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INFLUENCE OF MOTORIZATION DEVELOPMENT ON CIVILIZATION DISEASES

Summary. The health style of the population has deteriorated in the last 10 years, given the possibilities offered by an increasingly advanced civilization. The paper attempts to find the answer to the question whether the development of motorization has an effect on civilization diseases. To this end, the paper began with an analysis of the registered number of means of transport in Poland and an analysis of the number of cases of malignant and respiratory tract cancers. Then, the focus was on the analysis of exhaust toxicity, discussing its definition and determining the limit values for exhaust toxicity occurring in the means of transport. In the next section, the paper was carried out on the toxicity of exhaust gases of lorries and passenger cars affecting human health. Finally, the paper ends by summarizing the results and drawing the appropriate conclusions.

1. INTRODUCTION

Modern or even civilization diseases have spread widely throughout the population in recent years. They even came first in morbidity and mortality. After the elimination or reduction of parasitic and infectious diseases, these diseases of the modern world have come to the forefront. These include obesity; diabetes; tumor diseases; respiratory diseases; nervous and mental disorders; cardiovascular diseases such as ischemic heart disease, myocardial infarction, and stroke; allergies, etc. These diseases are now the major cause of death in practically all the nations of the world, with approximately 60% of the total number of human deaths from all causes, including diseases, famines, wars, crime, accidents, and natural catastrophes [1].

The first motor vehicles were built at the beginning of the 18th century, whereas trucks were in the 19th century. Nicolas Otto was also the first internal combustion engine in this age. Devices and machines were created to satisfy various human needs and relieve them in many activities of everyday life. These needs were undoubtedly put in the first place for a very long time. It was only after some time that negative aspects of such thinking started to appear, manifesting itself in various effects of the methods of production as well as the machines and devices themselves, on the natural environment and human health [2, 3]. People realized that lowering the quality of the environment in which they live affects the quality of their own lives [4]. Understanding the extent of air pollution effects on local communities from freight transport provides important information to design effective and efficient

mitigation strategies [5]. Reconciling the possibility of using the benefits of technology and taking care of the environment is a big challenge, especially as there is a continuous increase in the number of machines and devices used [6]. The continuous increase in the number of vehicles is shown in Fig. 1. It should be noted that many different types of machines and devices work based on internal combustion engines [7]. Emissions of combustion engines are the companion products of conventional means of transport. They consist of several hundreds of substances, most of them have an adverse effect on the environment and humans [8].

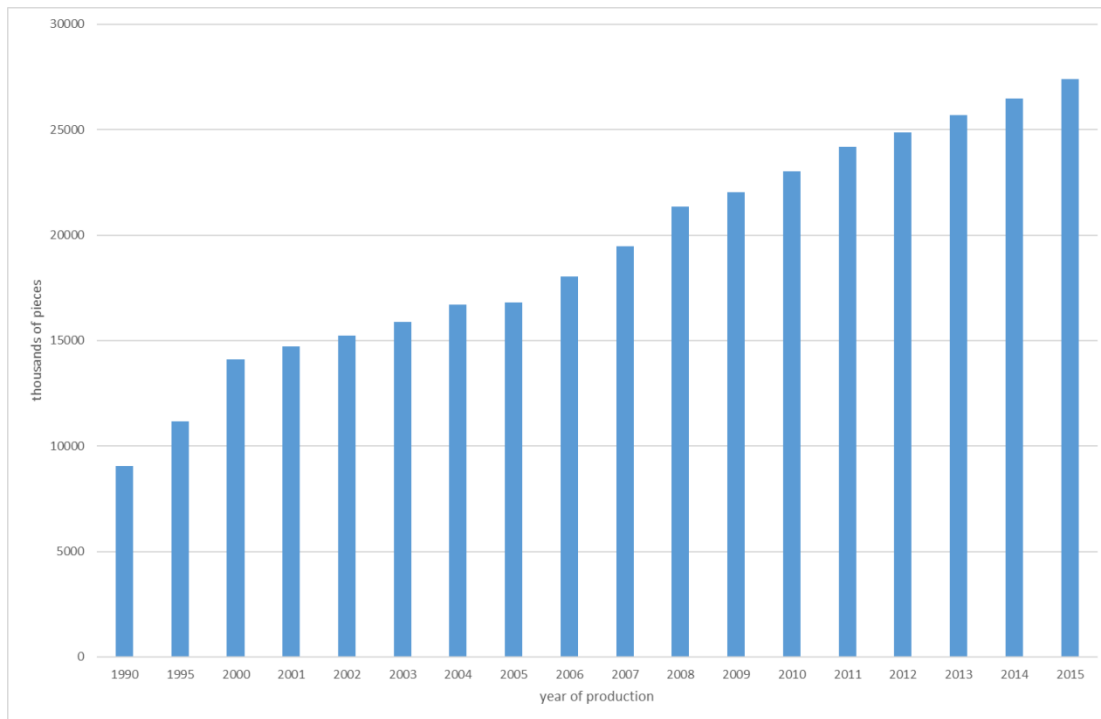


Fig. 1. The number of vehicles in the years 1990-2016 [9]

