The environmental quality profiles of Polish cities in the context of air and water pollution (2000-2009)[1)]

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Zusammenfassung

Um die Qualität der Umwelt in 307 Städten Polens zu bewerten, wurden Daten zur Luftverschmutzung (NO_2 SO_2, PM_{10}, C_6H_6, B (a) P) und Qualitätsklassen für Gewässer (Fließgewässer in zwei 4-Jahres-Perioden sowie unterirdische Gewässer) und Wassersedimente in den Jahren 2000 bis 2009 herangezogen. Die qualitative Beurteilung der Umweltqualität in den Städten zeigte, dass die schlechtesten Umweltbedingungen immer noch im südlichen Polen (Oberschlesien, die Region von Krakau und süd-westlich von Polen) sowie in den Umgebungen der größten städtischen Ballungsräume (Łódź und Warschau) vorzufinden sind. Neben den alt bekannten negativen Umwelteinflüssen durch Industrie und Landwirtschaft kamen neue Faktoren wie Transport und Nutzungsdruck durch Kommunen hinzu.

Abstract

In order to assess the quality of the environment in 307 Polish cities, having analyzed the accessibility of sozological data, we used information of a proper level of completeness with regards to concentration of air pollution (NO_2, SO_2, PM_{10}, C_6H_6, B(a)P) and the classes of the quality of waters (flowing waters in two 4-year periods and the underground waters) and water sediments in the years 2000-09. Qualitative (bonitac) assessment of environmental quality of the cities showed that the worst environmental condition is still characteristic for Southern Poland (Upper Silesia, the region of Cracow and south-west of Poland) as well as the surroundings of the biggest urban agglomerations (Łódź and Warsaw). The old – industrial and agricultural – factors of pressure on environment were completed with newer ones: transport and communal.

1. Introduction

The issues concerning environmental protection and quality of life in the cities are one of the essential research trends of natural and social sciences. Its importance is acknowledged in the policies of European Union (CEC 2006) and finds its reflection in the research and monitoring programs carried out (e.g. EEA 2009). The studies on the urban environment in Poland have also had quite a long tradition and vast range of application (e.g. BRÓDKA 2008). However, as a rule, they consider either particular cities or selected issues. There have been no review synthesis, in Polish scientific literature, of environmental quality in the cities over a long period of time. Available synthesis refers to the entire country or voivodeships (e.g. CIEP 2010). The author of this article carried out the research on the sozological diagnosis of Polish cities. The index method of complex sozological diagnosis was employed, taking into consideration earlier studies on working out and applying the system of measures of sustainable development and environmental protection for Polish regions (GOŃCZ & KISTOWSKI 2004). This method was described in more detail in the author's publication (KISTOWSKI 2011). The term "sozology"[2)] means the field of study dealing with the issues of environmental protection, causes and the effects of the anthropogenic changes on the structure and functioning of natural systems as well as the ways of preventing and reducing their effects. It was introduced by GOETEL (GOETEL 1966) and is used in Poland quite often. This method is based on the analysis of ca. 75 measures in regard to the environment, its quality and actions within the scope of environmental protection for almost 2500 basic Polish administrative units (communes). The research presented in this article refers to the indices of environmental quality for the selected 307 urban municipalities.

2. Data sources and study methods

In view of the way of aggregating statistical data regarding communes, 307 cities were selected for the study. They have their own city councils, which do not govern the neighboring rural communes. They make up 34.7% of Polish cities, with a human population of about 18.8 millions (49.3% of population of country), which is quite representative. Small towns (1.000 – 25.000 inhabitants) – 48% and the medium ones (25.000 – 100.000) – 39% are the majority. Above half a million people live only in five cities.

Majority of data needed in order to calculate the indices of the pressure on environment and its protection were taken from the Local Data Bank (LDB) of the Central Statistical Office. However, with regards to environmental quality, this source has got very limited information. The main institutions which gather data from the monitoring of environment are State and Regional Inspectorates of Environmental Protection, which annually publishes the reports on the condition of the environment. Data was gathered mainly from these 160 reports prepared for 16 Polish voivodeship cities in the years 2000-2009. There was a need for standardization as, within the study period the forms of these reports were very different and some of them were accessible only in the "paper" form. It had to be

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[2)] After ancient Greek language term "sódzo" means protection.

done in order to make the data comparative and applicable for all the cities. Some data were also obtained from the State Sanitary Inspectorates and the Polish Geological Institute. Having analyzed the data in regards to environmental quality, using the criterion of percentage of the cities, for which they are accessible, the research has taken into consideration data considering:

• quality of air – the annual average concentration in the air: nitrogen dioxide, sulfur dioxide, suspended particulate matter, benzene ($\mu g*m^{-3}$) and benzo-α-pyrene ($ng*m^{-3}$);

• quality of waters and water sediments – their classes of quality: flowing waters within the period of the years 2000-2003 (4 classes) and 2004-2007 (5 classes)[3], underground waters (5 classes) and water sediments (4 classes).

