Chapter 10

Short-Term Effect of Changes in Fine Particulate Matter Concentrations in Ambient Air to Daily Cardio-Respiratory Mortality in Inhabitants of Urban-Industrial Agglomeration (Katowice Agglomeration), Poland

Małgorzata Kowalska

Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/39235

1. Introduction

The impact of ambient air pollution on human health and the role of particulate matter in this relationship have been discussed for many years, and have been documented by numerous published studies (Pope & Dockery, 2006; Schwartz, 2004; CAFE, 2005; Brunekreef & Holgate, 2002; Katsouyanni et al., 2001; WHO, 2004). However, we still don't have enough evidence to clear explain the possible mechanisms that induce air pollutants related events (mortality or other health effects). The main reasons of these disturbances are: difficulties in understanding the mechanism of damaging impact on human body, but also variety of particulate pollutant sources, their various chemical composition and physical properties and their variability in time (Pope & Dockery, 2006; Schwartz, 2006; Wichmann et al., 2000). Moreover, the majority of evidence comes from studies conducted in North American or West European countries, only few concern the region of middle-east European (Katsouyanni et al., 2001; Jędrychowski, 1999; Krzyżanowski & Wojtyniak, 1991).

In proven health problems assessed with particulate air pollution are short-term effects such us increase of daily mortality. The presented work has been applied exactly to short-term health effects. The potential health risk in population living in urban-industry agglomeration exposed to $PM_{2.5}$ in Poland has not been studied yet. The work is complement of the lack in public health in range of risk communication to improvement of health status of population.

2. Results of Polish study – Purpose and accepted methods

The aim of presented study was assessment of an impact of short-term ultrafine particle concentration changes in ambient air to daily number of deaths due to cardio-respiratory diseases in population living in Katowice Agglomeration. In specific goals of the study was: assessment of daily risk of death due to cardio- and respiratory diseases related to an increase of PM_{10} and $PM_{2.5}$ concentration. Furthermore the most precise scenario of acute exposure to particulate air pollution in relationship with specific (cardio- respiratory) mortality in Katowice Agglomeration, expressed as concentration in day of death and as moving averages concentrations, was determined. Finally the quality of ambient air was rated according to Air Quality Index useful in environmental risk communication process. The established goals allowed to verify thesis very often described in many publications: deterioration of ambient air quality leads to increase health risk in exposed population. Simultaneously, the obtained results allowed to complement data in Poland in range of relative risk of daily death and related to $PM_{2.5}$ exposure.

To realize established goals of the work a time-series analyses was used, covering six calendar years in the period 2000-2005. Data concerning daily number of deaths and daily averages of ambient air quality applied Katowice Agglomeration in Silesian voivodeship and separately large city located in described region (Zabrze).

Mortality data was obtained from the registry at the Central Statistical Office in Warsaw. The records were analyzed according to the classification scheme of the International Classification of Diseases – 10^{th} edition (ICD-10). The category of deaths due to cardiovascular diseases included deaths with codes I00-I99, and to respiratory diseases included deaths with codes J00-J99, database contained the records in two age categories: less than 65 years and 65 or more years.

Data on ambient air pollution was provided by the State Environmental Agency in Katowice. For each day the 24-hour spatial average concentrations of PM_{10}, SO_2 and NO_2 were calculated as the average of all site-specific measurements, monitored in the Katowice Agglomeration. Additionally daily average concentrations of $PM_{2.5}$ measured in Zabrze were obtained. Moreover, for each study day the Institute of Meteorology provided additional data, such as daily mean temperature, daily mean relative humidity and daily mean atmospheric pressure. The data set included also a variable describing a climatic season and influenza epidemic.

Variability of the daily number of deaths and daily concentrations of pollutants was presented in two ways. First was used methods of descriptive statistics, where presentation of the pollutant concentration was based on tertile value of concentration. A low level concentration was established at a value below 33% percentile; a medium concentration between the range of 33% and 66% percentile, and high concentration above 66% percentile. Next, was assessed the relationship between daily mortality and daily concentrations of air pollutants using GLM procedure. Variables describing ambient air pollutant were expressed as average 24-hours concentration on the death day, day preceding death, and 3-day or

longer moving average concentration of each pollutant (PM_{10}, $PM_{2.5}$, SO_2, NO_2) (Kowalska et al., 2010). The formula (1) used in multivariate Poisson regression model was:

$$\begin{aligned} \text{Deaths} = b_0 + b_{1*}\text{season} + b_{2*}\text{air temperature} + b_{3*}\text{air humidity} + \\ + b_{4*}\text{atmospheric pressure} + b_{5*}\text{pollutant} \end{aligned} \quad (1)$$

Model tested the effect of the increase of air pollution concentration (single pollutant) by 10 μg/m^3 on a daily number of deaths in different specific scenarios: impact of concentrations of pollutants recorded on the day of death, on the day preceding a death and pollutions expressed as the moving average in the period preceding deaths and longer (3, 5, 7, 14, 30, 40, 50 and 60 days).

The relative risk (RR) estimates of the total and circulatory deaths in relation to a 10 μg/m^3 increase in each pollutant was calculated using the formula (2):

$$RR = e^{b\ delta} \quad (2)$$

where b is the regression coefficient of the pollutant in question and delta is its increase by 10 μg/m^3. Additionally, a percentage change in mortality was calculated as the (RR-1) times 100%.