Based on data European vehicle market statistics, 2019/2020 [20] in 2018, new car registrations in the EU remained roughly constant at 15.1 million. By far the strongest growth in vehicle sales took place in the sport utility vehicle (SUV) segment. Approximately 5 million new cars in 2018 were SUVs, more than 8 times as many as in 2001. Furthermore, the share of diesel cars sold in the EU dropped considerably from 44% in 2017 to 36% in 2018. This is significantly less than in 2011-2012, when 55% of new cars were still powered by diesel. The official level of average carbon dioxide (CO₂) emissions from new passenger cars in the EU, increased to 120 grams per kilometer (g/km) in 2018, which is 2 g/km higher than in the previous year. The market share of hybrid electric vehicles (HEV) in the EU was 3% of all new car sales in 2018. Plug-in hybrid (PHEV) and battery electric vehicles (BEV) each made up approximately 1% of new vehicle registrations in the EU.

Furthermore, based on the Second Assessment Report (SAR) of the Intergovernmental Panel on Climate Change (IPCC), it can be stated that two global automotive manufacturers are now selling hybrid automobiles 5-10 years ahead of what was anticipated just 5 years ago; dramatic reductions have been made in fuel cell cost and size, such that several manufacturers introduced fuel cell vehicles already 2005, 10-20 years ahead of what was previously anticipated, and improvements in fuels, engine controls, and emissions after-treatment led to the production of a gasoline internal combustion engine vehicle with virtually zero emissions of urban air pollutants [21].

Therefore, over time it became necessary to limit toxic compounds harmful to human health, emitted not only by the mentioned engines but also by other energy sources. Currently, for the authorities of most developed countries, one of the priorities is to reduce the harmful effects of the use of internal combustion engines [10]. The first required standards for exhaust gases were set at the beginning of the

20th century. The state authorities, who decide about legal provisions, may set increasingly strict emission standards, which may subsequently cause the emergence of new pro-ecological solutions, e.g. in the construction of engines (meeting the requirements of stricter regulations). The emission of exhaust fumes from means of transport is a challenge for designers who try to call each produced car ecological and not threatening the safety of people [11].

The civilization diseases have become a challenge of the 21st century, especially cancer. This paper solves the problem of development of motoring and its effect on civilization diseases.

2. GLOBAL CANCER DATA IN POLAND

Based on Yaoxian Huang's data, it can be stated that global annual total PM_{2.5}- and ozone-induced premature deaths for gasoline and diesel sectors approach 115 000 and 122 100 with corresponding years of lives lost of 2.10 and 2.21 million years. A substantial regional variability of premature death rates is found for the diesel sector when the regional health effects are normalized by the annual total regional vehicle distance travelled [22].

Considering the data from the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), it can be concluded that exhaust fumes from a diesel engine are year-forming for humans. This is associated with an increased risk of lung cancer. IARC mission is to coordinate and conduct research on the causes of human cancer, the mechanisms of carcinogenesis, and to develop scientific strategies for cancer control. Large populations are exposed to diesel exhaust in everyday life, whether through their occupation or through the ambient air. People are exposed not only to motor vehicle exhausts but also to exhausts from other diesel engines, including from other modes of transport (e.g. diesel trains and ships) and from power generators [23].

At this point, it should also be taken into account that based on the results of An Air Resources Board Environmental Science & Technology, it indicates that the risk of developing cancer as a result of exposure to major toxic substances in the air has fallen by 76 percent over 23 years in California, directly from the provisions governing unhealthy emissions from these air pollutants [24].

From year to year, the number of malignant tumors increases. In 1990, there were about 80 000 of them; in 2000, 115 000 (an increase of 35 000); in 2010, 140 000 (an increase of 25 000); and in 2015, 163 000 (increase by 20 000). The number of malignant tumours has doubled in 25 years. A slightly different situation concerns the incidence of malignant tumours of the bronchi and lungs, the number of which over the last 25 years was constant and amounted to approximately 20 thousand annually. This type of cancer is conditioned by, among others, motorization development. The results for the period considered are presented in the Fig. 2 [12].

