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STATE OF AIR POLLUTION IN SILESIA PROVINCE INCLUDING LOW EMISSION SOURCES

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Abstract

The result of the dominance of coal as a primary energy carrier is significant emissions of pollutants such as SO_2, CO, particulate matter and B(a)P, derived from the combustion processes of coal. One of the major sources of emissions of these pollutants into the air is a public utility sector, which form the so-called "low emission". The presented paper analyzes the state of air quality in Poland, including the province of Silesia, as well as an overview of fuels and heat sources used in the communal living conditions and the age structure of these sources, which has a large impact on emissions. Based on the data contained in the "Programs For Low Emission" created for many municipalities in Poland and the "Programme of Air Protection for zones in Silesian province in which oversize levels of substances in the air were found" the involvement of the various sources of emissions in the formation of PM_{10} and B(a)P (kg/person) and the individual sources contribution of these pollutants level concentration were discussed. The paper also summarizes the annual emissions of PM_{10} and B(a)P derived from the municipal sector in the Silesia province. These emissions were used to calculate the indicators characterizing exposure to annual emissions of these pollutants in different administrative units of the Silesian province. These indicators were related to the inhabitants number in the zone.

Streszczenie

Efektem dominacji węgla jako nośnika energii pierwotnej jest znacząca emisja takich zanieczyszczeń jak: SO_2, CO, pył zawieszony oraz B(a)P, pochodząca z procesów spalania węgla. Jednym z istotnych źródeł emisji tych zanieczyszczeń do powietrza atmosferycznego jest sektor komunalno-bytowy, który kształtują tzw. „niską emisję". W prezentowanym artykule omówiono stan jakości powietrza w Polsce z uwzględnieniem województwa śląskiego, jak również dokonano przeglądu stosowanych paliw i źródeł ciepła stosowanych w sektorze komunalno-bytowym oraz struktury wiekowej tych źródeł, która ma duży wpływ na wielkość emisji. W oparciu o dane zawarte w „Programach Ograniczenia Niskiej Emisji" utworzonych dla wielu gmin w Polsce oraz „Programie Ochrony Powietrza dla stref województwa śląskiego, w których stwierdzone zostały ponadnormatywne poziomy substancji w powietrzu" omówiono udział różnych źródeł emisji w kształtowaniu emisji PM_{10} i B(a)P oraz udział poszczególnych źródeł w kształtowaniu poziomu stężeń tych zanieczyszczeń. W artykule zestawiono także wartości rocznej emisji PM_{10} i B(a)P pochodzącej z sektora komunalno-bytowego na terenie województwa śląskiego. Emisje te wykorzystano do wyliczenia wskaźników charakteryzujących narażenie na roczną emisję tych zanieczyszczeń w poszczególnych jednostkach administracyjnych województwa śląskiego. Wskaźniki te odniesiono do liczby mieszkańców w danej strefie.

Keywords: **Pollution emission; Low emission; Air quality; Emission factor.**

1. INTRODUCTION

Reduction of air pollution is one of the most important tasks for Poland. Restructurization and technological changes during last 20 years caused that currently heavy and chemical industry and energy production are not the major sources of pollutant emission to the atmosphere any more. Much more serious problem in ecological, economical, health and social frame are gaseous and dust pollutants emitted from small source, i.e. municipal emission. Current participation of substances emitted from factories is small and still decreases [1,2,3]. Simultaneously, significant part of dust and other harmful pollutants, especially during winter time are from individual furnaces. Those sources are particularly important. Due to the economical conditions poor technical quality furnaces are used where weak quality fuel is very often burnt, such as coal mud or even plastic material wastes.

Emissions from this sector come mainly from the emitters, which does not exceed 10-12 m and takes place mostly in the area of compact development, characterized by its low breathability, and its effect is the large concentration of pollutants directly into the occupied people zone. These emissions are difficult to estimate and shows seasonal variations, which is associated with increased emissions during the heating season, during which the issue is particularly troublesome, especially during the smog character episodes [4].

Emission inventory is carried out in the various centers of the country into the emission sources classification system SNAP (Selected Nomenclature for Air Pollution). This system includes 11 major categories of emission sources divided into more than 400 subdetailed. Estimating emissions is based on national statistics (published by the GUS – Central Statistical Office) regarding: fossil fuel consumption, i.e.: natural gas, LPG, fuel oil, diesel, gasoline, coal and other, raw materials consumption, electricity or district heating, the industrial annual production or other size (called activity), characterizing the sector size and activities based on national or literature emission factors describing a given pollutant emissions [5].

Emissions inventory methodology is based on two basic methods:

– “bottom up”, which can be used with specific data source (e.g. energy consumption for individual public buildings), this method is accurate, but labor-intensive;
– “top down”, which can be used when we have the general values (e.g. heat consumption for the whole city divided into different groups of customers), the method less accurate, but fast.

