Sustainable development of urban areas in the context of global warming (on the example of assessing the methods of inventory of carbon dioxide emissions into the environment in the Russian Federation)

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Abstract. This article discusses an important scientific issue in the field of ecology and the environmental safety of urban areas - the pollution of the air of cities. In the context of global warming, the focus is on the problem of carbon dioxide (CO$_2$) emissions and their impact on the sustainable urban development. To solve the problems of climate change and sustainable development of urban areas, two main goals must be pursued: preserving the biosphere and creating a safe and comfortable environment compatible with the biosphere. In this case, the solution of these problems should begin with an assessment of the current situation. All in all, the article analyzes the methods of inventorying greenhouse gas emissions currently used in Russia (in particular, carbon dioxide emissions). Based on the results of a comparative analysis, their features were identified, and the most meaningful and comprehensive method was identified, which would provide reliable calculations when air pollution in urban areas is assessed. According to the author, it is necessary to improve the Russian regulatory, to development existing energy-efficient technologies, to switch over to renewable energies and use "green" building methods. This will allow in the future to form an environmentally safe and comfortable living environment and thereby ensuring sustainable development of urbanized areas.

1. Introduction

Nowadays, most of the population from European countries including Russia lives in urban areas. According to many world scientists, the urban activities is one of the sources of greenhouse gas emissions, which in turn cause anthropogenic climate change. Compared to the pre-industrial period (1850-1900), the average temperature on land has increased by 1.53 °C by now [1]. A report from the World Meteorological Organization (WMO) notes that signs and impacts of climate change have increased significantly between 2015 and 2019. These years have become the warmest in the history of observations in comparison with the previous five-year periods [2]. High rates of urbanization, coupled with climate change, threaten the world's environmental, social, and economic stability. Consequently, one of the tasks of the noosphere in modern conditions of continuous urban growth is to improve the environmental safety of urban construction and economy [3].

To solve the above-mentioned problems at international level, world politicians are taking urgent measures. They include climate conferences in the framework of the United Nations as the summit in 2014 in Paris and 2018 in Poland. In 2020 the European Commission established the European
Climate Change Program to identify the most environmentally and economically efficient measures to regulate the reduction of greenhouse gas emissions at the political level.

Last year the head of state of Russia signed the decree No. 666. This led to a contribution of Russia to the Paris Climate Agreement of 2015, to which Russia joined in September 2019. At the same time according to official media publication by «Kommersant» («Kommersant» is a nationally distributed daily newspaper published in Russia mostly devoted to politics and business) a new climatic goal for our country is being outlined. Greenhouse gas emissions should be reduced to 70% of the level of 1990 until 2030 if the maximum possible absorptive capacity of forests is considered. Currently, the reduction level is at 50%.

Urban transport is one of the largest drivers of climate change and a major source of air pollution and carbon dioxide (CO$_2$) emissions. According to the WHO (World Health Organization), transport accounts for approximately 13% of total world energy consumption [4]. The most harmful impact from the transport infrastructure falls on air pollution by road transport [5]. The exhaust gases of cars contain more than two hundred compounds and substances, most of which are toxic. Oxides of carbon (CO), nitrogen (NO), sulfur dioxide (SO$_2$), aldehydes, soot (C), lead (Pb) and others are released into the environment. A special group is made up of carcinogenic polycyclic aromatic hydrocarbons (PAHs), including the most active of them benzo(a)pyrene. Carbon dioxide (CO$_2$) is present in the group of non-toxic substances, however, under its influence, the pH value in the blood serum decreases, which leads to acidosis. Thus, with an increase in its concentration to 5%, breathing becomes more frequent and shortness of breath occurs, with 10%, a fainting state sets in. If the CO$_2$ concentration rises further, the person is at risk of death. Meanwhile, it should be noted that the share of CO$_2$ in the exhaust gases of cars is 5-12% for gasoline and 1-10% for diesel engines [5].

2. Materials and methods
The above-described situation determined the formulation of the research problem and the materials and methods used to achieve this goal. Currently, the issues of regulating greenhouse gas emissions into the atmosphere on a global scale are usually regulated at the political level. Therefore, it is necessary, first of all, to get acquainted and identify the features of the legislatively established and currently applied in the Russian Federation methods for assessing the impact of greenhouse gas emissions on global climate change (for example, using the example of CO$_2$ emissions from vehicles), which will allow identifying the most meaningful and informative ones for performing reliable calculations, field experiments and modeling the assessment of air pollution in urban areas by emissions from vehicles. Thus, the following research methods used by the author in this article can be noted: familiarization with the relevant regulatory documents and a comprehensive analysis of this type of documentation for solving the above formulated scientific problem.