To assess the quality of ambient air pollution in Katowice Agglomeration according to Air Quality Index (AQI) different methods of indexation (American, French, British and German) were used. Daily PM_{10} and sulphur dioxide (SO_2) concentrations were transformed to qualitative variable expressed by: good, medium and unhealthy air quality. Finally, mean value of daily number of deaths characteristic for days with particular categories quality of air was calculated. All analyses were performed using procedures available in the Statistica 7.0 or SAS statistical packages.

2.1. Quality of ambient air pollution in study agglomeration (Katowice Agglomeration)

Available published data suggests that in Poland, after the political and economical change in 1990 the quality of environment became one of the national target priorities, and the effort towards environmental clean-up has resulted in a substantial improvement of ambient air quality (National Health Program, 1996). The largest effect was seen in the urban area of Katowice, known for high levels of industry-related air pollution. A time-series analysis performed in years 1994-5 revealed the most significant effect of exposure to sulphur dioxide (SO_2), followed by particulate matter (PM_{10}) (Zejda, 2000). Since then the quality of ambient air has significantly improved. Between 1994 and 2005 ambient air daily average concentrations of pollutants have decreased by 38% in the case of SO_2 and by 28% in the case of PM_{10}. The apparent decline in ambient air pollution created an opportunity to find out if the pattern of acute mortality has responded to the decreased exposure, under 'natural experiment' scenario.

Database was constructed so that it was possible to analyze the number of deaths from the regard of the season of year: winter – months from 01 January to 31 March, the spring –

months from 01 April to 30 June, summer – months from 01 July to 30 September, and the autumn – months from 01 October to 31 December. The highest concentrations of ambient air pollutants were in cold season (winter and autumn), while the lowest related hot season (summer). Figure 1 shows daily concentrations of pollution in particular seasons in Katowice Agglomeration.

Moreover, the implementation of $PM_{2.5}$ concentration measurements in large city of region (Zabrze) makes it possible to estimate the risk of deaths related to fine particulate exposure, not unexplored in Poland yet. Table 1 presents data on concentrations of pollutants in this city. It was documented that in the study period the total number of days with exceedance of limit value (Polish Ministry of Environment, 2002) for $PM_{2.5}$ concentration (25 μg/m^3), PM_{10} (50 μg/m^3) and SO_2 (125 μg/m^3) in Zabrze city were 295, 448 and 15 days respectively. These exceedances were always associated with the cold season (autumn-winter).

The major source of particulate matter, SO_2 and NO_2 in the environment remained combustion of vehicle fuels (petrol, oil), burning of wood in fireplaces, as well as stoves and gasoline burning (Knol et al., 2009). Current data confirmed that fine particulates were the predominant fraction of suspended particles in air measured in the Katowice Agglomeration (Klejnowski et al., 2007). Simultaneously, other authors indicated that elemental and organic carbon are significant proportion (60 to 80%) of fine particles, which indirectly points to the advantage of municipal pollution sources (Pastuszka et al., 2003; Rogula et al., 2007). Finally, it should be noted, that extensive use of coal for heating, industrial purposes and mass production of energy in the Baltic countries of Eastern Europe makes another profile of air pollution in this region with dominant role of PM and sulphur dioxide (Jędrychowski, 1999; Medina et al., 2002).

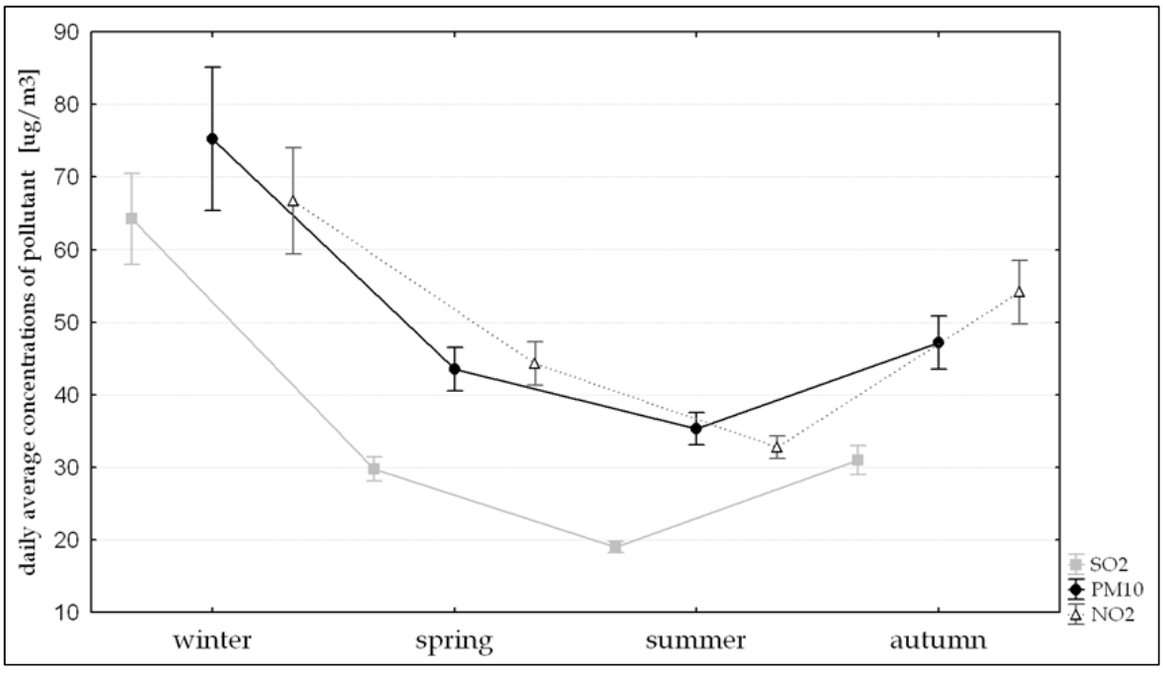

Figure 1. Daily concentrations of PM_{10}, SO_2 and NO_x in ambient air, Katowice Agglomeration in the study period (01.01.2000-31.12.2005).

