Evaluation of efficiency of the air purification Systems for Volvo vehicle's saloon under testing in urban traffic in Moscow

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Background

In order to improve the cabin air quality when driving in cities with high level of air pollutions, Volvo Cars offer IAQS (Interior air quality system) as an option to the ECC (Electronic Climate Control).

Previous tests made in Europe have shown that system improves the cabin air quality significantly.

Volvo Cars Russia are very interested in air quality and decided to prove the testing of IAQS and Premair system (for reducing the ozone content) in Moscow. Test was performed in Moscow during the period of 16/06/2004 – 18/06/2004.

The amount of diesel vehicles are low as well as the number of trucks along the entire test route.

The air quality in Moscow is affected by the heavy traffic. The vehicles are approximately 50% imported and 50% domestic. The emission of domestic vehicles was within level of Euro-0, Euro-1, imported vehicles - within level of Euro-3, Euro-4.

Test route and test object

Test route: the center of city: Sadovoe Koltso - Tverskaya street – Belorussky railway station – Leningradsky avenue – Dmitrovskoe highway – Novoslobodskaja street.

Time of testing: 16 – 18 June 2004, from10.00 am to 17.00 PM

Test object Volvo S60 MY 03, mileage 23 000 km.

Equipped with IAQS (sensor + combifilter) and ECC

The sensor: Paragon MKIV, reacts to oxidizing (NO_x and SO_2) and reducing gase (CO).

Premair system (coating on the radiator of testing vehicle to reduce O_3 – ozone).

Harmful Substances (HS) measured and test mode

Following HS were measured continuously (on-line mode) on the board of test vehicle:

SO_2 - sulfur dioxide

NO_2 – nitrogen dioxide

CO - carbon monoxide

O_3 - ozone

PAH – polyaromatic hydrocarbons

Test mode: -

- Measure HS in cabin air with IAQS in position on and off.
- Measure HS in atmospheric air when IAQS in cabin is in position on and off.

Equipment used

HS measured	Method, detector type	Range	Test mode
NO, NO_2	Chemiluminescence	0 – 10 mg/m^3	on line
SO_2	Chemiluminescence	0 – 20 mg/m^3	on line
CO	Electrochemical	0 – 500 mg/m^3	on line
Polycyclic Aromatic Hydrocarbons (PAHs)	GC-FID +capillary column 50m x 0,32 mm SE-54 the filter AFA-B-10,	preliminary sampling air volume - 90-150 l	stationary air probe on

Certificate of Analysis

DESCRIPTION: EPA 610 Polynuclear Aromatic Hydrocarbons Mix

CATALOG NO.: 48743 MFG DATE: May-2003

LOT NO.: LB12324 EXPIRATION DATE: May-2006

SOLVENT: METHANOL:METHYLENE CHLORIDE (1:1)

ANALYTE (1)	CAS NUMBER	PERCENT PURITY(2)	WEIGHT(3) CONCENTRATION	ANALYTICAL(4)	STD DEV	SUPELCO LOT NO
ACENAPHTHENE	83-32-9	99.8	1000	922	+/- 45.3	LB00490
ACENAPHTHYLENE	208-96-8	99.9	2000	1837	+/- 86.1	LB07910
ANTHRACENE	120-12-7	99.1	100.4	92.1	+/- 4.10	LB04901
BENZO (A) ANTHRACENE	56-55-3	99.9 (a)	100.2	90.7	+/- 4.29	LA91542
BENZO (A) PYRENE	50-32-8	97.3 (a)	99.8	91.5	+/- 4.42	LB04438
BENZO (B) FLUORANTHENE	205-99-2	99.9	200.0	183.0	+/- 8.55	LA94245
BENZO (G,H,I) PERYLENE	191-24-2	99.7	200.2	184.0	+/- 9.11	LB00514
BENZO (K) FLUORANTHENE	207-08-9	99.7	100.2	92.5	+/- 4.30	LA96760
CHRYSENE	218-01-9	99.0	100.2	91.7	+/- 4.49	LA38984
DIBENZ (A,H) ANTHRACENE	53-70-3	99.6	200.2	185.6	+/- 8.83	LB07166
FLUORANTHENE	206-44-0	98.2	200.2	184.5	+/- 8.67	LA88185
FLUORENE	86-73-7	98.6	200.4	184.4	+/- 8.38	LB04916
INDENO (1,2,3-CD) PYRENE	193-39-5	99.9	99.6	91.0	+/- 4.07	LB07167
NAPHTHALENE	91-20-3	99.9	1000	917	+/- 42.5	LA97766
PHENANTHRENE	85-01-8	98.6	100.4	92.2	+/- 3.98	LA92542
PYRENE	129-00-0	98.0	100.0	91.6	+/- 4.33	LA74472

(1) Listed in alphabetical order.

