The association between air pollution and the daily number of deaths: findings from the Slovak Republic contribution to the APHEA project

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Abstract

Study objective – To analyse the short term relation between daily air pollutant values and the daily number of deaths in Bratislava, Slovak Republic, during the study period 1987–91.

Design – This follows the APHEA protocol. The association between the daily number of total and cause specific deaths and daily variations in ambient air levels of sulphur dioxide (SO₂) and total suspended particulates (TSP) were analysed using Poisson regression that allowed control for meteorological data and variables that handle temporal and autoregressive patterns.

Setting – Bratislava is the capital town of Slovakia, the total population was 442 999 according to 1991 census data. The dominant sources of industrial air pollution are the chemical industry and oil refinery.

Main results and conclusions – After adjustment for season, temperature and relative humidity, days of week and holidays, secular trends, and autoregressive patterns no significant associations were found between the daily variations in the air pollutants, SO₂-24 h and TSP-24 h, and total mortality (RR 0.978, 95% CI 0.96, 0.99; RR 1.008, 95% CI 0.96, 0.99) and cause specific mortality in Bratislava during the study period.

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APHEA is an international multicentre project using an extensive database derived from 10 different European countries which represent various social, environmental, and air pollution situations. The aim is to provide quantitative estimates of the short term health effects of air pollution.¹ The Slovak group joined APHEA in January 1994, one year after it had begun, under the Program of Cooperation in Science and Technology with Central and Eastern European Countries and with New Independent States of the former Soviet Union (PECO), which has enabled Slovakia to collaborate with partners from the European Community in an ongoing research project. This report presents the results of analyses of daily mortality and air pollution during the period 1987–91 in Bratislava, Slovak Republic.

Methods

STUDY PERIOD

For the purpose of this study the period 1987–91 was selected. In 1992, a new automated monitoring system was installed in Bratislava and in other monitoring stations, and different measurement methods were introduced. The study period covers a period of political and economic changes, which can be characterised briefly in terms of an increase in traffic, intermittent reduction of industrial production, and the introduction of new technologies.

STUDY AREA

Bratislava is the capital of Slovakia. It is situated on the river Danube, at the foot of the Small Karpathian Mountains, close to the Austrian and Hungarian borders, and approximately 150 m above sea level. Chemical industry and oil refinery are the dominant sources of industrial air pollution. The population data used in this study were drawn from 1991 mid-year census; the total population was 442 999.

MORTALITY INDICES

The daily number of deaths classified according to ICD 9, and the place of residence of deceased subjects were provided by The Statistical Office of the Slovak Republic. The data were originally taken from death certificates. The mortality data were classified according to:

- Total daily number of deaths,
- Total daily number of deaths minus deaths from external causes (ICD> = 800),
- Total daily number of deaths from respiratory causes (ICD 460–519),
- Total daily number of deaths respiratory infections (ICD 480–486, 466),
- Total daily number of deaths from obstructive lung diseases (ICD9 490–496),
- Total daily number of deaths from cardiovascular causes (ICD 390–459),
- Total daily number of deaths from ischemic heart diseases (ICD 410–414),
- Total daily number of deaths from lung cancer (ICD 162),
- Total daily number of deaths from diseases of the digestive system (ICD 520–579).

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Table 1 Descriptive statistics of daily data on mortality in Bratislava for the study period 1987–91: Total mortality, deaths from respiratory diseases (ICD 460–519), deaths from cardiovascular causes (ICD 390–459), and deaths from diseases of the digestive system (ICD 520–579).

Mortality indices (deaths/day)	Season*	Mean	(SD)	(Range)
Total mortality	1	10·96	(3·36)	(3–21)
	2	10·47	(3·10)	(3–22)
	3	9·95	(3·42)	(2–21)
	4	10·38	(3·45)	(3–22)
ICD 460–519	1	0·70	(0·85)	(0–4)
	2	0·69	(0·85)	(0–4)
	3	0·68	(0·85)	(0–5)
	4	0·63	(0·83)	(0–5)
ICD 390–459	1	5·72	(2·46)	(1–18)
	2	5·15	(2·28)	(0–12)
	3	4·91	(2·34)	(0–4)
	4	5·18	(2·27)	(0–12)
ICD 520–579	1	0·55	(0·78)	(0–4)
	2	0·57	(0·77)	(0–4)
	3	0·51	(0·71)	(0–3)
	4	0·53	(0·73)	(0–4)

* 1 = winter; 2 = spring; 3 = summer; 4 = autumn

Table 2 Descriptive statistics of daily data on air pollution and meteorology in Bratislava for the study period 1987–91