Pollution	Descriptive statistics of air pollutants concentrations [μg/m³]					
	Mean	Min	Max	Perc 33%	Perc 66%	SD
SO_2 (daily limit value 125 μg/m³)	35.7	2.6	266.2	21.6	36.8	25.2
$PM_{2.5}$ (annual limit value 25 μg/m³)	40.5	4.9	323.7	21.8	40.0	34.5
PM_{10} (daily limit value 50 μg/m³)	40.8	5.6	407.5	26.0	42.4	28.1
NO_2 (annual limit value 40 μg/m³)	26.9	6.0	87.0	21.3	29.2	11.2

Table 1. Descriptive data of pollutants concentrations in ambient air, Zabrze in the study period 2000-2005

2.2. Daily specific mortality

Among documented short-term health problems associated with fine particulate air pollution are mentioned increase the daily number of deaths, especially deaths due to cardio-respiratory diseases (WHO, 2004). Systematic epidemiological studies indicated the occurrence of this relationship even when PM concentrations are at the levels safe for human health (Krzyżanowski & Wojtyniak, 1991; Anderson et al., 2001; EPA 2004). Some studies suggest the importance of two pollutants ie particulate matter and sulphur dioxide for a daily increase in mortality (Dockery et al., 1992; Ostro, 1993). Since the composition of air pollution in Polish agglomerations differs from profile in other countries (dominant role of SO_2) and measured levels are usually higher, it is necessary to estimate the relative risk of daily mortality related to ambient air pollutants in selected industrial region (Katowice Agglomeration).

During the study period (from 2000 to 2005 years), 146 592 people died due to cardio-respiratory diseases in Katowice Agglomeration, on average 67 people per day. Analysis showed that out of this cases, 115 635 (78.9%) was deaths in older population (people aged 65+ years). It was noted that only 8.3% of cardio-respiratory deaths (n=12 179) was related with respiratory diseases. Further analysis of available register data of infectious diseases incidence in Poland confirmed the occurrence of two influenza episodes, in the years 2003 and 2005. In both cases, the influenza episode occurred between 16th February to 22nd March (National Institute of Public Health, 2010) with no observable increase in the rate of mortality due to influenza. Seasonal diversity of average value of specific mortality shows figure 2. The highest level of deaths due to cardio-respiratory diseases was related to cold season (winter) and the lowest was characteristic for summer.

Figure 3 shows changes in daily number of deaths due to cardio-respiratory diseases in inhabitants of Zabrze according to the fine particulate concentrations. The obtained results suggest that the highest mortality were associated with the highest level of $PM_{2.5}$ concentration, the results of ANOVA test confirmed statistically significant relationship.

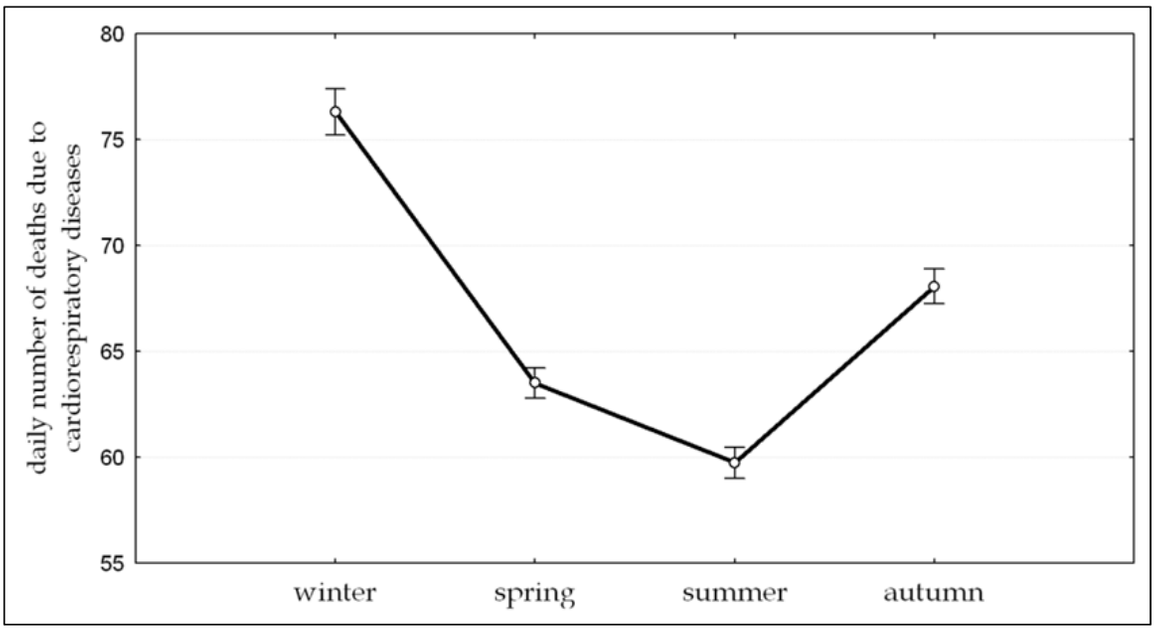

Figure 2. Daily average number of deaths due to cardio-respiratory diseases in Katowice Agglomeration according to season of year, study period 2000-2005.