The first national emission inventories, about 8 gas groups were conducted in 1993 and 1994 under the system CORINAIR’90 [6]. This consisted in the implementation of new IPCC methodology [7] and the UNECE-CORINAIR methodology [8], which gave the first inventory of emissions into the air comparable to other countries.

Currently KOBiZE (National Centre of Emission Balance and Management) is institution in Poland gathering emissions information and developing inventory reports. Here, particular entities shall submit the greenhouse gas and other substances emission reports. This institution is also developing the all activities requiring emission sources data list, it is: the production or consumption of raw materials and fuels volume, on the basis of national, official statistical publications (GUS, publishing ministries, central government offices and special institutions) and the information sources not covered by the official statistical publications. Emissions data are collected also in the system of charges for use of the environment (charging system) or emission permits. Wherever is possible “bottom up” method is used. However, emission data from this system does not include the number of emission sources relevant to the inventory, i.e. households surface sources emissions. In this case, the “top down” emission calculation method is used, which is based on the used fuels data.

Emission inventory is an essential creating part of the environmental national policy and the implementation of international commitments. There is therefore the need for constant updating and supplementing the data and their confrontation to the introduced technological changes.

2. BALANCE AND STRUCTURE OF USAGE OF PRIMARY ENERGY CARRIERS

The structure of primary energy carriers usage is very disadvantageous with coal as a major energy source in Poland [9]. This structure differs significantly in Europe, where participation of coal is less than 16%, and liquid and gaseous fuels more than 60% [9,10]. Currently, in Poland participation of coal and lignite equals 54%, whereas participation of liquid and gaseous fuels is only 36% [9, 11]. Estimated total heat consumption for Poland in 2012 amounted to approximately 467 PJ [11], which consists mainly of housing (38%), industry and construction (53%), and transportation. The greatest demand of energy (heat and electricity) relates mainly to the heating and hot water production.

According to Central Statistical Office (CSO), in households solid fuel is the main source of primary energy (ca. 44.5%), especially coal whit its participation ca. 29%. Only subsequently gaseous fuels are used (about 20%). In the district heating system case the thermal energy has largest share and is approximately 22%. In the not connected to the district heating system households participation of coal is about 45% (Fig. 1, Fig. 2). The structure of energy consumption is currently undergoing significant changes due to the use of more modern, more efficient equipment and increase awareness of the desirability of saving energy.

On the other hand, it is affected by a continuous increase in energy demand due to the needs of new technologies development. Despite the changes that occur, Poland among EU countries, still has the largest share in energy produced from coal in the household communal sector. The share of coal consumption in domestic and municipal sector to total domestic consumption in Germany is about 2%, Ireland 16%, in Austria about 2.5%, in the UK about 3%, and in Poland about 20% [12].

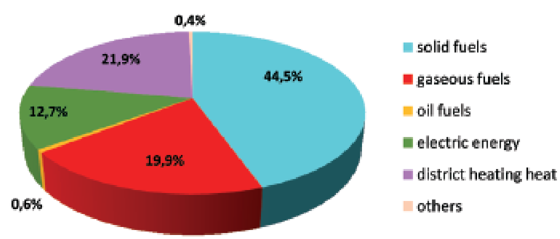

Figure 1.
Structure of primary energy carriers in households in 2012, based on CSO data CSO [9, 11]

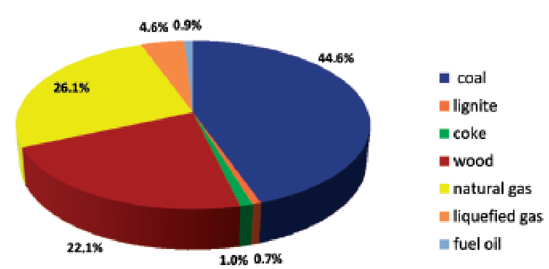

Figure 2.
Structure of fuel consumption in household not connected to the district heating system in 2012, based on CSO data [9, 11]

Heat energy supply to cities and villages is based on various local heat sources. According to [13, 14] approximate cover structure thermal needs of the municipal sector is as follows: heat network - 53%, local boiler fired with coal and coke – 17.4%, boilers and coal stoves – 25.9%, local boiler plants fired by oil or gas 3% and electrical heating accumulative 0.7%. On the basis of prepared for many communities in Poland "Projects for heat, energy and gaseous fuel supply" and "Programs of Municipal Emission Limitation" it can be estimated that in the big cities heat is supplied by heating systems (ca. 54%), whereas in town-village communities individual furnaces are in majority, roughly 62%.

