Environmental burden of disease associated with $PM_{2.5}$ exposure in Poland and selected neighboring countries

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Abstract

Environmental burden of disease (EBD) is a concept that facilitates the measurement of health outcomes in the population, associated with environmental determinants of health. It is useful in health policy for the determination of priority actions aimed at improving the health of the population. Detailed methods are described in documents of the World Health Organization (WHO). They allow us to trace the health inequalities which are the results of environmental impact or preferred life style of the selected population.

It was determined that the attributable burden of total mortality cases in DALYs related to an increase of $PM_{2.5}$ concentrations by unit (1 $\mu g/m^3$) in Poland is similar to data in the Czech Republic. The environmental burden of total mortality in Poland was 17.99 (95% CI: 6.48–28.54) and 17.9 (95% CI: 6.46–28.35) DALYs per 1000 inhabitants, respectively. The obtained results suggest that the highest value of EBD for cardio-respiratory diseases is observed in Hungary in comparison with other neighboring countries. The presented way of estimating calculates of the number of deaths and the number of life years lost due to death or disability (DALYs) associated with the relevant exposure, such as fine particles contained in the ambient air. Unfortunately, estimating focuses on single risk factors and selected diseases. Recommended by WHO, used methods imply certain conditions, among which are mentioned: the appropriate number of population, reliable data on exposure and health effects, knowledge of the dose–response relationship. Despite these limitations, it might be worthwhile

WIT Transactions on Ecology and The Environment, Vol 183, © 2014 WIT Press
www.witpress.com, ISSN 1743-3541 (on-line)
doi:10.2495/AIR140171

to use the proposed solutions and present them in training courses because of their considerable attractiveness in public health.
Keywords: $PM_{2.5}$, DALYs, public health.

1 Introduction

Environmental burden of disease (EBD) is a concept that facilitates the measurement of health outcomes in the population, associated with environmental determinants of health. It is useful in health policy for the determination of priority actions aimed at improving the health of the population. Detailed methods and obtained results of estimation for all countries of the world are described in documents of the World Health Organization [1, 2]. They allow us to trace the health inequalities which are results of environmental impact or preferred life style of the selected population. EBD study uses DALYs (disability adjusted life years) as a factor of synthetic measure of health in population. DALYs is the sum of two components: years of life lost due to premature deaths and years lived with disability [3–5].

The World Health Organization estimates the environmental burden of disease in the European countries at between 18 to 20% of DALYs; moreover the higher burden is noted in the eastern part of the region. Current data suggests, that the total burden of disease could be attributed to nine selected environmental factors, out of which particulate matter, and environmental tobacco smoke were leading [6]. For example, attributable death to outdoor air pollution in Poland, in 2008 year, was 6600 deaths (17.0 per 100000 inhabitants), and we can observed that given value is somewhat higher than those calculated for neighboring countries such as Czech Republic (14.0/100000 inhabitants) or Slovakia (9.0/100000 inhabitants) [7]. Unfortunately, described by WHO method of estimation focuses on single risk factors and selected disease. The recommended procedure implies certain conditions, among which are mentioned: the appropriate number of population; reliable data on exposure and health effects; knowledge of the dose-response relationship [1]. The priority is to determine the proportion of the population exposed to a specific environmental factor (e.g. $PM_{2.5}$). This measure, called the population attributable risk, is useful for visualization as far as possible to reduce the spread of the health effect in total population, if exposure to examined environmental factor were eliminate [8].

The aim of the study is to present the concept of the environmental burden of disease to fine particles ($PM_{2.5}$) exposure in Poland and moreover to present the health benefit related to reduction of $PM_{2.5}$ concentration in ambient air in one of the most polluted region of Poland (Silesia region).

2 Material and methods

The authors used detailed methods of dealing available on the World Health Organization website [9]. According to the recommendations the order of proceedings was as follows: it was decided to estimate EBD in response to $PM_{2.5}$ exposure among inhabitants of Poland and selected neighboring countries (Czech

Republic, Lithuania and Hungary); next authors defined the potential health effects such as total mortality and specific mortality due to cardio-respiratory diseases; finally authors determined the value of population weighted concentration [10] and adopted dose-response based on recommended references [11]. Table 1 shows selected data required to assess the environmental burden of disease (e.g. the exposure and the value of the national burden of disease) adopted according to WHO methodology. Calculation of environmental burden of disease (EBD) in DALYs was based on the formula:

$$EBD = PAF \cdot B_O D \tag{1}$$

where PAF is size of the population attributable risk (proportion of the population exposed to $PM_{2.5}$ concentration). This value is calculated based on the relationship:

