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Assessing the Impact of the Motor Transport Enterprises on the State of Urban Ecosystems (with the Example of Activity of the Kremenchug Motor Transport Enterprise, Ukraine)

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ABSTRACT

The growth in the number of road transport is an integral part of Ukraine's development. At the same time, this is a significant negative factor affecting urban ecosystems. In the paper, the most significant aspects and criteria for their evaluation were identified to assess the negative impact of the transport company on the urban ecosystem. The impact of the Kremenchuk Motor Transport Enterprise on the urban ecosystem of the city of Kremenchuk (Poltava region) was assessed. The main pollutants in the region's air basin are stationary sources. However, the predominant sources of air pollution are emissions from mobile sources. The criteria for assessing the level of environmental safety of a motor transport enterprise were improved. The "Comprehensive assessment of the level of environmental safety of the motor transport enterprise" software tool was developed. It was established that under modern conditions, the level of environmental safety of the motor transport enterprise corresponds to the level of average safety. Comprehensive measures were proposed to ensure the regulatory status of the components of the urban ecosystem and environmental safety on the territory of the Kremenchuk Motor Transport Enterprise.

Keywords: urban ecosystem, motor transport enterprise, source of pollution, environmental safety criterion

INTRODUCTION

Monitoring of pollution of all environment components (Chugai et al., 2020, Odnorih et al., 2020, Sakalova et al., 2019) is the basis for the assessment of environmental hazard degree and development of the strategies to minimize it. Regarding air pollution, it should be noted that the intensive growth in the number of road transport observed in Ukraine in the last decade contributes, on the one hand, to the economic development of the country, and on the other hand, is accompanied by a negative impact on urban ecosystems and human health.

Ukraine is a transit country; its foreign policy is aimed at increasing the transit capacity, so the growth of road transport is an integral part of the country's development (Hill et al., 2016). At the same time, it is a significant destabilizing factor influencing urban ecosystems. That is why the most important indicator of environmental safety of vehicles is an assessment of its impact on the environment. The research in this field was carried out by such scientists as V.V. Ambartsumyan, N.V. Vnukova, I.E. Evgeniev, D.N. Kavtaradze, P.M. Kanilo, V.N. Lukanin, V.O. Yurchenko, A. Delaney, H.-G. Dossler et al.

It is known that a car absorbs an average of 1 ton of oxygen per year and emits about

600–800 kg of carbon dioxide, 40 kg of nitrogen oxides, and 200 kg of unburned hydrocarbons (Fedotova, 2017; Gazda & Jedynak, 2011). The specificity of the negative impact of road transport is manifested in the location of sources of pollution close to the Earth's surface (surface layer), as a result, exhaust gases accumulate in the respiratory zone of people. Reducing the number of pollutant emissions and strengthening the environmental component in the activities of motor transport enterprises (MTE) is one of the priorities of environmental safety (Engeljehringer, 2018).

In this regard, several international transport organizations (IRU, IMO, IKAO, etc.) have committed themselves in the future to achieve the maximum compatibility between the safe and orderly development of their mode of transport and the quality of the environment (Heavy Vehicle, 2005).

Ukraine, as a member of most of these organizations, in accordance with the constitutional principles (Article 16 of the Constitution of Ukraine) and current legislation has committed itself to ensure the environmental safety of road transport and MTE at the national level.

Therefore, the task of developing assessment methods and measures to improve the environmental safety of motor transport enterprises in order to reduce the negative impact on urban ecosystems and public health is urgent.

MATERIALS AND METHODS

In order to assess the negative impact of MTE on the urban ecosystem, the most significant aspects and criteria for their evaluation were identified, following the methodology described in section 6 of ISO 14001 (State Standard of Ukraine ISO 14001:2006, 2006). Assessment of the factors of MTE impact on the urban ecosystem was performed. The assessment includes the following stages:

- data collection, the definition of technological processes;
- list and assessment of factors influencing the urban ecosystem;
- assessment of the consequences of their impact;
- assessment of used resources;
- planning measures to reduce the environmental safety of the urban ecosystem.

