UDC 547.271

***Anatoliy Ludyn, Viktor Reutskyy, Volodymyr Reutskyy***

# APPLICATION OF ALCOHOL WASTE TO IMPROVE THE ECOLOGY OF MOTOR FUELS

**Lviv Polytechnic National University, Lviv, Ukraine**

This article analyzes the impact of alcohol production waste on the ecological parameters of motor fuels and the possibilities of their use to reduce environmental pollution from road transport. It was found that the addition of alcohol waste improves the starting properties of the engine in cold conditions, facilitates fuel evaporation, and positively affects the completeness of its combustion and the uniformity of its supply to the engine cylinders. All these parameters have a positive effect on reducing emissions of carbon monoxide, nitrogen oxides, and benzo[a]pyrene into the atmosphere by a carburetor engine. The optimal concentration of fusel oil additives to gasoline is in the range of 5 to 7% by volume. It was found that the addition of alcohol waste improves the fractional composition of diesel fuels. When fusel oil is added, the density and viscosity of the fuel decrease, which facilitates its spraying and ignition, and leads to better combustion, resulting in less fuel consumption. It is important that the reduction in the density of the fuel mixture can cause a decrease in the amount of aromatic hydrocarbons in it, which will positively affect the composition of engine exhaust gases. The use of fusel oil additives allows increasing the cetane index, which ensures cleaner and faster fuel combustion and helps to reduce harmful emissions into the atmosphere. When fusel oil is added, the boiling point of 10% and 50% of the fuel mixture fraction decreases, which leads to improved diesel engine operation in various modes; easing its starting properties in cold conditions, and improving engine maneuverability. The addition of fusel oil to diesel fuels helps to improve their ecological parameters and ensures their compliance with Euro standards. The optimal concentration of fusel oil additives to diesel fuel is in the range of 10 to 12% by volume.

**Keywords**: fusel oil, ecology, carburetor engine, diesel engine, gasoline, cetane index, diesel fuel.

**DOI:** 10.32434/0321-4095-2025-163-6-39-49

***Introduction***

Emissions of harmful substances, which are released with exhaust gases produced during the combustion of fuels in road transport, negatively affect the state of atmospheric air and human health. The increase in environmental pollution due to the increase in the number of cars has led to increased requirements for the quality of ecological characteristics of fuel industry products. The problem of ecological safety of road transport, and especially internal combustion engines, is a component of the country's ecological safety. Around the world, there is a movement to reduce harmful emissions (Kyoto Protocol), and therefore the requirements for the ecological characteristics of motor fuels and oils obtained from petroleum products are constantly growing, for which billions of dollars are spent worldwide.

Road transport is one of the main polluters of the environment. The main regulated toxic components of engine exhaust gases are carbon monoxide, nitrogen oxides, and hydrocarbons. The composition of the main components of exhaust gases from carburetor and diesel engines is shown in Table 1 [1].

The toxicity of exhaust gases from carburetor engines is primarily due to the content of carbon monoxide and nitrogen oxides. In addition, high-octane gasoline, which is characterized by an increased content of aromatic compounds in their composition, contributes to the formation of higher concentrations of benzopyrene at high pressures and high temperatures in the internal combustion engine. Therefore, there is a tendency to increase atmospheric pollution with benzopyrene in recent decades [2,3].

When diesel fuel is burned, various substances are formed, the composition of which depends on the engine design, its power, and load. Mainly, water, harmless carbon dioxide, and relatively low concentrations of more harmful compounds are formed: carbon monoxide, unburned hydrocarbons, nitrogen oxides, as well as sulfur oxide, polycyclic hydrocarbons, and soot particles. The number of such components increases sharply when the engine is running at low speeds, when the engine is started, and when its speed increases [1,3]. Comparing ecology with gasoline engines, it should be noted that diesel fuel burns more completely, which is accompanied by slower oxidation of carbon and the formation of a smaller amount of unburned hydrocarbons. But, at the same time, due to the weaker air supply to the diesel engine, a larger amount of sulfur dioxide and soot is formed than in a carburetor engine [2]. Diesel consumes less fuel on the whole and, accordingly, emits less exhaust gases into the atmosphere than a gasoline engine of the same power. In addition, more complete fuel combustion occurs in a diesel engine, less carbon is oxidized, and less unburned hydrocarbons are formed.

For all types of engines, it should be noted that when fuel is completely burned, which is ensured by precise maintenance of the composition, there is a significant decrease in the concentration of harmful substances [3].

There is a European system for regulating the quality of automotive fuel, according to which ecological classes of fuel are distinguished. Currently, the release of Euro-3, Euro-4, and Euro-5 fuel classes is regulated on the territory of the EU. Requirements for the classes of fuel produced are established by technical regulations. The latest environmental standard Euro-6, which was introduced in Europe in 2015, became an important step in the development of diesel technologies, focusing on reducing the environmental impact of diesel engines and improving the quality of diesel fuel [3].

The main aspects of Euro standards for motor fuels are as follows:

1. Strict control over the quality of the fuel used.

2. Limiting the level of sulfur in diesel fuel and reducing emissions of harmful sulfur compounds that contribute to air pollution.

3. Restrictions on emissions of nitrogen oxides and particulate matter, which require the use of advanced exhaust gas purification technologies and improvement of combustion systems.

4. Control over the completeness of fuel

Table 1

**Composition of the main components of exhaust gases from carburetor and diesel engines**

| Components of engine exhaust gases | Concentration of exhaust gases in engines, vol.% | | Note |
|---|---|---|---|
| | carburetor | diesel | |
| nitrogen | 74.00–77.00 | 76.00–78.00 | non-toxic |
| oxygen | 0.300–8.000 | 2.0–18.000 | non-toxic |
| water vapor | 3.000–5.500 | 0.5–4.000 | non-toxic |
| carbon dioxide | 5.000–12.000 | 1.0–10.000 | non-toxic |
| carbon monoxide | 0.100–10.000 | 0.01–5.000 | toxic |
| nitrogen oxides | 0.010–0.800 | 0.004–0.060 | toxic |
| sulfur dioxide | 0–0.002 | 0–0.030 | toxic |
| hydrocarbons | 0.200–3.000 | 0.009–0.500 | toxic |
| aldehydes | 0–0.200 | 0.001–0.009 | toxic |
| soot | 0–0.040 | 0.010–1.100 | toxic |
| benzo[a]pyrene | 0.010–0.020 | up to 0.010 | toxic |

indicators, which are important for ensuring their cleaner and faster combustion, which helps to reduce harmful emissions [4].