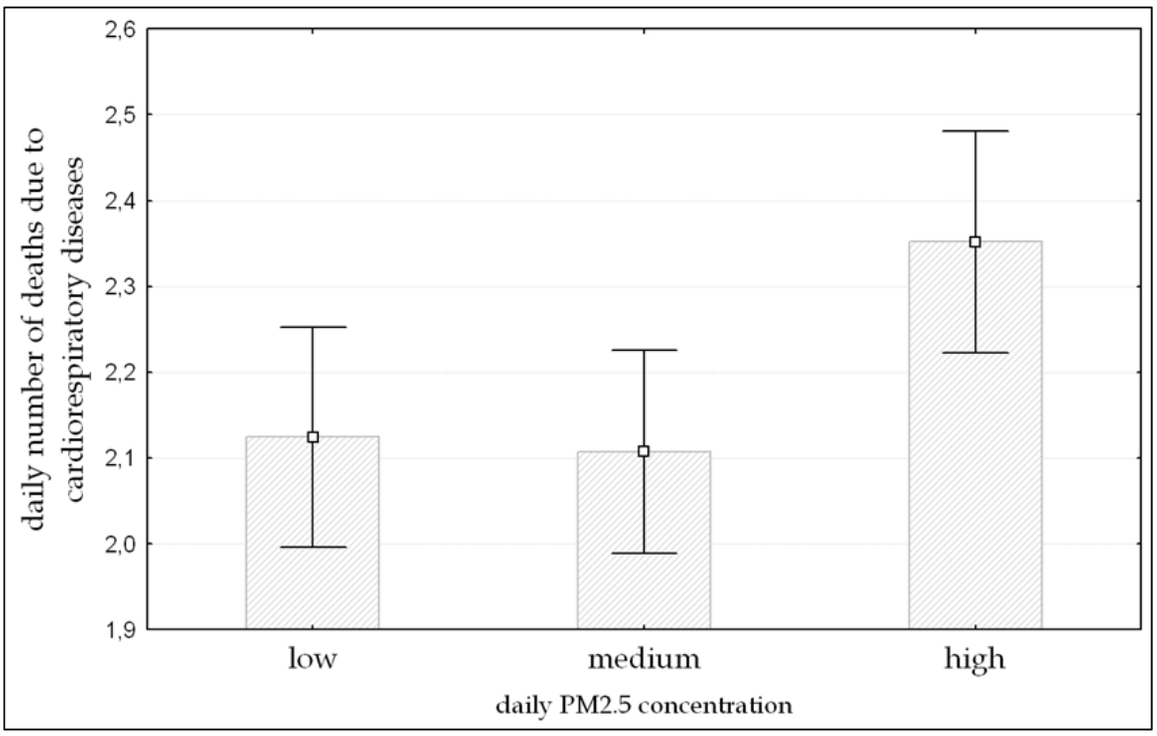

Figure 3. Daily average number of cardio-respiratory mortality in Zabrze city according to quality of daily concentration of $PM_{2.5}$, study period 2000-2005.

The results of multivariate analysis confirmed increase of cardio-respiratory death in both, total and older population of inhabitants living in Katowice Agglomeration in relation to increases in the daily average pollutant concentration by 10 μg/m^3. The values of relative risk depend on the time of exposure with a comparably higher risk for a longer time of

exposure. Simply, as the time of exposure gets longer, the risk gets higher. Figure 4 shows changes in relative risk of cardio-respiratory mortality in older population of Katowice Agglomeration related to changes of moving average concentrations of pollutants (PM10, SO2 and NO2).