In case of air quality, raw data of the concentration of selected air pollutions was used, while in case of water and water sediments processed data referring to the classes of their quality, defined according to the legal regulations in force was used.

Unfortunately, data considering the quality of the other components of the environment (soils, noise level and biotic elements) were accessible for less than ¼ of the studied cities so we gave up on using them. Moreover, we notified the lack of satisfactory data considering changes in the area coverage. The lack of data considering the area coverage is due to the lack of cadastral system for the Poland as a whole. In LDB at the city level, only data on the forest acreage is gathered. Maps drawn in the framework of CORINE Land Cover base for the years 2000 and 2006 are not detailed enough for the sake of this research. Thus, 9 indices were analyzed.

It shall be noticed, that there are great differences between the scopes of data accessible for the cities (Fig. 1). For 11 of them (located in the Warsaw and Upper Silesian agglomeration and near state border) data was non-existent, which made the assessment of environmental quality impossible. Data for 1-3 out of 9 indices were accessible for 50 cities, which essentially lowered the reliability of the assessment. Data, just, on the quality of water was accessible for 40 cities, data only on quality of the air for 15 cities, which also limited the complexity of assessment. 20 cities had full set of data and 100 of them information on 7-9 indices. All the voivodeship cities were among them. The completeness of data[4] increases with the number of people living in the cities (Fig. 2, Tab. 1). Taking the indices into consideration, the completeness is highest for the concentration of NO_2, SO_2 and PM_{10} pollution in the air (70-80%) and the quality of flowing and underground waters (65-75%), while the lowest for the concentration of B(a)P and the quality of the water sediments (28-40%).

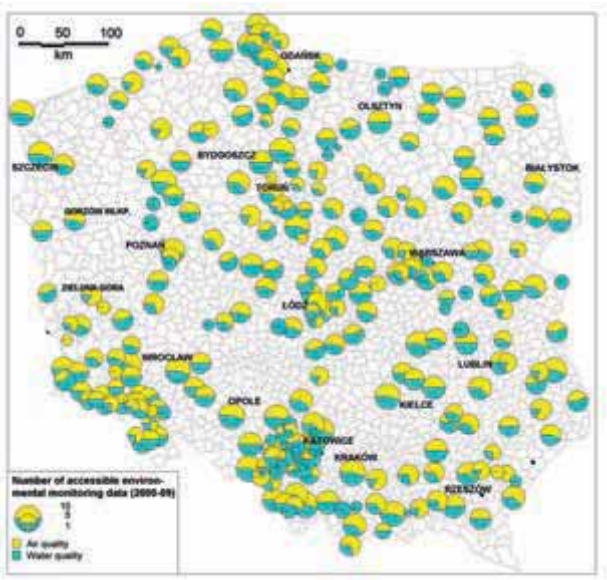

Fig. 1: Number and a kind of indices considered in the assessment of environmental quality in the cities

For each of the selected 9 indices for the cities, the average values for the period of data accessibility were calculated. These values were calculated as arithmetic means for the average annual values for the years taken into consideration. The range of values of each index was divided into 10 sections to which qualitative values were ascribed: from 1 point – which is the best quality of the environment to 10 points – the worst. The obtained points were summed up and divided by the number of indices accessible for the particular city. The result was a complex assessment of environmental quality of the cities in regards to the quality of the air and waters. The obtained results were presented for all the cities on the maps in the form of cartodiagrams and for the section of population in the form of charts.