In conclusion, Euro-standard motor fuels with their advanced environmental standards and strict emission standards are an important step towards a cleaner and more sustainable future for road transport, while increasing the efficiency and productivity of engines while reducing their harmful impact on the environment [5].

The main factors that influence the combustion process in a carburetor engine include: the time of preparation of the combustible mixture, environmental parameters, the thermal state of the engine, and the quality of the fuel used. The temperature and pressure of the environment and the thermal state of the engine are higher in cases where the fuel evaporates more completely and the quality of the combustible mixture is better. An important direction for further improvement of the carburetor engine power system may be to ensure the maximum possible evaporation of fuel before it enters the cylinder. To evaluate such a parameter, there is a point of fractional distillation of gasoline – the boiling point of 50% by volume. It characterizes the completeness of fuel evaporation and the engine's quick transition from one operating mode to another, as well as the uniform distribution of fuel among the cylinders.

Other indicators of carburetor engine fuels that affect the environment include: the boiling point of 10% of the fuel, which improves the starting properties of the engine in cold conditions, and its tendency to form gas plugs in the system, as well as the boiling points of 90% and the end of fuel boiling, which positively affect the completeness of its combustion and the uniformity of its supply to the engine cylinders [1,3].

Modern diesel fuel must meet many requirements to ensure reliable engine operation, the most important of which are: good fuel spraying and optimal mixture formation; complete combustion of fuel with a short ignition delay and minimal formation of soot and toxic substances; the possibility of good fuel pumping to ensure reliable and uninterrupted operation of the fuel system; low resin formation in the combustion chamber; no corrosion of fuel system parts; stability of technological properties during long-term storage [6].

The main operational indicators of diesel fuel that, to varying degrees, affect the environment include: cetane number (cetane index), fractional composition, viscosity, density, and the presence of sulfur compounds.

The cetane number and cetane index characterize the ignitability of diesel fuel, which affects the presence of harmful components in exhaust gases, such as CO and CH. The shorter the ignition delay period, the faster the fuel burns. This speeds up engine operation and increases its power, which in turn reduces the content of harmful components in the exhaust gases. The reduction in the ignition delay period depends on the rate of hydrocarbon oxidation during the reactions that occur before the rapid combustion phase. If the pre-flame reactions proceed slowly, the ignition delay period increases, resulting in fuel accumulating in the cylinder and then igniting a significant amount at once. A decrease in the cetane number worsens the performance of the diesel's operating cycle, noticeably increasing the harshness of operation, and wear of engine parts. If its value drops below 40 units, starting the engine becomes problematic even in warm weather due to the increased self-ignition temperature of the fuel [6].

Indicators such as viscosity and density determine the level of evaporation and mixture formation of diesel fuel, as well as the degree of its spraying in the combustion chamber. Denser and more viscous fuel ignites and burns worse, which leads to higher diesel fuel consumption and smoke in the exhaust gases. For all types of engines, a characteristic feature can be noted: the denser the diesel fuel, the higher the total content of aromatic hydrocarbons, and the more harmful compounds such as pyrene and benzopyrene are contained in the exhaust [7].

The fractional composition of diesel fuel determines the completeness of its combustion, the smoke, and the toxicity of the engine's exhaust gases. An analysis of the fuel fractional distillation points that affect the environment will be considered below.

Many methods for optimizing the ecological parameters of motor fuels are discussed in the scientific literature.

It is known that the operation of a car in low ambient air temperatures leads to a deterioration of the engine's thermal state, which has a significant impact on increasing fuel consumption (by 10...30% or more) and, as a result, increasing the emission of harmful substances with exhaust gases. In this case, the increase in fuel consumption is associated with an increase in fuel viscosity, a deterioration in its ability to spray and evaporate, and, as a result, a deterioration in mixture formation and the efficiency of the fuel-air mixture combustion [8]. Therefore, one of the methods to improve the fuel efficiency of engines and reduce the amount of exhaust gases with harmful substances in cold engine start-up modes is to provide air heating for its supply to the engine with a temperature at the level of $+35...+45^{0}C$ [9].

The ecological indicators of a diesel engine operating on various types of biodiesel made from rapeseed, soybean, and high-oleic sunflower oil were studied, and it was found that during diesel operation there is a decrease in emissions of carbon oxides, nitrogen oxides, unburned hydrocarbons, and a reduction in the smoke of exhaust gases [10]. However, biodiesel fuel has higher density and viscosity values compared to conventional diesel fuel, which can lead to its incomplete combustion, resulting in increased engine smoke [11].

Ethanol is another alternative fuel source. Ethanol, which is obtained from sugar molasses, is used to prepare fuel mixtures in internal combustion engines. The addition of ethanol improves the quality indicators, mixture formation, and combustion of diesel fuel. Such fuel contains oxygen, which increases the completeness of its combustion in diesel cylinders and, accordingly, reduces emissions of toxic products of incomplete combustion. However, there is a problem, which lies in the poor miscibility of ethanol with diesel fuel. It can be solved by using anhydrous ethanol, but this increases production costs [12].

In the production of alcohol, a significant amount of by-product is obtained, which can negatively affect the quality of marketable food-grade ethyl alcohol – fusel oil. Today, an urgent problem for the industry in Ukraine is the complex processing of by-products and waste-free technologies, which allow reducing the material consumption of products, and their cost, and also significantly reducing the level of air, water, and soil pollution. It is known that most of the fusel oil is not processed, so an important area of research may be the search for new and improvement of known methods of using this by-product. The process of dehydrating fusel oil alcohols to form esters, which can be used to obtain high-octane oxygen-containing additives, is well known [13].

Thus, one of the ways to use fusel oil may be to use it to improve the ecological parameters of motor fuels.

***Experimental***

For experimental studies, a straight-run fraction of gasoline and diesel fuel after atmospheric distillation was used, as well as fusel oil (FO) – a waste product of alcohol production. Fusel oil contains a mixture of higher alcohols (isoamyl, isobutyl, n-propyl, ethyl), water, and a small amount of esters.

The study was conducted in two stages – studying the effect of FO on the ecological parameters of gasoline (1st stage) and studying the effect of FO on the ecological parameters of diesel fuel (2nd stage). In the first stage, mixtures of gasoline with fusel oil (FO) additives were prepared in the following volumetric proportions:

1. gasoline (100%)+FO (0%);
2. gasoline (95%)+FO (5%);
3. gasoline (94%)+FO (6%);
4. gasoline (92.5%)+FO (7.5%);
5. gasoline (90%)+FO (10%);
6. gasoline (85%)+FO (15%).

