Associations between Mortality and Air Pollution in Central Europe

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Increased mortality has been observed in association with elevated concentrations of air pollutants in European cities and in the United States. We reassessed the effects of particulate matter in Central Europe. Mortality and air pollution data were obtained for a highly polluted region of the Czech Republic and a rural region in Germany. Poisson regression analyses were conducted considering trend, season, meteorology, and influenza epidemics as confounders in both a parametric and a nonparametric approach. The Czech Republic had a 3.8% increase in mortality [95% confidence interval (CI), 0.8–6.9%] in association with 100 µg/m^3 total suspended particles (TSP) (lagged 2 days) for the time period 1982–1994. During the last 2 years of study, 68% of the TSP consisted of particulate matter ≤ 10 µm in aerodynamic diameter (PM$_{10}$). An increase of 100 µg/m^3 TSP (lagged 1 day) was associated with a 9.5% increase in mortality (CI, 1.2–18.5%) and 100 µg/m^3 PM$_{10}$ (lagged 1 day) showed a 9.8% increase in mortality (CI, 0.7–19.7%). We found no evidence for an association between mortality and particulate matter in the rural area in Germany at the Czech border. Data from the coal basin in the Czech Republic suggested an increase in mortality associated with the concentration of particulate matter in a highly polluted setting in Central Europe that is consistent with the associations observed in other western European cities and in the United States.

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Acute exposure to particulate air pollution has been associated with adverse health effects (*1–3*). In particular, increases in mortality have been observed in association with particulate matter. Associations between mortality and air pollution were studied in 12 locations in 9 European countries as part of the Air Pollution and Health - a European Approach (APHEA) project (*4*). The study periods ranged from the mid-1970s to the end of the 1980s, when sulfur dioxide concentrations and total suspended particles (TSP) were still relatively high in Europe. The study confirmed the association between air pollution and mortality in combined analyses (*5*). Surprisingly, stronger associations between air pollutants and mortality were observed in the western European cities than in the eastern European cities, where local air pollution standards were frequently exceeded in the 1980s (*5*).

This paper reports data from a highly polluted area in the Czech Republic and a rural area in Germany during the time period 1982–1994. We analyzed a different data set from central Europe and evaluated the possibility that the air pollution effects seen consistently throughout the western world (*1–3*) are reduced in central Europe despite high exposures in the 1980s. The Czech Republic study region is the coal basin in the northwest of the country. The area is highly industrialized based on its rich resources in brown coal. Large power plants provide > 70% of the electric energy consumed in the Czech Republic. The comparison region consists of four districts in northern Bavaria, a rural German area at the Czech border. The main sources of pollution are local combustion, traffic, and regional transport.

Methods

Data acquisition. The coal basin includes the districts Chomutov, Most, Teplice, Usti n.L., and Decin. These districts have approximately 630,000 inhabitants in an area of approximately 700 km^2. The Bavarian study region includes the districts Hof, Landkreis Hof, Wunsiedel, and Tirschenreuth. The Bavarian districts have approximately 250,000 inhabitants in an area of approximately 1,000 km^2.

Mortality data from state authorities were obtained in both locations. For the Czech Republic, the cause of death, age, and sex were available for each death record. We calculated daily counts of all-cause mortality [*International Classification of Diseases, 9th revision* (*ICD-9*); World Health Organization, Geneva; code < 800], mortality caused by cardiovascular diseases (*ICD-9* code 390–459), respiratory diseases (*ICD-9* code 460–519), and cancer (*ICD-9* code 140–239). For the Bavarian region only daily counts of all-cause mortality (*ICD-9* code < 800) and mortality caused by cardiovascular diseases (*ICD-9* code 390–459) were released from the local authorities.

Air pollution data were obtained through local air hygiene units. The data were checked for plausibility and correlations between stations by year were taken as guidance to assess the quality of the measurements. Averaged 24-hr concentrations per study region were calculated. When values were missing, we calculated the average based on the remaining stations adjusted for season and year as suggested for the APHEA project (*4*).