(2) Determined by capillary GC-FID, unless otherwise noted.
a) HPLC UV-254NM

(3) NIST traceable weights are used to verify balance calibration with the preparation of each lot. Concentration of analyte in solution is ug/ml +/- 0.5%, based upon balance and Class A volumetric glassware. Weights are corrected for analytes less than 98% pure.

(4) Determined by chromatographic analysis against an independently prepared reference lot. Mean of replicate injections.

Elwood Doughty
Quality Control Supervisor

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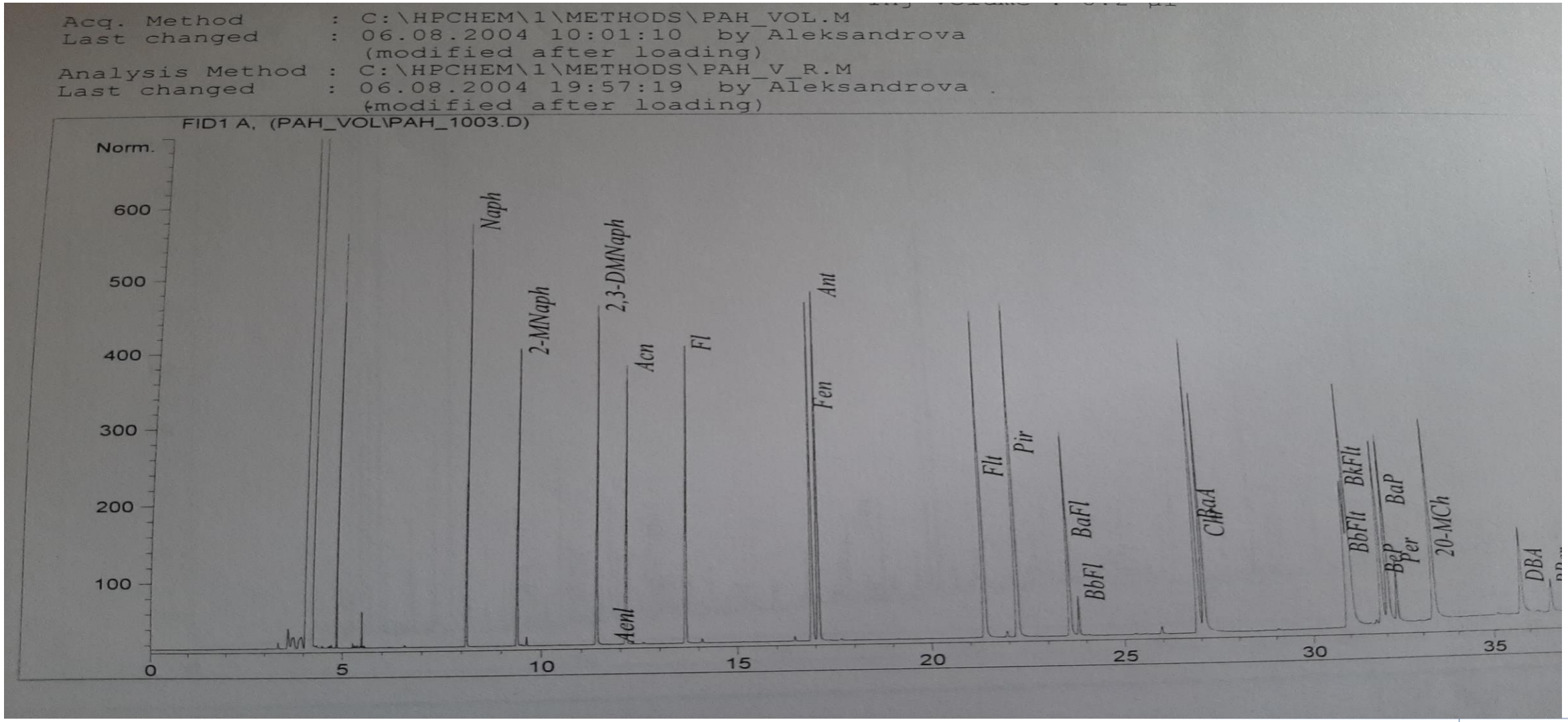
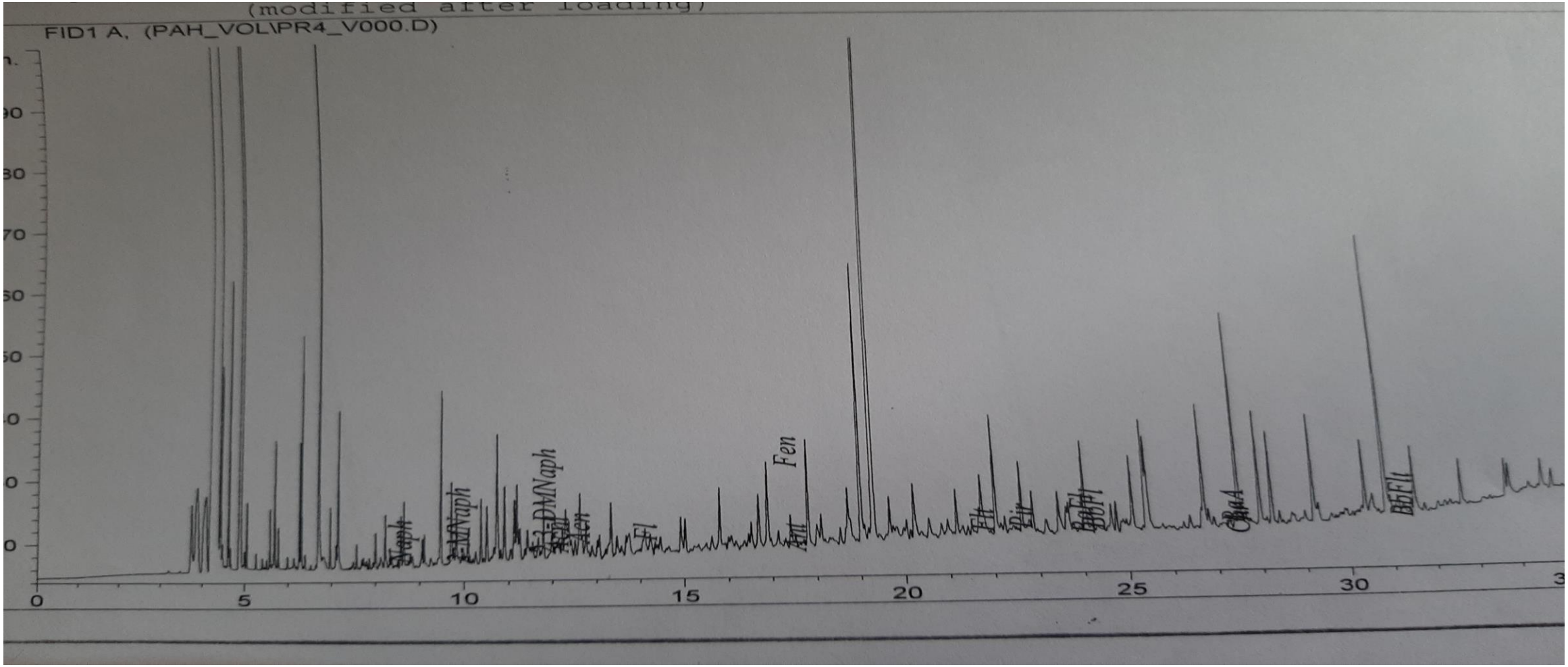
Chromatogram of PAHs calibration mixture from Naphtalene to Dibenz(a,h)antracene



Sample 4. The content of PAHs in the interior air, IAQS and ECC is on, volume of air sample -145 l. Carcinogenic PAH (benz(a)pirene was not detected

