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Air pollution and daily mortality in three Swiss urban areas

Summary

Particulate air pollution, in association with other common urban air pollutants, has been associated with various measured health endpoints, including the incidence and duration of respiratory symptoms, lung function, absences from work or school due to respiratory illness, hospitalization for respiratory disease, and cardiopulmonary disease mortality. In this study, the association between daily mortality and air pollution was assessed in Zurich, Basle, and Geneva (Switzerland) for the time period 1984 through 1989. Various regression modeling techniques were used to estimate the effect of air pollution on mortality, to control for time trends, seasonal factors, and weather variables, and to assess the sensitivity of the results. A positive, statistically significant association between daily mortality counts and measures of ambient air pollution in all three cities was observed. Mortality was associated with total suspended particulate pollution, sulfur dioxide, and nitrogen dioxide. The strongest association was with a 3-day moving average (including the concurrent day and the preceding 2 days) of these pollutants. The estimated mortality-air pollution effects were not highly sensitive to regression modeling techniques used to control for seasonality, long-term trends, and weather variables.

Early air pollution studies have documented substantially elevated respiratory and cardiovascular disease morbidity and mortality associated with severe air pollution episodes characterized by high concentrations of particulate and sulfur oxide pollution[1–3]. Elevated respiratory and cardiovascular disease morbidity and mortality have also been reported for a more moderate pollution episode in the North Rhine-Westfalia area of Germany[4]. A series of recent studies, conducted mostly in U.S. cities, have analyzed the temporal distribution of deaths and particulate air pollution[5–7]. These studies generally observed that changes in daily death counts were associated with short-term (1 to 5 days) changes in particulate air pollution, and that the relative risk of mortality increased monotonically with particulate concentrations in a near-linear fashion. Particulate air pollution generally had the largest effect on respiratory disease deaths, but also often had a significant effect on cardiovascular disease mortality. In addition to mortality, acute exposure to particulate air pollution has also been associated with a wide range of respiratory morbidity and health endpoints[8–10]. A study of respiratory symptoms of Swiss preschool aged children observed the incidence and duration of episodes of respiratory symptoms to be associated with particulate pollution[11].

Mortality has also been associated with more long-term or chronic exposure to particulate air pollution. Population-based (ecologic) cross-sectional studies that evaluated spatial distributions of mortality and air pollution have observed associations between mortality and sulfate or fine particulate pollution[12–15]. Also, recent prospective cohort studies have observed increased mortality risks associated with particulate air pollution, even after directly controlling for individual differences in age, sex, race, cigarette smoking, and other risk factors[16,17].

In this study daily mortality and air pollution data for three large Swiss urban areas were analyzed. This study had several specific objectives:

1) to test the hypothesis that daily mortality counts are associated with ambient concentrations of particulate air pollution;
2) to evaluate the sensitivity of the estimated pollution-mortality effect to various regression modeling techniques;
3) to evaluate the potential impact of confounding by time trends, seasonal factors, other long wavelength trends, or weather variables;
4) to weigh the evidence that the effect is due to alternative pollutants, and
5) to explore the linearity of the dose-response relationship between pollution and mortality.

Methods

Study areas

The study areas consisted of the three Swiss metropolitan areas of Zurich, Basle and Geneva, which in 1980 had 706000, 365000, and 335000 inhabitants respectively (according to the definition used by the Federal Office of Statistics). As for the whole of continental Europe, the influence of the warm airstream from the Atlantic ocean tempers the Swiss climate and results in relatively mild winters and summers. The plain regions where the three areas are located are subjected to marked seasonal changes in the hours of sunshine (with respect to the greatest possible duration) from 15% in winter to 50% in summer. The sunshine variation is due to the frequent layers of fog above the plain in the winter due to stagnating high pressure systems. These situations are mostly characterized by cold weather, low wind velocity and temperature inversions, so that pollution levels tend to become very high in the cities because of higher emissions and poorer diffusion.

Data

Daily mortality counts were obtained from mortality statistics of the Swiss Statistical Office for the time period 1984 through 1989. For each death, the underlying cause and as many as two immediate causes are recorded according to the International Classification of Diseases, 8th revision (ICD-8). Series of daily counts were calculated for the following mortality categories:

1) total mortality,
2) mortality for persons age 65 years or older,
3) respiratory mortality, including all deaths with underlying or immediate cause attributed to a respiratory disease (ICD-8 460-519),
4) cardiovascular disease mortality, including all deaths with an underlying cause of death attributed to a cardiovascular disease (ICD-8 390-459).

