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EMISSION OF SULPHUR OXIDES, NITROGEN OXIDES AND CARBON MONOXIDE IN THE SELECTED EUROPEAN UNION COUNTRIES IN THE YEARS 1995-2010

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ABSTRACT – The article presents the diversity and changes in the emission of typical pollutant gases: CO, SO_x and NO_x in the selected European Union countries in the years 1995-2010. This process was determined to be diverse both in time and space. There was an evident decrease in the total emission of the above-mentioned pollutants also in some countries with a dynamics higher in the years 1995-2000 than in the first decade of the 21st century. The highest actual emission of the analyzed pollutants took place in Poland, Bulgaria and Romania, with the lowest values in Slovenia, Estonia, Lithuania and Latvia. In the years 1995-2010, the disproportions between the countries in the spatial diversification of air pollution emission considerably diminished. One of the consequences of the decline in the air pollution emission is an improvement of air quality in numerous urbanized and industrialized areas in the research countries.

Keywords: emission, carbon monoxide, sulphur oxides, nitrogen oxides, European Union

INTRODUCTION

Due to both natural processes and human activities, various liquid, solid and gas substances enter the air causing its pollution. In total, the amount of pollution on the Earth generated from anthropogenic sources is lesser than from natural sources (Mannion, 1997; Dobrzańska et al., 2008). However, the amount of some gases emitted into the atmosphere by people is higher than those emitted by natural sources, e.g. sulphur dioxide or carbon monoxides. Together with nitrogen oxides, these compounds are commonly present air pollutants. They often pose a threat to the environment and, in greater concentrations, are dangerous to people's life or health. According to some researchers, those pollutants are the cause of global changes in the environment (Mannion, 1997; Strzałko and Mosso-Pietraszewska, 1999; Dobrzańska et al., 2008).

THE AIMS OF THE STUDY. USED MATERIALS

The article presents the diversity in the emission of carbon monoxides, sulphur oxides and nitrogen oxides in the selected countries of the European Union. Ten countries were chosen for analysis and comparison: Bulgaria, Estonia, Hungary, Lithuania, Latvia, Poland, Romania, Slovakia, Slovenia and the Czech Republic. These countries stem from one geopolitical area. Not long ago they were all socialist countries or republics belonging to the Soviet Union, where a planned economy predominated. Currently, processes of economic transformation take place in the aforementioned countries in order to adjust their economies to market mechanisms.

The aim of this paper is to present the diversity and changes in the emission of carbon monoxides, sulphur oxides and nitrogen oxides in the period preceding the accession of those countries to the European Union, as well as in the first years of their membership in this organisation. The article also attempts to determine whether the political transformation in the countries under analysis has influenced the emission of the aforementioned pollutants.

The statistical data used in the article has a high level of generality and concerns the emission of pollutants in individual countries due to the fact that only such general data was available. The

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author realizes that the amount of emission varied also regionally in each of the selected countries. However, the lack of access to the specific data hinders the possibility of making a more detailed analysis of pollution emission diversity within the research countries.

The sources of data concerning the amount of pollution in the aforementioned countries were the publications entitled "Environment" ("*Ochrona Środowiska*") from the years 1996-2011, yearly issued by the Polish Central Statistical Office, Statistical Yearbooks from the years 1999-2011, as well as statistical data from the "Eurostat" database.

The research period was established between 1995 and 2010 because the possession of complete data concerning the pollution emission for all the countries concerned started with 1995. Moreover, the majority of them started to aspire at becoming a member of the European Union at that time, while the newest data concerning the issue comes from the year 2010.

THE ANALYSIS OF DATA AND THE RESULTS

The scale of the pollution emission depends on various factors, mainly on socio-economic development, specificity of economic activity, used technologies, the volume of production and environmental prevention. The above factors are the causes of both temporal and spatial differentiation of the amount of pollution.

Emission of carbon monoxide (CO)

The anthropogenic emission of CO is mainly linked to the incomplete combustion of fossil fuels and compounds containing carbon. The gas is emitted into the air mainly by vehicles with internal combustion engines and by energy and chemical factory installations (Dobrzańska et al., 2008).

Between 1995 and 2010, a total of 128.5 million t of CO were emitted into the atmosphere in the countries under analysis (Table 1). Most of the gas was emitted by Poland (56.5 million t) and Romania (22.9 million t), which represented 62% of the total amount of this pollution. In Bulgaria, Hungary, and the Czech Republic about 10 million t of CO was emitted, while in the other countries the emission amounted from 1.7 to 5.0 million t.