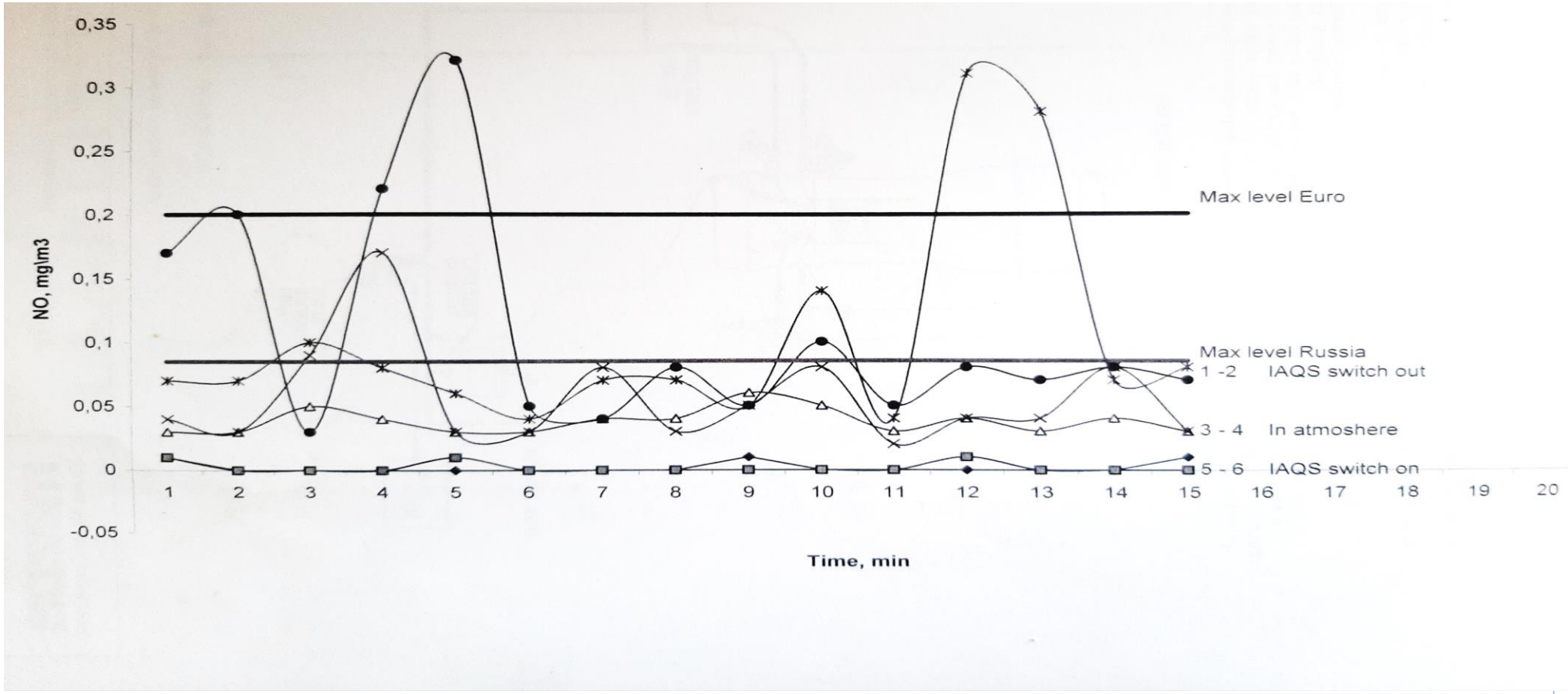


The results of qualitative and quantitative definition of Polyaromatic Hydrocarbons (PAHs) in interior air of test vehicle

- 16 PAHs were measured in the cabin air of test vehicle Volvo S60.
- Certificate of analysis of mix PAHs (EPA 610) and chromatogram of these PAHs mixture were shown on the next slides 6,7.
- It was found that IAQS + combifilter provided significant reduction of 3-5-nuclea PAHs which were retained by dust paper filter.
- Carcinogenic 4-5-nuclea PAHs were not detected In interior air with IAQS in position “on” (slide 8).
- By the way it was found that using only paper filter covered with activated carbon allowed to reduce of PAHs in cabin air.
- The main advantage of IAQS+ECC was its high efficiency in reducing PAHs in cabin air of test vehicle.

