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Changeability of Air Pollution in Katowice Region (Central Europe, Southern Poland)

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1. Introduction

The air, as an elementary component of the biosphere, is a conveyor of many pollutants in the form of dusts, gases and aerosols. Among others the basic factors shaping the quality of the air are: the size of the emission and ambient concentration of the pollutants and local conditions- the lie of the land, ground cover and meteorological conditions. Among the meteorological factors the biggest significance has the direction and the velocity of the wind, the height and the intensity of the rainfall and the thermic stratification of the atmosphere. There have been created many classifications of the pollutants, according to the basic one the pollutants fall into two categories: the natural and anthropogenic ones. Anthropogenic sources of pollutants' emission basically include: industrial plants and service centres, boiler plants and the housing estates' boiler rooms, domestic fires of the individual households and means of transport, which emit the pollutions in the organized or random (not organized) way. Regarding the quality we can distinguish the particulate pollutants (suspended dust and falling dust) and the gas pollutants (SO_2 , NO , NO_2 , O_3 , CO , CO_2 , etc.), which ambient concentration can occur because of dry and wet deposition.

2. Monitoring system

Environment monitoring is the research, analysis and the evaluation of the natural environment in order to observe the happening changes. The environment monitoring can be conducted on the local, nationwide, continental or global scale. The source of the systematic information concerning the state of the environment are the stable networks of observation and measurement or the moving measurement points. Generally, environment monitoring in Poland involves: air monitoring, monitoring of the surface and underground waters and monitoring of the soils, forests and noise.

In Silesian province air monitoring has been functioning for 30 years and it is the most developed monitoring system in the country. In 2006 it consisted of the network of 200 collecting points for taking the falling dust along with the contained heavy metals (manual measurements), and 30 points for measurement of the suspended dust concentration and the gas pollutants (automatic measurements).

Moreover, due to the European Union funds, since 1993 a regional air pollution monitoring has been functioning within the Upper Silesian Industrial Region (it was reorganized in

2005). It consists of eleven air pollution measurement stations, one meteorological conditions measurement station, one forest monitoring station and one station for the atmosphere stratification studies (Figure 1). The characteristics of the aforementioned measurement points is presented in Table 1. This monitoring system cooperates with the network of posts belonging to the Institute of Meteorology and Water Management in Katowice.

3. Air pollution

3.1 Spatial distribution and the dynamics of the dust fall changes

Air is considered to be polluted when it contains additional elements which are not included in its original composition and when the share of the stable elements exceeds their average contents in clean and dry air.

Within the area of Katowice Region the aerosanitary conditions are mostly shaped by the emission of local dust-gas pollutants, the source of which are domestic fires of the individual households, industrial plants and service centres, boiler plants and the housing estates' boiler rooms, means of transport and the pollution emitted from the adjoining areas. The analysis of the spatial distribution of the dust fall during the industrial period (at the turn of the 70s and 80s of the XX century) clearly indicates its increased values in the central part of the Katowice Region, nevertheless this distribution is not characterized by one, uniform area but by a few centres of increased (highest) values. These centres are: the areas of the central part of Gliwice, Ruda Śląska, Chorzów, Dąbrowa Górnicza, border areas

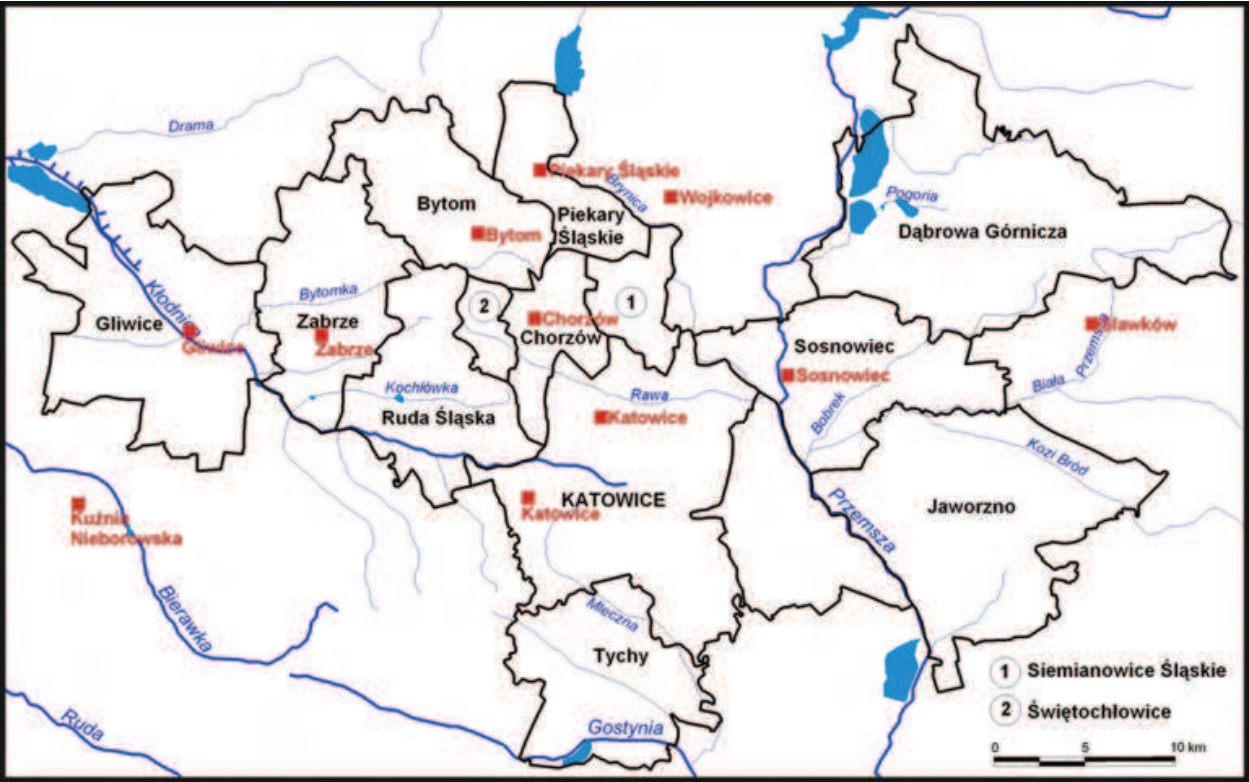


Fig. 1. Distribution of the research points of the Regional Air Pollution Monitoring within the area of Katowice Region

Name of the station	Coordinates: latitude longitude altitude	Type of the station	Measure- ment period	Polutants recorded	Sources of pollution around the station
A-1 Katowice	E 19°00'17" N 50°15'18" 275 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission, domestic emission
A-2 Chorzów	E 18°58'19" N 50°18'17" 308 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-3 Bytom	E 18°53'58" N 50°20'00" 285 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-4 Zabrze	E 18°47'52" N 50°18'07" 257 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-5 Gliwice	E 18°41'03" N 50°17'07" 232 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-6 Piekary Śląskie	E 18°57'08" N 50°23'42" 285 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-7 Wojkowice	E 19°03'40" N 50°20'58" 263 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-8 Sosnowiec	E 19°09'00" N 50°16'27" 255 m above MSL	Urban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Industrial works, vehicle emission domestic emission
A-9 Kuźnia Nieborowi cka	E 18°37'00" N 50°12'29" 235 m above MSL	Suburban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Small industrial, vehicle and domestic emission
A-10 Sławków- Okradzion ów	E 19°22'48" N 50°19'56" 321 m above MSL	Suburban station	1993-2004	PM10, SO ₂ , NO, NO ₂ , O ₃ , CO, meteorological conditions	Mean industrial, vehicle and domestic emission

Table 1. Characteristic of the measurement points

between Zabrze and Bytom and Bytom and Piekary Śląskie. Within these regions yearly values of the dust fall in places exceeded 1000 g/m².

In this distribution the maximum values, accounting for over 2 000 g×m⁻² (t×km⁻²), were registered in the central part of the Silesian province (Zabrze, Chorzów, Bytom, Katowice, Sosnowiec). In 1980 over the whole area the dust fall decreased and its maximum value was over 1 500 g×m⁻² (permissible norm is 200 g×m⁻²). The following ten years resulted in further, more visible improvement- maximum value of the dust fall registered at the beginning of the 90s was 760 g×m⁻². However, the fundamental change was observed at the end of the 90s when the highest level of the dust fall was only 200 g m⁻² and corresponded to the binding permissible norm (Leśniok & Radomski, 1999). The example given here can be the city of Sosnowiec where in the years 1995-2001 the doubled decrease of the dust fall was observed (Puszczewicz, 2003). The comparison of the dust fall within the area of Katowice Region in 1997 and 2002 as well as the dynamics of its changes is presented in the figures 2, 3 and 4.

Situation when the level of the dust fall decreases or stays on the same level takes place until these days, although within the present borders of the Silesian province there are some points where the yearly dust fall norm is exceeded (e.g. Zabrze Makoszowy). The decrease of the dusts emission was mainly caused by the general economic recession which took place in Poland at the turn of the 80s and 90s, as well as by the industry restructuring within the Upper Silesian Industrial Region (changes of the production profiles, moving the productions to the other regions, closing down the plants and factories) and by the pro-ecological activities aiming at the reduction of pollutants emission, mainly the dust ones which are emitted by the large and medium-size sources.