Coal basin measurements were taken at seven to nine measurement stations in each district. Automated air monitoring stations were mounted in each district at a background site in the town centers beginning in 1992. Data measured at the five district Institutes of Hygiene were used for the time period between 1982 and 1991. These measurement stations were maintained on a daily basis and they were located in the center of the towns. Thereafter, data from the automated stations were used. The SO$_2$ and the TSP concentrations of the district Chomutov were only poorly correlated with the four other locations (the correlation coefficients varied from year to year and ranged between 0.1 and 0.6 as compared to the mean of the other four stations), whereas the

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temperature measured at Chomutov was correlated perfectly with mean of the other four stations ($r = 0.99$). Chomutov is on the west side of the coal basin and hosts four large brown-coal power plants, which should have contributed to the pollution in the same way that the industrial facilities contributed in the other four districts. Therefore, air pollution data from Chomutov were not used in the calculation of the average air pollution concentrations. Analyses were repeated with and without data from Chomutov. Slightly smaller estimates were obtained when we considered measurements from Chomutov, suggesting that these measurements might not characterize exposures in Chomutov as well as the mean of the other four stations. Particulate matter ≤ 10 µm in aerodynamic diameter (PM_{10}) and particulate matter ≤ 2.5 µm in aerodynamic diameter ($PM_{2.5}$) were measured with a versatile air pollution sampler, as previously described (*6*). In Bavaria, there were three stations in small towns along the Czech border, and there were two others within the district of Hof. All five stations showed good correlation between their measurements and were therefore considered for the analyses ($r > 0.75$).

Data on acute respiratory infections were available for the Czech Republic from the National Institute of Health (Prague, Czech Republic) indicating influenza epidemics in 1983, 1986, 1987, 1989, 1991, 1992, and 1994. Unfortunately no data on influenza epidemics were available for the Bavarian study region during the study period. We attempted to use the data from the Czech Republic, the former German Democratic Republic (GDR), and The Netherlands, but they revealed large temporal differences between the putative influenza epidemics, probably caused by the restrictions on travel during the Cold War era.

Data analyses. We first applied the APHEA methodology (*7*). We calculated Poisson regression models approximated by logistic regression analyses and assessed an overall trend with a cubic function. We assessed seasonal variation by sine and cosine functions with periods between 1 year and one-sixth of a year. We considered temperature a quadratic function, modeled cold and warm temperatures separately, and considered relative humidity, influenza epidemics, and day of the week as additional confounders. We used periodograms and partial autocorrelation plots to assess the model fit, and we also used graphical presentations of the fitted values and the residuals. Although a good model fit was obtained for the data from the Czech Republic, the Bavarian data were an imperfect fit. In particular, increases in mortality during the winter were observed in those winters, whereas in The Netherlands, the former GDR, or the Czech Republic, we found evidence for possible influenza epidemics. Therefore, we conducted additional analyses using robust Poisson regression models in the framework of generalized additive models (*8*). Natural splines with 3 degrees of freedom (*df*) for each study year were used to fit a semiparametric seasonal function. Temperature and relative humidity were fitted with a natural spline of 4 *df*. We considered temperature on the same day and as a 3-day mean of the current day and the previous 2 days. The association between the air pollutants and mortality was checked for linearity using locally weighted least squares. The fit of the models was compared formally by using a goodness-of-fit test. Regression coefficients were expressed as relative risks and 95% confidence intervals (CI) were calculated.

Table 1. Distribution of daily deaths in the two study regions between 1982 and 1994.

Distribution	Mean	SD	Minimum	Median	Maximum
Coal basin					
Total mortality[a]	18.2	4.7	3	18	41
Cardiovascular diseases[a]	10.4	3.5	0	10	29
Respiratory diseases[a]	0.9	1.0	0	1	7
Cancer	4.6	2.2	0	4	16
Northeast Bavaria					
Total mortality[b]	412.0	3.7	2	12	31
Cardiovascular diseases[b]	6.4	2.6	0	6	19

[a] *n* = 4,748. [b] *n* = 4,723.