3. EXHAUST TOXICITY IN AUTOMOBILE INDUSTRY

The starting point in the considerations is the combustion process. Combustion is an exothermic (chemical) reaction that proceeds with the release of a large amount of thermal energy, between fuel or combustible material and the oxidant. This process is also accompanied by the separation of the flame, and thus, light. Both oxidants and fuels can occur in three states: solid, liquid, and gas. A commonly occurring gas oxidant is oxygen in the air. Combustion can also be determined by a physicochemical reaction in which the rate of the combustion process itself is the base, caused by the rapid combination of the combustible substance with the oxidant. As a result of this reaction, apart from heat and light, exhaust gases are generated. It is due to this adverse effect of burning that toxic compounds that vary in concentration and toxicity enter the atmosphere, which in the exhaust gas is very much, both with a gaseous, liquid, and solid fraction [13].

Fortunately, technological development creates more and more modern methods of reducing emissions, as well as new ways of testing them. The great ally of the natural environment, and thus also of human health, are legal norms that set theoretically impassable emission limits [14].

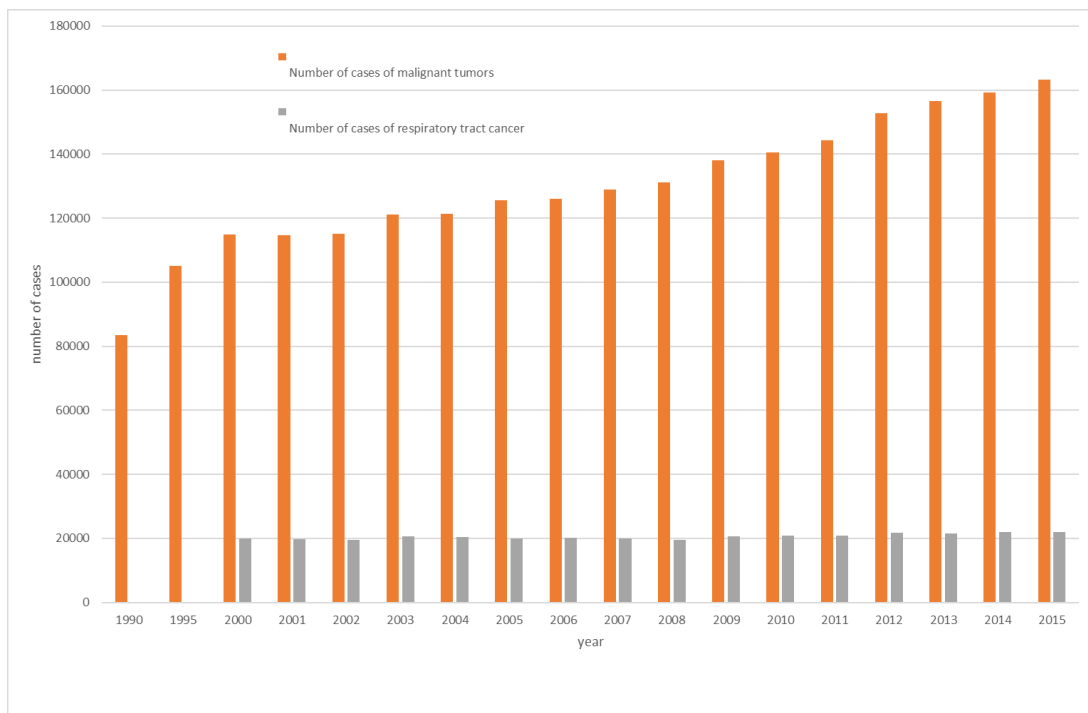


Fig. 2. The number of cases of malignant tumours and cancers of the respiratory tract in the years 1990-2015 [12]

The composition of the exhaust is directly dependent on the composition of the fuel-air mixture and the course of the combustion reaction itself. For complete combustion, in the exhaust gas, oxygen, nitrogen, carbon dioxide, and water vapor are recorded. On the other hand, incomplete combustion causes additional occurrence of hydrogen, traces of methane, and carbon monoxide in the exhaust gas. Naturally, if the fuel is sulfated, sulfur dioxide is present in the exhaust.