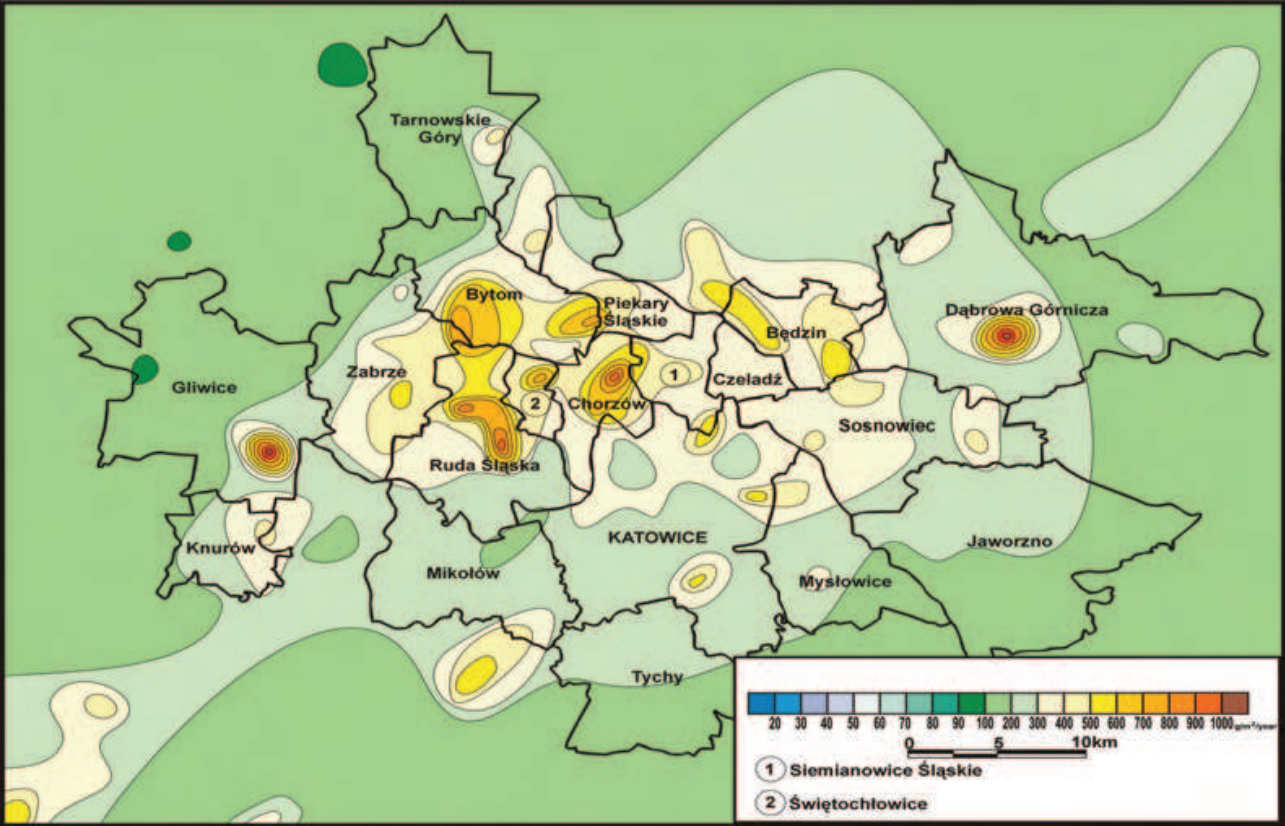


Fig. 2. Distribution of the dust fall within the area of Katowice Region in 1977 [in g/m²/year]

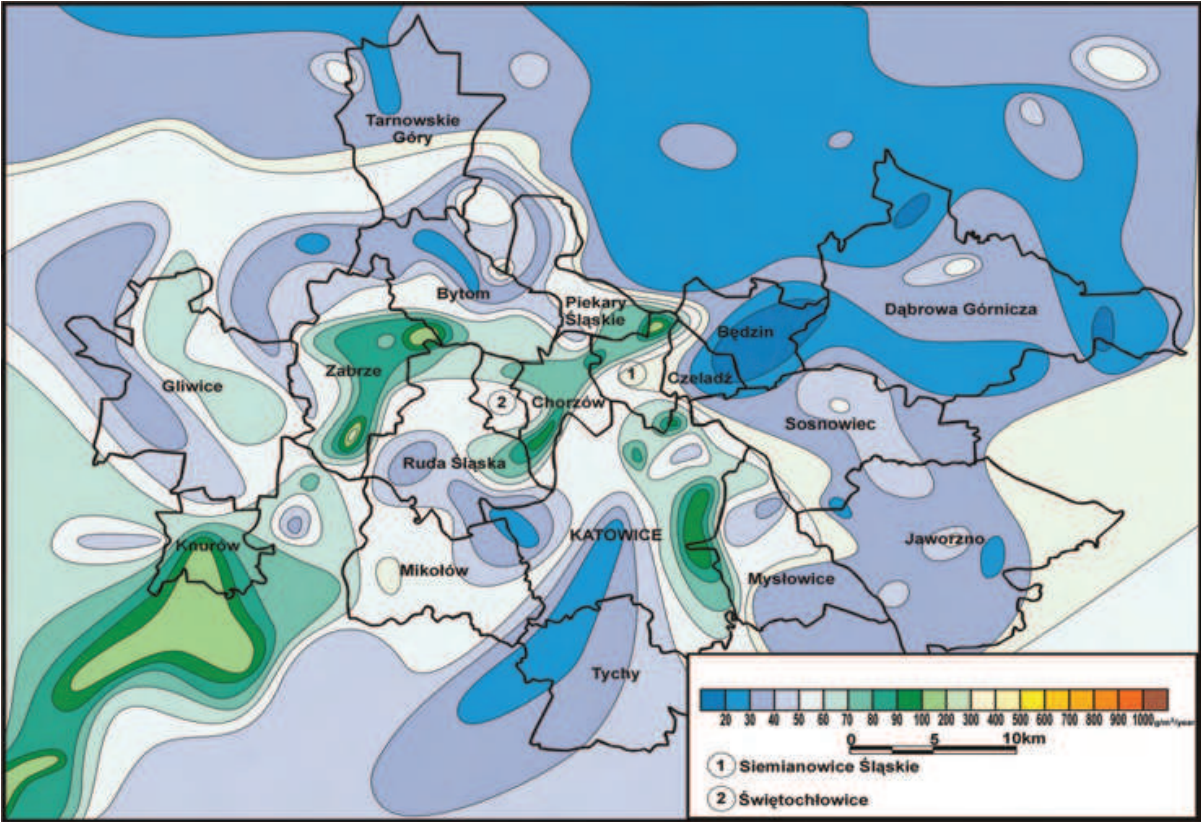


Fig. 3. Distribution of the dust fall within the area of Katowice Region in 2002 [in g/m²/year]

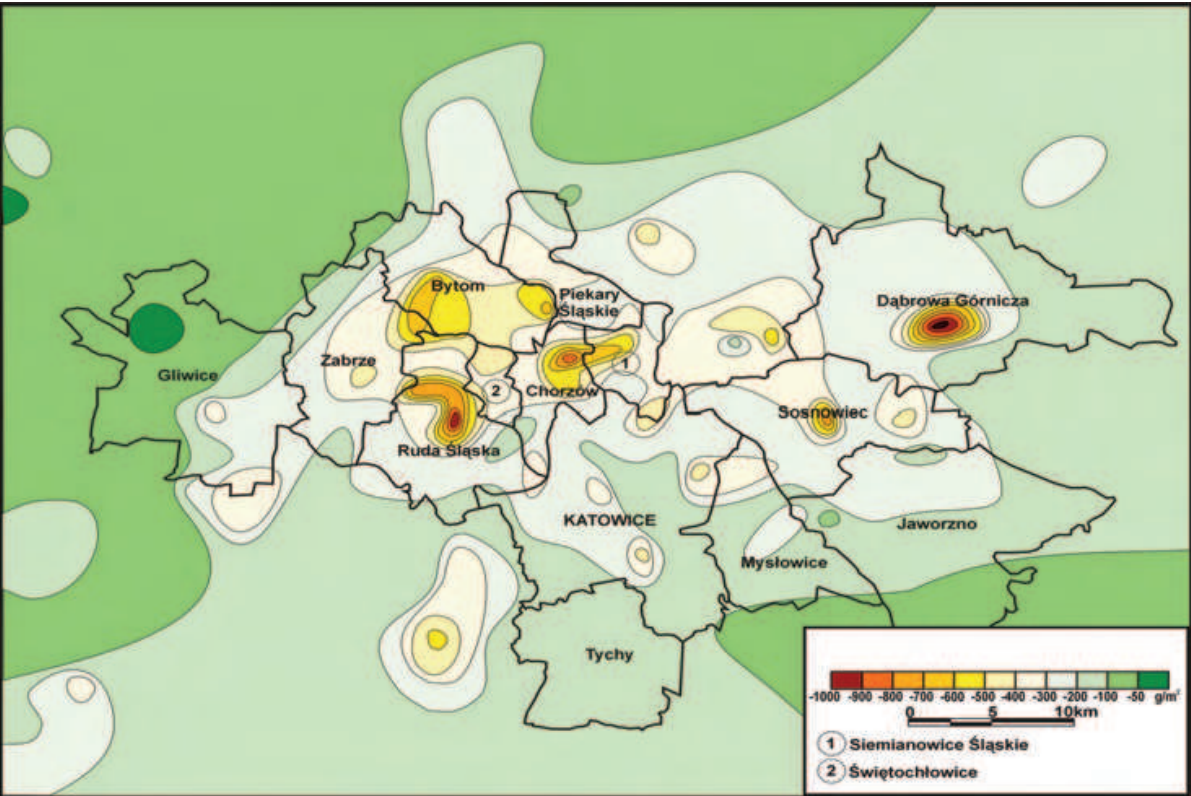


Fig. 4. Dynamics of the dust fall change within the area of Katowice Region in 1977–2002 [g/m²]

3.2 Differentiation of the distribution of the pollutants' concentrations

Apart from the dust fall the visible decrease of the suspended dust concentration can also be observed (PM10 – dust of the fraction up to 10 μm), nevertheless its average value for the whole area of Silesian Upland still exceeds the permissible norm of 40 $\mu\text{g} \times \text{m}^{-3}$ (fig. 5).

