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Effect of gasoline quality on toxicity of exhaust gases

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Abstract. The article gives the analysis of the amount and composition of exhaust gases released into the atmosphere by motor vehicles are analyzed, the restrictions used to improve the quality of fuels and reduce the harmful effects of exhaust gases. The environmental conditions of the quality indicators of automobile gasoline specified in the regulatory requirements are analyzed. The effects on human health are considered. Modern regulatory requirements and restrictions for the content of gasoline and exhaust gases are highlighted. The effect of fuel quality and optimal parameters of fuel air ratio on fuel consumption was analyzed. Engine malfunctions and environmental consequences caused by deviations from the norm in the quality indicators of fuel under operational conditions are described.

1 Introduction

In order to accelerate socio-economic development and improve the standard of living of mankind, the progress of science, development of industry, technical and technological achievements on the scale of our planet during the last two centuries seriously damaged the natural balance of our planet. As a result, the sharp increase in the consumption of natural fuels creates the risk of the depletion of energy reserves, the rational use of energy raw materials and the reduction of anthropogenic impact on the environment, and the use of environmentally friendly energy resources in the production of high-quality fuel and the preparation of commercial fuels for the transport sector clarifies [1].

As a result of the increase in the number and size of cities and urbanization, environmental problems that represent the standard of living are growing rapidly. In megacities, the main reason for such problems is the busy automobile industry, which is necessary for living in the brochure. According to statistics, a motorist drives an average of 10,000 km per year, burns 10 tons of gasoline, consumes 35 tons of oxygen, and emits about 200 different substances into the atmosphere, including 800 kg of carbon monoxide, 40 kg of nitrogen oxide, 200 kg of unburned hydrocarbons store 160 tons of exhaust gases.

Long-term traffic jams observed in large cities during peak hours cause air pollution to increase due to the long-term operation of the engine without transmission and low speed.

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As the increase in the number of cars causes an increase in the amount of toxic waste in the environment, it has led to a sharp tightening of the standards of emissions and the quality of motor fuels [2].

2 Methods

Based on the demand, needs and quality indicators of the market of oil products, the widely produced commodity products - gasoline, diesel and boiler fuel, lubricating oils are prepared by mixing (compounding) the components produced in various devices of oil refining plants. By mixing components, admixtures and additives, a commodity product of the required quality is prepared. The selection of basic components and additives used in the preparation of commercial fuel is primarily based on internal capabilities.

Modern automotive and aviation gasoline is a complex mixture of basic components such as proper driving, cracking, catalytic reforming products, polymer gasoline, and iso-paraffins and various additives, and its chemical composition is sufficiently diverse to prevent detonation of the fuel. has a decisive effect on its properties [3, 4].

The gasoline fraction consists mainly of hydrocarbons of three groups, consisting of alkanes, cyclanes and aromatic hydrocarbons such as benzene.

If the unbranched structure of alkanes, which are the basis of the hydrocarbon composition of gasoline, shows a very low detonation stability, their branched structure sharply increases the detonation stability of the fuel. A clear example of this is that the octane number of normal structure octane is 20, while that of 2.2.4-trimethylpentane is +100. A higher-octane number and grade are characteristic of isomers with a pair of methyl groups per carbon atom (neohexane, triptan, standard isooctane) and other trimethyl isomers of octane.

The formation of a double bond in a hydrocarbon molecule with a normal structure ensures that its detonation stability is significantly higher than that of the corresponding saturated hydrocarbons. The position of the coupling has a certain influence on the octane number. The closer the double bond is to the center of the molecule, the higher its octane number.

The first representatives of cyclopentane and cyclohexane series of cyclanes (especially cyclopentane) have good detonation stability. These hydrocarbons are among the valuable components of gasoline. However, the presence of side chains of normal structure in molecules of hydrocarbons with cyclopentane, as well as with cyclohexane, leads to a decrease in their octane properties.

