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Long-term exposure to urban air pollution and the relationship with life expectancy in cohort of 3.5 million people in Silesia☆

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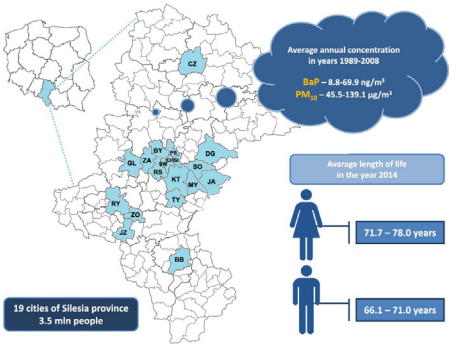
HIGHLIGHTS

- We analyzed the impact of air pollutants on the length of life of the 3.5 million people from the Silesia province in Poland.
- There is a statistically significant correlation between chronic exposure to PM_{10} and benzo(a)pyrene and the length of life.
- Long-term inhalation exposure to the mixture of PM_{10}, BaP, Cd and Pb showed the highest correlation with the length of life.
- Reduction of the annual average concentration of PM_{10} by 1 μg/m^3 results in life expectancy prolonged by 0.1 of the year.

GRAPHICAL ABSTRACT



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ABSTRACT

Air pollution is considered to be one of the most important environmental health determinants. The studies constitute an attempt to explain the role of air pollutants in the impact on the length of life of the 3.5 million people living in the cities of the Silesia province in Poland. The association between the long-term inhalation exposure to PM_{10}, benzo(a)pyrene, cadmium and lead in the period from 1989 to 2008 and length of life in the year 2014 of the inhabitants of 19 cities of the Silesia province has been estimated. The Pearson linear regression method was applied to calculate the relation between exposure to specific pollutants and length of life. In order to determine the influence of the mixture of the pollutants the multiple regression analysis was carried out. The studies have confirmed the significant correlations between the chronic exposure of Silesia province residents to PM_{10} and benzo(a)pyrene and their length of life. The stronger correlation was demonstrated in case of the long-term exposure to the mixture of examined air pollutants. Differentiated exposure of the inhabitants of the Silesia province to air pollutants results in existing inequalities in the life expectancy of men and women among the cities.

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1. Introduction

In the European region of the World Health Organization (WHO) the length of life of the population is systematically increasing, however, there are still significant inequalities in the estimated life expectancy of the inhabitants of the western countries and the population of the central and eastern Europe (WHO, 2015). According to WHO (2014a), in the year 2010, differences in the estimated life expectancy between the countries of WHO European Region were very high, amounted to 12 and 17 years, respectively in women and men population. However, the social and political transformations in the Central and Eastern European countries lead to levelling of the standard of living of the inhabitants, the differences in a life expectancy are still observed. The possible cause of the existing inequalities is differentiated concentration of the risk factors in the environment. Air pollution is considered to be one of the most important environmental health determinants. There is a range of scientific evidence confirming the relationship between the exposure of the population to particulate and gas air pollution and increased mortality rate translating into estimated life expectancy, both in the conditions of the acute and chronic exposure (Zhang et al., 2011; Chen et al., 2013; Li et al., 2015; Garcia et al., 2016). The WHO (2014b) data from the year 2012 indicates that air pollution was responsible for 3.7 millions of deaths worldwide and this number has been increasing over time. The deaths attributable to ambient air pollution in the European regions varied from 44 to 75 cases per 100,000 capita depending on the income levels. The highest mortality rates occur in the European LMI region comprising the low and middle-income countries (WHO, 2014b).

The most significant air pollution components believed to account for increased mortality rate are particulate matter of 10 μm (PM_{10}) and 2.5 μm ($PM_{2.5}$) aerodynamic diameter as well as sulphur dioxide, nitrogen oxides and ozone (Kampa and Castanas, 2008; Marchwinska-Wyrwal et al., 2011; Anderson et al., 2012). The cardiovascular diseases, including cerebral strokes and ischaemic heart diseases as well as respiratory system diseases, such as: chronic obstructive pulmonary diseases, inflammation of the lower respiratory tract or lung cancer constitute the major causes of deaths (Shah et al., 2015; Giorgini et al., 2016; Kurt et al., 2016; Tomczak et al., 2016).