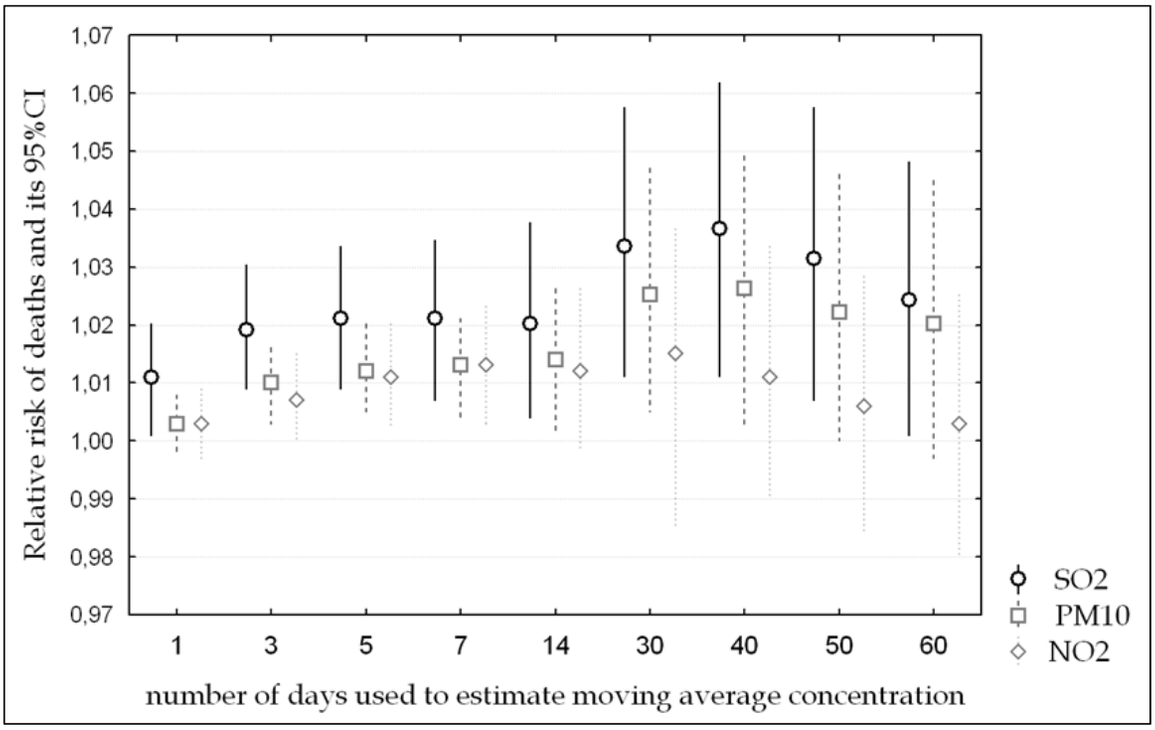

Figure 4. Relative risk of deaths due to cardio-respiratory diseases in older (65+) inhabitants of Katowice Agglomeration , study period 2000-2005.

Pollution	Moving average concentration	Relative risk of death	Author
PM_{10}	24-hours	0.2 – 0.8%	Pope & Dockery, 2006
PM_{10}	24-hours	0.3%	Kowalska et al., 2010
PM_{10}	5-40 days	1.3 -1.8%	Pope & Dockery, 2006
PM_{10}	5-40 days	0.7-1.3%	Kowalska et al., 2010
$PM_{2.5}$	24-hours	0.6-1.2%	Pope & Dockery, 2006
$PM_{2.5}$	3-day moving average, older population in Zabrze	0.5-2.0%	Kowalska, 2011

Table 2. The increase in relative risk of total mortality in relation to the increase in moving average concentration by 10 μg/m^3, comparative data.

A similar effect has been documented for cardio-respiratory mortality in the population of Zabrze, however a small number of inhabitants significantly reduces the precision of the risk estimation. The obtained results suggest that the most precise scenario useful for assessment of short term health effects (e.g. specific daily mortality) related to particulate

ambient air pollution in Katowice Agglomeration is presentation of longer exposure expressed by moving average concentration, from 3-day to 14-days. Similar observation is applicable to gaseous air pollutants: sulphur and nitrogen dioxide, relative risk of death was larger for longer time of exposure. The results of own research suggest that the relative risk of daily mortality related to short term of particulate matter (PM_{10} and $PM_{2.5}$) concentration in ambient air is similar to those given by others authors (Table 2).

2.3. Air Quality Index and its significance in environmental health risk communication, Polish study

Air Quality Index (AQI) is a standardized summary measure of ambient air quality used to express the level of health risk related to particulate and gaseous air pollution. The construction of AQI allows distinction between "good" and "dangerous" air quality. The index, first introduced by US EPA in 1998 classified ambient air quality according to concentrations of such principal air pollutants as PM_{10}, $PM_{2.5}$, ozone, SO_2, NO_2 and CO (EPA, 2003). Subsequently similar, index-based approach to express health risk, was developed in France, Great Britain and in Germany. Table 3 shows the cut-of PM_{10} values for the specific air quality zones used in European and US standards. No such environmental warning system exists in Poland, although some test-trials took place in Katowice area and in the city of Gdańsk. However, the operational value of AQI under environmental circumstances in Poland remains unknown. The aim of study was to examine current air pollution levels in Katowice Agglomeration and to confront AQI categories with local air quality, also in terms of health impact on the population as expressed by daily cardio-respiratory mortality.

Category of air quality	Cut-of values for daily PM_{10} concentration [$\mu g/m^3$]			
	USA	France	Great Britain	Germany
Good	0-54	0-39	0-49	0-34
Moderate	55-154	40-79	50-74	35-99
Dangerous	155 and more	80 and more	75 and more	100 and more

Table 3. Categorization of ambient air quality according to diferent methods of AQI indexation based on PM10 daily concentration.

The obtained results suggest significant discrepancy in range of air quality categories depending on applied system of classification. Percent of days with 'unhealthy' air quality (in the period 2001-2002) was running from 0.1% (American method of indexation) to 11.2% (British method) and usually applied winter season. The frequency of days with dangerous air quality for health (PM_{10} concentrations) calculated by French and German AQI were similar and amounted near 6% (Kowalska et al., 2009). Statistically significant Spearman correlation coefficients was obtained for relationship between air quality and total number of deaths, as well as number of deaths due to cardio-respiratory diseases in total and older population (aged 65+). However, the observed values of correlation coefficients are very low and don't exceed value 0.2 for each chosen method of indexation (Table 4).