$$PAF = \frac{f \cdot (RR-1)}{f \cdot (RR-1)+1} \tag{2}$$

in which f is the conventional exposure unit and is 1 μg/m^3 and RR means the health risk arising in response to an increase in the concentration of $PM_{2.5}$ on a conventional unit. According to the WHO methodology value of RR should be calculated from the formula:

$$RR = e^{E \ln RR_0} \tag{3}$$

in which E corresponds to the population weighted concentration (see Table 1) and RR_0 is the individual health risk arising in response to an increase in the concentration of $PM_{2.5}$ on a conventional unit. An important issue is the value of the unit relative risk, the authors of the EBD concept propose to use results of epidemiological data verified during the international project CAFE [12]. Should be assumed that the relative risk of death due to cardio-respiratory response to increased concentrations of $PM_{2.5}$ on a conventional unit (1 mg/m^3), in the adult population aged 30 years or more is RR_0 = 1.0077 (95% CI: 1.0020–1.0132). In the case of total mortality the risk is slightly smaller and is at the level RR_0 = 1.0058 (95% PU: 1.0020–1.0096).

Table 1: National burden of disease (B_0D) for selected diseases in Poland and neighboring countries in 2004 based on WHO data [4], and population weighted concentrations of $PM_{2.5}$ and PM_{10} in ambient air, data according to de Leeuw and Horálek [10].

Estimated total DALYs by cause of death (B_0D)	Poland	Hungary	Czech Republic	Lithuania
All causes	5703088	1814372	1460502	633014
Cardio-respiratory diseases	834374	448685	353680	169873
Total population	38246730	10113272	10194511	3440158
Population weighted concentrations [μg/m^3]	Poland	Hungary	Czech Republic	Lithuania
$PM_{2.5}$	22.4	24.6	23.1	13.6
PM_{10}	30.5	33.5	31.5	20.3

3 Results

Assessed size of the environmental burden of selected diseases in Poland and neighboring countries, in response to increase of $PM_{2.5}$ concentration in ambient air and expressed it in the form of DALYs (disability-adjusted life years) is presented in Table 2.

Table 2: Attributable burden of total and specific mortality cases in DALYs calculated for Poland and selected neighboring countries in relation to an increase of $PM_{2.5}$ concentration by unit (1 $\mu g/m^3$).

Country	Poland	Hungary	Czech Republic	Lithuania
		Total mortality		
Total population	38246730	10113272	10194511	2315283
RR_0	1.0058	1.0058	1.0058	1.0058
Lower RR_0	1.002	1.002	1.002	1.002
Upper RR_0	1.0096	1.0096	1.0096	1.0096
E	22.24	24.58	23.08	13.59
RR	1.1372	1.1527	1.1428	1.0818
BoD (in DALYs)	5703088	1814372	1460502	633014
PAF (f = 1)	0.1207	0.1325	0.1249	0.0756
EBD	688313.68	240423.79	182493.61	47846.43
Lower EBD	247872.06	86952.81	65820.17	16956.88
Upper EBD	1091731.39	379756.5	289020.7	77079.33
EBD per 1000 inhabitants	17.99 (6.48–28.5)	23.77 (8.60–37.55)	17.90 (6.46–28.35)	20.66 (7.32–33.29)
		Cardio-respiratory mortality		
RR_0	1.0077	1.0077	1.0077	1.0077
Lower RR_0	1.002	1.002	1.002	1.002
Upper RR_0	1.0132	1.0132	1.0132	1.0132
E	22.24	24.58	23.08	13.59
RR	1.1860068	1.2074866	1.1936732	1.1098692
BoD (in DALYs)	834374	448685	353680	169873
PAF (f = 1)	0.1568345	0.1718335	0.1622498	0.0989929
EBD	130858.66	77099.11	57384.50	16816.23
Lower EBD	36264.21	21502.99	15939.23	4550.48
Upper EBD	211070	123632.1	92364.17	27729.55
EBD per 1000 inhabitants	3.4 (0.94–5.51)	7.6 (2.13–12.22)	5.6 (1.56–9.06)	7.3 (1.96–11.98)

It turns out that the estimated value of EBD associated with an increase in the concentration of $PM_{2.5}$ for 1 $\mu g/m^3$ and leading to total deaths in Poland and in Czech Republic was similar, and was about 18 DALYs per 1000 population. However, the highest value of EBD is related to inhabitants of Hungary, EBD stands at 23.77 DALYs per 1000 population. With regard to the specific mortality due to cardio-respiratory disease obtained results are surprising, the lowest value of EBD associated with an increase in $PM_{2.5}$ concentration by unit (1 $\mu g/m^3$) was in Poland (3.4 DALYs per 1000 population). The observed results suggest twice as high environmental burden of disease with values 7.6 and 7.3 per 1000 inhabitants in Hungary and Lithuania, respectively.

