The Use of Alternative Fuels in Construction as a Factor for Increasing Technospheric Safety

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Abstract: Comparative characteristics of the impact on the atmospheric air of technical means operating on various types of fuel is an urgent task of green energy. To assess the carbon balance of the biosphere and characterize the technogenic load, a methodology has been developed for determining the level of technogenic risk by a complex indicator of total atmospheric air pollution by construction equipment. The calculated value of the complex total indicator of atmospheric air pollution by construction equipment indicates the effectiveness of the use of alternative fuels in construction. In the case of using rapeseed oil instead of diesel fuel, the level of pollution is reduced by almost 3 times. All this makes it possible to reduce the level of manufactured risk to the environment and human health, which is a priority for any country in the framework of the strategy for the development of green energy.

1 INTRODUCTION

The assessment of the risk of anthropogenic impact from stationary sources is the key point in the studies of many authors (Grzelak, 2021). The energy development plan and transport policy of the Russian Federation is aimed at revising existing technologies, expanding the use of green energy, reducing carbon emissions and improving energy efficiency and environmental safety from the impact of various technical means on it (Tsiakmakis, 2019; Alsultan, 2021).

This policy resonates with global demands to reduce environmental pollution and improve the quality of human life (Ismail, 2020).

Existing methods do not take into account many indicators and do not give an accurate description of the situation of pollutant emissions (Rito, 2021; GOST ISO 8178-1-2013; Ministry of Transport of Russia, 1998; Ministry of Natural Resources and Ecology of the Russian Federation, 2019).

There is even less accurate information on emissions of pollutants from technical equipment operating on alternative fuels (Seo, 2021).

Comparative characteristics of the impact on the atmospheric air of technical means running on alternative and traditional fuels is a priority and urgent task of green energy (Gohil, 2020).

To assess the carbon balance of the biosphere and characterize the technogenic load, a methodology was developed for determining the level of technogenic risk by a complex indicator of total atmospheric air pollution for the transport of construction equipment during its operation in the face.

Emission factors from vehicle activities, such as warm-up emissions or idling emissions, can be introduced into this methodology. In addition, this technique takes into account the toxicity coefficient of pollutants, which affects the quantitative values of the complex indicator of pollution. The calculation can be carried out taking into account annual emissions, from the point of view of collecting information for statistical information, or you can consider working hours on any equipment using different types of fuel.

All this expands the possibilities of using standardized methods for assessing the impact of technogenic factors on the environment, and refines the results obtained taking into account the real

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situation, which is undoubtedly important for monitoring the environment and assessing the risk of the impact of negative factors on human health (López-Martínez, 2021).

The main purpose of this work is to develop a methodology for assessing the technogenic risk from stationary sources of construction equipment, which includes internal combustion engines running on alternative fuels. To achieve this goal, several tasks were solved. A methodology has been developed for calculating the reduction of technogenic risk according to a complex indicator of total atmospheric air pollution from construction equipment operating on alternative fuels. A calculation was made to reduce the level of manufactured risk to the environment by construction equipment. The decrease in the level of technogenic impact on the environment from construction equipment operating on alternative fuels is estimated.

2 MATERIALS AND METHODS

The proposed technique is the author's. A complex indicator of total atmospheric air pollution, according to the expression, determined the level of technogenic safety:

$$I = \sum_{i=1}^{m} \left(\frac{q_{cp,i}}{MPC} \right)^{C_i} \tag{1}$$

where I - complex total indicator of atmospheric air pollution; m - number of types of pollutants, pcs; i - pollutant number; $q_{cp,i}$ - average gross emissions of pollutants from transport, t/year; MPC - average daily maximum allowable concentration of a pollutant, mg/m3; C_i - dimensionless coefficient that allows to bring the degree of harmfulness of the i-th pollutant to the degree of harmfulness of sulfur dioxide.