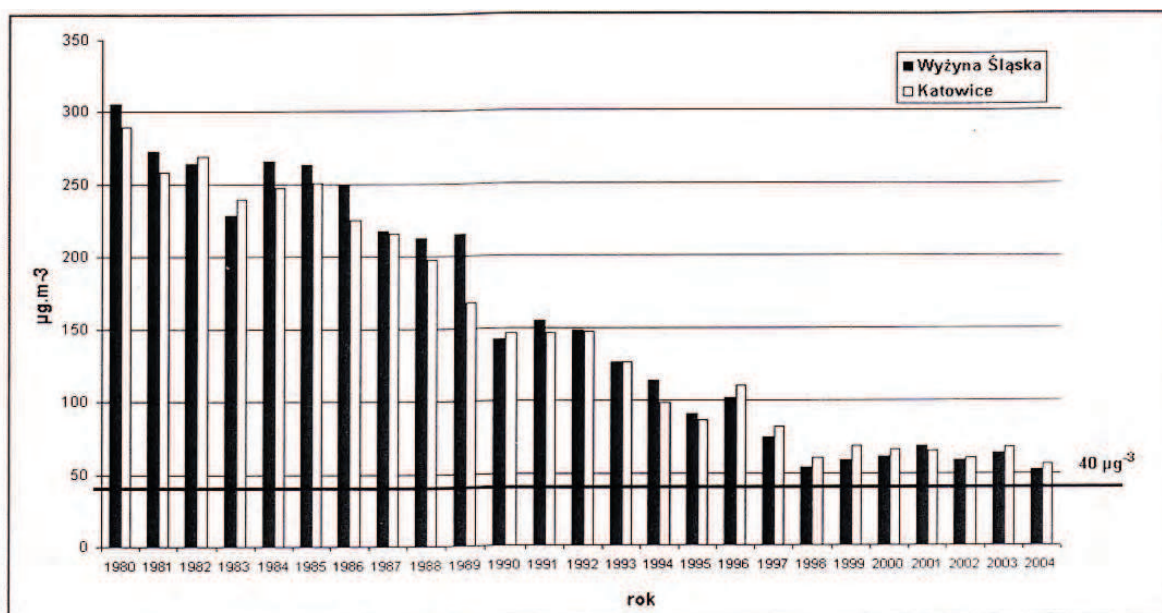


Fig. 5. Mean yearly distribution of the suspended dust concentration (PM 10) for Katowice Region and Katowice city in 1980–2004

As a result of the industry restructuring within the area of the Upper Silesian Industrial Region the significant improvement of the air quality is visible. The amount of the dust emitted into the atmosphere has decreased, what can be mainly observable during the measurement of the mean yearly concentrations of the suspended dust (Hubicki, 2007).

Complete analysis of the differentiation of the dust pollution covering the present-day period and the years before the industry restructuration is presented in the pictures 6-10.

The pictures illustrate the formation of the mean yearly suspended dust concentrations for five selected cities of Katowice Region. For each of these cities the decreasing tendency in contents of dust suspended in the air is visible (Hubicki, 2007). It can be clearly observed in the years when the industry restructuring was in progress.

In case of gas pollutants the decreasing tendency is also visible, however it is not so clear. Until now within the area of Katowice Region high concentrations of SO_2 , NO , NO_2 and O_3 are registered, moreover in case of these pollutants we can observe considerable daily differences (rush hours, heating peaks) and seasonal changes in concentrations' values (summer and winter season).

Among the gas pollutants the biggest amount of studies has been devoted to the sulphur dioxide. Sulphur is an element which occurs in all environment components, and is rated on the 16th place in the sequence of elements which are widely common in nature. It is included in the contents of the living organisms, occurring in many compounds which fulfil the metabolic, structural and functional functions. In the atmosphere it mainly appears in the form of SO_2 , which excessive concentration has bad influence on chemical and physical properties of the soils, the condition of the plants and health of human beings and animals. It is also the cause of accelerated corrosion, damages of constructions, devices and cultural monuments (Degórska, 2008).

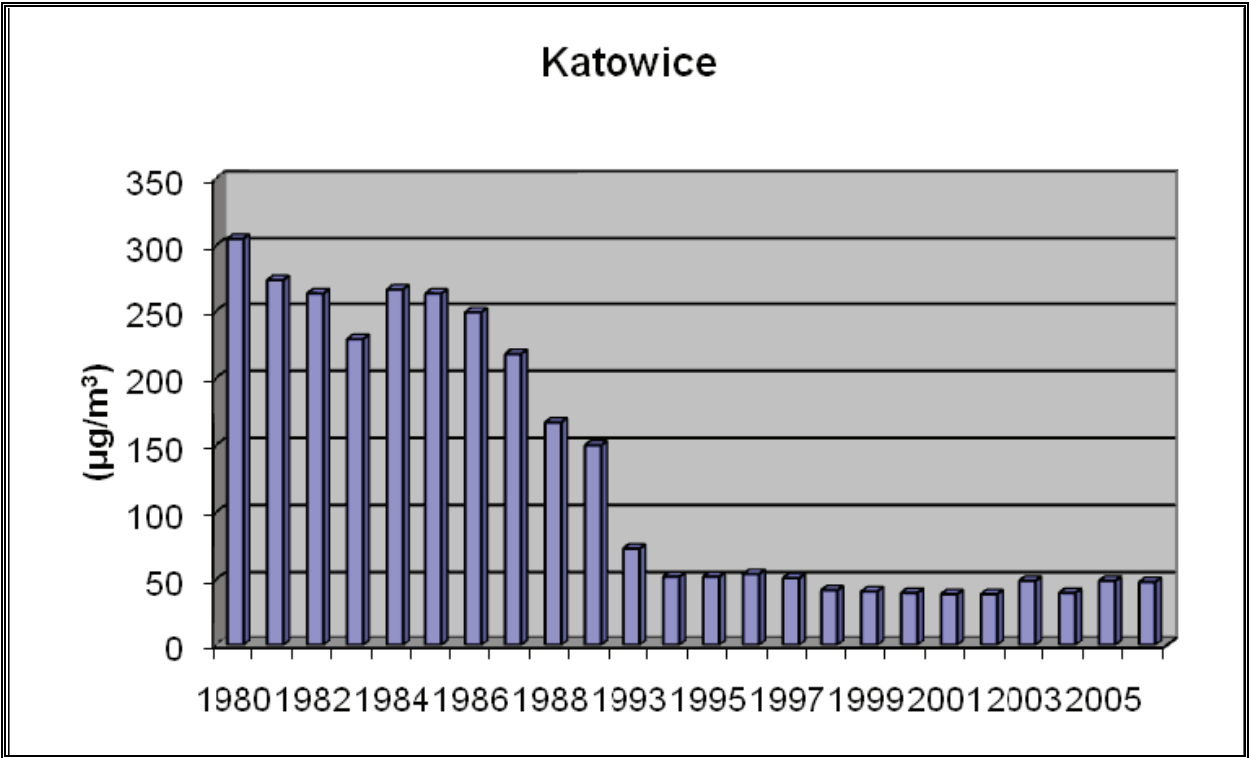


Fig. 6. Distribution of mean yearly suspended dust concentrations on the area of Katowice in 1980–2006

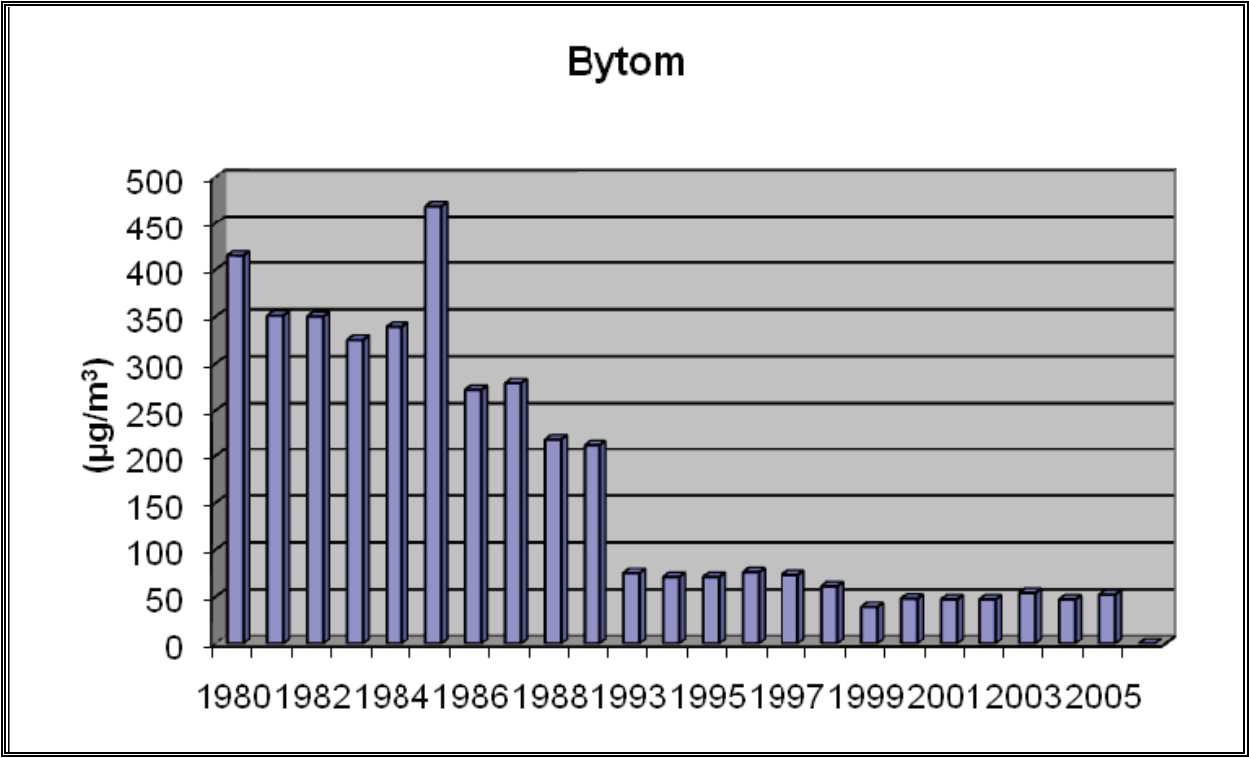


Fig. 7. Distribution of mean yearly suspended dust concentrations on the area of Bytom in 1980–2006

