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SOCIAL EFFECTS OF REDUCING ENVIRONMENTAL POLLUTION CAUSED BY EXHAUST GASES FROM VEHICLES

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***Key words**: alternative fuel, natural gas, hydrogen.*

***Abstract:** The increased quantities of pollutants in the natural environment causes both environmental and socio-economic damage in the real and services sectors.*

Environmental measures can not be implemented without a preliminary economic analysis. This means that the cost of environmental measures should be consistent with the environmental and economic outcomes achieved.

The paper describes the methodology for calculating the yearly socio-economic effect obtained by reducing the amount of toxic substances in exhaust gases.

The modern world is going to face a daunting challenge of solving global environmental problems, since the planet would be running ut of natural resources from human activity, and essential to life natural components such as air, water, soil are being polluted. There is thermal, acoustic, electromagnetic, chemical and biological pollution of the environment that causes the threat of the disruption of ecological balance of the planet. That is, any human activity causes environmental impacts, which instantly or after a period of time responses to the impact positively or negatively.

The present era is represented without the development of a transport system, because transport is the means of conveyance and is widely used in the country's social and economic activities, but during vehicle operation, the critical challenge of environmental security is to reduce toxic compounds, since emissions of toxic compound and heavy metals from fuel combustion have adverse effects on fauna and flora, as well as cause in the human body: severe pulmonary and respiratory diseases; the creation of malignant tumours; the development of hypertension, cardiac angina, bronchial asthma, disorders of the circulatory system and so on.

To carry out the environmental work and make decision, a preliminary economic analysis is required, which envisages comparison and analysis of environmental, social and economic outcomes. The socio-economic impact simultaneously covers both social and economic outcomes that are achieved through the implementation of environmental activities and expressed in the monetary form. For example, disease reduction, on the one hand, is healthy for human life, and on the other hand, it increases the working time fund.

Of pollutants of the natural environment, special mention should be made of petroleum and its processing products, since petrol, diesel fuel, lubricating materials and other sunstances pollute the environment in any physical state.

It has been estabished that the modern car spends about 200 l of oxygen on the combustion of 1 kg of petrol, which is more than the volume of the oxygen inhaled by the person within 24 hours. Considering the growth rates of the world's vehicle fleet, as well as air and sea transport, it is easy to imagine a crisis of lack of oxygen on the planet, the solution of which by plant community gives rise to a variety of difficulties.

The processes occurring in the engine are the main source of vehicular pollution, since the engine cylinders and the atmosphere are experiencing complex problems of heat and mass exchange. Besides, combustion products contain more than 200 kinds of substances, most of which are toxic. Among them particular mention should made of: carbon monoxide (CO); carbon dioxide (CO2); nitrogen and sulfur oxides; different types of hydrocarbons (CXHY); solid particles in the form of soot; heavy metals and so on. In addition, the quantity of toxic compounds emitted into the environment is determined by: the type and technical condition of vehicle; type of fuel consumed; operating mode and so on.

Harmful gases emitted by the industrial business-enterprises, as well as by motor, air and maritime transport, pollute the atmosphere, and industrial waste poison water and soil. Polluted rivers drain into the seas and oceans and poison the living world. Environmental pollution leads to destroying the food chains the water, land and air ecosystems, which negatively affects the country's economy and the social status of the population. This means that the increased quantities of pollutants in the natural environment causes both environmental and socio-economic damage in the real and services sectors.

Socio-economic damage (USD / year) caused by the impact of harmful compounds emitted by transport into environment can be calculated using the following formula:

$$Y = i\sigma f M, \quad (1)$$

where i is constant and its value depends on the year of vehicle manufacture. For vehicles manufactured before 2005 i = 2,4, while for vehicles manufactured after 2005 i =2,0;

f is a numerical quantity with no dimension and for road transport f =10;

σ is a relative indicator of the threat of the atmospheric air pollution and it is taken from Table [1].

M - the annual weight of harmful substances emitted into environment by vehicle and it is calculated by the following formula:

$$M = \sum_{1}^{n} A_i m_i, \quad (2)$$

where n – the total quantity of the harmful impurities emitted into the atmpsphere by vehicles;

A_i – relative aggressivity of the i-th type of impurity, which is taken from Table [2]

m_i – the annual weight of the i-th type of impurity (t/per year) emitted into the atmpsphere and it is calculated by the following formula:

$$m_i = m_{ik} \cdot L \cdot K_1 \cdot K_2 \cdot K_3 \cdot 10^{-6}, \quad (3)$$

where m_{ik} - specific weight of i-th component emitted by vehicle during 1 operational kilometer, g/kg; the values are given in Table [3];

L – operational kilometers of vehicle during the year, km;

K_1 – coefficient that takes account of the increase in the average age of vehicle fleet, K_1 = 1,0÷1,3;

K_2 - coefficient that takes account of the vehicle technical state, K_2 = 0,8÷2,0;

K_3 - coefficient that takes account of climate conditions, $K_3 = 1,2 \div 1,4$.

Table 1.

The relative threat of the atmospheric air pollution for the different territories

No	The type of the polluted territory	Value σ
1	The territory of resort, the natural reserve and hotel	1,0
2	Countryside recreation zone	0,8
3	The territory of the industrial enterprises	0,4
4	The territory of human settlements with the *n* density (human/per hectare)	0,1n
5	Forest	0,025÷0,2

Table 2.