2.1. Age structure of the heat sources used in households

Based on data from the Central Statistical Office the heat sources average age in Polish households ranges from 7 to 12 years. Above this range were furnaces, where the average age is over 23 years old. In contrast, younger installations include heat pumps, solar panels and fireplaces with water jacket [15]. However, on the basis of the data included in "Programs of Municipal Emission Limitation", age structure of the heat sources has been evaluated (Fig. 3).

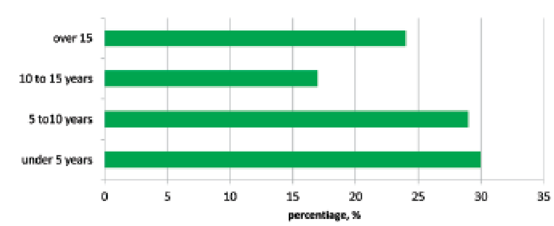

Figure 3.
Age structure of the heat sources used in households

Over 50% of all sources represent heat sources up to 10 years old, which is connected with modernization in many Polish communities, which was carried out by "Programs of Municipal Emission Limitation". However, significant participation is represented by older, over 15 years old equipment, which very often are old with very low efficiency, ca. 50%. Those old furnaces very often use poor quality coal and also all sorts of wastes.

3. FUEL COMBUSTION VERSUS AIR POLLUTION

Emission of dust and gaseous pollutants from coal combustion represents the highest environmental risk. Approximately 10 million tons of coal (including poor quality coal, e.g. coal mud) is burnt in Poland yearly, coal dust and coke is burnt occasionally [3]. Burning processes of those fuels in low power and low efficiency furnaces, without flue gas cleaning systems are sources of the following pollutants emission: sulphur dioxide, oxides of nitrogen, carbon monoxide, suspended particles, organic pollutants, including PAHs, BaP and heavy metals. The emission range is related to the combustion process conditions and the fuel properties [16, 17]. In opposite to energetic boilers, practically all atmospheric emission from domestic furnaces is concentrated within near-ground layer of the air. That is why this emission represents the highest danger for inhabitants.

According to KOBiZE and GUS data [2,18,19] power engineering and municipal-residential sector are responsible for ca 81% of SO_2 emission (which is the main reason for such a high sulfur dioxide emissions), 61% of PM_{10} emission, 63.5% of CO emission and 76% of B(a)P emission (tab. 1). Significant impact on emissions of CO and dust TSP also has a shuttle, whose share in 2012 amounted to 23% and 19%. In years 1990-2012 SO_2 and CO emission had decreased almost twice (Fig. 4, 5). The clear reduction of such emissions took place in the 90's. Contribution to this recession and economic transformation, marked decline in production (especially catalog material- and energy-intensive). The outdated technology causing the environment significant pollution were liquidated, changes have been made in the energy sector based on improving fuel efficiency by replacing them with causing lower emissions fuel [20]. The National Environmental Policy new lines developed also at this time and the air pollutants emissions legal standards were tightened too [21]. There has been also significant progress in the air protection equipment and installation field (increase of the number and effectiveness) [2, 22].

In the case of dust emissions in the years 2000-2012 TSP systematically decreased and fluctuated between 420-495 Gg (Fig. 6), which placed our country at the forefront of European countries [23]. The slight increase only can be observed in the years 2001 and 2003, which was mainly due to increased use of coal in households (SNAP02). The domestic level of domestic emission is caused mainly by non-effective combustion processes in municipal-residential sector (SNAP02), which is responsible for about 50% of PM_{10} emission (Table 1) [18, 19]. Analyzing the table it can be noted that the share of each fraction in the dust emitted from the individual economy sectors is variable and depends on, among others, the technology and the specific source and the technologies used to protect air. The highest content of $PM_{2.5}$ fraction in TSP occur in the case of combustion processes in the manufacturing sector (combustion processes in the sector of energy production) SNAP01 (about 42%) and are derived from sources within the municipal sector (SNAP02) about 35%. On the other hand, analyzing the fraction of $PM_{2.5}$ in PM_{10} is worth noting the fact that it is the greatest in the road transport sector (SNAP07) and it is about 90%. It should be noted that much of the dust emissions from road transport comes from processes other than fuel combustion, which include tire and brake attrition and the road surfaces abrasion.

Presented data show that municipal-residential sector (SNAP02) is a major contributor of domestic emission of B(a)P. It has a significant impact on the seasonal variability of air pollution (during the heating season the concentration of B(a)P in the air are much higher than in the warmer months). Subsequently, the size of the issue is also the transport, the share of which in 2012 amounted to about 6%.