Group of cities (x1000 dwellers)	Number	Completeness of data (%)									Average concentration in air ($\mu g*m^{-3}$) or waters/water sediments quality class									Av. completeness
		NO_2	SO_2	PM_{10}	Benzene	B(a)P	River waters		Underground water	Water sediments	NO_2	SO_2	PM_{10}	Benzene	B(a)P	River waters		Underground water	Water sediments	
							2000-2003	2004-2007								2000-2003	2004-2007			
1-10	52	52,0	52,0	23,0	13,5	9,6	59,6	48,0	69,2	23,0	12,8	8,8	23,5	3,83	5,63	3,73	3,73	2,81	1,33	38,9
10-20	96	66,7	72,0	55,2	32,3	8,3	54,2	61,5	67,7	33,3	16,8	6,9	25,7	2,86	5,06	3,70	3,93	2.91	1,73	50,1
20-50	73	93,0	93,0	93,0	37,0	28,8	71,2	65,8	67,0	42,5	21,0	7,3	28,1	2,65	6,16	3,60	3,86	2,80	2,05	65,8
50-100	47	93,6	93,6	89,4	61,7	44,7	68,0	70,2	91,5	61,7	21,9	9,6	33,5	3,11	6,43	3,72	3,99	2,92	2,12	74,9
100-250	28	96,4	96,4	100	96,4	82,0	89,3	85,7	82,0	43,0	24,3	12,5	37,5	3,69	8,39	3,85	4,27	3,10	2,10	85,7
250-500	6	100	100	100	100	83,3	100	100	100	33,3	22,3	9,3	29,1	2,52	3,63	3,65	3,94	2,79	2,50	90,7
>500	5	100	100	100	100	100	100	100	100	60,0	30,9	9,4	37,3	3,26	4,44	3,99	4,21	3,14	3,00	95,9
Av. completness		78,5	81,1	69,7	43,0	28,7	66,1	65,1	73,9	39,4										
Average concetration/class											19,7	8,4	29,8	3,04	6,41	3,71	3,95	2,89	1,95	

Tab. 1: Information on data completeness and average values of the assessed indices (2000-09) in the studied cities depending on the number of population

[3] This division is due to changes in the methods of measuring and classification of the quality of surface waters. Data on the ecological water state/potential from the years 2008-09 were not taken into consideration – as a result of the process of the complete alignment to the requirements of Framework Water Directive – the number of water monitoring points does not reach the threshold of 25% of the cities.

[4] Means the percentage of existing data in relation to the available data at large; that is the situation in which data on all the studied years and/or all the cities under study (in the particular class of population) was assessed.

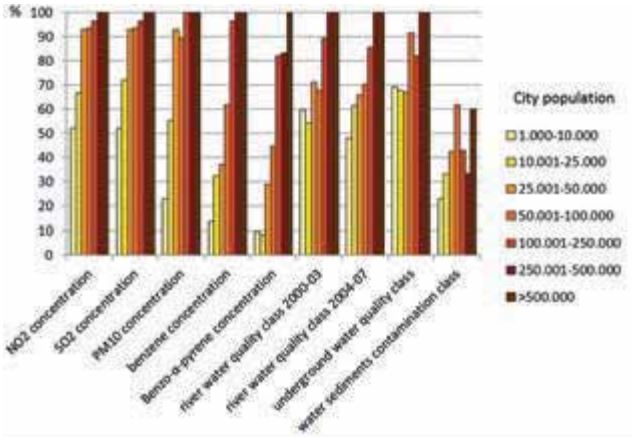

Fig. 2: Percentage of the cities which included data on environmental quality depending on the number of population

