Final Report of the Proficiency Testing in Vehicles Emissions 9th Round

Inmetro
Instituto Nacional de Metrologia, Qualidade e Tecnologia

PEP-Inmetro

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PROFICIENCY TESTING IN VEHICLES EMISSIONS – 9th ROUND

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SUMMARY

1. Introduction

The problem of air pollution is a serious threat to human health, decreasing their quality of life. Vehicles are potential agents of pollution worldwide. Gas emissions from vehicles carry several toxic substances, which, in some cases, in contact with the respiratory system, can produce several negative health effects and cause traffic accidents due to decreased visibility.

The analysis of pollutants is one of the most delicate items of a vehicle or an engine emission test. The Proficiency Testing Schemes (PT Scheme) of automotive emissions evaluate laboratories by the determination of the compound amounts in vehicle emissions, then providing subsidies to laboratories to identify and solve analytical problems, contributing to the harmonization of emission measurements in the country.

Proficiency testing scheme is a quality tool for the identification of interlaboratory differences, but the assessment is punctual. A PT Scheme aims to compare measurement results from different laboratories, performed under similar conditions, and then to obtain an assessment of the technical competence of participating laboratories in order to demonstrate the reliability of their measurement processes. The participating laboratories, in their turn, have the opportunity to review their analysis procedures and implement improvements in their processes, if necessary.

In this round, the following vehicle emission parameters were proposed to be evaluated: (CO, CO_2, THC, NO_x, NMHC and total aldehydes in g/km and urban autonomy, road autonomy and combined autonomy in km/L and evaporative emissions (g/test). Ten parameters were evaluated with participation of 20 (twenty) laboratories, three more than the last round.

This report presents the results of the performance evaluation of participants, the methodology used in the tests and the procedure used for the statistical analysis.

The objectives of this PT scheme were:

- To determine the performance of laboratories for the proposed tests;
- To monitor the ongoing performance of the analytical vehicle emissions laboratories;
- To increase the confidence of the measuring emission process of the vehicle emission laboratories;
- To improve continuously the measurement techniques of vehicle emissions laboratories.

2. Materials and Methods

2.1. Test Item

The test item is a vehicle supplied by Hyundai CAOA do Brasil having the following characteristics: Model TUCSON, gray color, identification code REPCAR2, 2.0L motor, Flex Fuel, four-speed automatic transmission, equivalent inertia of 1644 kg. The test vehicle was correlated with the purge system of the blow-by gas and canister (the test item was supplied with the necessary changes), since, in this edition, there was no evaporative emission measurement.

Each participating laboratory should use its own fuel (Gasool A22 as ABNT NBR 8689 standard in force).

2.2. Methodology

The standard methods used for emission measurements were ABNT NBR 6601, 7024 and 12026 The tests defined by these standard methods are complementary and were carried out simultaneously. The values of deceleration times (coast down) were provided by Hyundai do Brasil emission laboratory, vehicle owner, to participants in order to adjust their dynamometers to reproduce the deceleration time.

Three different tests were carried out, namely:

- Determination of THC, NMHC, total aldehydes, NO_x, CO, CO_2 and urban autonomy, according to ABNT NBR 6601 and 12026 standards;
- Determination of hot stage evaporative emissions according to ABNT NBR 11481 standard;
- Determination of CO, CO_2, THC, NO_x and NMHC, road autonomy in road cycle and combined autonomy according to ABNT NBR 7024 standard.

Participants should follow the test flow chart presented in figure 1 when performing the tests and preferably start the tests at 25 °C temperature, aiming minimizing cold start effects in results. A CETESB representative witnessed one of the three PT measurements of each participant.

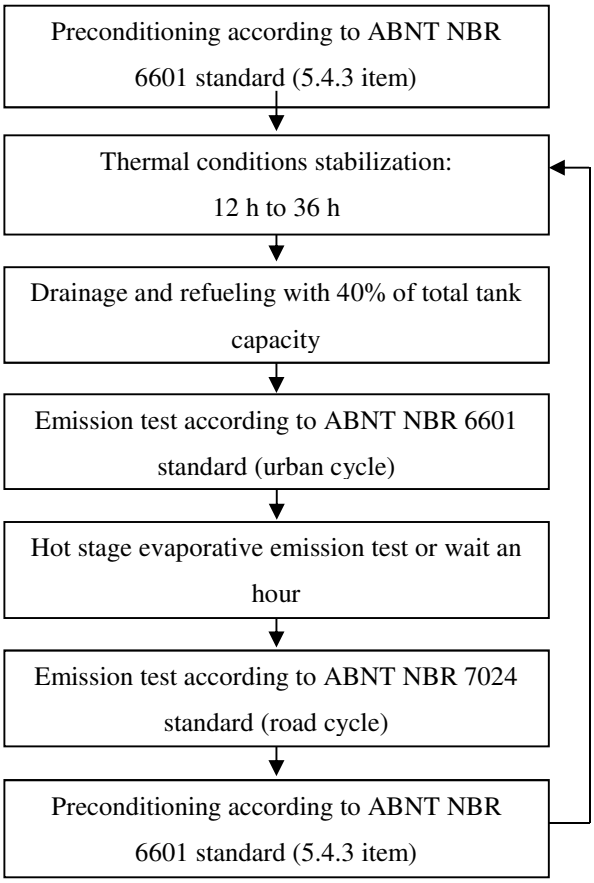

Figure 1 – Flow chart of PT measurement activities.

3. Test Item Integrity

Hyundai CAOA laboratory performed stability tests in the beginning and at the end of the cycle – first analysis (Y_1), second analysis (Y_2).

GM do Brasil CPCA laboratory performed stability tests in the beginning, in the middle and at the end do the cycle – first analysis (X_1), second analysis and third analysis (X_3).

It was verified if there were statistical differences between measurements of the 7 (seven) components of urban cycle CO, CO_2, THC, NO_x, NMHC, total aldehydes in g/km and urban autonomy in km/L, of the 8 (eight) components of road cycle, CO, CO_2, THC, NO_x e NMHC in g/km, urban autonomy, road autonomy and combined autonomy in km/L and 1 (one) hot stage evaporative emissions component in g/test.

All results were the same, with p-value greater than 0.05. Thereby, it can be assured that, to a level of confidence of 95 %, there are no difference statistically significant between the mean and the sample data can be considered as coming from the same population. Thus, the vehicle maintained integrity during the performance of this Proficiency Test.

Due to data confidentiality, once Hyundai CAOA do Brasil and GM do Brasil CPCA are also participants of this PT, these results were not presented.

4. Statistical Analysis of Participants' Results

4.1. z Score

For the participants' results evaluation, it was followed one of ABNT NBR ISO/IEC 17043:2011 criteria, z score (distance measurement related of the laboratory measurement result in relation to the PT designated value, that was calculated according to equation 1.

$$z_i = \frac{x_i - X}{\hat{\sigma}} \quad (1)$$

Where:

x_i is the mean measurement result of the ith participant;

X is the PT designated value;

$\hat{\sigma}$ is the standard deviation for the proficiency testing, that in this round was established as described in ISO 13528:2015 standard, that is, a robust standard deviation based on participants' results.

The interpretation of z score is presented as follows:

$|z| \leq 2{,}0$ - indicates "satisfactory" performance and generates no signal;

$2{,}0 < |z| < 3{,}0$ – indicates "questionable" performance and generates a warning signal;

$|z| \geq 3{,}0$ - indicates "unsatisfactory" performance and generates an action signal.

5. Assigned Values

According to available procedures for the establishment of designated values by ABNT NBR ISO/IEC 17043:2011, the designated values of this PT were calculated by statistical methods described in 7.7 item of ISO 13528:2015 standard, that is, consensus values from participant results.

ISO 13528:2015 standard describes the robust analysis involving employment of the A algorithm for the calculation of designated value and standard deviation. The robust statistical techniques are used to minimize the influence that extreme results can have on estimates of mean and standard deviation.

Initially, all values object of the analysis (values sent by participants) were put in ascending order. Next, robust values and standard deviation of these data were denoted by (x*) and (s*). Initial values of (x*) and (s*) were calculated according to equations below:

$$x^* = x_i \text{ median} \quad (2)$$

$$s^* = 1{,}483 \text{ x median } |x_i - x^*| \quad (3)$$

(x^*) e (s^*) values were updated as follows. It was calculated:

$$\delta = 1{,}5 s^* \quad (4)$$

For each x_i (i = 1, 2,..., p), it was calculated:

$$x_i^* = \begin{cases} x^* - \delta, & \text{if} \quad x_i < x^* - \delta \\ x^* + \delta, & \text{if} \quad x_i > x^* + \delta \\ x_i, & \text{otherwise} \end{cases} \quad (5)$$

new values of (x*) e (s*) should be calculated from the equations:

$$x^* = \sum x_i^* / p \quad (6)$$

$$s^* = 1{,}134 \sqrt{\sum (x_i^* - x^*)^2 / (p-1)} \quad (7)$$

Where the summation is over i.

The robust estimation (x*) and (s*) can be obtained by an iterative calculation, i.e. by updating the values of (x*) and (s*) several times using the modified data, until the process converges. Convergence may be assumed when there is no change from one iteration to the next in the third significant figure of the robust standard deviation and of the equivalent figure in the robust average.

The results out of 2 standard deviation intervals after the robust average and robust standard deviation calculation were considered as outliers and new assigned values as well new robust standard deviation results were calculated for each parameter of the PT, removing those outliers.

Tables 1, 2 and 3 present the assigned values and the robust standard deviation for all parameters, including all PT participants, as well as the new robust average and standard deviation values after removal of the outlier results.

Each participant in this report is identified by the last three characters of its identification code in tables, graphs and texts.

Table 1 - Assigned values and standard deviation of the PT – urban cycle emissions.

Parameter	Designated value	Standard deviation	Outliers (participants)	Recalculated designated value	Recalculated standard deviation
CO (g/km)	0.380	0.058	-	-	-
CO_2 (g/km)	239.9	5.2	-	-	-
THC (g/km)	0.034	0.005	-	-	-
NO_x (g/km)	0.065	0.013	064	-	-
NMHC (g/km)	0.030	0.004	-	-	-
Total aldeydes (g/km)	0.00103	0.00031	113	0.00105	0.00029
Urban autonomy (km/L)	9.04	0.20	-	-	-

Table 2 - Assigned values and standard deviation of the PT – evaporative emissions cycle.

Parameter	Designated value	Standard deviation	Outliers (participants)	Recalculated designated value	Recalculated standard deviation
Evaporative emissions	0.342	0.102	052	0.356	0.090

Table 3 - Assigned values and standard deviation of the PT – road cycle.

