Environmental problems of gasoline and diesel fuel use in Russia

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Abstract. The present study considers an environmental analysis of gasoline and diesel fuel use in Russia. Volume dynamics of atmospheric pollutant emission from stationary and mobile sources is presented. Chemical composition of vehicle exhaust gases is examined and toxicity of components is estimated as well as their adverse health effects in exposed people. The changes in the concentrations of detected substances in recent years are analyzed. Prospects for the use of NGV (natural gas vehicle) fuels are defined. Comparative characterization of toxic substances emissions into the environment when using natural gas instead of petroleum fuel is provided.

Currently, environmental issues in our country are coming to the fore. According to the annual State report of the Ministry of Natural Resources and Environment of the Russian Federation, the share of motor vehicles in atmospheric pollutant emission is 45.5 per cent of the gross emissions. In which connection, in comparison with 2010, transport atmospheric pollutant emission is increasing, as can be seen clearly in figure 1.

![Graph of atmospheric pollutant emission](image_url)

**Figure 1.** Volume dynamics of 2010-2017 atmospheric pollutant emission from stationary and mobile sources.
Based on the report, the largest volume of motor-vehicle transport atmospheric pollutant emission was observed in the Central Federal District - in 2017-2018 it amounted to 3 822 thousand tons or 26.2% of the all-Russian indicator. Significant mobile sources emissions in 2017 were recorded in the Ural Federal District (2 937.5 thousand tons or 20.2%), the Siberian Federal District (1 816.0 thousand tons or 12.4%) and the Southern Federal District (1 665.4 thousand tons or 11.4%) [1].

The main pollutants emitted by motor-vehicle transport are:

- solid substances (primarily soot, C and lead Pb);
- carbon oxide (CO);
- sulphur dioxide (SO2);
- nitrogen oxide (in terms of nitrogen dioxide NO2);
- benzopyrene (C20H12);
- aldehydes;
- various aromatic hydrocarbons (CH).

The main chemicals in the exhaust gases of internal combustion engines (ICE) may vary according to the engine type (carburetor or diesel), but the basic set remains the same (table 1).

| Component, Volume fraction. | Gasoline engine | Diesel engine | Toxicity |
|-----------------------------|-----------------|---------------|----------|
| Nitrogen (N2)               | 74–77           | 76–78         | nontoxic |
| Hydrogen (H2)               | 0–5.0           | –             | nontoxic |
| Oxygen (O2)                 | 0.3–8           | 2–18          | nontoxic |
| Carbon dioxide (CO2)        | 5–12            | 1–10          | nontoxic |
| Water vapor (H2O)           | 3–5.5           | 0.5–4         | nontoxic |
| Carbon oxide (CO – carbon monoxide) | 0.5–12 | 0.01–5 | toxic |
| Sulfur oxide (SO2)          | 0–0.002         | 0–0.3         | toxic    |
| Nitrogen oxide (NOx)        | 0–0.8           | 0.0002–0.5    | toxic    |
| Benzopyrene, μg/m3          | 10–20           | 0–10          | carcinogen |
| Aldehydes                   | 0–0.2           | 0.001–0.009   | toxic    |
| Hydrocarbons (C6H12)        | 0.2–3           | 0.009–0.5     | toxic    |
| Soot (C), g/m3              | 0–0.4           | 0.1–1.1       | carcinogen |

Also lead is present in the exhaust gas composition when the engine is running on leaded gasoline (ethyl alcohol is added) [2].

As can be seen from the above table the exhaust gases composition is sufficiently saturated and includes a plurality of both non-toxic and toxic elements along with carcinogens (substances capable of causing the development of malignant tumors). Each of these elements affects the human body differently.

Carbon oxide or, in the usual sense, carbon monoxide (CO) is a product of incomplete fuel combustion. Carbon oxide (carbon monoxide) irritates human mucous membranes and skin. When inhaled, it binds to blood hemoglobin, displacing oxygen from it, as a result of which oxygen starvation occurs, primarily affecting the central nervous system (CNS). Small doses of carbon monoxide can cause headache, feeling of tiredness, dizziness and retardation. With high concentration, even with short-term exposure, it can cause death. Carbon monoxide is also one of the factors causing heart disease angina pectoris (reduced oxygen transfer to tissues).

