Repeatability of the results of quantitative analysis of nitrogen oxides in the air of vehicle's cabin using “on-line” and stationary methods with preliminary sampling to the bags

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COMPARISON OF ON-LINE AND STATIONARY ANALYSIS OF NO, NO_2 WITH PRE-SAMPLING

The results of comparative tests, during which the repeatability of results of quantitative analysis of nitrogen oxide and dioxide in the air of a vehicle's cabin, which obtained with expose of two models of gas analyzers working in “on-line” and stationary modes with preliminary sampling to the bags, were evaluated.

The tests were carried out at the automobile proving ground

Number of test objects: 14 vehicles :
9 vehicles with petrol engines, 4 vehicles with diesel engines and 1 hybrid car - with electric and gasoline engines.

Testing time 9 -18 April 2019.

Test modes

Test modes were the same as the requirements of national standard of Russia and Custom Unions countries (GOST 33554-2015).

I – Steady-state movement at a speed of 50±5 km/h.

II – Idling: the vehicle was parked stationary with engine operating at minimal idle rate prescribed by the manufacture while operating two test modes of ventilation system:

- forced ventilation system was switched on in position “one”(minimal), internal air recirculation system – shall be off (Idling I).
- forced ventilation system was switched off, internal air recirculation system – shall be on (Idling 2).

Air temperature at the vehicle’s cabin was 20±2^{o}C during testing.

During idling, an air flow was created with using a system of high-power fans, and was directed to the exhaust pipe of the vehicle, so as that the exhaust direction from exhaust pipe would be opposite the wind.

The wind speed was at the range from 2.8 up to 4.2 m/s during testing.

Measuring instruments

Gas analyzer mod. R-310 (Optek, Russia) with chemiluminescense detector,

- range of measurable concentrations of NO, NO_2 - (0 – 1,000) mg/m^3,
- nominal resolution of LCD display is 0,001мг/м^3.
- weight – 12 kg
- power consumption – 400 W

Gas analyzer mod. CLD-60 (Swiss) with chemiluminescense detector,

- range of measurable concentrations of NO, NO_2 - (0 – 10,000) mg/m^3
- nominal resolution of LCD display is 0.0005 mg/m^3
- weight – 15 kg
- power consumption – 1000 W

Flow buster pump ABP-04, for collecting gas sample, speed – 1 l/min.
Hermetic bags for collecting gas sample, material – PTFE film.
Anemometer Almemo, range of measuring wind speed – 0.4 – 20 m/s

Test procedure

1 The test was performed on road (Mode I) and an open parking zone (Mode II).

2. Before fulfilling of driving and idling modes the vehicle was ventilated during 3-5 min.

3. The moving according Mode I was started and continued during 20 min. Idling according Mode II was started after finishing of Mode I and was continued during 20 min too. After 20±5 min recording of results of the on-line analysis and collecting gas samples were started.

4. On-line analysis and sampling were carried out at the central point of vehicle's cabin between passenger and driver seats.

5. The recording of results and sampling were carried out during 10-15 min during of each modes.

6. While testing of hybrid vehicle the collecting and recording of results were carried out only during test Mode I (moving), because the gasoline engine did not work during idling.

7. The measure of NO, NO_2 from the bags was fulfilled not later than 1-1,5 h after finishing test modes.

Test results

Results of the quantitative measure of nitrogen oxide NO (Table 1)

and nitrogen dioxide NO_2 (Table 2) are shown in Tables 1, 2.

Both gas analyzers have the same ranges of measuring and sensitivity of the determination, but differ by meaning of discreteness:

180 s for R-310, 1s for CLD-60.

However, despite the fact that the arithmetic mean values for the P-310 were calculated from 5-6 readings, and for CLD-60 - from 50-70 readings (with using computer program), calculated values were in good agreement.

As can be seen from the Tables, all obtained results are within the limits of sufficient repeatability.

In some cases quantitative readings of both direct measurements NO, NO_2 (with R-310 and CLD-60) and measurements ones in the gas samples taken to bags were coincided.

The better repeatability of test results was received for vehicles with gasoline engines

COMPARISON OF ON-LINE AND STATIONARY ANALYSIS OF NO, NO_2 WITH PRE-SAMPLING

The results of quantitative measurements of nitrogen oxide NO with using two models of gas analyzers, working in the “on-line” and stationary modes with preliminary sampling to the bags are shown in Table 1

Table 1

Model, mark of testing car	Test modes/ content of NO, mg/m^3												Fuel	Date of testing
	Idling I				Idling 2				Driving					
	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD		
1	0,002	0,034	0,010	0,050	0,004	0,016	0,010	0,052	0,000	0,020	n/meas	0,024	petrol	9.04
2	0,053	0,052	0,097	0,135	0,042	0,040	0,098	0,105	0,000	0,004	0,010	0,009	diesel	10.04
3	0,005	0,006	0,022	0,012	0,006	0,006	0,005	0,002	0,004	0,050	n/meas	0,004	petrol	10.04
4	0,006	0,005	0,010	0,009	0,019	0,018	0,029	0,035	0,000	0,004	n/meas	0,004	petrol	11.04
5	0.048	0,050	0,088	0,116	0,023	0,020	0,038	0,040	0,000	0,000	n/meas	0,005	diesel	11.04
6	0,089	0,072	0,193	0,201	0,033	0,028	0,100	0,083	0,000	0,000	0,003	0,001	diesel	12.04
7	0,046	0,050	0,133	0,131	0,046	0,047	0,136	0,157	0,000	0,000	0,005	0,000	diesel	12.04