We determined the average gross emissions of harmful substances from different construction equipment during its operation in the face on different types of fuel at a certain localization site, according to the following expression:

$$q_{cp,i} = \frac{\sum_{l}^{K} M_{k,i} \cdot T_{cm} \cdot T_{year}}{1000} \tag{2}$$

where K - the number of vehicles of one group, pcs.; l - number of transport groups, pcs.; T_{cm} - shift duration, h; T_{year} - number of work shifts per year, cm; $M_{k,i}$ - specific hourly mass emission of the i-th pollutant of the engine, k-th type, kg/h, was determined by the expression:

$$M_{k,i} = u_{k,i\,gas} \cdot M_{k,i} \cdot q_{k,mew} \tag{3}$$

where $u_{k,i\,gas}$ - the ratio of the densities of the i-th pollutant in the exhaust gases of the k-th engine to the density of the exhaust gases; $M_{k,i}$ - relative mass mole fraction of the i-th pollutant in the exhaust gases of the k-th type engine; $q_{k,mew}$ - mass hourly emission of wet exhaust gases of the k-type engine, kg/h.

The ratio of the densities of the i-th pollutant in the exhaust gases of the k-th engine to the density of the exhaust gases was determined:

$$u_{k,i\,gas} = \frac{\rho_{k,i,rgas}}{\rho_{k,e}} \tag{4}$$

where $\rho_{k,i,rgas}$ - density of the i-th pollutant of the exhaust gases of the engine, k-th type, kg/m^3; $\rho_{k,e}$ - density of exhaust gases of the k-type engine, kg/m^3.

The density of the i-th pollutant of the exhaust gases of the engine, the k-th type, was found:

$$\rho_{k,i,rgas} = \frac{M_{i,rgas}}{V_{rgas}} \tag{5}$$

where $M_{i,rgas}$ - molar mass of the i-th pollutant of the exhaust gases of the engine, kg/mol; V_{rgas} - molar volume of the i-th pollutant of the exhaust gases of the engine, m^3/mol.

The exhaust gas density of the k-th type engine was determined by:

$$\rho_{k,e} = \frac{q_{k,mew}}{q_{k,vew}} \tag{6}$$

where $q_{k,vew}$ - volumetric hourly emission of wet exhaust gases of the engine, type k, m^3/h.

The mass hourly emission of wet exhaust gases of the k-th type engine was found:

$$q_{k,mew} = q_{k,maw} + q_{k,mf} \tag{7}$$

where $q_{k,maw}$ - mass hourly consumption of moist air by the engine, type k, kg/h; $q_{k,mf}$ - mass hourly fuel consumption by the engine, type k, kg/h.

The volumetric hourly emission of wet exhaust gases of the k-th type engine was determined by:

$$q_{k,vew} = q_{k,vaw} + f_{k,fw} \cdot q_{k,mf} \quad (8)$$

where $q_{k,vaw}$ - volumetric hourly consumption of moist air by the engine, type k, m^3/h; $f_{k,fw}$ - the total additional volume of exhaust gases of the engine, k-th type, which forms 1 kg of fuel during combustion, m^3/kg.

The mass hourly consumption of moist air by the engine, k-th type, was found:

$$q_{k,maw} = q_{k,mad} + H_a \cdot q_{k,mad} \quad (9)$$

where $q_{k,mad}$ - mass hourly consumption of dry air by the engine, type k, kg/h; H_a - absolute air humidity, kg water/kg dry air.

The volumetric hourly consumption of moist air by the engine, k-th type, was determined:

$$q_{k,vaw} = q_{k,vad} + q_{k,vH_2Oaw} \quad (10)$$

where $q_{k,vad}$ - volumetric hourly consumption of dry air by the engine, type k, m^3/h; q_{k,vH_2Oaw} - volumetric hourly water consumption by the engine, type k, contained in moist air, m^3/h.

The volumetric hourly consumption of dry air by the engine, k-th type, was found:

$$q_{k,vad} = \frac{q_{k,mad}}{\rho_v} \quad (11)$$

where ρ_v - dry air density, kg/m^3.

The volumetric hourly consumption of water by the engine, type k, contained in moist air was determined:

$$q_{k,vH_2Oaw} = \frac{q_{k,mad} \cdot H_a \cdot V_{mH_2O}}{M_{rH_2O}} \quad (12)$$

where V_{mH_2O} - molar volume of water, m^3/mol; M_{rH_2O} - molar mass of water, kg/mol.