Considering the total emission of CO in all of the selected countries, a decreasing trend could be established. In the years 1995-2010, it decreased from 10.6 million t to 6.5 million t (by 39% in comparison with the amount from the beginning of the research).

The decreasing trend in the CO emission did not occur in all these countries (Table 1). It was strongly visible in Poland (from 4.8 to 2.6 million t yearly) and less visible in Hungary (from 0.76 to 0.5 million t yearly), in the Czech Republic (from 1.0 to 0.44 million t yearly) and in Slovakia (from 0.42 to 0.23 million t yearly).

In Lithuania, Latvia and Estonia there were slight differences in the emission of this gas in the subsequent years of the research period, while in Slovenia, a slight increase in the CO emission was noticed in the years 2006-2010 in comparison to the earlier period. Generally speaking, it needs to be emphasized that the downward trend or the stability in the amount of the pollutant emission in the years 1995-2010 is typical for the majority of countries.

Considering the volume of CO emission per one inhabitant in the subsequent years of the research period, it has been determined that this index reached its highest value in Estonia (115-160 kg) and Latvia (117-148 kg) (Table 2). In the first of the aforementioned countries it was usually higher in the years 1995-1999 than in the first decade of the 21st century, while in Latvia it had an upward trend until 2005 and a downward trend in the last five years of the period. Considerably lower average values of this index per year occurred in Poland (67-125 kg), Bulgaria (63-110 kg), Romania (51-93 kg), and in the Czech Republic (42-97 kg); however, in Poland and the Czech Republic, an evident downward trend of the index was registered between 1995 and 2010. The decrease in the value of the analysed index was also noticed in Hungary, from 75 kg/person in 1995 to 50 kg/person in 2010. The lowest average emission of CO per one inhabitant was noted in Slovenia (35-50 kg), in 2005; afterwards, the index increased up to 75-80 kg. It was caused by a double increase in the volume of the pollutant.

Table 1. *Emission of carbon monoxide in the selected EU countries in the years 1995-2010*

Country	Emissions (in million tonnes)																Total
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Poland	4,55	4,84	4,70	4,30	4,31	3,46	3,53	3,41	3,32	3,43	3,33	2,80	2,55	2,72	2,65	2,60	56,50
Romania	2,10	1,86	1,62	1,39	1,14	1,24	1,19	1,25	1,30	1,35	1,41	1,40	1,43	1,40	1,40	1,42	22,90
Bulgaria	0,85	0,61	0,52	0,65	0,62	0,71	0,62	0,70	0,72	0,75	0,74	0,58	0,53	0,50	0,50	0,49	10,09
Hungary	0,76	0,73	0,73	0,74	0,72	0,63	0,59	0,62	0,60	0,59	0,59	0,59	0,53	0,54	0,53	0,50	9,99
Czech Republic	1,00	1,00	0,94	0,77	0,72	0,65	0,65	0,55	0,58	0,57	0,51	0,48	0,51	0,44	0,45	0,44	10,26
Lithuania	0,29	0,31	0,36	0,36	0,32	0,28	0,23	0,22	0,22	0,18	0,19	0,23	0,25	0,26	0,25	0,26	4,21
Latvia	0,32	0,33	0,32	0,32	0,32	0,32	0,33	0,33	0,32	0,34	0,34	0,30	0,29	0,27	0,27	0,26	4,98
Slovakia	0,42	0,36	0,36	0,35	0,34	0,32	0,32	0,29	0,31	0,31	0,30	0,28	0,25	0,24	0,25	0,23	4,93
Estonia	0,21	0,23	0,24	0,20	0,20	0,18	0,18	0,18	0,18	0,17	0,16	0,15	0,17	0,17	0,16	0,17	2,95
Slovenia	0,09	0,10	0,09	0,08	0,07	0,10	0,09	0,08	0,08	0,08	0,08	0,16	0,16	0,15	0,15	0,16	1,72
Total	10,59	10,37	9,88	9,16	8,76	7,89	7,73	7,63	7,63	7,77	7,65	6,97	6,67	6,69	6,61	6,53	128,53

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

Table 2. *Emission of carbon monoxide in the selected EU countries in the years 1995-2010 (per capita in kg; in kg/km^2)*

