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Long-term trends of air pollutant concentrations in Poland

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Abstract. The assessment of changes in air pollution quality for 4 selected sites in Southern and Central Poland was presented in this paper. The evaluation was based on the sets of long-term data, recorded by the state air monitoring network. Concentrations of O_3, PM10, SO_2, NO_x, and CO, were considered. The basis for the calculations were 12-year time series of hourly concentrations. Using the hourly data, the monthly averages were calculated to illustrate seasonal changes of pollutant concentrations. Linear trends were adjusted to the concentration courses with the least squares method. Long-time trends were calculated for each pollutant separately. Based on the analysis of the trend lines slopes, risks those may arise in the future were identified.

1 Introduction

Before the accession to the European Union Poland had the reputation of a country with heavily polluted air. Joining the EU in 2004 was connected with the adoption of European standards of air protection, including a significant reorganization of the air monitoring system. At that time, a new air monitoring network was established that operates and collects data according to European standards up to the present [1, 2]. Long-term measurements of the air monitoring stations allow to answer the question how the air quality has changed in time.

One way of air quality evaluation is to identify trends in monitoring time series. The aim of the study was to identify the trends of changes in the concentration levels of main air pollutants at some different localisations in Poland. In this examination, 2005 was adopted as the starting point in the analysed time series. 12-year observations were used to determine the real trends. For various measuring stations and various air pollutants, a mathematical form of linear trends was found.

2 Methods

Concentrations of basic air pollutants such as: O_3, NO_x, CO, SO_2, PM_{10}, registered in the years 2005–2016 at four air monitoring stations in south and central Poland, were used in

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the analysis. Two stations Zabrze and Rybnik are located in big industrial cities and belong to the type of urban background monitoring sites [3]. The both stations are located in Upper Silesia, the most polluted area in Poland. The another two stations are located in central Poland, the first one in a quite big city Radom, and the second one in Granica, a village located in Kampinos National Park. The description of air monitoring sites was given in Table 1.

Table 1. The description of the air monitoring stations.

No.	Monitoring site	Address/localisation	Data source	Area type	Station type
1.	Granica	125/2 Granica, Kampinos National Park, Masovia, Central Poland	Voivodeship Inspectorate for Environmental Protection in Warsaw	rural	regional background
2.	Radom	1 Tochtermana Street, Radom City Masovia, Central Poland	Voivodeship Inspectorate for Environmental Protection in Warsaw	urban	urban background
3.	Rybnik	37d Borki Street, Rybnik City Upper Silesia, South Poland	Voivodeship Inspectorate for Environmental Protection in Katowice	urban	urban background
4.	Zabrze	34 Curie-Skłodowska Street, Zabrze City Upper Silesia, South Poland	Voivodeship Inspectorate for Environmental Protection in Katowice	urban	urban background

The analysed data were received from the Voivodeship Inspectorate of Environmental Protection in Katowice and from Inspectorate of Environmental Protection in Warsaw. Using time series of 1-hour (instantaneous) concentrations, the monthly mean concentrations were calculated. For each pollutant, 12-year courses of monthly concentrations were determined. Linear trends were adjusted to the courses with the least squares method. The obtained trends equations took the general form:

$$y = \mathrm{m} \cdot x + \mathrm{b} \tag{1}$$

where:
y was the concentration,
m was the slope of the line,
x was the number of years after 2005
b was the *y* intercept (the value of concentration at the beginning of 2005).

The values of parameters m and b, describing individual trend lines, were calculated. Using the slope values, the annual changes of concentrations were estimated for each trend line. Percentage annual changes in relation to the intercepts (m/b)·100% were calculated to assess relative annual increments. The relative annual increments allow to compare changes in concentrations of various pollutants at different stations. Values of relative annual increments assumed as the basis for the classification of trends.

3 Results

Results of the analysis were presented in Figures 1–5. The figures show 12-year courses of monthly concentrations with adjusted trend lines, separately for each pollutant and for each site. At the monitoring station Granica concentrations of PM_{10} and CO were not measured, therefore there were no relevant courses.