Daily mortality	Population aged	British AQI	French AQI	American AQI	German AQI
Cardio-respiratory diseases	0-64	0.00 (NS)	0.01 (NS)	0.04 (NS)	0.00 (NS)
	65 +	0.15 (p<0.05)	0.15 (p<0.05)	0.16 (p<0.05)	0.14 (p<0.05)
	Total	0.13 (p<0.05)	0.13 (p<0.05)	0.16 (p<0.05)	0.12 (p<0.05)
Total number of deaths	0-64	0.03 (NS)	0.03 (NS)	0.04 (NS)	0.04 (NS)
	65 +	0.17 (p<0.05)	0.17 (p<0.05)	0.13 (p<0.05)	0.16 (p<0.05)
	Total	0.15 (p<0.05)	0.15 (p<0.05)	0.11 (p<0.05)	0.14 (p<0.05)

Table 4. Spearman correlation coefficients for relationship between daily number of deaths and air quality index by different method of indexation, p value in the bracket; NS- not statistically significant.

Moreover it was calculated mean value of daily cardio-respiratory mortality characteristic for days with particular AQI defined as: good, moderate and dangerous category of air quality, determine by particular methods of indexation. It was observed that the highest mortality concerned days with dangerous quality of air. Figure 5 shows results of this analysis. The association between mortality and quality of air was similar for German, British and French method of indexation, but finally the obtained results confirm that the highest mortality concerned days with dangerous quality of air and the lowest concerned days with good quality of air. The observed variability was statistically significant in each AQI categories.

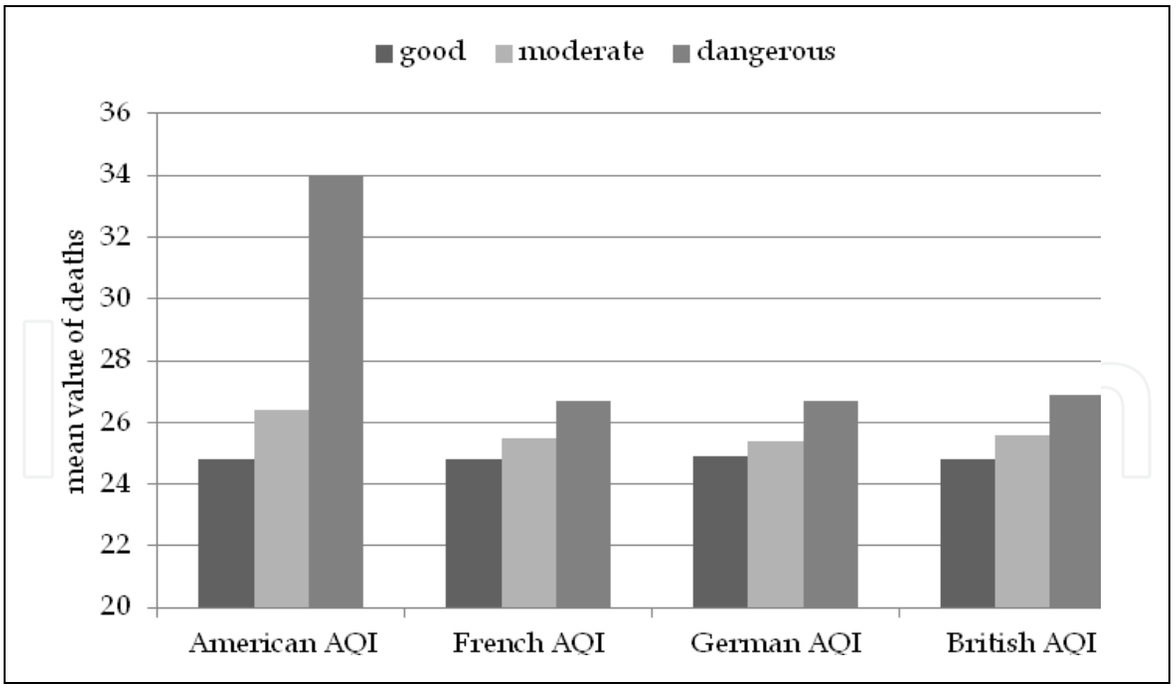

Figure 5. Number of daily deaths due to cardio-respiratory diseases in Katowice Agglomeration during days with different air quality, study period 2000-2005.

According to poor ambient air quality in Katowice Agglomeration, especially during the winter time, it is essential to inform inhabitants about environmental health hazard.

Confrontation data of local air quality with AQI categories and with daily total and specific (cardio-respiratory) mortality confirm, that British and French method of AQI indexation are the best way to risk communication in Poland. Probably, similar climate conditions and specific of air pollution are comparable in all described countries, so the association between air quality index and health effect is similar too. It is necessary to disclose the knowledge about air quality index and their association with health effect. Very important source of this information are medical doctors, especially general practitioner. Moreover well known websites or regional televisions are very useful sources to transmit important information about environmental health risk. Current position of public health experts suggest the need for a debate on the communication of real health risk associated with ambient air pollution (Schwartz, 2006).

3. Summary and conclusions

The impact of ambient air pollution, including fine particulate matter, to the health of the population in Poland was not often an undertaken research study. However, slow increases in the number of measurement data for fine particulate matter concentrations and its chemical composition allow for the estimation of environmental health risks. The lack of direct access to data describing the health status of population expressed by cardio-respiratory mortality, especially those which deals with lack of relevant rules of public health (e.g. the right of the Act), makes it difficult to obtain reliable information relating the impact of air quality to the real health risk of population living in a particular region of Poland.