Parameter	Designated value	Standard deviation	Outliers (participants)	Recalculated designated value	Recalculated standard deviation
CO (g/km)	0.487	0.086	--	--	--
CO_2 (g/km)	183.1	2.7	009, 015 e 045	182.9	2.0
THC (g/km)	0.013	0.001	015	0.013	0.001
NO_x (g/km)	0.030	0.007	--	--	--
NMHC (g/km)	0.011	0.001	015	0.010	0.001
Urban autonomy	9.04	0.20	--	--	--
Road autonomy	11.82	0.18	015 e 045	11.83	0.14
Combined autonomy	10.10	0.20	009 e 015	10.10	0.17

6. Results Dispersion

In the presented graphs for all tested parameters, a continuous line represents the assigned value and the last three digits of its identification code identify each laboratory. Dotted lines are representations of Ref ± 1s and Ref ± 2s, where "Ref" is the assigned value (robust average) and "s" is the robust standard deviation.

6.1. Urban Cycle Emissions

Figures 2 to 8 graphically present the means and standard deviations of the reported emission results by the laboratories for each analyzed parameter.

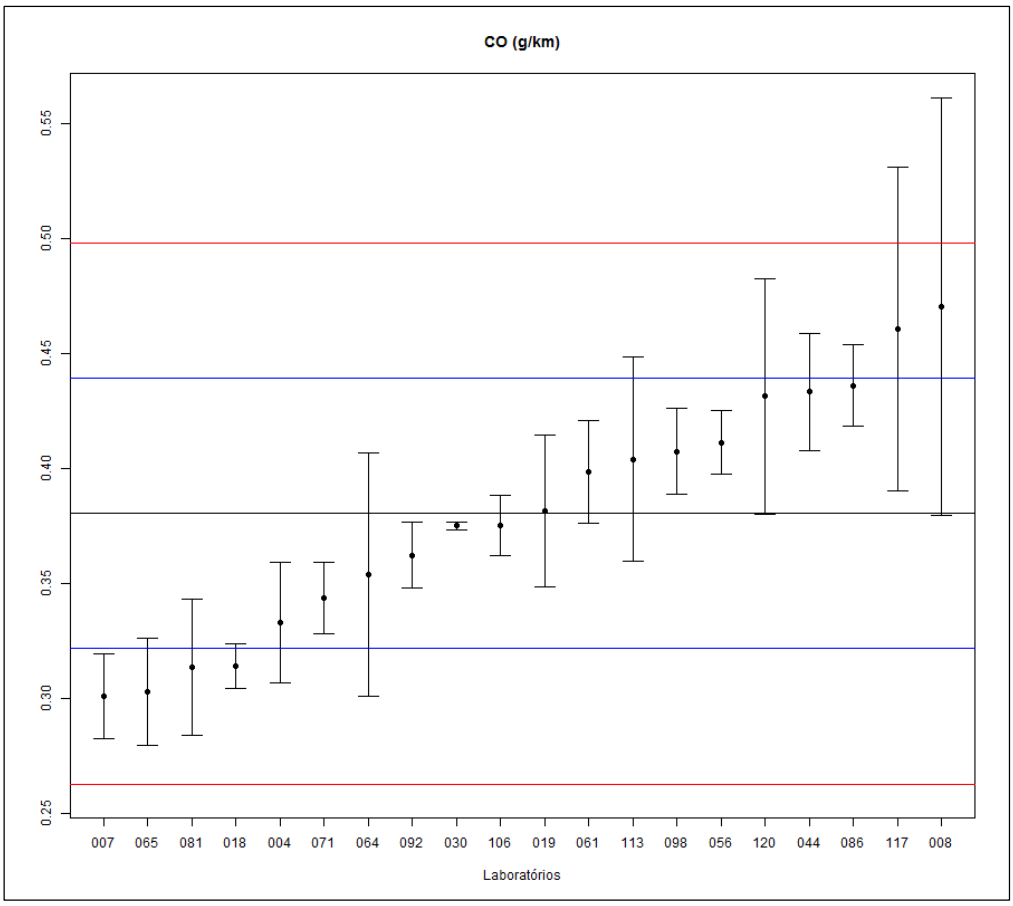

Figure 2 – Scatter plot of the results for CO determination – urban cycle.

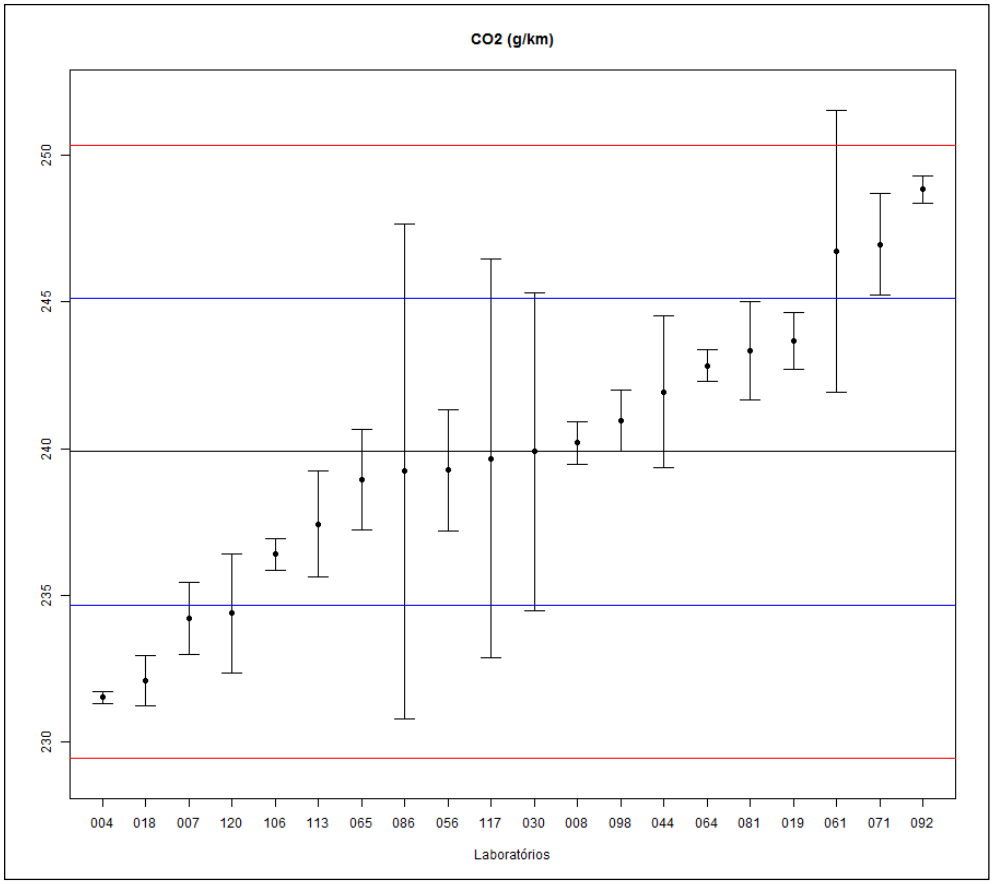

Figure 3 – Scatter plot of the results for CO_2 determination – urban cycle.

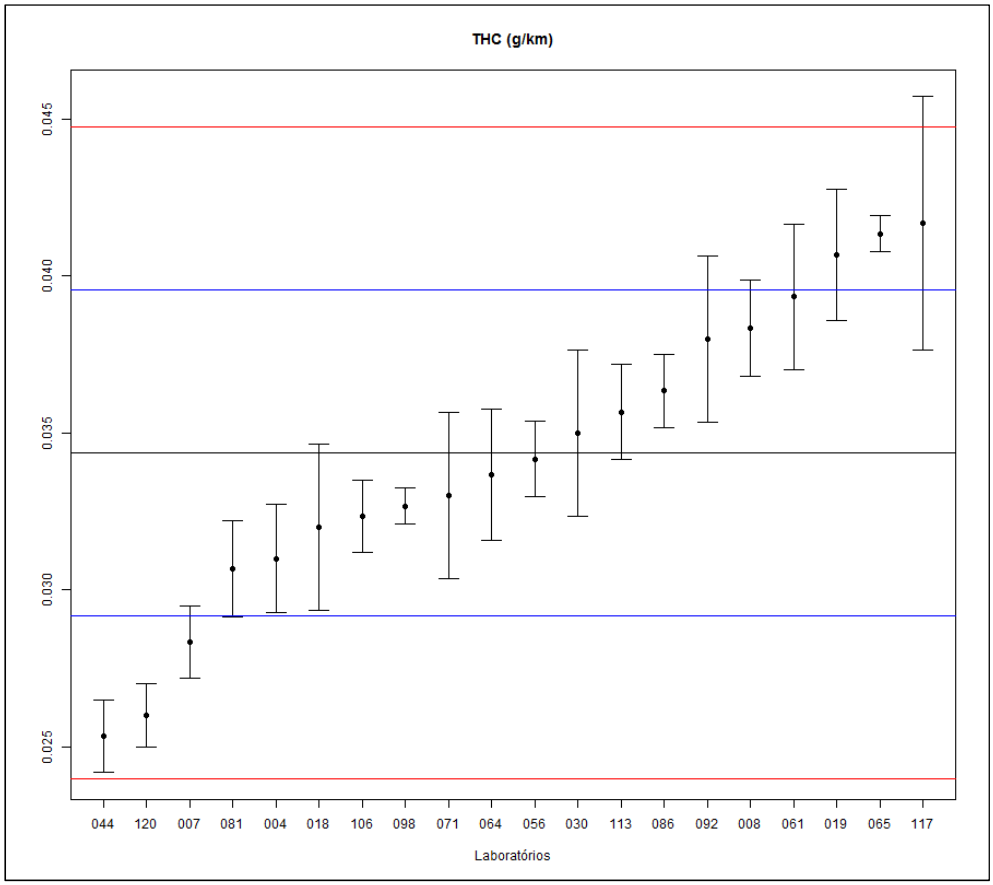

Figure 4 – Scatter plot of the results for THC determination – urban cycle.