Country		Emissions															
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Poland	A	118	125	121	111	111	90	91	89	87	90	87	73	67	71	69	68
	B	**15**	**15**	**15**	**14**	**14**	**11**	**11**	**11**	**11**	**11**	**11**	**9**	**8**	**9**	**8**	**8**
Romania	A	93	82	72	62	51	55	53	57	60	63	65	65	67	65	65	66
	B	**9**	**8**	**7**	**6**	**5**	**5**	**5**	**5**	**5**	**6**	**6**	**6**	**6**	**6**	**6**	**6**
Bulgaria	A	101	72	63	78	76	87	78	89	92	97	96	75	70	66	66	64
	B	**8**	**5**	**5**	**6**	**6**	**6**	**6**	**6**	**6**	**7**	**7**	**5**	**5**	**5**	**5**	**5**
Hungary	A	75	72	72	73	71	63	58	61	59	58	58	58	52	53	53	50
	B	**8**	**8**	**8**	**8**	**8**	**7**	**6**	**7**	**6**	**6**	**6**	**6**	**6**	**6**	**6**	**6**
Czech Republic	A	97	97	91	75	70	63	64	54	57	56	50	47	50	42	43	42
	B	**13**	**13**	**12**	**10**	**9**	**8**	**8**	**7**	**7**	**7**	**6**	**6**	**6**	**6**	**6**	**6**
Lithuania	A	78	84	97	97	86	76	66	63	63	53	56	68	74	76	73	79
	B	**4**	**5**	**6**	**6**	**5**	**4**	**4**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**4**
Latvia	A	128	132	128	128	128	133	138	143	139	148	148	130	126	117	117	118
	B	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**5**	**4**	**4**	**4**	**4**
Slovakia	A	78	67	67	65	63	59	59	54	57	57	56	52	46	44	46	43
	B	**9**	**7**	**7**	**7**	**7**	**7**	**7**	**6**	**6**	**6**	**6**	**6**	**5**	**5**	**5**	**5**
Estonia	A	140	153	160	133	143	129	129	129	129	131	123	115	131	131	123	131
	B	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**4**	**4**	**4**	**4**
Slovenia	A	45	50	45	40	35	50	45	40	40	40	40	80	80	75	75	76
	B	**4**	**5**	**4**	**4**	**3**	**5**	**4**	**4**	**4**	**4**	**4**	**8**	**8**	**7**	**7**	**7**

A: per capita in kg, B: in kg/km^2

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

The average CO emission per 1 km^2 varied (Table 2). In the subsequent years of the period from 1995 to 2010, the rate was between 3 kg and 9 kg in most countries. During that period, the index was higher only in Poland (between 1995 and 2005) and in the Czech Republic (between 1995 and 1998): 11-15 kg and 10-13 kg, respectively. In the period concerned, the changes in the index value presented two trends: downward (Poland, Slovakia and the Czech Republic) and stable (Hungary, Lithuania, Latvia and Estonia). Nevertheless, it needs to be also emphasized that the average amounts of CO emission per 1 km^2 in particular countries were usually higher between 1995 and 1999 than in the first decade of the 21st century.

Emission of sulphur oxides (SO_x)

Sulphur oxides are one of the most common air pollutants which have both natural and anthropogenic sources. It is estimated that the anthropogenic sources emit approximately 66% of the global SO_x emission from which as much as 70% comes from the combustion of sulphated fuels in industry and municipal engineering (Strzałko and Mosso-Pietraszewska,1999; Dobrzańska et al., 2008). The presence of SO_x (mainly SO_2) in the air is responsible, among others, for the formation of acid rains.

In the period 1995-2010, the ten countries emitted approximately 69 million t of SO_x into the atmosphere (Table 3). A systematic decrease in the emission of those gases, from 7.2 million t in 1995 to 2.6 million t in 2012 (by approximately 64%), took place during the research period. In comparison with the total emission for the period between 1995 and 2010, its amount was reduced from 10.4% to 3.8% yearly.

Large amounts of SO_x were emitted in Poland (24.4 million t) and considerably less in Bulgaria (15.9 million t) and Romania (11.7 million t). The aforementioned countries emitted 75% of the total volume of those pollutants. A considerable amount of SO_x was emitted also on the territory of the Czech Republic and Hungary (11.5 million t; 16.8% of the total emission). In the other countries, it amounted from 1 up to 2 million t in total, except Lithuania (0.8 million t) and Latvia (0.2 million t) (Table 3).

A trait of the SO_x emission was a considerable diversity in the amount of those pollutants in the subsequent years of the period 1995-2010. The analysis of the collected data indicates a decrease in the volume of SO_x emission in all countries. However, the process differed both in dynamics and time. It had the highest speed in Hungary, the Czech Republic and Poland, especially between 1995 and 2000, and the lowest in Romania, Lithuania and Estonia. In some countries (Hungary, the Czech Republic and Slovakia), the amount of SO_x emission decreased even several times (Table 3).

