Analysis of some indicators of environmental safety of buses with diesel engines (on the example of Moscow)

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Abstract. The results of studies performed personally by the author and under his leadership on the current level of environmental safety of city buses of Russian-made ecological class Euro-4 (LiAZ-5292-21) and Euro-5 (LiAZ-5256-13 and LiAZ-529-22) according to the smoke level of the exhaust gases provided by GOST R 52160-2003, and not required in actual operation in terms of the content of nitrogen oxides NO\textsubscript{X} in the exhaust gases of a diesel engine when operating at idle modes. Previous studies on passenger cars and light commercial vehicles with diesel engines (using the operating method developed by us) in accordance with UNECE rules 83.03 (based on urban driving cycles with the results of environmental pollution in g/km) showed an excess of NO\textsubscript{X} emissions from 7 to 15 times, on the basis of which a simplified technology was developed to control the environmental safety of these vehicles by indicators of the content of CO\textsubscript{2} and NO\textsubscript{X} at idle for a conventional engine with a working volume of 1 liter. This technique is appropriate to apply for a large vehicle mass, for which NO\textsubscript{X} emissions at idle is much higher. This will provide operational control of environmental safety by NO\textsubscript{X} and increased requirements for manufacturers. In a first approximation, the maximum permissible value of the NO\textsubscript{X} content is justified – no more than 530 ppm. (For comparison, this indicator for cars is significantly lower – no more than 200 ppm). It was additionally established that for estimating CO\textsubscript{2} greenhouse gas emissions it is enough (with an error of no more than 10 %) to use the general indicator of fuel economy – actual fuel consumption: at the same time per 1 kg of diesel fuel, gasoline, liquefied and compressed natural gas, used in operation, 1,500 g of CO\textsubscript{2} will be accounted for (conversion to liters is carried out according to the energy density indicators). The studies were carried out as part of comprehensive work to improve the quality of technical servicing of cars, trucks and buses, conducted at the department "Operation of automobile transport and car service" MSARTU (Head of the Department of Doctor of Technical Sciences, Professor A.A. Solntsev).

Keywords: buses, Euro environmental classes, bench tests for compliance with the EB-RO class, emissions of CO, CO\textsubscript{2}, CH and NO\textsubscript{X}, diagnostics of the ecological safety of diesel engines.

1. Introduction
City buses carry the vast majority of passenger traffic in medium and large cities, including in megacities, such as Moscow, which are characterized by the most stringent requirements for air pollution from car exhaust due to their specific (almost circular diameter up to 40 km according to MRHW) planning and high density construction of multi-storey buildings. The latter leads to the need
to limit the use of a classic single or articulated diesel bus for the central districts of the city. Currently, single Russian-made electric buses are already used for individual routes, however, they cannot be widely distributed in the near future, and for non-central regions, as well as for communication with cities and settlements of the Moscow Region, full-size and route buses will be increasingly used buses with diesel engines. It is generally accepted that the exhaust gases of these cars, despite the modern achievements of scientific and technological progress, are much more aggressive compared to gasoline or using cheaper gas fuel. However, to obtain significant power (during bus transportation), the diesel engine remains a priority, which has always been given great attention to the environmental safety of the whole world. At the same time, the current level of solving this problem is still far from complete despite the rather stringent state restrictions [3–5], which is confirmed by numerous foreign studies on passenger cars with diesel engines [6–9], and made by us [10]. As for city buses, with obviously worse environmental safety indicators, here manufacturers use an information sign on the back of a vehicle of an environmental class value (for Moscow it is usually 4th or 5th), which according to Russian laws should be confirmed during routine maintenance by checking exhaust gases for smokiness in the free acceleration mode of the crankshaft without external load (according to GOST R 52160-2003: FUMES OF EXHAUST GASES. Standards and methods for control when assessing the technical condition). At the same time, such an important indicator of the level of exhaust gas pollution as the content of $\text{NO}_x$ nitrogen oxides in them, due to technical regulations adopted in the last century, which have long been necessary to revise to improve the environmental safety of diesel engines of heavy trucks and buses, is not used in operation. Therefore, the development of possible options for solving this problem is relevant.