The largest country of the central part of Europe is Poland where the estimated life expectancy at birth of the inhabitants as compared to the population of the western countries is several years lower than in the neighbouring western countries. The estimated life expectancy of men and women in Poland in the year 2012 was 72.7 years and 81.2 years respectively, whereas in Germany it was 78.7 years and 83.4 years and in France it was 78.4 years and 85.4 years (WHO, 2015). Standardized mortality rate taking into account age (people aged from 30 to under 70) for 100,000 inhabitants due to cardiovascular diseases, neoplasms, diabetes and chronic diseases of the respiratory tracts in the year 2011 was 421.7 for 100,000 inhabitants in Poland whereas in Germany and France it was 264.4 and 237.6 respectively (WHO, 2015). It is likely that at least a portion of this difference is attributable to the bad quality of the atmospheric air in Poland. Among 50 cities of the European Union with the worst quality of the atmospheric air expressed by the highest concentration of the $PM_{2.5}$ as many as 33 are located within the territory of Poland, including 7 Polish cities among the top ten most polluted cities of the European Union (WHO, 2016). These cities are situated in the Silesia and Malopolska provinces where the mining industry of hard coal is concentrated and the inhabitants who use coal as the source of energy have access to cheap kinds of the lowest quality coal, such as: coal fines and coal sludge characterised by a high content of sulphur and ash.

This study evaluates the relationship between varied exposure to air pollution of the inhabitants of the cities of the Silesia province and the length of life of women and men in these cities. The objective was to assess the role/share of air pollutants, such as: particulate matter of 10 μm and less diameter (PM_{10}), benzo(a)pyrene (BaP), lead (Pb), cadmium (Cd) in the impact on the length of life.

2. Material and methods

2.1. Justification of the choice of the examined population

The study population consisted of 3,574,394 people living in all the cities with county rights of the Silesia province (50°15′51.623″N and 19°1′15.161″E) located in the southern Poland in the Central Europe. This applies to the cities: Bielsko-Biała (BB), Bytom (BY), Chorzów (CH), Częstochowa (CZ), Dąbrowa Górnicza (DG), Gliwice (GL), Jastrzębie Zdrój (JZ), Jaworzno (JA), Katowice (KT), Mysłowice (MY), Piekary Śląskie (PS), Ruda Śląska (RS), Rybnik (RY), Siemianowice Śląskie (SI), Sosnowiec (SO), Świętochłowice (SW), Tychy (TY), Zabrze (ZA), Żory (ZO) (Fig. 1) where the majority of the hard coal mines and numerous exploration and processing plants of the non-ferrous metal ores functioned in the past, which generated the highest emission of contaminants. The average length of life of the deceased in the year 2014 (the latest available data) of the inhabitants of these cities was examined excluding deaths from external causes. Changes of the places of residence during the period of life of the deceased in the year 2014 were not taken into account as - according to the Central Statistical Office (2015) - in the year 2014 total net migration in all examined cities was negative ranging from −0.7 to −5.8 for 1000 people and during the period of the last 27 years, i.e. since the beginning of the examined period of exposure (year 1989) it displayed a similar trend caused by the gradual closure of the heavy industry after the year 1989.

The average length of life of women and men in 19 cities of the Silesia province in the year 2014 was calculated on the basis of register of deaths that was made available by the Central Statistical Office after excluding deaths caused by external causes.

2.2. Assignment of exposure to ambient air pollution

For each city the mean concentration of the examined air pollutants in the period from 1989 to 2008 was calculated. The data regarding the annual average concentration of PM_{10} as well as cadmium, lead and benzo(a)pyrene in the particulate matter in particular cities of the Silesia province for the years from 1989 to 1998 comes from the Provincial Sanitary and Epidemiological Station in Katowice (PSES, 1990–99) and for the years from 1999 to 2008 from the networks of the measurement stations of the State Environment Monitoring (SEM) (CIEP, 2016). The measurement stations of the SEM are part of the European Air Quality Network and they carry out measurements of the air pollutants with the application of aspiration methods: manual (gravimetric) ones and automated methods (Table 1).

The gravimetric method is applied to examine the concentrations of the particulate matter and heavy metals, polycyclic aromatic hydrocarbons, including BaP. The so-called particulate matter samplers where air is sucked are used for this purpose. Every two weeks 14 disposable filters that are changed automatically every 24 h are placed in the samplers.

The automated method is applied to measure the concentration of the particulate matter and gaseous pollutants. Automated meters that allow to present the results of measurements online are used in this method. The measurement stations of the SEM functioned within the territory of all 19 cities until 2008, thus the exposure period ended six years before the year in which life expectancy was examined.

The range of average annual concentration of PM_{10}, BaP, Cd and Pb in 1989–2008 in the cities of the Silesia province were: 45.5–139.1 μg/m^3, 8.8–69.9 ng/m^3, 0.8–93.7 ng/m^3 and 19.0–1285.0 ng/m^3, respectively.

2.3. Statistical analysis of the results

In the thesis the scenario of the cause-and-effect relation between the long-lasting inhalation exposure to PM_{10}, benzo(a)pyrene,