The highest annual SO_x emission per inhabitant was registered in Bulgaria (86-176 kg). It was also very high in Estonia (54-80 kg) and Slovenia (50-65 kg), in 1995-2000, in the Czech Republic (68-107 kg), in 1995-1997, and in Hungary (58-70 kg), in 1995-1999. The lowest annual SO_x emission per inhabitant was registered in Latvia (2-20 kg), Lithuania (9-24 kg) and Romania (25-39 kg). In the first two of the above-mentioned countries, this index was gradually decreasing, while in Romania, the downward trend was disturbed during the period from 1999 to 2002 (Table 4).

The volume of SO_x emission per km^2 was also diverse in time and space (Table 4). The highest average annual rate of this index was registered in Bulgaria (6-13 kg) and in the Czech Republic (6-14 kg), but only between 1995 and 1998. In the other countries, the index varied from 1 to 8 kg and usually reached higher values at the beginning of the research period than in the first decade of the 21st century. A decrease in the index values occurred in all the countries; however, it varied in dynamics and time. The highest values were recorded in the Czech Republic, Bulgaria, Slovenia, and Hungary and the lowest in Romania, while a slight diversity in the analyzed index was registered in Lithuania and Latvia.

Table 3. *Emission of sulphur oxides in the selected EU countries in the years 1995-2010*

Country	Emissions (in million tonnes)																Total
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Poland	2,38	2,37	2,18	1,90	1,72	1,51	1,56	1,46	1,37	1,24	1,22	1,22	1,22	1,00	1,00	1,00	24,35
Romania	0,89	0,86	0,84	0,81	0,70	0,73	0,83	0,81	0,78	0,75	0,73	0,70	0,58	0,56	0,55	0,53	11,65
Bulgaria	1,48	1,42	1,37	1,25	0,94	0,98	0,94	0,97	0,97	0,93	0,90	0,88	0,83	0,72	0,69	0,65	15,92
Hungary	0,71	0,67	0,66	0,59	0,59	0,47	0,40	0,36	0,35	0,25	0,13	0,12	0,09	0,09	0,09	0,09	5,66
Czech Republic	1,1	0,94	0,70	0,44	0,27	0,26	0,25	0,24	0,23	0,23	0,22	0,21	0,22	0,18	0,19	0,19	5,87
Lithuania	0,09	0,09	0,08	0,09	0,07	0,04	0,05	0,04	0,04	0,04	0,04	0,04	0,04	0,03	0,03	0,03	0,84
Latvia	0,05	0,05	0,04	0,03	0,02	0,01	0,01	0,01	0,005	0,004	0,004	0,00	0,00	0,00	0,00	0,00	0,23
Slovakia	0,25	0,23	0,21	0,18	0,17	0,13	0,13	0,10	0,11	0,10	0,09	0,09	0,07	0,07	0,07	0,06	2,06
Estonia	0,12	0,12	0,12	0,10	0,10	0,10	0,10	0,09	0,10	0,09	0,08	0,07	0,09	0,07	0,07	0,07	1,29
Slovenia	0,13	0,11	0,12	0,12	0,10	0,10	0,07	0,07	0,07	0,05	0,04	0,02	0,01	0,01	0,01	0,01	1,04
Total	7,20	6,86	6,32	5,51	4,68	4,33	4,34	4,15	4,00	3,68	3,45	3,35	3,15	2,73	2,70	2,63	69,11

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

Table 4. *Emission of sulphur oxides in the selected EU countries in the years 1995-2010 (per capita in kg; in kg/km^2)*

