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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 CO_2, and NO_x 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 CO_2 emission owing to the use of standard modern biodiesel fuel is followed by significant increase in NO_x 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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 CO_2 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.

Optimum 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 CO_2 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]. CO_2 emission, resulting from biomass combustion, is neutral from the viewpoint of climate owing to the fact that the biomass captures CO_2 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 (NO_x) is the determinant air pollutant in cities. Suspended particles ($PM_{2.5}$), 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 NO_x 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 *1st* 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, CO_2 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 lifecycle 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 CO_2 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 only carbon dioxide emission is taken into consideration in the process of biodiesel use, then 100 % biofuel (for instance, B100) is CO_2 neutral. However, the integrated biofuel impact on the sustainable development can be assessed while applying exclusively WTW analysis methods involving 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 CO_2 emission;
- among the diverse raw materials applied for biofuels (i. e. biogas, bioethanol, and biodiesel), combustive 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 CO_2. 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 CO_2, and NO_x 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 CO_2 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 petrodiesel 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-

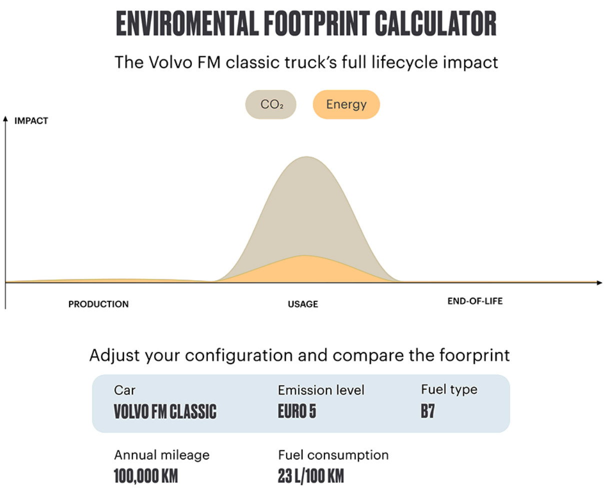

Fig. 1. Natural resource consumption and pollutant emission during full lifecycle of VOLVO FM truck

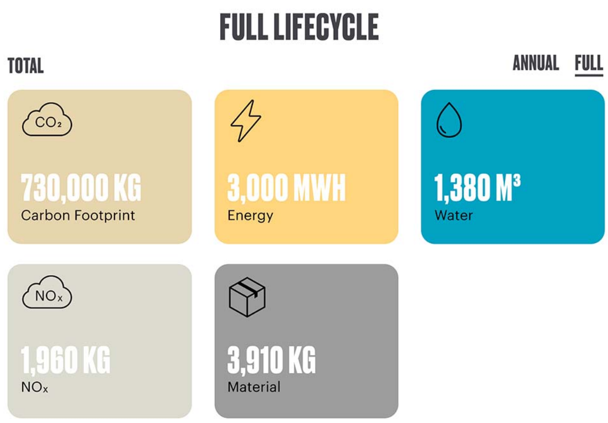

Fig. 2. Calculation results of the natural resource consumption and pollutant emission in terms of B100 fuel use

Table 1

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

Euro-3 fuel					
Fuel type	CO_2 emission kg of CO_2 equivalent	Power consumption; MWh	Water consumption; m^3	NO_x 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

Table 2

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

Euro-3 fuel					
Fuel type	CO_2 emission kg of CO_2 equivalent	Power consumption; MWh	Water consumption; m^3	NO_x 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

onstrates calculations for VOLVO FM model. In terms of the calculations, carbon dioxide emission for petrodiesel (B0) was assumed as 100 %.