The car's engine exhaust is a mixture of many substances, molecules, compounds, and groups of chemical compounds. The exhaust consists of non-toxic and toxic substances. For the most part, these gases are not toxic, contained in the air we breathe. Only a relatively small part of the exhaust gases is a burden for the natural environment (harmful substances), even smaller has poisonous properties (toxic substances). However, it is necessary to act to reduce emissions of harmful and toxic compounds. The exhaust gases of modern cars complying with the Euro 6 standard are cleaner in terms of the content of some toxic compounds than the air that these engines suck in. The burden on the environment is currently owing to, among others, the number of cars.

The components of the exhaust gases that affect human health include the following chemical compounds [14-16]:

Nitrogen (N_2) - under normal conditions, nitrogen is inert to living organisms. In higher concentrations, it can cause symptoms of poisoning.

Oxygen (O_2) and steam (H_2O) - they do not cause any adverse effects on human health.

Carbon dioxide (CO_2) - it is a colourless, non-flammable gas, characterized by a slightly sour aftertaste. Its high concentrations in the inhaled air, exceeding its normal level in the exhaled air, lead to tinnitus, headaches, and palpitations. Levels of 8% to 10%, which cause loss of consciousness, breathlessness, or respiratory arrest, are dangerous for life. A concentration of 12% leads to rapid death. The mechanism of interaction of carbon dioxide on the human body is the disruption of natural processes regulating breathing, which leads to hypoxia. Carbon dioxide, although in high concentrations can lead to human death, is not considered a toxic gas, as it naturally occurs in nature and regulates many life processes in the animal and plant world. It is worth noting here that CO_2 also negatively affects global warming [19, 25].

Hydrocarbons (HC) - hydrocarbons contained in the exhaust gas affect human being by irritating the respiratory tract and mucous membranes. Hydrocarbons are very numerous groups of chemical compounds. The most important ones include olefins, aromatic hydrocarbons (ring-shaped), paraffin hydrocarbons (alkanes of a chain structure, aliphatic hydrocarbons), aldehydes (mainly formaldehyde), and polycyclic-polycyclic connections. The carcinogenic properties of approximately 20 polycyclic aromatic hydrocarbons have been proven. Hydrocarbons are adsorbed on the surface of soot forming solid particles, and owing to their small size, they get into the alveoli with the inhaled air. The following are most dangerous for human health: xylol (dimethylbenzene $C_6H_4(CH_3)_2$), benzene (C_6H_6), and toluene. Long-term breathing of air, in which there are even small amounts of benzol, leads to damage to the nervous system and cancer of the blood, leukemia.

Carbon monoxide (CO) – it is a colorless, odorless gas. It gets into the human body through breathing. The first sign of intoxication is the disruption of the proper functioning of the central nervous system and the circulatory system. At this point, it should also be noted that a high dose of CO can lead to death.

Nitric oxide (NO_x) – it can cause central nervous system paralysis and severe blood poisoning. In addition, NO_x and VOCs combine in the atmosphere and affect human health. NO_x emissions also transform in the atmosphere to form nitrate particles, negatively affecting human health [17].

Particulate matter (PM) – it is very fine dust. Dust with a smaller diameter gets into the lungs and then into the bloodstream, which can result in health problems.

Sulphur oxide (SO_x) – it is a gas that dissolves in water and irritates the upper respiratory tract and mucosa of the eyes. SO_x emissions also transform in the atmosphere to form sulfate particles, negatively affecting human health [26].

Hydrogen sulphide (H_2S) - acute poisoning with hydrogen sulphides is manifested by dyspnea and breathing problems, and even loss of consciousness may occur.

Ammonia (NH_3) - contact of ammonia with eyes causes damage to the cornea and even loss of eyesight. Too often inhaling ammonia can lead to breathing problems, even for many years in the form of shortness of breath.

4. LIMIT VALUE OF EXHAUST TOXICITY

There are EURO standards in the European Union that regulate emission limits for harmful substances such as nitrogen oxides (NO_x), hydrocarbons (HC), particulates (PM), and carbon oxides (CO) in all new vehicles sold in the EU [18]. Road transport companies are faced with this problem for decades. The first European emission standards Euro 1 took into effect in 1992. Compliance with this standard required a substantial change of engine elements such as installation-controlled three-way catalytic converter and lambda probe.

EURO 6 has been in force since 2015 under the Regulation of the European Parliament and of the EC Council No. 2007/715 / EC of 20 June 2007 for heavy vehicles. The permissible emission of nitrogen oxides of this standard is 400 mg / kWh, which is 80% less than the Euro 5 standard. Tab. 1 presents the requirements about the emission limit values for new diesel vehicles for subsequent EURO standards [11].