Almost all simple aromatic hydrocarbons, including benzene, show high stability against detonation. Their Octane number is around 100 and above. The presence of side chains in them, especially the branched ones, further increases the resistance to detonation. The only exception is o-xylol.

When comparing the octane number of hydrocarbon mixtures with the true octane number of individual hydrocarbons, large deviations between them can be observed in unsaturated and aromatic hydrocarbons. In this case, we can see that the octane number of unsaturated hydrocarbons is lower than the true value, and on the contrary, it is higher in aromatic hydrocarbons. Their difference can reach 5-10 units of octane number [5].

3 Results

Modern car gasolines have good volatility, which allows to ensure economical and reliable operation of the engine and obtain a homogeneous fuel-air mixture with an optimal composition at any temperature; having a hydrocarbon composition that ensures a stable, detonation-free combustion process in all engine operating modes; stability in composition and properties during long-term storage; requires compliance with operational requirements such as non-harmful effects on fuel system components, rubber technical items, etc.

Having the above-mentioned properties, such as carbon monoxide, unburned or unburned hydrocarbons, nitrogen oxides, heavy metals and carcinogenic substances in the flue gas is the reason for them in the fuel content. Strict restrictions are placed on receiving components.

Aromatic hydrocarbons artificially increase the octane number of the fuel and increase its detonation stability. While benzene exhibits high detonation stability among aromatic hydrocarbons, the negative effects of benzene are manifested in the increase of its amount in the soot layer on the engine piston and cylinder walls, deformation of rubber gaskets, plastic tubes and other plastic parts, and destruction due to melting and corrosion. because aromatic hydrocarbons characterized by density and high refractive index, despite having a high-octane number, their amount in gasoline is limited. According to the requirements of the Euro-5 environmental standard, the maximum concentration of aromatic hydrocarbons is 35% [6-8].

The main source of atmospheric air pollution is exhaust gas emitted from motor vehicles; pre-burned or unburned hydrocarbons; nitrogen oxides; On the basis of the legal limitation of the amount of heavy metals and carcinogenic substances emissions and the standards regulating the emissions of automobile fuels, the EURO environmental standard of the European Economic Commission tightened the amount of aromatic hydrocarbons (including benzene) and standardized them as shown in the following chronological table (Table 1).

Table 1. Chronology of gradual change of EURO requirements for fuels.

Euro-0	This standard was considered the base, and with the appearance of "Euro-1" received the name "Euro-0". This standard, which was adopted in Europe in 1988, does not apply any special restrictions, but only slightly regulates the harmful emissions of gasoline engines that have a negative impact on the environment.
Euro-1	This standard was developed by the UN and adopted by the European Union in 1992. This was a major step towards improving the environment as it significantly reduced the permissible level of carbon monoxide emissions.
Euro-2	Along with the adoption of Euro-2, in 1995, the sale of gasoline with an octane number of less than 95 was banned. This standard has seriously strengthened the requirements for vehicles with a diesel engine. Euro-2 standards were initially adopted in the CIS 10 years later than the European Union.
Euro-3	This standard, adopted in 2000, strengthened the requirements, reducing the permissible level of emissions of harmful substances by an average of 40%. For example, the maximum amount of sulfur in gasoline has been reduced from 500 g/km to 150 g/km. Since the development of new Euro-3 compliant engines led to a significant reduction in engine power, difficulties were first encountered with the need to replace the injection system.
Euro-4	Since 2005, all cars have been required to have a certificate confirming compliance with the new demanding engine specifications. This standard further reduced the permissible limit by 70%. One of the reasons for the delay in the adoption of this standard in the CIS countries is due to the inevitable increase in the price of domestic cars after the adoption of the new standard.

Euro-5	This standard was adopted by the European Union in 2008. However, it was initially introduced only to trucks. These standards for light vehicles began to be applied after one year. Euro-5 not only strengthened the requirements, but also provided for the withdrawal of all fuels that do not meet the new standards by the end of 2015. The new standard takes into account the vehicle's mileage, the installed emission reduction system, and the ability to retrofit the engine to new requirements.
Euro-6	The current standard was adopted in Europe in 2015. It did not significantly affect the standards of gasoline engines. However, it seriously increased the requirements for diesel. The permissible amount of harmful substances was reduced by an average of 3 times. For example, the maximum allowable drop has decreased.

