Wheeled vehicles and environmental pollution

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Abstract. Urbanization and human activity have led to an increase in the negative impact on the environment in urban agglomerations. According to the UNECE, every year more than 3 million people die prematurely because of ambient air pollution. A significant role in this belongs to road transport, the polluting effect of which can be divided into the following main components: exhaust emissions of internal combustion engines; non-exhaust emissions (products of wear of friction pairs); pollution with fuels, lubricants and operational materials, as well as noise pollution. Emissions of non-exhaust particulate matter are among the most dangerous emissions of pollutants generated by the movement of wheeled vehicles. At the same time, scientific research and legal regulation in this area are insufficient for making informed decisions on the reduction of the impact of these emissions on the environment and public health. The article presents an overview of the main types of environmental pollution from cars, the priority directions of scientific research and development of the regulatory framework for reducing the negative impact on the environment from wheeled vehicles.

1. Introduction
Currently, about 4.3 billion people, or 55.7% of the world's total population, live in cities and megacities. According to forecasts, by 2050, the urban population will reach 6.3 billion people, bringing its share in the total world population to more than 70% [1, 2]. In Europe, three-quarters of the population already lives in cities [3]. In the Russian Federation, the urban population accounts for more than 74% of all residents of the country [4].

In urban agglomerations, human activity leads to dangerous pollution of the surrounding air, and the greatest contribution to this pollution is made by road transport.

Ambient air pollution causes 3.7 million premature human deaths per year, which is almost three times the number of deaths in road accidents, which annually claim more than 1.35 million lives [5, 6].

In the current period of time, the negative impact of wheeled vehicles on the environment (exhaust emissions, noise and electromagnetic pollution, etc.) is limited by the relevant international and national regulatory legal documents (international agreements, technical regulations, UN rules, standards, directives, etc.). These documents are reviewed periodically, amended and supplemented, as well as new documents are created aimed at tightening restrictions on environmental pollution by wheeled vehicles.

At the same time, there are no regulatory legal acts that limit environmental pollution by emissions of non-exhaust particulate matter (wear of brakes, tires and roadway), the share of which is constantly growing due to the global increasing of the world vehicle fleet.
2. Materials and methods

Most of the current methods for estimating non-exhaust particulate matter emissions are mainly related to obtaining data on gross emissions of pollutants from vehicles obtained from stationary measurement sources located along highways and motorways. This data is used to compile national and international inventories of air pollutants. The estimation and forecasting of emissions in this case are usually carried out by an experimental calculation method without breaking them down by the source of origin.

At the same time, in some cases it is necessary to assess the actual contribution of individual sources of pollutant emissions in order to take appropriate regulatory or design and technological measures that reduce the negative impact of these emissions on the environment and public health.

The methodologies for estimating emissions of exhaust origin are sufficiently developed and formalized by the relevant UN regulations, while there are no generally accepted methodologies for estimating emissions of non-exhaust origin.

In different countries, different researchers in each specific case apply their own methods for measuring the amount and composition of non-exhaust particulate matter emissions. The review and analysis of domestic and foreign scientific research in this area have revealed a wide variety of these methodologies. The results of emission estimates obtained by different methods may differ tenfold [7].

For an example, Figure 1 (a) shows the installation of a receiving pipe for the sampling of solid particle emissions from the tire contact with the roadbed according to the method of FSUE "NAMI". The amount and dispersion of solid particle emissions are measured directly using the Lighthouse HANDHELD 3016 laser particle counter manufactured in the USA (Figure 1 b), which has 6 counting channels showing the number of particles of six size ranges in the selected sample [8].

![Figure 1](image-url)

Figure 1. Installation of a receiving pipe for the sampling of solid particle emissions from the tire contact with the roadbed (a) and Lighthouse HANDHELD 3016 Laser Particle Counter (b)

3. Results from monitoring studies of the negative impact of wheeled vehicles on the environment

In general, the negative impact of road transport on the environment can be divided into the following main components:

- emissions from the exhaust gases of internal combustion engines (greenhouse gases and pollutants);
- non-exhaust emissions – environmental pollution by wear products of friction pairs (tire-roadbed, brakes, clutches, transmission elements, drives, etc.);
- contamination with fuel and lubricants and operational materials;
- noise pollution.

