INFLUENCE OF DIESEL VEHICLES ON THE BIOSPHERE

Purpose. To identify environmental climatic impacts resulting from the biodiesel fuel use for vehicles (Vs).

Methodology. The methods are based on computation of natural resource consumption and toxic emission with the help of environmental footprint calculator being a software program.

Findings. The results of integral assessment of the environmental impact (namely, consumption of water, power, natural resources, and emission of greenhouse gases CO₂ and NOₓ in terms of such base traction trucks as VOLVO FM, FH, FE, and FL) were computed for biodiesel fuel types B0, B7, B30, B100 depending upon different standards of EURO propellants. Both positive and negative environmental impact factors have been determined for consuming biofuels during full lifecycle of Vs. It has been defined that minor decrease in CO₂ emission owing to the use of standard modern biodiesel fuel is followed by significant increase in NOₓ emission as well as power and water consumption in terms of first-generation biodiesel fuel utilization. VOLVO FE Vs were applied for comparative analysis of environmental impact by first-generation biodiesel fuel (i.e. B7, B30, B100) and second-generation fuel being hydrotreated vegetable oil (HVO). Similar tendencies were recognized. Moreover, opportunity to apply biodiesel fuels along with other measures decreasing CO₂ emission was analyzed.

Originality. Originality is stipulated by the use of the integrated assessment of impact of vehicles on climate change as well as use of natural resources while applying biodiesel fuel for vehicles.

Practical value. It is possible to forecast environmental consequences resulting from the use of various biodiesel fuels for Vs.

Keywords: greenhouse effect, biodiesel fuel, life cycle of Vs, nitrogen oxides

Introduction. Currently, Ukrainian automotive fleet includes almost 11 million units of vehicles (Vs) whose structure is as follows [1, 2]: cargo vehicles are 15.5 %; buses are 2.6 %; light Vs are 81.9 %. Almost all cargo Vs [3] and buses [4] consume diesel fuel, which has unfavourable effect on the environment. These transport vehicles are not the only consumers of diesel fuel which is also used by such industrial conveyance facilities as railway locomotives [5] and mine diesel locomotives [6].

Use of alternative fuel types for Vs is one of the key tendencies to avoid critical environmental impact. Among other things, it concerns biodiesel fuels. Measures, minimizing environmental impact by vehicles and their infrastructure may improve drastically the environmental quality influencing positively the human health. Evaluating efficiency of certain tendencies should involve integrated approach to analyze motor transport operation during full lifecycle. Such an approach will help identify the optimum balance between positive and negative consequences of any decision implementation (namely, biodiesel fuel) and prevent the increase in consumption of natural resources as well as emission of definite substances in terms of the decreased effect of other environmental pollutants. According to data by [1], Ukraine ranks 29th in the world rating as for the CO₂ emission being 196.4 million tons. In the context of the decreasing industrial production and an increasing number of Vs, automotive transport becomes more important for the process. It is known that 18 % of the CO₂ amount falls at transportation facilities; mainly, road vehicles [2]. In Ukraine, 10–15+ motor vehicles are a large portion of Vs; they cannot comply with the current European environmental standards. The majority of the vehicles are poorly adapted for alternative fuel types, specifically for biodiesel ones. In this regard, Ukraine should apply such environmental measures that are suitable for old Vs as well.

Topicality of the research is stipulated by the fact that currently, motor transport is a powerful source of global anthropogenic emission of carbon monoxide; hence, determination of tendencies to reduce natural resource consumption as well as emission of toxic substances during Vs life cycle will make it possible to minimize its impact on climatic change of our planet.

Literature review. The European Union tightened restrictions for carbon dioxide emission by Vs with ICEs. The European Parliament determined the targeted indicator of CO₂ reduction emission as 37.5 % up to 2030 to compare with 2021 limit. Temporary goal is to reduce CO₂ emission by 15 % for vehicles up to the year 2025. Also, legislation has determined CO₂ emission standards for new minibuses at the level of 31 % up to 2030 [7]. Mainly, power consumption in a transport sector depends upon:

- traffic intensity;
- diversity of vehicles (ratio between automobiles, buses, and so on);
- consumption of different fuels and their ratio in terms of each transport type;
- power consumption (inclusive of efficiency of the fuel use by different transport types).