3. Results
To solve the above-mentioned problem, the author analyzed and studied the currently existing legislative mechanisms in the Russian Federation to regulate greenhouse gas emissions. The focus is on the methods used for calculating CO$_2$ emissions from road traffic. Furthermore, the author analyses the main aspects of the current methods to assess greenhouse gas emissions. This made it possible to carry out a comparative analysis of the features of this type of calculations for vehicles. The results of the research are presented in the following form (figure 1).

4. Discussion
Nowadays, the following regulatory acts in the field of inventory of greenhouse gas emissions have been developed and are legally approved in the Russian Federation: "Guidelines for the Quantification of the Volume of Absorption of Greenhouse Gases", "Methodological Instructions and Guidelines for Quantifying the Volume of Emissions of Greenhouse Gases by Corporations Carrying out Economic and other Operations in Russia", "Methodological Guidelines for Quantifying of the Volume of Greenhouse Gases’ Indirect Energy Emissions", "Methodological Recommendations for Carrying out
Voluntary Inventory of the Volume of Emissions of Greenhouse Gases in the different Regions of Russia". Furthermore, there is a drafted law in Russia, that is called "On state Regulation of Greenhouse Gas Emissions and on Changes to certain legislative Acts of the Russian Federation”. It should be noted that the calculations of CO$_2$ emissions from road traffic are discussed in detail in the "Methodological Recommendations for Carrying out Voluntary Inventory of the Volume of Emissions of Greenhouse Gases in the different Regions of Russia”. Because of that, the author summarizes the features of this methodology in the following paragraph. Moreover, this methodology was approved by the Ministry of Natural Resources of Russia with the order No. 15-P from April 2015. According to the methodology it is recommended to calculate CO$_2$ emissions for all vehicles based on data on the consumption (sale) types of fuel. If possible, it is recommended to consider the separation of fuel by ecological classes [6]. The calculation method is the product of the amount of fuel burned for a certain type and the carbon content in it (in terms of thermal units) and the corresponding CO$_2$ emission factor. The results of the calculations for the individual fuels are then added together to estimate the CO$_2$ emissions for the entity. Motor transport is divided into cars, light and heavy-duty trucks, buses, as well as motorcycles (including mopeds, scooters, and motorcycles with a sidecar) that run on various types of liquid and gaseous fuels. When estimating CO$_2$ emissions from fuel combustion, a method (the so-called Tier 1 method) can be applied based on the amount and type of fuel burned and the recommended average CO$_2$ emission factors. In this case, the formula for calculating CO$_2$ emissions from vehicles can be presented in the following form:

$$E_{CO_2} = \sum a [AD_a \times EF_a]$$  \hspace{1cm} (1)

Where: $E_{CO_2}$ - CO$_2$ emissions (kg); $a$ - type of fuel (for example, gasoline, diesel fuel, natural gas, liquefied petroleum gas, etc.); $AD_a$ - data on fuel consumption of type $a$ (TJ); $EF_a$ - emission factor for fuel type $a$ (kg / TJ), the CO$_2$ emission factor is calculated as the carbon content of the fuel multiplied by 44/12. The recommended CO$_2$ emission factor is calculated considering the total carbon content of the fuel, including emissions in the form of CO$_2$, CH4, CO, NMVOC and particulate matter.

Figure 1. Visualisation of the results.

The Tier 2 method presented in this methodology is like the Tier 1 method described above and is also calculated using Formula 1. But the calculation uses regional values of emission factors. These factors are either based on the real carbon content in fuel consumed in one year in Russia or in one of

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its regions. In the above-mentioned order of the Ministry of Natural Resources Recommended the CO₂ emission factors are given [5].

Most of the data needed to calculate greenhouse gas emissions in Russia (especially CO₂), can be obtained from Rosstat - the Federal State Statistics Service. At the same time, when making calculations, the emissions from vehicles in those regions where fuel was sold should be considered. Data on the production and supply of motor gasoline and diesel fuel to the market can be obtained from the Ministry of Energy of the Russian Federation, and on sales of motor fuel - from the Ministry of Industry and Trade of the Russian Federation. To estimate the fuel consumed by vehicles, other data of regular statistical reporting submitted to the territorial and federal bodies of Rosstat can also be used. Data should be collected on other fuels used in the region that are less common and usually not included in the sales statistics (for example, LPG, compressed natural gas or biofuels). In the absence of inadequacy of data on fuel sales, data on fuel consumption by vehicles in various sectors of the economy should be used. Primary data from business entities are also sent to Rosstat, where they are processed, and then summarized and analyzed according to the industry principle. Only legal entities (except for small businesses) are subject to mandatory statistical reporting. Moreover, most of the park belongs to individuals who do not submit statistical reports. Information on the fuel sold may also be absent or unreliable, since it provides limited information on fuel consumption in transport, especially automobiles. In this case, estimates of the volume of fuel use should be carried out based on data on the vehicle types and vehicle fleet that is registered in the relevant region [6].