This paper explains in details the health risks (expressed by daily mortality due to cardio-respiratory diseases) in response to increased concentrations of particulate pollutants, including $PM_{2.5}$ in Katowice Agglomeration, the most polluted region in Poland. The results obtained in own study confirm a slight decrease in the relative risk of death from cardio-respiratory causes in response to air quality improvement in PM_{10} concentrations during the last decade. The simultaneous observed improvement in air quality in the range of SO_2 concentrations in the study area did not change the relationship between air pollution and daily mortality. The higher profile of air pollution and health risk may be attributed to higher gas and other alternative sources of heat and electricity costs. Not without significance is the relatively low degree of environmental risk hazards in Polish population and the resulting consequences in the form of a number of behaviors such as grass and garbage burning, a high percentage of smokers in the country and lack of solutions for a rapidly growing flow of traffic. Even though the source of air pollution may be different in Poland as opposed to other countries, the risk of daily mortality in association with the exposure to fine dust is similar to those observed in other countries. Our findings, explaining the effect of seasonal influence on the size of the daily deaths due to cardio-respiratory diseases are consistent with those documented in literature. As a rule, greater number of adverse health effects in populations (mostly marked for deaths after the age of 65) varies with the different seasons; winter associated with the highest adverse effect more than the summer. It can be concluded that the relationship between concentrations of air

pollution and daily deaths probably reflect exacerbation of existing disease in people suffering from respiratory or circulatory system diseases (e.g. coronary artery disease and chronic obstructive pulmonary disease, but also arrhythmia, atherosclerosis or diabetes) and instead of new diseases.

Another issue was to determine the best possible presentation of short-term exposure of air pollution in the population. The obtained results suggest that the most precise scenario useful for assessment of short term health effects (e.g. specific daily mortality) related to particulate ambient air pollution in Katowice Agglomeration is the presentation of longer exposure expressed by moving average concentration, from 3-day to 14-days. A similar observation is applicable to gaseous air pollutants such as sulphur and nitrogen dioxide showing the relative risk of death being larger when the duration of exposure is longer. Furthermore, the results of our research suggests that the relative risk of daily mortality related to short term of particulate matter (PM_{10} and $PM_{2.5}$) concentration in ambient air is similar to those given by others authors.

Finally, due to poor ambient air quality in Katowice Agglomeration, especially during the cold season, it is essential to inform inhabitants about real environmental health risk. An important role in risk communication can play the Air Quality Index. Comparison of air quality data with data on daily cardio-respiratory mortality confirms that the British and French method of AQI indexation are the best way to communicate risk in Poland. Due to similar climate and cause of air pollution in these described countries, it may be possible to make a similar association between air quality index and health effect. It is necessary to integrate ideas and opinions from researchers in environmental epidemiology and public health as well as journalist and politicians in the evaluation of air quality in order to develop an effective and proper health policy.

Author details

Małgorzata Kowalska
Medical University of Silesia, Poland

Acknowledgement

The study was supported by the Medical University of Silesia, Katowice, Poland (Grant: KNW-1-034/P/1/0)

4. References

Anderson H.R.; Bremner S.A.; Atkinson R.W.; Harrison R.M.; Walters S. (2001). Particulate matter and daily mortality and hospital admission in the west midlands conurbation of the United Kingdom: associations with fine and coarse particles, black smoke and sulphate. *Occupational and Environmental Medicine*, Vol.58, pp. 504-510

Brunekreef B. & Holgate S.T. (2002). Air pollution and health. *Lancet* , Vol.360, pp. 1233-1242

CAFE, (February 2005). CAFE Programme: Baseline scenarios for Clean Air for Europe. Final report. Luxemburg, Austria , 07.02.2012, Available from http:// ec.europa.eu/ environment/archives/cafe/activities/pdf/cafe_scenario_report_1.pdf

Dockery D.W.; Schwartz J.; Spengler J.D. (1992). Air pollution and daily mortality: Associations with Particulates and Acid Aerosols. *Environmental Research*, Vol.9, No.2, pp.362-373

Jędrychowski W. (1999). Ambient air pollution and respiratory health in the east Baltic region. *Scandinavian Journal of Work, Environment & Health* , Vol.25, Suppl 3, pp. 5-16

Katsouyanni K.; Touloumi G.; Samoli E.; Gryparis A.; Le Tertre A.; Monopolis Y.; Rossi G.; Zmirou D.; Ballester F.; Boumghar A.; Anderson H.R.; Wojtyniak B.; Paldy A.; Braunstein R.; Pekkanen J.; Schindler Ch.; Schwartz J. (2001). Confounding and effect modification in the short-term effects of ambient particles on total mortality: results from 29 European cities within the APHEA2 project. *Epidemiology*, Vol.12, No.5, pp. 521-531

Klejnowski K.; Krasa A.; Rogula W. (2007). Seasonal variabitity of concentrations of total suspended particles (TSP) as well as PM10, PM2,5 and PM1 modes in Zabrze, Poland. *Archives of Environmental Protection,* Vol.33, No.3, pp. 15-29