Distillation of gasoline and prepared mixtures was carried out, during which their fractional composition was determined, namely: the boiling points of the 10%-, 50%-, 90%-points, and the final boiling point [14]. The obtained fractional compositions were analyzed to determine.

In the second stage, mixtures of diesel fuel (DF) with fusel oil (FO) additives were prepared in the following volumetric proportions:

1. DF (100%)+FO (0%);
2. DF (95%)+FO (5%);
3. DF (92%)+FO (8%);
4. DF (90%)+FO (10%);
5. DF (88%)+FO (12%);
6. DF (85%)+FO (15%).

For the resulting mixtures, the density, $\rho^{15}$, was determined by the pycnometric method, and the kinematic viscosity,$\nu$, by a capillary viscometer. After that, distillation of diesel fuel and prepared mixtures was carried out, during which their fractional composition was determined, namely: the initial boiling point, and boiling points of the 10%- and 50%-points. The obtained fractional compositions were analyzed and the cetane indices for the analyzed samples were determined.

For diesel fuels, the main parameters characterizing the ignition delay period of the fuel-air mixture under compression are the cetane number and the cetane index (CI), an indicator used in European standards.

The CI was determined according to the Ukrainian state standard DSTU ISO 4264:2009 (ISO 4264:1995, IDT) by a method that consists of determining the density of diesel fuel at 15$^0$C and the average boiling point of 50% (by volume) of its quantity. The cetane index was calculated using the formula:

$$CI=454.74-1641.416\cdot\rho+774.74\rho 2-0.554\cdot T_{50\%}+97.803(\log t)2,$$

where $\rho$ is the diesel fuel density at 15$^0$C (g/cm$^3$); and $T_{50\%}$ is the boiling point of 50% (by volume) of the analyzed mixture ($^0$C).

***Results and discussion***

In the first stage of the research, the influence of fusel oil on the fractional composition of the fuel mixture was determined, as a result of which it was analyzed how changes in boiling points would affect the ecological properties of gasoline. The results of the experiments showed (Table 2) that alcohol waste affects the ecological parameters of fuels for carburetor engines, namely: the boiling points of the 10%-, 50%-, 90%-points, and the final boiling point.

To assess the environmental parameters of the prepared fuel mixtures, their fractional composition was analyzed. Based on the analysis, the following conclusions can be drawn.

With the addition of fusel oil, the boiling point of 10% of the fuel decreases (Fig. 1), which improves the starting properties of the engine in cold conditions and its tendency to form vapor locks in the system. This property makes it possible to reduce the time for preparing the combustible mixture in the cold season, and therefore reduce harmful emissions into the atmosphere. The optimal value of the FO additive concentration in the fuel mixture lies within the range of 5–7% by volume (Fig. 2).

An important parameter that affects the environmental friendliness of the carburetor engine fuel system is ensuring the maximum possible evaporation of fuel before it enters the cylinder. From the fractional distillation points, this parameter is determined by the boiling point of 50% of the fuel. As can be seen from Fig. 3, with the addition of fusel oil, the $T_{50\%}$ of gasoline decreases, which facilitates its evaporation and the engine's quick transition from one operating mode to another, as well as the uniform distribution of fuel among the cylinders. The percentage decrease in the boiling point of 50% of the fuel mixture with the addition of different amounts of FO is shown in the diagram (Fig. 4).

With the addition of fusel oil, the boiling points of 90% and the end of boiling of the fuel decrease, which positively affects the completeness of its combustion and the uniformity of its supply to the engine cylinders (Fig. 5). This is important for reducing emissions of carbon monoxide and nitrogen oxides into the atmosphere. The optimal concentration of

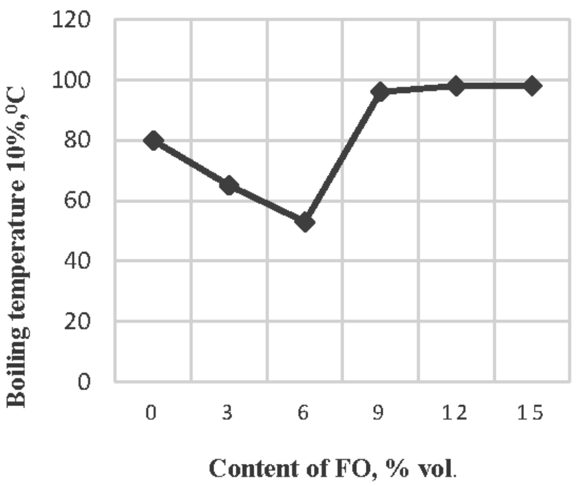


Fig. 1. Dependence of the boiling point of the 10% fraction of the fuel mixture on the concentration of fusel oil (FO) in gasoline

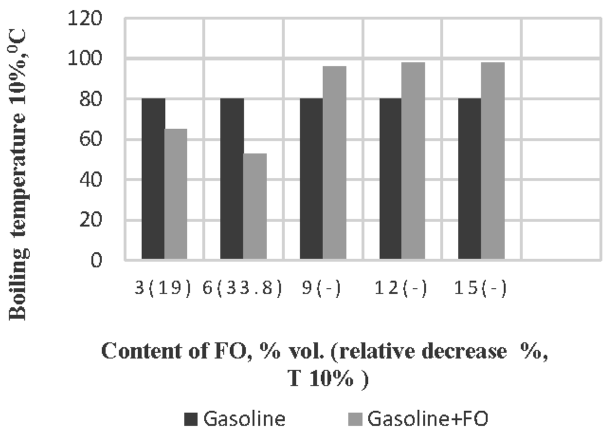


Fig. 2. Comparison of boiling points of the 10% fraction of gasoline and the fuel mixture (Gasoline+Fusel Oil) at different concentrations of fusel oil in gasoline

Table 2

**Main characteristics of the fuel mixture with fusel oil (FO) additives for assessing the ecology of a carburetor engine**

| Fuel mixture content, vol.% | | Main characteristics of the fuel mixture | | | | |
|---|---|---|---|---|---|---|
| Gasoline | CO | $\rho_4^{20}$ | $T_{10\%}$, $^0$C | $T_{50\%}$, $^0$C | $T_{90\%}$, $^0$C | $T_{кк}$, $^0$C |
| 100 | – | 0,7633 | 80 | 130 | 174 | 174 |
| 95 | 5 | 0,7653 | 62 | 118 | 172 | 172 |
| 94 | 6 | 0,7263 | 53 | 87 | 160 | 155 |
| 92,5 | 7,5 | 0,7663 | 88 | 125 | 157 | 157 |
| 90 | 10 | 0,7674 | 98 | 127 | 158 | 160 |
| 85 | 15 | 0,7688 | 98 | 130 | 170 | 175 |

the FO additive for this parameter in the fuel mixture lies within the range of 6–10% by volume (Fig. 6).