After substituting expressions (11) and (12) into (10), (13) into (8) and transforming, we got:

$$q_{k,vew} = q_{k,mad}\left(\frac{1}{\rho_v} + \frac{H_a \cdot V_{mH_2O}}{M_{rH_2O}}\right) + f_{k,fw} \cdot q_{k,mf} \quad (13)$$

Substituting expression (9) into (7) and transforming, we found:

$$q_{k,mew} = q_{k,mad}\left(1 + H_a\right) + q_{k,mf} \quad (14)$$

After substituting expressions (13) and (14) into (6), we determined:

$$\rho_{k,e} = \frac{q_{k,mad}\left(1+H_a\right) + q_{k,mf}}{q_{k,mad}\left(\frac{1}{\rho_v} + \frac{H_a \cdot V_{mH_2O}}{M_{rH_2O}}\right) + f_{k,fw} \cdot q_{k,mf}} \quad (15)$$

The total additional volume of exhaust gases of the k-type engine, which forms 1 kg of fuel during combustion, is equal to:

$$f_{k,fw} = V_{H_2} \cdot W_{ALF} + V_{C_2} \cdot W_{BET} + V_{S_2} \cdot W_{GAM} + V_{N_2} \cdot W_{DEL} + V_{O_2} \cdot W_{EPS} \quad (16)$$

where $V_{H_2}, V_{C_2}, V_{S_2}, V_{N_2}, V_{O_2}$ - additional volumes of gas formed during the oxidation of hydrogen, carbon, sulfur, nitrogen and oxygen contained in the fuel, m^3/kg; $W_{ALF}, W_{BET}, W_{GAM}, W_{DEL}, W_{EPS}$ - mass fractions of hydrogen, carbon, sulfur, nitrogen and oxygen in 1 kg of fuel.

Additional volumes of gases:

$$V_{H_2} = \frac{2V_{mH_2O} - V_{mO_2}}{4A_{rH}} \quad (17)$$

$$V_{C_2} = \frac{\left(V_{mCO_2} + V_{mCO}\right)}{A_{rC}} - \frac{3V_{mO_2}}{2A_{rC}} \quad (18)$$

$$V_{S_2} = \frac{V_{mSO_2} - V_{mO_2}}{A_{rS}} \quad (19)$$

$$V_{N_2} = \frac{\left(V_{mNO_2} + V_{mNO}\right)}{A_{rN}} - \frac{3V_{mO_2}}{2A_{rN}} + \frac{V_{mN_2}}{M_{rN_2}} \quad (20)$$

$$V_{O_2} = \frac{V_{mO_2}}{M_{rO_2}} \quad (21)$$

where V_{mO_2}, V_{mN_2}, V_{mH_2O}, V_{mCO}, V_{mNO}, V_{mCO_2}, V_{mSO_2}, V_{mNO_2} - molar volumes of oxygen, nitrogen and water, carbon monoxides and nitrogen, carbon dioxide, sulfur and nitrogen, respectively, m^3/mol; A_{rH}, A_{rC}, A_{rS}, A_{rN}, - molar atomic mass of hydrogen, carbon, sulfur and nitrogen, respectively, kg/mol; M_{rN_2}, M_{rO_2} - molar mass of nitrogen and oxygen molecules, respectively, kg/mol.

The relative mass mole fraction of the i-th pollutant in the exhaust gases of the k-th type engine was determined:

$$M_{k,i} = \frac{M_{r,i}}{M_{r,e}} \qquad (22)$$

where $M_{r,i}$ - molar mass of the i-th pollutant molecule, kg/mol; $M_{r,e}$ - molar mass of exhaust gases, kg/mol, determined as:

$$M_{r,e} = \frac{1+k_m}{k_m \cdot k_e + \dfrac{k_a + \dfrac{1}{M_{r,a}}}{1+H_a}} \qquad (23)$$

where k_m - specific mass ratio coefficient, kg fuel/kg air, found:

$$k_m = \frac{q_{k,mf}}{q_{k,maw}} \qquad (24)$$

k_e - the coefficient taking into account the composition of the fuel used was determined as:

$$k_e = \frac{\dfrac{\alpha}{4}+\dfrac{\varepsilon}{2}+\dfrac{\delta}{2}}{12{,}011\beta + 1{,}00794\alpha + 15{,}9994\varepsilon + 14{,}0067\delta + 32{,}065\gamma} \qquad (25)$$

where α, β, γ, δ, ε - molar concentrations of hydrogen H, carbon C, sulfur S, nitrogen N, oxygen O relative to carbon, found as:

$$\alpha = 11{,}9164\frac{W_{ALF}}{W_{BET}} \qquad (26)$$

$$\beta = \frac{W_{BET}}{W_{BET}} = 1 \qquad (27)$$

$$\gamma = 0{,}37464\frac{W_{GAM}}{W_{BET}} \qquad (28)$$

$$\delta = 0{,}85752\frac{W_{DEL}}{W_{BET}} \qquad (29)$$

$$\varepsilon = 0{,}75072\frac{W_{EPS}}{W_{BET}} \qquad (30)$$

k_a - coefficient taking into account air humidity, kg water/kg dry air:

$$k_a = \frac{H_a}{2 \cdot 1{,}00794 + 15{,}9994} \qquad (31)$$

$M_{r,a}$ - molar mass of air, kg/mol.

Using the proposed method, it is possible to determine the level of technogenic safety by calculating and evaluating emissions of pollutants into the atmospheric air from construction equipment operating on alternative fuels.

3 RESULTS AND DISCUSSION

To perform the calculations, the construction site of the R-176 "Vyatka" highway 29 km was selected, passing within the boundaries of the municipality of Kirov, Kirov region, Russian Federation, the category of the considered highway is 1 a.

The results of a comparative assessment of the calculated indicator of the complex indicator of atmospheric air pollution are shown in Figure 1.

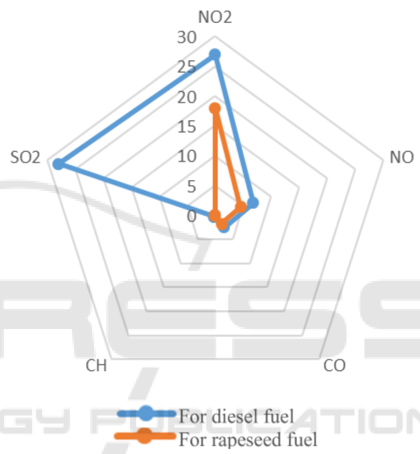

Figure 1: Air pollution index values.

The calculated value of the complex total indicator of atmospheric air pollution for construction equipment operating on traditional diesel fuel indicates a high level of pollution and is 64.57. In the case of using an alternative fuel such as rapeseed instead of diesel fuel, the level of pollution is reduced by almost 3 times and amounts to 24.47.

In addition, the results show that the characteristics of emissions of pollutants from the transport of construction equipment during its operation in the face on an alternative type of fuel and on a traditional one differ significantly both in quantitative indicators and in quality. The content of nitrogen dioxide decreases, and sulfur dioxide disappears from the composition of the exhaust gases. The composition of emissions changes, which leads to a change in the technogenic load in the study areas. Thus, rapeseed oil is an environmentally friendly type of fuel that has the best properties. This is a promising type of alternative fuel for internal combustion engines, construction equipment.

All this makes it possible to reduce the level of manufactured risk to the environment and human health, which is a priority for any country in the framework of the strategy for the development of green energy.

4 CONCLUSIONS

Because of the research, a methodology was developed for assessing the level of technogenic risk from construction equipment operating on alternative fuels.

The calculated values of the levels of technogenic risk of atmospheric air during the operation of construction equipment on clean diesel fuel 64.57 and rapeseed oil 24.47 were obtained.

An assessment of the levels of technogenic risk of atmospheric air during the operation of construction equipment at a construction site using pure diesel fuel compared to using rapeseed oil showed a decrease of almost 3 times.

The practical significance of the research is to obtain reliable information about the levels of technogenic risks of their changes depending on various factors, as well as reliability close to real conditions. The main prospects for further research are modeling the situation of technogenic risk assessment depending on the composition of construction equipment when they work in urban conditions.

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