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ENVIRONMENTAL IMPACT OF PUBLIC TRANSPORT IN THE GÓRNOŚLĄSKO-ZAGŁĘBIOWSKA METROPOLIS

Summary. This paper discusses the environmental characteristics of assets of the public transport systems in Górnośląsko-Dąbrowska Metropolis. The public transport is served by a number of companies. This poses the problem of integrating their behaviour in a coherent manner for environment protection. The Metropolis includes regions highly populated with good road networks as well as small localities which generates small transport demands. The transport potential is assessed and categorised in relation to its impact on the environment. The volume of emission of pollutants and the severity of their presence in the environment are summarised. Conditions of the functioning of the constituents of the systems were analysed, accounting for their contribution to pollution as well as health hazards cases.

Keywords: transport, public transport, exhaust emission, emission standards, emission, Euro, GZM

1. INTRODUCTION

Górnośląsko-Zagłębiowska Metropolis (GZM) was established on 1 July 2017 and started operation on January 1, 2018. It is an association of administrative units subject to regulations of a metropolitan region [1]. GZM is constituted of 41 municipalities in the central part of

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Silesian Voivodeship. It has a human habitation of over 2.3 million people, with an area of 2553 km^2.

The association carries out public domain tasks such as shaping spatial order, social and economic development of the region, development and integration of public transport and sustainable mobility, cooperation with road authorities in determining the routes of national and regional roads, promotion of the GZM. GZM's budget is built on contributions from the municipalities and a 5% share of the PIT (personal income tax) of inhabitants of the region which amount to over 360 mln PLN (2018) [2].

The region has a very favourable geographical location; it is an attractive area for investors and various economic activities. A dense network of communal infrastructure, an extensive transport network and a diversified range of services in passenger and freight transport which promotes investments.

The GZM Metropolis is located in the centre of Europe at the intersection of two trans-European transport corridors, TEN-T III and VI. Six European capitals are located in a radius of 600 km from Katowice: Berlin, Bratislava, Budapest, Prague, Warsaw and Vienna. In addition, it connects via various means of transport to many regions in Poland and thanks to Katowice International Airport, it connects with most European cities.

The GZM region has a well-developed communication infrastructure in comparison to the rest of Poland. The region is characterised by a strong developed network of infrastructure, consisting of national roads and highways, regional and local roads. There is over 21,000 km of public roads, which is 8% of the total number of national roads. Two-lane roads amount to 2.6% of the total, which gives the highest road density indicator in the country, 161.9 km/100 km^2, while the average density is 79.6 km/100 km^2. The network of transport infrastructure connections using various means of transport is extensive and this creates considerable opportunities for the mobility of people and goods.

Public transport services are provided by bus, train and tram operators. The public bus transport system consists of over 500 bus lines operated by transport associations, city budget units and commercial carriers using a very diverse fleet of vehicles. Diverse in terms of capacity (seating, standing), dimensions, manufacturer, year of manufacture and even the number and methods of opening the doors of the vehicles.

In Górnośląsko-Zagłębiowska Metropolis, the public bus transport system is served by more than 1.1 thousand buses stopping at over 7 thousand bus stops and used by 1.2 million people daily. Large urban agglomerations, which extend over large areas usually have public transport systems consisting of overlapping and complementary subsystems. The main public transport operator in Górnośląsko-Zagłębiowska Metropolis is the Municipal Transport Union of the Upper Silesian Industrial District (Komunikacyjny Związek Komunalny Górnośląskiego Okręgu Przemysłowego), named KZK GOP, founded in 1991. It is a transport organiser for 29 municipalities and covers almost the entire Metropolis area. The basic tasks of KZG GOP are:

- organisation of local public transport and maintenance and the development of infrastructure.
- development and maintenance of ticket services.
- promotion and provision of travel information services.
- coordination of activities related to traffic management.

KZK GOP outsources transport services to local companies. The largest operators, in terms of volume of transport are:

- Public Transport Company in Sosnowiec (Przedsiębiorstwo Komunikacji Miejskiej w Sosnowcu) – PKM Sosnowiec.
- Public Transport Company in Katowice (Przedsiębiorstwo Komunikacji Miejskiej w Katowicach) – PKM Katowice.
- Public Transport Company in Gliwice (Przedsiębiorstwo Komunikacji Miejskiej w Gliwicach) – PKM Gliwice.