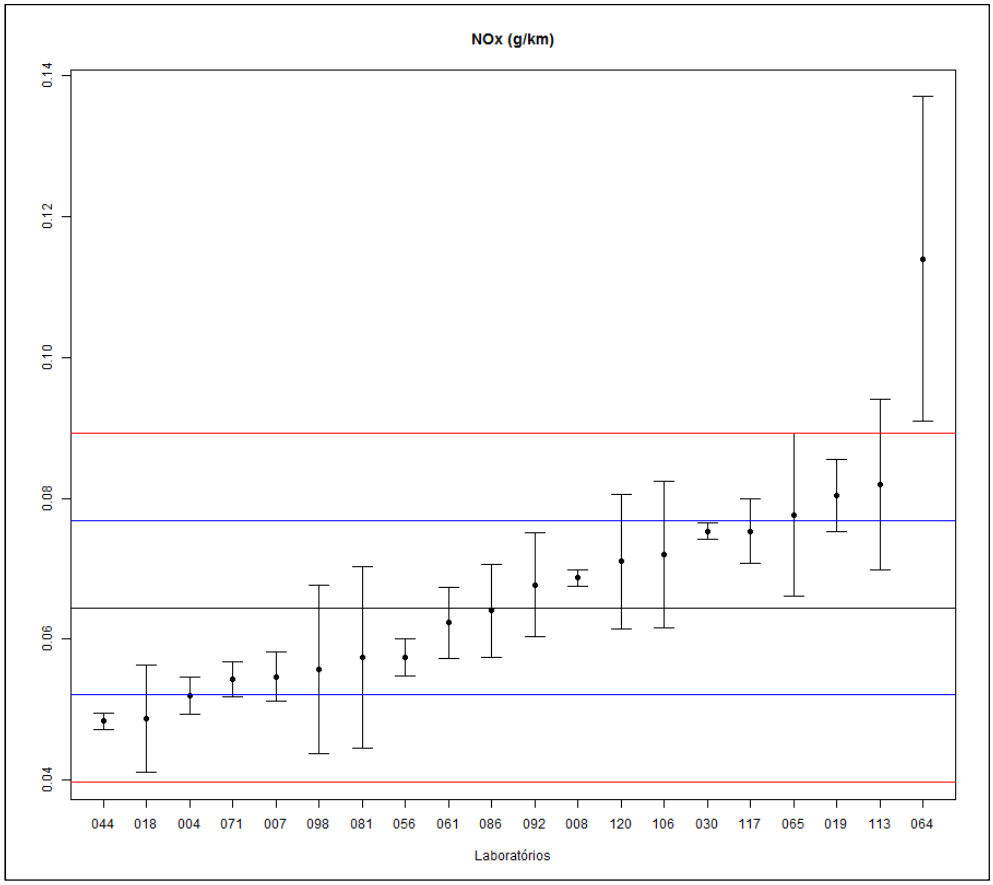

Figure 5 – Scatter plot of the results for NO_x determination – urban cycle.

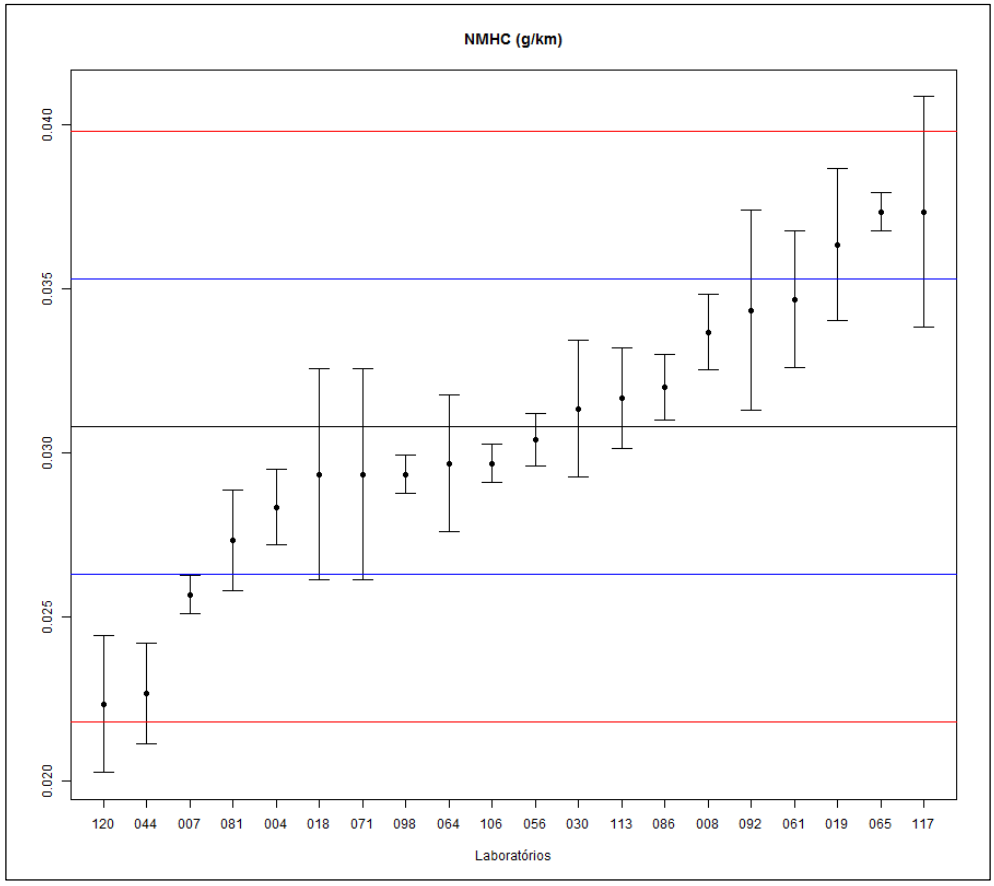

Figure 6 – Scatter plot of the results for NMHC determination – urban cycle.

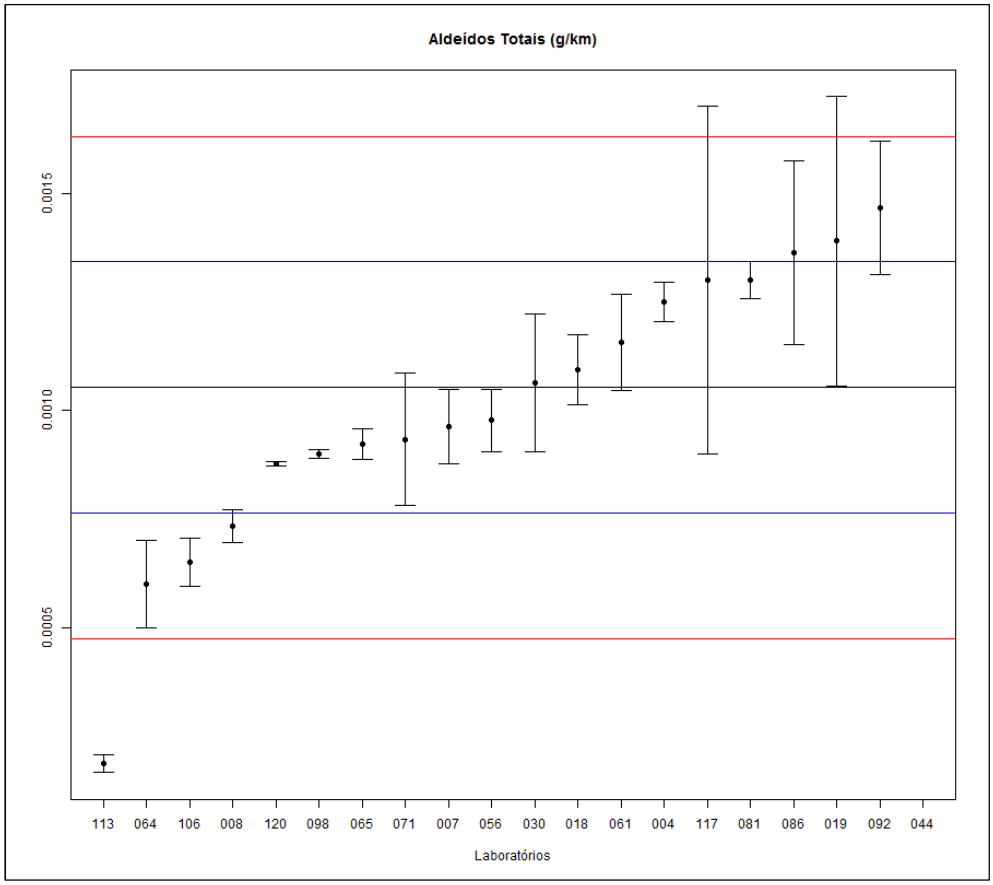

Figure 7 – Scatter plot of the results for total aldehydes determination – urban cycle.

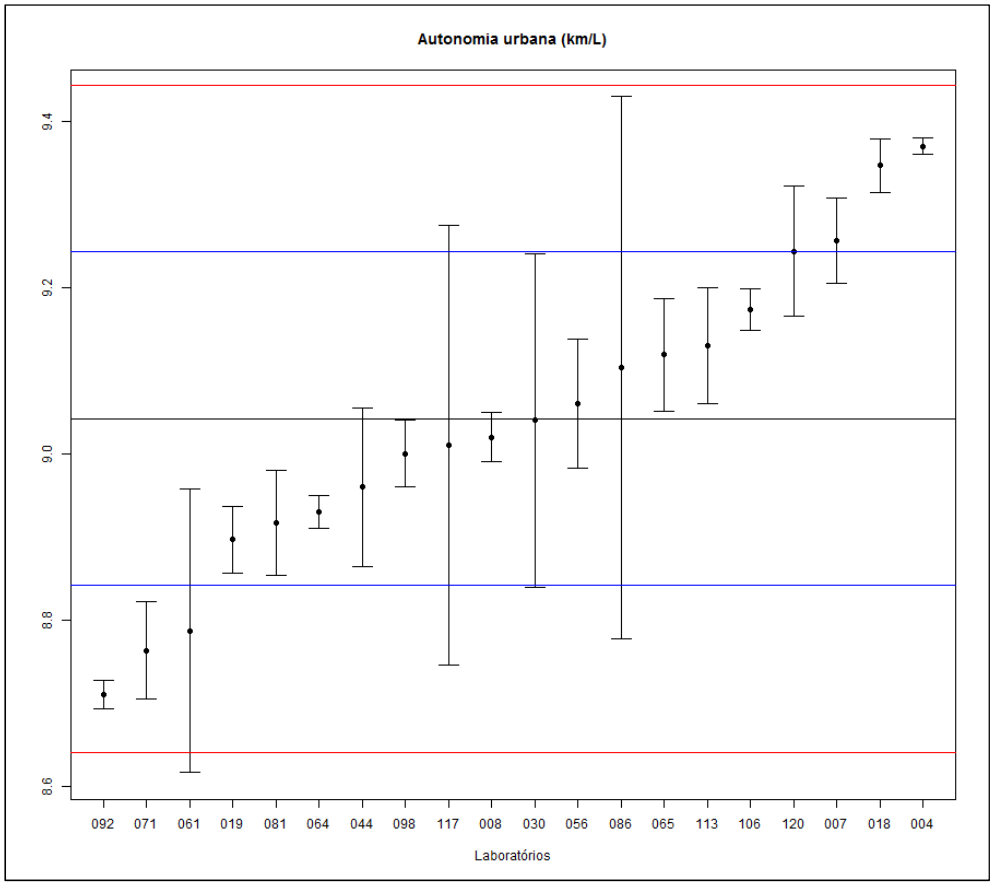

Figure 8 – Scatter plot of the results for urban autonomy determination – urban cycle.