2. Statement of the problem and analysis of possible methods for solving it

Here it is necessary to take into account that traditionally in our country the environmental characteristics of the diesel engine in operation were checked by the parameters of exhaust smoke according to GOST 17.2.2.03-87, which was adjusted in the direction of tightening, and since 2005 has been replaced by GOST R 52160-2003, harmonized with European standards – UNECE Regulations 49 and 83, which contain environmental requirements for vehicles with compression-ignition engines and sparks. According to these rules, in Russia from 1992 to 2016, manufacturers must ensure the release of new cars in accordance with EURO 1–6 standards, and thus ensure the gradual replacement of rolling stock with environmentally friendly cars.

In this regard, UNECE Regulation 83 with its current supplements regarding the certification of cars and light commercial vehicles (weighing up to 3,500 kg) with gasoline and diesel engines, according to the standards of the ecological classes EURO, is of the greatest interest. A general idea of the essence of the EURO standards for cars can be obtained from the Internet materials [4], and in general and a more detailed presentation for cars and heavy vehicles and buses can be found in the Internet resource [5], although there are certain inaccuracies in the list indicators. A theoretical presentation of the features of testing cars and engines for environmental certification is given in the textbook [4]. In ordinary operation, as a rule, there is no clear idea of these standards and methods for their assessment, more so as in Russia the environmental class indicator was reflected in the data sheet only for cars (Russian and foreign) manufactured in 2006 and later. Therefore, for the bulk of passenger cars in operation, it is indicated that this indicator is “not defined”, although for foreign models it could be quite high – EURO-3 or more. For this reason, it turned out to be practically impossible to regulate air pollution in the central zones of large cities by allowing cars with a high environmental class to enter there, and the application of this rule for municipal (state) rolling stock was limited only to bureaucratic procedures (for a fee for foreign cars it was confirmed by the basis of the year of release, its regulated environmental class, although in fact as a result of using the resource it could s is much lower). Therefore, there was a need to develop a method for the rapid assessment of the actual level of the ecological class, primarily for gasoline cars, since the modernized GOST R 52033-2003 (Cars with gasoline engines. EMISSIONS OF POLLUTING EMISSIONS WITH EXHAUST GASES. Norms and control methods for assessment technical condition), intended mainly
for carburetor feed systems, did not foresee any measurements of NO\textsubscript{X} emissions underlying EURO. Similarly, a similar situation was observed in the operational practice of the countries of Western Europe. In addition, the automatic engine control systems for some foreign models were not adapted for emission tests for emissions from CO and CH at elevated frequencies of rotation of the crankshaft (0.6 \textit{nmax}) and gave anomalous values from CO (for example 3\% ) with a high environmental class. Therefore, for cars of ecological classes Euro-3 and higher, such control no longer provided high-quality maintenance of exhaust gas aftertreatment systems based on platinum catalysts, primarily regarding NO\textsubscript{X}, and required the development of more complex technologies applicable in operation.