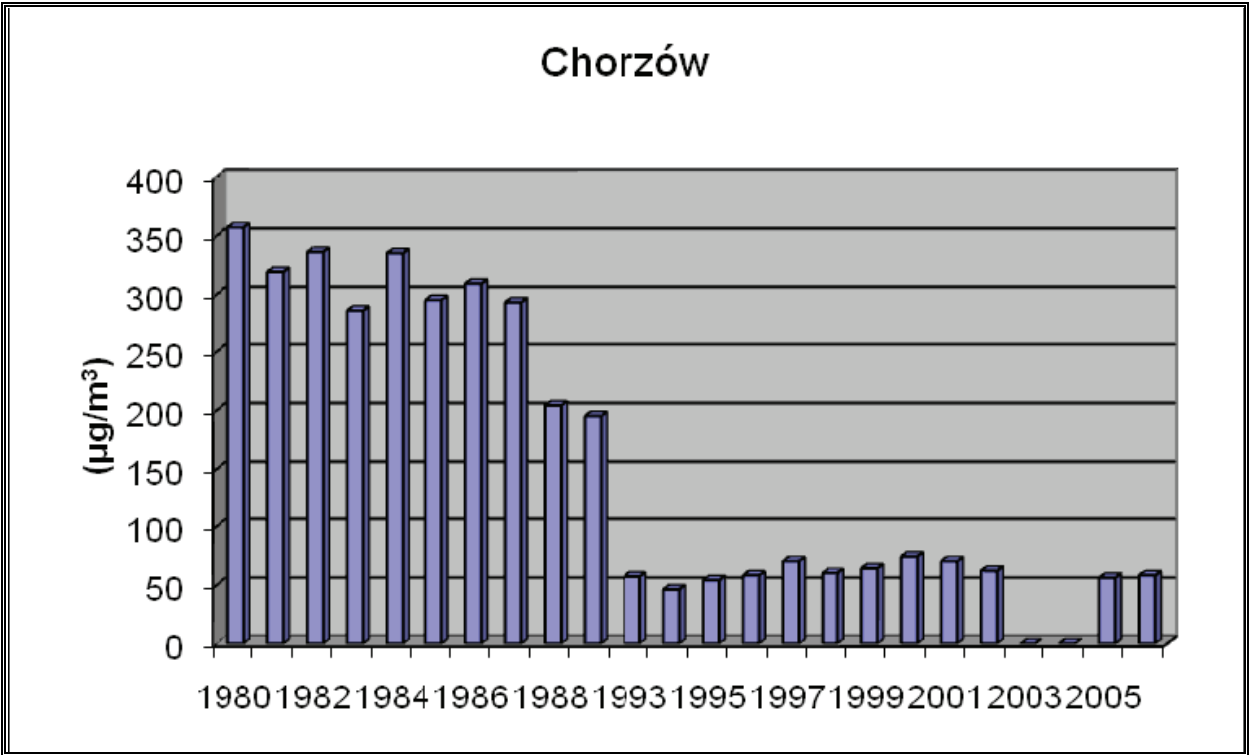


Fig. 8. Distribution of mean yearly suspended dust concentrations on the area of Chorzów in 1980-2006

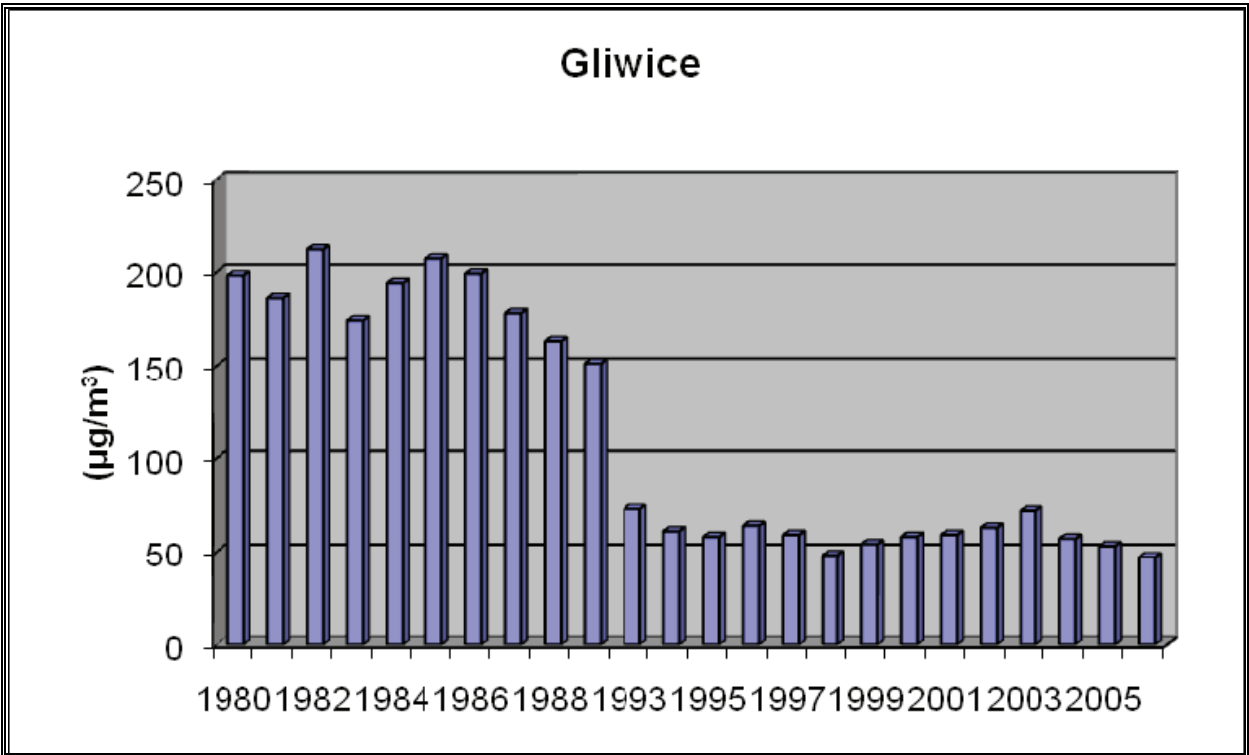


Fig. 9. Distribution of mean yearly suspended dust concentrations on the area of Gliwice in 1980-2006

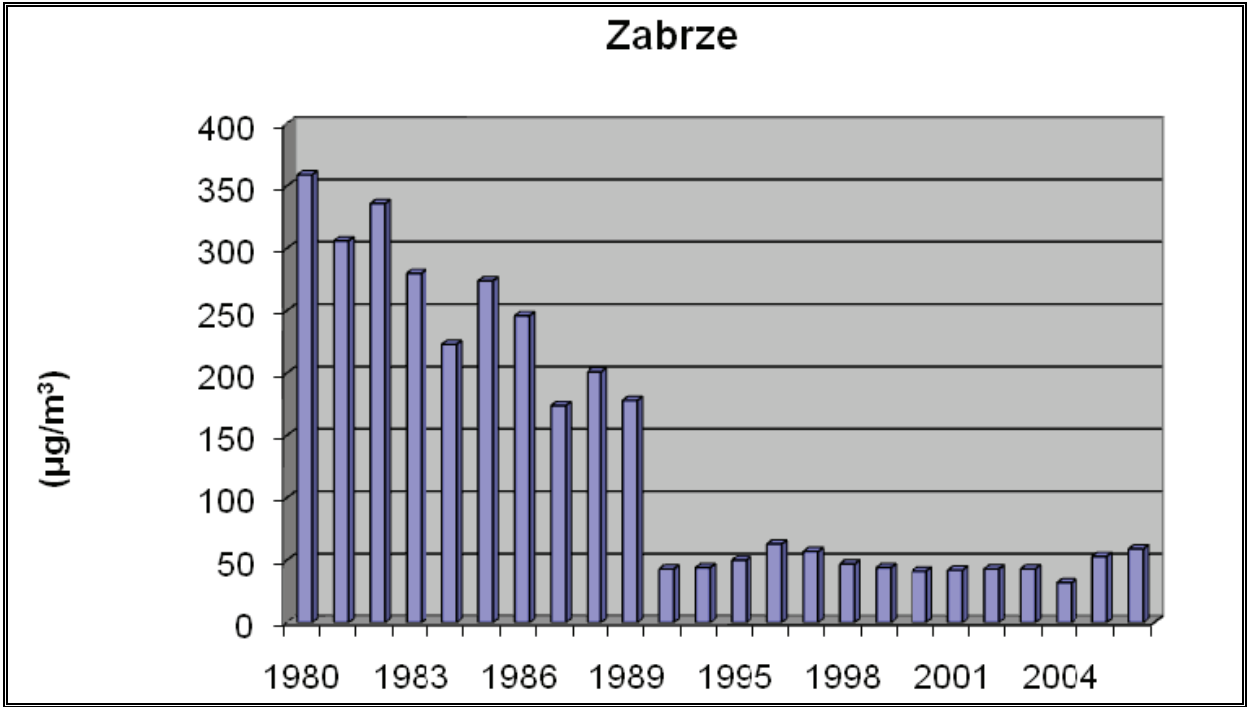


Fig. 10. Distribution of mean yearly suspended dust concentrations on the area of Zabrze in 1980-2006

Data juxtaposition presented in the form of the graphs, which refer to the mean yearly concentrations of the sulphur dioxide from the years before the industry restructuration and the present-day period, allows to analyse the formation process of the aforementioned pollution in the area of Katowice Region (fig. 11-15).

