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Black smoke air pollution and daily non-accidental mortality in Nis, Serbia

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Abstract: The short-term effects of ambient black smoke concentrations on total non-accidental, cardiovascular and respiratory mortalities in Nis, during the 2000–2003 period, were investigated.
Daily measurements for black smoke (BS), as well as the daily number of deaths have been collected. Generalised linear models extending Poisson regression were applied. The effects of time trend, seasonal variations, days of the week, temperature, humidity and air pressure were adjusted.
The per cent increase in the daily number of total deaths associated with a 10 μg/m^3 increase in BS was 1.13% (0.08–2.20%). The effect size was slightly higher for cardiovascular mortality (1.25%, 95% CI: 0.53–1.97%). There was no significant association between air pollution and respiratory mortality.
These results indicate that current levels of ambient BS have significant effects on total and cardiovascular mortalities in Nis.

Keywords: Air pollution, mortality, time series

1 Introduction

The quoted time series studies discuss daily increasing outdoor air pollutants concentrations in relation to a range of adverse health events such as daily number of deaths, hospital admissions, general practitioner consultations etc. In these studies, exposure to air pollution was not assessed at an individual level but from ambient concentrations measured by air quality monitoring networks. Daily mortality rates have been shown to increase in relation to variations in ambient pollutants concentrations [1]. The estimated increase in the daily number of deaths associated with a 10 μg/m^3 increase in ambient

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black smoke obtained from the individual analyses varied across studies and cities [2–5].

In Serbia the mortality dataset is available to medical researchers from 2005 and so this is the first study providing quantitative estimates of the short-term effects of air pollution on mortality in our country. Nis is the second biggest city in Serbia with 250000 inhabitants, of which 171000 live in an urban area of about 32 km^2, according to the 2002 national census. Since 1991 the natural increase is negative and present population type is regressive. The climate is moderate continental. After the industrial collapse (international economic blockade from 1992 to 1999) a major source of air pollutants is fuel combustion including motor vehicle emissions and residential wood, coal and oil burning [6]. One of the known indicators of ambient air quality is black smoke (BS) and it has been monitored in local monitoring network since 1965.

The aim of our paper was to investigate the association between ambient concentrations of BS and daily total non-accidental, cardiovascular and respiratory mortalities in Nis.

2 Statistical methods and experimental procedures

Daily mortality data between 2000 and 2003 were obtained from the Republic Institute for Statistics in charge of coding the medical causes of death according to the International Classification of Diseases - 10^{th} Revision (ICD-10). We separately considered all non-accidental deaths (A00-R99), respiratory (J00-J99) and cardiovascular deaths (I00-I99). Air pollution data were provided by the Public Health Institute Nis. Daily concentrations of BS were monitored in local monitoring network using refractometry method. Daily mean temperatures, air pressure and relative humidity for the same period were obtained from the Republic Meteorological Department. Missing air pollution data for 8% days of the period are replaced by a simple average of values for the days before and after the absent value.

Generalized linear model (GLM) extending Poisson regression was applied allowing for overdispersion. This model used mortality counts as the response variable, the natural cubic splines of the calendar time, temperature, relative humidity and air pressure, the day of the week and season as indicator variables, and air pollution as predictor variable.

The model fitting as well as the method to replace missing data selection was based on Akaike Information Criteria (AIC). To construct the model, the appropriate lag periods for weather variables and BS that gave the smallest AIC value were used. Individual lags from day 0 to day 7 were all examined, as well as the cumulative lags. In the same way the degrees of freedom for natural spline functions of time and weather variables influence approximation were selected. The pollutant was fitted as linear term. A separated model was constructed for each of the mortality type. Analyses were done using S-PLUS 2000 software (S-Plus for Windows, Seattle, WA). The specific model formulation for total mortality is given below:

E[log(Yi)] = a + ns(i, df=16) + indicator(season) + indicator(day of week) + ns(mean temperature$_{lag=0-2}$, df=6) + ns(mean relative humidity$_{lag=0-2}$, df=2)+ ns(mean air pressure$_{lag=2}$, df=2) + air pollution$_{lag=0}$.

3 Results

Table 1 shows the daily number of deaths, pollutant concentrations and weather data. During the 4 years, there were 7914 non-accidental deaths in Nis, 3746 from cardiovascular and 348 from respiratory diseases. The daily mean number of deaths was 5.42±2.37 (0 to 17) for all causes, 2.56±1.64 (0 to 10) for cardiovascular, and 0.24±0.50 (0 to 4) for respiratory mortality. The daily mean level for BS was 23.04±22.74μg/m^3, minimum 0.50 μg/m^3 and maximum 180.00 μg/m^3.

Table 1 Summary statistics.

	Mean	SD	Min	25%	Median	75%	Max
Total number of death (n)	5.42	2.37	0	4	5	7	17
Cardiovascular diseases (n)	2.56	1.64	0	1	2	4	10
Respiratory diseases (n)	0.24	0.50	0	0	0	0	4
BS (μg/m^3)	23.04	22.74	0.50	9.50	16.00	26.50	180.00
Temperature (°C)	12.60	9.02	-12.2	5.60	13.10	19.85	31.5
Humidity (%)	67.58	13.92	26.00	58.00	68.00	78.00	98.00
Air pressure (mBar)	993.76	6.58	966.20	989.80	993.40	997.80	1014.00

The Pearson's correlation coefficients between air pollutant and meteorological variables are presented in table 2.