4 Discussion

This paper describes the concept of the environmental burden of disease (EBD) related to $PM_{2.5}$ exposure contained in ambient air, and some health problems such as total deaths or deaths due to cardio-respiratory diseases in selected countries of Eastern Europe. Step-by-step, in detail, a method of DALYs' calculation in Poland and selected neighboring countries was shown. These indicators are increasingly used in public health and its better understanding and proper interpretation need trainings combined with the presentation of own data.

Proposed by WHO methodology applies to similar assumptions regarding dose-response relationship. It is recommended to assume that this is the same value for different populations, arguing the lack of differences in biological response between the inhabitants of different countries [11]. This assumption seems reasonable, since the published results of different authors confirm that the risk ratio for total or specific mortality is similar for different populations [13]. It has been estimated that exposure to the currently measured concentrations of $PM_{2.5}$ leads to a shortening of the average life expectancy of Europeans by nearly 9 months [14]. Simultaneously the cited report of the European Environment Agency shows that a third of the urban resident within the European Union countries are exposed to concentrations of $PM_{2.5}$ exceeding the annual limit values. It is worth noting that the proposed by WHO methodology of EBD calculation takes into account the differences in current exposure which reflects different levels of concentrations in selected countries [10]. It can be considered that in the worst situation are those countries which use coal to electricity and heat production, including Poland and neighboring countries. Obtained results confirmed the highest value of DALYs in Hungary probably because the population weighted concentration of $PM_{2.5}$ in this country was the highest. Interesting is fact, that equally high value of EBD was confirmed for the residents of Lithuania, although the size of the population attributable risk was one of the lowest. This observation suggests that the place of residence and related specific socio-economic and environmental conditions are significant for the value of estimated EBD rate [9]. It is well known that the preferred life style, with registered high frequency of tobacco smoking, is an important determinant of health. According to current data presented by WHO, the frequency of current smokers in people aged 15+ years in Hungary is 31.4%

and is one of the highest in the EU [15]. On the other hand the estimated value of total health expenditure as % of gross domestic product (GDP) is the lowest in Lithuania, was 6.6% in 2011 year [15]. Impact of those both factors on the estimated value of EBD cannot be excluded. Statement of own data with the WHO data is almost impossible, as the official website are available only the value of DALYs estimated for total air pollution [16]. However, it is worth noting, that the cited indicators expressing the overall burden due to exposure to air pollution in 2004, as in our study, were lower in Poland, than in Hungary and Lithuania. The corresponding values of DALYs per 100,000 inhabitants were: 136 in Poland, 178 in Hungary and 174 in Lithuania [16].

To conclude that proposed by the WHO and described in the work method is an interesting example of estimating the potential environmental effects of health in public health. Unfortunately, quite a complicated methodology makes independent work is quite troublesome without detailed instructions. Once again it should be emphasized that DALYs represent only be indicative ranking of the impact of selected environmental factors, such as $PM_{2.5}$ on health. The proposed indicators are useful in health policy for the determination of priority actions aimed at improving the health of the population, furthermore increase of public concern in this subject is observed, in the context of deterioration of air quality on each winter season.

Besides describing the work methodology WHO proposes useful tools for assessing the impact on the health of different scenarios taking into account air quality improvement (i.e. reduction of particular pollutant concentrations) [17, 18]. They allow us to calculate health benefits related to reduction of $PM_{2.5}$ concentration in ambient air e.g. to assess the life gain expectancy, even to assess the monetary benefits. All cited tools are useful in environmental and health policy; however require specific training of experts who will use them. Presented paper may constitute a kind of educational material for those interested in the field of environmental health.

It was determined that the attributable burden of total mortality cases in DALYs related to increase of $PM_{2.5}$ concentrations by unit (1 $\mu g/m^3$) in Poland is similar to data in Czech Republic. Environmental burden of total mortality in Poland was 17.99 (95% CI: 6.48-28.54) and 17.9 (95% CI: 6.46-28.35) DALYs per 1000 inhabitants, respectively. The obtained results suggest, that the highest value of EBD for cardio-respiratory diseases is observed in Hungary in comparison to other neighboring countries (Poland, Czech Republic, Lithuania).

Presented way of estimating calculates of the number of deaths and the number of life years lost due to death or disability (DALYs) associated with the relevant exposure such as fine particles contained in the ambient air, unfortunately estimating focuses on single risk factors and selected disease. Recommended by WHO and used methods imply certain conditions among which are mentioned: the appropriate number of population, reliable data on exposure and health effects, knowledge of the dose-response relationship. Despite these limitations, it might be worthwhile to use proposed solutions and present them in the training courses of public health workers, epidemiologists

and other staff responsible for improving the quality of environment and the health of population.

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