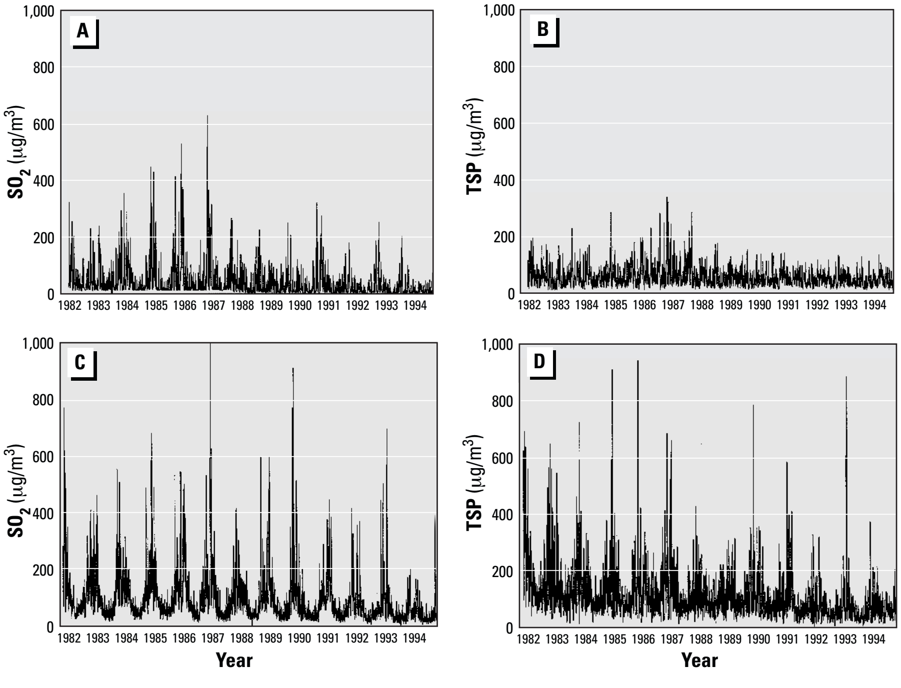

Figure 1. Daily concentrations of (*A*) SO_2 and (*B*) TSP for northeast Bavaria study area. Daily concentrations of (*C*) SO_2 and (*D*) TSP for the coal basin study area, Czech Republic.

Results

In the coal basin, 18.2 persons died/day on average (Table 1). Fifty-seven percent of all deaths were attributable to cardiovascular disease, 25% to cancer, and 5% to respiratory diseases. On average, 12.0 persons died/day in the Bavarian study region; 53% of these had an underlying diagnosis of cardiovascular disease.

During the early 1980s, air pollution concentrations were high in the coal basin as well as in the rural northern Bavarian region (Figure 1). SO_2 concentrations repeatedly exceeded 500 µg/m^3, but concentrations were on average higher in the coal basin than in northeast Bavaria (Table 2). Concentrations of SO_2 and TSP decreased during the study period (Figure 1). Carbon monoxide concentrations decreased over time and nitric oxide concentrations remained the same in the rural area in Germany (data not shown). For the coal basin, NO_2, PM_{10}, and $PM_{2.5}$ measurements were performed during the last 2 years of the study (1993–1994). PM_{10} concentrations exceeded 165 µg/m^3 on 6.4% of the days and $PM_{2.5}$ concentrations were > 65 µg/m^3 on 22% of the days. On average, 68% of the TSP was PM_{10}, and most of the PM_{10} was $PM_{2.5}$ (75%). During the study period, SO_2 and TSP showed a correlation of approximately 0.7 both in the coal basin and in Bavaria (Table 3). Whereas both NO_2 and CO were moderately correlated with SO_2 and TSP in Bavaria, NO_2 was highly correlated with SO_2 and TSP in the coal basin (Table 3). PM_{10} and $PM_{2.5}$ were highly correlated (r = 0.98) with each other and with TSP (Table 3).