Through the graphs, it can be seen that:

CO (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participants 064, 113, 120,117 and 008 presented the greatest dispersions.

CO_2 (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participants 086, 117, 030 and 061 presented the greatest dispersions.

THC (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participant 117 presented the greatest dispersion.

NO_x (g/km): Among 19 participants that reported results within the Ref ± 2s interval, participant 064 presented result out of this interval and had the greatest data dispersion.

NMHC (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participants, 018, 071, 092 and 117 presented the greatest dispersions.

Total aldehydes (g/km): Among 19 participants that reported results within the Ref ± 2s interval, participant 113 presented result out of this interval and participants 117 and 019 presented the greatest dispersions.

Urban autonomy (km/L): Among all 20 participants that reported results within the Ref ± 2s interval, participants, 061, 117, 030 and 086 presented the greatest dispersions.

6.2. Evaporative Emissions (g/test)

Figure 9 graphically presents the means and standard deviations of the reported results for evaporative emissions data (g/test) by participants for each analyzed parameter.

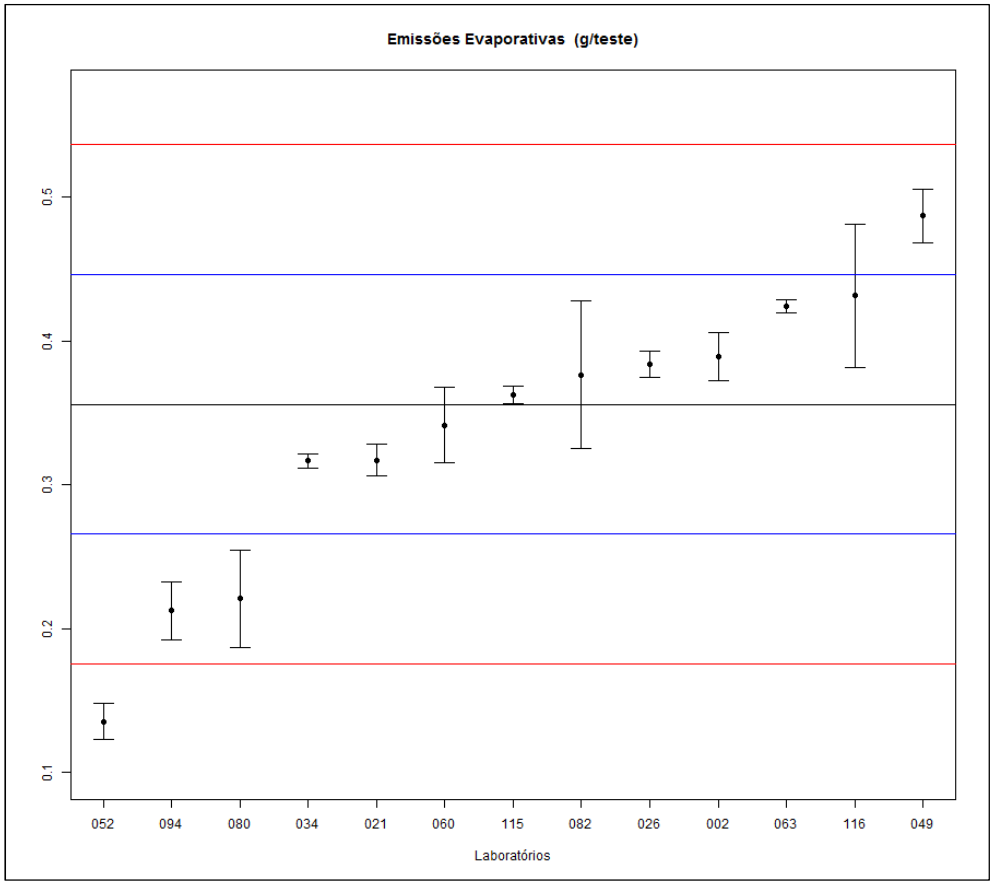

Figure 9 – Scatter plot of the results for evaporative emissions (g/test).

Through the graphs, it can be seen that:

Evaporative Emissions (g/test): Among 12 participants that presented results within the Ref ± 2s interval, participant 052 presented result out of this interval and participants 082 and 116 presented the greatest data dispersions.

6.3. Road Cicle Emissions

Figures 10 to 17 graphically presents the means and standard deviations of the reported results for road cycle emission data by participants for each analyzed parameter.

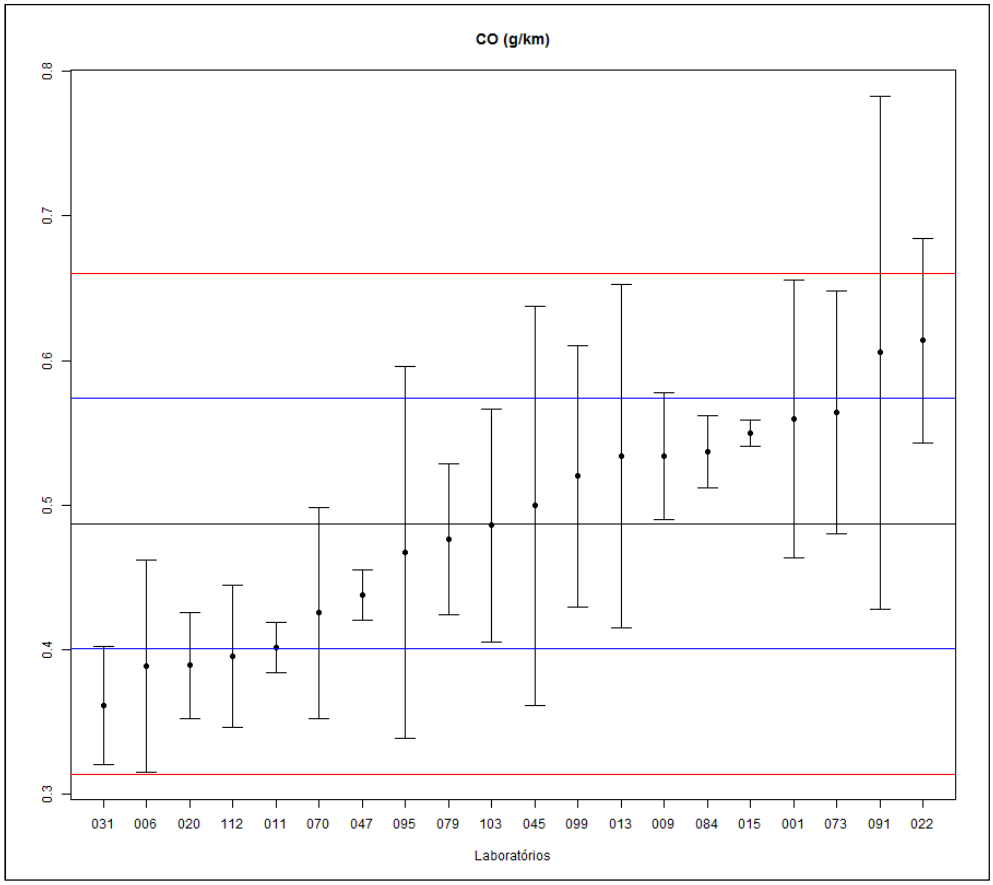

Figure 10 – Scatter plot of the results for CO – road cycle.

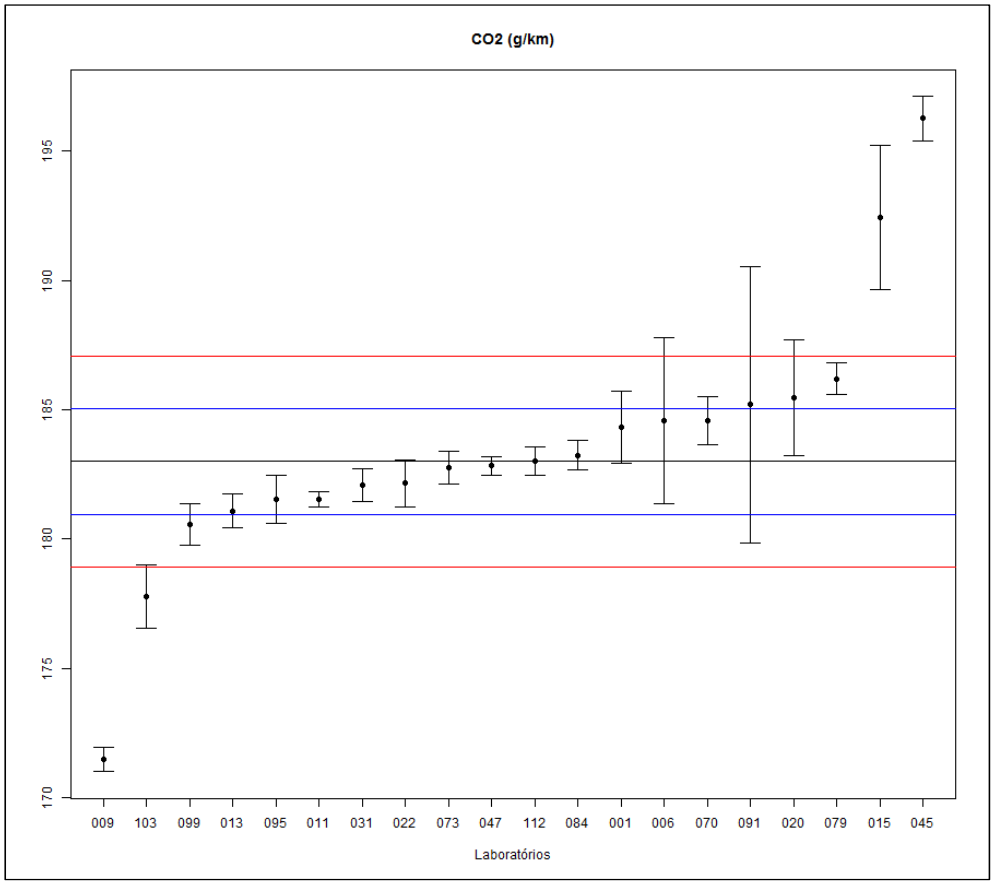

Figure 11 – Scatter plot of the results for CO_2 – road cycle.