The results of the experimental and calculated data, which were determined for diesel fuel and its mixtures with fusel oil additives, are presented in Table 3. The results provided were used to analyze the main operational and ecological indicators of the fuel mixtures.

The viscosity and density of diesel fuels are of great importance for their environmental impact. The lower the viscosity of the fuel, the better its atomization, the faster it ignites and the better it burns, resulting in less fuel consumption, which has a positive effect on the ecology of the environment. In contrast, more viscous fuel ignites and burns worse, which leads to higher fuel consumption and more smoke in the exhaust gases. Reducing the density of diesel fuels helps to reduce the mass flow rate of fuel during operation.

It can be concluded from Fig. 7 that the addition of fusel oil to diesel fuel lowers its density and viscosity approximately equally, which positively affects the indicators discussed above. It is also clear from this figure that the decrease in density and viscosity begins at the initial concentration of added FO and reaches a stable decrease at an FO concentration of 10–15% by volume. Within the optimal FO concentration range in the mixture, the viscosity of the fuel mixture decreases by 19% compared to pure diesel fuel, and the density decreases by 4%. The percentage decrease in the density of the fuel mixture with the addition of different amounts of FO is shown in the diagram (Fig. 8).

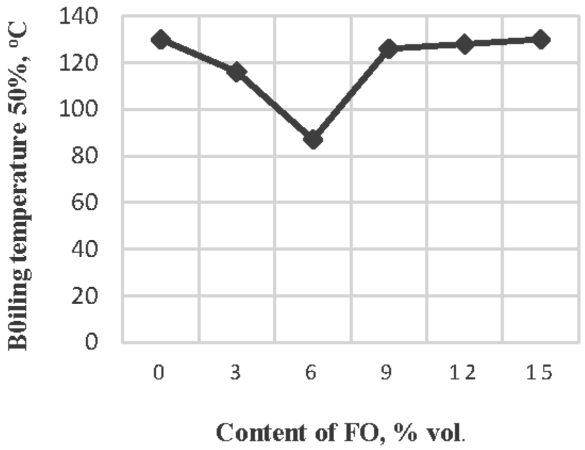


Fig. 3. Dependence of the boiling point of the 50% fraction of the fuel mixture on the concentration of fusel oil (FO) in gasoline

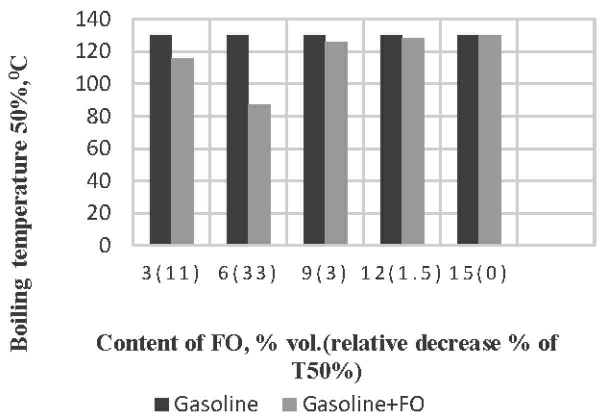


Fig. 4. Comparison of boiling points of the 50% fraction of gasoline and the fuel mixture (Gasoline+Fusel Oil) at different concentrations of Fusel Oil in gasoline

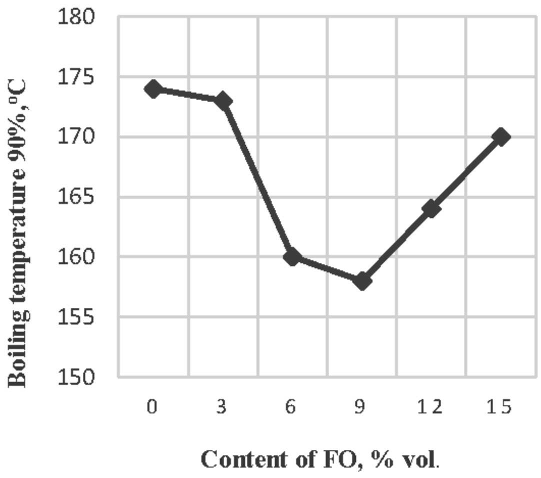


Fig. 5. Dependence of the boiling point of the 90% fraction of the fuel mixture on the concentration of fusel oil (FO) in gasoline

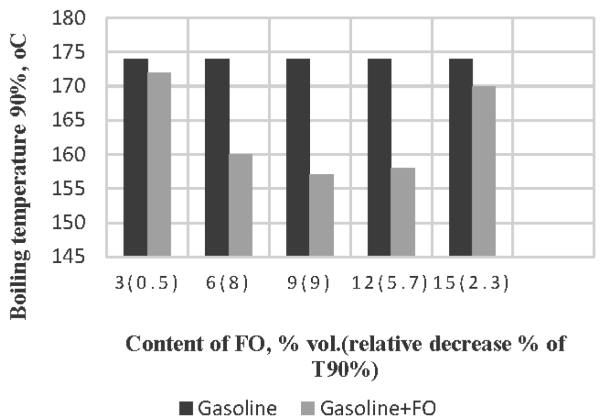


Fig. 6. Comparison of boiling points of the 90% fraction of gasoline and the fuel mixture (Gasoline + Fusel Oil) at different concentrations of fusel oil in gasoline

The evaluation of diesel fuel density is also important because it characterizes the content of aromatic hydrocarbons, which can form pyrene and benzopyrene when burned, which is undesirable for the purity of the surrounding air. For example, there are studies that consider the following pattern: a decrease in the density of diesel fuel from 860–870 to 800 kg/m$^3$ causes a decrease in the content of aromatic hydrocarbons from approximately 27 to 15%. According to this pattern, the relative decrease in fuel density in our case (4%) means an approximate decrease in the amount of aromatic hydrocarbons by 6–9%, which positively affects the composition of gases in engine exhaust.