This list does not take into account the processes of production and disposal of motor vehicles, their components, production and disposal of fuel and lubricants and technological materials, as well as light and electromagnetic pollution.
One of the dangerous types of anthropogenic impact on the environment is the presence of greenhouse gases in the Earth's atmosphere, which lead to an increase in radiation exposure, which in turn causes climate warming. Due to the growth of the greenhouse gases, the total radiation exposure of the Earth has now increased by 43% compared to 1990 and amounted to 3.1 W/m². For this reason, according to the World Health Organization (WHO), currently about 30% of the world's population lives in climatic conditions in which potentially deadly temperatures are at least 20 days a year. It should be noted that 23% of global greenhouse gas emissions are from internal combustion engines of wheeled vehicles in operation [5, 9, 10, 11].

On July 2, 2021 the President of the Russian Federation signed the Federal Law "On limiting Greenhouse Gas Emissions". The Federal Law establishes the principles of limiting greenhouse gas emissions, defines measures to limit such emissions. The Federal Law involves the powers of the Government of the Russian Federation and federal executive authorities, the rights and obligations of legal entities and individual entrepreneurs in the field of limiting greenhouse gas emissions. This is the first real step towards reducing CO₂ emissions in the Russian Federation.

The exhaust gases of internal combustion engines are a source of more than 200 different pollutants, accounting for 18% of all anthropogenic emissions in the world economy [5, 12, 13]. Currently, the main substances that pollute the air environment include sulfur oxides (SOₓ), nitrogen oxides (NOₓ), ozone (O₃) and dispersed or solid particles (Particulate matter, hereinafter – PM). At the same time, ozone and aerosols are the basis of fine particles and the main components of smog.

A striking example of the impact of smog on a person can be seen in December 1952 in London, where as a result of the impact of smog in a few days, 12 thousand people died and about 100 thousand people fell ill. At the end of 2015, due to smog in Rome, Milan and other major cities in Italy, local authorities were forced to restrict the movement of private transport after the Christmas holidays. In Milan, in addition, the speed limit is no more than 30 kilometers per hour. In Rome, they also limited the heating regime to eight hours a day and the air temperature in the rooms to no more than 18 degrees. In Turin, free public transport was introduced [14].

Currently, in the Russian Federation, exhaust gas emissions from internal combustion engines are regulated by the Technical Regulation of the Customs Union "On the Safety of Wheeled Vehicles" TR CU 018/2011 (hereinafter referred to as the Technical Regulation), the UN Regulations nos. 24, 40, 47, 49, 83, 96, 101. In accordance with these documents, internal combustion engines have limited emissions of nitrogen oxides and carbon, hydrocarbons and solid particles. These regulations are periodically amended and supplemented to tighten the requirements for the content of pollutants. Over the past decades, this has reduced the emissions of pollutants from the exhaust gases of engines more than 40-60 times, while solid particles – almost 30 times [8].

Also, paragraph 2 of Annex 3 to the Technical Regulations regulates the content of harmful (polluting) substances in the air of the vehicle's habitable space, depending on the type of engine installed on the vehicle and the used fuel.

The main sources of emissions from the wear of friction pairs are:
- wear of brake mechanisms;
- wear of transmission parts (clutches, gears, etc.);
- wear of drive elements (belts, gear chains and gears);
- tire wear;
- wear and tear of the roadway.

These emissions contribute to overall environmental pollution and can cause respiratory diseases in humans. For example, Table 1 shows the growth in the share of PM₁₀ and PM₂.₅ particulate emissions from brake, tire and pavement wear in the total primary PM₂.₅ and PM₁₀ emissions from all UK sources. The value of the year 2030 is calculated. Figure 2 shows the trend of PM₂.₅ emissions in kilotons in the UK from brake wear, tire wear, and roadway wear, as well as the trend of particulate emissions contained in vehicle exhaust gases [15].
As Figure 2 shows, the share of PM$_{2.5}$ emissions from brake, tire and pavement wear increased from 26% of total UK road transport emissions in 2000 to 60% in 2016. At the same time, the estimates do not include resuspending of road dust. A similar trend is observed for PM$_{10}$ emissions.