The analysis of exhaust toxicity is a quite an important aspect and barrier for engine manufacturers. They must meet the toxic emission values given in the Euro standards established by the European Commission. The ordinances also specify the specification and requirements of flue gas analysers, as well as their legalization and control by the relevant state authorities. Technological progress is still developing, as new technologies are emerging that are not only more efficient but environmentally friendly. Their goal is to reduce the emission of toxic compounds from motor vehicle engines, which are not only dangerous for organisms but also for the environment in which these organisms live. These compounds include primarily NO_x and $HC+NO_x$. Now, the introduction of the EURO 7 standard is not planned.

Table 1

Emission limits for new vehicles with a diesel engine [11]

	Valid from	CO [g/km]	HC [g/km]	NO _x [g/km]	HC+NO _x [g/km]	PM
EURO 1	01.1992	3.16	-	-	1.13	0.14
EURO 2	01.1996	1.00	0.15	0.55	0.70	0.08
EURO 3	01.2000	0.64	0.06	0.50	0.56	0.05
EURO 4	01.2005	0.50	0.05	0.25	0.30	-
EURO 5	09.2009	0.50	0.05	0.18	0.23	0.005
EURO 6	06.2015	0.50	0.09	0.08	0.17	0.005

5. METHODOLOGY FOR TESTING EXHAUST TOXICITY

The composition and concentration of individual exhaust components tell us about the correctness of the combustion process in the piston combustion engine. They are not indifferent to human health. The measure of the imperfection of this process is the mass or volume share in the exhaust fumes of these components, the presence of which may indicate incomplete or incomplete combustion of the fuel-air mixture (HC, CO, C). The exhaust gas analysis is a diagnostic method used during the tests of engines with ZI (Spark Ignition Engine) and ZS (Compression Ignition Engine), enabling the exact determination of individual components of the exhaust gas discharged to the environment in the form of exhaust gases. The measurement consists in determining the volume fraction of exhaust components in the exhaust gas mixture, using methods that are based on physical or chemical characteristics. The ratio of the measured components is determined as a percentage (% vol) or in parts of a million of the total volume of exhaust gas (ppm vol.). The unit in which the component is determined depends on its concentration level. The level of concentration of individual components depends on the design and operation factors of the engine. The main purpose of performing exhaust gas analysis at diagnostic stations is as follows:

- checking the technical condition of the fuel supply system,
- measurement of the actual amount of toxic compounds emission in the exhaust,
- adjusting the engine operation at idle speed,
- checking the operation of devices limiting the emission of toxic compounds in the exhaust, and
- checking the operation of the mixture composition control system.

To analyze the toxicity of exhaust fumes of vehicles with spark ignition, the vehicle should be checked in the field of general engine operation (organoleptic method) and the leak tightness of the exhaust system, and connections between the flue gas intake probe and the analyzer should be checked. Measurements should be made according to the following essential operations for passenger cars:

- start the engine and drive the vehicle onto the test stand,
- activate the parking brake,
- turn off all electricity receivers,
- enable the analyzer and calibrate it,
- warm up the engine to the optimal temperature (about 70°C),
- place the measuring probe in the exhaust pipe to a minimum depth of 30 cm,
- test at high idle speed (n = 2000-3000 rpm),
- print the received values for n = 2000-3000 rpm,
- test at low speed, unloaded (n = 800-1000 rpm),
- print the received values for n = 800-1000 rpm, and
- withdraw the measuring probe from the vehicle's exhaust pipe.

In the case of cars equipped with self-ignition engine, a periodic assessment of the technical condition of the vehicle is made to measure the content of only one component of the exhaust - particulate matter, whose basic component is carbon black (coal). This measurement is called smoke control and consists in determining the absorption coefficient k for the hot engine, according to the following procedure:

- start the engine and drive the vehicle onto the test stand,
- activate the parking brake,
- turn off all electricity receivers,
- activate the opacimeter and calibrate it,
- warm up the engine to the optimal temperature (about 70°C),
- place the measuring probe of the opacimeter in the exhaust pipe to a minimum depth of 30 cm,
- perform three measuring cycles in 1.5 seconds increasing the speed to the maximum value,
- print the obtained results, and
- remove the opacimeter measuring probe from the exhaust pipe of the vehicle.

To ensure an adequate control procedure and quality assurance, random vehicles were selected at the testing station to perform the periodic test when the tests were carried out.