In addition to the above, KZK GOP collaborates with 32 more bus services companies. Not all municipalities in the Metropolis partner with KZK GOP, but many support and provide services for the KZK GOP or their own locations, notably:

- Municipal Communication Board in Tychy (Miejski Zarząd Komunikacji w Tychach) – MZK Tychy.
- Public Transport Company in Jaworzno (Przedsiębiorstwo Komunikacji Miejskiej w Jaworznie) – PKM Jaworzno.
- The Inter-communal Union of Passenger Communications in Tarnowskie Góry (Międzygminny Związek Komunikacji Pasażerskiej w Tarnowskich Górach) – MZKP Tarnowskie Góry.

To meet the demand and maintain the comfort of transport services KZK GOP constantly expands and unifies its assets by modernising its bus fleet and introducing uniform IT systems for managing them. One of the first problems tackled by KZK GOP was the unification of the transport offer, which is, devising a common ground for all of its operators, platform for accounting costs, informing travellers and managing joint undertakings. Currently, there is a common ticket – One-Ticket, for all the services and a complex web-based system with mobile applications for travel information [3].

2. ASSETS OF THE PUBLIC TRANSPORT IN GZM

Readily available publications give only an approximate account of the public transport assets [4]. Information, especially in the case of small commercial entities, is not publicised because assets are constantly changing and this highly influences the economy of the entities. Large companies readily provide data, but only when directly approached.

Table 1 presents the summary of assets of big companies providing public transport services in GZM. These are public transport companies in Gliwice, Katowice, Tychy, Sosnowiec, Świerklaniec and Jaworzno, which carry out in total over 80% of the public transport work in GZM. Vehicles in service were classified according to the pollution level of their engines. Data is based on current company registers, only total journey lengths of vehicles are noted, as detailed information contained ambiguous entries.

The fleets of vehicles of the companies present a diversified combination of vehicles. The least polluting (Euro 5 and Euro 6) vehicles constitute 65 % of the whole fleet. PKM Świerklaniec is the most environmentally friendly company with a share of 87%.

Tab. 1

Assets of public transport operators and total lengths of journeys per operator per year

Operator	The length of transport journeys in one year (2017)	The total number of vehicles in compliance with Euro standards						Total number of vehicles
		Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	
PKM Gliwice	11,503,931	0	20	30	17	87	26	180
PKM Tychy / MZK Tychy	9,531,507	0	1	7	24	64	40	136
PKM Katowice	16,583,755	0	12	52	5	90	93	252
PKM Świerklaniec	6,708,644	0	0	2	5	47	1	55
PKM Sosnowiec	17,488,237	0	0	108	28	20	95	251
PKM Jaworzno	4,900,000	0	0	9	2	30	4	45
Totals	66,716,074	0	33	208	81	338	259	919

Source: [5-10]

Tychy also uses the fleet of trolleybuses, which, however, were not included in the calculations.

3. ENVIRONMENTAL IMPACT OF PUBLIC TRANSPORT

The main pollutants are substances emitted by vehicle engines due to fuel combustion. In the combustion process, the chemical energy of the fuel (compression and decompression of the gas) is converted into mechanical energy. The combustion process involves the production of large amounts of harmful gases, including nitrogen oxides (NOx) and solid particles. Pollutants emitted during the combustion of liquid fuels in automotive vehicles affect the processes of acidification of the environment and the ground ozone production. Despite the use of various types of mechanisms to reduce the harmful effects, it is almost impossible to completely purify exhaust gases, and thus neutralize their negative impact on the natural environment. Other important constituents of pollution are particles of gum and asphalt, which are raised into the air by vehicle tyres in the course of driving.