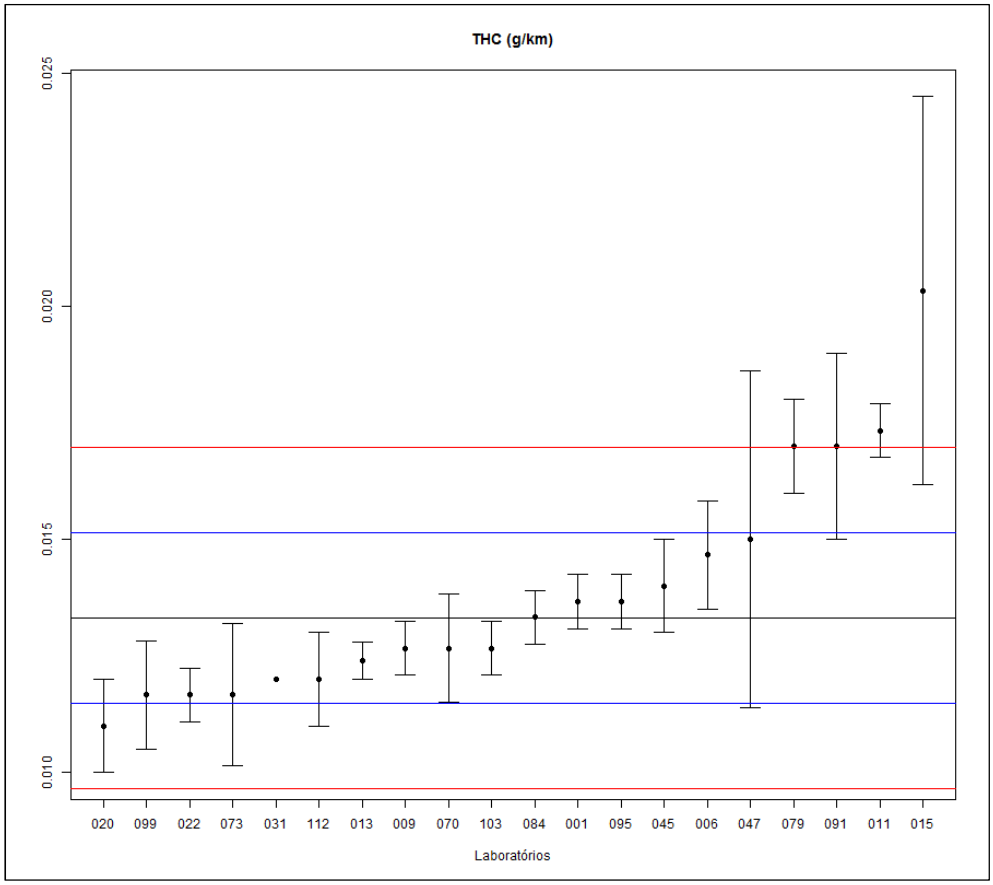

Figure 12 – Scatter plot of the results for THC – road cycle.

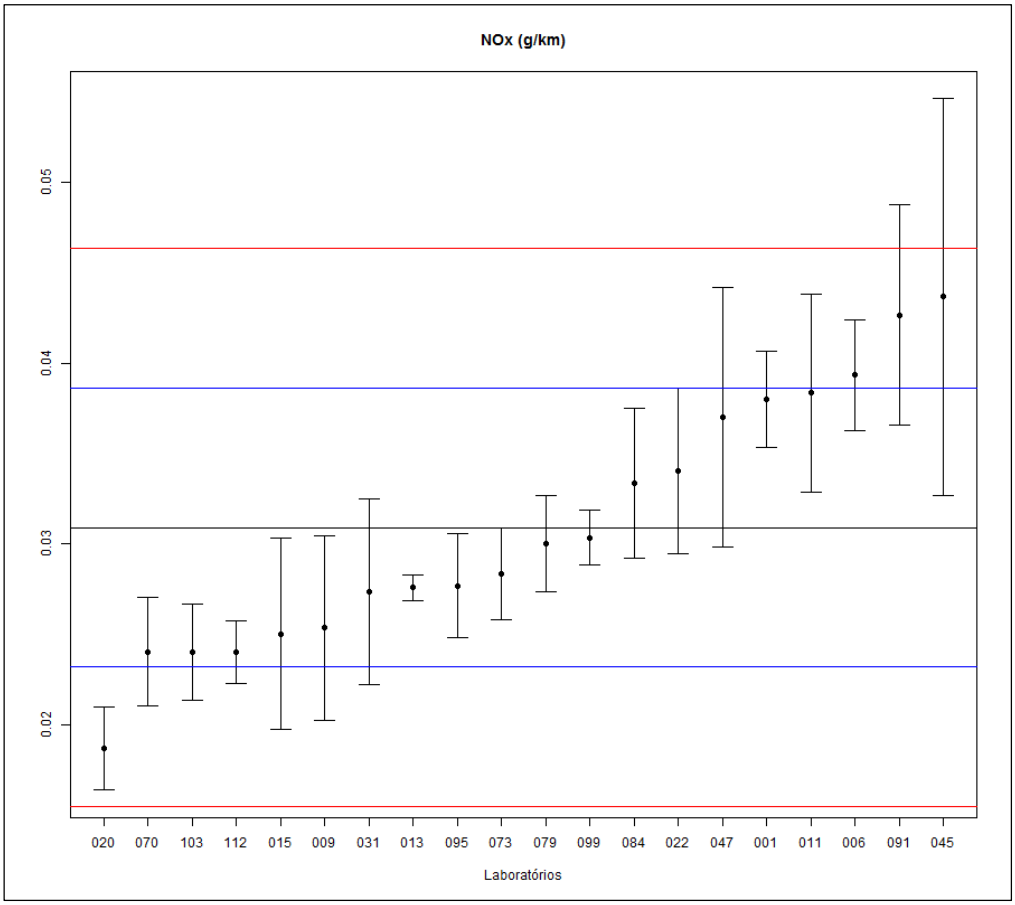

Figure 13 – Scatter plot of the results for NO_x – road cycle.

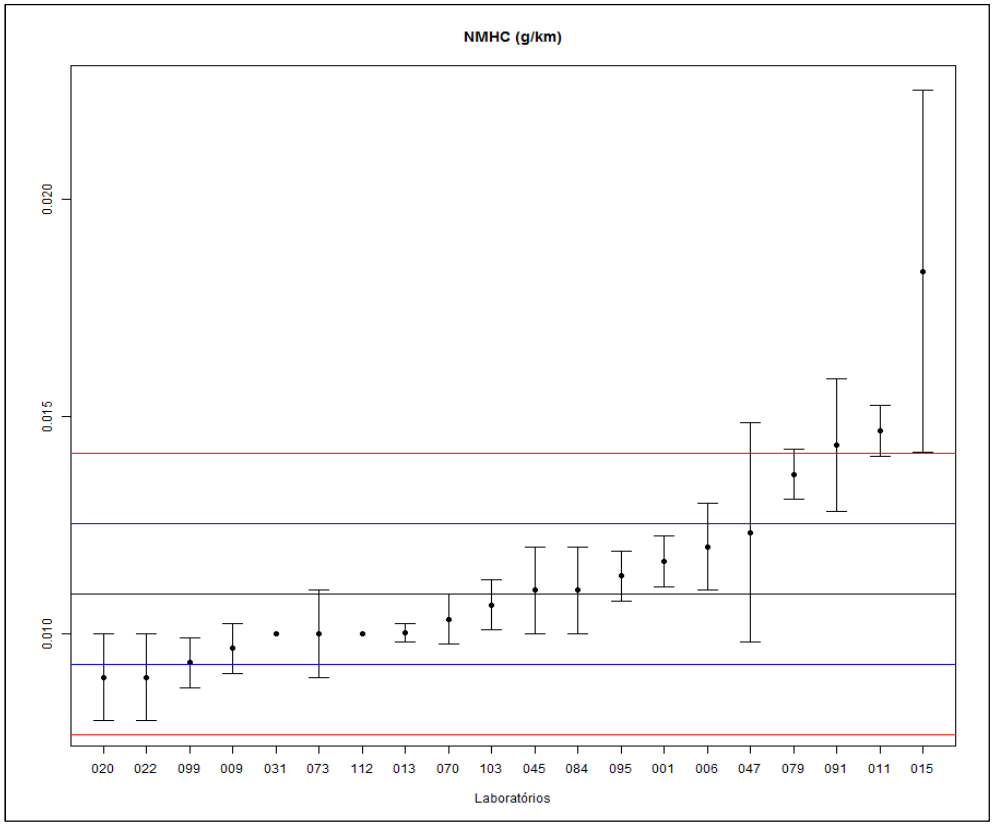

Figure 14 – Scatter plot of the results for NMHC – road cycle.

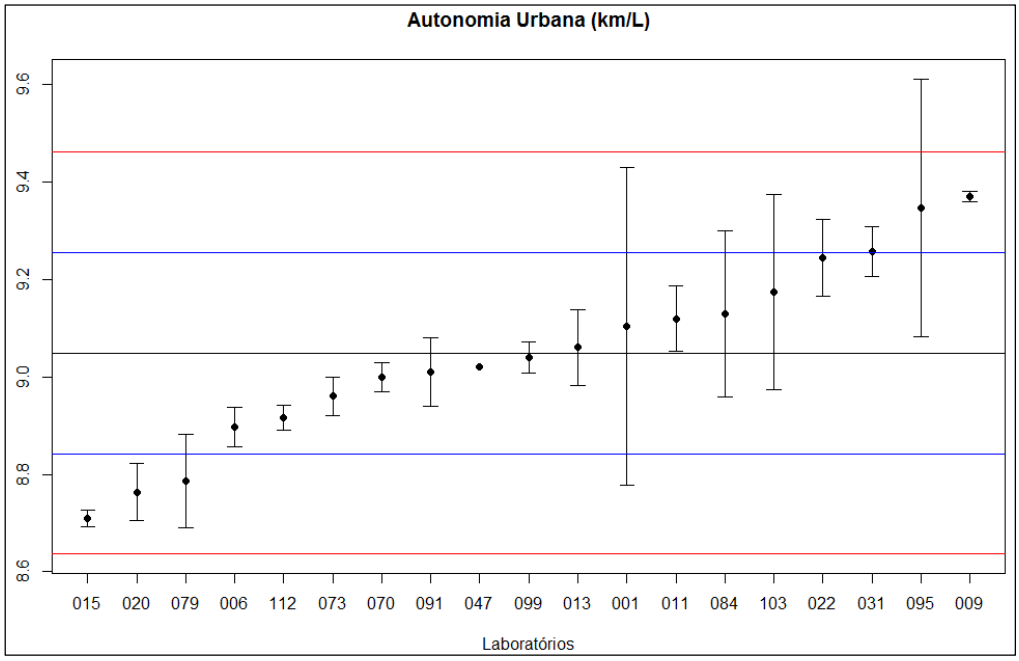

Figure 15 – Scatter plot of the results for urban autonomy (km/L) – road cycle.