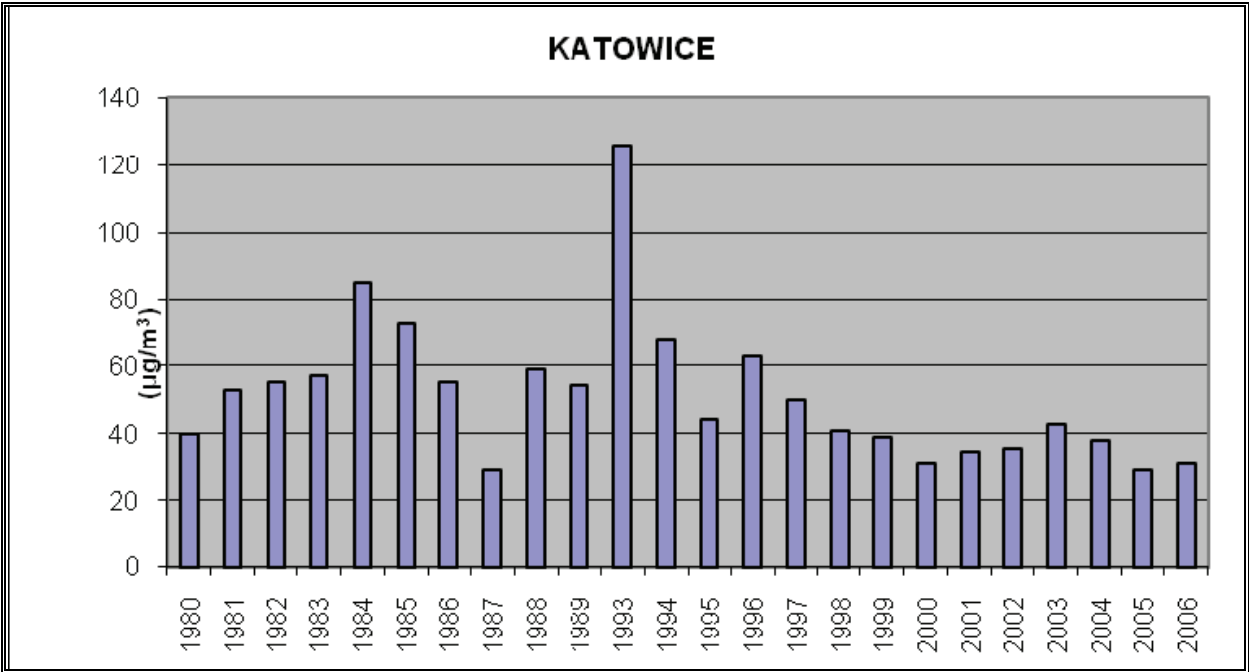


Fig. 11. Distribution of mean yearly sulphur dioxide (SO₂) concentrations on the area of Katowice in 1980-2006

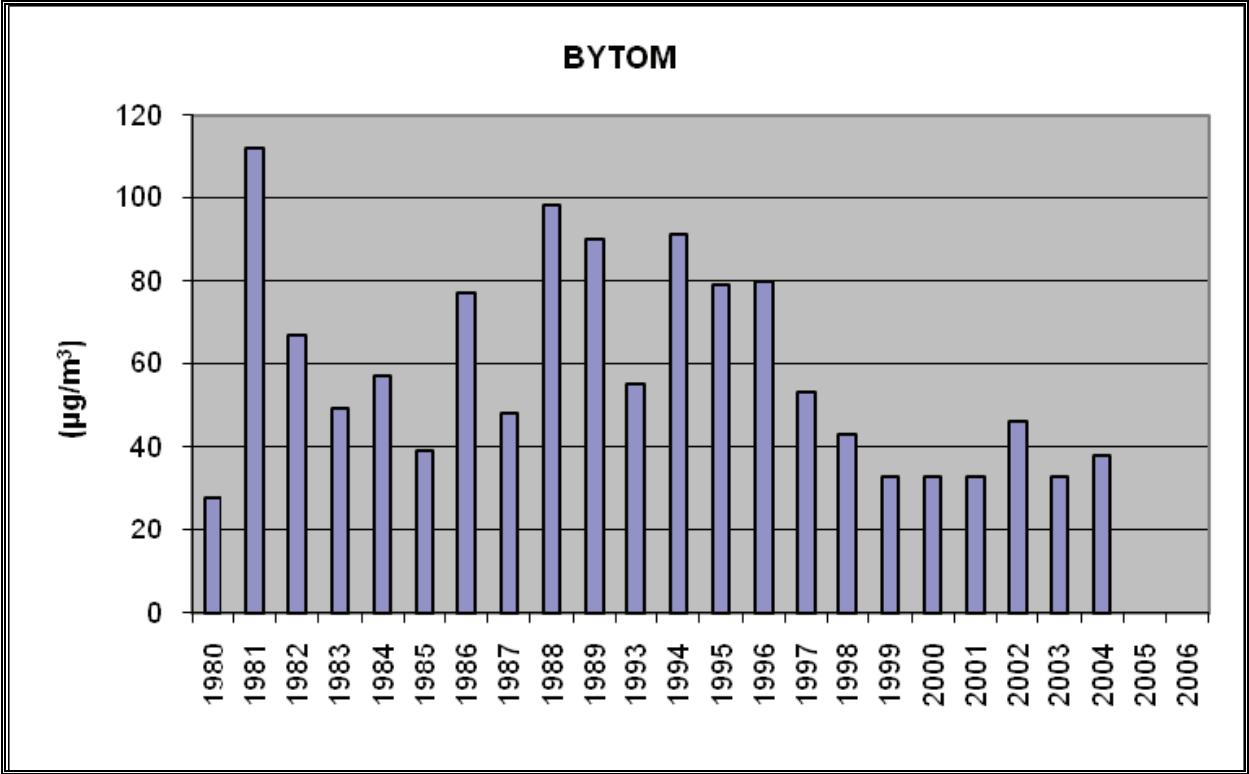


Fig. 12. Distribution of mean yearly sulphur dioxide (SO₂) concentrations on the area of Bytom in 1980-2006

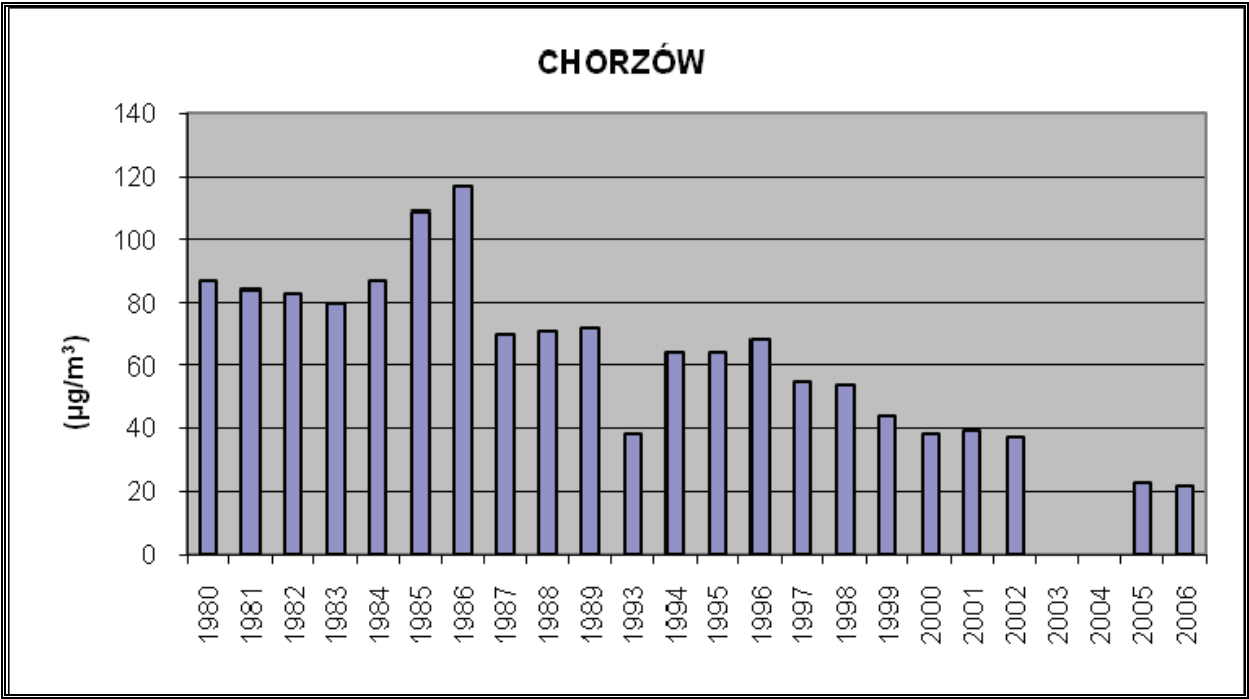


Fig. 13. Distribution of mean yearly sulphur dioxide (SO₂) concentrations on the area of Chorzów in 1980-2006

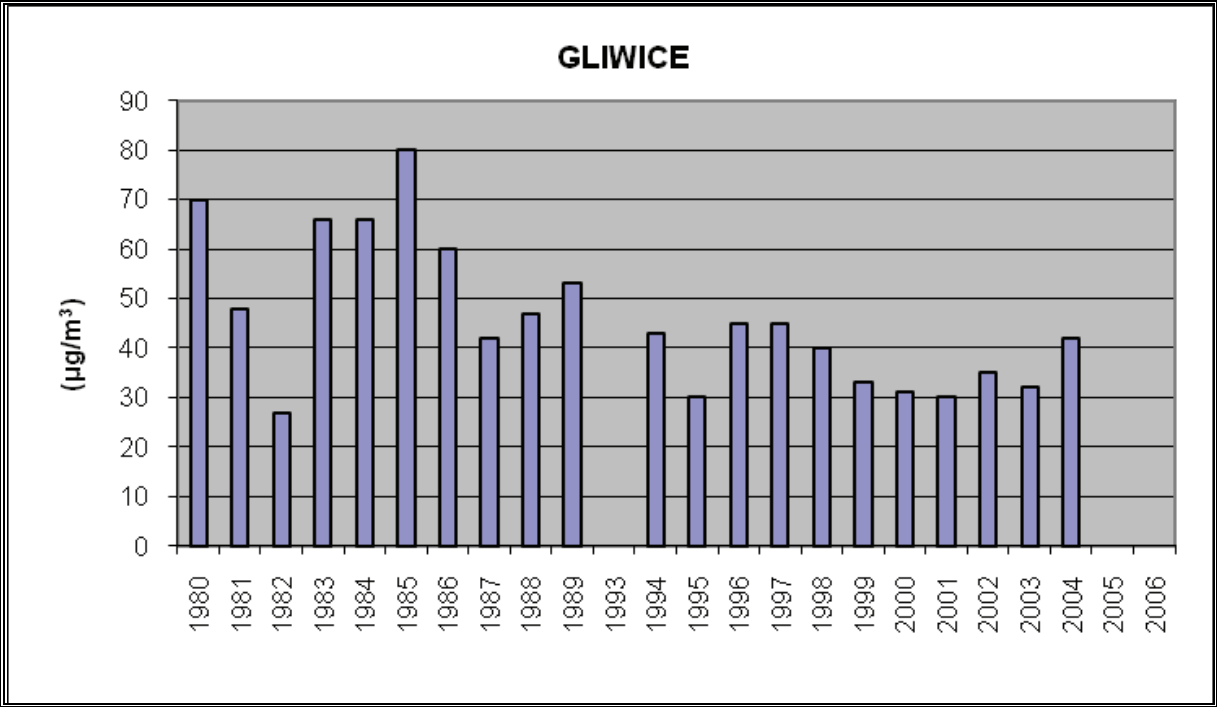


Fig. 14. Distribution of mean yearly sulphur dioxide (SO₂) concentrations on the area of Gliwice in 1980-2006