Consequently, the complexity of obtaining information, the lack of the necessary information in the public domain complicates the calculation of greenhouse gas emissions, in particular CO₂ emissions from road traffic using the above method.

By order of the Ministry of Transport of the Russian Federation in 2008, OJSC NIIAT (Open Joint Stock Company Scientific Research Institute of Road Transport) developed a "Settlement Instruction (Methodology) for the Inventory of Pollutant Emissions from Motor Vehicles in the Territories of Major Cities" [7]. This methodology is based on the calculation of pollutant emissions and the assessment of air pollution by vehicles of various environmental categories when operating in urban conditions. The main provisions of this methodology were harmonized with the international EMEP/CORINAIR [8] pollutant emission inventory methodology, considering the peculiarities of the structure and modes of movement of vehicles operated in the largest Russian cities with a population of over 1 million people.

These approaches can be used by environmental and regulatory organizations, as well as companies involved in urban planning, transport, and road construction activities when performing calculations to determine the amount of gross emissions of pollutants into the atmosphere from vehicles, that are needed for the works. It should be noted that this instruction replaced the "Methodology for determining the mass of emissions of pollutants by vehicles into the atmospheric air", approved by the Ministry of Transport of Russia on 02.06.1993, which was widely used in training at the University the author working (currently NRU MGSU) students in the specialties "Industrial and civil construction", "Urban construction and economy", "Mechanization and automation of construction", "Applied mechanics" [9]. The methodology provides two calculation schemes: simplified and detailed. A simplified calculation scheme is used to inventory the emission of pollutants from road traffic flows into the atmospheric air in the presence of data on fuel consumption, that is like the method described above. Therefore, the author is on the opinion, that the most interesting calculation scheme is the detailed one. She is based on data of the traffic density.

The calculations are performed for the main polluting parameters, including CO₂. The previous method from 1993 did not consider CO₂. To carry out calculations according to this method it is necessary to determine the transport load. This information can be obtained based on an analysis of registered vehicles, while approximate data for the Moscow region are given in this methodology. The initial data for calculations are cartograms of daily traffic intensity for the billing period by types of vehicles. The intensity of traffic during the peak and between-peak periods is calculated using the formulas given in the methodology. At the same time, the average daily traffic intensity of each type
of vehicle is divided by the traffic intensity of Russian and foreign vehicles, which in turn depend on the type of fuel they use, the corresponding environmental class, engine displacement, gross weight and class of the vehicle based on traffic police data in terms of number various brands and models of cars, trucks, and buses, registered in the largest cities and passed the state technical inspection. To carry out the calculations, it is also necessary to establish in accordance with SNiP 2.07.01-89 “Urban planning. Planning and development of urban and rural settlements” categories of city streets and roads along which the considered vehicles move. In this case, it is better possible to get the data necessary for the calculations above. The intensity of traffic during the peak and between peak periods is calculated using the formulas given in the methodology. The average daily traffic intensity of each type of vehicle is divided by the traffic intensity of Russian and foreign vehicles, which in turn depend on the type of fuel they use, the corresponding environmental class, engine displacement, gross weight and class of the vehicle based on traffic police data in terms of number various brands and models of cars, trucks, and buses, registered in the largest cities and passed the state technical inspection. According to the author, in this case, obtaining the above data necessary for the calculations is more possible.

5. Conclusion
To solve the problems of climate change and sustainable development of urban construction and economy two main goals must be pursued: the preservation of the biosphere and the creation of a safe comfortable human environment, compatible with the biosphere. The solution of these scientific problems should begin with an assessment of the current situation; it is for this purpose that this article analyzed the methods for calculating the impact of road traffic flows of urban areas on global climate change.

According to the author, the most perspective is the "Settlement Instruction (Methodology) for the Inventory of Pollutant Emissions from Motor Vehicles in the Territories of Major Cities", which allows calculating CO₂ emissions from vehicles and assessing the impact of this type of emissions on global climate change. For the most effective assessment, it is necessary to improve the Russian regulatory framework, formulate new development goals and objectives, such as: mastering energy efficient technologies, switching to renewable energy sources and green building, which will make it possible in the future to form an environmentally safe and comfortable living environment.

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