We managed to develop such a technology on the basis of tests of a heated car on unloaded running drums in direct transmission at speeds of 40, 60 and 80 km/h, at which the content of carbon monoxide CO, carbon dioxide CO\textsubscript{2}, hydrocarbons \textit{CmHn} (abbreviated CH) was measured and nitrogen oxides NO\textsubscript{X} using a five-channel non-dispersed gas analyzer infrared type \cite{1}. The results obtained were then adjusted for conditions according to EURO standards (a detailed description of the test technology is given in the textbook \cite{3}). They are based on a four-fold repetition of the so-called European city driving cycle (ECE test), which was used even before using the EURO classification, according to which, at a specialized dynamometer stand with automatic control, the vehicle idling and subsequent accelerations were simulated using I-th gear, I-II-th, and I-II-III-th gears to speeds of 15, 30 and 50 km/h, respectively. Over a period of four test cycles, the car theoretically “traveled” 4,052 km of track, while all exhaust gases were collected in a common tank and diluted with clean air in a ratio of 1: 3 (to exclude vapor condensation). Then, the resulting mixture was analyzed for the content of CO and CO\textsubscript{2} by a non-dispersed infrared gas analyzer, and \textit{CmHn} and NO\textsubscript{X} were respectively evaluated by ionization-flame and chemiluminescent methods (not used in ordinary operation). Moreover, according to the research of Doctor of Technical Sciences, Professor V.A. \v{Z}vonov, the figures of the \textit{CmHn} infrared gas analyzer used in carburetor engines operations turned out to be half lower than the ionization-flame method (due to the underestimation of non-vaporized fuel droplets when working on enriched mixtures). When testing on EURO since 1993 in accordance with the rules of the EEC No. 83.03, a speed cycle of up to 120 km / h (EUDC test) with a duration of 400 s and a track length of 6.955 km was added to the 4th city cycles. At the same time, for EURO-2, the engine was preheated from the initial temperature of 200 °C for 40 s, for EURO-3, such heating was already excluded, and for EURO-4, tests should have started when the car and engine were cooled to negative temperatures of –70 °C. Tests for cars with gasoline and diesel engines were completely identical, although the standards for NO\textsubscript{X} diesel emissions were set much less stringent (three times higher), and for CO – more stringent (about four times lower). In Russia, facilities for testing cars can be counted practically on the fingers, and the complexity of the process did not allow the possibility of its use in operation. In Russia, facilities for testing passenger cars can be counted practically on the fingers, and the complexity of the process did not allow the possibility of its use in operation.

At the same time, the operational methodology developed by us for testing cars on unloaded running drums and the recalculation model of the obtained indicators provided the maximum approximation to the certification test 4 \times \text{ECE + EUDC “1”}, and the values of mass emissions of explosives (CO, CH and NO\textsubscript{X} in g/km) in a first approximation could be compared with the environmental standards of Euro [3–5]. (Here it is necessary to take into account the inevitable error in underestimating the NO\textsubscript{X} values due to the exclusion of the speed cycle, which could be compensated by its initial low values for an unheated or cold engine, and, accordingly, the underestimation of the indicators for CO and CH for the same reason). However, the final analysis of the diagnostic results obtained in this way for passenger cars with gasoline engines showed a good agreement between the components of CO and CH with the standards of the declared environmental class, although deviations beyond the standards could be observed by NO\textsubscript{X} indicators for cars of Russian models (2–3 times), due to the insufficient efficiency of the exhaust gas neutralization system, which could be eliminated by certain technical influences \cite{1}. At the same time, for cars of foreign manufacture of ecological classes Euro-2 and higher, there was a “zeroing” of NO\textsubscript{X} values during tests at idle mode and at 3-speed platforms on unloaded running drums (a similar “zeroing” was recorded , as a rule, also in
terms of CO and CH for Euro-4-class cars). At the same time, it was revealed that the increase in the mass of emissions of all three harmful substances (even outside Euro-1) was associated with an unacceptable deterioration in the condition of the cylinder-piston group, and this defect was not detected by the diagnostic parameters customary for operation - the deterioration of vehicle dynamics and increased fuel consumption. After replacing the pistons and rings, the environmental performance of the engine in test modes for testing the car was fully restored, although there were no technological impacts on the neutralizers. Therefore, an excess of the calculated emission values compared to Euro standards is certainly evidence of a deterioration in the state of operation of the engine and the neutralization system as a whole or for individual components.

During logical processing, it is necessary to consider such specifics of technical diagnostics as the need to use the inevitable statistical practice of estimating the maximum permissible value of a diagnostic parameter, the rationale of which is given in the textbook [2]. This is due to the fact that in operation it is impossible to maintain the “ideal” technical condition of the controlled object for a long time, and its deterioration to the level at which its further use by social or technical and economic criteria becomes undesirable or ineffective is allowed. In other words, if the manufacturer manufactures a car of the required environmental class, then in actual use their condition will inevitably be one or two classes worse (controlled emission figures will approximately double [3–5].