In order to determine the criteria for assessing the significant environmental aspects of the impact of MTE on the urban ecosystem the study of S. Kolomiyets (Kolomiets et al., 2012; Pontikakis & Stamatelos, 2001; Gritsuk et al., 2018), the relevant standards ISO 14001 and ISO 14004 were used (State Standard of Ukraine ISO 14001:2006, 2006; State Standard of Ukraine ISO 14004:2006, 2006). The following factors were also taken into account:

- risk of impact on the urban ecosystem (probability, intensity, and importance of consequences);
- scale of influence;
- compliance with laws and regulations;
- social significance;
- financial costs of bringing to the norms.

The criteria for assessing the negative impact of MTE on the urban ecosystem respectively (State Standard of Ukraine ISO 14001:2006, 2006; State Standard of Ukraine ISO 14004:2006, 2006) are:

- indicators of energy consumption – fuels, oils, and grease;
- indicators of emissions of harmful substances – *CO*, *CnHm*, *NOx*, solid particles;
- indicators of waste generation – used oils, worn tires, batteries, etc.

According to the Methodology (Kolomiets, 2017), based on the analysis of the costs of certain types of energy resources, emissions of certain harmful substances, and waste generation, 10 criteria of environmental safety of MTE impact on the urban ecosystem were identified, which are further combined into a group and integrated criteria. The group criteria include the energy consumption criteria K_{EC}, emissions K_E, and waste generation K_{WG}:

$$К_{EC} = \sum_{i=1}^{3} \beta_i \frac{E_i}{E_{iб}} \quad (1)$$

$$К_E = \sum_{i=1}^{4} \delta_i \frac{С_i}{С_{iб}} \quad (2)$$

$$К_{WG} = \sum_{i=1}^{7} \gamma_i \frac{В_i}{В_{iб}} \quad (3)$$

where: E_i, $E_{iб}$ – the value of the individual i-th criteria of energy consumption and resources of the studied MTE and their desired level;
C_i, $C_{iб}$ – the value of individual i-th criteria for emissions of harmful substances of the studied MTE and their desired level;
B_i, $B_{iб}$ – the value of the individual i-th criteria for waste of the studied MTE and their desired level;
β_i, δ_i, γ_i – weights, respectively, of certain types of costs, emissions, waste ($B_i = 1$; $\delta_i = 1$; $\gamma_i = 1$).

On the basis of group criteria, the integrated criterion of ecological safety of MTE is formed (Kolomiets, 2017):

$$К_{ES} = \alpha_1 К_{EC} + \alpha_2 К_E + \alpha_3 К_{WG} \quad (4)$$

where: α_1, α_2, α_3 – weight coefficients of the components of environmental safety of MTE ($\Sigma\alpha_i = 1$).

According to the methodology (Kolomiets, 2017), the value inverse to the integral criterion, formed a one-dimensional objective function to assess the level of environmental safety of MTE for the urban ecosystem:

$$R_{ES} = \frac{1}{К_{ЕБ}} => 1 \quad (5)$$

A comprehensive assessment of the environmental safety of MTE, based on the value of the expected desirability function given by the interval (0; 1), with different options for situational studies and taking into account the excess of sanitary and hygienic standards, can be performed by safety categories (Table 1) using Harrington's desirability function (Kolomiets, 2017).

Table 1. Degrees of level of ecological safety of MTE for urban ecosystem

Degrees of the level of ecological safety	The value of the integrated indicator
Completely safe	1,00–0,80
Safe	< 0,80–0,63
Moderately safe	< 0,63–0,37
Dangerous	< 0,37–0,20
Especially dangerous	< 0,20–0,00

RESULTS AND DISCUSSION

The paper evaluated the impact of the Kremenchuk MTE 1628 on the urban ecosystem of the city of Kremenchuk, Poltava region (Fig. 1).