Knol A.B.; de Hartog J.J; Boogaard H.; Slottje P.; van der Sluijs J.P.; Lebret E.; Cassee F.R.; Wardekker J.A.; Ayres J.G.; Borm P.J.; Brunekreef B.; Donaldson K.; Forastiere F.; Holgate S.T.; Kreyling W.G.; Nemery B.; Pekkanen J.; Stone V.; Wichmann H.E.; Hoek G. (2009). Expert elicitation on ultrafine particles: likelihood of health effects and causal pathways. *Particle and Fibre Toxicology*, Vol.6, pp. 19, 13.09.2010, Available from http://www.particleandfibretoxicology.com/ content/6/1/19

Kowalska M.; Zejda J.E.; Skrzypek M. (2010). Short-term effects of ambient air pollution on daily mortality. *Polish Journal of Environmental Studies*, Vol.19, No. 1, pp. 101-105

Kowalska M.; Ośródka L.; Klejnowski K.; Zejda J.E.; Krajny E.; Wojtylak M. (2009). Air quality index and its significance in environmental health risk communication. *Archives of Environmental Protection,* Vol.35, No.1, pp. 13-21

Kowalska M. (2011). Short-term effects of changes in the levels of fine particulates in ambient air on daily mortality and hospitalization due to cardio-respiratory diseases in urban-industrial population (Katowice Agglomeration). Medical University of Silesia, Katowice, Poland, ISNN 1689 6262 [In Polish]

Krzyżanowski M. & Wojtyniak B. (1991). Air pollution and daily mortality in Cracow. *Public Health Review*, Vol.19, pp. 73-81

Medina S.; Plasencia A.; Artazcoz L.; Quenel P.; Katsouyanni K.; Mucke H.G.; DeSaeger E.; Krzyżanowski M.; Schwartz J. and the contributing members of the APHEIS group. (2002). APHEIS Health Impact Assessment of Air Pollution in 26 European Cities. Second Year Report 2000-2001. Institut de Veille Sanitaire, Saint-Maurice, 06.02.2012, Available from http://www.apheis.org/Pdf/ Apheis_1_60.pdf

National Health Program. Polish Ministry of Health. (1996), 02.02.2012, Available from http://www.mz.gov.pl/wwwfiles/ma_struktura/docs/zal_urm_npz_90_15052007p.pdf [In Polish]

National Institute of Public Health in Warsaw. (2010). Influenza and new cases, 23.07.2010, Available from http://www.pzh.gov.pl/oldpage/epimeld/ grypa/index.htm [In Polish]

Ostro B.D. (1993). The association of air pollution and mortality. Examining the case for inference. *Archives of Environmental Health*: *An International Journal*, Vol.48, No.5, pp.336-342

Pastuszka J.S.; Wawroś A.; Talik E.; Paw K.T. (2003). Optical and chemical characteristics of the atmospheric aerosol in four towns in southern Poland. *Science of the Total Environment*, Vol.309, pp. 237-251

Polish Ministry of Environment. (June 2002). The Minister of Environment dated 6 June 2002 on the assessment of levels of substances in the air. Official Set 2002 year No 87, item 798 and 796, 07.02.2012, Available from http://isap.sejm.gov.pl/ VolumeServlet?type=wdu&rok=2002&numer=087 [In Polish]

Pope, C.A. & Dockery D.W. (2006). Health effects of fine particulate air pollution: lines that connect. *Journal of the Air & Waste Management Association*, Vol.56, pp. 709-742, ISSN 1047-3289

Rogula W.; Pastuszka J.S.; Talik E. (2007). Concentration level and surface chemical composition of urban airborne particles near crossroads in Zabrze, Poland. *Archives of Environmental Protection*, Vol.33, No.2, pp.23-34

Schwartz, J. (2004). Is the association of airborne particles with daily deaths confounded by gaseous air pollutants? An approach to control by matching. *Environmental Health Perspectives*, Vol.112, No.5, pp. 557-561, PMC1241921

Schwartz J., (2006). Air pollution and health: do popular portrayals reflect the scientific evidence? *American Enterprise Institute for Public Policy Research,* Vol. 2, 13.09.2010, Available from http://www.aei.org/article/energy-and-the-environment/ contaminants/ air/air-pollution-and-health/

US EPA. (2003). Air Quality Index. A Guide to Air Quality and Your Health. EPA-454/K-03-002, 15.06.2008, Available from http://www.njaqinow.net/ App_AQI/AQI.en-US.pdf

US EPA. (October 2004). Final Report: Air quality criteria for particulate matter. Vol. I. EPA/600/P-99/002aF. US Environmental Protection Agency, 02.02.2012, Available from http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid= 87903#Download

WHO, (June 2004) WHO Report: Health aspects of air pollution. Results from the WHO project Systematic review of health aspects of air pollution in Europe. WHO Regional Office for Europe, document E83080, Copenhagen 2004a, Denmark, 07.02.2012, Available from http://www.euro.who.int/__data/assets/ pdf_file/0003/74730/E83080.pdf

Wichmann H.E.; Spix C.; Tuch T.; Wolke G.; Peters A.; Heinrich J.; Kreiling W.G.; Heyder J. (2000). Daily mortality and fine and ultrafine particles in Erfurt, Germany. Part I: role of particle number and particle mass. *Research Report Health Effects Institute* Vol.98, pp. 5-86

Zejda J.E. (2000). Health effects of ambient air pollution – the magnitude of risk and current hazard in Poland. In: *Environment and Health*, K. Janicki; W. Klimza; J. Szewczyk, (Eds.), Cmyk-Art, pp.221-235, Częstochowa, Poland [In Polish]

IntechOpen