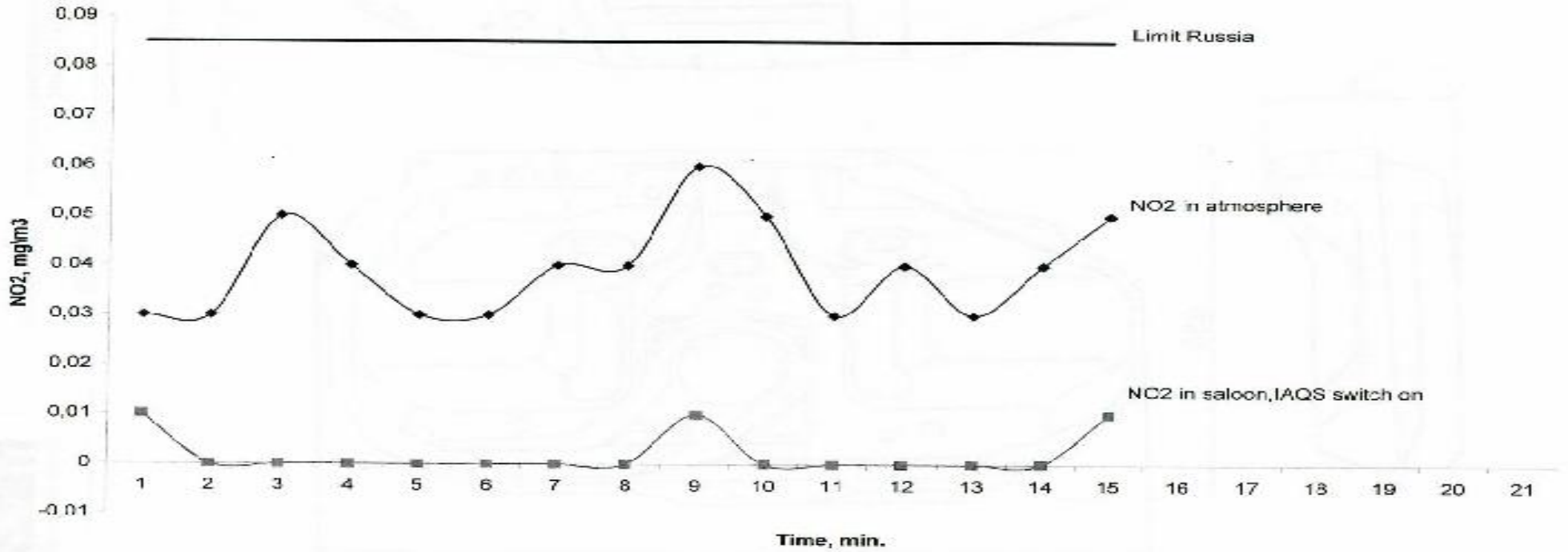
NO_2 in interior air when IAQS is on and off and in atmosphere

The content of NO_2 in the interior air with the IAQS in position “on and off” and in atmospheric air. Time of testing: June 17, 2004, 11.00-12.30. Route: Sadovoe Koltso- Leningradsky Prospect - Rechnoy Station.



NO_2 in atmosphere and interior air with IAQS "on"

The content of NO_2 in the interior air with the IAQS in position "on" and in atmospheric air». Time of testing: June 17, 2004,10.00-11.00. Route: Belorussky railway station –Sadovoe Koltso