Another important parameter that affects the ecology of diesel fuels is the cetane index, which is important for ensuring its cleaner and faster combustion, which helps to reduce harmful emissions. The higher the cetane index of diesel fuel, the faster its pre-oxidation will occur in the combustion chamber, and the faster the mixture will ignite and the engine will start. Thus, the cetane index of Euro diesel fuel should be at least 46.0. As can be seen in Fig. 9, adding fusel oil increases the CI, and at its concentration of 10% by volume in the mixture, it increases this indicator to the value required by Euro standards. The optimal concentration of the FO additive is 12% by volume, at which the CI reaches a value of 47.3. The percentage increase in the CI of the fuel mixture with the addition of different amounts of FO is shown in Fig. 10.

Some fractional distillation points of diesel fuel are also used to assess its ecological parameters. It is known that facilitating the injection of diesel fuel into the combustion chamber reduces the concentration of toxic components in the combustion products of diesel engines. The indicator that characterizes the starting properties of the fuel is the boiling point of the 10% fraction. The lower this temperature, the more easily flammable substances are contained in

Table 3

**Main characteristics of the fuel mixture with fusel oil (FO) additives for assessing the ecology of a diesel engine**

| Fuel mixture content, % vol. | | Main characteristics of the fuel mixture | | | | | |
|---|---|---|---|---|---|---|---|
| DF, vol.% | FO, vol.% | $\nu_{20}$, cSt | $\rho_{15}$, kg/m$^3$ | $T_{пк}$, $^0$C | $T_{10}$, $^0$C | $T_{50}$, $^0$C | CI |
| 100 | – | 4.05 | 835.52 | 94 | 208 | 277 | 42.53 |
| 95 | 5 | 3.84 | 807.42 | 90 | 165 | 275 | 43.75 |
| 92 | 8 | 3.45 | 802.65 | 91 | 148 | 270 | 45.59 |
| 90 | 10 | 3.42 | 802.73 | 92 | 151 | 271 | 46.84 |
| 88 | 12 | 3.39 | 801.66 | 93 | 172 | 272 | 47.26 |
| 85 | 15 | 3.39 | 801.45 | 93 | 183 | 281 | 46.87 |

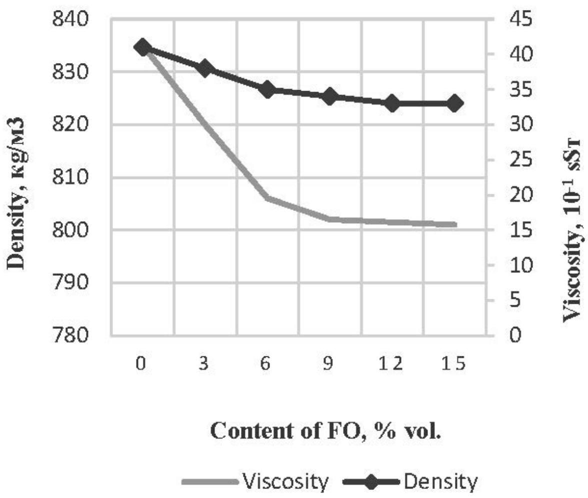


Fig. 7. Dependence of density and viscosity of the fuel mixture on the concentration of fusel oil (FO) in diesel fuel

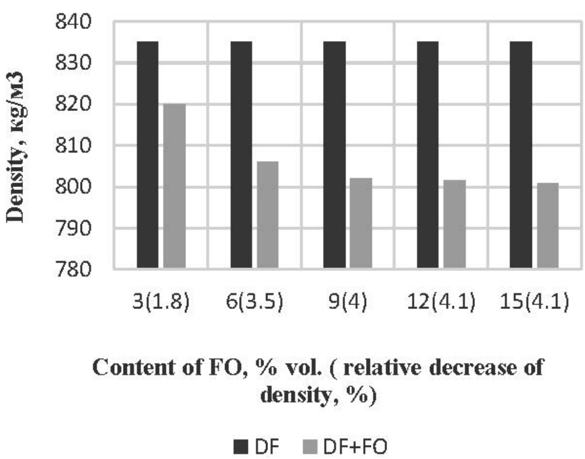


Fig. 8. Comparison of densities of diesel fuel (DF) and the fuel mixture (DF+Fusel Oil) at different concentrations of fusel oil in diesel fuel

the fuel and the easier and at a lower temperature a cold engine can be started. Faster engine starting means less carbon monoxide and nitrogen oxides in engine emissions. It can be concluded from Fig. 11 that the FO additive lowers the boiling point of the 10% fraction of the studied fuel mixture, thereby improving the ecological quality of the engine operation. The optimal value of the FO additive concentration in the fuel mixture lies within the range of 8–10% by volume (Fig. 12).

Another fractional distillation point of diesel fuel is important for assessing the ecological parameters of diesel: this is the boiling point of the 50% fraction. It has a decisive influence on the warm-up speed of an engine started in the cold and on the corresponding fuel consumption. With a decrease in this temperature, the engine warms up faster, and the fuel consumption for it decreases. It is also important that with a decrease in t50, the engine's maneuverability improves significantly, i.e., the ease of its transition from one mode to another, which will have a positive effect on car engines in urban driving conditions. Figure 13 shows a significant decrease in the boiling point of the 50% fraction of the fuel mixture when FO is added, which contributes to improving the engine's ecology. The optimal concentration of the FO additive in the fuel mixture is 10% by volume (Fig. 14).

***Conclusions***

Fusel oil as a waste product of alcohol production can be used for addition to motor fuels to reduce environmental pollution from road transport.

Alcohol waste improves the fractional composition of gasolines. Fusel oil additives improve the starting properties of the engine in cold conditions, facilitate fuel evaporation, and positively affect the

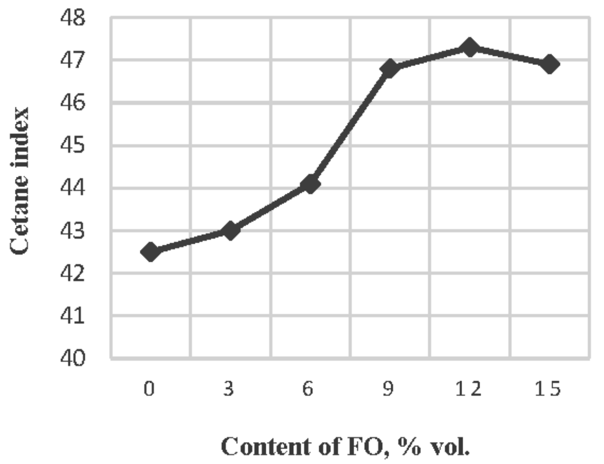


Fig. 9. Dependence of the cetane index of the fuel mixture on the concentration of fusel oil (FO) in diesel fuel