Table 1. Particulate matter emissions of PM$_{2.5}$ and PM$_{10}$ in UK

| Emissions | 2000  | 2016  | 2030 |
|-----------|-------|-------|------|
| PM$_{10}$, % | 5.8   | 8.5   | -    |
| PM$_{2.5}$, % | 4.9   | 7.4   | 9.5  |

Figure 2. UK PM2.5 emissions from road transport

In Moscow, road transport accounts for 80% of all harmful emissions. A passenger car emits about 14 kg of rubber dust until the tread is completely worn out, and a truck or bus emits 92 kg [13]. Emissions from the operation of brake mechanisms for passenger cars are 0.0192 g/km, for trucks – 0.168 g/km [16].

At the same time, there is no legislation in the world that restricts environmental pollution by emissions of solid particles from the wear of brakes, tires and roadways, the share of which is constantly growing due to the global growth of the global fleet. Also there is no generally accepted methodology for studying such emissions.

Contamination of fuel, lubricants and operating materials from vehicles can occur as a result of fumes or leaks. At the same time, the main danger is the emissions of volatile organic compounds associated with the evaporation of fuel and the release of crankcase gases. For vehicles with diesel engines, it is generally assumed that due to the presence of heavier hydrocarbons and the relatively low saturated vapor pressure in diesel fuel, emissions in the form of diesel fuel vapors are insignificant, and therefore they are not regulated by regulatory documents.

Emissions from the evaporation of gasoline from vehicles are regulated by Annex No. 7 to the 07 series of amendments to UN Regulation No. 83 and UN GTR No. 19. In the countries of the European Union, Directive 98/69/EC is in force "Concerning measures to be taken against air pollution from vehicle emissions and the amendment of Council Directive 70/220/EEC/98/69/EC". The requirements for the tightness of the supply and exhaust systems, as well as the absence of leaks and drops in vehicles, are regulated by the Technical Regulations.

According to WHO, 10% of the world's population is exposed to increased noise exposure. The main source of noise in cities is the noise from road transport. Analysis of a large number of studies has shown that increased noise exposure can lead to hearing impairment, an increase in traffic noise by 10 dBA can lead to an increase in the risk of high blood pressure or heart disease by 7-17%. In Europe, at least 20% of the population lives in areas where the noise level exceeds 55 dBA (the
threshold at which the negative impact of noise on human health can be observed). In wheeled vehicles, the dominant source of noise pollution is the noise from the contact of the tire with the road, starting at speeds above 30 km/h (from about 35 km/h – for passenger cars and from 55 km/h – for trucks). Below these speeds, the main source of noise is the engine. Driving style can also affect the noise level (turning on/off the ignition, stopping and starting traffic, sudden acceleration/braking, beeping, etc.) [17, 18].

Abroad, the limit values of the external noise level are regulated by the relevant regulatory legal documents. In the Russian Federation, the limit values of the level of external noise produced by wheeled vehicles are regulated by the Technical Regulations and the UN Regulations nos. 9, 41, 51, 63, 117. Also, paragraph 2 of Annex 3 to the Technical Regulations normalizes the permissible levels of internal noise of vehicles measured while driving.

4. Conclusion
The current national and international regulatory legal documents regulate and limit the emissions of harmful substances from the exhaust gases of internal combustion engines, emissions from the evaporation of gasoline and crankcase gases, pollution of fuel and lubricants and operational materials, as well as noise pollution of the environment by wheeled vehicles.

Emissions of solid particles from the wear of brake mechanisms, tires and roadway are not regulated, moreover, there is no generally accepted methodology for studying such emissions.

It seems necessary:
- to develop a single, generally accepted methodology for measuring emissions of non-exhaust particulate matter from wheeled vehicles;
- to develop a regulatory framework that limits the emissions of non-exhaust particulate matter from wheeled vehicles;
- to determine the main directions for reducing emissions of non-exhaust particulate matter from wheeled vehicles.

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