Regression analyses of daily mortality counts showed a general downward trend of 0.4%/year in Bavaria and 0.2%/year in the coal basin. Sine and cosine functions showed the maximal mortality in February and the minimal mortality in August. Cold temperature (daily averages < 10°C) on the preceding days was associated with an increase in mortality in both locations. Evidence for an increase in mortality at hot temperatures (daily averages > 15°C) were found in both locations. A day-of-the-week pattern with a reduced mortality on Sundays as compared to Wednesdays was observed in the rural German study region but not in the coal basin. Increases in acute respiratory infections were a powerful predictor of mortality in the Czech Republic. The strongest effects were seen with a lag of 1 week. An influenza epidemic was defined as > 10,000 acute respiratory events/week in the five districts and was associated with a 21.5% increase in all-cause mortality (CI, 15.9–27.4%).

There was an association between the logarithm of TSP and all-cause mortality for the coal basin, when TSP concentrations were lagged 1 or 2 days (Table 4). Nonparametric smooths also were consistent, with a logarithmic transformation of the TSP concentrations (Figure 2). SO_2 showed lightly weaker associations (Table 4). Estimates for 2-day lags were statistically significant for both TSP and SO_2. Joint analyses of TSP and SO_2 in one model showed an increased risk of 3.3% in association with 100 µg/m³ TSP (CI, -0.5–7.2%) and a risk of 1.0% in association with 100 µg/m³ SO_2 (CI, -3.0–5.2%). The exclusion of days with SO_2 concentrations > 200 µg/m³ (excluding 8.8% of all observations) resulted in an increased risk of 3.2% for 100 µg/m³ TSP (CI, -1.0–7.5%). Similarly, the exclusion of days with TSP concentrations > 200 µg/m³ (excluding 11.6% of all observations) led to risk estimations of 3.0% for 100 µg/m³ TSP (CI, -1.5–7.7%).

PM_{10} and $PM_{2.5}$ were both associated with all-cause mortality in 1993–1994 with a lag of 1 day (Table 4). TSP concentrations showed stronger effects during the 2 last years than during the whole study period (Table 4). PM_{10} and $PM_{2.5}$ were only measured in Teplice, the central district of the coal basin. Analyses with the TSP concentrations as measured in Teplice confirmed the results for 1993 and 1994 [7.9% increase for 100 µg/m³ TSP (CI, 1.5–15.0%)]. NO_2 showed a positive association with mortality, but did not achieve statistical significance (Table 4). No association was observed between CO and all-cause mortality. A positive, but not statistically significant, association was observed between TSP (lagged 2 days) and mortality of cardiovascular or respiratory causes (Table 5). However, we observed associations between cancer mortality and TSP.

We did not observe associations between elevated levels of TSP or SO_2 and the all-cause mortality in the Bavarian study region (Table 6). In addition, we found no evidence that associations with a lag of > 3 days

Table 2. Distribution of daily concentrations of air pollutants and meteorologic variables in the two study regions between 1982 and 1994.

Pollutant/variable	No.	Mean	SD	Minimum	Median	Maximum
Coal basin						
SO_2 (µg/m³)	4,748	99.7	89.4	9	73	987
TSP (µg/m³)	4,725	121.2	85.3	17	99	940
NO_2 (µg/m³)^a	1,013	33.6	13.6	6	32	156
CO (mg/m³)^b	496	0.58	0.39	-0.1	0.52	2.88
O_3 (µg/m³)^b	585	40.3	25.0	1	38	140
PM_{10} (µg/m³)^b	391	65.9	79.8	10	45	832
$PM_{2.5}$ (µg/m³)^b	400	51.0	70.6	2	32	780
Temperature (°C)	4,748	8.8	8.1	-19.5	9.1	28.7
Relative humidity (%)	4,748	73.6	12.1	35	74	99
Northeast Bavaria						
SO_2 (µg/m³)	4,709	41.4	58.9	2	20	630
TSP (µg/m³)	4,698	51.6	34.1	5	44	333
NO_2 (µg/m³)	4,437	25.2	11.3	4	23.7	104
CO (mg/m³)	4,303	0.88	0.69	0.1	0.6	6.2
O_3 (µg/m³)	4,353	38.2	21.9	0	38	149
Temperature (°C)	4,715	8.02	7.92	-18.0	8.1	27.1
Relative humidity (%)	4,719	77.0	11.0	40	79	99

^{a}Time period 1992–1994. ^{b}Time period 1993–1994.

Table 3. The Pearson correlation coefficients for the two study regions.