Country		Emissions															
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Poland	A	62	61	56	49	44	39	40	38	36	32	32	32	32	26	26	26
	B	**8**	**8**	**7**	**6**	**6**	**5**	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**3**	**3**	**3**
Romania	A	39	38	37	36	31	33	37	37	36	35	34	32	27	26	26	25
	B	**4**	**4**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**	**2**
Bulgaria	A	176	167	165	151	115	120	118	123	124	121	117	114	109	95	91	86
	B	**13**	**13**	**12**	**11**	**8**	**9**	**8**	**9**	**9**	**8**	**8**	**8**	**7**	**6**	**6**	**6**
Hungary	A	70	66	65	58	58	47	39	35	34	25	13	12	9	9	9	9
	B	**8**	**7**	**7**	**6**	**6**	**5**	**4**	**4**	**4**	**3**	**1**	**1**	**1**	**1**	**1**	**1**
Czech Republic	A	107	91	68	43	26	25	25	24	23	23	22	20	21	17	18	18
	B	**14**	**12**	**9**	**6**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**2**
Lithuania	A	24	24	22	24	19	11	14	11	11	12	12	12	12	9	9	9
	B	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**0**	**0**	**0**
Latvia	A	20	20	16	12	8	4	4	4	2	2	2	0	0	0	0	0
	B	**1**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Slovakia	A	46	43	39	33	31	24	24	19	20	19	17	17	13	13	13	11
	B	**5**	**5**	**4**	**4**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**1**	**1**	**1**	**1**
Estonia	A	80	80	80	67	71	71	71	64	71	69	62	54	69	54	54	54
	B	**5**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Slovenia	A	65	55	60	60	50	50	35	35	35	25	20	10	5	5	5	5
	B	**6**	**5**	**6**	**6**	**5**	**5**	**3**	**3**	**3**	**2**	**2**	**1**	**0**	**0**	**0**	**0**

A: per capita in kg, B: in kg/km^2

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

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Emission of nitrogen oxides (NO_x)

The air pollution with NO_x from anthropogenic sources is connected with high temperature fuel combustion in industrial processes and with internal combustion engines. The emission of those gases is therefore mainly linked to the industrial areas (energy and chemical industry) and to the areas with high intensity of motorization (Mannion, 1997; Strzałko and Mosso-Pietraszewska, 1999). Those pollutants are responsible for the formation of acid rains and photochemical smog (Dobrzańska et al., 2008).

In the years 1995-2010, the ten countries emitted 36.1 million t of NO_x. The majority of these pollutants were emitted by Poland (14.5 million t). In Romania and the Czech Republic the total NO_x emissions amounted to approximately 5 million t, while in Bulgaria and Hungary there were about 3.4 and 3.1 million t, respectively. In the other five countries, the total volume of emission varied from 0.6 million t in Estonia to 1.8 million t in Slovakia (Table 5).

The highest annual NO_x emission was recorded during the years 1995-1999 (2.26-2.67 million t). Moreover, at that time, a decline in the emission of those pollutants was noticed. In the first decade of the 21st century the scale of this process was less diverse (2.09-2.17 million t) and their dispersion in time changed without evident trends.

Based on the diversity of NO_x emission in the particular countries, three trends of change were established: upward, downward, and stable trend. The downward trend occurred in Slovakia, the Czech Republic, Bulgaria and Poland, mainly in the period from 1995 to 2000. In the first decade of the 21st century the volume of emission of those pollutants did not undergo any significant changes. A slight upward tendency in NO_x emission was recorded in Lithuania and Latvia, while in other countries (Hungary, Estonia and Slovenia) the emission of those pollutants was stable. Romania, where the amounts of emissions per year were more diverse (Table 5), was the only exception.

Among the analysed pollutants, the scale of NO_x emission per one inhabitant and 1 km^2 in the particular countries indicates the lowest diversity both in time and space (Table 6). The highest emission of those pollutants per inhabitant yearly was recorded in the Czech Republic (25-36 kg), Slovenia (25-35 kg), and Bulgaria (24-32 kg), while the lowest was recorded in Romania (13-16 kg), and, in the years 1995-2005, also in Lithuania (14-19 kg) and Latvia (16-17 kg).

Considering the diversity of NO_x emission per inhabitant in the analysed period, four trends of change were established: downward, upward, stable and unstable. The downward trend was registered in Poland, the Czech Republic, Slovakia, and Slovenia, while the upward in Lithuania and Latvia. A slight diversity occurred in Romania, Hungary, whereas alternatively rising and declining trends were typical of Bulgaria and Estonia.

The annual average NO_x emission per 1 km^2 in the countries concerned varied from 1 to 5 kg (Table 6). The analysis of the gathered data leads to the distinction of two groups of countries: countries with a stable rate of the index in time and countries with a declining rate. The declining trend occurred in Poland, the Czech Republic, and Slovakia, while in the other countries the index was stable during the research period. Slovenia was the only exception, with a higher dispersion of the index in the years 2005-2010.

When analysing the diversity of CO, SO_x and NO_x emission in the selected countries of the European Union, in the years 1995-2010, the author referred to the population and economic potential of those countries, expressed in GDP (gross domestic product), owing to the fact that the process of production of goods results in emitting pollution. In order to make the comparison, the actual values were converted into percentages referring to the total population and amount of GDP in each of the countries (Table 7).