3. Study results

The results of the research were presented in a spatial layout with reference to the population sections of the cities for each index in Table 1 and Fig. 3-6. The average concentration of NO_2 in the air in the selected cities reached 19.7 $\mu g*m^{-3}$ in the years 2000-2009, with an annual norm of 40 $\mu g*m^{-3}$, going beyond the norms in 5 cities: with 4 of those cities located in the Upper Silesia and Soc-chaczew, west of Warsaw (Fig. 3a). In light of WHO guidelines (WHO 2006), the recommended annual concentrations are: up to 40 $\mu g*m^{-3}$ for NO_2 and up to 20 $\mu g*m^{-3}$ for PM_{10}. The average concentration of SO_2 within this period is 8.4 $\mu g*m^{-3}$. Acceptable annual concentration (20 $\mu g*m^{-3}$) was exceeded in 17 cities, including 15 cities in Upper Silesia, Żywiec, south of the Silesian voivodeship and Boguszów-Gorce nearby Wałbrzych (Lower Silesia) (Fig. 3b). The concentration of PM_{10} reached in the cities on average is 29.7 $\mu g*m^{-3}$, so the annual norm (40 $\mu g*m^{-3}$) was exceeded in 45 cities, mainly in Upper Silesia but also in Cracow, Nowy Sącz, Nowy Targ, Zakopane (Lesser Poland), which are located in valleys or mountainous basins, which is conducive for the phenomena of smog (Fig. 3c). Similar reasons, connected with emission not only of industrial pollutions but also from the traffic and communal pollutions, as well as the location of the cities, created also concentration of benzene and benzo-α-pyrene respectively. The average concentration of the former reached 3 $\mu g*m^{-3}$ and exceeded the acceptable level (5 $\mu g*m^{-3}$) in 8 cities: 5 in Upper Silesia, Kędzierzyn-Koźle in Opole voivodeship, Szczawno-Zdrój in Lower Silesia and, quite surprisingly, in Kostrzyn at the Polish-German border (Fig. 3d). The average concentration of B(a)P in the studied cities reached 6.4 $ng*m^{-3}$, while the norm (1 $ng*m^{-3}$) was exceeded in 76 cities in Poland, mainly in Upper Silesia, but also in those located in the valleys and mountainous basins. It needs to be emphasized that data on the concentration of B(a)P were from the second half of the study period and were incomplete. Studies carried out over shorter periods, e.g. the years 2005-2006 (IOŚ 2007) confirm the results obtained in the author's studies (e.g. the highest concentration of NO_2 occur in the following agglomerations: Upper Silesia, Łódź, Warsaw, Cracow and PM_{10} concentration in the following agglomerations: Warsaw, Cracow, Upper Silesia), however, with partially regard to a small number of measure points, the results are divergent considering the concentration of benzene.

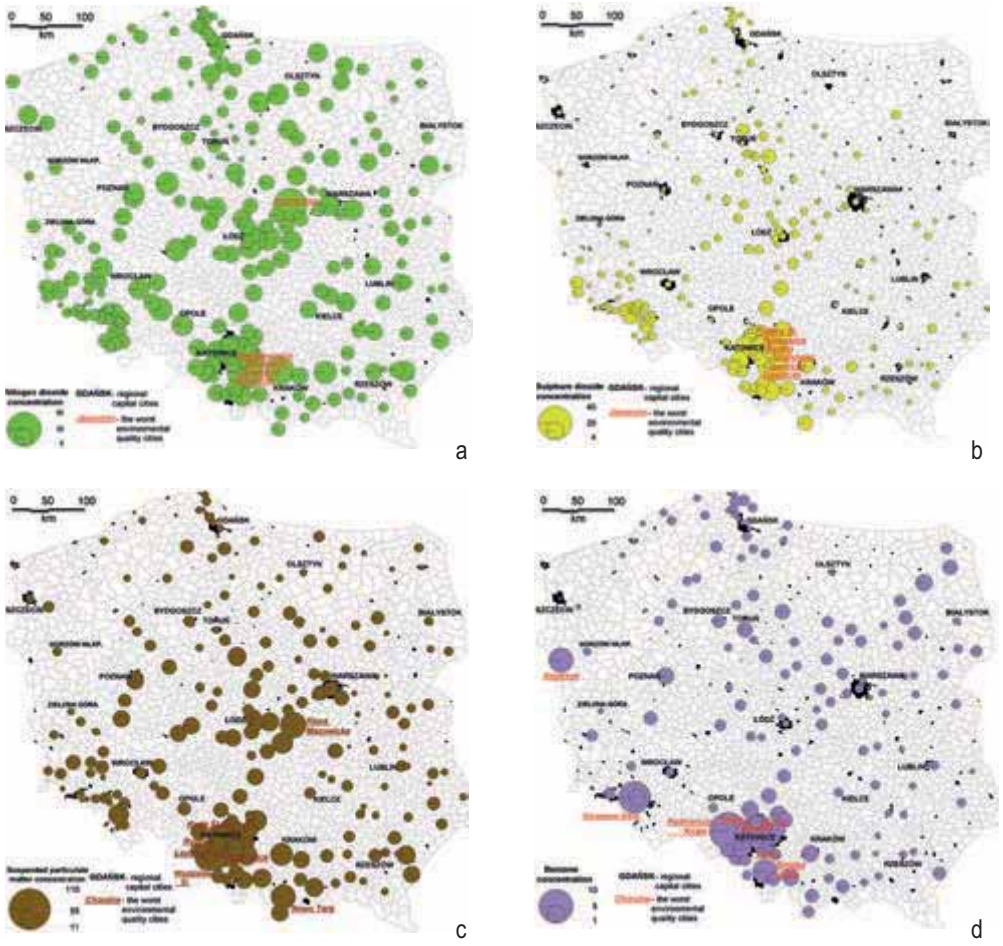

Fig. 3: Average concentration of the air pollution ($\mu g*m^{-3}$) in the selected cities in the years 2000-09: a) NO_2, b) SO_2, c) PM_{10}, d) benzene