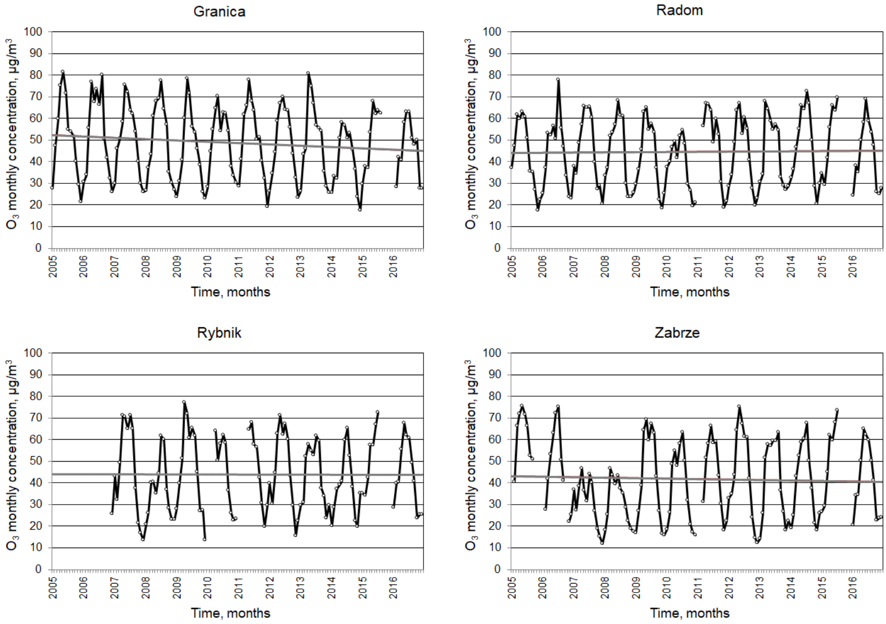

Fig. 1. The 12-year courses of monthly average concentrations of O_3 at some different air monitoring stations, with adjusted linear trends.

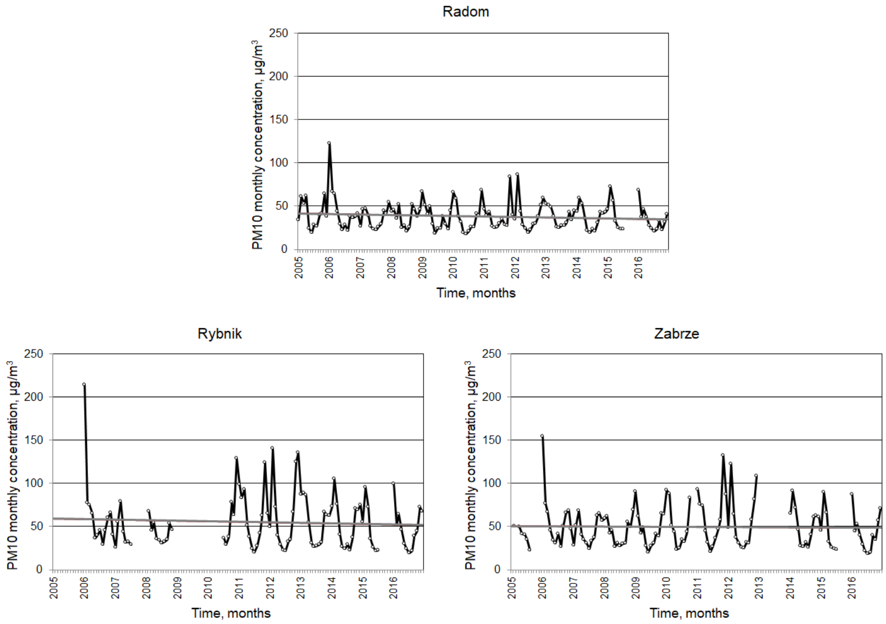

Fig. 2. The 12-year courses of monthly average concentrations of PM_{10} at some different air monitoring stations, with adjusted linear trends.