Daily weather variables were extracted from the centralized data base of the Swiss Meteorological Institute, located in Zurich. Daily pollution data from a centrally located reference station were obtained for each city. The centrally located reference stations were designed to reflect the mean air pollution levels of the corresponding metropolitan area, and were not situated close to major local sources of pollution emissions. For Zurich the air pollution data were obtained from the national net of air pollution stations (the so-called NABEL net). For Basle the pollution data were obtained from the "Lufthygieneamt beider Basel". For Geneva the pollution data were obtained from the "Service cantonal d'Ectotoxicologie". Missing values for periods of one or two days were completed by linear interpolation, and for longer periods by adjusting on the pollution levels of a nearby station.

Statistical analysis

The association between daily mortality and air pollution was analyzed using a variety of regression models. Mortality is classically modeled as following a Poisson process which can generally be described as a process that generates independent and random occurrences across time or space. If time is divided into discrete periods such as 24-hour periods, or days, the daily death counts theoretically would be distributed as a Poisson distribution. Poissonian variation may account for most of the day-to-day variation in death counts, but the underlying mean of the process may be determined by pollution levels, season, weather or other factors. Therefore, Poisson regression techniques are often used to estimate the pollution effects. For large counts (more than 10 or 15) the Gaussian distribution is a close approximation of the Poisson distribution and Gaussian (or normal) regression models can reasonably be used. Poisson regression may still be preferred, even when the number of daily deaths is large, because the variance of the data is not constant, as is assumed using normal least squares regression.

In this paper three basic regression modeling approaches were used. First, a series of standard Poisson models was estimated. To evaluate the potential impact of confounding of time trends, seasonal factors and weather variables, various combinations of indicator variables for each year, each month, and ranges of minimum temperatures and humidity were included as covariates in the models along with pollution levels. These "parametric Poisson" models were estimated using the GENMOD procedure of SAS/STAT statistical software[18].

Second, a series of "semi- and fully-nonparametric Poisson" models were estimated. For the semi-nonparametric Poisson models, pollution variables were included as linear variables in the models. However, rather than using indicator variables for years and months to account for time trends and seasonality, these models were fit using local regression smoothing of time. Similarly, rather than using indicator variables for different ranges of temperatures and humidity to account for nonlinear associations with these variables, these models were fit using local regression smoothing of temperature and humidity. Fully-nonparametric models were fit using local regression smoothing of pollution variables as well as time, temperatures and humidity. In order to evaluate if the association between mortality and air pollution is significantly different from linear, models that allow for nonlinear smooths of pollution levels were statistically compared with pollution included as a simple linear term. These models were estimated using the generalized additive model (gam) function and locally weighted regressions smooths (loess) of S-PLUS statistical software[19].

Third, a series of Gaussian regression models was estimated. As with the parametric Poisson models, various combinations of indicator variables for each year, each month, and ranges of minimum temperatures and humidity were included as covariates in the models along with pollution levels. Tests of autocorrelation were conducted by estimating these models as autoregressive models using the maximum likelihood estimation method in the AUTOREG procedure of SAS/STAT statistical software[20].