Table 5. *Emission of nitrogen oxides in the selected EU countries in the years 1995-2010*

Country	Emissions (in million tonnes)																Total
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	
Poland	1,12	1,15	1,11	0,99	0,96	0,84	0,81	0,80	0,81	0,80	0,81	0,92	0,86	0,83	0,85	0,83	14,49
Romania	0,32	0,33	0,33	0,33	0,29	0,29	0,35	0,34	0,33	0,32	0,31	0,33	0,32	0,29	0,30	0,29	5,07
Bulgaria	0,27	0,26	0,23	0,22	0,20	0,19	0,19	0,20	0,21	0,22	0,23	0,19	0,19	0,18	0,18	0,19	3,35
Hungary	0,19	0,20	0,20	0,20	0,20	0,19	0,18	0,18	0,18	0,18	0,20	0,20	0,20	0,20	0,20	0,19	3,09
Czech Republic	0,37	0,37	0,35	0,32	0,31	0,32	0,33	0,32	0,32	0,33	0,28	0,28	0,28	0,26	0,27	0,26	4,97
Lithuania	0,07	0,07	0,06	0,06	0,05	0,05	0,06	0,05	0,05	0,05	0,06	0,08	0,09	0,09	0,08	0,09	1,06
Latvia	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,04	0,05	0,05	0,05	0,05	0,05	0,69
Slovakia	0,18	0,14	0,13	0,13	0,12	0,11	0,11	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	0,10	1,82
Estonia	0,04	0,04	0,04	0,04	0,03	0,03	0,04	0,04	0,04	0,04	0,03	0,03	0,04	0,03	0,04	0,03	0,58
Slovenia	0,07	0,07	0,07	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,05	0,05	0,06	0,05	0,06	0,96
Total	2,67	2,67	2,56	2,39	2,26	2,12	2,17	2,13	2,14	2,14	2,12	2,23	2,18	2,09	2,12	2,09	36,08

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011; OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010; Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011; Statistical Portrait…, 2007.

Table 6. *Emission of nitrogen oxides in the selected EU countries in the years 1995-2010 (per capita in kg; in kg/km^2)*

Country		Emissions															
		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Poland	A	29	30	29	26	25	22	21	21	21	21	21	24	23	22	22	22
	B	**4**	**4**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Romania	A	14	15	15	15	13	13	16	16	15	15	14	15	15	13	14	14
	B	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Bulgaria	A	32	31	28	27	24	23	24	25	27	29	30	25	25	24	24	25
	B	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Hungary	A	19	20	20	20	20	19	18	18	18	18	20	20	20	20	20	19
	B	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	2
Czech Republic	A	36	36	34	31	30	31	32	31	31	32	27	27	27	25	26	25
	B	**5**	**5**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**4**	**3**	**3**	**3**
Lithuania	A	19	19	16	16	14	14	17	14	14	15	18	24	26	26	24	27
	B	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Latvia	A	16	16	16	16	16	17	17	17	17	17	17	22	22	22	22	23
	B	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Slovakia	A	33	26	24	24	22	20	20	19	19	19	19	19	19	19	19	19
	B	**4**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Estonia	A	27	27	27	27	21	21	29	29	29	31	23	23	31	23	31	23
	B	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
Slovenia	A	35	35	35	30	30	30	30	30	30	30	30	25	25	30	25	29
	B	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**2**	**2**	**3**	**2**	**3**

A: per capita in kg; B; in kg/km^2

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

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The highest CO emission in relation to the total population occurred in Poland, Latvia, and Estonia, whereas the lowest was in Romania, the Czech Republic, Slovakia, Slovenia, and Hungary. In Bulgaria and Lithuania, the percentage of total population and CO emission were similar. The highest SO_x emission related to the number of population was recorded in Bulgaria, home to 7.7% of the total population of the countries under analysis, while the SO_x emission amounted to 23%. The population of Estonia comprises 1.3% of the total population, while the percentage of the total SO_x emission was 1.9%. In the other countries, the percentage of the emission of these pollutants was predominantly lower than the percentage of population, especially in Latvia and Lithuania. The highest NO_x emission related to the total population was noted in Poland, the Czech Republic, and Bulgaria, with the lowest in Romania.