The targets to reduce GG emission for the EU in the long run have been identified by the European Commission in the Road Map to transit to competitive low-carbon economy up to the year 2050. Provision is made for the EU countries to reduce GG emission by 60 % in the context of transport sector up to 2050 to compare with 1990 [8].

Several key tendencies to reduce carbon dioxide emission by vehicles have been proposed according to BLUE MAP scenario. The International Energy Agency considers the tendencies [9]. Paper [7] analyzes them in detail. According to paper [9], the following is preferred in the decrease in CO₂ emission by Vs:
- increase in fuel economy (52 %);
- use of biofuels (17 %);
- use of electric vehicle and vehicles with the combined energy units (17 %);
- use of hydrogen (14 %).

Paper [2] analyzes in detail potential ways to reduce both power consumption and CO₂ emission in Ukraine. Three tendencies are singled out:

Improvement of the efficiency of operating road vehicles is the most powerful measure in the context of current Ukraine. It involves travel managing and planning; control technology of a vehicle operation; health control of a vehicle; improvement of the fuel quality; reduction in exhaust gas (EG) toxicity, and so on.

Improvement of transport system efficiency together with the enhancement of different transport types and infrastructure advance; development of information systems in terms of transport sector as well as interaction between different transport types; improvement of traffic management and others are important measures too.

It is also required to substitute car fleet by more energetic designs of vehicles.

Optimization temporal combination of the abovementioned measures will help provide fulfillment of international obligations of Ukraine to protect the environment. Among other things, it concerns reduction of CO₂ emission.

Several scientific sources emphasize the importance of biofuel role consideration for the potential GG emission reduction during a life cycle compared with fossil fuel to formulate and develop policies concerning selection of the best biofuel types of the first, second, and third generations [10, 11]. CO₂ emission, resulting from biomass combustion, is neutral from the viewpoint of climate owing to the fact that the biomass captures CO₂ during cultivation [12]. Naturally, vegetable raw materials are consumed by aerobic organisms. The biogenic process releases certain amount of energy like technogenic oxidation process does (i.e. fuel combustion in engine).

Generally, biogas, bioethanol, and biodiesel fuel are considered as biofuel for transport. We considered environmental issues to apply biodiesel fuel for Vs. For instance, many researchers believe that diesel engines have optimum ratios of size, weight, operational, environmental, power, and economic characteristics remaining an energy unit having no alternative for quite a long time [13].

The data from paper [8] support the idea that currently nitrogen oxide (NOₓ) is the determinant air pollutant in cities. Suspended particles (PM₁₀), mainly produced by Vs with ICEs, go second [8]. As a result, owing to the improved efficiency of engine operation, improvement of fuel economy of Vs rises temperature of a thermodynamic cycle and, hence, increases emission of nitrogen oxide itself. The increased share of diesel Vs as well as use of bioethanol as a part of the mixed gasolines initiates increase in emission of NOₓ and other pollutants.

It goes without saying that a manufacturing technique (i.e. raw material preparation; reaction conditions; and biodiesel fuel purification) influences heavily quality of the biodiesel fuel. There are two basic approaches to solve the problem. Approach one means use of the current biodiesel fuel types and minimization of disadvantages of their operational characteristics while applying the mixed fuels with low content of biodiesel fuel (for instance, B5–B7).

In this context, disadvantages of fuel characteristics of biodiesel will have minor influence on the combustive system. On the other hand, engine modification (i.e. fuel tank heating; manufacturing of hoses and space fillers from the materials being resistant to biodiesel, and so on) is proposed to be applied for biodiesel consumption.

Approach two is intended to manufacture biodiesel with higher operational characteristics and lower prime cost [14].