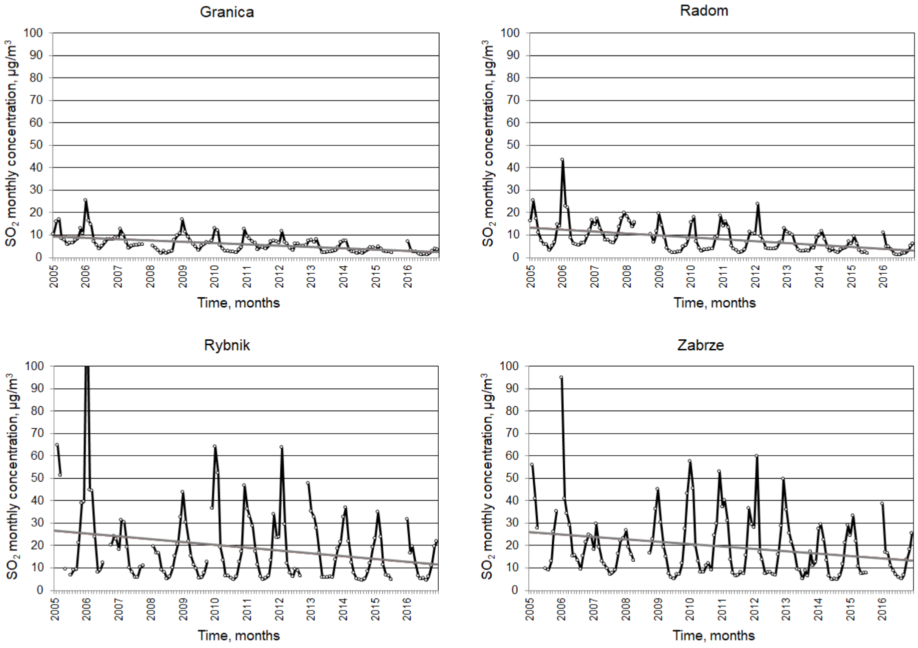

Fig. 3. The 12-year courses of monthly average concentrations of SO_2 at some different air monitoring stations, with adjusted linear trends.

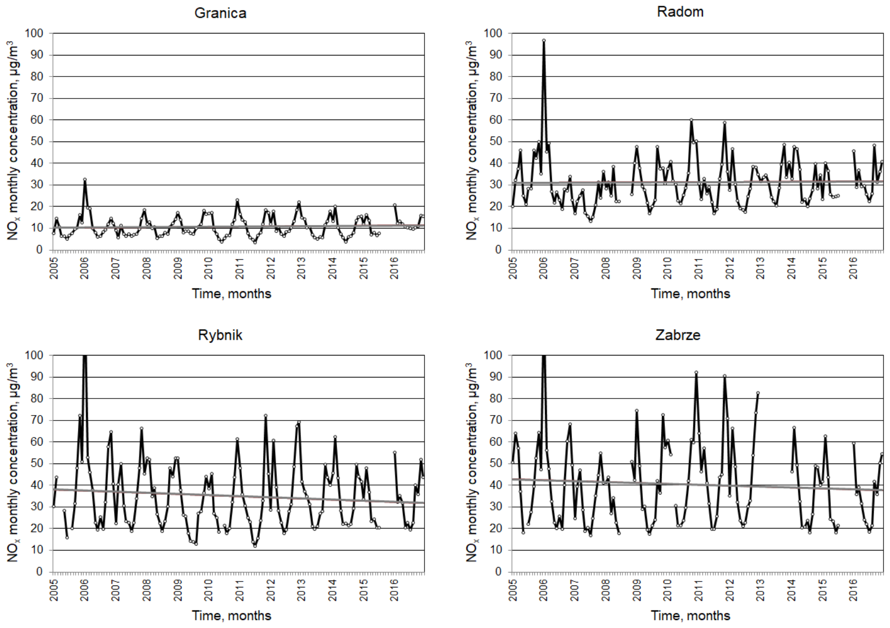

Fig. 4. The 12-year courses of monthly average concentrations of NO_x at some different air monitoring stations, with adjusted linear trends.