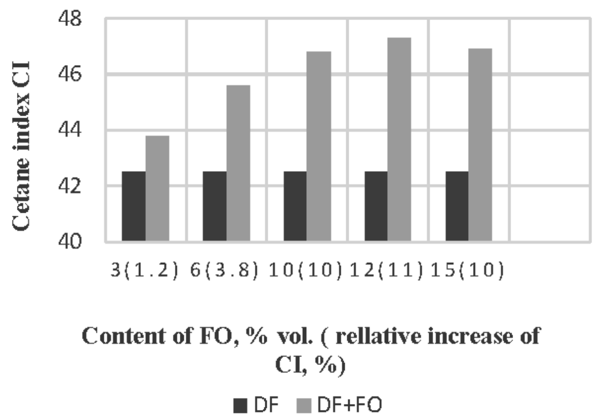


Fig. 10. Comparison of cetane indices of diesel fuel (DF) and the fuel mixture (DF+FO) at different concentrations of FO in diesel fuel

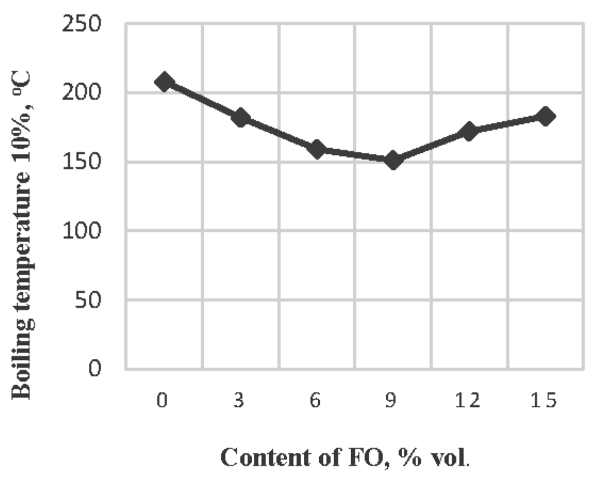


Fig. 11. Dependence of the boiling point of the 10% fraction of the fuel mixture on the concentration of fusel oil (FO) in diesel fuel

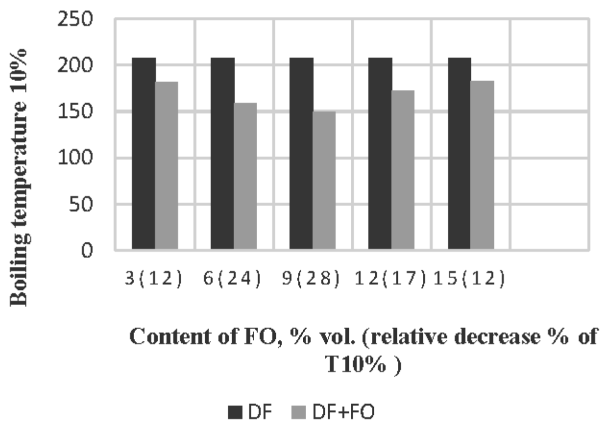


Fig. 12. Comparison of boiling points of the 10% fraction of diesel fuel (DF) and the fuel mixture (DF+Fusel Oil) at different concentrations of fusel oil in diesel fuel

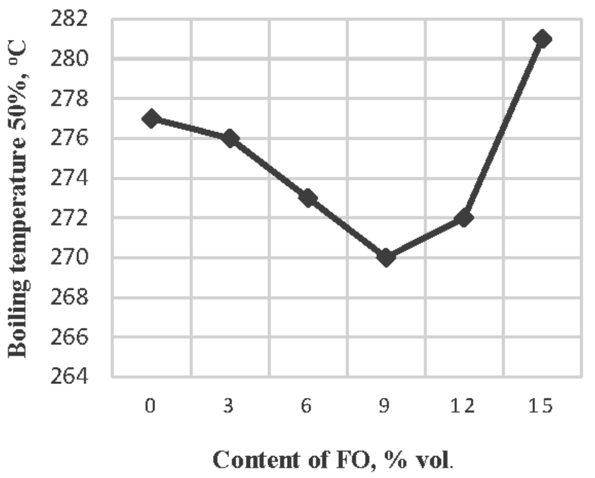


Fig. 13. Dependence of the boiling point of the 50% fraction of the fuel mixture on the concentration of fusel oil (FO) in diesel fuel

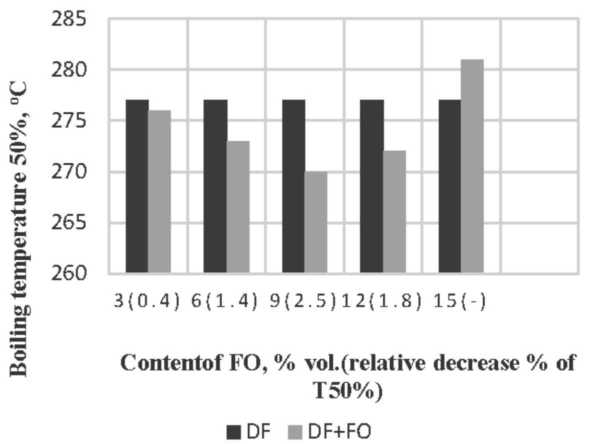


Fig. 14. Comparison of boiling points of the 50% fraction of diesel fuel (DF) and the fuel mixture (DF+Fusel Oil) at different concentrations of fusel oil in diesel fuel

completeness of its combustion and the uniformity of its supply to the engine cylinders. All these parameters have a positive effect on reducing emissions of carbon monoxide and nitrogen oxides into the atmosphere. The optimal concentration of fusel oil additives to gasolines is in the range of 5 to 7% by volume.

Fusel oil additives also positively affect the main parameters that can influence the ecology of diesel fuels. When fusel oil is added, the density and viscosity of the fuel decrease, which facilitates its spraying, ignition, and leads to better combustion, resulting in less fuel consumption. It is important that the reduction in the density of the fuel mixture can cause a decrease in the amount of aromatic hydrocarbons in it, which will positively affect the composition of engine exhaust gases. The use of fusel oil additives allows increasing the cetane index, which ensures cleaner and faster fuel combustion and helps to reduce harmful emissions into the atmosphere. When fusel oil is added, the boiling point of 10% and 50% of the fuel mixture fraction decreases, which leads to improved engine operation in various modes; easing its starting properties in cold conditions, and improving engine maneuverability. This means a decrease in the amount of carbon monoxide and nitrogen oxides in emissions from car engines.