According to the new EU requirements, acting from the F° of May 2018, diesel fuel is complemented by the biocomponents of two types: FAME (Fatty Acid Methyl Esters) and HVO (Hydrotreated Vegetable Oil). Currently, FAME is the more popular global fuel supplement. It belongs to biodiesel of the first generation. Rapeseed oil, being mainly used in the EU countries to manufacture biodiesel fuel, is raw material for FAME. If FAME is applied abundantly then motor issues may arise. HVO is fuel supplement of the second generation. Organic bio-waste (for instance, hydrotreated vegetable oil, fish liver oil, etc.) is raw materials for HVO. Being the second-generation bioadditive, HVO is quite applicable for all Vs. FAME, being the first-generation bioadditive, cannot be used for old vehicle models [8, 15].

To obtain equal amount of biodiesel energy, raw material crops should occupy three times more land than sugar cane to manufacture ethanol. Moreover, CO₂ emission in the process of raw material cultivation for biodiesel is 4–14 times higher than that one for bioethanol and biomethane [13]. The abovementioned is the significant obstacle preventing biodiesel fuel expansion [13]. Sunflower and rapeseed cultivation is much less efficient as for the biofuel amount obtained per hectare. Common yield of soybeans, cultivated in Brazil, is 600–700 l of diesel equivalent per hectare; in turn, rapeseed yield in Europe is almost 1100 l of diesel equivalent per hectare. As a rule, EU countries apply rapeseed oil to manufacture biodiesel. According to the data by International Energy Agency (IEA), biofuel competes with cultivation of plant foods [16].

Biodiesel fuel with FAME is suitable for the standard diesel engines. It may be applied in the pure state (B100) or as a mixture with traditional diesel fuels. B5, B7, and sometimes B10 are the most popular biodiesel types in the EU.

According to WTW analysis, applied to energy carriers and their use by vehicles, reduction of natural resource consumption as well as emission of toxic substances should be introduced during full life cycle of Vs. WTW involves raw material extraction, production of energy carrier, its delivery to a vehicle, and end use. The idea was applied by paper [15] to analyze environmental impact at each stage of biofuel manufacturing for the basic industrial technological processes. A process is divided into four main stages:

- an agricultural stage during which high energy consumption and nitrogen oxide emission, resulting from mineral fertilizer use, are observed. In addition, biofuel production competes for the land where food is cultivated;
- an industrial stage during which methyl FAMEs are obtained using oil raw materials. The stage demonstrates high consumption level of power, natural gas, electricity, ethanol, and so on;
- a transportation stage during which CO₂ emission depends upon delivery distance of the raw material;
- a storage stage of the end product which should take into consideration the fact that expiration date of biodiesel fuel does not exceed three months.

Consequently, if carbon dioxide emission is taken into consideration in the process of biodiesel use, then 100 % biofuel (for instance, B100) is CO₂ neutral. However, the integrated biofuel impact on the sustainable development can be assessed while applying exclusively WTW analysis methods.
involve broader environmental aspects starting from GG emission and fossil mineral depletion up to the aspects of land acidification; changes in land use; and increase in water consumption as well as substance toxicity used to produce FAME and formed as by-products while its manufacturing.

The analysis of the problem to reduce carbon dioxide emission by vehicles demonstrates the following:

- the accelerated global warming process is one of the cardinal present-day problems where vehicles play a leading role in the increase in carbon dioxide emission;
- improvement of fuel economy of Vs; use of biofuels; introduction of combined energy units as well as hydrogen fuel cells are the main ways to reduce CO₂ emission;
- among the diverse raw materials applied for biofuels (i.e. biogas, bioethanol, and biodiesel), combusive techniques of biodiesel have the heaviest impact on the environment independently of a production stage;
- biodiesel consumption results in the decreased emission of toxic substances and CO₂. Nevertheless, the process is often followed by the increased emission of nitrogen oxides. In addition, significant positive effect is observed if bioadditives are involved (starting from B20). Currently, the EU countries mainly use B5 and B7 fuels.