	Season	Mean	(SD)	(Range)
SO ₂ -24 h (µg/m ³)	1	42·82	(47·56)	(10–490)
	2	20·14	(18·88)	(10–180)
	3	11·86	(4·99)	(10–90)
	4	20·32	(16·84)	(10–160)
TSP-24 h (µg/m ³)	1	101·79	(83·06)	(0–680)
	2	83·98	(56·70)	(10–720)
	3	77·84	(56·81)	(10–590)
	4	93·86	(69·46)	(10–690)
24 h temperature (°C)	1	0·87	(4·77)	(–16·00–12·20)
	2	10·27	(5·50)	(–9·20–23·00)
	3	19·97	(3·43)	(11·40–29·20)
	4	10·01	(6·10)	(–6·10–22·90)
24 h relative humidity (%)	1	80·95	(9·97)	(45·00–98·00)
	2	68·12	(11·07)	(36·00–94·00)
	3	65·22	(10·25)	(39·00–90·00)
	4	77·27	(9·07)	(49·00–97·00)

AIR POLLUTION DATA

The daily mean concentrations of sulphur dioxide (SO₂-24 h) and of total suspended particles (TSP-24 h) were measured. For determination of the SO₂-24 h concentration in ambient air, an aspiration colorimetric method was used; for the determination of TSP-24 h a filtration gravimetric method was employed. Nine monitoring stations were operating during the period 1987–91 in Bratislava. Of these, two urban stations were located near roads with frequent traffic, four stations were located in the neighbourhood of chemical factories, and three were in suburban areas. For further analysis, four stations were selected fulfilling the following criteria: they had the highest concentration of measured pollutants and the percentage of missing data did not exceed 15% for the whole study period and 25% for each year.

METEOROLOGIC DATA

The daily data for 24 hour average temperature and 24 hour average relative humidity were available from the regular meteorological database of the Slovak Hydrometeorologic Institute.

MODELLING

Poisson regression was used for data analysis, the procedure for model building followed the general rules of the APHEA protocol. The complete model for daily counts of deaths included the following variables: (1) long term trends, (2) seasons, (3) days of week and holidays effect, (4) short term effect of meteorological conditions – temperature and relative humidity, (5) short term effects of air pollutants SO₂-24 h and TSP-24 h.

Long term trends were controlled for by introducing both linear and quadratic transformations for trend and a dummy variable per each year. Sinusoidal terms were introduced into the model up to the 6th order to control for seasons. Six dummy variables were formed for the days of the week and for holidays to control for the day of the week effect. Linear and quadratic transformations of humidity and temperature of the current day values, and 1 day lag for transformed values of temperature and humidity were introduced. Air pollution variables were assessed with up to three days lag in the model. The best model was fitted for current daily values of SO₂-24 h and TSP-24 h (lag for 0, 1, and 2 days, and averages of consecutive lags were tested). Finally, Poisson regression models were fitted including up to the 3rd autoregressive parameters.

Results

The total number of deaths during the five year period was 19 062. Results of the descriptive statistics for mortality over the period 1987–91 are presented in table 1.

Relatively low levels of SO₂-24 h were observed during the study period. The mean daily concentrations measured in Bratislava exceeded the upper recommended limit according to the air quality guidelines for Slovakia² (150 µg/m³) in 14% of cases. The mean daily TSP-24 h values exceeded the upper recommended limit of 150 µg/m³ in 26% of cases. Results of the descriptive statistics for air pollution and meteorological data, characterising the situation in Bratislava, are presented in table 2.

The correlation coefficients between daily SO₂-24 h values measured at four stations on the same day were relatively high (0·832, 0·851, and 0·762). Correlations were lower for TSP-24 h values from different stations (0·340, 0·301, and 470). Correlation coefficients between TSP-24 h and SO₂-24 h measured at the same stations were low, between 0·008 and 0·230.

The results of the final Poisson model for SO₂ and TSP are presented in tables 3 and 4. After adjusting the data for long term trends, seasons, days of week and holidays, temperature, and relative humidity, no effect of SO₂ and TSP was apparent over the whole study period (table 5).

Discussion

Several explanations can be proposed for the lack of relation between the daily variations of

Table 3 Results of the final Poisson model for total daily mortality for sulphur dioxide (SO₂)

Parameter	Estimate	SEM	(95% CI)
Intercept	2.3332	0.2803	(1.7833, 2.8831)
SO ₂	-0.0004	0.0005	(-0.0014, 0.0005)
L1temp	-0.0062	0.0036	(-0.0133, 0.0008)
L1temp2	0.0001	0.0003	(-0.0005, 0.0008)
L1temp3	0.0000	0.0000	(-0.0000, 0.0000)
L1hum	-0.0017	0.0076	(-0.0167, 0.0131)
L1hum2	0.0000	0.0000	(-0.0000, 0.0001)
Year 88	0.0133	0.0276	(-0.0409, 0.0675)
Year 89	0.0481	0.0270	(-0.0050, 0.1012)
Year 90	0.0550	0.0284	(-0.0008, 0.1108)
Year 91	0.0706	0.0280	(0.0156, 0.1257)
Tuesday	-0.0399	0.0309	(-0.1006, 0.0208)
Wednesday	-0.0289	0.0309	(-0.0895, 0.0317)
Thursday	-0.0325	0.0306	(-0.0925, 0.0275)
Friday	0.0056	0.0303	(-0.0537, 0.0651)
Saturday	-0.0498	0.0308	(-0.1103, 0.0105)
Sunday	-0.0761	0.0310	(-0.1370, -0.0153)
Cos1	0.0834	0.0283	(0.0277, 0.1391)
Sin1	0.0410	0.0144	(0.0127, 0.0694)
Cos2	-0.0188	0.0136	(-0.0456, 0.0080)
Sin2	-0.0384	0.0131	(-0.0642, -0.0125)
Autoregression1	-0.0042	0.0255	(-0.0542, 0.0458)
Autoregression2	-0.0379	0.0254	(-0.0879, 0.0120)
Autoregression3	-0.0511	0.0254	(-0.1010, -0.0011)