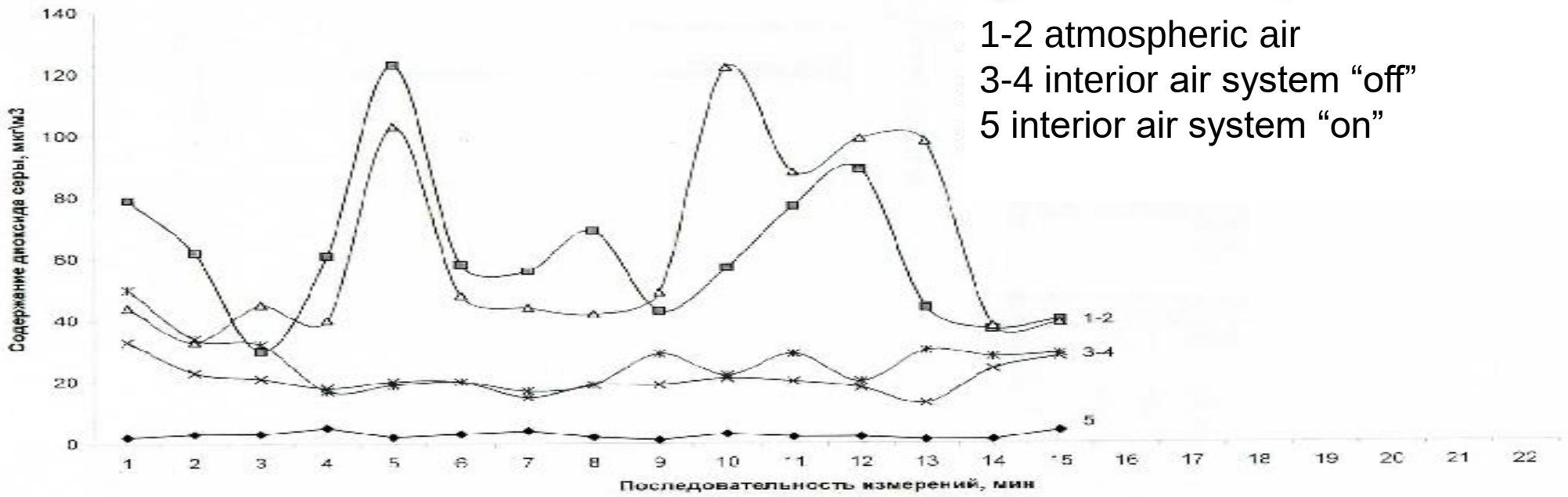


Test results of NO_2

- It was determined that NO_2 was practically absent in interior air when IAQS was on.
- The concentrations of NO_2 were increased several times in interior air when IAQS was off.
- In some cases these concentrations of NO_2 were exceeded their hygiene limits in several times.
- The example of test was shown at the next slide 11. You may see that content of NO_2 was very high in atmospheric air and interior air when IAQS was off.

SO_2 in atmospheric and interior air with IAQS in position “on and off”

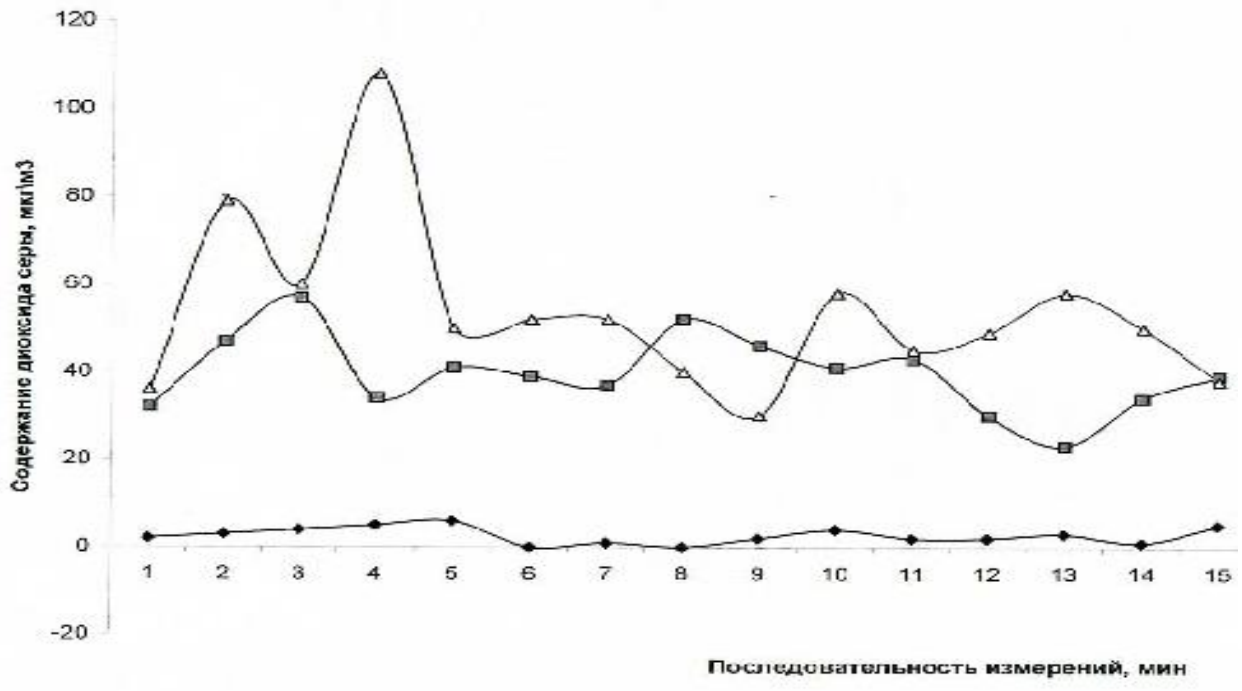
The content of SO_2 in the interior air with the IAQS in position “on and off” and in atmospheric air. Time of testing: June 17, 2004, 9.30-11.00, Route: Leningradsky Prospect - Belorussky railway station, Tverskaja street, Novoslobodskaja street