The analysis of carbon dioxide emission shows that biodiesel consumption instead of traditional B0 fuel demonstrates increase in CO_2 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 CO_2 emission values. As the data from Table 3 support, changes in fuel standards from Euro-3 to Euro-6 have minor impact on CO_2 emission. As for the B7 fuel, average CO_2 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 CO_2 emission. For the majority of currently popular biodiesel fuels (B7), the reduced CO_2 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 NO_x 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

Decrease in carbon dioxide emission depending upon Euro standards and fuel type

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

Increase in nitrogen oxide emission depending upon Euro standards and fuel type

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_x is quite higher than that of CO_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_2 emission in the process of any biodiesel consumption, being a positive effect, is followed by the increased NO_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_x emission compared to B0; nevertheless, B60 demonstrates 6.49 % increase in NO_x emission. The aforementioned correlates with our results, obtained as for the NO_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_x emission only starting from B15 compared to B0. Moreover, further increase in bioadditive share up to 40 % (B40) cannot influence NO_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_x and CO_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 Vs. 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 CO_2 emission reduction per one vehicle will be 30 tons. Consequently, the figure for 51 Vs is 1530 tons. However, consumption of water, power, and NO_x emission will increase as follows: by 16 320 cubic meters of H_2O for 51 vehicles; as well as 6.6 tons' increase in NO_x emission. Consequently, it is impossible to give unequivocally positive definition of the biodiesel fuel use in terms of its environmental impact.

The results supports the idea that despite biodiesel fuel-petrodiesel ratio, consumption of the former by any V model results in the decreased CO_2 emission while being followed by the increased NO_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_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_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

Table 5

Increase in water consumption depending upon the Euro standards and fuel type

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

Increase in power consumption depending upon the Euro standards and fuel type

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%

on the integrated analysis of their environmental impact taking into consideration each component inclusive of the vehicle lifecycle. The integrated analysis of the environmental impact by VOLVO trucks helped determine that increase in a bioadditive share in biodiesel fuel results in the increased consumption of water and power. Moreover, nitrogen oxide emission also increases from 3 % (for B7 fuel) up to 13 % (for B30 fuel) irrespective of Euro standard. As for the B100 fuel, in terms of Euro-6 standard, nitrogen oxide emission increases by 70 % compared to petrodiesel B0.

4. Consumption of the second-generation biodiesel fuel HVO makes it possible to increase substantially (i.e. by more than 2–3 times) CO_2 emission to compare with B0 fuel; in addition, it helps 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 CO_2 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 automotive fleet.

References.

1. Knoema (n.d.). *World Data Atlas. Ukraine. Environment*. Retrieved from https://knoema.com/atlas/Ukraine/topics/Environment.

2. Redziuk, A. M., & Klymenko, O. A. (2018). On the strategy of increasing efficiency of energy consumption in road transport. *Avtoshliakhovyk Ukrayiny, 4*(256), 2-10. https://doi.org/10.33868/0365-8392-2018-4-256-2-11.

3. Gritsuk, I., Pohorletskyi, D., Mateichyk, V., Symonenko, R., Tsiuman, M., Volodarets, M., ..., & Sadovnyk, I. (2020). Improving the Processes of Thermal Preparation of an Automobile Engine with Petrol and Gas Supply Systems (Vehicle Engine with Petrol and LPG Supplying Systems). *SAE Technical Paper*, 2020-01-2031. https://doi.org/10.4271/2020-01-2031.

4. Taran, I., & Litvin, V. (2018). Determination of rational parameters for urban bus route with combined operating mode. *Transport Problems*, *13*(4), 157-171. https://doi.org/10.20858/tp.2018.13.4.14.

5. Kozachenko, D., Dovbnia, M., Ochkasov, O., Serdiuk, V., Shepotenko, A., & Keršys, A. (2018). Rationale for Choosing the Type of Traction Rolling Stock for the Enterprise of Industrial Transport. *Proceedings of 22nd International Scientific Conference. Transport Means 2018*, 991-995. Retrieved from https://transportmeans.ktu.edu/wp-content/uploads/sites/307/2018/02/Transport-means-II-A4-2018-09-25.pdf.

6. Taran, I. (2012). Interrelation of circular transfer ratio of double-split transmissions with regulation characteristic in case of planetary gear output. *Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu*, (3), 78-85.

7. Kutenev, V. F., Kozlov, A. V., Terenchenko, A. S., & Shiute, Yu. V. (n.d.). *Challenging issues in limiting CO_2 emissions from vehicles*. Retrieved from. http://www.aae-press.ru/j0062/art016.htm.

8. Achinas, S., Horjus, J., Achinas, V., & Euverink, G. J. W. (2019). A PESTLE Analysis of Biofuels Energy Industry in Europe. *Sustainability*, *11*, 5981. https://doi.org/10.3390/su11215981.