Sulfur oxide or sulfurous gas (SO2) usually occurs in exhaust gases when low-quality fuel with increased sulfur content is used. Sulfurous gas has an irritating effect on the mucous membranes of the
nose, throat, and eye of a person. The exposure to sulfur oxide is particularly dangerous for people suffering from chronic respiratory and cardiovascular diseases. Prolonged inhalation of increased concentration sulfur oxide causes a disorder of the nervous system.

Nitrogen oxides (NOx) are among the most hazardous compounds to human health. They are the most dangerous ones when converted to nitrogen dioxide (NO2). Nitrogen dioxide (NO2) poses the greatest risk. It is a red-brown gas with a sharp asphyxiating smell. When exposed to humans, the mucous membranes of the respiratory tract are highly irritated, causing functional, sensory and pathological changes. When exposed to nitrogen dioxide, throat irritation and pharyngoxerosis appear. In prolonged exposure the ability to detect NO2 is lost because it weakens the sense of smell. Gas affects eye adaptation in the dark, increases effort of breathing. When NO2 is absorbed into the human body it in contact with moisture forms nitric and nitrogenous acids which eat through the parietes of lungs alveoli. Blood capillaries become permeable which in turn leads to blood serum being passed through the lung cavity. Gas exchange is disturbed. Prolonged exposure to nitrogen dioxide leads to increased mortality rate from heart and cancer diseases. This gas is a hazard even if its concentration does not exceed the permissible concentration limits but it is of long duration.

Benzo(ghi)pyrene is an organic substance containing carbon and included in the group of polycyclic hydrocarbons. Benzo(ghi)pyrene is a highly toxic carcinogen settling in large quantities along roads and at facilities nearby. Together with atmospheric precipitation it enters the soil, water from where it rises into the air during evaporation. At the time of release with exhaust gases, especially during traffic jams, it enters the human respiratory tract. In the body it has the property to bioaccumulate that is to increase concentration over time. In high concentrations benzo(ghi)pyrene causes diseases of the circulatory system, has a mutagenic effect (penetrates DNA, causing irreversible processes affecting offspring). As a carcinogen benzo(ghi)pyrene contributes to the emergence of malignant tumors [3].

Aldehydes. Mainly, formaldehyde, acrolein and acetic aldehyde are contained in the exhaust gases. These compounds irritate the visual organs, human respiratory tract; affect the central nervous system, kidneys, liver. The photochemical smog inflames the eyes, mucous membranes of the nose and throat; symptoms of asphyxiation, exacerbation of pulmonary and nervous diseases, bronchial asthma are noted [4].

Hydrocarbons (more than 200 compounds) are contained in the exhaust gases. They are highly toxic. In areas where traffic is intense they do not cause harm to health but they can cause reactions that lead to the formation of harmful compounds even in a small concentration. This group of compounds is formed as a result of pyrolysis of various fuel fractions. Along with the highly toxic action they are carcinogens having the property of accumulating in the body, they are not excreted and lead to the formation of malignant tumors.

Soot, dust and other dispersed particles affect the respiratory organs; they can cause disease of the respiratory system. But the greatest danger is that these particles adsorb carcinogenic substances leading to the formation of malignant tumors.

Lead and its compounds. These components appear in exhaust gases when leaded gasoline is used. Lead compounds affect body organs and tissues, nervous system, gastrointestinal tract, disrupt body metabolic processes and result in increased oncology diseases. The risk of lead poisoning is exacerbated by the fact that lead compounds, like carcinogens, are not removed from the body but accumulate in it. In humans, lead is retained by erythrocyte proteins, and then injected into the blood plasma to kidneys, liver and other organs. Also lead accumulates gradually in the bones and remains long in the bones. Gingival change, functional bowel disorders, kidney disease, atherosclerotic vascular disease and diseases of the central nervous system (CNS), protein synthesis inhibition, negative effect on the cell genetic apparatus – it’s all is due to lead poisoning [5-6].

