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Toxic urban waste's assault on cardiovascular risk

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ABSTRACT

A cardiovascular health survey of 1203 persons in households located near the hazardous waste disposal sites and in a reference community, was conducted from 2009 until today to assess whether rates of adverse cardiovascular health outcomes were elevated among persons living near the sites. Data included medical records of reported cardiovascular disease certificates and hospital admission for cardiovascular diseases from hospital database. The study areas appeared similar with respect to mortality, cancer incidence, and pregnancy outcomes. In contrast, rate ratios were greater than 1.5 for 2 of 19 reported diseases, i.e., angina pectoris, and strokes. The apparent broad-based elevation in reported diseases and symptoms may reflect increased perception or recall of conditions by respondents living near the sites. Our study found that cardiovascular risk is associated only with $PM_{2.5}$ concentrations, derived from uncontrolled burning of municipal solid waste in particular sites of our country. Their analysis demonstrated a relationship between increased levels of eventual fine particulate pollution and higher rates of death and complications from cardiovascular and cerebrovascular diseases. Management of solid waste releases a number of toxic substances, most in small quantities and at extremely low levels. Because of the wide range of pollutants, the different pathways of exposure, long-term low-level exposure, and the potential for synergism among the pollutants, concerns remain about potential health effects but there are many uncertainties involved in the assessment. Future community-based health studies should include medical and psychosocial assessment instruments sufficient to distinguish between changes in health status and effects of resident reporting tendency.

1. Introduction

Population-based research has indicated an association between ambient fine particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) and cardiopulmonary mortality and morbidity [1–4]. Most of the studies focused on the effects of $PM_{2.5}$, but very few considered the differential toxicity of $PM_{2.5}$ based on its component species. Since ambient $PM_{2.5}$ consists of species from various sources, including traffic emission, biomass combustion, and crustal origination, the $PM_{2.5}$ species originating from different sources and their mixtures may have greater or lesser toxicity. Nevertheless, recent epidemiologic and toxicological findings have suggested the importance of examining particulate matter species-associated biologic responses and possible underlying mechanisms across the range of cardiopulmonary outcomes [5]. A few studies further examined the association of mortality and morbidity outcomes with seasonal and annual averages of $PM_{2.5}$ species, trying to explain the differential city-to-city $PM_{2.5}$ health risk [6–9]. Secondary particulates such as sulfate and nitrate, as well as trace elements like elemental carbon, organic carbon, and sulfur, have been found most responsible for increased mortality and hospital admission. However, controversy remains regarding the specific $PM_{2.5}$ species associated with adverse health effects across locations and seasons. Differences in sources, chemical characteristics, and meteorology might have contributed to the variations. In Asia, although air quality has improved in many urban areas despite increased combustion of fossil fuels, many cities remain highly polluted. Ongoing research efforts support analyses examining variability in air pollution sources and the geographic, meteorological, and population characteristics of Asian populations [10]. From 1994 to early 2008, in southern Italy, existed under a formal State of Emergency, declared due to the saturation of regional waste treatment facilities. There is growing evidence, including a World Health Organization study of the region, that the accumulation of waste, illegal and legal, and urban and industrial, has contaminated the soil, the water, and the air with a range of toxic pollutants including dioxins. A high correlation between incidences of cancer, cardio-respiratory illnesses, and genetic malformations and the presence of industrial and toxic waste landfills was also found [11]. The most affected zones are the areas of north-east Naples' and south-west Caserta which mark the border between the two provinces. The Campania Mortality Atlas published by the Regional Epidemiological

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Observatory showed that from 1998 to 2001 the first cause of illness was cardiovascular related (40% of men, 50% of women) [12]. In the last phase of the research, the health and environmental data were analyzed to specify the links between contamination from waste and the increase of some health issues. It showed statistically relevant correlations between health and waste, confirming the hypothesis that the high rates of mortality and malformation are concentrated in areas contaminated by waste [12].

2. Methods

2.1. Study site and population

A cardiovascular health survey of 1203 persons in households located near the hazardous waste disposal sites and in a reference community, in Southern Italy, was conducted from year 2009 until 2012 to assess whether rates of adverse cardiovascular health outcomes were elevated among persons living near the sites.

2.2. Data collection

We obtained daily mortality data for urban residents from southern Italy Center for Disease Control and Prevention, with medical records for reported cardiovascular disease certificates and with hospital admissions for cardiovascular diseases from hospital database, for the period between January 1, 2009, and December 31, 2012 (3 years of data). The mortality data were for all causes in all age groups, age-specific groups (0–44 years, 45–64 years, ≥65 years), sex-specific groups (female, male), and all-age cause-specific groups (cardiovascular diseases). The *International Classification of Diseases*, Tenth Revision (ICD-10), codes of mortality were as follows: all natural causes (ICD-10 codes A00–R99), respiratory diseases (ICD-10 codes I00–I98), and cardiovascular diseases (ICD-10 codes I00–I99). We also obtained cause-specific death counts for coronary disease, stroke, and chronic obstructive pulmonary disease. We removed the death counts on December 31 and January 1 of each year, because the daily death counts appeared to be much higher than the average death counts on other days, which likely resulted from the recording of unspecified death counts that had accumulated throughout the year.