The industry of the Poltava region is one of the leading sectors of the region's economy. According to the volume of sold industrial products, it ranks 6th among the regions of the state. Among the stationary sources, the main pollutants in the region's air basin are Kremenchuk and Horishni Plavni enterprises (Fig. 2). Increases in air pollution in Kremenchug are also observed during the periods of biodegradation of cyanobacteria, which grow uncontrollably in the Dnieper under the conditions of climate change and increasing inflows of nitrogen and phosphorus compounds into surface waters (Nykyforov et al., 2016, Malovanyy et al., 2016). However, the predominant sources of air pollution (about 60 % of the total) are the emissions from mobile sources (Chugai et al. 2020).

According to the data on the average annual content of certain pollutants in the air basin in 2019 (Fig. 3), the maximum permissible concentration (*MPC*) were observed for the content of dust, formaldehyde, and nitrogen dioxide. The increased content of the last two substances indicates a significant impact of vehicles on the level of air pollution in the urban ecosystem of the city.

Figure 4 shows a map diagram of the area of MTE 1628 location in Kremenchuk, which is the largest enterprise of the motor transport industry in the city.

After analyzing the composition of the fleet of cars operated by the company, among the 24 models of cars, the six typical ones were selected, the total number of which is more than 80 %. All vehicles use diesel fuel. The general characteristics of the buses used for experimental research as the basic composition of the vehicle fleet are given in the table. 2.

The study determined that the most optimal in terms of environmental safety of the urban ecosystem is a route that includes the following stages:

- return from the route (arrival at the checkpoint, where the technical condition is checked by the relevant technical staff);
- stay in the waiting area;
- performing daily maintenance operations;
- storage of vehicles;
- release on the route through the checkpoint.

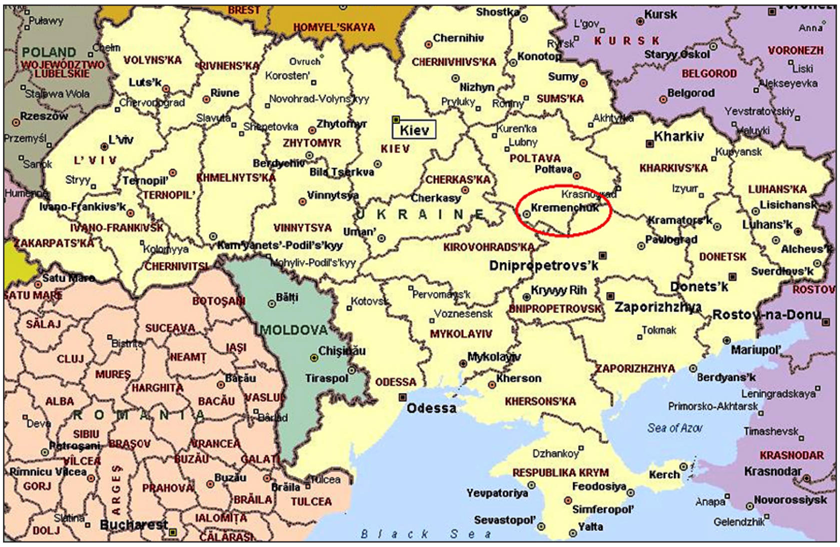


Figure 1. Location of Kremenchug

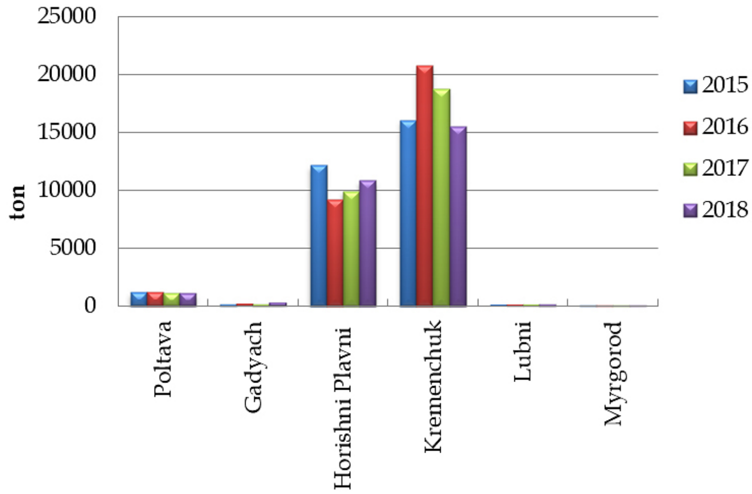


Figure 2. Dynamics of pollutant emissions from stationary sources in the cities of Poltava region (Industry of Poltava region, 2020; DENR-PRSA, 2019)