The toxicity of automobile gasoline and combustion products is mainly evaluated according to the amount of aromatic and olefinic hydrocarbons and sulfur in it. Aromatic hydrocarbons, particularly benzene, are more toxic than paraffinic hydrocarbons. At the same time, benzene contained in car gasoline increases soot formation in the engine and increases the concentration of soot and polycyclic aromatic hydrocarbons in exhaust gases. As a result of the formation of soot, the heat release through the walls of the engine deteriorates, and the temperature at the flame front increases, which leads to an increase in the amount of nitrogen oxides, which are highly toxic, in the exhaust gases.

Equipping vehicles with an exhaust gas neutralization system (catalyst economizer) prohibits the use of various gasolines with anti-detonation additives, sulfur; benzene; Table 1 shows the dynamics of changes in the norms of toxic components of exhaust gases due to the reduction in the amount of aromatic, olefin and low-boiling hydrocarbons [9,10].

Table 1. Standards set for harmful emissions from cars, g/km.

Toxic components	**EURO-1**	**EURO-2**	**EURO-3**	**EURO-4**	**EURO-5**	**EURO-6**
CO	2.72	2.2	2.3	1.0	1.0	1.0
CH	-	-	0.2	0.10	0.10	0.10
NO_x	0.97	0.50	0.15	0.08	0.060	0.060
Total	3.69	2.70	2.65	1.18	1.16	1.16

It is worth noting that the technical condition of the car is closely related to the quality of the fuel, which fully complies with such established regulations. The use of gasoline that deviates from these requirements in terms of quality will worsen the technical condition of the engine and lead to an increase in the release of harmful substances. Emissions from technically defective vehicles are 1.5-2 times higher than emissions from a technically correct engine.

The graph of the effect of fuel quality and vehicle speed on the emissions of low-quality gasoline, prepared in accordance with the standard requirements established in the standards, and with deviations from the standard requirements observed, is shown in the graph (Fig. 1) of the amount of emissions when they are used change is described.

The use of low-quality gasoline causes vapor plugs, loss of power characteristics of the engine, overheating, increased fuel consumption, and an increase in soot and resin deposits in engine parts. When gasoline with a high final boiling point is used, a small part of it passes into the cylinder in the form of liquid droplets. The non-evaporated part of gasoline flows through the walls of the cylinder and piston into the oil sump and dilutes the engine oil. As a result, the lubricating property of the oil deteriorates sharply, and wear of engine parts increases [11-13].

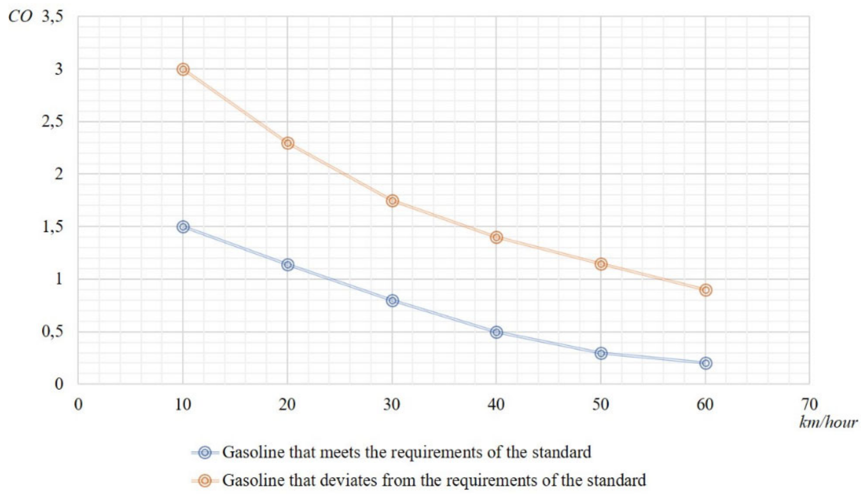

Fig. 1. Effect of fuel quality and vehicle speed on CO emissions.