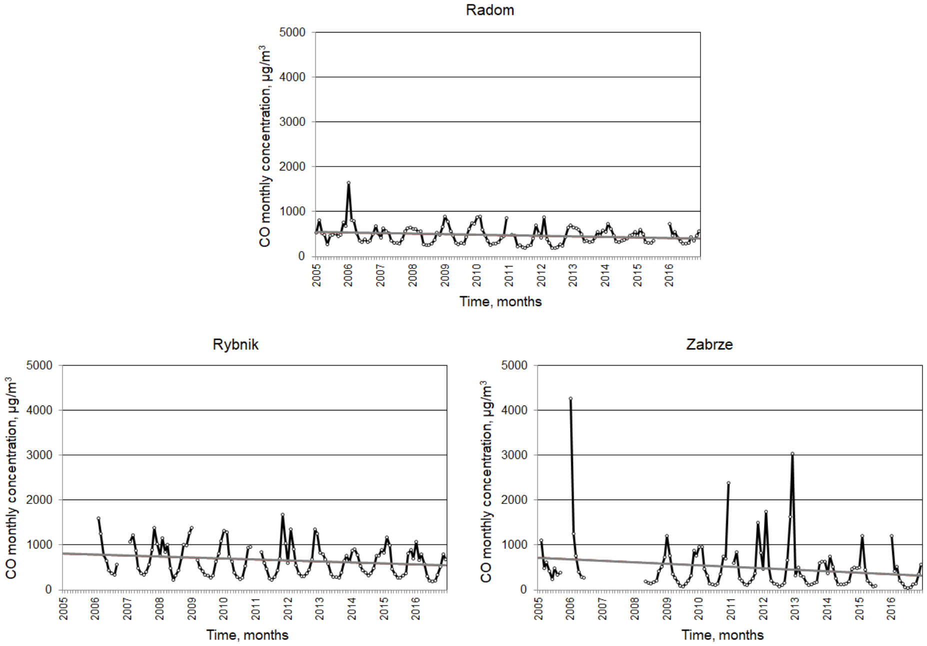

Fig. 5. The 12-year courses of monthly average concentrations of CO at some different air monitoring stations, with adjusted linear trends.

4 Summary and discussion

The direction coefficient values of the obtained trend equations were analysed to estimate the direction and the strength of concentrations changes. Summary of the results was included in Table 2. The table shows slope-intercept forms ($y = \mathrm{m} \cdot x + \mathrm{b}$) of the individual trend equations, the values of parameters m and b, relative annual increments (given in %/year), as well as estimation of trends.

In a very generalized assessment, concentrations of the most of main air pollutants tend to decrease. The strongest decreases are observed in the case of SO_2 concentrations. The annual drops are in the range 4.07–6.46% per year. CO concentrations are also clearly reduced, at a rate of 2.20–4.68%/year. Concentrations of PM_{10} decrease at all monitoring stations, but slower than SO_2 and CO concentrations (0.35–1.35% annually). Changes in O_3 and NO_x concentrations are not so significant, and they do not show consistent trends. They depend on the location of the air monitoring station. For example, at the rural station Granica, NO_x concentrations tend to increase, while at Radom they are stable, but at Zabrze and Rybnik they drop.

According to Polish Central Statistical Office, since 2000 in Poland the following drops of emission has been estimated: 51% for SO_2, 25% for CO, 22% for PM, 14% for NO_x [4]. The decreasing in concentrations of these pollutants in the ambient air is obviously related to the emission drops. Similar trends have been observed in other European countries. As it was reported by European Environment Agency, in the years 2000-2015 total emissions of the mentioned air pollutants also decreased in EU [5].