9. International Energy Agency (n.d.). *Energy Technology Perspectives 2010. Scenarios and Strategies to 2050*. https://doi.org/10.1787/energy_tech-2010-en.

10. Achinas, V., & Euverink, G. J. W. (2019). Feasibility Study of Biogas Production from Hardly Degradable Material in Co-Inoculated Bioreactor. *Energies*, *2*, 1040. https://doi.org/10.3390/en12061040.

11. Ghanimeh, S., Khalil, C. A., & Ibrahim, E. (2018). Anaerobic digestion of food waste with aerobic post-treatment: Effect of fruit and vegetable content. *Waste Management and Research*, *36*, 965-974. https://doi.org/10.1177/0734242X18786397.

12. Cherubini, F., & Strømman, A. H. (2011). Life cycle assessment of bioenergy systems: state of the art and future challenges. *Bioresource Technology*, *102*(2), 437-51. https://doi.org/10.1016/j.biortech.2010.08.010.

13. Presser, C., Nazarian, A., & Millo, A. (2018). Laser-Driven calorimetry measurements of petroleum and biodiesel fuel. *Fuel*, *214*, 656-666. https://doi.org/10.1016/j.fuel.2017.09.086.

14. Kuchkina, A. Yu., & Sushchik, N. N. (2014). Feedstocks, Methods and Perspectives of Biodiesel Production. *Journal of Siberian Federal University. Biology*, *1*(7), 14-42.

15. Bonomi, A., Klein, B. C., Chagas, M. F., & Dias Souza, N. R. (2018). *Technical Report Comparison of Biofuel Life Cycle Analysis Tools Phase 2, Part 1: FAME and HVO/HEFA*. Campinas: IEA Bioenergy.

16. Campbell, J. E., & Block, E. (2010). Land-Use and Alternative Bioenergy Pathways for Waste Biomass. *Environmental Science & Technology, 44*, 8665-8669. https://doi.org/10.1021/es100681g.

17. *Environmental Footprint Calculator* (n.d.). Retrieved from https://www.volvotrucks.com/en-en/trucks/alternative-fuels/environmental-footprint.html.

18. Markov, V., Devyanin, S., & Zykov, S. (2016). Optimization of biofuel mixtures with rapeseed oil methyl ester and sunflower oil methyl ester additives. *Transport na alternativnom toplive*, *5*(53), 12-31.

19. UNEP (2011). *The Bioenergy and Water Nexus*. Nairobi: Oeko-Institut and IEA Bioenergy. Retrieved from https://www.cbd.int/agriculture/2011-121/UNEP-WCMC2-sep11-en.pdf.

20. Naumov, V., Taran, I., Litvinova, Y., & Bauer, M. (2020). Optimizing resources of multimodal transport terminal for material flow service. *Sustainability (Switzerland)*, *12*(16), 6545. https://doi.org/10.3390/su12166545.

21. Sabraliev, N., Abzhapbarova, A., Nugymanova, G., Taran, I., & Zhanbirov, Zh. (2019). Modern aspects of modeling of transport routes in Kazakhstan. *News of the National Academy of sciences of the Republic Kazakhstan*, *2*(434), 62-68. https://doi.org/10.32014/2019.2518-170X.39.

Вплив дизельних транспортних засобів на біосферу

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

Методика. Заснована на розрахунку споживання природних ресурсів і емісії токсичних 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 CO_2, NO_x для базових моделей тягачів VOLVO FM, FH, FE, FL, були розраховані при роботі на біодизельному паливі B0, B7, B30, B100 для різних стандартів EURO палива. Визначені позитивні й негативні фактори впливу на довкілля при використанні біопалив протягом усього життєвого циклу ТЗ. Встановлено, що незначне зменшення емісії CO_2 при застосуванні типового сучасного біодизельного палива супроводжується суттєвим зростанням емісії NO_x, витрат води та енергії при використанні біодизельного палива першого покоління. На прикладі ТЗ VOLVO FE проведено порівняльний аналіз впливу на оточуюче середовище біодизельного палива першого (B7, B30, B100) та другого покоління – гідроочищеної рослинної олії (HVO) – та встановлені однакові для них тенденції. Проаналізована можливість застосування біодизельних палив поряд з іншими заходами зменшення емісії CO_2.

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

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

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

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