	Czech Republic								
Northeast Bavaria	SO_2	TSP	NO_2^{a}	CO^b	Temperature	Rel humidity	O_3^{b}	PM_{10}^{b}	$PM_{2.5}$^{b}
SO_2		0.70	0.66	0.33	-0.60	0.38	-0.34	0.77	0.73
TSP	0.70		0.80	0.49	-0.35	0.21	-0.21	0.93	0.92
NO_2	0.37	0.46		0.61	-0.41	0.31	-0.45	0.84	0.82
CO	0.37	0.37	0.32		-0.49	0.44	-0.57	0.44	0.42
Temperature	-0.46	-0.12	-0.30	-0.25		-0.52	0.57	-0.38	-0.38
Rel humidity	0.13	-0.09	0.05	0.15	-0.55		-0.75	0.23	0.21
O_3	-0.28	-0.12	-0.35	-0.37	0.58	-0.63	-0.23	-0.22	

Rel, relative.
^{a}Time period 1992–1994. ^{b}Time period 1993–1994.

Table 4. Associations between mortality and the logarithm of air pollutants for the coal basin in the Czech Republic.

		All-cause mortality	
Log (air pollutant)	Unit^a	RR	CI
1982–1994			
SO_2 same day	100 µg/m³	0.991	0.958–1.026
Lagged 1 day	100 µg/m³	1.028	0.994–1.063
Lagged 2 day	100 µg/m³	1.032**	1.000–1.065
Lagged 3 day	100 µg/m³	1.005	0.975–1.036
TSP same day	100 µg/m³	0.993	0.964–1.023
Lagged 1 day	100 µg/m³	1.019	0.989–1.051
Lagged 2 day	100 µg/m³	1.038**	1.008–1.069
Lagged 3 day	100 µg/m³	1.008	0.979–1.037
1992–1994			
TSP^b same day	100 µg/m³	1.063	0.983–1.150
Lagged 1 day	100 µg/m³	1.095**	1.012–1.185
Lagged 2 day	100 µg/m³	1.062	0.983–1.146
Lagged 3 day	100 µg/m³	0.992	0.922–1.068
PM_{10}^{b} same day	100 µg/m³	1.041	0.955–1.136
Lagged 1 day	100 µg/m³	1.098**	1.007–1.197
Lagged 2 day	100 µg/m³	0.996	0.918–1.079
Lagged 3 day	100 µg/m³	1.031	0.954–1.114
$PM_{2.5}$^{b} same day	100 µg/m³	0.987	0.914–1.065
Lagged 1 day	100 µg/m³	1.059	0.980–1.144
Lagged 2 day	100 µg/m³	0.979	0.908–1.055
Lagged 3 day	100 µg/m³	1.006	0.936–1.081
NO_2^{c} same day	100 µg/m³	1.066	0.967–1.176
Lagged 1 day	100 µg/m³	1.057	0.957–1.167
Lagged 2 day	100 µg/m³	1.026	0.935–1.125
Lagged 3 day	100 µg/m³	1.045	0.954–1.144
CO^b same day	1 mg/m³	1.016*	0.998–1.035
Lagged 1 day	1 mg/m³	1.016*	0.998–1.034
Lagged 2 day	1 mg/m³	1.013	0.996–1.030
Lagged 3 day	1 mg/m³	1.012	0.995–1.028
O_3^{b} same day	100 µg/m³	0.982	0.905–1.065
Lagged 1 day	100 µg/m³	1.052	0.950–1.164
Lagged 2 day	100 µg/m³	1.078	0.982–1.184
Lagged 3 day	100 µg/m³	1.025	0.938–1.121

RR, relative risk. Adjusted for trend, season, influenza, temperature, and relative humidity using a generalized additive model.
^{a}Of increase. ^{b}Time period 1993–1994. ^{c}Time period 1992–1994. *$p < 0.1$; **$p < 0.05$.

was present. The linearity assessment of the associations confirmed a linear but weak association for all pollutants; neither the nonlinear nor the linear terms of the locally weighted least squares estimator achieved statistical significance. Increases in CO on the previous day were associated with an increase in all-cause mortality.