Table 4 Results of the final Poisson model for total daily mortality for total suspended (TSP)

Parameter	Estimate	SEM	(95% CI)
Intercept	2.6134	0.3334	(1.9590, 3.2678)
TSP	0.0000	0.0002	(-0.0004, 0.0004)
L1temp	-0.0043	0.0042	(-0.0127, 0.0041)
L1temp2	0.0006	0.0005	(-0.0004, 0.0016)
L1temp3	-0.0000	0.0000	(-0.0000, 0.0000)
L1hum	-0.0116	0.0090	(-0.0294, 0.0061)
L1hum2	0.0000	0.0000	(-0.0000, 0.0001)
Year 88	0.0342	0.0310	(-0.0266, 0.0950)
Year 89	0.0780	0.0307	(0.0176, 0.1384)
Year 90	0.0799	0.0343	(0.0125, 0.1474)
Year 91	0.0633	0.0432	(0.0215, 0.1483)
Tuesday	-0.0198	0.0399	(-0.0982, 0.0585)
Wednesday	-0.0115	0.0390	(-0.0881, 0.0651)
Thursday	0.0005	0.0394	(-0.0768, 0.0779)
Friday	0.0615	0.0382	(-0.0134, 0.1365)
Saturday	-0.0125	0.0385	(-0.0882, 0.0631)
Sunday	-0.0354	0.0386	(-0.1113, 0.0404)
Cos1	0.0874	0.0379	(0.01304, 0.1618)
Sin1	0.0221	0.0184	(-0.0140, 0.0584)
Cos2	-0.0334	0.0174	(-0.0449, 0.0236)
Sin2	-0.0106	0.0164	(-0.0657, -0.0011)
Autoregression1	-0.0066	0.0317	(-0.0688, 0.0556)
Autoregression2	-0.0315	0.0312	(-0.0928, 0.0298)

Table 5 Relative risks (RR) and 95% confidence intervals for total mortality, deaths from cardiovascular causes (ICD 390–459), and deaths from diseases of the digestive system (ICD 520–579) in relation to sulphur dioxide (SO₂) and total suspended particulates (TSP)

	SO ₂ -24 h		TSP-24 h	
	RR	(95% CI)	RR	(95% CI)
Total mortality	0.978	(0.96, 0.99)	1.008	(0.96, 0.99)
ICD 390–459	0.986	(0.94, 1.00)	0.989	(0.93, 1.02)
ICD 520–579	1.035	(1.01, 1.05)	0.999	(0.95, 1.01)

air pollutants, SO₂ and TSP, and total and cause specific mortality in Bratislava during the study period 1987–91. Firstly, the relatively

small number of inhabitants in Bratislava, resulted in small numbers of deaths per day. There are two main objections to this explanation. In comparable or even smaller towns significant associations were found.³⁴ Mortality as a rare event can be modelled by Poisson regression.

The second explanation may lie in the availability of data. Before the installation of the automated monitoring system in 1991, limited data on air pollution were available – only the mean daily concentration of SO₂ and TSP. These data might not express sufficiently the air pollution in the town.

The last explanation concerns effect modifiers. International comparison showed that a newborn boy in the Slovak Republic had an average life expectancy in 1990 of 66.6 years, in contrast to 72 years for his neighbour in Austria, 73 years in United Kingdom, and 79 years in Japan. Less pronounced is the difference in female life expectancy: 75.4 years in the Slovak Republic versus 78 years in Austria and 78.5 years in the United Kingdom. The most important causes of death according to potential years of life lost are cardiovascular diseases and cancer. The likely contributors to these differences, for example newborn mortality or prevalence of smoking and smoking related diseases, are comparable in the Slovak Republic to those in other countries. The newborn mortality was 11.2 in 1990. The prevalence of smoking in the Slovak Republic during the period 1981–89 was 44.8% in the male population aged 30–59 years and 11.9% for the female population. The incidence of lung cancer in 1990 was 11.3/1 000 000 for females (compared with the European standard of 11.31) and 83.15 for males (European standard 108.87).⁵⁶

In the 1960s, the mortality in Slovakia (in former Czechoslovakia) was comparable to that in other developed European countries. Negative trends in mortality and rates of non-communicable diseases started in the 70s, and in contrast to most west European countries the trends are still negative. It is not fully understood why this situation has developed and more detailed studies are therefore being carried out.

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