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COMPARISON OF THE NUMBER OF ULTRA-FINE PARTICLES AND THE MASS OF FINE PARTICLES WITH RESPIRATORY SYMPTOMS IN ASTHMATICS

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INTRODUCTION

Recently it has been recognised that ambient particles might play an important role in pollution-induced respiratory responses (Dockery and Pope, 1994; Pope *et al.*, 1995a,b; Brunekreef *et al.*, 1995; Bascom *et al.*, 1996). However, it is unclear which properties of the particles are responsible for the observed health effects. Fine and even ultra-fine particles might be more "toxic" than coarse particles and the "physical" toxicity of these particles might even exceed their "chemical" toxicity. Consequently more insight into health related aspects of particulate air pollution will be obtained by correlating respiratory responses with mass and number concentration of ambient particles. Therefore, the role of fine and ultra-fine particles in eliciting respiratory health effects was studied in adults with a history of asthma in Erfurt, Eastern Germany (Peters *et al.*, in press). The present paper presents more detailed analyses on the temporal relationship between particles and respiratory symptoms.

METHODS

The aerosol size spectrometer consisted of two sensors covering different size ranges. In the range 0.01–0.3 μm ambient particles were classified with an electrical mobility analyses (TSI, model 3071) according to their volume-equivalent diameter and counted with a condensation particle counter (TSI, model 3760). In the size range 0.1–2.5 μm particles were classified by an optical particle counter (PMS, model LAS-X): particles smaller than the wavelength of the applied laser light according to their volume-equivalent diameter; larger particles according to their cross-section illuminated by the laser beam. However, while the electrical classification is independent of the chemical properties, the optical classification is not. Therefore, the response function of the optical counter requires adjustment to the refraction index of the particles to be classified. For this adjustment, monodisperse particles selected from the ambient aerosol by electrical classification were frequently used in this study (Tuch *et al.*, submitted). The number distribution can be converted into a particle volume distribution, which was used to calculate the particle mass distribution assuming an average density of the aerosol particles. When daily total particle volume concentrations and occasional $PM_{2.5}$ measure-

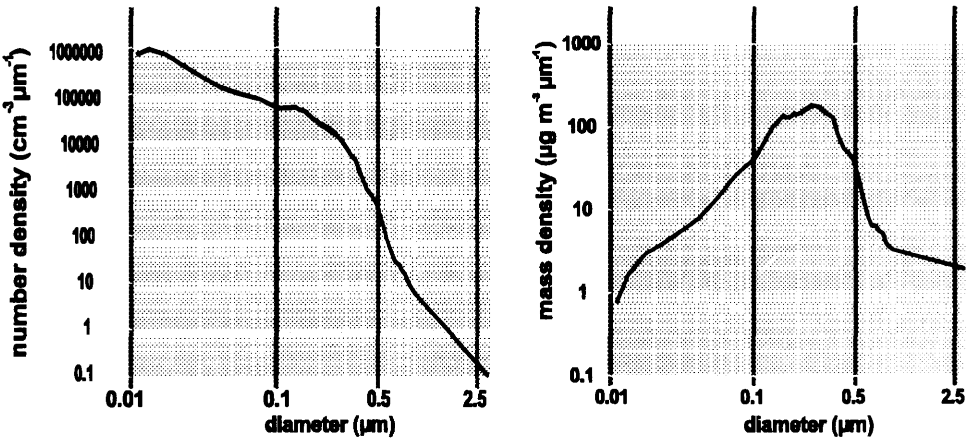

Fig. 1. Mean number and mass distribution of ambient particles in Erfurt, 1991/92 (Tuch *et al.*, submitted).

ments were compared an apparent particle density of 1500 kg m^{-3} could be determined for Erfurt. The derived particle mass distributions were used to calculate integral mass concentrations of particles between selected cut-off diameters. The following abbreviations will be used consequently: $NC_{0.01-0.1}$ for the number concentration of the ultra-fine particles, $NC_{0.01-2.5}$ for the total number concentration of fine particles, $MC_{0.1-0.5}$ for the mass concentration of fine particles with a diameter between 0.1 and 0.5 µm and $MC_{0.01-2.5}$ for the mass concentration of the fine particles.