The addition of fusel oil to diesel fuels helps to improve their ecological parameters and ensures their support according to Euro standards. The optimal concentration of fusel oil additives to diesel fuel is in the range of 10 to 12% by volume.

## REFERENCES

1. *Terentjev O.M., Sergienko M.I., Smolajr V.G.* Vplyv promyslovogo avtomobilnogo transportu na navkolyshne seredovyshche // Energetyka: Ekonomika, Tekhnologii, Ekologiya. – 2020. – Vol.3. – P.85-91.

2. *Ashok B., Denis Ashok S., Ramesh Kumar C.* LPG diesel dual fuel engine – a critical review // Alex. Eng. J. – 2015. – Vol.54. – No. 2. – P.105-126.

3. *Rusilo P.O., Kostuk V.V., Afonin V.M.* Vplyv na dovkillya avtomobilnogo transportu na vsikh stadiyakh yogo zhyttevogo tsyklu // Naukovyi Visnyk NLTU Ukrainy. – 2008. – Vol.18. – No. 3. – P.85-89.

4. *The research* of spark ignition engine fuel economy and environmental performance with using the fuel containing ethanol / Tsiuman M.P., Shevchuk I.O., Artemenko R.V., Borysko S.H. // Visnyk National Transport University. Series «Technical Sciences». – 2017. – Vol.1. – No. 37.

5. *Shehata W.M., Shoaib A.M.* Simple optimization method for partitioning purification of hydrogen networks // Egypt. J. Pet. – 2015. – Vol.24. – No. 1. – P.87-95.

6. *Gutarevich Y.F., Trifonov D.M., Sirota A.V.* A study of fuel efficiency and environmental performance of the car ZAZ-1102 when working in warm-up mode on the road // Visnyk National Transport University. Series «Technical Sciences». – 2017. – Vol.1. – No. 37.

7. *Roberts A., Brooks R., Shipway P.* Internal combustion engine cold-start efficiency: a review of the problem, causes and potential solutions // Energy Convers. Manag. – 2014. – Vol.82. – P.327-350.

8. *Mikucka W., Zielinska M.* Distillery stillage: characteristics, treatment, and valorization // Appl. Biochem. Biotechnol. – 2020. – Vol.192. – No. 3. – P.770-793.

9. *Reiter M.S., Kockelman K.M.* The problem of cold starts: a closer look at mobile source emissions levels // Transp. Res. D: Transp. Environ. – 2016. – Vol.43. – P.123-132.

10. *Vojtov V., Karnaux M., Dacenko M.* Tekhniko-ekspluatatsiini ta ekologichni pokaznyky dyzelnykh dvyguniv z vykorystanyam biodyzelya // Technika i Technologii APK. – 2009. – Vol.1. – P.13-17.

11. *Demirbas A.* Biodiesel: a realistic fuel alternative for diesel engine. – London: Springer-Verlag London Ltd, 2008. – 208 p.

12. *Terentiev O., Sergienko N., Huzan A.* Use of innovative systems for efficient drilling of wells in the quarry of Ukraine // Energetyka: Ekonomika, Tekhnologii, Ekologiya. – 2020. – No. 2. – P.71-78.

13. *Brezgina M.Y., Ludyn A.M., Reutskyy V.V.* Synthesis ether alcohol-based fusel oil // Bulletin of the National University «Lviv Polytechnic». Chemistry, Technology Matters and Use of Them. – 2017. – No. 868. – P.112-117.

14. *Kogushko M.I., Ludyn A.M.* Vplyv spyrtovykh vidkhodiv na yakist' motornykh palyv // Visnyk Natsional'noho Universytetu «L'vivs'ka Politekhnika». Seriya: Khimiya, Tekhnolohiya Rechovyn ta yikh Zastosuvannya. – 2007. – Vol.590. – P.195-199.

15. *Semytkivska T.O.* Analiz zakordonnykh dyzelnykh palyv ta perspektyvy pokrashchenya yikh ekologichnykh kharakerystyk // Technology Audit and Production Reserves. – 2015. – Vol.5. – No. 7(25). – P.16-21.

Received 24.02.2025

## ЗАСТОСУВАННЯ СПИРТОВИХ ВІДХОДІВ ДЛЯ ПОКРАЩЕННЯ ЕКОЛОГІЇ МОТОРНИХ ПАЛИВ

***Анатолій Лудин, Віктор Реутський, Володимир Реутський***

В даній статті проаналізовано вплив відходів спиртового виробництва на екологічні параметри моторних палив і можливості їх використання для зменшення забруднення навколишнього середовища від автомобільного транспорту. Показано, що добавки спиртових відходів покращують пускові властивості двигуна в холодних умовах, полегшують випарювання палива, позитивно впливають на повноту його згоряння та рівномірність його подачі в циліндри двигуна. Усі ці параметри позитивно впливають на зменшення викидів карбюраторним двигуном оксиду вуглецю, оксидів азоту та бензо[а]пірену в атмосферу. Оптимальна концентрація добавок сивушної олії до бензинів знаходиться в інтервалі від 5 до 7 об.%. Виявлено, що добавки спиртових відходів покращують фракційний склад дизельних палив. При додаванні сивушної олії відбувається пониження густини та в'язкості палива, що полегшує його розпил, запалювання та веде до кращого згоряння, в результаті чого витрачається менше палива. Важливим є те, що пониження густини паливної суміші може спричинити зменшення в ній кількості ароматичних вуглеводнів, що позитивно вплине на склад відпрацьованих газів двигунів. Використання добавок сивушної олії дозволяє підвищити цетановий індекс, що забезпечує більш чисте та швидке згоряння палива та сприяє зниженню шкідливих викидів в атмосферу. При додаванні сивушної олії понижується температура википання 10% та 50% фракції паливної суміші, що веде до покращення роботи дизельного двигуна на різноманітних режимах; полегшення його пускових властивостей в холодних умовах, поліпшення маневреності двигуна. Додавання сивушної олії до дизельних палив сприяє поліпшенню їх екологічних параметрів і забезпечує їх підтримку за стандартами Євро. Оптимальна концентрація добавок сивушної олії до дизельного палива знаходиться в інтервалі від 10 до 12 об.%.