1-2 atmospheric air
3-4 interior air system “off”
5 interior air system “on”

SO_2 in atmospheric and interior air when IAQS is “on”

The content of SO_2 in the interior air with the IAQS in position “on and off” and in atmospheric air.
Time of testing: June 16, 2004, 16.00-17.00, Route: Leningradsky Prospect - Rechnoy Station, Belorussky railway station.



1-2 atmospheric air

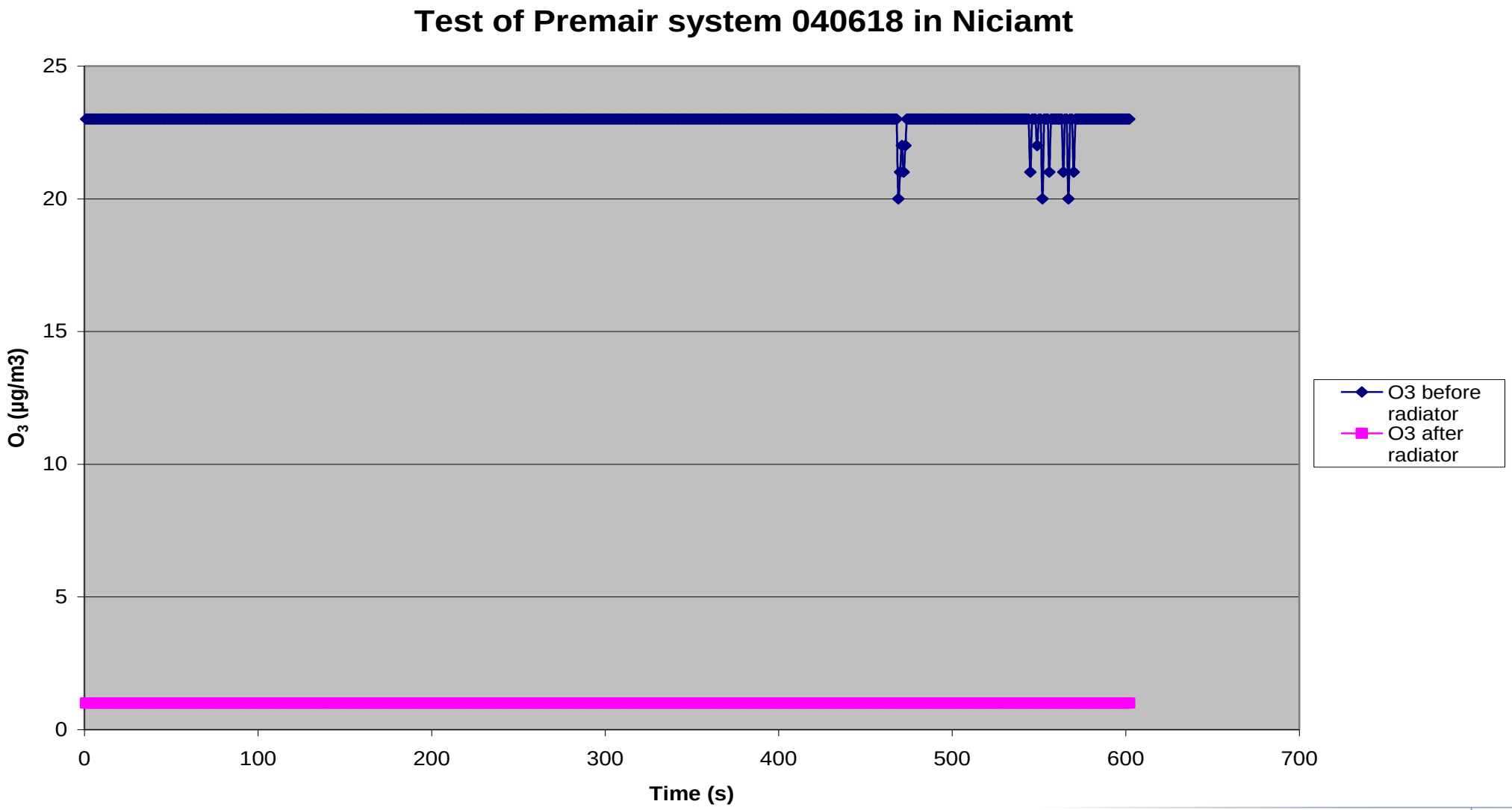
3 interior air system “on”