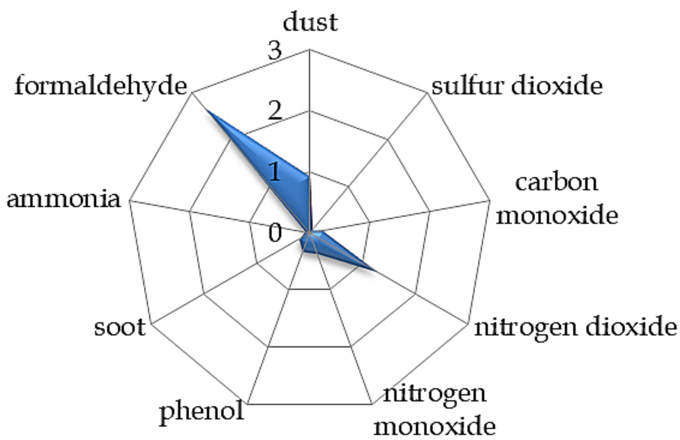


Figure 3. Diagram of the average annual content of pollutants in the air of Kremenchuk in 2019 (*MPC* unit) (Chugai et al. 2020)

Figure 4. Map diagram of the area of location of MTE 1628, Kremenchuk

In order to determine the level of environmental safety of MTE on the state of urban ecosystems, a "Comprehensive assessment of the level of environmental safety of the transport enterprise" software tool was developed.

Initial information is entered when registering a new vehicle (Fig. 5).

Figure 6 shows an example of the operation of certain components of the software (information on fuel consumption, engine oil, and grease, emissions of harmful substances, waste generation).

Using the methods of assessing the level of environmental safety of MTE (Fedotova, 2017; Kolomiets, 2017; Bazarov, 2012) and statistical information on the activities of Kremenchuk MTE 1628 in the created software, the value of individual criteria of environmental safety of the enterprise, as well as the value of the integrated criterion we calculated (Fig. 7).

The obtained data show that under modern conditions the level of ecological safety of the enterprise corresponds to the level of average safety (according to Table 1).

Table 2. Characteristics of the basic composition of the MTE 1628 vehicle fleet (Kremenchuk)

Basic composition	Number	Compliance with EURO standards
Bogdan A 092	22	EURO 2
Bogdan A 1445	18	EURO 2
LAZ A 183	17	EURO 3
MAZ 103	23	EURO 3
MAZ 203	22	EURO 3
KrAZ-256	5	EURO 3
KAMAZ	4	EURO 3
GAZ-307	4	EURO 3
MAZ 107	19	EURO 4

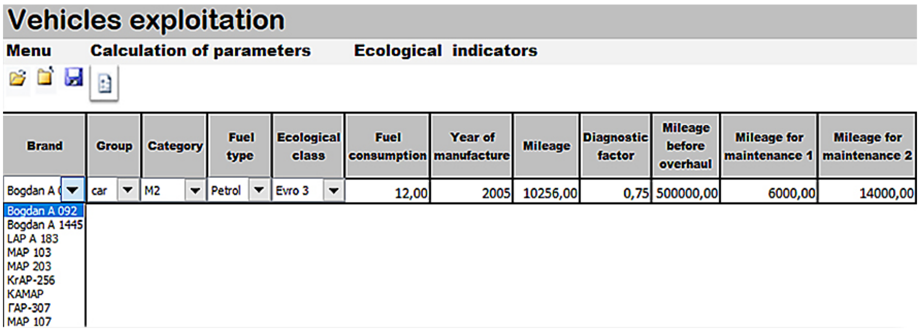
Thus, as a result of the activity of Kremenchuk MTE 1628, there is a significant impact on the urban ecosystem of the city during the use of rolling stock of the park, but there is also significant pollution of the environment, which the enterprise carries out on its territory.