Table 1.
Main air pollutants emission according to SNAP97 (Selected Nomenclature for Air Pollution) [2,19]

Emission source based on SNAP97 classification	Emission in 2012 [Gg]					
	SO_2	CO	TSP	PM_{10}	$PM_{2.5}$	B(a)P*
Total:	853.31	2818.41	427.70	265.86	137.46	43 418
01. Combustion in energy production and transformation industries	437.12	60.16	36.38	24.11	15.20	63.7
02. Non-industrial combustion plants	253.45	1729.39	180.38	139.22	62.53	32 852
03. Combustion in industry	150.97	236.14	30.39	18.30	10.08	110
07. Road transport	1.35	653.55	80.11	25.46	22.80	2 657

*emission in kg

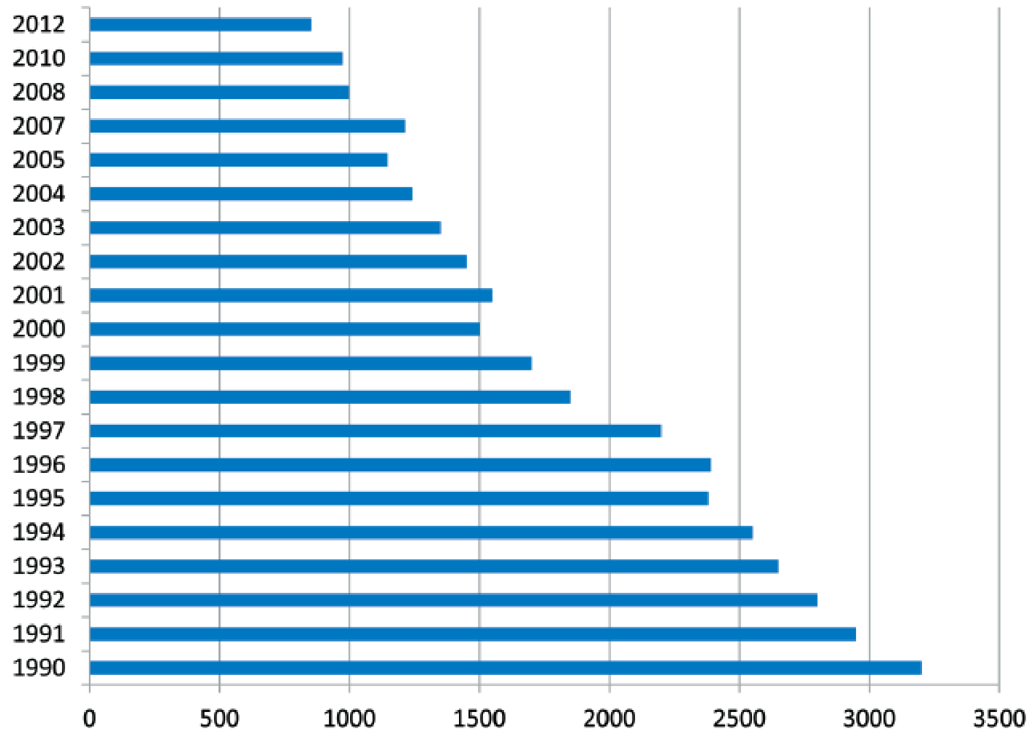

Figure 4.
SO_2 emission in Poland during 1990-2012, in Gg according to [19,20,21]

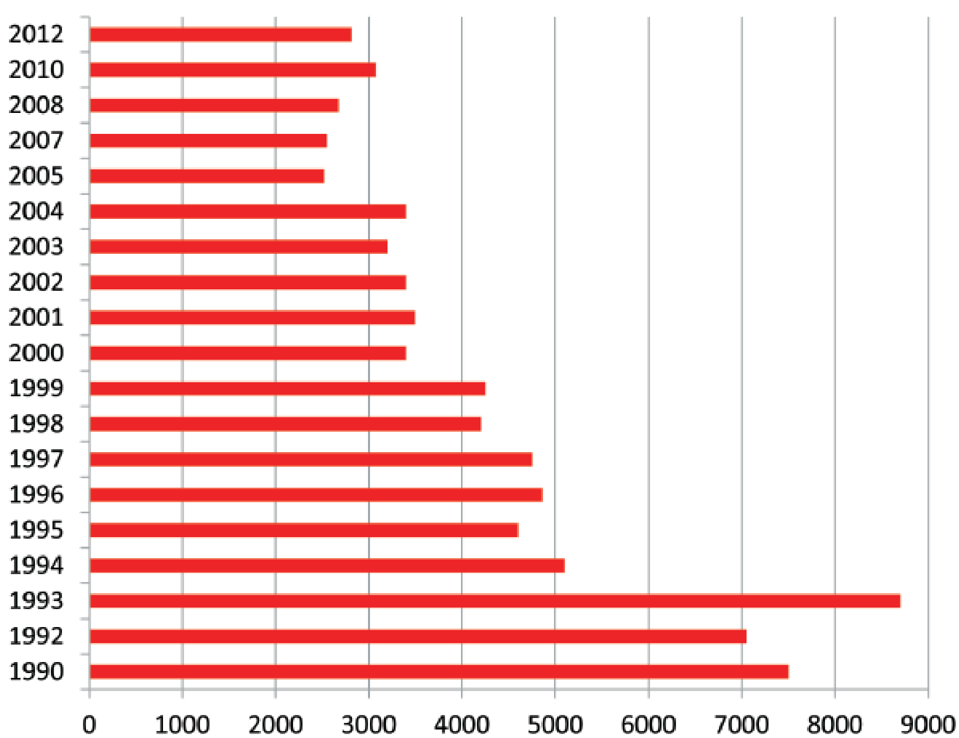

Figure 5.
CO emission in Poland during 1990-2012, in Gg according to [19,20,21]