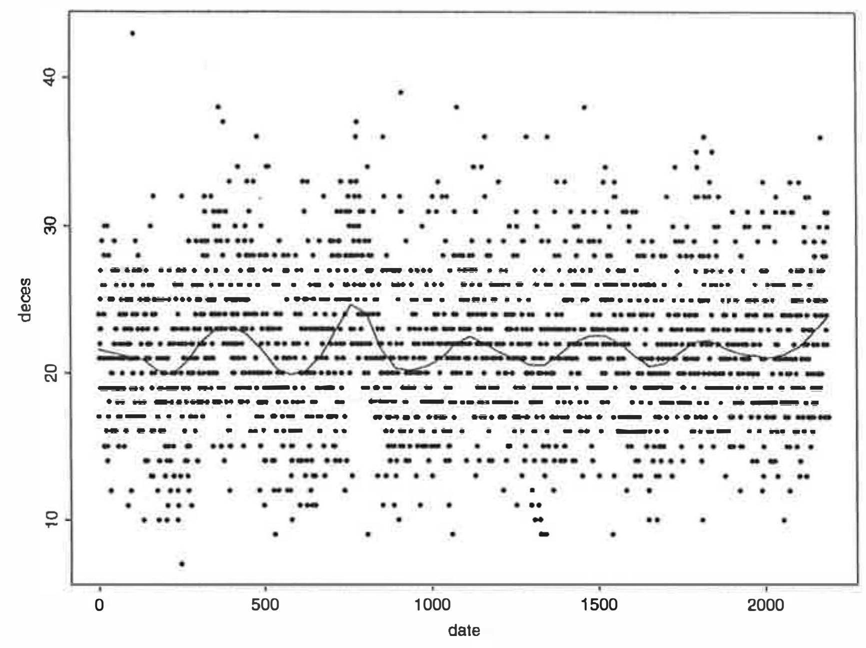

Figure 1. *Daily mortality counts in Zurich plotted versus time. The dots represent the number of deaths on each of the 2192 days of the study period. The smoothed curve was fitted using locally weighted regression smoothing to account for seasonality and other long term time trends.*

Results

Daily mortality count, pollution, and weather data used in the analysis for each of the cities are summarized in Table 1. Inasmuch as high pollution periods may occur for several consecutive days, and because pollution may have a lagged and/or cumulative effect, in the analysis we considered pollution levels for the concurrent day, and 2- to 5-day-lagged moving averages of the pollution concentrations. In the regression models a 3-day-lagged moving average, which was calculated as the mean pollution values of the concurrent and preceding two days, generally fit best.

Daily death counts plotted over the study period for Zurich are presented in Figure 1. There was much variability in daily death counts, as would be expected based on Poissonian variation alone. Underlying the Poissonian variability in daily death counts is evidence of seasonality. This seasonality is easily observed in the smoothed curve that is also plotted in Figure 1. This smooth function was fit to the data for all three cities using locally weighted regression smoothing (loess), with a local span of 8.5% of the data, using a tri-cube weight function. This analysis demonstrated similar seasonal non-stationarity for all three-cities, which must be accounted for in any analysis of the effects of air pollution.

Regression coefficients of mortality counts and TSP from various models using data from Zurich and Basle are presented in Tables 2 and 3. Statistically significant positive associations between mortality counts and particulate pollution were observed even after controlling for seasonality and daily differences in temperatures and relative humidity.

Care must be taken when interpreting and comparing the regression coefficients presented in Tables 2 and 3. The regression coefficients of the Poisson models (models 1–7) are approximately equal to the proportional increase in daily mortality counts associated with an increase in pollution. The actual proportional increase in mortality counts is easily calculated as exp (coefficient) – 1. The regression coefficients from the Gaussian models, however, are not directly

	Zurich N	Mean	Std Dev	Max	Basle N	Mean	Std Dev	Max	Geneva N	Mean	Std Dev	Max
Total mortality	2192	21.7	5.0	43	2192	10.3	3.3	25	2192	8.8	3.0	21
Mortality, age > = 65	2192	16.9	4.4	34	2192	8.2	2.9	20	2192	6.7	2.7	18
Respiratory mortality	2192	3.4	2.0	15	2192	2.3	1.6	9	2192	1.4	1.2	7
Cardiovascular mortality	2192	9.8	3.3	25	2192	4.2	2.1	14	2192	3.6	1.9	11
TSP (µg/m³)	2192	46.2	27.5	182	1970	45.2	28.9	216	0	–	–	–
SO_2 (µg/m³)	2192	35.4	35.5	397	1461	26.5	25.3	282	2192	40.2	32.7	219
NO_2 (µg/m³)	2192	58.0	21.3	178	1461	53.9	18.7	145	2192	59.4	25.4	264
CO (mg/m³)	2192	1.25	0.63	5.1	731	0.95	0.36	4.6	2192	1.93	1.18	7.90
O_3 (µg/m³)	2192	26.9	21.0	114	731	23.9	19.4	91	0	–	–	
Min Temperature (°C)	2192	5.3	6.6	19.2	2192	5.8	6.6	19.9	2192	5.2	6.3	20.6
Relative Humidity (%)	2192	77.4	11.5	99	2192	75.8	10.9	97	2192	73.3	11.7	99