Hence, the purpose is to identify the integrated impact on the climate change and natural resource consumption by VOLVO traction trucks during their whole life cycle if biodiesel is applied.

The following problems have to be solved to achieve the purpose:

- to apply environmental footprint calculator to assess CO₂ and NOx emission as well as water, power, and natural resource consumption by VOLVO Vs using various biofuels;
- to compare the environmental impact by the base models of traction trucks in terms of their consumption of various biofuels and in terms of different requirements of EURO standards as to the fuel;
- to identify both positive and negative environmental impact factors while using biofuel in terms of VOLVO Vs, and analyze their ratio;
- to analyze current prospects to implement different measures for CO₂ emission reduction.

Methods. Basic models of VOLVO FM, FH, FL, and FE Vs were the subject of our research. Environmental Footprint Calculator software was developed by the Corporation to improve ecological indices of the traction trucks and reduce their environmental impact [17]. The assessment was made for full lifecycle of the Vs. The environmental impact was analyzed in terms of both current diesel fuel types and potential ones as well as in terms of different fuel standards (Euro 3–6). B7 and B30 marks mean consumption of biofuel containing 7 and 30 % of FOAM respectively, mixed with the traditional diesel fuel. B0 is a petrol diesel fuel containing no additives. It is also possible to identify mass of Vs materials subjected to recycling. Average fuel consumption is 23LPKM; and distance driven for all the models is 100 000 km.

Evaluation of the impact of biodiesel types on the climatic change. VOLVO pays much attention to the problems of environmental impact during full lifecycle of Vs; among other things, it concerns trucks. Since the 1970s, emission of toxic gases by trucks has reduced by 90 %. Moreover, fuel consumption has reduced; and carbon dioxide emission in the process of a vehicle movement has decreased by 40 % [17] by VOLVO traction truck, consuming Euro-6, is half the size as well as almost by 80 % decreased amount of NOx emission.

Environmental Footprint Calculator helps users of VOLVO Vs evaluate efficiency of different tendencies reducing the truck impact on the climatic change as well as implement such measures providing efficient use of natural resources and lower carbon dioxide emission during full lifecycle of VOLVO Vs.

Fig. 1 demonstrates a calculation example as for the natural resource use and pollutant emission during full lifecycle of VOLVO FM in terms of B7 fuel consumption as well as Euro-5 standards. As Fig. 1 explains, almost all the amount of toxic pollution emission as well as material consumption takes place at a stage of the V operation. Fig. 2 shows results concerning the material consumption and the pollutant emission.

Table 1 represents calculation results of the pollutant emission as well as natural resource consumption upon a fuel type in terms of VOLVO FM traction truck model.

The calculations for standards concerning Euro-3 fuel have been performed since there are many 12–14 year old Vs in Ukraine inclusive of VOLVO traction trucks. They can consume such a fuel. It is known that currently Euro-6 standards function in the EU countries.

The program makes it possible to calculate toxic substance emission and natural resource consumption for the second-generation biodiesel fuel; namely, HVO is meant for certain models of VOLVO traction trucks. As an example, Table 2 represents calculation results for VOLVO FE in terms of HVO consumption. Similar tendencies are observed for other models of the Vs.

As it is understood, biodiesel use reduces significantly (i.e. by more than 2–3 times) carbon dioxide emission if HVO fuel is B0 consumed; in addition, more than 2 times’ decrease in water consumption occurs. However, nitrogen oxide emission increases for all the fuel standards (for instance, the increase is 2.5 times if Euro-6 is applied). In this context, 38 % increase in power consumption is also observed during full V lifecycle to compare with B0 in terms of Euro-6 consumption.