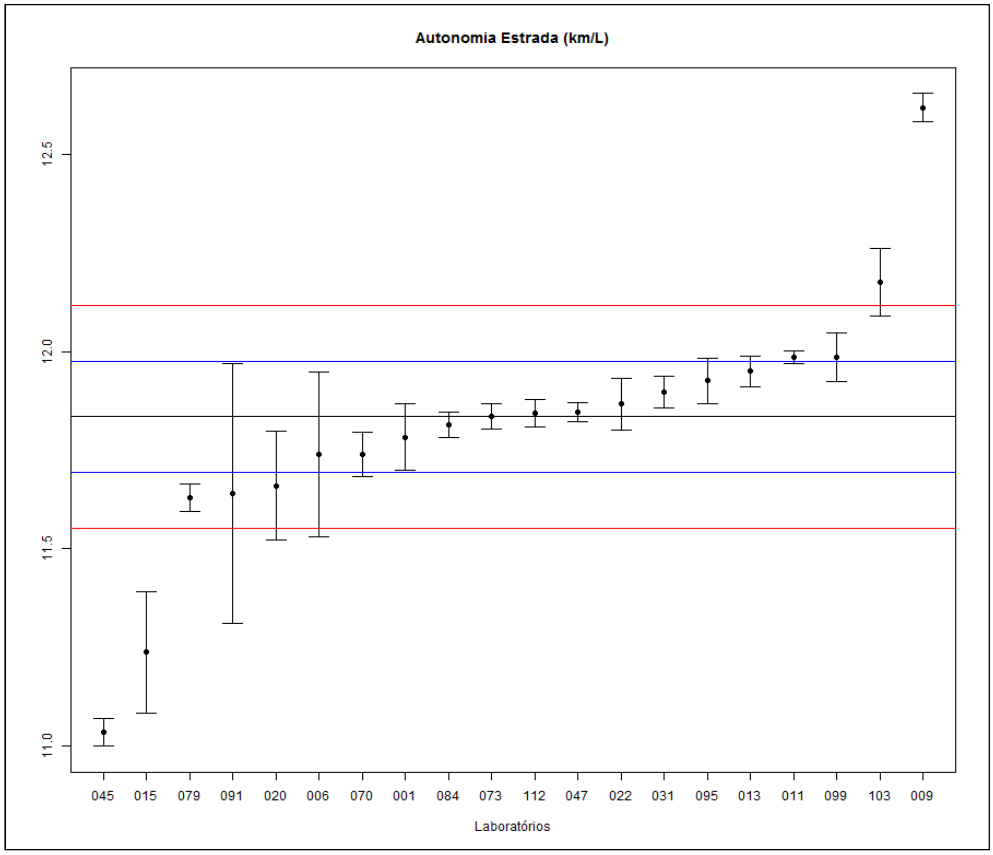

Figure 16 – Scatter plot of the results for road autonomy (km/L) – road cycle.

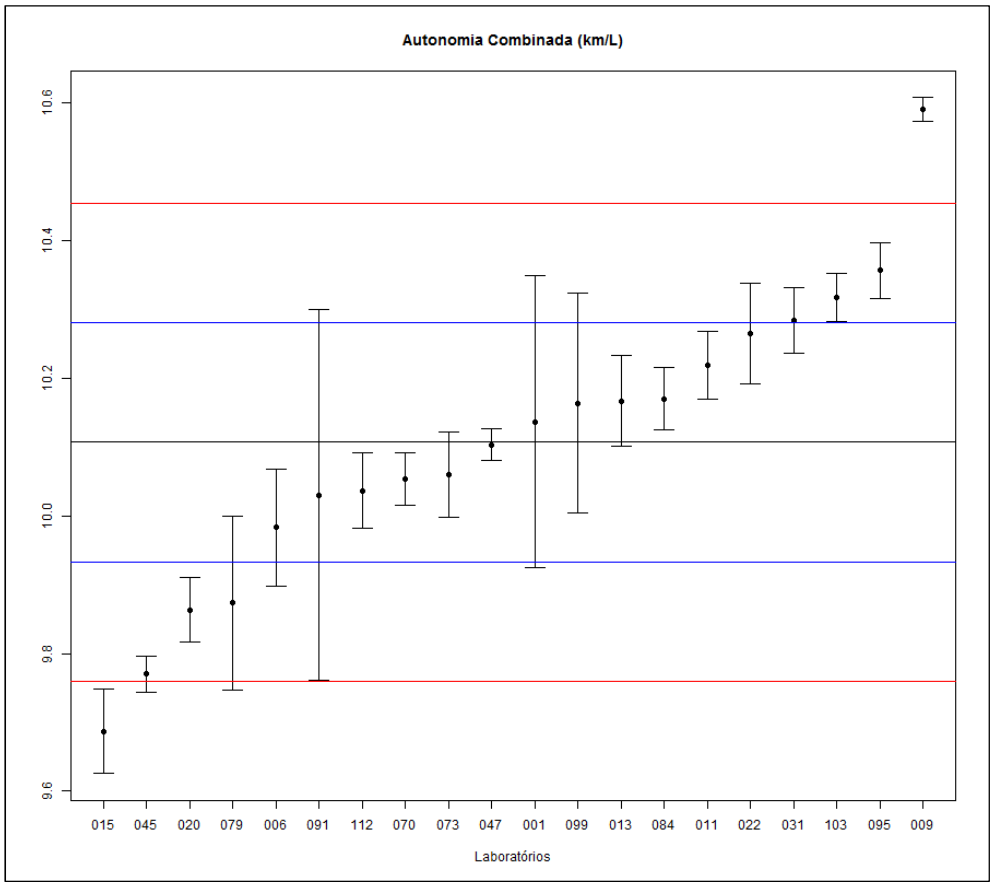

Figure 17 – Scatter plot of the results for combined autonomy (km/L) – road cycle.

Through the graphs, it can be seen that:

CO (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participants 095, 045, 013 and 091 presented the greatest dispersions.

CO_2 (g/km): Among 16 participants that reported results within the Ref ± 2s interval, participants 009, 015 and 045 presented result out of this interval and participant 091 presented the greatest dispersion.

THC (g/km): Among 19 participants that reported results within the Ref ± 2s interval, participants 011, 079 and 091 were borderlines, participant 015 is out of this limit and participants 047 and 015 presented the greatest dispersions.

NO_x (g/km): Among all 20 participants that reported results within the Ref ± 2s interval, participants 015, 009, 031, 022, 047, 011, 091 and 045 presented the greatest dispersions.

NMHC (g/km): Among 19 participants that reported results within the Ref ± 2s interval, participant 015 is out of this interval and participants 047 and 015 presented the greatest dispersions.

Urban autonomy (km/L): 19 participants reported results within the Ref ± 2s interval. Participant 045 did not present results.

Road autonomy (km/L): Among 17 participants that reported results within the Ref ± 2s inteval, participants 103, 009, 015 and 045 are out of this interval and participants 091 and 006 presented the greatest dispersions.

Combined autonomy (km/L): Among 18 participants that reported results within the Ref ± 2s interval, participants 009 and 015 are out of this interval and participants 091, 001 and 099 presented the greatest dispersions.

7. Participants' Results

Measurement results reported by participants in this PT are presented in sections 7.1 to 7.3.

In this report each participant is identified only by the final numbering of its identification code in the tables and graphs.

Participants 050, 053, 075, 110 and 111 did not send their results report, due to problems in their equipment and reported this situation to the PT coordination.

7.1. Urban Cicle Emissions

Tables 4 and 5 present the average and standard deviations of each participant, where the result is the mean value of the replicates.

Note: All decimal places were considered for calculations, but the values in the tables 4 and 5 were rounded to the same number of decimal places as requested in the results form.

Table 4 – Average and standard deviation of participants for CO, CO_2, THC, NO_X and NMHC (g/km) parameters – urban cycle.

Code	CO (g/km)		CO_2 (g/km)		THC (g/km)		NO_x (g/km)		NMHC (g/km)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
004	0.333	0.026	231.5	0.2	0.031	0.001	0.052	0.002	0.028	0.001
007	0.301	0.018	234.2	1.2	0.028	0.001	0.054	0.003	0.025	0.000
008	0.470	0.090	240.2	0.7	0.038	0.001	0.069	0.001	0.033	0.001
018	0.314	0.009	232.1	0.8	0.032	0.002	0.048	0.007	0.029	0.003
019	0.381	0.033	243.6	0.9	0.040	0.002	0.080	0.005	0.036	0.002
030	0.375	0.001	239.9	5.4	0.035	0.002	0.075	0.001	0.031	0.002
044	0.433	0.025	241.9	2.5	0.025	0.001	0.048	0.001	0.023	0.001
056	0.411	0.013	239.2	2.0	0.034	0.001	0.057	0.002	0.030	0.001
061	0.398	0.022	246.7	4.8	0.039	0.002	0.062	0.005	0.035	0.002
064	0.354	0.052	242.8	0.5	0.033	0.002	0.114	0.023	0.029	0.002
065	0.303	0.023	238.9	1.7	0.041	0.000	0.077	0.011	0.037	0.000
071	0.343	0.015	246.9	1.7	0.033	0.002	0.054	0.002	0.029	0.003
081	0.313	0.029	243.3	1.6	0.030	0.001	0.057	0.012	0.027	0.001
086	0.436	0.017	239.2	8.4	0.036	0.001	0.064	0.006	0.032	0.001
092	0.362	0.014	248.8	0.4	0.038	0.002	0.067	0.007	0.034	0.003
098	0.407	0.018	241.0	1.0	0.033	0.000	0.056	0.011	0.029	0.000
106	0.375	0.013	236.4	0.6	0.032	0.001	0.072	0.010	0.030	0.001
113	4.040	0.044	237.4	1.7	0,036	0.001	0.082	0.012	0,032	0.001
117	0.460	0.070	239.6	6.7	0.041	0.004	0.075	0.004	0.037	0.003
120	0.431	0.051	234.3	2.0	0.026	0.001	0.071	0.009	0.022	0.002

Table 5 – Average and standard deviation of participants for total aldehydes (g/km) and urban autonomy (km/L) parameters – urban cycle.