COMPARISON OF ON-LINE AND STATIONARY ANALYSIS OF NO, NO2 WITH PRE-SAMPLING

The end of Table 1

Model, mark of testing car	Test modes/ content of NO, mg/m^3												Fuel	Date of testing
	Idling I				Idling 2				Driving					
	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD		
8	0,019	0,016	0,031	0,031	0,027	0,022	0,051	0,055	0,000	0,000	0,02	0,005	petrol	15.04
9	0,006	0,002	0,012	0,014	0,027	0,018	0,039	0,048	0,002	0,002	0,0098	0,010	petrol	15.04
10	0,026	0,026	0,042	0,032	0,042	0,042	0,079	0,066	0,002	0,008	0,011	0,071	petrol	16.04
11	0,013	0,010	0,015	0,009	0,012	0,008	0,009	0,018	0,008	0,008	0,011	0,006	petrol	16.04
12	-	-	-	-	-	-	-	-	0,004	0,004	0,014	0,010	petrol hybrid	17.04
13	0,020	0,048	0,014	0,052	0,018	0,056	0,031	0,107	0,000	0,002	0,010	0,007	petrol	16.04
14	0,032	0,123	0,061	0,180	0,075	0,094	0,135	0,185	0,000	0,054	0,009	0,062	petrol	16.04

COMPARISON OF ON-LINE AND STATIONARY ANALYSIS OF NO, NO_2 WITH PRE-SAMPLING

The results of quantitative measurements of nitric oxide NO_2 with using two models of gas analyzers, working in the "on-line" and in stationary modes with preliminary sampling to the bags are shown in Table 2

Table 2

Model of testing vehicle	Test modes/ content of NO_2, mg/m^3												Type of fuel	Date of testing
	Idling I				Idling 2				Driving					
	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD		
1	0,002	0,010	0,000	0,010	0,002	0,005	0,000	0,008	0,002	0,010	n/meas.	0,013	petrol	9.04.
2	0,004	0,006	0,002	0,003	0,002	0,004	0,001	0,001	0,002	0,004	0,002	0,025	diesel	10.04
3	0,012	0,014	0,011	0,018	0,013	0,014	0,011	0,035	0,019	0,018	n/meas	0,016	petrol	10.04
4	0,003	0,004	0,000	0,002	0,002	0,004	0,000	0,001	0,002	0,006	n/meas	0,006	petrol	11.04
5	0,006	0,012	0,003	0,003	0,002	0,016	0,000	0,012	0,002	0,005	n/meas	0,002	diesel	11.04
6	0,007	0,006	0,006	0,001	0,004	0,004	0,000	0,001	0,004	0,004	0,000	0,004	diesel	12.04
7	0,006	0,008	0,003	0,003	0,004	0,004	0,000	0,002	0,004	0,004	0,000	0,000	diesel	12.04

COMPARISON OF ON-LINE AND STATIONARY ANALYSIS OF NO, NO_2 WITH PRE-SAMPLING

The end of Table 2

Model of testing vehicle	Test modes/ content of NO_2, mg/m^3												Type of fuel	Date of testing
	Idling I				Idling 2				Driving					
	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD	on-line R310	Bag R310	on-line CLD	Bag CLD		
8	0,002	0,005	0,000	0,005	0,002	0,004	0,000	0,001	0,004	0,004	0,000	0,001	petrol	15.04
9	0,004	0,008	0,000	0,009	0,002	0,004	0,002	0,009	0,002	0,007	0,000	0,008	petrol	15.04
10	0,002	0,008	0,000	0,015	0,002	0,010	0,001	0,016	0,002	0,008	0,000	0,017	petrol	16.04
11	0,016	0,016	0,012	0,020	0,011	0,010	0,007	0,011	0,018	0,012	0,012	0,014	petrol	16.04
12	-	-	-	-	-	-	-	-	0,008	0,012	0,001	0,003	Petrol hybrid	17.04
13	0,008	0,013	0,000	0,017	0,006	0,012	0,000	0,014	0,007	0,008	0,000	0,016	petrol	17.04
14	0,012	0,026	0,000	0,002	0,010	0,018	0,001	0,000	0,018	0,044	0,000	0,016	petrol	18.04

Conclusions

1. Gas analyzers with chemiluminescence detector are used for the determination of nitrogen oxides in the air of the vehicle's cabin, both on-line on board the vehicle and in a stationary mode with preliminary sampling in bags
2. The high repeatability of the obtained results of the analysis showed the full applicability of using direct methods for measuring nitrogen oxides on vehicle's board and a stationary method of measurement with preliminary sampling into bags.
3. The recommended sampling rate to the bags is about 1 l/min.
4. The use of the stationary method of measuring nitrogen oxides with preliminary sampling in bags can be recommended in case when the dimensions of the vehicle's cabin do not allow the installation of measuring instruments with large dimensions in it.
5. In some cases, the use of a bulky high-power CLD-60 gas analyzer in "on-line mode" was impossible during road tests (Mode I), since the trunk in which the equipment was located was isolated from the cabin of test vehicle (positions 1,3,4,5 of Tables 1,2).

Thank you for your attention!

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