure and health effect, the relation between the true regression coefficient (β_t) and the observed regression coefficient (β_o) can be estimated as $\beta_t = \beta_o / R^2$.[15] With the median *R* of 0.6 found in our study, this implies that the use of outdoor concentrations would result in a threefold underestimation of the relation between exposure and disease. This reasoning, however, strongly depends on the assumption that personal PM_{10} concentrations are the best measure of the relevant exposure. If fine particles or a specific component in PM_{10} and not PM_{10} mass is the causal agent responsible for the health effects found, personal PM_{10} mass may not necessarily be the best exposure estimate.

The median slope between personal and outdoor concentrations of about 0.6 in our study was comparable with the slopes found for adults who did not smoke in Amsterdam[14] and in the THEES and PTEAM study.[10] Slopes were similar for children with parents who did and who did not smoke.

It has been argued that the low (cross sectional) correlation between personal and outdoor exposure to particles makes associations between day to day variations in outdoor air pollution and health effects implausible. The significant correlation between outdoor and personal exposure within subjects, over time, found in this study documents, however, that short term increases in outdoor air pollution are reflected in increased personal exposures. This finding provides support for the use of fixed site measurements as a measure of exposure to PM_{10} in time series studies linking day to day variations in outdoor concentrations to day to day variation in health end points.

DIFFERENCE BETWEEN PERSONAL AND AMBIENT CONCENTRATIONS

Personal exposures were on average 67 μg/m^3 higher than corresponding outdoor concentrations. The main part of this difference could be attributed to exposure to ETS, high PM_{10} concentrations in the classrooms, and indoor physical activity.

Children exposed to parental smoking had personal exposures that were about 40 μg/m^3 higher than children with parents who did not smoke. This value is within the range of a 25 to 45 μg/m^3 increase in $PM_{2.5}$ concentrations in homes with smokers that was recently suggested by Wallace.[10]

The PM_{10} concentrations in classrooms were significantly higher than the corresponding outdoor concentrations. PM_{10} measurements conducted in 11 other primary schools in The Netherlands have confirmed this finding.[16] Indoor physical activity was a third important source of increased personal exposures. Both findings are probably a result of resuspension of particles caused by the activity of the children. Thatcher and Layton[17] studied the effect of resuspension by measuring different ranges of particle size before and after several resuspension activities. Five and 30 minutes of normal activity by four people and two minutes of continuous walking and sitting by one person resulted in a twofold to fourfold increase of particles in the 5–10 μm size range. In the PTEAM study,[18] an estimated dirt level in homes was significantly associated with 24 hour averaged personal and indoor PM_{10} concentrations. Dirt and dust levels were estimated on a seven point scale (0 to 3 by halves) by two technicians. A 12–24 μg/m^3 increase in PM_{10} concentrations per unit increase in the index was predicted.

Excess personal exposures compared with indoor or outdoor concentrations have been found in most personal exposure studies.[10] Resuspension of coarse particles by personal activities and proximity to particle generating sources have been suggested as causes of this so called "personal cloud".[10] This study shows that for children both particle generating-sources (smoking) and resuspension are important factors, causing significant differences between personal and outdoor PM_{10} concentrations.

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Medical editors' trial amnesty

As described in an editorial in the *British Medical Journal*,[1] medical editors of nearly 100 international medical journals are taking action to try to ensure that the results of unpublished randomised controlled trials become available to be included in systematic reviews. This could have important benefits for patient care.

Any reader who would like to take up this opportunity to register the results of a trial that did not get published can do so on a special *unreported trial registration form*. Copies are available from the *Occupational and Environmental Medicine* editorial office.

I do not expect that many *Occupational and Environmental Medicine* readers will need to take up this offer, given the nature of our field, but perhaps I will be proved wrong.

ANNE COCKROFT
Editor

1 R Smith, I Roberts. An amnesty for unpublished trials. *BMJ* 1997;**315**:622.

Childhood exposure to PM10: relation between personal, classroom, and outdoor concentrations.

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