***Table 1.** Summary of daily mortality, pollution, and weather data for Zurich, Basle, and Geneva, 1984–1989.*

related to proportional increases in mortality, but are estimated of absolute increases in daily mortality associated with pollution. Therefore, for comparison purposes, the coefficients from the Gaussian models presented in Table 2 and 3 were converted to proportional changes by dividing by the mean death count. These converted values are presented in brackets beneath the actual regression coefficients. When the regression coeffcients from the Poisson models are compared with the converted values in brackets for the Gaussian models, it is observed that very similar effect estimates were obtained.

After controlling for time trend and seasonality, the estimated pollution effects were not very sensitive to the type of model or the other covariates included in the model. Some of the models reported here were estimated as autoregressive models. However, the autoregressive parameters of these models were generally statistically insignificant. Furthermore, the regression coefficients and standard errors were nearly identical with standard regression models with no autoregressive terms.

Regression models that included other air pollutants individually were also estimated (Table 4). Mortality was associated with TSP, SO_2 and NO_2. Somewhat smaller associations were observed with CO. Associations with ozone were very weak and inconsistent. When TSP, SO_2, NO_2, CO, and O_3 are included in the models together, the regression coefficients on the pollutants were unstable and statistically insignificant.

When fully-nonparametric models were fit using local regression smoothing of pollution variables as well as time and temperatures, and humidity, chi-square tests of nonlinearity indicated that the associations between mortality and particulate pollution were not significantly different from linear ($p > 0.10$). However, for SO_2 the association mortality was highly nonlinear with declining marginal effects at higher levels of SO_2. In fact, in Basle, at the highest levels of SO_2 the association between SO_2 and mortality is negative. No such declining marginal effect is observed for TSP. Interestingly, across the full range of pollutants, TSP and SO_2 are highly correlated. In Zurich and Basle the Pearson correlation coefficients between TSP (3) and SO_2 (3) equal 0.62 and 0.67 respectively. However, for higher levels of SO_2 pollution, the correlation with TSP was weaker. For example, when SO_2 was greater than 100 µg/m³, the correlation between TSP (3) and SO_2 (3) equal 0.35 and – 0.06 for Zurich and Basle respectively.

Discussion

This study observed a statistical association between daily mortality counts and ambient air pollution in three Swiss cities. Mortality was most strongly associated with

Model	Covariates in model	Mortality Counts Total	65 or older	Respiratory	Cardiovascular
	Parametric Poisson models				
1	TSP (3)	0.100 (0.019)*	0.121 (0.021)*	0.339 (0.044)*	0.123 (0.027)*
2	Model 1 + indicator variables for month and year	0.054 (0.020)*	0.073 (0.023)*	0.196 (0.047)*	0.067 (0.030)*
3	Model 2 + indicator variables for four equal ranges of daily minimum temperatures	0.048 (0.021)*	0.066 (0.024)*	0.164 (0.049)*	0.0483 (0.031)
4	Model 3 + indicator variable for hot/humid days (min temp >15 and humidity > 85 %)	0.047 (0.021)*	0.066 (0.024)*	0.166 (0.019)*	0.0477 (0.031)
	Semi-nonparametric Poisson models				
5	Model 1 + loess smooth of time to account for trend and seasonality	0.053 (0.019)*	0.068 (0.021)*	0.187 (0.044))*	0.053 (0.028)*
6	Model 5 + loess smooth of daily minimum temperatures	0.038 (0.020)*	0.053 (0.022)*	0.138 (0.047)*	0.028 (0.029)
7	Model 6 + loess smooth of daily relative humidity	0.038 (0.020)*	0.051 (0.022)*	0.136 (0.047)*	0.024 (0.029)
	Autoregressive Gaussian models				
8	TSP (3) + indicator variables for months and years	1.227 (0.487)* [0.057][a]	1.292 (0.413)* [0.076]	0.788 (0.204)* [0.232]	0.631 (0.307)* [0.064]
9	Model 8 + indicator variables for quartiles of minimum temperatures	1.086 (0.501)* [0.050]	1.170 (0.427)* [0.069]	0.676 (0.209)* [0.199]	0.492 (0.318) [0.050]
10	Model 9 + indicator variables for hot and humid days	1.077 (0.501)* [0.050]	1.166 (0.419)* [0.069]	0.684 (0.209)* [0.201]	0.486 (0.318) [0.050]

* Statistically significant ($p < 0.05$).
ᵃ The values in brackets equal the regression coefficient (× 100) divided by the mean death count.