$PM_{2.5}$ monitoring was conducted at a site located in an urban residential area approximately 10 miles (1 mile = 1.6 km) south of Naples and Caserta, southern Italian cities. $PM_{2.5}$ mass and species analyses were conducted at the laboratories of Institute for Environmental Protection and Research, Air Emission Inventory Unit, Rome ITALY. For these analyses, we obtained daily average concentrations of $PM_{2.5}$ mass between January 1, 2009, and December 31, 2012 (3 years of data). Two subsets of $PM_{2.5}$ samples were further analyzed for elements and anions, which were selected mainly on the basis of the results of health effects assessed in previous studies [6]: organic carbon, elemental carbon, sulfur, potassium, calcium, iron, zinc, chlorine, lead, manganese, bromine, cadmium, nickel, chromium, and the water-soluble anions: ammonium, sulfate, and nitrate. Two sub-data sets included one for daily average concentrations of organic carbon, elemental carbon, and other elements from January 1, 2009, to December 31, 2012 (3 years of data), and one for water-soluble anion data from January 1, 2009, to December 31, 2009 (1 year of data). To adjust for the effects of weather on mortality, we obtained information on the daily averaged temperature and the relative humidity for the study period from the Italian State Meteorology Bureau.

2.3. Statistical methods

Because daily counts of mortality data follow a Poisson distribution, we used Poisson regression models to evaluate the associations between mortality and exposure to $PM_{2.5}$ and to specific species. Natural spline functions [13] of calendar time, temperature, and relative humidity were used to adjust for seasonality and long-term trends and to control for the potential confounding effects of weather. Degrees of freedom of natural spline functions were determined by the Akaike Information Criterion [14], generalized cross-validation, and the literature [15]. If there was an over dispersion in the variance, we applied a partial autocorrelation function (PACF) to guide the selection of degrees of freedom until the absolute values of the sum of PACF for lags up to 30 days reached a minimum. Analyses were also adjusted for year and day of the week as dummy variables to control for different baseline mortality rates for each year and each day of the week. Residuals of each model were examined to check whether there were discernible patterns and autocorrelation by means of residual plots and PACF plots, respectively.

We first assessed the mortality risk in association with exposure to $PM_{2.5}$ mass on the same day (lag 0) and up to 6 prior days (lag days 0–6), using an individual-lag model. We fit the following individual-lag model to obtain the estimated pollution-associated relative rate of increased mortality:

$$\begin{aligned}\text{Log}\ \ E(Yt) = \beta Z_{t-n} &+ \text{ns}(\text{time}, \text{d f}) + \text{ns}(\text{temperature}, \text{d f}) \\ &+ \text{ns}(\text{relative humidity}, \text{d f}) \\ &+ \text{day of the week} + \text{year} + \text{intercept},\end{aligned}$$

where $E(Y_t)$ is the expected number of deaths at day t; β represents the log-relative rate of mortality associated with a unit increase of air pollutants; Z_{t-n} indicates the pollutant concentrations at day t to n ($n = 0, 1, \ldots, 6$) to represent concentrations at various lag days; day of the week and year represent the effects of the day of the week and the time over years; and ns(time, df) denotes the natural spline function of calendar time, whereas ns(temperature, df) and ns(relative humidity, df) denote the natural spline functions of temperature and humidity, respectively.

Because most of the significant associations estimated in the individual-lag model occurred across lag days 0–6, we applied a constrained distributed-lag model to investigate the association between mortality risk and cumulative exposures to $PM_{2.5}$ and major species of the previous week, accounting for the daily effect in the prior week. Our distributed-lag model constrains lag-specific regression coefficients to be a step function by including variables that are averages of the same day's and previous 6 days' concentrations.

Finally, because central space heating is operated for a specific set of months each year in Naples and Caserta, we further stratified the whole-year analysis into the heating period (November 15–March 15) and the no heating period (March 16–November 14). We examined the excess relative risk of $PM_{2.5}$ and selected species on all causes of mortality for the whole year, as well as for the heating and no heating periods, using the individual-lag model and the distributed-lag model. We conducted separate regression analyses of the distributed-lag model for each period and examined the heterogeneity of effect estimates across periods.

All results were presented as the percentage change of excess relative risk of mortality and its 95% confidence interval in association with each 10-μg/m^3 or interquartile-range increase in $PM_{2.5}$ and major species. All analyses were performed by using R, version 2.12.1, statistical software available on the Comprehensive R Archive Network [16].

3. Results

Table 1 provides a descriptive summary of $PM_{2.5}$ mass and species concentrations, as well as meteorological conditions, in for a north-east Naples and south-west Caserta whole year and for the heating and no heating periods between 2009 and 2012. The average $PM_{2.5}$ concentration during the heating period was approximately 60% higher than that observed during the no heating period. Most $PM_{2.5}$ species, except for calcium and iron, had somewhat higher concentrations during the heating period. However, most proportions of major species