Generally, the changes in pollution levels at 4 examined sites should be considered advantageous for the environment. The rapid fall in SO_2 and CO levels indicates an effective policy of reducing air pollution threat. Several years ago Poland was classified as a country with exceptionally high SO_2 emission. The evident drop of SO_2 concentrations indicates that long-term programs for limitation emission of this gas are resultful. Noteworthy is the fact that decreasing trends are noticeable in Upper Silesia, the most polluted Polish region where coal is mined and burned on a large scale.

Table 2. Long-term concentration changes – summary.

Pollutant	**Monitoring site**	**Slope-intercept form of trend equation (x – number of year in the time series)**	**The slope of a trend line m, ($\mu g/m^3$)/year**	**The intercept b, $\mu g/m^3$**	**Relative annual increments (m/b)·100%, %/year**	**Estimation of trend**
O_3	Granica	y = -0.612x + 52.4	-0.612	52.4	-1.17	Decrease
	Radom	y = 0.083x + 44.1	0.083	44.1	0.19	Stabilization
	Rybnik	y = -0.009x + 44.0	-0.009	44.0	-0.02	Stabilization
	Zabrze	y = -0.222x + 43.2	-0.222	43.2	-0.51	Decrease
PM_{10}	Granica	-	-	-	-	-
	Radom	y = -0.562x + 41.5	-0.562	41.5	-1.35	Decrease
	Rybnik	y = -0.617x + 59.3	-0.617	59.3	-1.04	Decrease
	Zabrze	y = -0.178x + 50.7	-0.178	50.7	-0.35	Slight decrease
SO_2	Granica	y = -0.602x + 9.5	-0.602	9.5	-6.34	Strong decrease
	Radom	y = -0.866x + 13.4	-0.866	13.4	-6.46	Strong decrease
	Rybnik	y = -1.264x + 26.8	-1.264	26.8	-4.72	Strong decrease
	Zabrze	y = -1.061x + 26.1	-1.061	26.1	-4.07	Strong decrease
NO_x	Granica	y = 0.091x + 10.3	0.091	10.3	0.88	Increase
	Radom	y = 0.058x + 31.1	0.058	31.1	0.19	Stabilization
	Rybnik	y = -0.523x + 38.2	-0.523	38.2	-1.37	Decrease
	Zabrze	y = -0.433x + 42.9	-0.433	42.9	-1.01	Decrease
CO	Granica	-	-	-	-	-
	Radom	y = -11.95x + 544	-11.95	544	-2.20	Decrease
	Rybnik	y = -21.75x + 806	-21.75	806	-2.70	Decrease
	Zabrze	y = -33.67x + 719	-33.67	719	-4,68	Strong decrease

Trends observed in Poland coincide with European trends. Europe's air quality is slowly improving, but particulate matter (PM) and ground-level ozone continue to cause serious impacts on health [6]. According to European Environment Agency the biggest problem in Poland are PM concentrations [7]. It is estimated that every year in Poland over 44,000 people die prematurely due to high concentrations of fine particular matter [8]. The problem concerns especially the southern voivodeships. Although the gradual decrease in concentration can be noted, but still the levels of concentration during heating periods are too high. Monthly concentrations of PM_{10} may still exceed 100 $\mu g/m^3$, as the graphs in Figure 2 show. The main reason is emission from very common domestic installations that burn coal waste. It can be assumed that smog episodes resulting from high concentrations of PM_{10} will continue to occur in Poland, because government politicians want to maintain the leading role of coal in the Polish power industry and economy.

5 Conclusions

The long-term observations of concentration levels of the basic pollutants registered at four air monitoring stations allow the following conclusions:

1. Concentrations of the most of main air pollutants tend to decrease.

2. The strongest drops are observed in the case of SO_2 concentrations. The annual drops are in the range 4.1–6.5 %.
3. CO concentrations are also evidently reduced (2.2–4.7 % annually).
4. Concentrations of PM_{10} decrease slower (0.35–1.35 % annually).
5. Changes in O_3 and NO_x concentrations are not significant, and they do not show consistent trends. They depend on the location of the air monitoring station.

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