The range of permissible changes is determined by the statistical processing the values of the diagnostic parameters for the same type of aggregates, units and mechanisms of a car of various states, usually during the next service, while for informative parameters of its the scattering should be described by a unimodal theoretical distribution law (usually normal or gamma distribution with an offset parameter). The permissible value is then determined by unilaterally or bilaterally limiting the range of variation of the theoretical law with a probability of 0.9 for non-relevant elements (while minimizing the so-called error of the 1st kind – a false malfunction), and with a probability of 0.8 for socially significant elements (while minimizing the so-called error of the second kind – malfunction skipping) [2]. From these positions, the “inaccuracies” of the theoretical or instrumental nature of the technological process of determining the diagnostic parameter are compensated by final statistics – the diagnosis is logically made by comparing the parameter with its maximum permissible value. At the same time, the significance of the test test mode (in this case, on unloaded running drums) is confirmed. In this case, the parameter should be considered informative, in which the a priori (practical) probability of going beyond the range of the permissible value will be at least 25–30 %.

Thus, in a real diagnosis of the compliance of a car and an engine with the ecological class of Euro, a situation can be observed when the test (tied to equipment and technology of its application) parameter values can exceed the ecological standards of Euro, but it is enough to objectively identify the need for technical influences to improve the condition within the design limits features of this system and technological capabilities of maintenance and repair. It is necessary to add to this that even with worse parameters compared with the declared values, they generally turn out to be better in comparison with the still used cars of older models (lower environmental class), the compulsory prohibition or restriction on the use of which will undoubtedly lead to increased social tension.

A certain misunderstanding for the operators may be caused by the environmental standards given on the Internet for cars and light commercial vehicles with both gasoline and diesel engines [4, 5]. First, unlike the educational literature [3], there is a substitution of the concept of the content of carbon-hydrogens \( C_mH_n \) in the exhaust gases, which is traditional for car ecology, with the content of \( HC \) hydrocarbons (acid salts of carbonic acid, formed during prolonged transmission of \( CO_2 \) through an aqueous solution containing carbonates). The latter has nothing to do with the operation of automobile engines, but for several practitioners it leads to the conclusion that it is impossible to directly control environmental indicators, since the measurement of LS cannot be performed by an infrared gas analyzer. In addition, there are certain discrepancies in the control figures, even considering the comments made, which leads to additional confusion and does not contribute to more complex types of direct control. Based on the comments made, it is advisable to have one agreed table of Euro environmental standards on the Internet, reflecting the specifics of road transport (similar to
that presented in the textbook [3] on p. 110), with a more “soft” adjustment depending on the category of cars. In this case, the permissible NOX emission standards for cars (category M) with Euro-4 diesel engines are 0.25 g/km, and for light commercial vehicles (vans) weighing up to 3500 kg (category N1-III & N2) increase to 0.39 g/km.

Thus, the recalculation principles outlined above were also aimed at obtaining lower calculated values of harmful emissions in relation to the specifics of the tests according to the ECE test, which is convenient for operation due to the reduced likelihood of receiving a negative result during diagnosis. Based on this, and also due to the complexity of the recalculation procedure for real practice, it was concluded that it is possible to universalize the proposed diagnostic technology for all passenger cars with gasoline engines, which may have larger or lower values of their own masses and some differences in the design of power transmission, in particular when using automatic transmissions, which are mainly installed on foreign models. As noted above, the application of the statistical method of substantiating the maximum permissible values allows us to compensate for technical diagnostic errors, which may be small due to the stability of the test test mode on unloaded running drums (slight deviations of the simulated speed practically do not affect the readings recorded by the infrared gas analyzer). On the other hand, since the Euro environmental classes for cars and small commercial vehicles with diesel engines are determined according to standards similar to gasoline cars (4 × ECE + EUDC combined test), it is appropriate to use both the technology and the allocation model for the diagnosis of diesel engines. It is important to know that the pattern of changing the content of the base harmful substance from the load for the diesel engine as a whole is similar to gasoline in nature (a significant increase in NOX with increasing load), and the engine's reaction to the load change, which was recorded for a gasoline car through the vacuum values in the intake manifold can also be considered similar. In addition, the Euro standards for diesel engines of Euro-3 and higher class [3–5] are no longer identified as an independent indicator of the emission of hydrocarbons CH, unlike gasoline, and the main attention is paid to NOX (CO and CH indicators when checking a conventional infrared gas analyzer, as shown by our measurements, is practically zeroed). At the same time, the technology is based on the correct estimation of mass emissions of harmful substances by a car while simulating its operation at stationary speed modes on unloaded running drums, which is unchanged for passenger cars with gasoline and diesel engines [1]. Therefore, from the standpoint of the systematic approach outlined in the textbook [2], the universalization of the technology described above for operational tests is advisable.