With regards to the concentration of NO_2, SO_2 and PM_{10} we can observe the increasing tendency of pollutions along with the increase of the cities' population. This tendency is clearly uneven in the case of cities inhabited by 250.000-500.000 people (Gdańsk, Szczecin, Lublin, Bydgoszcz, Katowice, Białystok), where the accessible results show lower concentration than in the more populated cities and a bit smaller ones (Fig. 4).

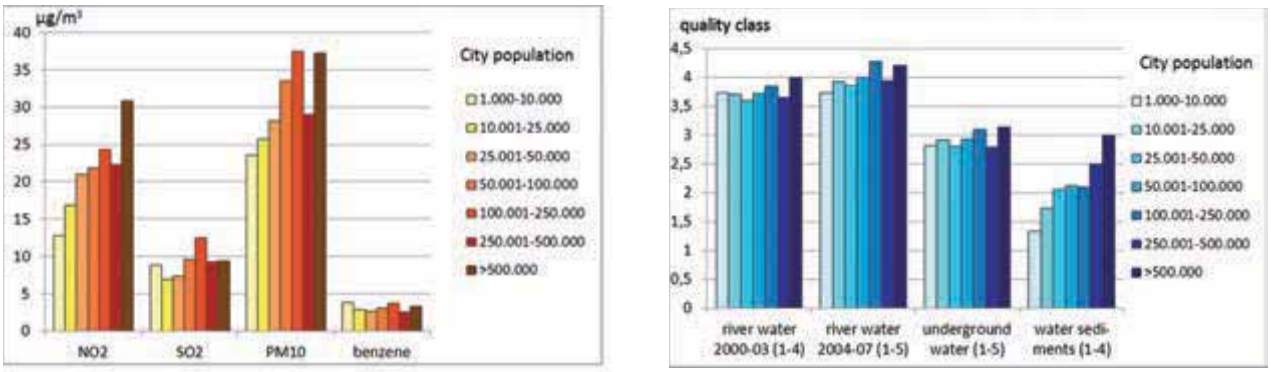

Fig. 4: Average concentration of the air pollution (µg*m^{-3}) and classes of cleanness of the waters and water sediments within the years 2000-09 depending on the population

The reasons of this situation are quite obvious. It may result from both the lower pressure on environment, which is due to the preventive actions, advantageous location of the cities (good urban ventilation) but also due to the false localization of the measuring points or underestimation of the results in order to improve the values of the indices of environmental quality, which influences the assessment of the living quality and the image of the cities. Similar tendencies are observed in other European cities (EEA 2007, EUROSTAT 2007). The annual NO_2 concentration in many cities in northern Italy, western part of Germany and England, are higher than in majority of Polish cities; while the concentration of PM_{10} in southern Poland corresponds to the highest concentrations in other European cities (southern Italy, southern Spain, Bulgaria, Romania, Serbia).

Among the indices referring to the quality of waters, we can observe the lower (except the class of pollution of the water sediments) tendency of worsening environmental quality along with an increase of population in the cities, although this still exists. Data on the quality of flowing waters show very bad conditions of these in Polish cities. On the basis of the results of water monitoring in the years 2000-03 it was determined, that their middle class (in the range of 1 – being the best, 4 – the worst) reaches 3.7. The worst grade (4) was given to 111 cities relatively and evenly distributed across the entire country, while the rivers in the eastern and northern Poland were cleaner than the ones in southern and central Poland (Fig. 5a). This situation is due to less untreated and partially treated communal sewages disposed into the waters and less introduction of chemical substances into agriculture in eastern and northern than in the western, southern and central Poland. Within the next four years (2004-07), the condition of waters slightly improved, which only seems apparent, as it results from a change in the criteria of assessment of their quality. In the range 1 (the best waters) – 5 (the worst waters), the average assessment of the quality of the flowing waters in the cities reached 3.95. 26 cities were diagnosed with the worst quality of water. Majority of those cities are located around the biggest urban agglomerations (Upper Silesia, Warsaw, Łódź, Trójmiasto, Wałbrzych) (Fig. 5b).