The value A_i for different componds emitted into the atmosphere

No	Compound	The maximum allowable coefficient, per day, kg/m^3	A_i
1	Carbon dioxide	3	1,0
2	Sulfur trioxide	0,05	16,5
3	Hydrogen sulfide	0,008	41,1
4	Nitrogen oxides	0,04	42,1
5	Hydrocarbons	1,5	1,5

Table 3.

The amount of toxic substances (g/kg) in combustion products by the type of vehicles and consumed fuel

Type of fuel	Fuel consumption, l/km	CO	NO_X	C_XH_Y	Soot	CO_2	SO_2	Lead compounds
Passenger car with a full weight of 2500÷5000 kg								
Petrol	0,191	40,2	1,3	3,1	-	382,9	0,27	0,045
Diesel	0,109	1,6	2,0	0,4	0,35	251,3	0,87	-
Liquified natural gas	0,123	10,0	0,5	2,9	-	321,4	0,02	-
Truck with a full weight of 3500÷12000 kg								
Petrol	0,367	118,5	10,1	10,7	-	725,6	0,52	0,086
Diesel	0,265	9,2	8,4	2,0	1,49	666,1	2,3	-
Liquified natural gas	0,217	28,4	3,5	10,4	-	569,8	0,04	-

When hydrogen is used as fuel, only nitrogen oxides are emitted into the atmosphere in a quantity ranging from 0,62 to 0,70 g/kg.

Environmental measures can not be implemented without a preliminary economic analysis. This means that the cost of environmental measures should be consistent with the environmental and economic outcomes achieved. Evaluation criteria for these undertaken measures should be represented by indicators such as the improvement of the well-being of

population, the reduction of the risk of diseases, physical and mental development of human beings, productivity improvement and so on.

The assessment of these indicators is known as the socio-economic effect and indicates the achievement of social and economic outcomes in the implementation of environmental measures.

One of the realistic methods for reducing environmental pollution by vehicles is the use of various alternative energy sources [1,3], including bio-diesel, alcohol, liauefied petroleum gas, compressed natural gas, synthesis gas, hydrogen, etc. Moreover, the ways of introducing electric vehicles are also realistic.

To evaluate the advantage of different types of alternative fuel as compared with petroleum products, it is important to calculate economic benefits due to the reduction of the toxicity of exhaust gases, and we perform the analysis using the existing methodology [2]., The annual economic benefits obtained by reducing the amount of toxic compounds in exhaust gases for a specific type of the vehicle engine is calculated by the following formula

$$E = \left[C \cdot \left(\frac{B\ ex}{B_b} \cdot \frac{P_1 + E_n}{P_2 + E_n} - 1\right) + E_{as} + Z - X\right] \cdot N, \quad (4)$$

where C – the cost of the base engine in dollars;

B_b and B_{ex} - the yearly amount of work performed by vehicle under operating conditions of the base and experimental engines; the value $\frac{B_{дв}}{B_{баз}}$ is a coefficient of performance of vehicle;

E_n= 0,12 is a norm coefficient of economic efficiency;

P_1 and P_2 represent the inverse value of the duration of work of the base and new engines and take account for the share of the cost of engine spent on their repairs;

The value $\Psi = \frac{P_1 + E_n}{P_2 + E_n}$ - the operating time coefficient of the engine under study as compared to the base engine;

Z – the cost of reducing the economic zone for vehicle equipped with the engine under study during the entire period, in dollars;

X – the incremental cost for the creation of the engine with improved environmental characteristics for one engine, in dollars;

E_{as} - annual saving of transport company for vehicle equipped with a new engine, in comparison with the base engine, in dollars;

N – the number of the new type of engines used on road transport.

The values E_c, Z and X are determined based on the following formulas [2]:

$$E_{as} = \frac{Hb - H_{ex}) - E_n \cdot (\,Kex - Kb\,)}{P_2 + E_n}$$

$$Z = \frac{Yb - Y\ ex}{P + E_n} \quad (5)$$

$$X = \Delta C + \frac{\Delta K + K_{research}}{N_X},$$

where H_b and H_n –annual operating costs of transport company for vehicles with the base and new engines, respectively, in dollars;

K_b and K_n – investments of transport company in equipping the vehicles with the base and new engines;

ΔC – cost price fluctuation of the engine with improved environmental characteristics, in dollars;

Y_b and Y_{ex} - socio-economic damage caused by harmful compounds emitted during operation of vehicle in the cases of the base and new engines, respectively, in dollars:

N_x - the number of engine with improved environmental characteristics;

$K_{research}$ - sums spent on works performed during the research, in dollars;

ΔK - additional investment in the improvement of the total engine production.

Based on practical and theoretical studies, it is possible to conclude that the use of alternative fuel (natural gas) leads to reducing the environmental damage caused by one vehicle, in comparison with traditional fuel by 0,8 $/tkm, which produces social effect of 19735 $ (per 1000 vehicles).

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СОЦИАЛЬНЫЕ ЭФФЕКТЫ СНИЖЕНИЯ ЗАГРЯЗНЕНИЯ ОКРУЖАЮЩЕЙ СРЕДЫ ВЫХЛОПНЫМИ ГАЗАМИ ТРАНСПОРТА

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Ключевые слова: *альтернативное топливо, природный газ, водород.*

Аннотация: *Увеличение количества загрязняющих веществ в природной среде наносит как экологический, так и социально-экономический ущерб в реальном секторе и сфере услуг. Экологические меры не могут быть реализованы без предварительного экономического анализа. Это означает, что стоимость природоохранных мероприятий должна соответствовать достигнутым экологическим и экономическим результатам. В статье описана методика расчета годового социально-экономического эффекта, получаемого за счет снижения количества токсичных веществ в выхлопных газах.*