On the basis of the analysis of scientific sources (Fedotova, 2017; Kolomiets et al., 2012; Kolomiets, 2017; Bazarov, 2012), assessment of the impact on the urban ecosystem of the city of production activities of Kremenchuk MTE 1628 to reduce the negative impact on the environment during the operation of the vehicle, several measures were proposed:

- increase of speed of technological movement in the territory of MTE;
- replacement of the entire fleet of MTE vehicles with vehicles of ecological class EURO-5;
- installation of a solar battery for the rational use of energy resources.

The proposal to replace the entire fleet of Kremenchuk MTE 1628 with the vehicles of ecological class EURO-5 while maintaining passenger capacity and the number of vehicles is based on the research by many scientists and the strategy of development of the transport and road complex of Ukraine as a whole (Ministry of Transport of Ukraine, 2001; Delphi Power Train, 2020). This is the most effective measure to reduce the emissions of certain harmful substances.

In recent years, the world has undergone changes in the approaches to the formation of energy policy. After the introduction of the "Green" tariff, solar energy became the most popular.

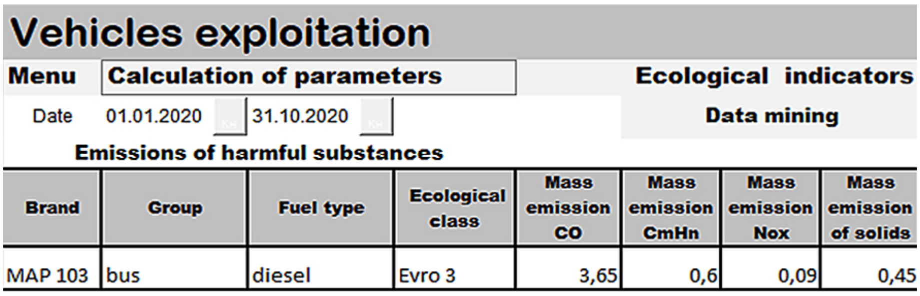


Vehicles exploitation

Menu | Calculation of parameters | Ecological indicators

Brand	Group	Category	Fuel type	Ecological class	Fuel consumption	Year of manufacture	Mileage	Diagnostic factor	Mileage before overhaul	Mileage for maintenance 1	Mileage for maintenance 2
Bogdan A (	car	M2	Petrol	Evro 3	12,00	2005	10256,00	0,75	500000,00	6000,00	14000,00

Figure 5. The start window of the program



Vehicles exploitation

Menu | Calculation of parameters | Ecological indicators

Date 01.01.2020 31.10.2020 | Data mining

Emissions of harmful substances

Brand	Group	Fuel type	Ecological class	Mass emission CO	Mass emission CmHn	Mass emission Nox	Mass emission of solids
MAP 103	bus	diesel	Evro 3	3,65	0,6	0,09	0,45

Figure 6. Example of information on emissions of harmful substances on MTE

Fixed prices for the "Green" tariff for industrial enterprises are given in the Table 3.

The advantages of solar panels are autonomy, no need to transmit energy over long distances, which is accompanied by its large losses and environmental pollution.