***Table 2.** Regression coefficients for mortality counts and TSP (3) (× 100) and standard errors, Zurich.*

3-day-lagged moving averages of particulate air pollution, although similar associations with SO_2 and NO_2 were also observed. Similar mortality/particulate pollution associations have been observed in other cities [5,6]. A study of mortality and air pollution in Lyons and Marseilles, France, observed similar associations between daily mortality and SO_2 but not with TSP[21]. A recent review of the particulate pollution daily mortality studies[7] compared the estimated percent change in daily mortality of each 10 µg/m³ increase in particulate matter mess than 10 micrograms in aerodynamic diameter (PM_{10}) for U.S. cities. Because not all of these studies actually used PM_{10} as the measure of particle pollution, other particulate pollution measures were converted to PM_{10}. TSP was converted to PM_{10} using a conversion factor of 0.55. Based on the previously reported U.S. studies, the estimated percent change in mortality for each 10 µg/m³ increase in PM_{10} ranged from 0.7 to 1.6 %, with a weighted mean of 1 %. Some of the studies evaluated death due to respiratory and cardiovascular disease separately. The

Model	Covariates in model	Mortality Counts Total	65 or older	Respiratory	Cardiovascular
	Parametric Poisson models				
1	TSP (3)	0.187 (0.026)*	0.200 (0.029)*	0.204 (0.054)*	0.234 (0.040)*
2	Model 1 + indicator variables for month and year	0.158 (0.028)*	0.149 (0.032)*	0.116 (0.059)*	0.184 (0.044)*
3	Model 2 + indicator variables for four equal ranges of daily minimum temperatures	0.166 (0.024)*	0.158 (0.034)*	0.124 (0.062)*	0.211 (0.046)*
4	Model 3 + indicator variable for hot/humid days (min temp >15 and humidity > 85%)	0.166 (0.030)*	0.157 (0.034)*	0.125 (0.062)*	0.210 (0.046)*
	Semi-nonparametric Poisson models				
5	Model 1 + loess smooth of time to account for trend and seasonality	0.139 (0.026)*	0.133 (0.029)*	0.105 (0.054)*	0.153 (0.039)*
6	Model 5 + loess smooth of daily minimum temperatures	0.141 (0.028)*	0.135 (0.031)*	0.099 (0.058)*	0.170 (0.043)*
7	Model 6 + loess smooth of daily relative humidity	0.146 (0.028)*	0.140 (0.031)*	0.105 (0.058)*	0.175 (0.043)*
	Autoregressive Gaussian models				
8	TSP (3) + indicator variables for months and years	1.705 (0.318)* [0.166][a]	1.286 (0.277)* [0.157]	0.290 (0.147)* [0.126]	0.833 (0.205)* [0.198]
9	Model 8 + indicator variables for quartiles of minimum temperatures	1.790 (0.333)* [0.173]	1.362 (0.290)* [0.166]	0.309 (0.153)* [0.134]	0.959 (0.214)* [0.228]
10	Model 9 + indicator variables for hot and humid days	1.812 (0.333)* [0.176]	1.380 (0.290)* [0.168]	0.320 (0.153)* [0.139]	0.972 (0.214)* [0.231]

* Statistically significant ($p < 0.05$).
[a] The values in brackets equal the regression coefficients (× 100) divided by the mean death count.