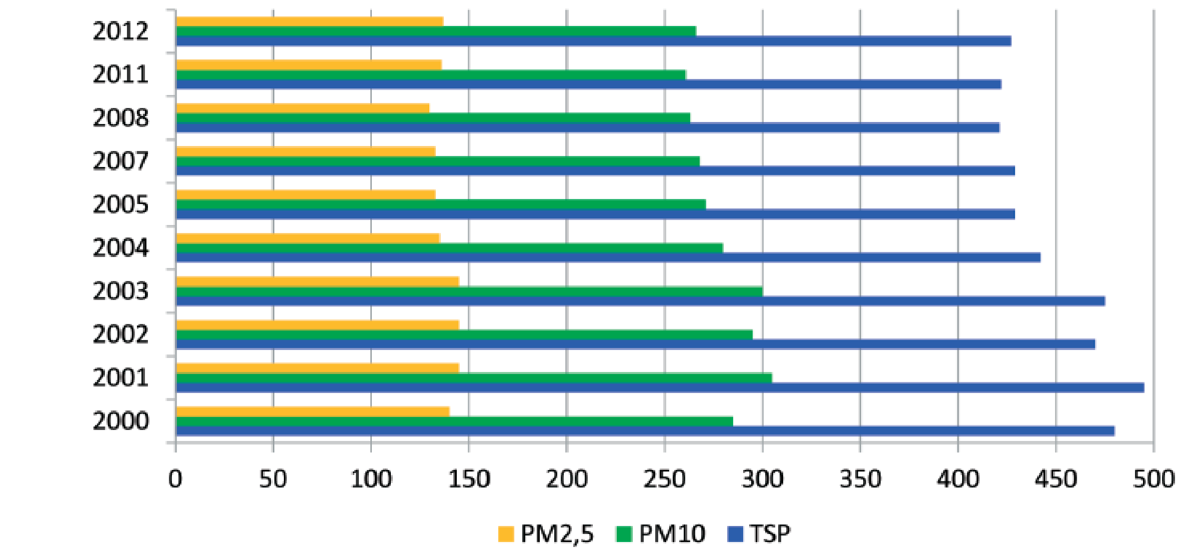

Figure 6.
TSP, PM_{10}, $PM_{2.5}$ emission in Poland during 2000-2012, in Gg according to [19, 20, 21]

3.1. Atmospheric air quality in the Silesia Province

According to GUS data, Silesia Province is considered as a region with the highest dust (ca 20.2% of domestic emission) and gaseous (ca 41.3% of domestic emission) pollutants emission, excluding carbon dioxide. It is important to mention that Silesia Province takes only 3.9% of total area of Poland [2].

Annual assessment of ambient air quality in Silesia Province in 2012 indicated that 5 zones had been classified as a zone C for PM_{10} and B(a)P [24]. This situation was caused by significant participation of point and surface (source from the municipal sector) sources of PM_{10} and B(a)P emission, which are represented mainly by domestic heating [1]. PM_{10} emission is mainly represented by "low emission" – surface emission, from fuel combustion, mainly coal in individual heating systems (e.g. boilers, tiled stoves), and it constitutes 43-83%. Only Rybnicko-Jastrzębska Agglomeration has much lower index, about 24% (Fig. 7). For emission B(a)P situation is similar – "low emission" dominates, however, its participation is higher and ranges between 50% and 97% (Fig. 8). This structure of emission sources influences level of pollutants concentra-