Discussion

In the coal basin there was an increase in mortality in association with elevated levels of TSP lagged 2 days. Analyses using the PM_{10} and $PM_{2.5}$ data, which were available during the last 2 years of the study, confirmed the association between particulate matter and mortality. In January 1993, a major air pollution episode occurred (*6*) that might explain the stronger associations for TSP observed during the last 2 years of study as compared to the entire study period. A logarithmic transformation fit better than a linear parameterization of the particle concentrations, indicating that less consistent effects were observed at TSP concentrations > 400 µg/m^3. At these concentrations spatial variation might have been high or the contribution of coarse mass might have reduced the health effects observed per microgram per cubic meter TSP (*9*). A logarithmic transformation also fit better in analyses of data from Erfurt, in the former East Germany, between 1980 and 1989 (*10*). The pollution situation in the former GDR might be comparable to the coal basin, although SO_2 concentrations were nearly twice as high in Erfurt as compared to the coal basin during the mid-1980s.

Associations between mortality and air pollution were studied in 12 locations in 9 European countries as part of the APHEA project (*4*). The APHEA central European sites were Bratislava in Slovakia and four cities in Poland (Cracow, Lodz, Poznan, and Wroclaw). In Bratislava, a small but nonsignificant association was observed with TSP (*11*). There was a positive association between all-cause mortality and black smoke in two of the four cities in Poland (*12*). A combined analysis estimated an increase of 0.6%, which was statistically significant for 50 µg/m^3 black smoke (*5*). The increase was substantially smaller than the 3.2% combined effect of 50 µg/m^3 black smoke in the western cities. A recent meta-analysis estimated an 0.8% increase associated with 10 µg/m^3 PM_{10} (*13*). To compare the results, the black smoke could be considered equal to PM_{10} (*13*). Therefore, the results for the coal basin seem to be comparable to the APHEA results (we estimated that an increase from 10 to 60 µg/m^3 PM_{10} was associated with a 3.7% increase in mortality) and the recent meta-analyses (we estimated that an increase from 20 to 30 µg/m^3 PM_{10} was associated with a 0.8% increase in mortality).

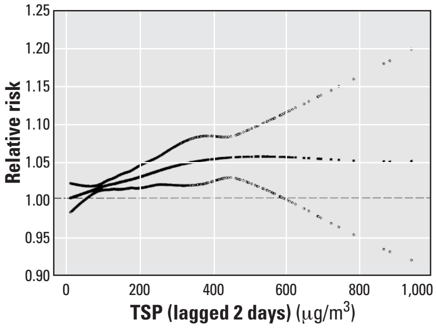

Figure 2. Nonparametric smooth for the association between all-cause mortality and TSP (lagged 2 days) adjusted for trend, season, influenza, temperature, and relative humidity using a generalized additive model.

The strongest association in the coal basin was observed between mortality caused by cancer and TSP. Other causes of death such as respiratory or cardiovascular diseases, which were associated with exposure to ambient particles in previous studies (*1*), were positively associated but did not achieve statistical significance. Lung cancer is prevalent in the coal basin and is mentioned as an underlying disease on the death certificates of 35 and 10% of men and women, respectively. Associations between particulate air pollution and pneumonia (a common complication in lung cancer patients) have been noted in Philadelphia, Pennsylvania (*14*), and in the Six Cities Study (*15*). In addition, a consistent association has been observed between hospital admissions for pneumonia and PM_{10} in five cities in the United States (*16*). Therefore, the association between cancer mortality and air pollution might reflect the exacerbation of a chronic disease by air pollution.

No association was observed between elevated concentrations of SO_2 or TSP and mortality in the rural Bavarian study region, although the air pollution concentrations were not low during the mid-1980s and the five stations showed a high correlation between each other throughout the study period. There is a possibility that none of the pollutants might be a good indicator for fine

Table 5. Associations between mortality and the logarithm of TSP for the coal basin in the Czech Republic in 1982–1994.