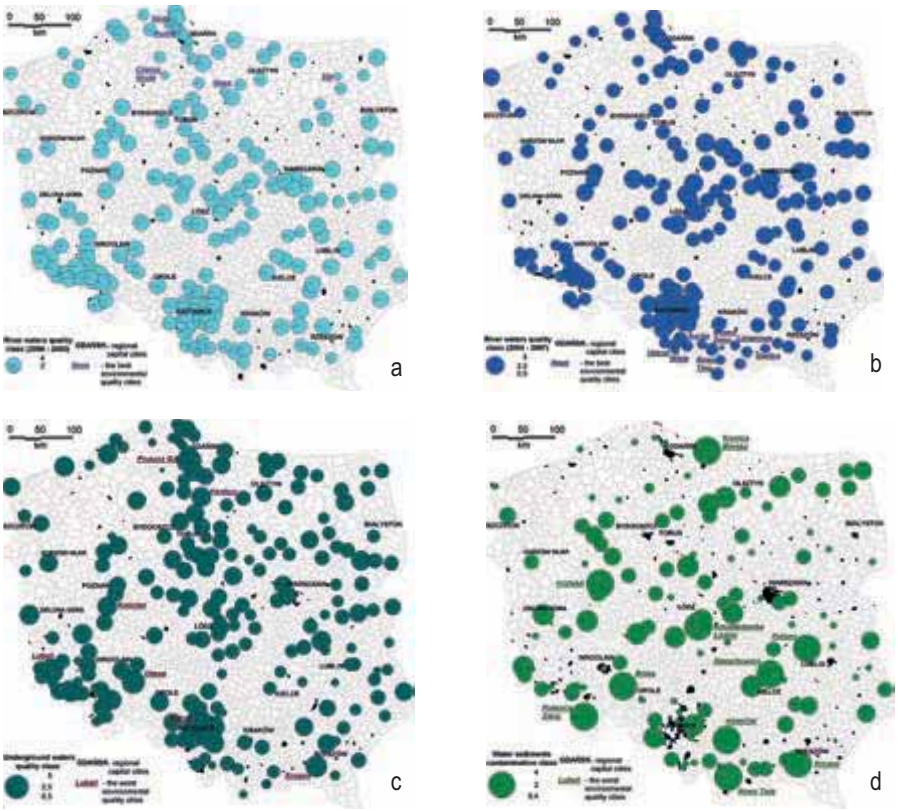

Fig. 5: Average classes of quality of waters and water sediments in the selected cities within the years 2000-09: a) river waters (2000-03), b) river waters (2004-07), c) underground waters, d) water sediments

The underground waters were of significantly better quality. Their average assessment in the range 1-5, reached 2.9. The worst quality of water (grade >4) was found only in 7 cities, across the entire country, however, majority of those were in the southern and northern parts (Fig. 5c). The causes

of the poor quality of the underground waters can have both anthropogenic (input of the industrial, mining, agricultural and communal effluents) and natural (shallow-lying of the water-bearing levels, poor isolation from the surface by geological formations, infiltration of the salty sea waters) character, and most often there are their synergic connectivity.

The assessment of the quality of water sediments, in range 1-4 shows that they are relatively slightly polluted (for the cities on average 1.95). 10 cities in the whole of Poland were given the worst note (4) (Fig. 5d). It seems that the quality of sediments is generally worse in the southern and central part of the country and better in the eastern and northern, however, the local factors connected with the input of effluents were significant. In case of water pollutions, the cities with population 250.000-500.000 were assessed higher, which can support the opinion of underestimation of data on effluences in regards to the quality of air.

The complex assessment of the quality of urban environment on the basis of indices in regard to waters and the air was presented in Fig. 6. It depicts that the greater concentration of the cities with poor environmental condition is in Upper Silesia as well as in some other industrial centers (e.g. Cracow, Tarnów, Rejowiec Fabryczny with metallurgy, chemical and cement industry) or in the disadvantageously located cities with tendency for concentration of effluents (Nowy Targ, Nowy Sącz, Bielsko-Biała). The condition of environment was assessed the lowest in Łaziska Górne south-west of Katowice. The poor assessment of quality refers also to several smaller cities situated in more peripheral regions of the country (e.g. Brańsk, Sławno, Zielonka), however, due to a small number of assessment criteria with reference only to the waters, it cannot be considered as fully reliable. The best condition of the environment among the studied cities was in Wałcz (Western Pomeranian). Generally, the main reason for a better quality of the environment in the cities of eastern and northern Poland than the ones in southern Poland is the diversity of anthropogenic pressure on environment, more than the differences in environmental resistance and its ability for pollutants dispersion.