The results of our respective tests for compliance with the declared environmental classes EURO-4–5 of foreign models of cars and minibuses with diesel engines are reflected in the work [10]. First of all, attention was paid to the fact that the fact of a substantial, about two-fold, decrease in the mass of emissions of the non-toxic component of CO₂, which has recently been given increased attention due to the increase in the greenhouse effect of the atmosphere, is practically not covered by the operation, especially for major cities. Data processing according to the above algorithm showed practical compliance with the declared Euro standards for mass emissions of CO (and CH) [3–5], which confirmed the universality of the test and recalculation method. However, according to the calculated mass emission indices of nitrogen oxides, NOX was found to be significant, from 6 (1.5 g/km against the norm of 0.25) to 35 times (6.74 g/km against the norm of 0.18 for a Volkswagen car-Caddy), exceeding Euro standards. This differed from the data on the four-fold increase in emissions of the Volkswagen-Caddy car given in Article [7] of the permissible values of the Euro standards (0.85 g/km), and indicates a certain lack of efficiency in the operation of the NOX component neutralization system for passenger car diesel engines in general, which is already evident when checking in idle mode (in our measurements, these values were in the range of 120-160 ppm for EURO-5 models, 180–280 ppm for EURO-4 and 630 ppm for Volkswagen-Caddy). Further experiments revealed a certain difficulty in conducting operational tests on the unloaded running drums of modern passenger cars with diesel engines due to the predominant presence of automatic transmissions and all-wheel drive for all 4 wheels, which required complicating the design of the mechanical stand, allowing at least “to hang out” “On the lift one of the axles of the car (preferably the
However, the corresponding statistical processing of the measurement results for already examined cars with mechanical gearboxes [1], taking into account the practical “zeroing” of the readings of the infrared gas analyzer in CO and CH in all modes, allowed us to obtain an extremely simplified method for diagnosing a car in accordance with the environmental class in the mass of NO\textsubscript{X} emissions during measurements only for idle modes, followed by an assessment of the concentrations of NO\textsubscript{X} and CO\textsubscript{2} for sites 40, 60 and 80 km/h, according to the final evaluation conducted mass emission in km.

Despite the negative level of these indicators, foreign publications, in particular those reflected in the Internet resource [5], confirm the practical unsolved problem of the operational ecology of diesel cars in relation to NO\textsubscript{X} emissions (some of them reflect competition in the sales markets [6] and may lead to erroneous conclusions). It is noted that studies conducted by the International Clean Transport Council (ICCT) in October 2014 showed an average seven-fold excess NO\textsubscript{X} pollution for EURO-6 vehicles (0.56 g/km instead of 0.08 g/km). At the same time, it is noted that diesel cars (LDDV) in the European Union make up more than 50 % of all new brands and are one of the main sources of NO\textsubscript{X} air pollution, and in order to reduce emissions, it has been recommended since 2017 to automakers to carry out certification except for laboratory on dynamometer stands, real road tests using portable emission measurement systems (PEMS). Thus, the EEC technical regulation excluded the possibility of any direct NO\textsubscript{X} measurements for passenger diesel cars in operation (using five-channel infrared gas analyzers), which, in our opinion, was and will be the main reason for the multiple exceeding of the content of this most aggressive component compared with EURO standards, and ongoing fraud regarding the actual level of environmental safety for Russian users (in Europe and the USA, a similar process with the name “Dieselgate”).