The use of unconditioned gasoline leads to premature failure of cylinder-pistons and fuel system, engine defects and increased toxicity of exhaust gases.

When there are deviations in the quality indicators of the fuel according to the regulatory requirements, the significant impact on the engine and its details and the serious defects caused, the consequences of using low-quality gasoline and the descriptive changes can be seen in Table 2.

Table 2. Defects observed in the engine when using gasoline with deviations from GOST.

Naming of indicators	**Description of the standard change**	**Remote defects in the engine**
Octane number	decrease from the norm	Metallic sizzle, smoky exhaust. Detonation combustion. Deterioration of power characteristics. Increase in fuel consumption. Premature wear of cylinder-piston parts.
Saturated vapor pressure	exceeding the norm	Increased probability of formation of steam plugs. Interruptions in operation and fuel transmission. Premature deterioration of the fuel system.
true resin composition	exceeding the norm	An increase in the amount of particles in the combustion chamber and solid particles in the combustion products. Reduction of permeability and minority of the working mixture of nozzles with a calibrated hole intended for the transfer of metered fuel. Scorching. Detonation combustion. Premature wear of cylinder-piston parts.
Acidity	exceeding the norm	An increase in the corrosion activity of the fuel and the tendency to formation of fuel in the supply system and combustion chamber.
Fractional composition		
initial boiling point, 10% boiling point	decrease from the norm	Increase in fuel consumption. Formation of steam plugs and tar deposits. Defects in fuel transmission. Engine overheating and

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		interruptions in operation. Premature wear of cylinder-piston parts.
Final boiling point	decrease from the norm	Decrease in completeness of combustion, smoky waste. Increase in fuel consumption. Increased deposits in the combustion chamber. Incomplete combustion of fuel. Fuel transfer to engine crankcase. Dilution of oil.

Since the combustion of fuel in the engine represents the intense interaction of hydrocarbons with oxygen in the air, it is important to achieve timely, rapid and complete ignition of the fuel.

The combustion of fuel depends on many factors, including the amount of air supplied. Lack or excess of air in the combustible mixture slows down combustion and lowers the temperature.

The quality of the combustion mixture, that is, the fuel/air ratio, is considered an important factor affecting the main characteristics of the engine, such as power and fuel consumption, as well as stability of operation and toxicity of exhaust gases (the amount of exhaust gases) (Figure 2).

