Original Article

Health Risk Impacts of Exposure to Airborne Metals and Benzo(a)Pyrene during Episodes of High PM_{10} Concentrations in Poland

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Abstract

Objective To check whether health risk impacts of exposure to airborne metals and Benzo(a) Pyrene during episodes of high PM_{10} concentrations lead to an increased number of lung cancer cases in Poland.

Methods In this work, we gathered data from 2002 to 2014 concerning the ambient concentrations of PM_{10} and PM_{10}-bound carcinogenic Benzo(a)pyrene [B(a)P] and As, Cd, Pb, and Ni. With the use of the criterion of the exceedance in the daily PM_{10} mass concentration on at least 50% of all the analyzed stations, the PM_{10} maxima's were selected. Lung cancer occurrences in periods with and without the episodes were further compared.

Results During a 12-year period, 348 large-scale smog episodes occurred in Poland. A total of 307 of these episodes occurred in the winter season, which is characterized by increased emissions from residential heating. The occurrence of episodes significantly ($P < 0.05$) increased the concentrations of PM_{10}-bound carcinogenic As, Cd, Pb, Ni, and B(a)P. During these events, a significant increase in the overall health risk from those PM_{10}-related compounds was also observed. The highest probability of lung cancer occurrences was found in cities, and the smallest probability was found in the remaining areas outside the cities and agglomerations.

Conclusion The link between PM pollution and cancer risk in Poland is a serious public health threat that needs further investigation.

Key words: Poland; Episodes; Smog; PM_{10}; Metals; B(a)P; Lung cancer; Administrative distribution; Monitoring stations

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INTRODUCTION

In Poland, excessive airborne particulate matter (PM) pollution (often referred to by the mass media as PM smog phenomenon) has been occurring for decades[1]. The problem is so serious that Poland has now become the smog capital of Europe. The main source of Polish smog is the so-called municipal emission, more specifically, burning fossil fuels and biomass for residential heating. In some periods and/or selected locations, traffic emissions can be a significant source of

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smog[2-3]. Unlike the energy sector of most European Union (EU) countries, the Polish energy sector is almost totally dependent on coal, which is the main source of primary PM and precursors of secondary atmospheric particulates[4]. Although Poland has undergone a significant industrial transformation in the last 20 years, with a marked decrease in PM pollution, PM-related smog episodes are still frequent, especially in the southern part of the country[1-2,5]. The phenomenon of PM smog (which can be physically felt as a noticeable burnt odor or manifests as visibility reduction) occurs under unfavourable meteorological conditions, such as atmospheric stagnation, low wind speed, and high relative humidity[6]. In Poland, smog is observed mostly in the winter season under strong ground-based temperature inversions. Despite conditions that favor pollutant dispersion, PM exceedances are sometimes caused by unusually high local emissions, such as those in densely built-up residential areas, where houses are equipped with outdated and inefficient boilers. Smog episodes can vary and include local smog, which covers small-range areas and is often associated with specific emission events[7]; regional smog, which covers medium-sized regions, like industrial districts or cities, and includes instances such as the famous Ruhr District episode in 1962[8] or the London episode in 1952[9]; and also, most interestingly, mesoscale smog, in which the impacted area is extended to metropolitan scale or even covers a whole country[10]. Results of epidemiological and clinical studies indicate that high concentrations of $PM_{2.5}$ and PM_{10} in Poland are correlated with the total mortality rate due to respiratory and blood diseases[11-12]. More than 42,000 premature deaths are attributable to the excessive concentrations of $PM_{2.5}$[13]. Recent findings show that Polish cities struggle with increased incidences of PM-induced lung cancer (from 9.6 to 22.8 cases per 100,000 inhabitants in cities)[14]. So far, there has been no indication of the extent to which PM concentration or its chemical properties [e.g., the content of toxic compounds, some metals, and polycyclic aromatic hydrocarbons (PAHs)] are responsible for the occurrence of lung cancer effects in the population. Although an increase in the frequency of these effects is usually hardly observable, the chronic character of exposure to those pollutants allows us to infer that PM episodes have a significant impact on human health[15]. The extent to which the incidence of smog events, especially on a large scale, increases the probability of negative health outcomes, is currently unclear. Given the lack of a threshold in PM concentration below which no cancer effects will occur, even low concentrations of PM-bound carcinogens may lead to the development of lung cancer. The purpose of this work is to answer to the following question: To what extent does the occurrence of the large-scale PM_{10} smog episodes in Poland elevate the concentrations of PM_{10}-bound ambient carcinogens As, Cd, Ni, Pb, and Benzo(a)pyrene [B(a)P]?

We also aim to check whether these situations lead to an increased number of lung cancer cases in the general population. In this work, we compared the magnitude of inhalation exposure to these pollutants between three types of areas, namely, Polish cities, large urban agglomerations, and the remaining areas.

METHODS

Selection of Episodes

Our analysis was performed based on data concerning PM_{10} and PM_{10}-bound As, Cd, Ni, Pb, and B(a)P concentrations, which were measured across the whole country between 2002 and 2014 under the Polish National Air Monitoring Program. The number of air monitoring stations that provide such measurements is presented in Table S1 (available at www.besjournal.com). The episodes were selected from a series of daily (24 h) PM_{10} concentrations registered within the mentioned period. At present, clearly defined thresholds of PM_{10} daily concentrations that classify a given day as a smog episode are not available[16]. Although a couple of examples are available where these thresholds were defined by appropriate statistical processing of the daily data series[17-18], none of them can be treated as a gold selection standard. Before setting the selection criteria for these episodes, each series of the PM_{10} concentrations from each monitoring site was directed to distribution testing by using the Shapiro-Wilk test (P = 0.05). The assumption was that if the log-normal distribution was prevailing (i.e., more than 50% of all cases), then the median value (or arbitrarily defined percentile) of the annually averaged daily concentrations could be set as a criteria of episode occurrence in a given location[10]. If, however, the distribution was mostly normal (Gaussian), then each PM_{10} concentration that exceeded the value of the arithmetic mean from the