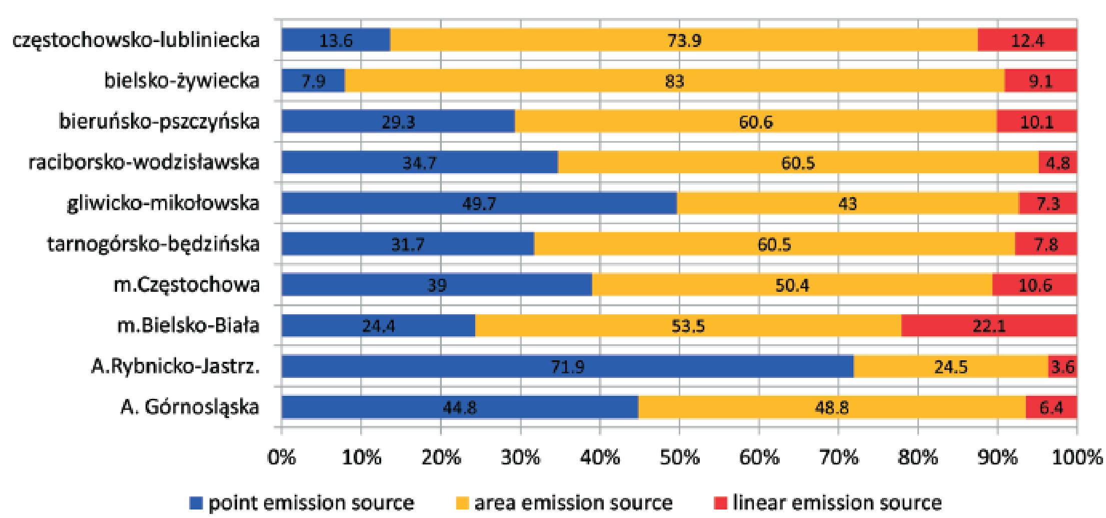

Figure 7.
Structure of PM_{10} emission in individual regions according to [1]

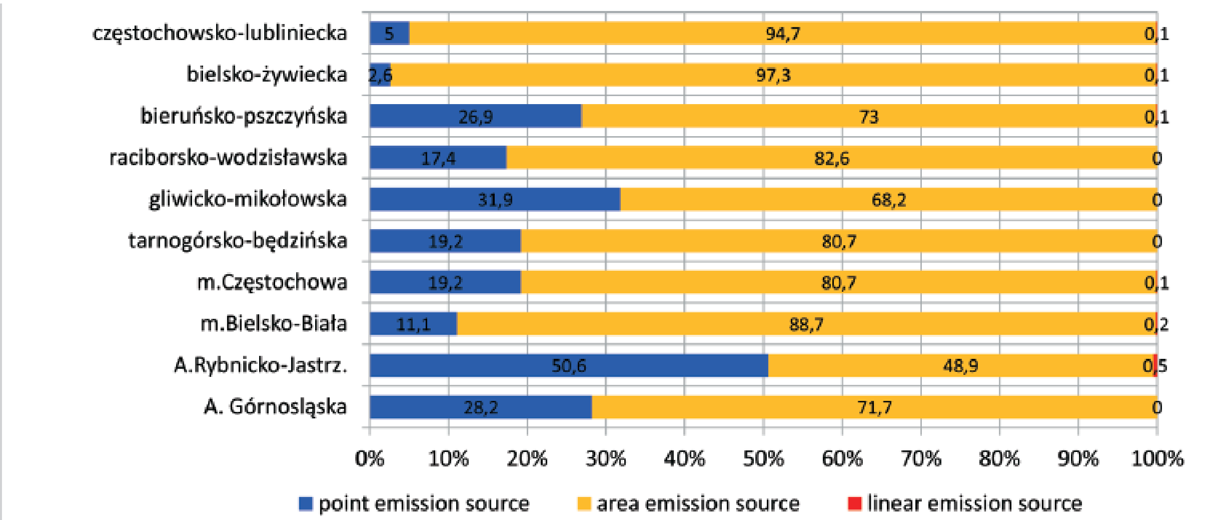

Figure 8.
Structure of B(a)P emission in individual regions according to [1]

tion due to way of pollutants emission (low emission and low efflux velocities). For that reason participation of "municipal emission" is significant in terms of exceedence of allowable pollutant concentrations and it ranges between 64% to 82% for PM_{10} and 84%-94% for B(a)P [1]. Whereas participation of linear sources of PM_{10} and B(a)P emission is significantly lower and varies from 13-26% and less than 0.1%, respectively [1]. Additionally unfavorable climate conditions, such as light winds, atmospheric calms, temperature inversions and topography, have a negative effect on air quality in analyzed zones.

Table 2 shows emission levels of PM_{10} and B(a)P according to [1] from surface sources in Silesia Province. Cities of Agglomeration, i.e. Bytom, Katowice, Dąbrowa G., Sosnowiec, Tychy, Gliwice, Zabrze and Chorzów have the highest participation in this emission, which is associated with the greatest amount of the sources of this type in this area. Analyzing the data attention should be paid to będziński and żywiecki counties, for which the number of residents is comparable (about 150 thousand). In this case the difference in the amount of emissions of both PM_{10} and B(a)P is significantly bigger. This steams from the fact that in the będziński district, greater part of the population (about 112 thousand) lives in cities, where more than 50% of households are connected to the central heating system. It results in a lower emissions. However, in the Żywiec County only 32 thousands people live in cities while the rest of population and the remainder lives in rural areas, where over 90% energy for heating is produced in the coal boilers.