Twenty trucks with self-ignition engines (Tab. 2) and twenty vehicles with spark ignition (Tab. 3) were used in the study.

Table 2

Tested lorries

Ordinal number	Brand	Year of production	Engine volume [cm ³]	Mileage [km]
1	Renault Premium 270 dCi	2003	6174	970 645
2	Renault Premium 270 dCi	2005	11100	653 000
3	Mercedes Atego 1523	2006	6374	1 120 145
4	Man TGX 18.440	2012	10500	540 142
5	Man Me250b	2002	6871	820 323
6	Scania r310	2008	8867	490 930
7	Renault Premium 320	2005	6174	1 470 145
8	Volvo FH12 500	2016	12900	110 000
9	Iveco Stralis 450	2010	10000	1 043 000
10	DAF XF	2015	12902	342 153
11	Scania P380	2006	11705	500 101
12	Mercedes Actros 1832	2016	7698	389 540
13	Scania P230	2007	8867	369 650
14	Renault Premium	2009	10837	951 580
15	Renault KERAX 370 DCI	2006	11116	532 256
16	Volvo FM330	2013	10837	158 568
17	Volvo FH 500	2012	12777	890 587
18	Renault MIDLUM 220	2012	4764	272 487
19	DAF FT 460 XF	2014	12902	664 578
20	Volvo Fh12 6x4	2005	12900	894 257

Table 3

Tested passenger cars

Ordinary number	Brand	Engine capacity [cm ³]	Year of production
1	Toyota Starlet	1332	1992
2	Opel Zafira A	1598	2000
3	Renault Twingo	1149	2002
4	Fiat Seicento	1108	1999
5	Volkswagen Polo	1390	2003
6	BMW 312	1895	1999
7	Alfa Romeo 156	1598	2000
8	Volkswagen Passat	1595	2001
9	Volkswagen Golf	1595	1999
10	Renault Clio	1197	2000
11	Audi A4	1781	2002
12	Nissan Juke 1.6	1598	2010
13	Toyota Yaris 1.3	1329	2010
14	Ford Fusion	1388	2007
15	Volkswagen Golf VI	1595	2009
16	Volkswagen New Beetle	1595	2001
17	Opel Astra IV	1364	2013
18	Skoda Fabia	1198	2006
19	Opel Corsa	1398	2011
20	Volkswagen Fox	1198	2005

6. RESULTS OF TOXIC TEST OF EXHAUST GASES OF LORRIES

The first group of transport vehicles tested are lorries whose exhaust emission negatively affects human health. To perform the toxicity tests of exhaust gases in trucks, the MAHA MDO 2 LON ophthalmic meter was used (Fig. 3), which is intended for testing exhaust emissions of cars with self-ignition engines. It complies with the ECE R24, ISO 3173, ISO / TC22 / SC 5 N 650 directives. The device saves time and enables flawless inspection and diagnosis of exhaust gases using the partial flow procedure under free acceleration or under load of the tested engine.

The test results for twenty trucks with ignition engines are presented in Tab. 4.

It should be remembered that, in the absence of specification on the nameplate, smoke emission of a vehicle with self-ignition engine, measured with free acceleration of the engine in the range from idle speed to maximum speed, expressed in the form of a coefficient of light absorption cannot exceed 2.5 m⁻¹ and 3.0 m⁻¹ - for vehicles equipped with a turbocharged engine, and 1.5 m⁻¹ - for vehicles registered for the first time after 30 days June 2008. After analyzing the results obtained, we can conclude that the engines of the tested vehicles are in the state of fitness. For all vehicles except No. 5 and No. 7, the smoke opacity is much less than the permissible one.