At the same time, foreign publications using certain methods make attempts to assess the consequences of exceeding NO\textsubscript{X} emissions of diesel cars (in Europe, their emissions are considered the main reasons for exceeding NO\textsubscript{X} limit values in the atmosphere) to public health and nature [7–9]. Most impressive in this regard are the collective data cited in publication [9], although the authors note the conditionality of these estimates regarding the relationship between NO\textsubscript{X} and health. They noted that the sharp increase in the share of LDDV sales in the UES since the late 1990s was associated with an increase in the cost of gasoline and a potential reduction in CO\textsubscript{2} greenhouse gas emissions compared to similar gasoline engines. Although the main danger from diesel cars is particulate emissions (more than 400,000 deaths and 15,000 premature deaths were associated with excess concentrations of particulate matter and ozone), it is estimated that about 3.5 % of premature deaths from particulate matter (PM, the amount of which increases with increasing smoke), and 2.3 % of the effects of ozone can be attributed to NO\textsubscript{X} emissions from LDDV, and 80 % of deaths could be avoided if diesel emissions corresponded to the level of gasoline cars. For Germany, for 2015, 6,900 premature deaths from excess LDDV emissions were calculated, and another 4,650 premature deaths from the effects of NO\textsubscript{X} emissions from heavy trucks and buses. According to [9] estimates, Italy, Germany and France accounted for two-thirds of premature deaths in the EU-28 + from excess NO\textsubscript{X} LDDV emissions, with a specific rate (from 2.85 to 4.4 per 100,000 inhabitants) per 40–140 % higher than the EU-28 + average (1.8 cases per 100,000 inhabitants). However, it is noted that for some countries (Belgium, the Netherlands, the United Kingdom) a decrease in NO\textsubscript{X} emissions led to a decrease in ozone production, and an increase of 70–90 cases of deaths associated with the influence of ozone. Also, a generally insignificant effect of NO\textsubscript{X} emissions on the deterioration of freshwater quality (eutrophication) in the Po Valley and in the western parts of France was noted.

As for buses (and heavy trucks), the current technical regulations (in Europe and Russia) practically exclude any kind of control of NO\textsubscript{X} emissions in operation, since the environmental certification of these cars, unlike cars, is not carried out using specialized dynamometer stands, and is carried out by testing a new engine mounted on a motor stand in the laboratory (UNECE Regulation R49) [3]. At the same time, 13 modes of the so-called 13-step European cycle specialized in speed, load and time are simulated, and the results for CO, CH, NO\textsubscript{X} and PM are given (and normalized) in terms of g/(kW·h), which are difficult to compare with operational tests by the car itself (on running
drums or in road conditions). Obviously, for the conditions of large megalopolises in Russia (primarily Moscow), the negative consequences of NO\textsubscript{X} emissions can be several times greater than the above average values for the EU-28 + from light diesel engines, and the level of emissions of this component for buses (and especially the heavier trucks, access to which on the MRHW is possible only at night) also have a significantly higher value. This makes it expedient to develop additional methods for estimating NO\textsubscript{X} emissions for buses (and heavy trucks) for operation and standardizing them to reduce negative consequences, since there are no other options at present.

3. The results of experimental studies

At the initial stage, we carried out the simplest (for a preliminary assessment of the level of environmental safety) measurements of NO\textsubscript{X} (and CO\textsubscript{2}) emissions at the minimum engine crankshaft rotational frequencies and smoke free acceleration indicators for 14 LBP (Likinsky Bus Plant) city buses. Such measurements are currently not difficult to carry out even in the field (outside the production and technical bases of motor transport organizations), however, this requires the use of a five-channel infrared gas analyzer for CO, CO\textsubscript{2}, CH, NO\textsubscript{X} and O\textsubscript{2} (instead of the four-channel one provided by GOST R 52033-2003 for gasoline-new cars). Such gas analyzers are produced (on a four-channel platform) upon the submission of a special application by several Russian manufacturers (the necessary information is available on the Internet).