Table 2 Correlation between pollutant and weather variables.

	Temperature	Humidity	Pressure
BS	-0.258**	0.196**	0.081**
Temperature		-0.619**	-0.388**
Humidity			0.202**

** Significant at the 0.01 level

Table 3 and Figure 1 summarise the results of analysis. Estimated OR for total mortality was 1.0113 (95% CI: 1.0008 to 1.0220), that is, an increase of 10 μg/m^3 in black smoke augmented 1.13% the probability of death on a given day. Risk was slightly higher for cardiovascular mortality, OR=1.0125 (95% CI: 1.0053 to 1.0197). For respiratory mortality OR was the highest, but non-significant. The best fitting lag day of pollutant for all three models was 0.

Table 3 ORs (95% CIs)/10 $\mu g/m^3$ increase in concentration of BS for daily numbers of deaths.

Mortality	Lag	β	SE	OR	Lower 95%	Upper 95%
Total	0	0.01127*	0.00534	1.0113	1.0008	1.0220
Cardiovascular	0	0.01240*	0.00364	1.0125	1.0053	1.0197
Respiratory	0	0.01715	0.01355	1.0173	0.9906	1.0447

* Significant at the 0.05 level

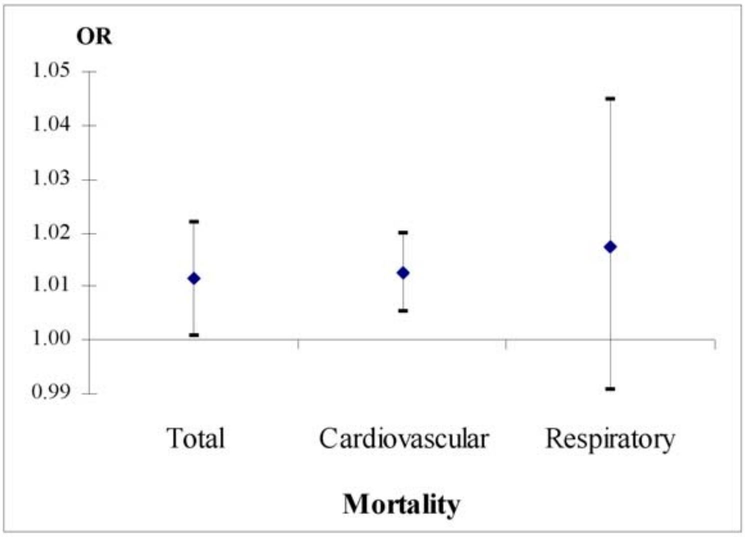

Fig. 1 Association between BS concentration and the number of deaths.

4 Discussion

In past few years numerous epidemiological studies bring new evidence on the effects of particle air pollution on mortality [7]. Particulate matter has most consistently been associated with short-term effects in mortality, but the independence of this association from other pollutants has been questioned at first, as it has been shown in the US [8, 9].

In recent European studies black smoke was found to be at least as predictive of negative health outcomes as PM_{10} or $PM_{2.5}$ [10]. It is well understood that black smoke represents a mixture with varying chemical and physical characteristics and different toxicity. Also it is a combination of primary and secondary particles from different sources. In shortage of the equipment for measuring PM_{10} and $PM_{2,5}$ we used black smoke measurement data for calculation. WHO documents [11] indicate that black smoke could serve as a useful marker in epidemiological studies and that BS concentration are much more directly influenced by local traffic sources than other pollutants. Black smoke measurement does not provide a reliable quantification of the mass concentration of particles in atmosphere, but rather reflect the contribution of combustion sources.

In our town most important source of air pollution is incomplete fossil burning during the heating and traffic as a result of low quality fuel and vehicles. Measured levels of black smoke are not very high, and they are generally below national standard (50 μm/m^3). During the 2000-2003 period daily mean level for sulphur dioxide (SO_2) was 15.1$\pm$12.6 μg/m^3, median 11.5 μg/m^3, minimum 0.0 μg/m^3 and maximum 83.00 μg/m^3 (using spectrofotometry method).

The above results are consistent with result in majority of published studies and the study has found significant associations between relative low concentration of black smoke (average concentration was 23.04 μmg/m^3) and risk for total and cardiovascular mortality. For respiratory mortality OR was non-significant.

Limitations of this study are the same as in other similar studies [12–15]. Primarily, environmental monitoring data do not essentially characterize individual exposures. However, this kind of measurement error is known to cause a bias toward the null and to underestimate pollution effects. Second, individual risk factors, such as underlying disease or exposure to smoking and infectious agents, were not considered in this analysis.

A large amount of the evidence on susceptibility to air pollution involves its effects on the elderly population. There is less evidence about the susceptibility of infants, even though effects of air pollution on infants have more implications than those on any other age groups. Recently, a number of studies found that infants would be more susceptible to air pollution than the general population. In response to air pollution exposure, different age groups may respond differently. Who is at risk or who is more susceptible to the adverse health effects of air pollution is an important question and it has not been fully considered [16–20].

Our mortality time series study have shown, that cardiovascular and total non-accidental mortality are related to ambient black smoke concentrations. However, it has become clear that not all methodological questions surrounding the modelling of time series data on air pollution and mortality will be resolved in the near future. Our epidemiological database is still small, but additional investigation should involve more pollutants and different age groups in order to find parameters that play the most important role for eliciting undesirable health outcome.

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