Dependence of the decreased carbon dioxide emission upon the Euro standards and fuel type was analyzed. Almost similar results were obtained for all the models. Table 3 dem-

![Fig. 1. Natural resource consumption and pollutant emission during full lifecycle of VOLVO FM truck](image)

![Fig. 2. Calculation results of the natural resource consumption and pollutant emission in terms of B100 fuel use](image)
Dependence of the pollutant emission and natural resource consumption upon a fuel type in terms of VOLVO FM trucks

| Fuel type | CO₂ emission; kg of CO₂ equivalent | Power consumption; MWh | Water consumption; m³ | NOx emission; kg | Mass of recycling materials; kg |
|-----------|------------------------------------|------------------------|-----------------------|-----------------|--------------------------------|
| Euro-3 fuel | | | | | |
| B0 | 1 680 000 | 6350 | 1920 | 10 500 | 3390 |
| B7 | 1 630 000 | 6630 | 2290 | 10 800 | 3390 |
| B30 | 1 490 000 | 7540 | 3510 | 11 800 | 3390 |
| Euro-4 fuel | | | | | |
| B0 | 1 690 000 | 6430 | 2070 | 7390 | 3490 |
| B7 | 1 650 000 | 6700 | 2440 | 7630 | 3490 |
| B30 | 1 500 000 | 7620 | 3670 | 8340 | 3490 |
| Euro-5 fuel | | | | | |
| B0 | 1 700 000 | 6440 | 2240 | 4250 | 3490 |
| B7 | 1 650 000 | 6720 | 2610 | 4410 | 3490 |
| B30 | 1 510 000 | 7630 | 3830 | 4880 | 3490 |
| Euro-6 fuel | | | | | |
| B0 | 1 710 000 | 6510 | 10 000 | 1050 | 3520 |
| B7 | 1 670 000 | 6790 | 10 400 | 1110 | 3520 |
| B100 | 1 070 000 | 10 500 | 15 300 | 1840 | 3520 |

Dependence of the pollutant emission and natural resource consumption upon a fuel type in terms of VOLVO FE trucks

| Fuel type | CO₂ emission; kg of CO₂ equivalent | Power consumption; MWh | Water consumption; m³ | NOx emission; kg | Mass of recycling materials; kg |
|-----------|------------------------------------|------------------------|-----------------------|-----------------|--------------------------------|
| Euro-3 fuel | | | | | |
| B0 | 228 000 | 877 | 259 | 1400 | 1690 |
| B7 | 222 000 | 913 | 308 | 1440 | 1690 |
| B30 | 203 000 | 1030 | 469 | 1570 | 1690 |
| HVO | 95 600 | 1230 | 96 | 1640 | 1690 |
| Euro-4 fuel | | | | | |
| B0 | 230 000 | 886 | 350 | 989 | 1690 |
| B7 | 225 000 | 922 | 399 | 1020 | 1690 |
| B30 | 205 000 | 1040 | 559 | 1110 | 1690 |
| HVO | 97 600 | 1240 | 186 | 1220 | 1690 |
| Euro-5 fuel | | | | | |
| B0 | 231 000 | 888 | 372 | 576 | 1690 |
| B7 | 225 000 | 925 | 421 | 596 | 1690 |
| B30 | 206 000 | 1040 | 581 | 658 | 1690 |
| HVO | 98 100 | 1240 | 208 | 811 | 1690 |
| Euro-6 fuel | | | | | |
| B0 | 232 000 | 895 | 438 | 157 | 1700 |
| B7 | 227 000 | 932 | 487 | 165 | 1700 |
| B100 | 148 000 | 1422 | 1140 | 260 | 1700 |
| HVO | 98 200 | 1240 | 208 | 387 | 1700 |

The analysis of carbon dioxide emission shows that biodiesel consumption instead of traditional B0 fuel demonstrates increase in CO₂ emission for each basic model. Under equal conditions, maximum absolute values are observed in terms of VOLVO FM models. In the context of each of the standards and each fuel type, considered by the paper, VOLVO FE vehicles demonstrate minimum CO₂ emission values. As the data from Table 3 support, changes in fuel standards from Euro-3 to Euro-6 have minor impact on CO₂ emission. As for the B7 fuel, average CO₂ emission reduce is only 2.65 % to compare with B0. In turn, such a composition of biodiesel fuels, applied currently worldwide, is the most popular one. Significant emission reduction is observed if only essential increase in biocomponents in biodiesel occurs. For instance, it is 11.23 % averagely for B30 fuel (Table 3); it is 37.4 % for B100 fuel subject to Euro-6 standards (Table 3).