Fig. 3. Opacimeter

Table 4

Tested lorries

Ordinal number	Brand	Engine volume [cm ³]	Measurement 1	Measurement 2	Measurement 3	Average of measurements	Standard [m ⁻¹]
1	Renault Premium 270 dCi	6174	1.22	1.16	1.43	1.27	3.0
2	Renault Premium 270 dCi	11100	0.96	0.89	0.92	0.92	3.0
3	Mercedes Atego 1523	6374	1.85	1.86	1.83	1.85	3.0
4	Man TGX 18.440	10500	0.43	0.39	0.45	0.42	1.5
5	Man Me250b	6871	2.19	2.28	2.33	2.27	3.0
6	Scania r310	8867	0.62	0.68	0.6	0.63	1.5
7	Renault Premium 320	6174	2.11	2.09	2.2	2.13	3.0
8	VOLVO FH12 500	12900	0.36	0.19	0.19	0.25	1.5
9	IVECO Stralis 450	10000	0.91	0.87	0.93	0.90	1.5
10	DAF XF	12902	0.34	0.48	0.21	0.34	1.5
11	Scania P380	11705	1.25	1.22	1.30	1.26	3.0
12	Mercedes Actros 1832	7698	0.28	0.31	0.29	0.29	1.5
13	Scania P230	8867	1.14	1.18	1.36	1.23	3.0
14	Renault Premium	10837	0.74	0.72	0.84	0.77	1.5
15	Renault KERAX 370 DCI	11116	1.05	1.12	1.09	1.09	3.0
16	Volvo FM330	10837	0.65	0.58	0.61	0.61	1.5
17	Volvo FH 500	12777	0.78	0.77	0.84	0.80	1.5
18	Renault MIDLUM 220	4764	0.54	0.58	0.49	0.54	1.5
19	DAF FT 460 XF	12902	0.39	0.38	0.42	0.40	1.5
20	Volvo Fh12 6x4	12900	1.59	1.53	1.63	1.58	3.0

7. RESULTS OF TOXIC TEST OF EXHAUST GASES OF PASSENGER CARS

Another group of means of transport dedicated to research are passenger cars, whose exhaust gases also negatively affect human health. The Hermann MHC 218 type NDIR flue gas analyzer was used for the test (Fig. 4), which uses the phenomenon of infrared radiation absorption. It is intended for spark-ignition vehicles.



Fig. 4. Hermann exhaust gas analyser MHC 218

This device measures the values of four gases: hydrocarbons (HC), carbon monoxide (CO), carbon dioxide (CO₂), and oxygen (O₂). In addition, based on the information collected regarding the above gases, the value of the excess air coefficient determined with the lambda symbol (λ) is determined.

The test results for 20 vehicles with spark ignition together are presented in Tab. 5 and Tab. 6.

A reluctantly used test can sometimes help with the diagnosis of the vehicle and the failures occurring in it. This is a very time-consuming test that must be carried out in quite specific conditions. The obtained values accurately reflect the operating state of the engine. In addition, lambda values allow to determine the operation of the system that controls the composition of the fuel-air mixture. Too much hydrocarbon content can mean engine faults, incorrect operation of the power system, and even problems with the crank system. The values of carbon dioxide, although not toxic, allow to assess the work of the catalyst; the higher the CO₂ concentration, the better the catalyst works.

Based on the data received, it can be concluded that the vehicles may be authorized for road traffic because they meet the requirements specified in § 9. 1 of the Regulation of the Minister of Infrastructure of 31 December 2002 on the technical conditions of vehicles and the scope of their necessary equipment, as amended. The abovementioned regulation is a legal act applicable to both vehicle manufacturers and all inspection institutions admitting motor vehicles in terms of toxicity of exhaust gases using internal combustion engines to drive. The aforementioned provisions are created and updated on the basis of international provisions, primarily based on EU directives and regulations [27-29].

It is noteworthy that the criterion for assessing the toxicity of exhaust gases in vehicles covered by the Regulations applies to two parameters: the type of combustion engine used (ignition ZI or ZS) and the date of the first registration of the vehicle (not production). There is no division according to the type of vehicle (e.g. vehicles with a GVW of up to 3.5 t and an area of 3.5 t).

At this point, it should also be considered that the applicable exhaust gas toxicity standards are measured only at specific engine speed ranges and in practice the engine still works at various loads and in a wide range of rotational speeds. Even in the most modern vehicles, computers are not installed to perform temporary measurements of exhaust gas toxicity owing to the high costs of these devices. Currently, vehicle manufacturers, and in particular American manufacturers (there are the most stringent standards), are appealing that they will not be able to meet the new standards prepared for 2021.

The results obtained are also consistent with the results presented in the reports of the EPA- United States Environmental Protection Agency, which deals with the protection of human health and the environment in the United States [30].