During the winter 91/92 27 non-smoking adults with a history of asthma participated in a panel study (Peters *et al.*, 1996, in press). They were 44–80 years old in 1992 and 63% of them were women. The panelists recorded their respiratory symptoms daily in a diary. The analysis was restricted to the winter period (from September through March). Data on fine and ultra-fine particles was only available after 1 October, 1991. Data were obtained on 145 days. Regression analyses of population averaged time-series were used to control for possible confounding by time-varying influences on respiratory symptoms as has been described previously (Peters *et al.*, 1996, in press). The prevalence of feeling ill during the day and cough was analysed using a logistic regression model adjusting for a linear trend, temperature, weekend and an autocorrelated error structure of order one. A 5-day mean was used to estimate the cumulative impact of air pollution. It was calculated by averaging the exposure on the current day and 4 days prior. In case of missing data the remaining measurements were taken. All regression coefficients were expressed as effects associated with a change of the exposure for one inter-quartile range.

RESULTS

Daily mean number and mass distributions were obtained with the mobile aerosol spectrometer. Figure 1 presents the mean distribution of the number and

Table 1. Odds ratios (OR) for the symptom feeling ill during the day in association with the fine and ultra-fine particles

	IQR [# cm^{-3}]	$NC_{0.01-2.5}$ OR	$NC_{0.01-2.5}$ 95% CI	IQR	$NC_{0.01-0.1}$ OR	$NC_{0.01-0.1}$ 95% CI
same-day	15 120	1.29	(1.05, 1.58)	12 000	1.21	(0.98, 1.50)
lag 1	15 120	1.36	(1.11, 1.66)	12 000	1.30	(1.07, 1.58)
lag 2	15 120	1.27	(1.04, 1.54)	12 000	1.26	(1.04, 1.52)
lag 3	15 120	1.11	(0.90, 1.37)	12 000	1.06	(0.87, 1.29)
lag 4	15 120	1.22	(1.00, 1.48)	12 000	1.20	(1.00, 1.45)
lag 5	15 120	1.23	(1.02, 1.49)	12 000	1.19	(0.99, 1.43)
5 day mean	10 508	1.39	(1.15, 1.68)	9 200	1.44	(1.15, 1.81)
	[μg m^{-3}]	$MC_{0.01-2.5}$ OR	$MC_{0.01-2.5}$ 95% CI	[μg m^{-3}]	$MC_{0.1-0.5}$ OR	$MC_{0.1-0.5}$ 95% CI
same-day	57	1.24	(1.09, 1.41)	47.5	1.23	(1.09, 1.40)
lag 1	57	1.27	(1.09, 1.49)	47.5	1.23	(1.07, 1.41)
lag 2	57	1.15	(0.97, 1.33)	47.5	1.12	(0.97, 1.30)
lag 3	57	1.13	(0.96, 1.33)	47.5	1.11	(0.97, 1.27)
lag 4	57	1.14	(0.98, 1.33)	47.5	1.12	(0.98, 1.28)
lag 5	57	1.18	(1.02, 1.38)	47.5	1.16	(1.01, 1.32)
5 day mean	50	1.21	(1.06, 1.38)	33.7	1.19	(1.05, 1.35)

the mass of the particles during the winter 91/92. Seventy-three per cent of the particles were smaller than 0.1 μm in diameter. Eighty-two per cent of the mass concentration were associated with particles in the size range 0.1–0.5 μm (Tuch *et al.*, submitted; Peters *et al.*, in press). Since the number concentration of the particles smaller than 0.1 μm was not highly correlated with the mass concentration of particles with a diameter between 0.1 and 0.5 μm ($r = 0.51$) (Peters *et al.*, 1996), these two fractions and the total number and the total mass of the fine particles were chosen to evaluate the impact of the fine and ultra-fine particles on respiratory symptoms.