Hence, changes in fuel standards from Euro-3 to Euro-6 are not important for CO₂ emission. For the majority of currently popular biodiesel fuels (B7), the reduced CO₂ emission, compared to B0, is not essential. Significant positive effect is seen starting from B30 fuel. Dependence of the increased nitrogen oxide emission upon the Euro standard and fuel type was analyzed for each model of the traction truck. The results are similar for all the models. Table 4 represents their average values. While calculating, NOx emission for B0 fuel it was assumed as 100 %.

The analysis of nitrogen oxide emission shows the following: if biodiesel is consumed instead of traditional B0 fuel, its increase can be observed for each traction truck model. Under equal conditions, maximum absolute values of nitrogen oxide emission are determined for VOLVO FM models (Table 1). In each case, the increased share of bioadditives within biodiesel (i.e. from B0 to B100) results in the increased nitrogen oxide emission. In terms of B7 fuel, the increase in nitrogen oxide emission is 2.86 up to 5.4 % depending upon the Euro standard (Table 4); it is 11.82 up to 15.12 % for B30 %. B100 fuel demonstrates maximum NOx emission increase being 25.3 %.

It goes without saying that all the models demonstrate absolute reduction of nitrogen oxide emission if standards are changed from Euro-3 to Euro-6 for similar fuel types. For instance, in this case, almost 10 times’ reduction in nitrogen oxide emission is for VOLVO FE model if B0 fuel is consumed.

Table 3

| Fuel type | Euro-3 | Euro-4 | Euro-5 | Euro-6 |
|-----------|--------|--------|--------|--------|
| B0 | 100 % | 100 % | 100 % | 100 % |
| B7 | −3.0 % | −2.4 % | −2.9 % | −2.3 % |
| B30 | −11.30 % | −11.2 % | −11.2 % | − |
| B100 | − | − | − | −37.4 % |

Table 4

| Fuel type | Euro-3 | Euro-4 | Euro-5 | Euro-6 |
|-----------|--------|--------|--------|--------|
| B0 | 100 % | 100 % | 100 % | 100 % |
| B7 | +2.83 % | +3.35 % | +4.07 % | +5.44 % |
| B30 | +11.82 % | +12.75 % | +15.12 % | − |
| B100 | − | − | − | +71.2 % |
It should be noted that the global warming potential (GWP) of NO\textsubscript{x} is quite higher than that of CO\textsubscript{2}. The fact has to be especially focused on when motor transport impact of the greenhouse effect is taken into consideration. In our case, the reduction of CO\textsubscript{2} emission in the process of any biodiesel consumption, being a positive effect, is followed by the increased NO\textsubscript{x} emission whose impact on the greenhouse effect is much more serious.

The obtained results correlate with the data, concerning other trucks (for instance, Д—245.12С) [18]. Paper [18] proposes the methods optimizing biodiesel composition consisting of diesel fuel and rapeseed (or sunflower) oil mixture applied in tests where diesel engines Д—245.12С were involved. Smoke and nitrogen oxide content in the diesel engines were selected as the basic parameters to optimize composition of biodiesel fuels. In the process of testing Д—245.12С diesel engine, B20 fuel, consisting of petrodiesel and methyl ethers of rapeseed oil (MERO), demonstrated 10.2 % decrease in NO\textsubscript{x} emission compared to B0; nevertheless, B60 demonstrates 6.49 % increase in NO\textsubscript{x} emission. The aforementioned correlates with our results, obtained as for the NO\textsubscript{x} emission during the increase in bioadditive share within diesel fuel for VOLVO trucks. It should be mentioned that sunflower oil-based biodiesel demonstrates 4.4 % reduce in NO\textsubscript{x} emission only starting from B15 compared to B0. Moreover, further increase in bioadditive share up to 40 % (B40) cannot influence NO\textsubscript{x} emission reduction.