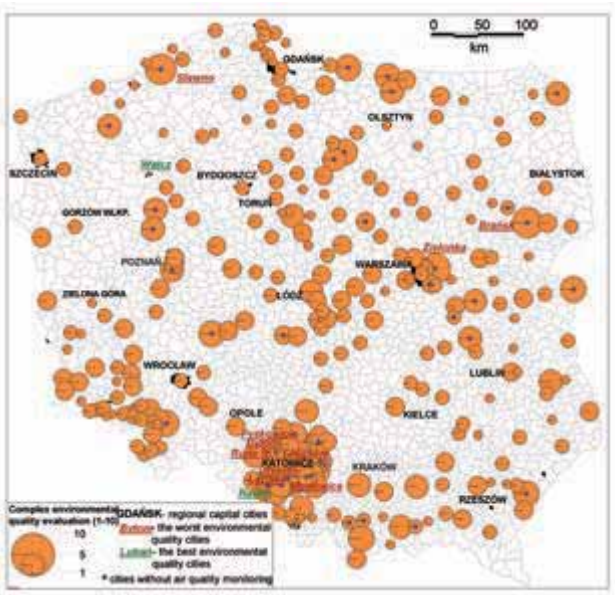

Fig. 6: Complex assessment of environmental quality in the selected cities on the basis of indices of air and water quality in the years 2000-09

4. Discussion and conclusions

An attempt to carry out a complex environmental quality assessment for 307 Polish cities, which have their own city councils, showed a limited possibility of the objective study on the basis of accessible data. There is lack of data for a small number of cities (4%) and for another 25%, data was either incomplete or referred only to a quality of one or two considered components of the environment. Completeness of data was lowest (50% and less) in the small cities (below 20 thousand dwellers) which limited the reliability of the assessment. This situation can be explained by the financial limitations and restrictions in environmental monitoring, which has – according to the European tendencies – cautionary character and is introduced in the areas with the highest probability that the norms of air and water pollution standards would be exceeded. The incompleteness of data on the quality of soil and the biotic elements was the greatest limitation to the complexity of assessment. Another problem was also the diversity of the study methods and the assessment of environment within the study period (2000-2009).

Despite the above-mentioned difficulties, we obtained a partially reliable picture of the environmental quality of cities in the aspects of quality of the air and waters. It shows, that despite the significant limitation of industrial influence, within the last 20-year period, on the environment, the worst quality is still observed in the southern part of the country – the cities of agglomerations of Upper Silesia, Cracow, south-west of Poland and Łódź and Warsaw agglomerations. Adverse conditions characterize also cities, which are located e.g. in the mountainous basins (Nowy Targ, Nowy Sącz), which is favorable for concentration of pollutions, especially the air. Lawful standards for the annual air pollutions exceeded permissible concentrations in case of all the analyzed indices – less frequent for NO_2 (5 cities), and most frequent for benzene (65 cities) and PM_{10}, where – applying the national regulations – annual concentrations were exceeded in 45 cities, however, applying the twice as rigorous WHO recommendations – concentrations were exceeded in as many as 126 cities.

Transport sources have much greater significance among the sources of air pollution, although locally, the industrial sources play a significant role. A few industrial companies still do not fulfill legal requirements of BAT. Emission of untreated or partially treated communal sewages is the main cause of water pollutions, especially in the rural areas, where the sewage disposed into river waters reaches the cities. Another cause is an excessive and inappropriate usage of mineral fertilizers and plant protection chemicals in agriculture. In southern Poland, the quality of waters is worsened by collection of salty waters from the mines, while in the northern part by the natural processes of diffusion of sea waters into the hinterland.

More detailed recognition of the picture of environmental quality in Polish cities will require broadening the network of environmental monitoring on some terrains, and a precise definition of the causes of the described regularity, e.g. better assessment of the condition of the environment in a few large voivodeship cities (population of 250.000-500.000), than in the smaller centers, requires recognition of several factors, including reliability of data.

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