Code	Total aldehydes (g/km)		Urban autonomy (km/L)		Code	Total aldehydes (g/km)		Urban autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation		Standard deviation	Average	Standard deviation	Average
004	0.00125	0.00004	9.37	0.01	**065**	0.00092	0.00003	9.11	0.06
007	0.00096	0.00008	9.25	0.05	**071**	0.00093	0.00015	8.76	0.05
008	0.00000	0.00003	9.02	0.03	**081**	0.00130	0.00004	8.91	0.06
018	0.00109	0.00008	9.34	0.03	**086**	0.00136	0.00021	9.10	0.32
019	0.00139	0.00033	8.89	0.04	**092**	0.00146	0.00015	8.71	0.01
030	0.00106	0.00015	9.04	0.20	**098**	0.00090	0.00001	9.00	0.04
044	-	-	8.96	0.09	**106**	0.00065	0.00005	9.17	0.03

Code	Total aldehydes (g/km)		Urban autonomy (km/L)		Code	Total aldehydes (g/km)		Urban autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation		Standard deviation	Average	Standard deviation	Average
056	0.00097	0.00007	9.06	0.07	**113**	0.00018	0.00002	9.13	0.07
061	0.00115	0.00010	8.78	0.17	**117**	0.00130	0.00040	9.01	0.26
064	0.00060	0.00010	8.93	0.02	**120**	0.00087	0.00000	9.24	0.07

For the performance evaluation of the participants, z-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results for each parameter as assigned value and its standard deviation. Tables 6 and 7 and figures 18 to 24 show these results.

Table 6 – z-score values for the CO, CO_2, THC, NO_X and NMHC parameters – urban cycle.

Code	CO (g/km)	CO_2 (g/km)	THC (g/km)	NO_X (g/km)	NMHC (g/km)
	z score	z score	z score	z score	z score
004	-0.80	-1.60	-0.64	-1.00	-0.54
007	-1.35	-1.08	-1.16	-0.79	-1.13
008	1.53	0.05	0.76	0.34	0.63
018	-1.12	-1.49	-0.45	-1.27	-0.32
019	0.01	0.72	1.21	1.28	1.23
030	-0.09	-0.00	0.12	0.87	0.12
044	0.90	0.38	-1.73	-1.30	-1.80
056	0.52	-0.12	-0.03	-0.57	-0.08
061	0.30	1.30	0.95	-0.17	0.86
064	-0.44	0.56	-0.13	**4.00**	-0.25
065	-1.31	-0.18	1.34	1.06	1.45
071	-0.62	1.35	-0.26	-0.81	-0.32
081	-1.13	0.65	-0.71	-0.57	-0.76
086	0.94	-0.12	0.37	-0.03	0.26
092	-0.30	1.71	0.69	0.25	0.78
098	0.45	0.20	-0.32	-0.71	-0.32
106	-0.08	-0.67	-0.39	0.60	-0.25
113	0.40	-0.47	0.25	1.41	0.19
117	1.36	-0.04	1.40	0.87	1.45
120	0.86	-1.05	-1.61	0.52	-1.88

* Satisfactory result
* Questionable result
* Unsatisfactory result

Table 7 – z-score values for the total aldehydes (g/km) and urban autonomy (km/L) parameters – urban cycle.

Code	Total aldehydes (km/L)	Urban autonomy (km/L)	Code	Total aldehydes (km/L)	Urban autonomy (km/L)
	z score	z score		z score	z score
004	0.68	1.63	**065**	-0.45	0.38
007	-0.31	1.07	**071**	-0.41	-1.38
008	-1.10	-0.10	**081**	0.85	-0.62
018	0.13	1.51	**086**	1.07	0.30
019	1.16	-0.72	**092**	1.42	-1.65
030	0.03	-0.00	**098**	-0.53	-0.20
044	-	-0.40	**106**	-1.39	0.65
056	-0.26	0.09	**113**	**-2.99**	0.43
061	0.35	-1.27	**117**	0.85	-0.15
064	-1.56	-0.55	**120**	-0.61	1.00