The analysis of water consumption increase (Table 5) dependence upon the Euro standards and fuel type showed almost similar results for all the models. Table 5 represents their average values. Water consumption by B0 fuel was assumed as 100 % during the calculations.

Analysis of water demand showed that biodiesel consumption instead of B0 demonstrates significant water intake in terms of each VOLVO model as well as each Euro standard. VOLVO FM models have the worst indices similarly to NO\textsubscript{x} and CO\textsubscript{2} emission (Table 1).

According to the data from Table 5, transition from B0 fuel to B7 fuel factors into 13.9 % increase in water consumption; use of B30 fuels results in 55—65 % increase (Table 5).

Paper [8] mentions that water consumption in the field of biofuel manufacturing influences social stability. Constant growth of biofuel production is the extra load on water resources of many areas suffering from their deficit [19]. It concerns both cultivation stage and a stage of the plant raw material processing into fatty acid methyl esters [15, 19].

In many situations, water deficit rather than land deficit may become the key limiting factor to produce raw materials for biofuel. Almost 70 per cent of fresh water in the world is consumed by agriculture. Many countries are suffering more and more from a scarcity of water resources for agrarian sector due to rising competition with residential sector and industrial sector. The problem is that biodiesel manufacturing involves significant water consumption. In this context, the greater bioadditive share is involved, the more water the fuel production will need.

Dependence of the increased power consumption upon the Euro standards and fuel type was analyzed. All the models demonstrated similar results shown in Table 6. Power consumption by B0 fuel was assumed as 100 % during the calculations. Power consumption during the full V lifecycle depends slightly upon the type of Euro standards for one truck model.

VOLVO FM models demonstrate the heaviest power consumption. It increases by 4.2 % if B7 fuel is applied (Table 6); the increase is 18 % in terms of B30 fuel. As Table 6 explains, significant increase is observed if B100 fuel is used.

It has been identified that increase of rapeseed oil content in biodiesel mixture prolongs its combustion; if the oil amount is more than 60 %, then the combustion process cannot terminate before the moment the exhaust valve of the engine opens.

Use of composite propellant B20 reduces the output by 1—2 % being almost insensible for operation. Use of pure biodiesel B100 decreases the output by almost 8 % to compare with diesel fuel.

The results made it possible to analyze the efficiency of biodiesel fuel in Kharkiv Region using VOLVO Fm. According to the data by the Regional Service Centre of the BSC of MIA of Ukraine, in general, 50 VOLVO FH traction trucks and one VOLVO FMX traction truck are registered in Kharkiv Region.

If we assume that the trucks consume B7 fuel, then NO\textsubscript{x} emission during the increase is 18 % in terms of B30 fuel. As Table 5 explains, the figure for 51 Vs is 1530 tons. However, consumption of water, power, and NO\textsubscript{x} emission will increase as follows: by 16 320 cubic meters of H\textsubscript{2}O for 51 vehicles; as well as 6.6 tons’ increase in NO\textsubscript{x} emission. Consequently, it is impossible to give unequivocally positive definition of the biodiesel fuel use in terms of its environmental impact.

The results support the idea that despite biodiesel fuel-petrrodiesel ratio, consumption of the former by any V model results in the decreased CO\textsubscript{2} emission while being followed by the increased NO\textsubscript{x} emission. The data help predict significant increase in water consumption if biofuel production is developed in Ukraine. The matter is that the country ranks almost last in Europe as for the provision of its own water resources per capita.

As it has been mentioned before, biofuel consumption is not the only measure to reduce carbon dioxide emission in the process of vehicle operation. We consider the ways, specified by paper [2], as more efficient ones for the current situation in Ukraine.

Stimulation of the production of alternative motor fuel types and generation of energy sources should rely exclusively on the integrated analysis of their efficiency taking into consideration each component inclusive of WTW analysis, expenditures connected with infrastructure [20], lifecycle of a vehicle [21], and so on.

**Conclusions.**

1. The key ways to reduce CO\textsubscript{2} emission by Vs were analyzed. The improved fuel economy of a vehicle, use of biofuels, combined energy units and hydrogen are among them.