Table 7. *The diversity in the emission of carbon monoxide, sulphur oxides, and nitrogen oxides related to population and economic potential expressed in the GDP index in the selected European Union countries in the years 1995-2010*

Country	Population (in 2010 year)		Emissions (in % total)			Gross Domestic Product (PKB) (in % total)
	mln	% of total	carbon monoxide	sulphur oxides	nitrogen oxides	
Poland	38,2	37.5	44.0	35.3	40.1	38.2
Romania	21,4	20.1	17.8	16.9	14.1	13.1
Bulgaria	7,6	7.7	7.9	23.0	9.3	4.0
Hungary	10,0	9.8	7.8	8.3	8.6	10.6
Czech Republic	10,5	10.3	8.0	8.5	13.8	15.6
Lithuania	3,3	3.2	3.3	1.3	2.9	3.9
Latvia	2,2	2.2	3.9	0.3	1.9	2.1
Slovakia	5,4	5.3	3.8	3.0	5.0	7.1
Estonia	1,3	1.3	2.2	1.9	1.6	1.6
Slovenia	2,1	2.1	1.3	1.5	2.7	3.8
Total	100,0	100.0	100.0	100.0	100.0	100.0

Source: Author's own elaboration based on: Ochrona Środowiska (Environment) from 1996-2011, OECD. Environmental Data… 1997, 2002, 2005, 2007, 2008, 2009, 2010, Rocznik Statystyczny… GUS (Statistical Yearbook) from 2001-2011, Statistical Portrait…, 2007.

Among the research countries, the highest GDP percentage was generated in Poland (38.2%). In the Czech Republic it represented 15.6%, in Romania 13.1%, and in Hungary 10.6% of the total GDP. In Poland and Romania, the percentage of CO, SO_x and NO_x emission was usually higher than their GDP percentage, while in the Czech Republic and Hungary this value was lower. Considering Bulgaria as a specific country, its GDP amounted to only 4% and the percentage of CO, SO_x and NO_x emission amounted to 7.9%, 23%, and 9.3%, respectively. A considerably lower percentage of the emission of the aforementioned pollutants compared to the percentage of GDP was registered in Slovakia and Slovenia. A similar percentage of pollutant emission and GDP occurred in Estonia and Lithuania. Therefore, it has been determined that the amount of the emission of the analyzed gases was not always directly proportional to the total population and the GDP rate. The conducted comparisons indicate that there is no evident relationship between the economic potential expressed in the GDP index and the volume of the pollutant emission. The diverse volumes of the emission should be rather linked to the character and development of the economy in particular countries, the structure of industry, the specific traits of municipal engineering, the diverse development of motorization, as well as prevention in environmental protection.

CONCLUSIONS

In order to summarize the above analyses and comparisons, a collation of CO, SO_x and NO_x emission was made for the selected countries of the European Union, for the years 1995-2010 (Table 8). It presents the actual amounts of emission of the aforementioned pollutants, indicating which countries had the highest and the lowest gas emissions, also per inhabitant and per km^2.

As result, the highest actual CO, SO_x and NO_x emissions were registered in Poland, while high SO_x emissions were recorded in Romania and Bulgaria. Considerable CO emissions were also noticed in Romania. The lowest emission of the analysed pollutants was registered in Slovenia, Estonia, Lithuania, and Latvia.

The scope of emission of the analysed gases per inhabitant in particular countries also varied. Depending on the pollutant, the highest emissions were registered in Poland, Bulgaria, the Czech Republic, and Estonia, while the lowest in Lithuania and Romania. Considering this factor, Latvia and Slovenia are specific countries. In the first of the aforementioned countries, the highest CO and the lowest SO_x and NO_x emissions were recorded, while in the second, the highest NO_x and the lowest CO emission per inhabitant occurred (Table 8).

Table 8. *The diversity in the emission of carbon monoxide, sulphur oxides, and nitrogen oxides in the selected European Union countries in the years 1995-2010*

Specification		**Emission**		
		total	**per capita in kg**	**in kg/km^2**
Countries with the highest emission	CO	Poland, Romania	Estonia, Latvia, Poland	Poland, Czech Republic
	SO_x	Poland, Bulgaria, Romania	Bulgaria	Bulgaria
	NO_x	Poland	Slovenia, Czech Republic, Bulgaria	Czech Republic
Countries with the lowest emission	CO	Slovenia, Estonia, Lithuania	Slovenia	Slovenia, Estonia, Lithuania, Latvia
	SO_x	Slovenia, Estonia, Lithuania, Latvia	Lithuania, Latvia	Lithuania, Latvia
	NO_x	Estonia, Slovenia, Latvia, Lithuania	Romania, Latvia, Lithuania	Lithuania, Latvia, Estonia, Romania

Source: Author's own elaboration

Considering the average emission of the analyzed pollutants per km^2, the index reached the highest value in Poland, the Czech Republic, and Bulgaria, whereas the lowest was in Romania, Estonia, Slovenia, Lithuania, and Latvia.