Table 5

Test results at engine speed 800-1000 [rpm]

	CO [% cap.]	CO ₂ [% cap.]	O ₂ [% cap.]	HC [ppm]	[λ]
Toyota Starlet	0.33	13.49	2.06	427	1.081
Opel Zafira A - gasoline	0.24	14.52	0.82	265	1.025
Opel Zafira A - LPG	0.04	13.52	0.63	229	1.024
Fiat Seicento	0.01	11.5	4.47	140	1.264
Volkswagen Golf	0.82	14.1	0.73	308	0.998
Volkswagen Passat	0.57	14	2.1	217	1.017
Renault Twingo	0	14.5	0.33	15	1.015
Volkswagen Polo	0.13	14.8	0.1	26	1
Alfa Romeo	0.69	13.4	1.55	252	1.044
BMW 312	0.01	13.8	1.84	81	1.09
Renault Clio	2.22	12.7	1.24	442	0.974
Limit values (except Toyota Starlet)	Up to 0.5	undefined	undefined	Up to 100	undefined
Limit values (for Toyota Starlet)	Up to 3.16	undefined	undefined	undefined	undefined
Audi A4	0.15	14.0	0.42	14	1.058
Nissan Juke 1.6	0.22	12.5	0.25	40	0.988
Toyota Yaris 1.3	0.25	13.2	0.41	60	1.015
Ford Fusion	0.36	11.5	1.05	47	1.010
Volkswagen Golf VI	0.13	12.2	0.89	35	0.998
Volkswagen New Beetle	0.58	13.6	2.8	195	1.020
Opel Astra IV	0.11	13.1	1.84	89	0.999
Skoda Fabia	0.17	14.6	0.34	33	1.001
Opel Corsa	0.35	12.9	0.33	57	1.014
Volkswagen Fox	0.18	14.2	0.15	36	1.013

8. CONCLUSION

Based on the research, it can be concluded that the number of cars in Poland and throughout Europe is increasing every year. Therefore, the amount of pollutants emitted by them into the atmosphere is also increasing. Although new cars emit less pollution into the atmosphere, from year to year, we cover an increasing number of kilometers, primarily to work or school, because people very often move from the city center to the outskirts or out to them, e.g. on village, which was confirmed by studies carried out by the authors.

This fact is confirmed by conducting an exhaust gas toxicity test. In the case of lorries, exhaust gas toxicity standards were not exceeded, on the contrary, in most vehicles tested, the smoke opacity index is much lower than the permissible one. Amazing test results were obtained for tested passenger vehicles. In this case, of the vehicles tested, only 40% of them had no problems with the test results. In 60% of tested vehicles, these values were exceeded, especially CO, HC, and λ. For this reason, the scope of the exhaust toxicity test should be increased, especially for passenger cars, and the introduction of more stringent emission test standards should be done. One of the most important factors limiting

exhaust emissions is the introduction of hybrid and zero-emission electric vehicles. It cannot be unequivocally stated that the automotive industry has affected the incidence of malignant tumours, especially bronchi and lungs, because the number of cars is increasing, and this type of incidence remains stable over the period considered.

Table 6

Test results at engine speed 2000-3000 [rpm]

	CO [% cap.]	CO ₂ [% cap.]	O ₂ [% cap.]	HC [ppm]	[λ]
Toyota Starlet	0.72	14.19	0.81	205	1.011
Opel Zafira A – gasoline	0.88	13.2	2.03	282	1.065
Opel Zafira A - gasoline + LPG	0.65	12.38	1.86	255	1.07
Fiat Seicento	2.99	12.2	0.97	294	0.945
Volkswagen Golf	0.48	14	0.99	342	1.019
Volkswagen Passat	2.69	11.8	2.2	234	1.013
Renault Twingo	0.01	15	0.02	32	1
Volkswagen Polo	0.24	14	0.05	42	1.029
Alfa Romeo	1.08	1.21	12.2	720	1.084
BMW 312	0.37	14.3	0.7	82	1.019
Renault Clio	2.82	12.4	1.28	294	0.964
Limit values (except Toyota Starlet)	Up to 0.3	undefined	undefined	Up to 100	0.97-1.03
Limit values (for Toyota Starlet)	Up 3.5	undefined	undefined	undefined	undefined
Audi A4	0.05	24	0.04	42	1.011
Nissan Juke 1.6	0.14	14	0.14	85	1.001
Toyota Yaris 1.3	0.11	12	0.25	41	0.989
Ford Fusion	0.36	11.8	0.87	98	1.014
Volkswagen Golf VI	0.47	14.2	0.99	158	1.012
Volkswagen New Beetle	1.89	12.4	0.89	278	1.011
Opel Astra IV	0.58	11.6	0.47	78	0.997
Skoda Fabia	0.39	12.9	0.14	39	1.013
Opel Corsa	0.09	17	0.07	37	1.007
Volkswagen Fox	0.17	18	0.17	23	1.004

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