Table 3. *Regression coefficients for mortality counts and TSP (3) (× 100) and standard errors, Basle.*

estimated percent change in respiratory disease mortality ranged from 1.5 to 3.7%, with a weighted mean of 3.4%. The estimated percent change in cardiovascular mortality for each 10 µg/m³ increase in PM_{10} ranged from 0.8 to 1.8%, with a weighted mean of 1.4%.
Comparable calculations can be made for the estimated effects of particulate pollution in Zurich and Basle. Using the same conversion factor, and based on the regression results of model 6 in Table 2 and 3, the estimated expected percent increase in mortality associated with a 10 µg/m³ increase in PM_{10} equals 0.7% for Zurich and 2.6% for Basle. The estimated expected percent increases in respiratory disease mortality associated with a 10 µg/m³ increase in PM_{10} equals 2.5% for Zurich and 1.8% for Basle. The estimated expected percent increases in cardiovascular disease mortality in Zurich and Basle equal 0.5 and 3.1% respectively. These results suggest that air pollution mortality effects are observable in these Swiss cities that are comparable to those that have recently been observed in U.S. cities. In Basle, for total and cardiovascular mortality, the association with mortality is relatively large. There are several potential explanations for

	Zurich	Basle	Geneva
Total mortality			
TSP (3) (× 100)	0.039 (0.020)*	0.141 (0.028)*	–
SO_2 (3) (× 100)	0.027 (0.018)	0.139 (0.040)*	0.120 (0.049)*
NO_2 (3) (× 100)	0.048 (0.025)*	0.240 (0.048)*	0.107 (0.050)*
O_3 (1) (× 100)	0.012 (0.027)	0.075 (0.074)	–
CO (3)	0.013 (0.009)	0.072 (0.043)*	0.009 (0.012)
Mortality, age > = 65			
TSP (3) (× 100)	0.053 (0.022)*	0.135 (0.031)*	–
SO_2 (3) (× 100)	0.027 (0.020)	0.161 (0.044)*	0.143 (0.036)*
NO_2 (3) (× 100)	0.057 (0.028)*	0.218 (0.054)*	0.171 (0.036)*
O_3 (1) (× 100)	0.005 (0.030)	0.145 (0.083)*	–
CO (3)	0.020 (0.010)*	0.091 (0.048)*	0.028 (0.008)*
Respiratory mortality			
TSP (3) (× 100)	0.138 (0.047)*	0.099 (0.058)*	–
SO_2 (3) (× 100)	0.109 (0.042)*	0.076 (0.085)	0.287 (0.077)*
NO_2 (3) (× 100)	0.203 (0.060)*	0.346 (0.100)*	0.241 (0.076)*
O_3 (1) (× 100)	– 0.151 (0.067)*	0.193 (0.155)	–
CO (3)	0.080 (0.021)*	0.022 (0.091)	0.055 (0.018)*
Cardiovascular mortality			
TSP (3) (× 100)	0.028 (0.029)	0.170 (0.043)*	–
SO_2 (3) (× 100)	0.014 (0.026)	0.218 (0.062)*	0.120 (0.049)*
NO_2 (3) (× 100)	0.030 (0.037)	0.259 (0.075)*	0.107 (0.050)*
O_3 (1) (× 100)	– 0.003 (0.040)	– 0.163 (0.116)	–
CO (3)	0.006 (0.013)	0.137 (0.068)*	0.009 (0.012)

* Statistically significant ($p < 0.05$).
[a] The models used were semi-nonparametric models that included the pollution variable, a loess smooth of time to account for trend and seasonality, and a loess smooth of daily minimum temperatures (model 6 in Tables 2 and 3).

Table 4. *Estimated regression coefficients (and standard errors) for daily mortality counts and various measures of air pollution.*[a]

this relatively large estimated association, including:

1) It may simply be due to statistical variation across studies;
2) PM_{10} may make up a much larger proportion of TSP than the 0.55 that was assumed in the conversion;
3) particle pollution and/or its constituents are relatively more toxic in Basle;
4) TSP is serving only as a good proxy over time for another pollutant or group of pollutants that are really causing the health effects, and concentrations of these pollutants are relatively high in Basle; or
5) the monitored pollution levels are correlated with but on average lower than actual exposures.