European Union (EU) is the legal body, which issues directives on the limitation of air pollution – EURO. Euro is the European emission standard of permissible exhaust emissions in new vehicles sold in the European Union. These standards were developed in a series of European Directives that successively increased their stringency. Every few years, new increasingly stricter emission standards are introduced. Euro 1 was introduced in 1992, that is over 25 years ago. Currently, Euro 6 is in effect and vehicle producers have no problems adapting their products to its applicable requirements. At least theoretically, as recent scandals revealed that some cars were specially prepared to fulfil these regulations only in laboratory conditions. Table 2 shows the levels of pollution constituents as defined in the standards, for

vehicles equipped with diesel engines. Diesel engines are the predominant type of engines used by public transport vehicles.

Tab. 2

The emission standards for vehicles with diesel engines

Emitted substance [g/km]	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6
CO	3.16	1	0.64	0.5	0.5	0.5
HC	0	0.15	0.06	0.05	0.05	0.05
NO_X	0	0.55	0.5	0.25	0.18	0.08
$HC+NO_X$	1.13	0.7	0.56	0.3	0.23	0.17
PM	0.14	0.08	0.05	0.009	0.005	0.005

Source: [11]

Lack of split of travel lengths into vehicle categories maintains an assumption of the way companies' fleets are exploited in order to assess the compound pollution effect. Available reports indicate that companies do not assign vehicles to bus lines according to their Euro emission levels. Vehicles in working order are dispatched to service bus lines daily, which accounts usually for more than 80% of the company's fleet. Considering this, on average, each vehicle in service, travels yearly about 80,000 km. Table 3 summarises vehicle travel lengths. Transport companies in Świerklaniec and Jaworzno exploit their assets exceedinly by 80% and 60%, respectively, more than the average length of vehicle operation.

Tab. 3

Average yearly length of vehicle operation [km]

PKM Gliwice	79,888
PKM Tychy / MZK Tychy	87,606
PKM Katowice	82,261
PKM Świerklaniec	152,469
PKM Sosnowiec	87,093
PKM Jaworzno	136,111

The total volume of pollutants is calculated as the product of the number of vehicles, the average operation length and the volume of emitted substances as defined in the appropriate emission standards.

Using the values from Tables 2 and 3, the total mass of pollutants is obtained as shown in Table 4. The sums are split into categories of vehicles used for the transportation business. The largest share of pollutants is emitted by Euro 3 vehicles. This standard was introduced 18 years ago. It indicates that the average age of these vehicles servicing public transport is at least 18 years. Presumably, these vehicles will go out of service in the near future. Euro 4 vehicles contribute to a similar extent as very old Euro 2 vehicles. New vehicles complying with Euro 5 approach the levels of pollution of the Euro 3 vehicles, with an almost larger fleet of 63%. The contribution of Euro 4 vehicles is four times smaller than that of Euro 3, this is attributable to the very small number of these vehicles, which is as a result of certain changes in the vehicle replacement policies of the companies in recent years.

The sum of pollutants of Euro 5 and 6 vehicles presents 51% of the total pollution although these add up to 65% of the total number of vehicles. This shows that companies care for the reduction of pollution. There are incentives for such behaviours. For instance, companies can apply for subsidies from environment protection bodies such as the National Fund for Environmental Protection and Water Management. Tender documents, in the case of buying vehicles for public transport, must include terms of reference, which contain clauses that restrict the pollution levels of the vehicles.

Tab. 4

The total value of emissions of each of the substances for all public transport operators

Emitted substance [kg/km]	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Euro 6	Total emissions [kg]
CO	0	2,138	9,330	2,938	13,181	8,881	36,468
HC	0	321	875	294	1,318	888	3,696
NO_X	0	1,176	7,289	1,469	4,745	1,421	16,100
$HC+NO_X$	0	1,497	8,164	1,763	6,063	3,020	20,507
PM	0	171	729	53	132	89	1,174
total	0	5,303	26,387	6,517	25,439	14,299	77,944

The current strategy of activities for GZM [12] defines programs for the development of public transport based on a modern low-emission bus fleet and creation of an integrated public transport system (tram/bus/train). It aims to promote the use of alternative means of transport, from private cars to public transport, and reduce the entry of private vehicles to the already congested city centres. GZM is also involved in programs for the enlargement of the electric vehicle fleet. This is coincident with the directives of the EU Transport Commissions [13].