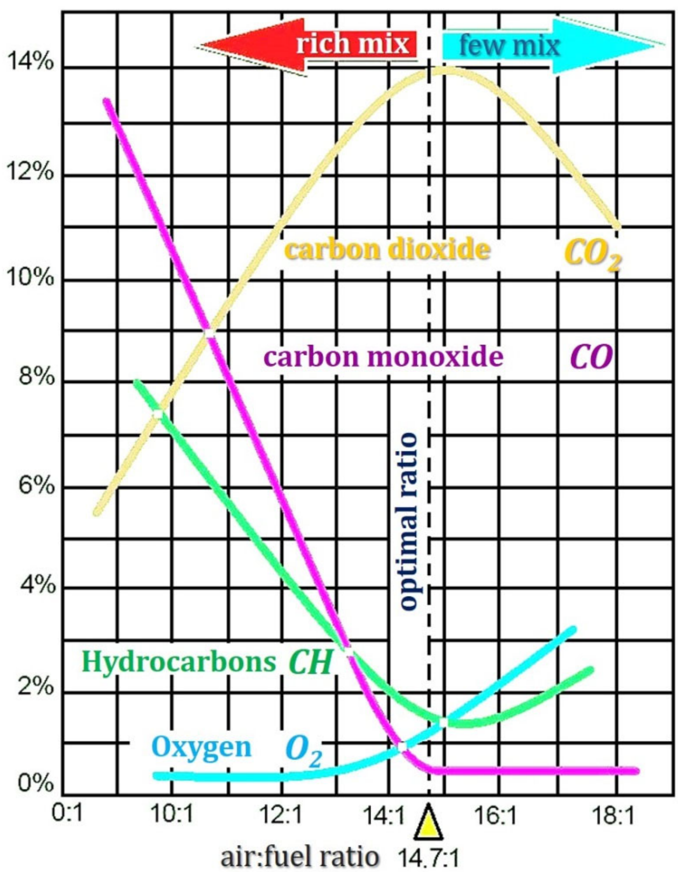

Fig. 2. A graph of the exhaust gas composition as a function of the air/fuel ratio.

Lack of air in the combustible mixture increases fuel consumption, reduces power, and produces incomplete combustion products (gas, soot, etc.). In the presence of excess air, a lot of heat is used to heat nitrogen and excess oxygen, which are the main components of air, the temperature and burning rate slow down, and fuel consumption increases. The chemical composition and quantity of the fuel used, its ratio with air, as well as residual gases, temperature and pressure values in the engine cylinder, the design of the combustion chamber and a number of other factors significantly affect the combustion rate.

It is usually the ratio of fuel and air in the combustible mixture (when a cold engine is started). The effect of this value on the operational characteristics of the engine is presented in Table 3.

Table 3. Effect of air/fuel ratio in the combustible mixture on engine characteristics.

Air/fuel ratio	Description	Explanation
6/1 − 7/1	Finally, a rich mixture. Malfunctions in fire.	A rich mixture. Burning for a long time will cause the temperature to drop.
7/1 − 12/1	A highly enriched mixture	
12/1 − 13/1	A rich mixture. Maximum power.	
13/1 − 14,7/1	A slightly enriching mixture	A normal mixture
14.7/1	Chemical ideal ratio	
14.7/1 − 16/1	Slightly diluted mixture	
16/1 − 18/1	A slight mixture. Maximum savings	A slight mixture. Burns quickly and shows high temperature.
18/1 − 20/1	A very small mixture	
20/1 − 22/1	Finally, a little mixture. Malfunctions in fire.	

4 Discussions

The operational factors affecting the combustion process of the air/fuel mixture in the engine are the ignition angle, the air excess coefficient, the structure of the combustion chamber, the frequency of rotation of the crankshaft.

As shown in Figure 2, the air/fuel ratio is 14.7:1, the optimal value, and the maximum increase in carbon dioxide output is explained by the fact that there is enough oxygen in the combustible mixture, therefore, the concentration of exhaust gas and the amount of unburned or incompletely burned hydrocarbons decrease sharply. In Table 3, the ratio 14.7/1 is recognized as the ideal chemical ratio.

According to the graph in Figure 2, a decrease in the air/fuel ratio from the optimal value leads to an increase in the amount of fuel in the mixture, creating a rich mixture, as a result, an oxygen deficiency occurs, an increase in the amount of greenhouse gas, a toxic gas, and incomplete combustion products. causes an increase. It is characterized by high engine power and a sharp increase in fuel consumption.

An increase in the air/fuel ratio from the optimal value leads to a decrease in the amount of carbon dioxide, an increase in the oxygen excess coefficient, and an increase in incomplete combustion products, while the amount of carbon dioxide in the exhaust gas does not change.

5 Conclusions

Preparation of commercial fuels that fully meet the existing standard requirements, production of high-quality automobile gasolines that do not have deviations from established regulatory requirements, prolonging the maintenance of motor vehicles, extending the life of the engine, it allows to save fuel and raw materials, to minimize the amount of carcinogenic substances released into the atmosphere. Accordingly, research is being conducted in order to reduce the amount of aromatic hydrocarbons and benzene in gasoline to the standard requirements by adding basic components and additives that do not contain benzene. In this case, serious attention is being paid to obtaining a high-octane base component based on GTL naphtha with a boiling range, the composition of which consists mainly of paraffin hydrocarbons.

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