		Cardiovascular disease mortality		Respiratory disease mortality		Cancer mortality	
Log (TSP)	Unit of increase	RR	CI	RR	CI	RR	CI
TSP same day	100 µg/m^3	0.967*	0.929–1.005	1.027	0.897–1.176	1.030	0.971–1.091
Lagged 1 day	100 µg/m^3	1.007	0.967–1.048	0.960	0.836–1.103	1.066**	1.005–1.131
Lagged 2 day	100 µg/m^3	1.020	0.982–1.061	1.063	0.929–1.216	1.086**	1.025–1.150
Lagged 3 day	100 µg/m^3	1.004	0.966–1.042	1.033	0.906–1.177	1.051*	0.994–1.112

RR, relative risk. Adjusted for trend, season, influenza, temperature, and relative humidity using a generalized additive model.
*$p < 0.1$; **$p < 0.05$.

Table 6. Associations between mortality and air pollutants for the rural study area in Northeast Bavaria in 1982–1994.

		All-cause mortality		Cardiovascular disease mortality	
Pollutant	Unit of increase	RR	CI	RR	CI
SO_2 same day	100 µg/m^3	1.009	0.988–1.030	1.001	0.974–1.029
Lagged 1 day	100 µg/m^3	1.009	0.989–1.030	0.988	0.961–1.015
Lagged 2 day	100 µg/m^3	1.003	0.983–1.023	0.987	0.961–1.014
Lagged 3 day	100 µg/m^3	1.011	0.992–1.030	0.985	0.960–1.010
TSP same day	100 µg/m^3	1.016	0.989–1.045	1.015	0.977–1.054
Lagged 1 day	100 µg/m^3	1.009	0.982–1.038	0.988	0.951–1.026
Lagged 2 day	100 µg/m^3	1.004	0.977–1.031	0.983	0.947–1.020
Lagged 3 day	100 µg/m^3	1.016	0.989–1.043	0.980	0.945–1.016
NO_2 same day	100 µg/m^3	1.011	0.919–1.112	1.055	0.927–1.200
Lagged 1 day	100 µg/m^3	0.997	0.908–1.094	1.005	0.885–1.143
Lagged 2 day	100 µg/m^3	1.022	0.933–1.118	1.028	0.908–1.164
Lagged 3 day	100 µg/m^3	0.997	0.913–1.090	0.960	0.850–1.083
CO same day	1 mg/m^3	1.014	0.994–1.034	1.018	0.994–1.044
Lagged 1 day	1 mg/m^3	1.023**	1.005–1.041	1.012	0.987–1.038
Lagged 2 day	1 mg/m^3	1.013	0.995–1.031	1.016	0.991–1.041
Lagged 3 day	1 mg/m^3	1.003	0.985–1.021	1.004	0.980–1.029
O_3 same day	100 µg/m^3	1.082**	1.004–1.167	1.061	0.963–1.170
Lagged 1 day	100 µg/m^3	0.999	0.933–1.069	0.982	0.894–1.077
Lagged 2 day	100 µg/m^3	0.960	0.899–1.025	0.971	0.888–1.063
Lagged 3 day	100 µg/m^3	0.918	0.862–0.977	0.940	0.862–1.025

Adjusted for trend, season, temperature, relative humidity, and day-of-the-week effects using a generalized additive model, 1982–1994.
**$p < 0.05$.

particles under the circumstances in Germany. Unfortunately no PM_{10} measurements were available; therefore it is not known which fraction of the TSP consists of inhalable particles. The German study region is a rural area and sources for TSP might be different as compared to an industrialized region such as the coal basin. In particular, windblown dust might play a larger role in a rural than in an industrialized area. We found an association for CO, which might be a traffic-related indicator pollutant and which was increasing over time in the study region. In the APHEA project, the results for Cologne, Germany, ranked in the lower third of all study results (*5*). Extensive attempts have been made to model season and meteorologic variables with nonparametric functions; therefore, it is unlikely that confounding might have obscured the effect. However, the effect estimates are within the confidence bounds of the overall APHEA study results and therefore might be considered consistent with the APHEA study, although they did not achieve statistical significance by themselves.

The data presented here show an increase in mortality associated with the concentration of particulate matter in a highly polluted setting in central Europe that is consistent with the associations observed in other western European cities and in the United States (*1,3,5*).

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