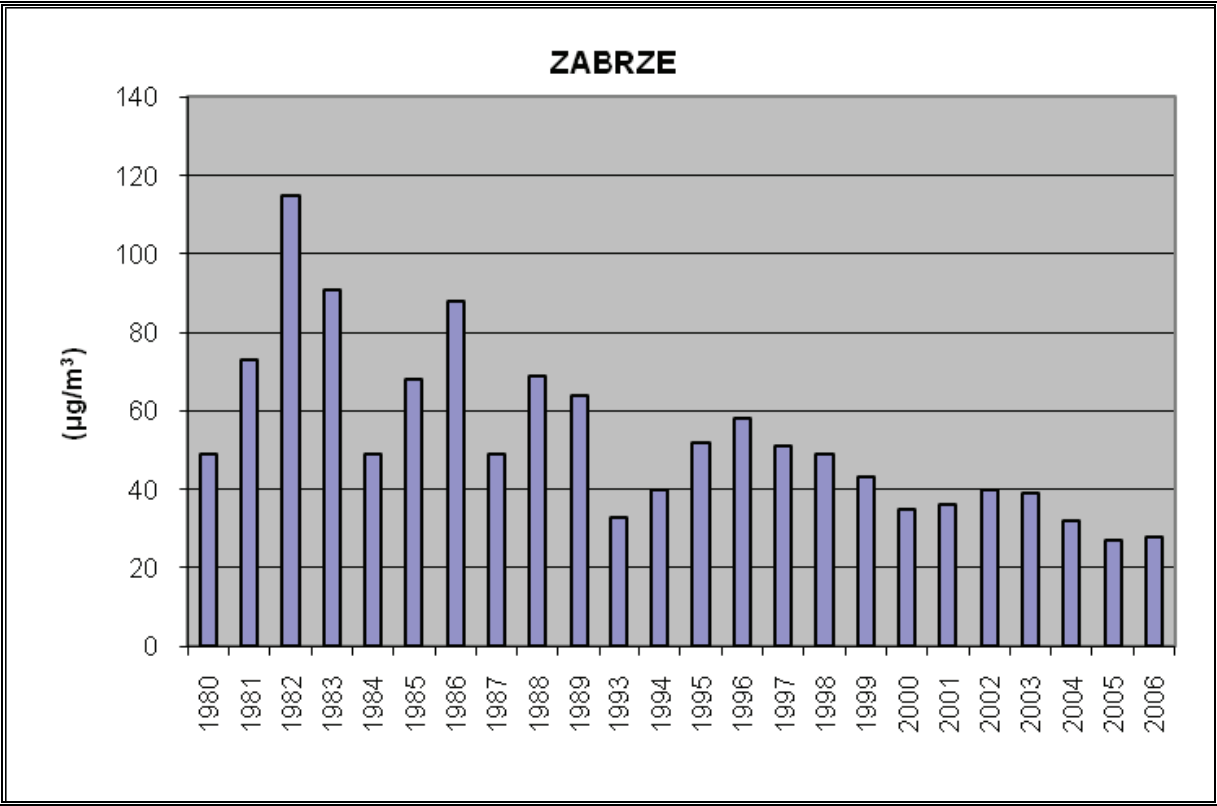


Fig. 15. Distribution of mean yearly sulphur dioxide (SO₂) concentrations on the area of Zabrze in 1980-2006

The above figures present formation of the mean yearly concentrations of sulphur dioxide for the particular cities in the years before the industrial restructuring and present-day period. For the majority of the cities period before 1989 is characterized by the chaotic account of the mean yearly concentrations of SO₂. Frequent increases and decreases of the yearly concentrations of the sulphur dioxide are noticeable. Only after 1996 there occurs a gradual decreasing tendency of the mean yearly concentrations of the sulphur dioxide (Hubicki, 2007).

Nitric compounds, just after the sulphur compounds, are the most frequent cause of air contamination. They are less toxic than sulphur dioxides or ozone, but they play a role of the forerunners for the other pollutants, which regarding fitotoxicity exceed the initial products. Like in the case of sulphur nitrogen is an important compound (main building material of the protein) for plants, therefore the influence of NO_x should be examined regarding both its positive and negative effect, and the result of their absorption depends on the taken dose and physiological condition of the plant (Degórska, 2008).

Complete analysis of the differentiation of the nitric oxides atmospheric pollution within the area of Katowice Region, and particularly with nitric dioxide, is presented in the figures 16-20. The pictures show the mean yearly concentration of the nitric oxide in the years 1980-1987, as well as the values of the nitric dioxide concentration from 1988 and at intervals until the year 2006. This division is related to the fact that during the years 1980-1987 the Voivodship Sanitary and Epidemiological Station gave only the general information concerning the mean yearly concentrations for the nitric oxides, regardless the separate division into NO i NO₂. Only since 1988 the results regarding the mean yearly concentrations of the nitric dioxide have been revealed. Therefore the following analysis

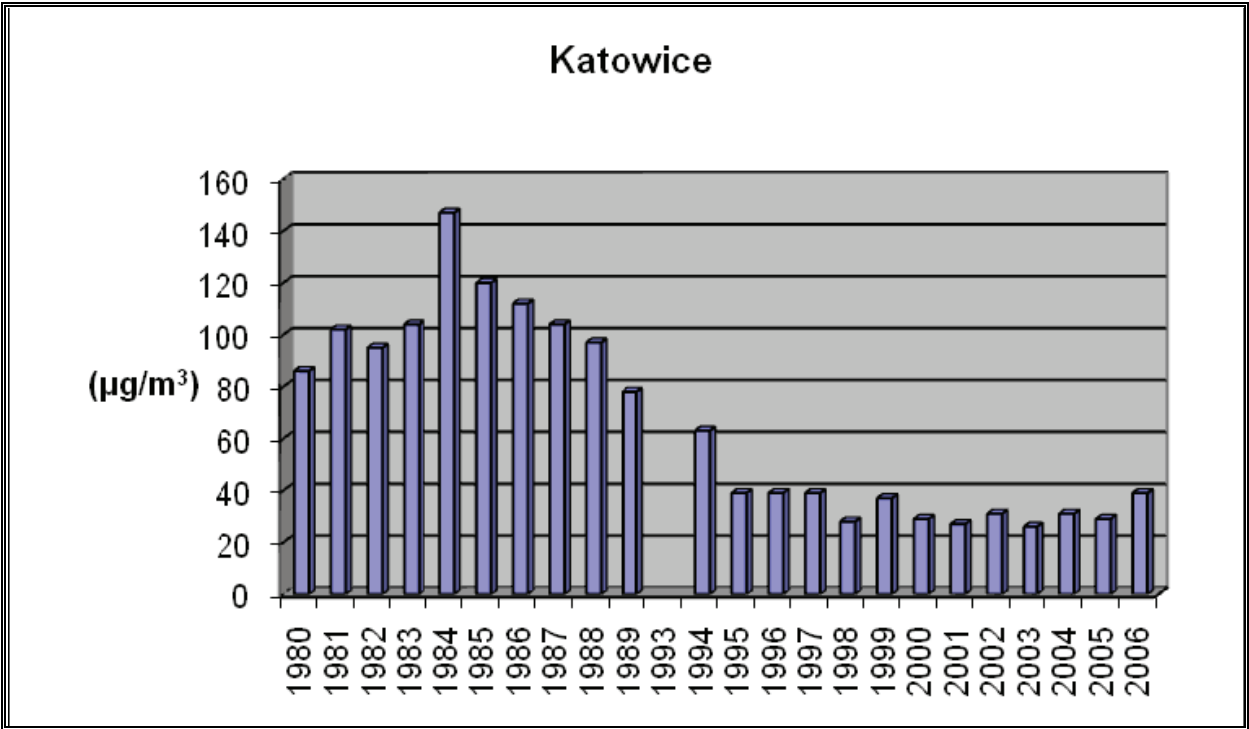


Fig. 16. Distribution of mean yearly nitric oxides concentrations on the area of Katowice in 1980-1987 and nitric dioxide concentrations on the area of Katowice in 1988-2006