There is little evidence that the mortality-air pollution effects observed were due to the statistical modeling technique used. Simple plots of mortality counts over particulate pollution levels illustrate that, underlying the Poissonian variation in daily mortality counts, there is a small subtle association between mortality and air pollution. The estimated mortality-air pollution effect was not highly sensitive to the type of regression model used in the analysis to control for seasonality, other long-term trends, and daily differences in temperature and relative humidity. Furthermore, although there was a significant seasonal and temperature effect, there was little evidence that the association is due to residual confounding by inadequate control for seasonality, daily changes in temperature, or daily changes in relative humidity. After accounting for seasonality, the estimated pollution-mortality effect was quite stable to the inclusion or exclusion of variables to control for temperature and relative humidity.
The results of this analysis cannot conclusively establish which pollutant or combination of pollutants is specifically responsible for the observed mortality effects. Mortality was similarly associated with TSP, SO_2 and NO_2. Also, it remains possible that the true culprit pollutant is a constituent of TSP such as inhalable particles, fine or ultrafine particles, combustion particles, or sulfate particles. It may also be possible that the pollutants measured are serving as proxy variables for an unknown or unmeasured pollutant or combination of pollutants. Nonetheless, this study provides little evidence of a safe threshold level of particulate or related pollutants. Statistical tests of non-linearity indicated that the associations between mortality and particulate pollution were not significantly different from linear.

Zusammenfassung

Luftverschmutzung und tägliche Todesfälle in drei Regionen der Schweiz

In der Vergangenheit konnte gezeigt werden, dass Luftverschmutzung in Städten, insbesondere durch Schwebestaub, einen Zusammenhang mit verschiedenen Gesundheitsindikatoren wie Inzidenz und Dauer von respiratorischen Symptomen, Lungenfunktion, Abwesenheit am Arbeitsplatz oder in der Schule aufgrund respiratorischer Krankheit, Hospitalisationen bei Atemwegserkrankungen und kardio-pulmonärer Mortalität aufweist. In der vorliegenden Studie wurde in Zürich, Basel und Genf der Zusammenhang zwischen täglicher Mortalität und Luftverschmutzung für die Periode von 1984 bis 1989 bestimmt. Unterschiedliche Regressionsmodeltechniken wurden benützt, um den Effekt der Luftverschmutzung auf die Mortalität zu schätzen, um zeitliche Trends zu kontrollieren, saisonale Faktoren und Wettervariable zu korrigieren und die Sensitivität der Resultate zu prüfen. Ein positiver statistisch signifikanter Zusammenhang zwischen täglicher Mortalität und der gemessenen Luftschadstoffbelastung konnte in allen drei Städten für den totalen Schwebestaub, Schwefeldioxyd und Stickstoffdioxyd beobachtet werden. Am deutlichsten wurde der Zusammenhang für einen drei Tage gleitenden Mittelwert (inklusive dem selben Tag und den zwei vorhergehenden Tagen) dieser Schadstoffe. Der beobachtete Effekt der Luftschadstoffe auf die Mortalität war nicht sehr empfindlich auf die Anwendung verschiedener Regressionsmodeltechniken, welche benützt wurden, um Saisonalität, Langzeitveränderungen und Wetterbedingungen zu kontrollieren.

Résumé

Pollution atmosphérique et mortalité journalière dans trois régions suisses

La concentration atmosphérique des poussières en suspension, de même que celle d'autres polluants communs dans l'air des grandes villes, a été associée à de nombreux indicateurs de santé liés aux maladies respiratoires: la capacité pulmonaire, l'incidence et la durée de certains symptômes, l'absentéisme à l'école ou au travail, le nombre d'hospitalisations et la mortalité. Dans cette étude, la relation entre la pollution atmosphérique et le nombre de décès par jour a été analysée dans trois agglomérations urbaines suisses, à savoir Zurich, Bâle et Genève, sur la période 1984–1989. Différents techniques de régression ont été utilisées pour estimer l'effet de la pollution atmosphériques sur la mortalité, pour prendre en compte les évolutions temporelles, les facteurs saisonniers et les variables météorologiques, et pour évaluer la sensibilité des résultats obtenus. Dans les trois villes, une association directe et statistiquement significative avec le nombre de décès par jour a été observée pour les poussières en suspension, le dioxyde de soufre et le dioxyde d'azote. L'association la plus forte a été obtenue pour le niveau moyen de ces polluants sur le jour même et les deux jours précédents. Les estimations des effets des polluants sur la mortalité ne sont pas très sensibles aux différents modèles de régression utilisés pour le contrôle des tendances à long terme, de la saisonnalité et des variables météorologiques.

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