A trait of CO, SO_x and NO_x emission was the considerable diversity of the process both in time and space. An evident downward trend in the total pollution emission was noticed also in the particular countries, which had a higher dynamics between 1995 and 2000 than in the first decade of the 21st century. When analyzing the volume of emission of the aforementioned gases from a spatial point of view, it was ascertained that the emission was also diverse: the highest in Poland, Bulgaria, and Romania, and the lowest in Slovenia, Estonia, Lithuania, and Latvia. In the years 1995-2010, the disproportions between the selected countries as regards the spatial diversification also diminished considerably. This is indicated in smaller differences in actual emissions between the particular countries and per 1 km^2 surface during the research period.

FINAL REMARKS (REGIONAL ASPECT)

A characteristic process, undergone at the beginning of the 1990s, was the political transformation and its related changes, such as the economic reforms in order to facilitate the market. It was mainly related to the geopolitical changes in the respective countries. The disbandment of COMECON and the loss of traditional output markets, savings in economy and industrial restructuring, together with the shutdown of some plants and smaller demand for goods caused a decline in production. As a consequence, in numerous industrial and urban areas the pollution emission decreased, which resulted in the amelioration of the air quality. An example of such an area is the borderland between Poland, the Czech Republic and Germany, where, for several dozens of years, the energy production based on lignite developed intensively. There are 12 large thermal power stations, which, until recently, emitted substantial amounts of sulphur and nitrogen oxides (Hunová et al., 2005). Abnormal concentrations of those compounds were registered in the air even a few or a few dozen kilometres from the plants (Zwoździak, 1993; Baron and Sobik, 1995; Błaś et al., 1999; Hunová et al., 2005). As a result of acid rains, thousands of hectares of forests in the Sudety and Rudawy Mountains were degraded and destroyed (Raj, 1992; Zwoździak et al., 1993; Sienkiewicz and Twarowski, 1996). This area covering the surface of 32 000 km^2 was called "The Black Triangle". During the economic transformation the usage of lignite in the energy production decreased. Moreover, the changes connected with the enlargement of the European Union being undergone at that time conditioned the possibility of the usage of external aid resources to repair and protect the environment (Zwoździak, 2005; Knippschild, 2010). In the years 1989-2004, the annual SO_2 emission in the Czech part of the area decreased from 882 thousand t to 92 thousand t, while in the Polish and the German part of "The Black Triangle" those values were equal to 15% and 10% of the amount in 1989 (Joint Report…, 2004). After 1996, a systematic improvement of air quality was recorded there, especially in the areas of broadly reaching industrial emissions (Report…, 2000; Zwoździak et al., 2000; Hunová et al., 2005). As a result of the considerable decrease in the air pollution, some researchers proposed to change the name "The Black Triangle" into "The Triangle of Sustainable Development" (Renner, 2002) or "The Green Triangle" (Knippschild, 2010).

The other example is the largest Polish industrialized and urbanized area: the Upper Silesian Industrial Region. It was an area of an ecological catastrophe even in the 1980s (Kassenberg and Rolewicz, 1985). During the last 20 years, as result of industrial restructuring and pro-ecological actions, the concentrations of some pollutants fell even by 60% (Barowska and Dyduch, 1995; Report…, 1995, 2010; Pełka-Gościniak and Rzętała, 1999; Oleś, 1998; Jankowski, Myga-Piątek and Ostaficzuk, 2000; Jankowski, Myga and Jankowski, 2002; Świątczak, 2002; Hubiak, 2007; Degórska, 2008; Leśniok and Degórska, 2009).

The industrial restructuring was also conducted in Ostravsko-Karvinska Industrial Region (the Czech Republic). As a result, an evident amelioration of the air quality was recorded there too between 1990 and 2004 (Pełka-Gościniak and Rzętała, 1999; Blazek et al., 2000; Unacka et al., 2001; Eckert 2002; Jankowski and Rzętała, 2003; Suchacek, 2004).

Generally speaking, it has to be emphasized that during the period of economic transformation a significant decrease in the volume of air pollution was apparent in numerous industrialized and urbanized areas. This indicates the favourable influence of economic changes on the air quality. Those changes were related to various actions, specific for particular areas: the shutdown of some branches of industry, industrial restructuring, lowering the amount of production or modernization of factory installations, as well as pro-ecological actions which were supported by the EU funds (Wójcik, 2011). All those actions were often conducted simultaneously so that the measurable result is the amelioration in the air quality.

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