The measurement results are given in the electronic table of the STATISTICA-12 program (Fig. 1), using the modules of which the necessary processing [2] was carried out. First of all, the presence of a statistical relationship was determined, which reflects the degree of influence of the engine’s technical condition in terms of smoke on NO\textsubscript{X} emissions, for which the graphic module of the program selected a polynomial model of one-factor regression, shown in Fig. 1 in a separate window with the obtained scatter of experimental data (the model is shown in the upper part of the graph window). Already from the graphical representation, one can see the lack of correlation between these main indicators, and additional mathematical processing confirmed their independence (the Fisher test, reflecting the informativeness of the regression dependence, had an estimate of $F=0.6$ at a significance level of $p<0.56$, and the determination coefficient, reflecting the degree of variation of the experimental data from the polynomial model was an insignificant value of $R^2=0.1$). Thus, the NO\textsubscript{X} emission indicator during engine operation at minimum engine speeds is an independent diagnostic parameter, and it must be used to identify the need for maintenance of city buses, in particular, to improve the functioning of the exhaust gas recirculation system, on which NO\textsubscript{X} emissions, and to test the effectiveness of some operational impacts, such as urea additives in diesel fuel, etc.

A more aggressive level of NO\textsubscript{X} emissions by buses compared to cars (more than double) can be seen from the histograms of their scatter in Fig. 2 (indicators for cars are taken from work [10]). The scattering of the value of this indicator (when processing the results of the STATISTICA [2] program) can be written by the normal distribution law with an average value of 635 ppm (ppm) and a standard (mean square) deviation of 131 ppm (ppm), with its high the probability of consistency with experimental data (according to the Kolmogorov-Smirnov criterion, the value of $D$, showing the maximum value of the modulus of the difference between the statistical function obtained from the experiment, the distribution function and the corresponding theoretical function, was 0.112, which corresponds to the probability of consistency $R_{sogl}>0.964$). From fig. 2 this scattering range only covers the emission value for the Volkswagen passenger car, which in the USA fell under the Dieselgate process [6, 8]. However, from the data in Fig. 2, it can be seen that, in general, cars and even heavier trucks and buses are still far from the actual implementation of the declared EURO standards, and for this, manufacturers may require new, more radical and easily controlled in operation, approaches in comparison with applicable now. Therefore, for practical purposes, it is currently reasonable to use the intermediate value of the diagnostic parameter as the lower limit of the 90 % limit of the theoretical distribution of the NO\textsubscript{X} emission indicator at idle (in the STATISTICA program a 10 % percentile), which amounted to 530–540 ppm (ppm); it is possible to obtain a reduction in environmental pollution of the order of 20 %. 
Figure 1. STATISTICA-12 program window with the results of parallel measurement of the content of nitrogen oxides NO\(_X\) (and CO\(_2\)) in the exhaust gases of 14 city buses LBP (Likinsky Bus Plant) of ecological classes Euro-4-5 when the engines are idling and smoke levels on the acceleration mode of free acceleration of the engine crankshaft without external load, and the obtained schedule of the proposed regression, reflecting the tightness of the relationship between these indicators.

Figure 2. Histograms of the distribution of NO\(_X\) nitrogen oxide in the exhaust gases of 14 cars and vans with diesel engines of the declared environmental classes Euro-4-5 at the nominal engine speed at idle speed, and for 14 city buses of LBP (Likinsky Bus Plant) declared environmental classes Euro-4-5.
Figure 3. Nomograms for the rapid estimation of the mass of NOX emissions (in g / 1 km for a car with a 1-liter diesel engine, subject to its European urban driving cycle test) depending on the content of NOX and CO2 in the exhaust gases when idling [10]