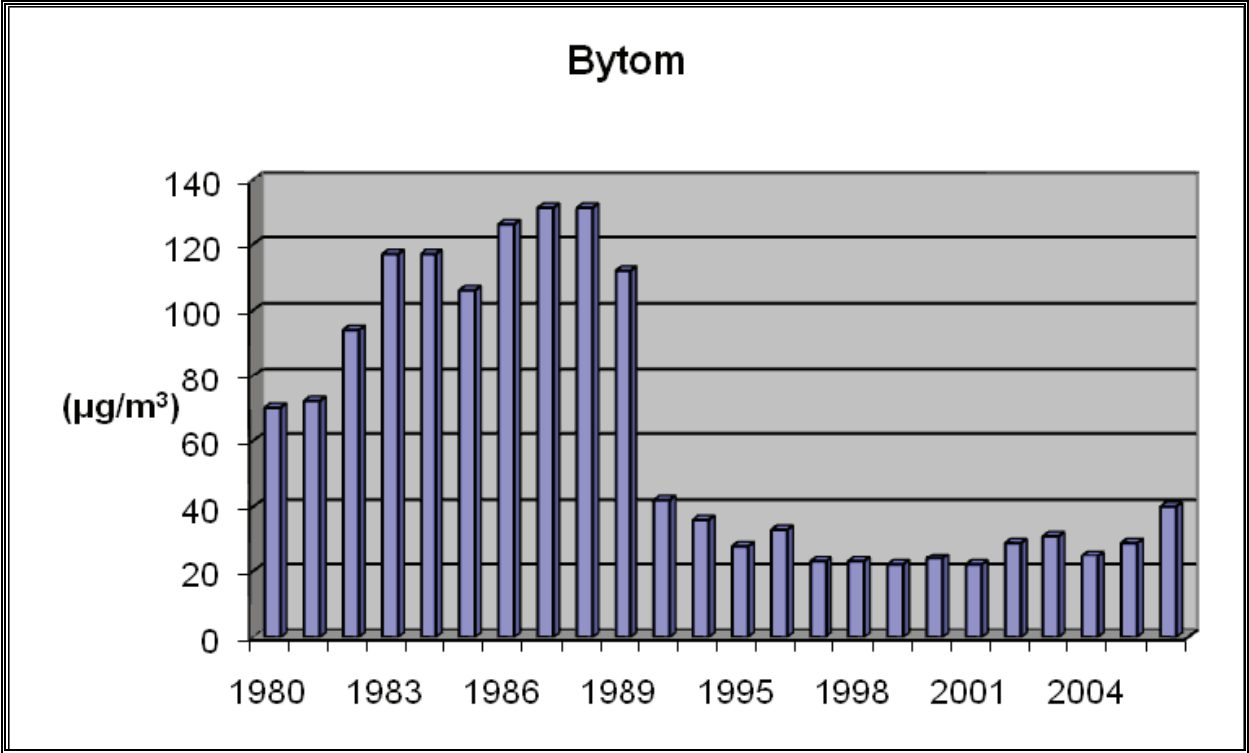


Fig. 17. Distribution of mean yearly nitric oxides concentrations on the area of Bytom in 1980-1987 and nitric dioxide concentrations on the area of Bytom in 1988-2006

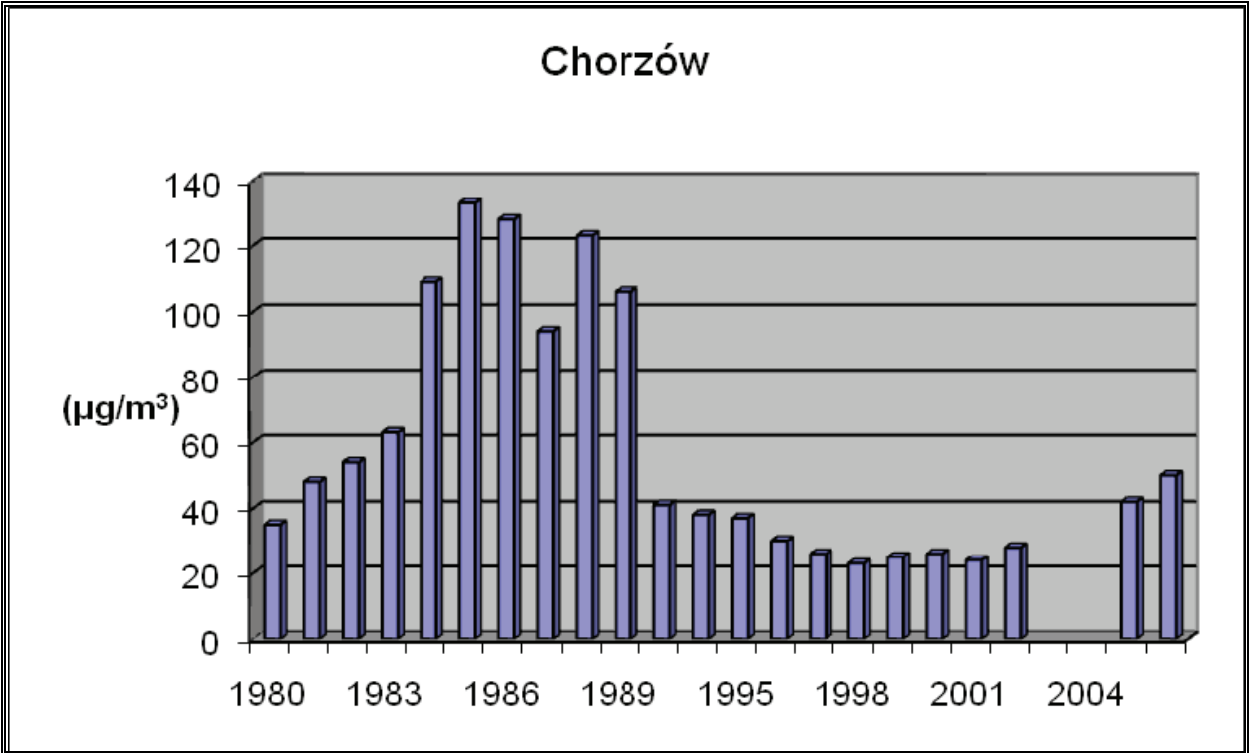


Fig. 18. Distribution of mean yearly nitric oxides concentrations on the area of Chorzów in 1980-1987 and nitric dioxide concentrations on the area of Chorzów in 1988-2006

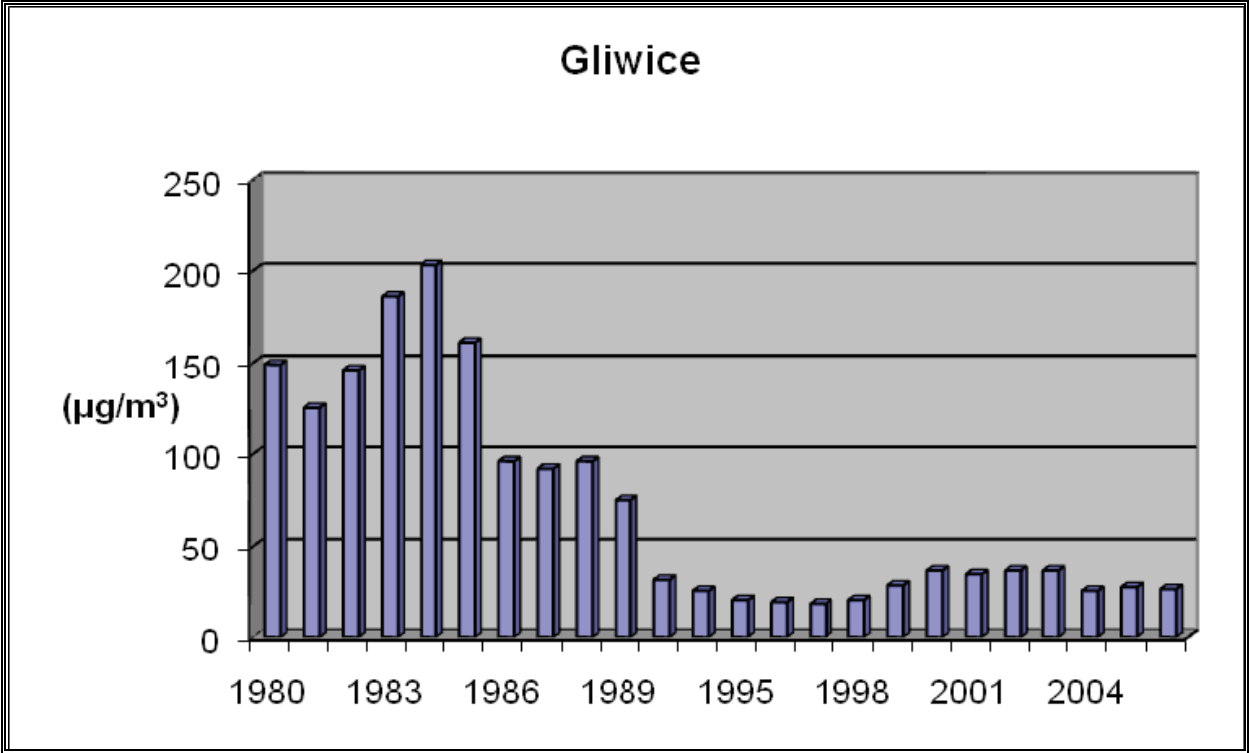


Fig. 19. Distribution of mean yearly nitric oxides concentrations on the area of Gliwice in 1980-1987 and nitric dioxide concentrations on the area of Gliwice in 1988-2006

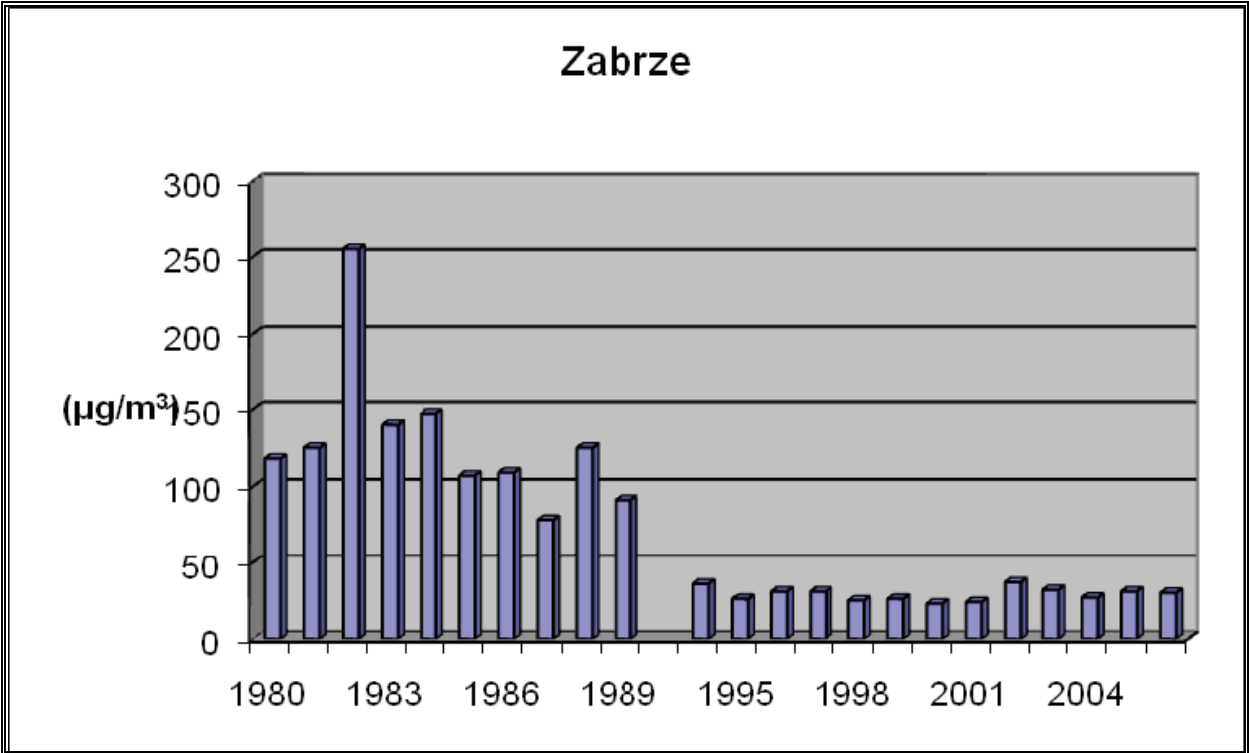


Fig. 20. Distribution of mean yearly nitric oxides concentrations on the area of Zabrze in 1980-1987 and nitric dioxide concentrations on the area of Zabrze in 1988-2006

should be treated symbolically. The values given for the nitric oxide in the years 1980-1987, roughly show the contents of the nitric dioxide for this period (Leśniok, 1996). Such perspective is possible due to the fact that majority of the pollutants are emitted in the form of NO which in the atmosphere, as the result of dilution of the smoke trail and the presence of the oxygen, is quickly transformed into NO₂, and therefore becomes the dominant component (Degórska, 2008).