4. HEALTH HAZARDS CAUSED BY POLLUTANTS

Exposure to pollutants to a large extent causes dysfunction of the respiratory, cardiovascular and immunologic systems. It is a source of toxicity, which leads to a variety of cancers in the long term. Many factors affect the human health condition, including the level and availability of health care, lifestyle or the level of affluence of the society.Additionally, other factors which have no direct influence, such as modifiable environmental factors; air quality, noise, radiation, green areas, that is, those whose quality or level impacts depend largely on human activity. Transport contributes to the degradation of the natural environment and has a negative impact on humans. On the scale of the European Union, transport is a source of almost 54% of the total emissions of nitrogen oxides, 45% carbon monoxide, 23% non-methane volatile organic compounds (NMVOC), 23% PM10 dust and 28% PM2.5 dust. It is also responsible for over 41% of ozone precursor emissions troposphere and 23% of CO_2 emissions and almost 20% of other greenhouse gases [14, 15]. However, there has been a 30% decrease in CO2 emissions in newly registered cars in recent years [16]. Preparing a true reliable research, which presents the results of the emission of harmful substances, demands the input of certain determinants; fuel quality, climate conditions, vehicle fleet and data on the

activities of vehicles [17]. CO_2 emissions decrease when the quality level of road infrastructure increases, a good-consistent road segment was observed to have a lower emission rate of 20–30% than a poor-consistent one [18, 19, 20, 21].

The first effect of pollutants is noticed in the vocals due to its damage to the human respiratory tract. Pollutants favour the development of asthma and lung cancer, especially PMs and hydrocarbons which cause serious damage to the respiratory tract. Studies have shown that traffic-related air pollution increases the risk of chronic obstructive pulmonary disease (COPD) [22, 23].

Exposure to pollutants can lead to changes in white blood cell counts, which affects cardiovascular functions. High levels of NO_X, are associated with ventricular hypertrophy. Air suspended toxic materials have damaging effeects on the nerve system. Reports have revealed that pollutants increase the incidence rate of neuroinflammation, Alzheimer's and Parkinson's diseases. Furthermore, there is evidence that neurobehavioral hyperactivity is increased due to exposure to pollutants [24].

Immune system dysfunction brings about an increased risk of numerous diseases. Air pollutants modify antigen presentation, increase in the serum levels of the immunoglobulin, which decreases resistance to illnesses.

Cancer risk caused by air pollutants is severe. Lung cancer is the most dominant disease observed yearly; about 19,000 new cases are reported in Poland. Based on the analysis prepared by the Health and Environmental Alliance, it follows that every 8th lung cancer case in Poland is caused by air pollutants [25].

In 2016, malignant tumours were the second cause of death in Poland, causing 27.3% of deaths among men and 24.1% in women. The incidence of malignant tumours in the Silesia region in 2016 was 9852 for men for every 100,000 inhabitants and 9704 for women for every 100,000 inhabitants [26, 27].

The amount of the average annual PM10 dust concentrations has slightly decreased in recent years. There is a visible decrease in concentrations at sites in Gliwice or Sosnowiec. Many factors influenced this condition, including meteorological conditions, as well as the activity of both organisational units and numerous remedial actions taken by the local governments or the new fleet of local transport organisations.

5. CONCLUSIONS

In Górnośląsko-Zagłębiowska Metropolis, carbon monoxide has the largest volume of emission. Other emitted substances that are harmful to the human health and environment are nitrogen oxides, hydrocarbons and solid particles (PM). The level of pollution generated by public transport is high and dangerous to the health of GZM residents, but companies are aware of the risks and therefore take the necessary actions in this regard. The European transport sector has achieved significant reductions in the emissions of some of the major air pollutants, primarily due to the introduction of emission standards, financial measures and, to a lesser extent, the use of alternative fuels and avoiding transport activities. Thanks to the introduction of increasingly stringent standards, emissions of bus fleets are gradually being reduced. This is evidenced by the high share of new low-emission buses and other activities, including the purchase of electric buses, the creation of joint strategies and plans for emission reduction.

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