Table 2.
PM_{10} and B(a)P emission from area emission sources, in Mg according to [1]

County or agglomeration	PM_{10}	B(a)P
Aglomeracja Górnośląska	5352.95	3.225
Aglomeracja Rybnicko-Jastrz.	903	0,434
m.Bielsko-Baiła	311.41	0.192
m.Częstochowa	528.05	0.302
p.gliwicki	522.91	0.322
p.mikołowski	356.65	0.221
p.tarnogórski	573.79	0.348
p.będziński	496.66	0.305
p.zawierciański	630.23	0.381
p.raciborski	540.07	0.328
p.rybnicki	418.63	0.258
p.wodzisławski	704.26	0.433
p.bieruńsko-lędziń.	264.22	0.153
p.pszczyńsk	526.56	0.335
p.bielski	703.61	0.419
p.cieszyński	407.23	0.244
p.żywiecki	1049.3	0.637
p.częstochowski	715.65	0.426
p.kłobucki	622.81	0.38
p.myszkowski	435.48	0.262
p.lubliniecki	517.4	0.296

Emission levels were used for evaluation of emission factors for PM_{10} and B(a)P characterizing exposure to the annual emissions of PM_{10} dust and B(a)P. These indices are referred to the residents number in each zone (Table 3). It can be noticed that in large cities (ca. 200 000 inhabitants and more), where participation of domestic heating is lower (since heat is transported by gas network and heating network), emission level per capita is significantly lower in comparison with town-

Table 3.
Emission factor for PM_{10} and B(a)P in kg/person

Regions	Population	PM_{10} emission factor	B(a)P* emission factor
Aglomeracja Górnośląska, Aglomeracja Rybnicko-Jastrzębska, m. Bielsko-Biała, m. Częstochowa	2710270	2.42	1.53
tarnogórsko-będziński	412894	4.12	2.5
gliwicko-mikołowski	205960	4.27	2.63
raciborsko-wodzisławski	340078	4.88	2.99
bieruńsko-pszczyński	160845	4.92	3.03
bielsko-żywiecki	472106	4.57	2.75
częstochowsko-lubliniecki	366501	6.25	3.72

*emission factor in g/person

rural districts, where participation of domestic heating is much higher. Most vulnerable to the effects of PM_{10} and B(a)P are residents of a rural communes for which the indicators are about 27-52% higher than the rates set for the urban-rural municipalities. This is mainly due to the greater occurrence of heating and gas systems in urban and town-rural municipalities. In rural municipalities share of the network heat in the heat production infrastructure is minimal. It is dominated by the hearth individual whose participation may be as high as 95%. It makes that lowest exposed for PM_{10} and B(a)P are residents of large industrial cities, for which emission factors are almost twice smaller. Similar results have been obtained for the PM_{10} emissions in the project "Improvement of air quality in the border region Czech Republic-Poland" carried out by the Institute for Ecology of Industrial Areas [25].

4. SUMMARY

Territory of Silesia Province is a place of huge energy consumption and also a place of large concentration of emission sources within rather small area. These facts indicate that this is an area of intensive emission, especially "low emission", coming largely from the municipal sector. The large impact on emissions from this sector has the share of district heating in an overall balance of energy, as well as the sources of heat structure in the individual households and their insulation. Additionally this is an area of huge road transport and poor air flow, which has an impact on arising extremely high concentrations of air pollutants. Especially the municipality of an urban-rural areas are presence of the higher pollutants concentrations, mainly in the heating season, when the weather conditions are not conducive to good being spread contaminants in the air. For this reason and due to the large number of population exposed to adverse health effects especially living in the municipalities of the urban-rural nature for which indicators of exposure to emissions may be even twice as high, why limitation of "low emission" should be a priority in ecological policy. Limitation of coal combustion in domestic furnaces is the key, since its industrial role had been reduced significantly due to restructuring and modernization of industry. Replacement of coal by oil or gas would be the simplest solution, however, that is the most expansive path and for many inhabitants costs are still too high. Reduction of air pollution by limitation of "low emission" is connected with replacement of fuel but also with minimalization of heat loss, which results in lower emission. This activity is also related to development of heating networks.