On the basis of regulatory documents changes in the concentrations of the detected substances in recent years (from 2012 to 2018) were analyzed.

The results are as follows (table 2):
Table 2. Dynamics of 2012-2018 atmospheric pollutant emission from motor-vehicle transport.

| Year | Solid substances, thousand tonnes | Carbon oxide, thousand tonnes | Sulphur dioxide, thousand tonnes | Volatile organic compounds (VOCs), thousand tonnes | Nitrogen oxides, thousand tonnes |
|------|----------------------------------|-------------------------------|-------------------------------|--------------------------------------------------|--------------------------------|
| 2012 | 23.70                            | 10091.1                       | 74.50                         | 913.9                                            | 1419.0                         |
| 2013 | 24.90                            | 10406.6                       | 75.90                         | 1368.0                                           | 1459.1                         |
| 2014 | 25.30                            | 10554.6                       | 77.00                         | 1390.0                                           | 1482.9                         |
| 2015 | 25.90                            | 10706.8                       | 78.00                         | 1411.0                                           | 1504.3                         |
| 2016 | 26.30                            | 10929.1                       | 79.60                         | 1440.2                                           | 1534.6                         |
| 2017 | 26.54                            | 11195.0                       | 81.11                         | 1477.5                                           | 1570.0                         |
| 2018 | 28.14                            | 11700.7                       | 85.28                         | 1543.7                                           | 1647.7                         |

As can be seen from the table carbonic oxide (II) contributes the most to air emissions. For the last reporting year (2018), it accounted for 77.5% of all emissions of pollutants from motor-vehicle transport.

From the data obtained it can be concluded that the use of liquid automotive fuels with increasing environmental characteristics does not provide a radical solution to the problem of emissions from motor-vehicle transport. There is an increase in each of the indicators compared to 2012 which gives a disappointing forecast as the number of cars increases every year.

In this regard, we would like to focus on the prospects for gas engine fuel. The reduction of toxic emissions into the environment when using natural gas instead of petroleum fuel is shown in figure 2.

![Figure 2. Reduction of toxic substances emissions into the environment using natural gas instead of petroleum fuel.](image)

When burning 1000 liters of liquefied petroleum motor fuel, 180-300 kg of carbonic oxide, 20-40 kg of hydrocarbons, 25-45 kg of nitrogen oxides are emitted into the air along with exhaust gases. When using natural gas instead of petroleum fuel, the release of toxic substances into the environment is
reduced by about 2-3 times for carbon oxide, for nitrogen oxides - by 2 times, for hydrocarbons - by 3 times, for smoke - by 9 times, and soot formation inherent in diesel engines is absent.

The study carried out in 2017 and assessing the environmental impact of natural gas use based on the "well-to-fuel tank filler neck" approach found that compressed natural gas reduces greenhouse gas emissions by 23% compared to gasoline and 7% compared to diesel for passenger cars. For heavy trucks, the reduction in emissions is even more impressive: by 16% compared to diesel. Taking into account emissions other than greenhouse gases the use of a car powered by a methane engine becomes even more attractive. Combustion of natural gas in the engine leads to a decrease in emissions of particulate matter by 95% and nitrogen oxides by 70% compared to diesel and gasoline.

The expansion of NGV (natural gas vehicle) fuel market is reflected in a number of regulations of the Government of the Russian Federation. This is promising and the arguments in favor of NGV fuel are understandable. The economic and ecological effect of market expansion is connected with high environmental friendliness of this fuel type, low price, large natural reserves, development of the country's petrochemical sector, reducing financial costs for the repair and reconstruction of physically and morally outdated oil and gas processing facilities, advanced technical and technological solutions to transport problems [7-8].

Both specific companies and the state are interested in the development of NGV (natural gas vehicle) fuel market. This allows us to hope that the current wave of transport infrastructure and transport development will be successful and will solve many environmental problems.

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