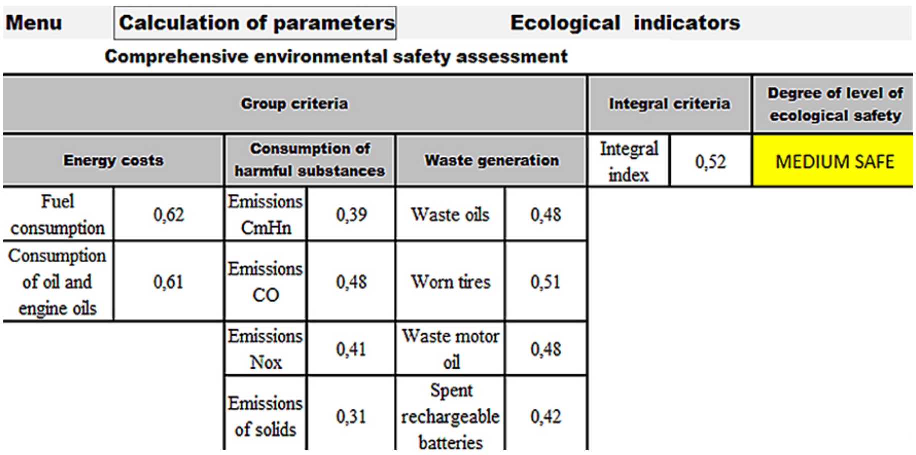
In order to reduce the negative impact on the urban ecosystem of Kremenchuk and the health of the population, it is necessary to plant greenery in the surrounding areas. Protective landscaping of the territory of Kremenchuk MTE 1628 with tree and shrub plantations should occupy an area (based on the width of the zone) of at least 50% (for zones with a width of 300 to 1000 m).

CONCLUSIONS

The article is devoted to solving the scientific and practical problem, which is to determine the impact of motor transport enterprises on the state of urban ecosystems.

The conducted studies allow drawing the following conclusions:

1. The main negative factors of MTE influence on the level of ecological safety of the urban ecosystem were determined.
2. The analysis of production activity of Kremenchuk municipal MTE 1628 and its influence on the urban ecosystem was carried out.



Menu | Calculation of parameters | Ecological indicators

Comprehensive environmental safety assessment

Group criteria						Integral criteria		Degree of level of ecological safety
Energy costs		Consumption of harmful substances		Waste generation		Integral index	0,52	MEDIUM SAFE
Fuel consumption	0,62	Emissions CmHn	0,39	Waste oils	0,48			
Consumption of oil and engine oils	0,61	Emissions CO	0,48	Worn tires	0,51			
		Emissions Nox	0,41	Waste motor oil	0,48			
		Emissions of solids	0,31	Spent rechargeable batteries	0,42			

Figure 7. Comprehensive assessment of ecological safety of Kremenchuk MTE 1628 on the state of the urban ecosystem of the city

Table 3. Fixed prices for the "Green" tariff for industrial enterprises

Input timing	Fixed prices for the «Green» tariff
01.01.2016 to 31.12.2016	0.19 EUR / kWh
01.01.2017 to 31.12.2019	0.163 / 0.15 EUR / kWh
01.01.2020 to 31.12.2024	0.15 / 0.14 EUR / kWh
01.01.2025 to 31.12.2029	0.13 / 0.12 EUR / kWh

3. The criteria for assessing the level of environmental safety of MTE was improved, which consist of separate assessment criteria: stationary and mobile sources of harmful effects of MTE, identified by the analysis of significant environmental aspects of individual technological processes of maintenance and repair of vehicles, and grouped by factors resource costs, emissions and waste and integrated criteria.
4. A software tool "Comprehensive assessment of the level of environmental safety of the vehicle" was developed, which allows one to constantly calculate the parameters of the state of the vehicle, fleet, and their environmental performance, and the level of environmental safety of vehicles.
5. Based on the analysis of production activity of Kremenchuk municipal MTE 1628 it was established that at present the level of environmental safety corresponds to the level of average safety.
6. Comprehensive measures were proposed to ensure the regulatory status of the components of the urban ecosystem and environmental safety in the Kremenchuk municipal MTE 1628: increasing the speed of technological traffic in the Kremenchuk municipal MTE 1628; replacement of the entire fleet of vehicles of the enterprise with vehicles of environmental class EURO-5; improvement of the scheme of movement of technological flows of motor transport in the territory of the enterprise; installation of solar panels for the rational use of energy resources; carrying out the works on protection of green plantings and its improvement.

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