As the result of the industry restructuring which took place at the beginning of the 90s, within the area of Katowice Region mean yearly concentrations of the nitric dioxide were decreased in a significant way. For the majority of the analysed cities, after 1997 a rapid decrease in the level of nitric dioxide contents can be noticed. In the majority of the measurement stations the decrease of the nitric dioxide contents in the air lasts until 1998. While in the years 1998-2006 within the area of Katowice Region we can observe a slight increase in mean yearly concentrations of NO₂ (figures 16-20) which is mainly related to the dynamic development of transport industry as well as to the clearer tendency towards replacing the compact cars with the ones having a bigger cylinder capacity.

4. Pollution of the precipitation waters

Rainfalls are one of the main elements shaping the quality of the air. The pollutants which are removed along with the rainfalls, in the diluted or non-diluted form, by getting into the ground quickly enter the particular stages of the hydro-geo-chemical circulation. Regarding the quantity and quality of the transported substances and the scope of their effect, rainfalls are good indicators for the evaluation of the degree of atmospheric pollution. Simultaneously, however, they contribute to degradation of the remaining elements of the environment.

As the result of soil acidification we can observe the increase in the mobility of the heavy metals, suppression of the mineralization processes and humification of the organic matter as the result of dying of bacteria and protozoans which are replaced with the selected fungi species. Similarly, in the rivers and lakes the increase in the water acidity caused by the atmospheric acid rainfall leads to the increase in contents of diluted, potentially toxic metals, what results in significant limitation of the species diversity (Degórska, 2008).

The quality of the precipitation waters is mainly influenced by the acid-forming and alkaline compounds. The biggest role in the process of precipitation acidification is attributed to the gas compounds, which mostly include: sulphur dioxide (SO₂), nitric dioxides (NO_x), carbon dioxide (CO₂) and ozone (O₃). Alkalization, and thus weakening of the process of precipitation acidification, is caused by the calcium compounds (Ca) which are elements in the composition of the emitted dusts and ammonia (NH₃). All the aforementioned substances get into the atmosphere as the result of energetic and kinetic fuel combustion and photochemical and natural processes.

So far in Poland there has not been created one, uniform system for analysing the precipitation pollution. Many institutions are involved in this type of research (universities, research institutes, The State Forests National Forest Holding, national parks, etc.). But only within the area of the Lower Silesian province the research are conducted by the Institute of Meteorology and Water Management in Wrocław. In the years 1986-1995 in the Department of Climatology of the University of Silesia the detailed research on the chemical composition of the rainfall in connection with meteorological conditions were being carried out at the 12

points located within the area of Silesian-Cracow Upland (Leśniok,1996). Currently these research are being carried on at three points located in different areas (in Sosnowiec- the industrialized area, in Cieszyn- the area located in the zone of transboundary air pollution transfer, in Ojców National Park- the protected area).

The dusts of the upper Silesian region contain many elements (quickly or slowly soluble in water), which are acidificating and alkalizing, and thus neutralizing “acid rains”, these are mostly calcium compounds (e.g. CaCO_3).

Due to the significant air pollution in the 70s and 80s, especially with the dust compounds containing alkalizing calcium carbonate, the phenomena od the “acid rain” ($\text{pH} < 5$) did not occur at all or it happened very episodically. During these years in the central part of the Upper Silesian Industrial Region the average value of pH was fluctuating from 6,5 to 7,4 (Jankowska, 1982). After the decrease of pollution and slight fall in the contents of the acid-forming compounds, especially in the central part of the Upper Silesian Industrial Region occurred the increase in the frequency of the acid rains, for example in Sosnowiec the frequency was risen from 60% (1990–1992) to 91% (1996–1998), and the average pH value decreased from 6,1 in 1987 to 4,0 in 2004 (fig. 21, Table 2).

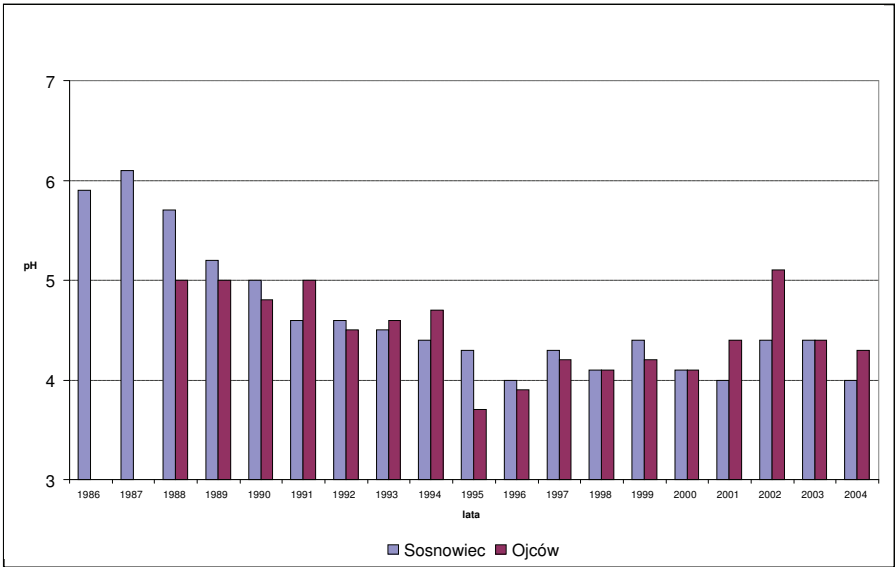


Fig. 21. Distribution of mean yearly values of the precipitation pH reaction in Sosnowiec and Ojców

pH scope	Sosnowiec				Ojców				Cieszyn			
	1990	1993	1996	2000	1990	1993	1996	2000	1990	1993	1996	2000
	1992	1995	1998	2003	1992	1995	1998	2003	1992	1995	1998	2003
< 5,0	60	78	91	84	72	80	90	76	71	87	88	71
5,0–6,0	32	19	9	14	16	17	9	15	25	11	12	23
> 6,0	8	3	0	2	12	3	1	9	4	2	0	6

Table 2. Percentage of the precipitation pH reaction in the particular scopes in Sosnowiec, Ojców and Cieszyn, in the years 1990-2003

Similar changes can be observed in the remaining points, although they are not as dynamic. Currently the pH reaction remains on the 4,2-4,4 level. The amount of the dissolved compounds has also decreased, especially of calcium ions (Ca^{2+}), however the sulphur ions are still dominating in the composition of the participation waters and are mainly responsible for their acidification (Leśniok et al., 2005).

5. Conclusions

- The results of the research on the air pollution and precipitation revealed significant spatial differentiation of the degree of air pollution and precipitation which is the result of the change in proportion between the quality and quantity of the pollutants emitted into the atmosphere.
- As the result of the industry restructuring after the year 1989 the quantity of the emitted dust and gas pollutants within the area of Katowice Region decreased, however, in comparison with the other regions in Poland, it is still very big.
- On the whole area of Katowice Region the significant decrease in emission of dust pollutants was observed. This decrease contributed to the increase in the occurrence of "acid rains" phenomenon. "Acid rains" currently are present in 85% of the rainfall and their frequency is still increasing. Due to this fact central part of Katowice Region becomes similar to the peripheral areas.
- Gradual increase in the acidification of the precipitation during the last 10 years can be the signal for the initiation and further progress of the acidification processes of the remaining environment elements such as soil, surface waters and underground waters, what can have negative effect on flora and fauna. This problem is especially crucial for Katowice Region area which has been polluted for over one hundred years. The pollution accumulated on this area (mostly the heavy metals), due to the increase of acidification, can become active and contribute to the irreversible changes in the sphere of the remaining environment elements.
- Precipitation can be an important element in the evaluation of the air pollution. Knowing the quantity and quality of the pollutants, which are transported along with the rainfalls, is significant information which in a serious way can contribute to prevent the phenomenon of the natural environment acidification.
- In spite of the noticeable interference of the human and strong transformation of the natural environment, part of the areas within Katowice Region has been considered valuable and are under the different types of environment protection e.g. natural reserves ("Murckowski Forest", "Segiet", „Ochojec"), ecological sites (swamps in Antoniów), Natura 2000 areas (Tarnogórsko-Bytomskie Undergrounds and Błędowska Desert under the Habitat Directive).

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Leading air quality professionals describe different aspects of air pollution. The book presents information on four broad areas of interest in the air pollution field; the air pollution monitoring; air quality modeling; the GIS techniques to manage air quality; the new approaches to manage air quality. This book fulfills the need on the latest concepts of air pollution science and provides comprehensive information on all relevant components relating to air pollution issues in urban areas and industries. The book is suitable for a variety of scientists who wish to follow application of the theory in practice in air pollution. Known for its broad case studies, the book emphasizes an insightful of the connection between sources and control of air pollution, rather than being a simple manual on the subject.

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