**Ключові слова**: сивушна олія, екологія, карбюраторний двигун, дизельний двигун, бензин, цетановий індекс, дизельне паливо.

## APPLICATION OF ALCOHOL WASTE TO IMPROVE THE ECOLOGY OF MOTOR FUELS

*Anatoliy Ludyn* *, *Viktor Reutskyy, Volodymyr Reutskyy*
**Lviv Polytechnic National University, Lviv, Ukraine**
* **e-mail: anatolii.m.ludyn@lpnu.ua**

This article analyzes the impact of alcohol production waste on the ecological parameters of motor fuels and the possibilities of their use to reduce environmental pollution from road transport. It was found that the addition of alcohol waste improves the starting properties of the engine in cold conditions, facilitates fuel evaporation, and positively affects the completeness of its combustion and the uniformity of its supply to the engine cylinders. All these parameters have a positive effect on reducing emissions of carbon monoxide, nitrogen oxides, and benzo[a]pyrene into the atmosphere by a carburetor engine. The optimal concentration of fusel oil additives to gasoline is in the range of 5 to 7% by volume. It was found that the addition of alcohol waste improves the fractional composition of diesel fuels. When fusel oil is added, the density and viscosity of the fuel decrease, which facilitates its spraying and ignition, and leads to better combustion, resulting in less fuel consumption. It is important that the reduction in the density of the fuel mixture can cause a decrease in the amount of aromatic hydrocarbons in it, which will positively affect the composition of engine exhaust gases. The use of fusel oil additives allows increasing the cetane index, which ensures cleaner and faster fuel combustion and helps to reduce harmful emissions into the atmosphere. When fusel oil is added, the boiling point of 10% and 50% of the fuel mixture fraction decreases, which leads to improved diesel engine operation in various modes; easing its starting properties in cold conditions, and improving engine maneuverability. The addition of fusel oil to diesel fuels helps to improve their ecological parameters and ensures their compliance with Euro standards. The optimal concentration of fusel oil additives to diesel fuel is in the range of 10 to 12% by volume.

**Keywords**: fusel oil; ecology; carburetor engine; diesel engine; gasoline; cetane index; diesel fuel.

**REFERENCES**

1. Terentjev OM, Sergienko MI, Smolajr VG. Vplyv promyslovogo avtomobilnogo transportu na navkolyshne seredovyshche [The impact of industrial road transport on the environment]. *Energetyka: Ekonomika, Tekhnologii, Ekologiya.* 2020; 3: 85-91. (*in Ukrainian*).

2. Ashok B, Denis Ashok S, Ramesh Kumar C. LPG diesel dual fuel engine – a critical review. *Alex Eng J.* 2015; 54(2): 105-126. doi: 10.1016/j.aej.2015.03.002.

3. Rusilo PO, Kostuk VV, Afonin VM. Vplyv na dovkillya avtomobilnogo transportu na vsikh stadiyakh yogo zhyttevogo tsyklu [Impact on the efficiency of automobile transport at all stages of its life cycle]. *Naukovyi Visnyk NLTU Ukrainy.* 2008; 18(3): 85-89. (*in Ukrainian*).

4. Tsiuman MP, Shevchuk IO, Artemenko RV, Borysko SH. The research of spark ignition engine fuel economy and environmental performance with using the fuel containing ethanol. *Visnyk National Transport University. Series «Technical Sciences».* 2017; 1(37).

5. Shehata WM, Shoaib AM. Simple optimization method for partitioning purification of hydrogen networks. *Egypt J Pet.* 2015; 24(1): 87-95. doi: 10.1016/j.ejpe.2015.02.009.

6. Gutarevich YF, Trifonov DM, Sirota AV. A study of fuel efficiency and environmental performance of the car ZAZ-1102 when working in warm-up mode on the road. *Visnyk National Transport University. Series «Technical Sciences».* 2017; 1(37).

7. Roberts A, Brooks R, Shipway P. Internal combustion engine cold-start efficiency: a review of the problem, causes and potential solutions. *Energy Convers Manag.* 2014; 82: 327-350. doi: 10.1016/j.enconman.2014.03.002.

8. Mikucka W, Zielinska M. Distillery stillage: characteristics, treatment, and valorization. *Appl Biochem Biotechnol.* 2020; 192(3): 770-793. doi: 10.1007/s12010-020-03343-5.

9. Reiter MS, Kockelman KM. The problem of cold starts: a closer look at mobile source emissions levels. *Transp Res D Transp Environ.* 2016; 43: 123-132. doi: 10.1016/j.trd.2015.12.012.

10. Vojtov V, Karnaux M, Dacenko M. Tekhniko-ekspluatatsiini ta ekologichni pokaznyky dyzelnykh dvyguniv z vykorystanyam biodyzelya [Technical, operational and environmental indicators of diesel engines using biodiesel]. *Technika i Technologii APK.* 2009; 1: 13-17. (*in Ukrainian*).

11. Demirbas A. *Biodiesel: a realistic fuel alternative for diesel engine.* London: Springer-Verlag London Ltd; 2008. 208 p. doi: 10.1007/978-1-84628-995-8.

12. Terentiev O, Sergienko N, Huzan A. Use of innovative systems for efficient drilling of wells in the quarry of Ukraine. *Energetyka: Ekonomika, Tekhnologii, Ekologiya.* 2020; (2): 71-78. doi: 10.20535/1813-5420.2.2020.220713.

13. Brezgina MY, Ludyn AM, Reutskyy VV. Synthesis ether alcohol-based fusel oil. *Bulletin of the National University «Lviv Polytechnic». Chemistry, Technology Matters and Use of Them.* 2017; (868): 112-117. (*in Ukrainian*).

14. Kogushko MI, Ludyn AM. Vplyv spyrtovykh vidkhodiv na yakist' motornykh palyv [The influence of alcohol waste on the quality of motor fuels]. *Visnyk Natsional'noho Universytetu «L'vivs'ka Politekhnika». Seriya: Khimiya, Tekhnolohiya Rechovyn ta yikh Zastosuvannya.* 2007; 590: 195-199. (*in Ukrainian*).

15. Semytkivska TO. Analiz zakordonnykh dyzelnykh palyv ta perspektyvy pokrashchenya yikh ekologichnykh kharakerystyk [Analysis of foreign diesel fuels and prospect of improvement of their ecological performance]. *Technology Audit and Production Reserves.* 2015; 5(7(25): 16-21. (*in Ukrainian*). doi: 10.15587/2312-8372.2015.51420.