Test results of SO_2

- During the tests, it was found that the IAQS - ECC system allows to reduce the content of SO_2 in the interior air of the test vehicle with maximum efficiency, almost to zero values.
- On the slides 13,14 the levels of SO_2 were shown in the ambient air and in the cabin air of the test vehicle with the IAQS-ECC system “on and off”, obtained on different days and test routes.
- The interior of the test vehicle with the IAQS - ECC switched on, the SO_2 content did not exceed 1-2 μg/m^3, that is 1-2 orders lower than the SO_2 content in the atmosphere.

Input of sampling tubes from atmosphere to gas analyzers placed in saloon

Placement of equipment in the test vehicle interior


Test of Premair system 040618 in Niciamt
25
20
15
10
5
0
O3 (µg/m3)
0
100
200
300
400
500
600
700
Time (s)
O3 before radiator
O3 after radiator

Sampling points of Premair system before and after radiator of test vehicle

Test results of ozone

- The effectiveness of the coating applied to the radiator of the test vehicle and designed to reduce ozone in the near-ground air layer was evaluated. The coating should work in such a way that there should be no ozone in the air zone behind the radiator of the vehicle when it is moving. To evaluate the performance of the Premair system, air sampling points were located in front of and after the radiator of the test vehicle, as shown in Figure 19.
- The tests showed the effectiveness of the Premair coating, which completely neutralized ozone. In the diagram shown in Fig. 18, it can be seen that the ozone content after the radiator has dropped to zero.

Test results of CO

- the IAQS - ECC system does not significantly reduce the CO level in the interior air to minimum values, however, it was found that during the tests it was possible to avoid maximum CO fluctuations in those cases when values CO of 60-100 mg/m^3 were recorded outside the test vehicle. In the interior of the test vehicle, in these cases, the ECC climate control system was triggered, which did not allow the CO content to be exceeded to a certain limit. As usual, in the interior, CO fluctuations are smoothed and do not exceed 20 mg/m^3 (limit value).

Conclusions

- The IAQS-ECC system ensured a decrease in SO_2 concentrations in the interior air of the Volvo S60 test car by 1-2 orders up to 1-2 μg/m^3;
- The content of NO_2 in the interior air of the test vehicle with activated IAQS - ECC does not exceed 0.01 mg/m^3. When the system is turned off, the content of NO_2 in the vehicle interior increases several times,
- The use of the IAQS - ECC system makes it possible to reduce by several orders of magnitude the content of 3 - 5 nuclear PAHs in the interior air, while there are no 5-nuclear PAHs at all - from benzfluoranthenes to dibenzanthracene, which have high carcinogenic activity.
- The use of only a dust filter, which starts to work when the IAQS - ECC system is turned off, also allows to reduce the PAHs content in the interior air to very low values that are safe for human health.

Conclusions

- The high efficiency of the "Premair" coating on the radiator of the Volvo S60 designed to neutralize the ozone formed in the near-ground air layer, has been established - in the air zone after the radiator, the ozone content has dropped to zero.
- The IAQS - ECC system does not reduce the CO level in the interior air to minimum values, however, it was possible to avoid maximum CO fluctuations in those cases when values CO of 60-100 mg/m^3 were recorded outside the test vehicle. In the interior of the test vehicle, in these cases, the ECC climate control system did not allow the CO content to be exceeded to a certain limit - not more than 20 mg/m^3 (limit value).
- Conducted research have not lost their relevance currently and due to the fact that similar works are rather few in number, there is a need to continue this kind of work.
- The intensity of traffic flow in big cities has increased several times than in 2005, that creating the need for wider use of filters and devices for purifying the air inside the vehicles.

Thank you for your attention!

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