2. Impact by the traditional and biodiesel fuel types on the climatic change was assessed in terms of VOLVO FM truck. Specialized software was applied. It was demonstrated that the traditional diesel fuel substituted by the biodiesel fuel really results in the decreased carbon dioxide emission; however, only B30 and B100 fuel types demonstrate significant decrease (i.e. 12 % and 62 % respectively. As for the typical current biodiesel B7, CO\textsubscript{2} emission decrease is not more than 3 %).

3. Stimulation of the production of alternative motor fuel types and generation of energy sources should rely exclusively

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### Table 5

| Fuel type | Euro-3 | Euro-4 | Euro-5 | Euro-6 |
|-----------|--------|--------|--------|--------|
| B0        | 100 %  | 100 %  | 100 %  | 100 %  |
| B7        | +12.82 % | +16.3 % | +12.53 % | +12.7 % |
| B30       | 54.70 % | +69.56 % | +64.65 % | —      |
| B100      | —      | —      | —      | +25.30 % |

### Table 6

| Fuel type | Euro-3 | Euro-4 | Euro-5 | Euro-6 |
|-----------|--------|--------|--------|--------|
| B0        | 100 %  | 100 %  | 100 %  | 100 %  |
| B7        | +4.25 % | +4.20 % | +4.18 % | +4.13 % |
| B30       | +18.15 % | +18.30 % | +17.87 % | —      |
| B100      | —      | —      | —      | +59.77 % |
14. Consumption of the second-generation biodiesel fuel HVO makes it possible to increase substantially (i.e. by more than 2–3 times) CO2 emission to compare with B0 fuel; in addition, it helps to halve water consumption. At the same time, nitrogen oxide emission experiences its 2.5 times’ increase along with the 38% increase in power consumption.

5. It is quite possible for current Ukraine to reduce CO2 emission, power consumption, and environmental impact by vehicles using more efficient measures than the use of biodiesel fuel if its disadvantages are taken into consideration. For instance, it can be done while improving the efficiency of transport system, vehicle control, and updating automobile fleet.

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Вплив дизельних транспортних засобів на біосфери

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Мета. Визначення екологічних наслідків для клімату застосування біодизельного палива на транспортних засо­бах (Т3).

Методика. Зазначена на розрахунку споживання природ­них ресурсів і емісій токищних речовин за допомогою комп’ютерної програми – екологічний калькулятор.

Результати. Результати комплексної оцінки впливу на довкілля, а саме, витрати води, енергії, природних ре­сурсів і емісії парникових газів СО2, NOx для базових мо­делей тягачів VOLVO FM, FH, FE, FL, були розраховані при роботі на біодизельному паливі В0, Б7, Б30, Б100 для різних стандартів EURO палива. Визначені позитивні й негативні фактори впливу на довкілля при використанні біопалив протягом усього життєвого циклу Т3. Встанов­лено, що незначне зменшення емісії СО2 при застосуванні ні типового сучасного біодизельного палива супрово­джується суттєвим зростанням емісії NOx, витрат води та енергії при використанні біодизельного палива першого покоління. На прикладі Т3 VOLVO FE проведено порів­няльній аналіз впливу на оточуюче середовище біоди­зельного палива першого (B7, B30, B100) та другого по­коління – гідроочищеної рослинної олії (HVO) – та вста­новлено однакові для них тенденції. Проаналізовано можливість застосування біодизельних палив поряд з ін­шими заходами зменшення емісії СО2.

Наукова новизна. Обумовлена застосуванням кількох комплексної оцінки впливу транспортних засобів на зміни клімату та споживання природних ресурсів при викорис­танні біодизельного палива на прикладі тягачів VOLVO.

Практична значимість. Полегшає у можливості прогноз­ування екологічних наслідків застосування різних біо­дизельних палив транспортними засобами.

Ключові слова: парниковий ефект, біодизельне паливо, життєвий цикл Т3, оксиди азоту

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