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REFERENCES

[1] Pogram ochrony powietrza dla stref województwa Śląskiego, w których stwierdzone zostały ponadnormatywne stężenia substancji w powietrzu (Programme for Air Protection zones Silesian province in which were found oversize levels of substances in the air), Katowice 2010 (in Polish)

[2] Rocznik statystyczny, Ochrona Środowiska 2012 (Statistical Yearbook, Environment), GUS, Warszawa 2012 (in Pollish)

[3] *Stala-Szlugaj K.*; Spalanie węgla kamiennego w sektorze komunalno-bytowym – wpływ na wielkość niskie emisji (The coal combustion in the municipal and household sector – the impact on the volume of low emissions), Rocznik Ochrona Środowiska 2011, Vol.22, p.1877-1889 (in Polish)

[4] *Klojzy-Kaczmarczyk B., Mazurek J.*; Zadania samorządów lokalnych w procesie likwidacji niskiej emisji (The local governments tasks in the process of low emissions liquidation), Polityka ekologiczna 2009, Vol.12, z.2/2, p.277-284 (in Polish)

[5] *Olendrzyński K., Kargulewicz I., Kołsut W., Skośkiewicz J., Dębski B., Grochowalski A.*; Krajowa inwentaryzacja emisji TZO do powietrza i analiza uwolnień do pozostałych komponentów środowiska (TOZ emissions national inventory to the air and the releases analysis into the other environmental components), Raport IOŚ, Warszawa 2002 (in Polish)

[6] Corinair 90 – Comprehensive Summary Report, Report to the European Environment Agency from the European Topic Centre on Air Emissions, European Environment Agency 1996

[7] IPCC, Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories, 1996

[8] EMEP/CORINAIR Atmospheric Emission Inventory Guidebook – 3rd Edition, European Environment Agency 2002

[9] Gospodarka Paliwowo-Energetyczna w latach 2010-2011 (Energy Statistics 2011, 2012), GUS, Warszawa 2012 (in Polish)

[10] *Pałamarczuk P., Konieczyński J.*; Ekologiczne walory stosowania kotłów fluidalnych w sektorze komunalnym (The use of fluidized bed boilers ecological values in the municipal sector), Prace naukowe GIG Górnictwo i Środowisko, No.3, 2005; p.13-24 (in Polish)

[11] GUS, Zużycie paliw i nośników energii w 2012 r. (Consumption of fuels and energy carriers in 2012), Warszawa 2013 (in Polish)

[12] *Pye S., Jones G., Stewart R., Woodfield M., Kubica K., Kubica R., Pacyna J.*; Costs and environmental effectiveness of options mercury reduction, AEAT/ED48706/ Final report v2, January 2006

[13] *Kurczabiński L.*; Węgiel kamienny w sektorze komunalno-bytowym (The coal in the municipal and household sector), VII Ekoenergetyczna konferencja, Gliwice 2011 (in Polish)

[14] *Gajos S., Klusek M., Kurczabiński L.*; Podaż i jakość węgli produkowanych przez Katowicki Holding Węglowy SA w świetle przewidywanych zmian jakościowych na rynku odbiorców energetycznych (The carbons produced by the Katowice Coal Holding SA supply and quality in the light of the expected qualitative changes in the energy consumers market), XXIII Konferencja: Zagadnienia surowców energetycznych i energii w gospodarce krajowej, IGSMiE PAN, Zakopane 2009 (in Polish)

[15] Zużycie energii w gospodarstwach domowych w 2009 roku (Energy consumption in households in 2009), GUS, Warszawa 2012 (in Polish)

[16] *Mizielińska K., Olszak J.*; Gazowe i olejowe źródła ciepła malej mocy (The gas and oli low-power heat source), Oficyna Wydawnicza Politechniki Warszawskiej, Warszawa 2011 (in Polish)

[17] *Lorenz U.*; Skutki spalania węgla kamiennego dla środowiska przyrodniczego i możliwości ich ograniczania (The coal combustion effects for the environment and their limiting possibilities), Wyd. Instytutu GSMiE PAN, Kraków 2005 (in Polish)

[18] Raport „Inwentaryzacja emisji do powietrza SO_2, NO_x, CO, NH_3, pyłów, metali ciężkich, NMLZO i TZO w Polsce za rok 2008" (The report "Inventory of SO_2, NO_x, CO, NH_3, particulate matter, heavy metals and TZO NMVOC emissions to the air in Poland for the year 2008"), Instytut Ochrony Środowiska, KASHUE-KOBiZE, Warszawa 2010 (in Polish)

[19] Raport „Krajowy bilans emisji do powietrza SO_2, NO_x, CO, NH_3, NMLZO, pyłów, metali ciężkich, i TZO za lata 2011-2012 w układzie SNAP" (The report "National balance of SO_2, NO_x, CO, NH_3, NMVOC, particulates, heavy metals and TZO emissions to the air for the years 2011-2012 in the SNAP system"), Krajowy Ośrodek Bilansowania i Zarządzania Emisjami, KOBiZE, Warszawa 2013 (in Polish)

[20] Efektywność wykorzystania energii w latach 1997-2007 (Energy efficiency in the years 1997-2007), Informacje i opracowania statystyczne GUS, Warszawa 2009 (in Polish)