Analyses were adjusted for a linear trend, mean daily temperature and weekend, but only a negative linear trend showed to be statistically significant. A stronger association with the prevalence of feeling ill during the day was observed for the number concentration of particles ($NC_{0.01-2.5}$) than for their mass concentration ($MC_{0.01-2.5}$) (Table 1). The exposure on previous days appeared to contribute to the prevalence of feeling ill concurrently (Peters *et al.*, in press). This observation was supported both by estimating the impact of previous days alone or by using a 5 day mean (Table 1). While no strong association between the particle number concentrations on the same day and the prevalence of cough was observed, some indication was found that prolonged exposure to elevated number concentrations of ultra-fine particle might be associated with increasing reporting of cough (Table 2). The difference between the odds ratios for the 5 day means of $NC_{0.01-0.1}$ and $MC_{0.1-0.5}$ was statistically significant ($p < 0.05$). Both the mass of the fine particles $MC_{0.01-2.5}$ and the mass of the particles between 0.1 and 0.5 μm $MC_{0.1-0.5}$ showed only associations with cough when the same-day concentrations were considered.

Table 2. Odds ratios for the symptom cough in association with the fine and ultra-fine particles

	IQR [# cm^{-3}]	$NC_{0.01-2.5}$ OR	$NC_{0.01-2.5}$ 95% CI	IQR	$NC_{0.01-0.1}$ OR	$NC_{0.01-0.1}$ 95% CI
same-day	15 120	1.16	(0.98, 1.37)	12 000	1.12	(0.95, 1.33)
lag 1	15 120	1.06	(0.89, 1.26)	12 000	1.04	(0.88, 1.23)
lag 2	15 120	1.10	(0.94, 1.29)	12 000	1.12	(0.97, 1.31)
lag 3	15 120	1.07	(0.91, 1.27)	12 000	1.08	(0.92, 1.27)
lag 4	15 120	1.06	(0.90, 1.25)	12 000	1.09	(0.94, 1.28)
lag 5	15 120	0.96	(0.82, 1.13)	12 000	0.97	(0.83, 1.14)
5 day mean	10 580	1.17	(1.01, 1.37)	9 200	1.26	(1.06, 1.50)
	[μg m^{-3}]	$MC_{0.01-2.5}$ OR	$MC_{0.01-2.5}$ 95% CI	[μg m^{-3}]	$MC_{0.1-0.5}$ OR	$MC_{0.1-0.5}$ 95% CI
same-day	57	1.19	(1.07, 1.32)	47.5	1.18	(1.06, 1.31)
lag 1	57	1.07	(0.92, 1.25)	47.5	1.06	(0.93, 1.21)
lag 2	57	0.93	(0.80, 1.09)	47.5	0.94	(0.82, 1.08)
lag 3	57	0.97	(0.84, 1.12)	47.5	0.97	(0.86, 1.10)
lag 4	57	0.88	(0.76, 1.03)	47.5	0.90	(0.75, 1.03)
lag 5	57	0.95	(0.82, 1.09)	47.5	0.95	(0.84, 1.08)
5 day mean	50	1.02	(0.91, 1.15)	39.7	1.02	(0.91, 1.14)

DISCUSSION

The measured total particle number concentration was determined by ultra-fine particles in Erfurt during the winter 91/92. The mass of the fine particles was dominated by particles between 0.1 and 0.5 μm in diameter. The relatively low correlation between the mass and the number concentrations of the particles enabled us to analyse their contribution to health effects in adults with a history of asthma (Peters *et al.*, in press).

Increases in the prevalence of feeling ill during the day and of cough were observed both for the mass and the number concentrations of the particles. The general health of the panellists meliorated in associations with elevated levels of particles on the same day as well as on previous days. The strongest association with the prevalence of feeling ill during the day was found for the 5-day mean of the number concentrations of ultra-fine particles. Similarly, the prevalence of cough increased in association with the 5-day mean of the number concentrations of ultra-fine particles. Therefore, the increases in symptoms and the decrease in lung function (Peters *et al.*, in press) might be caused by an inflammation in the alveoli as a reaction to ultra-fine particles, as has been hypothesised recently by Seaton *et al.* (Seaton *et al.*, 1995).

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