For a physical estimate of the amount of emissions, we can use the nomograms calculated by us to convert the NOX values at idle to the mass emission indicators when tested according to EURO standards (in g/km) for a conventional passenger car with a 1 liter diesel engine, according to which it is not difficult to carry out practical assessments (Fig. 3 [10]). Since the actual values of NOX emissions for buses are more than three times the range of Fig. 3, when calculating, simultaneously taking into account the working volume of the bus engines (about 6 liters versus 1.3–2.2 liters for cars and vans) it is possible to proportionally increase the results obtained from the nomograms of Fig. 3, the more so since the range of CO2 indicators for buses (Fig. 1) coincides with the nomograms. (As noted above, the latter were obtained without taking into account the high-speed test section and therefore practically correspond to the specifics of using city buses, for which in the future it will be possible to develop more sophisticated operational monitoring methods on unloaded running drums of an extremely simple design compared to cars) Although as a result of such calculations extremely negative indicators (about 20 g/km) are obtained, it can be argued that with real road measurements, as provided for in the certification of diesel cars in the EU-28 +, they will turn out to be even worse, in view of significantly more tense parameters of traffic flows at the entrance of cars to megacities, especially to Moscow [11].

Another important environmental indicator, which has recently been given increased attention due to climate change, is the problem of reducing greenhouse gas emissions, primarily CO2, from automobile transport (affected in work [8]), while in our opinion, targets were given unreasonable preference due to the reduction of these emissions. In particular, in recent foreign developments of portable means for continuous monitoring that are built into a car (the ELM327 adapter, connected to the OBDII universal diagnostic connector and transmitting data to mobile phones), CO2 emissions in g/km are provided (Torque application is installed via the Internet for a small fee), although for a more important NOX indicator, such control is absent due to its complexity. When reducing the CO, CH, and NOX emission indicators when testing on unloaded running drums [1] to the EURO standards, similar calculations were also carried out for CO2 emissions measured by a five-channel
infrared type gas analyzer to estimate the current values of excess air coefficients $\alpha$ for different test steps. At the same time, at 3 sites of constant load mode (at speeds of 40, 60 and 80 km/h in direct transmission), the total CO$_2$ emissions in g/h and fuel consumption in kg/h were easily determined. The ratio of these two indicators both for gasoline and especially for diesel cars always led to the same value – 1,500 g of CO$_2$ per 1 kg of spent fuel (with a maximum error of 10 % in the direction of decrease with the maximum enrichment of the mixture for carburetor engines). This was due to an almost insignificant difference in the ratios of carbon content (approximately 85–86 %) and hydrogen (12.5–13 %) for all types of hydrocarbon fuels, including kerosene, as well as compressed (methane) and liquefied (butane -propane) of natural gases, for which this ratio is somewhat different – approximately 82.2 % and 17.85, respectively, but falls within the above 10 % range. Accordingly, in operation it is extremely simple (and clear) to estimate CO$_2$ emissions by indicators of car efficiency – fuel consumption in liters per 100 kilometers, recalculating taking into account the density (800–845 kg/m$^3$ for diesel fuel, 770–780 kg/m$^3$ for gasoline and 550 kg/m$^3$ for liquefied gas. Thus, the above technology (in conjunction with smoke testing) will provide in operation a fairly complete control of the environmental safety of city buses and stimulate new technical and technological directions for its increase.

4. Conclusion
The carried-out research phase revealed the need to use an additional diagnostic parameter – NO$_X$ emissions – to strengthen control over the level of environmental safety of city buses in operation. A lower level of environmental safety (by 2–3 times) was confirmed for this indicator compared to diesel cars that still do not fit significantly into the EURO standards (practical excess of 7–10 or more times), and the expediency of operational monitoring the technical condition of buses at present by the NOX content in the engine exhaust gas at idle. Based on the statistical approach, the maximum permissible value of this indicator is substantiated – no more than 530 ppm (ppm), the maintenance of which during maintenance will reduce environmental pollution by about 20 %. Based on previously developed calculation models for recalculating the toxicity indicators of gasoline and diesel light-vehicle exhaust gases during their operational tests on unloaded running drums to test modes in accordance with EURO standards, an estimate of the mass of CO$_2$ greenhouse gas emissions based on car economy indicators is justified – the total fuel consumption in liters when carrying out transportation, or specific consumption per 100 km, taking as a basis the theoretically established value: 1500 g of CO$_2$ per 1 kg of consumed about fuel. Final calculations must be carried out considering the density of the fuel used: 800–845 kg/m$^3$ for diesel engines, 770–780 kg/m$^3$ for gasoline and 550 kg/m$^3$ for liquefied gas.

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