* Satisfactory result
* Questionable result
* Unsatisfactory result

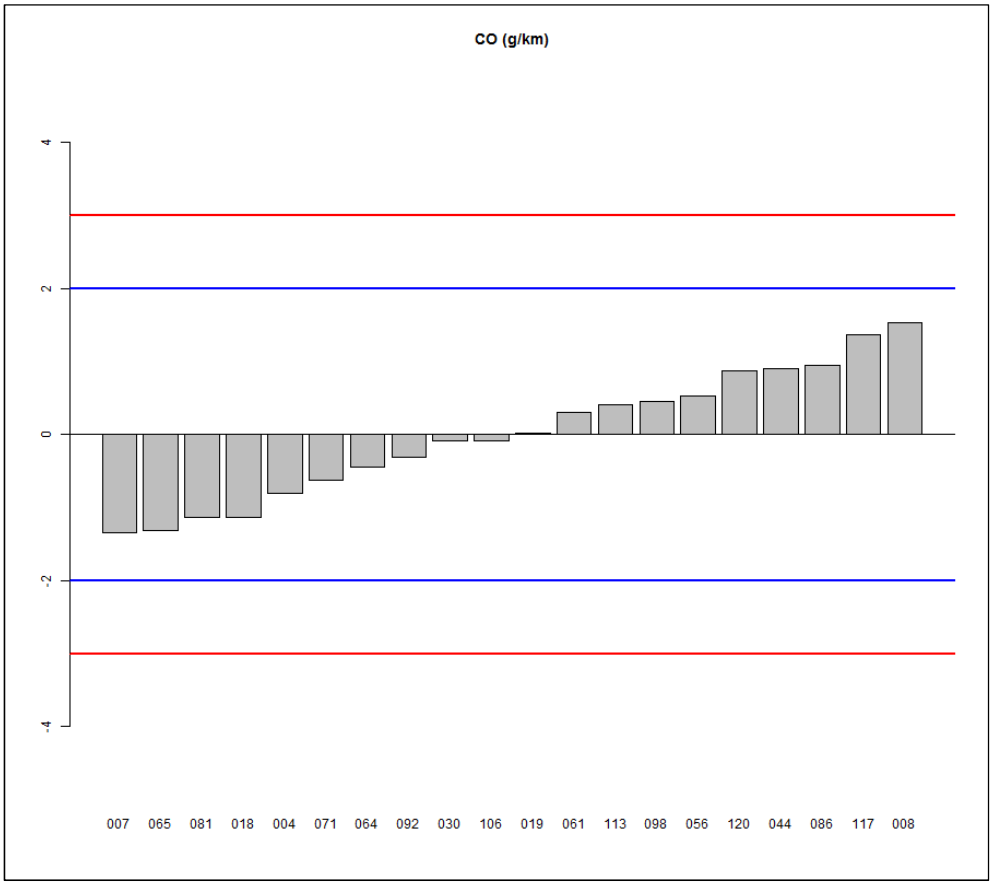

Figure 18 – z-score graph for CO measurement – urban cycle

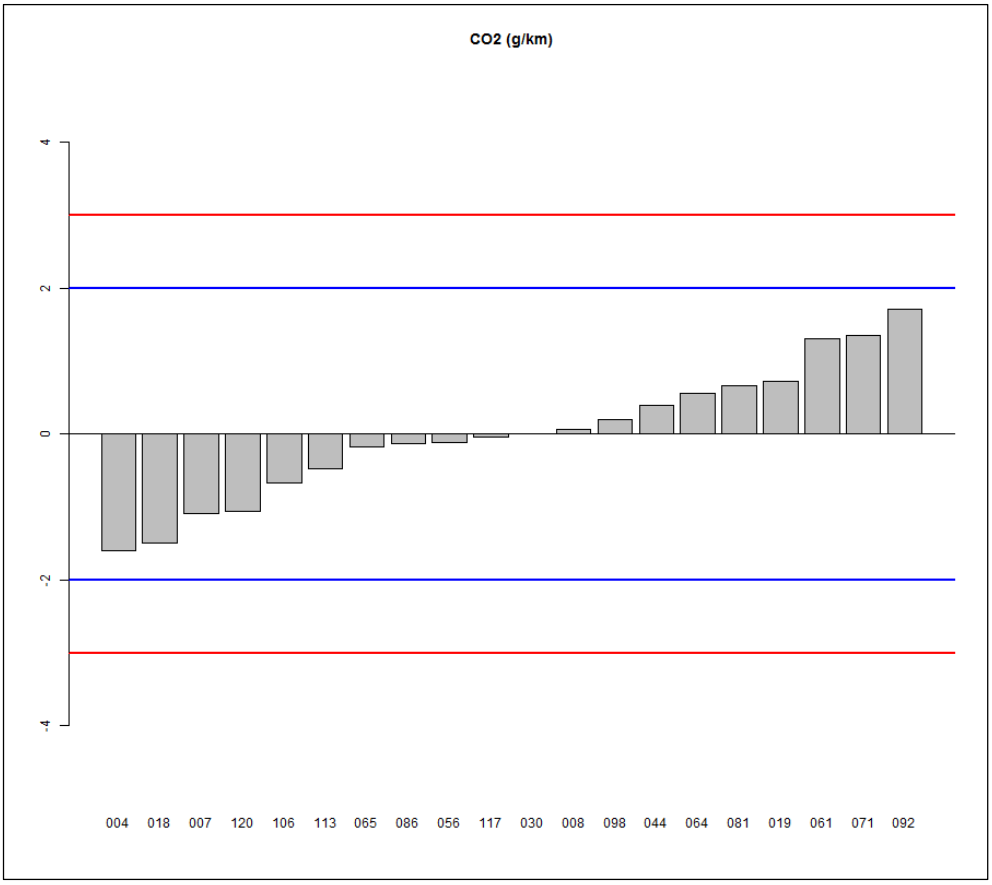

Figure 19 – z-score graph for CO_2 measurement – urban cycle

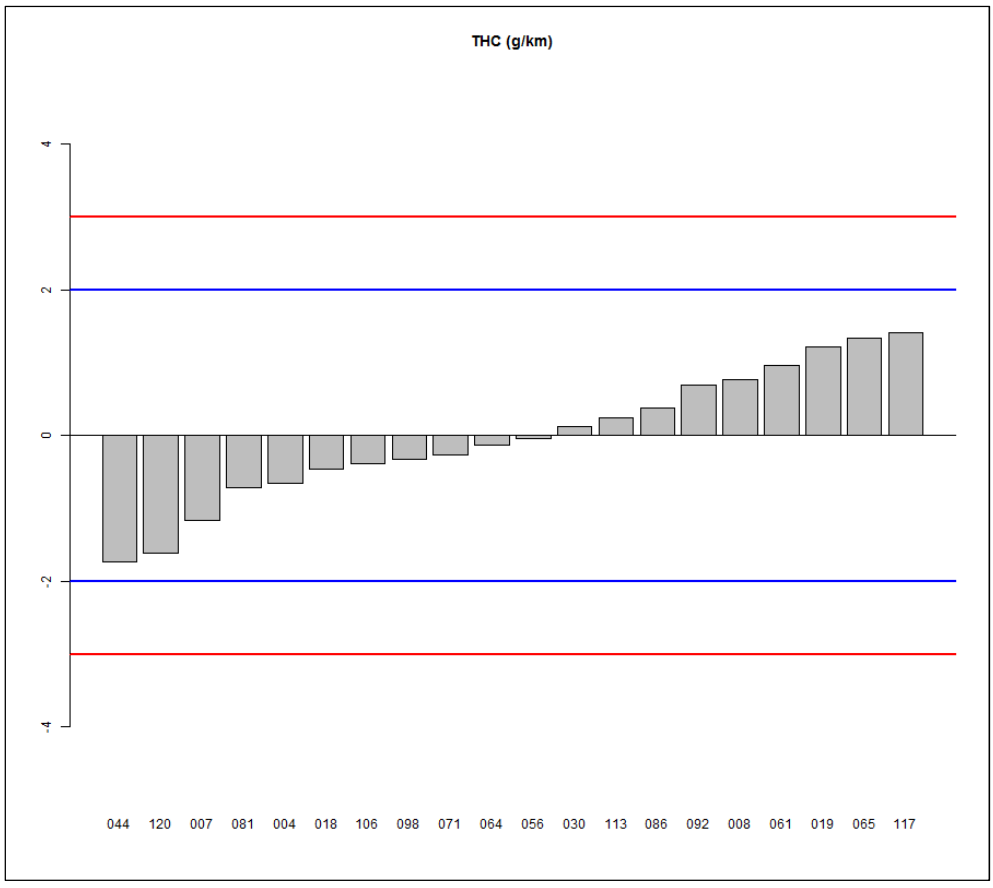

Figure 20 – z-score graph for THC measurement – urban cycle

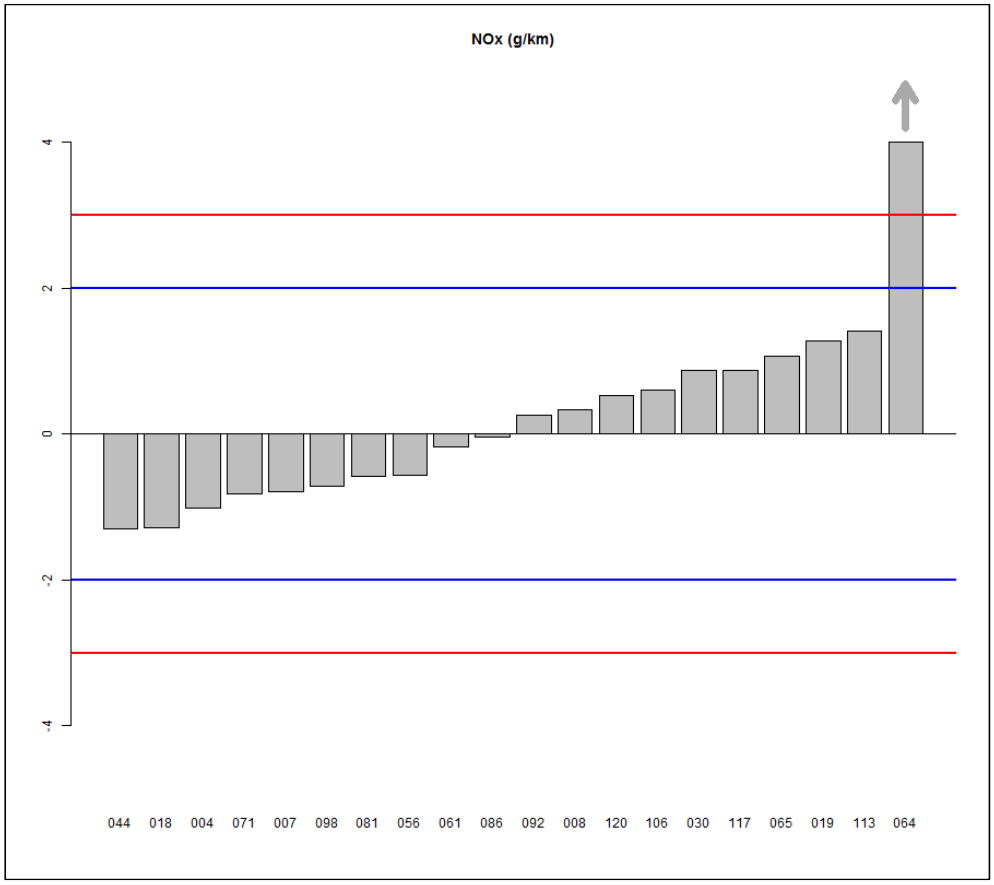

Figure 21 – z-score graph for NO_x measurement – urban cycle

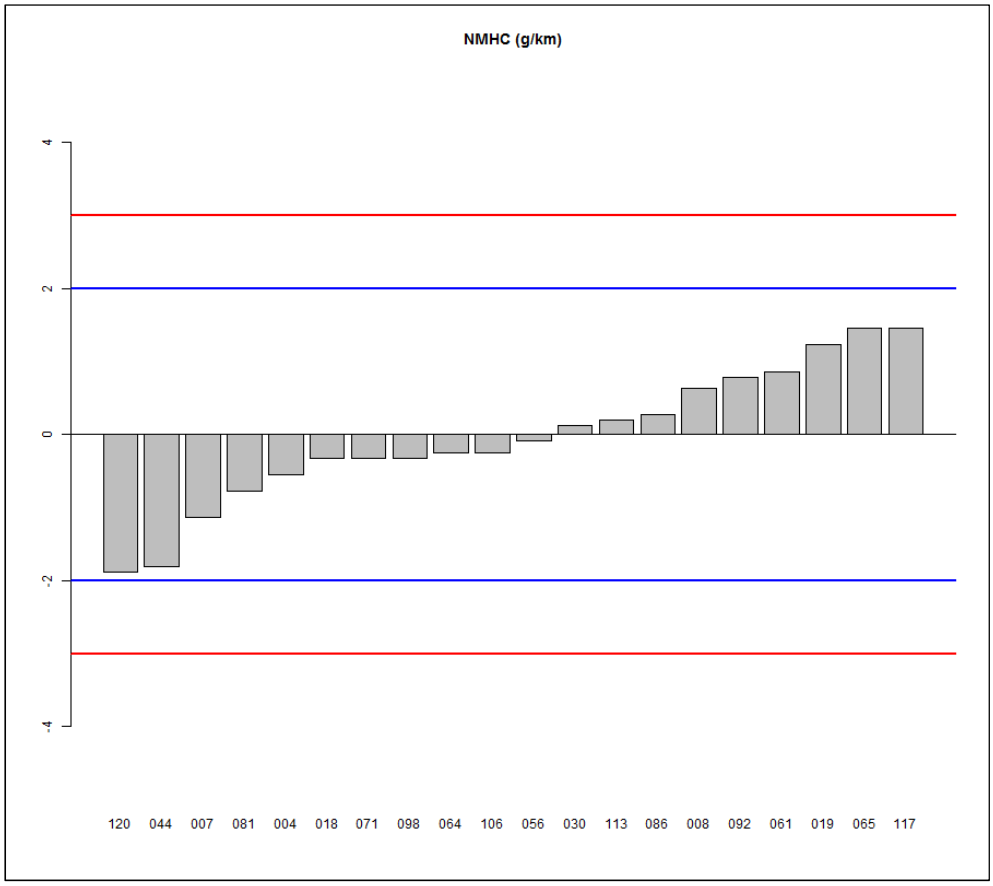

Figure 22 – z-score graph for NMHC measurement – urban cycle

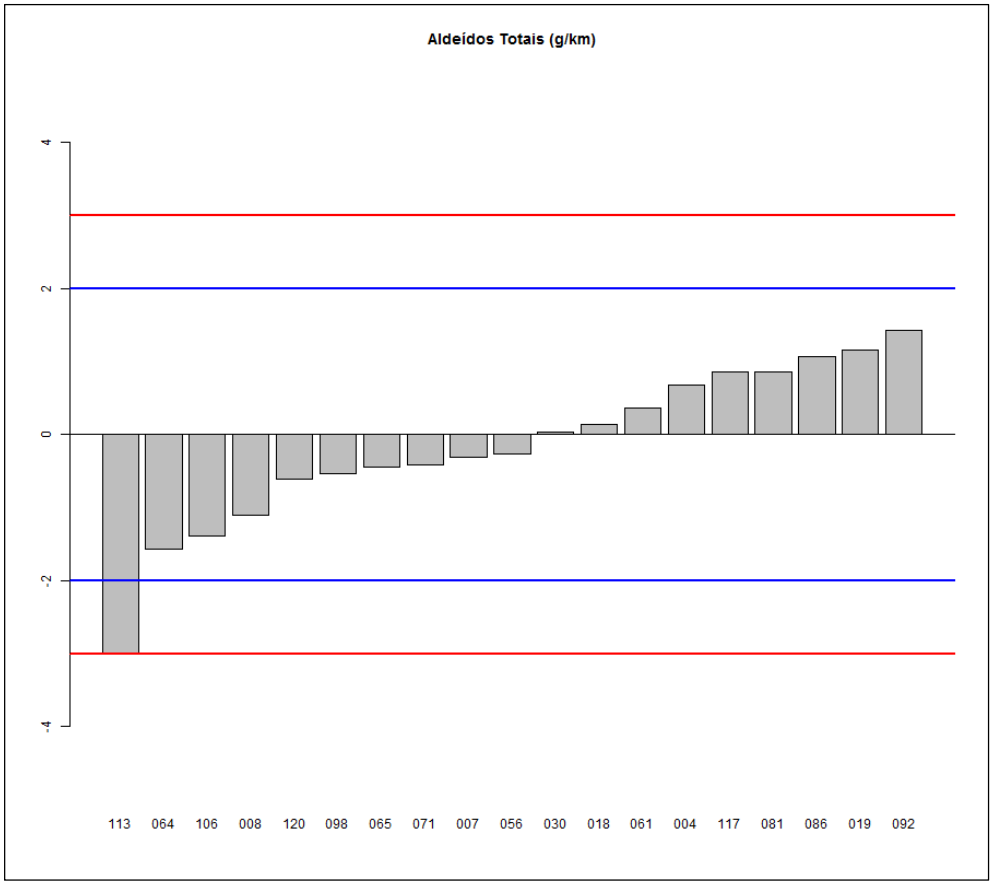

Figure 23 – z-score graph for total aldehydes measurement – urban cycle.

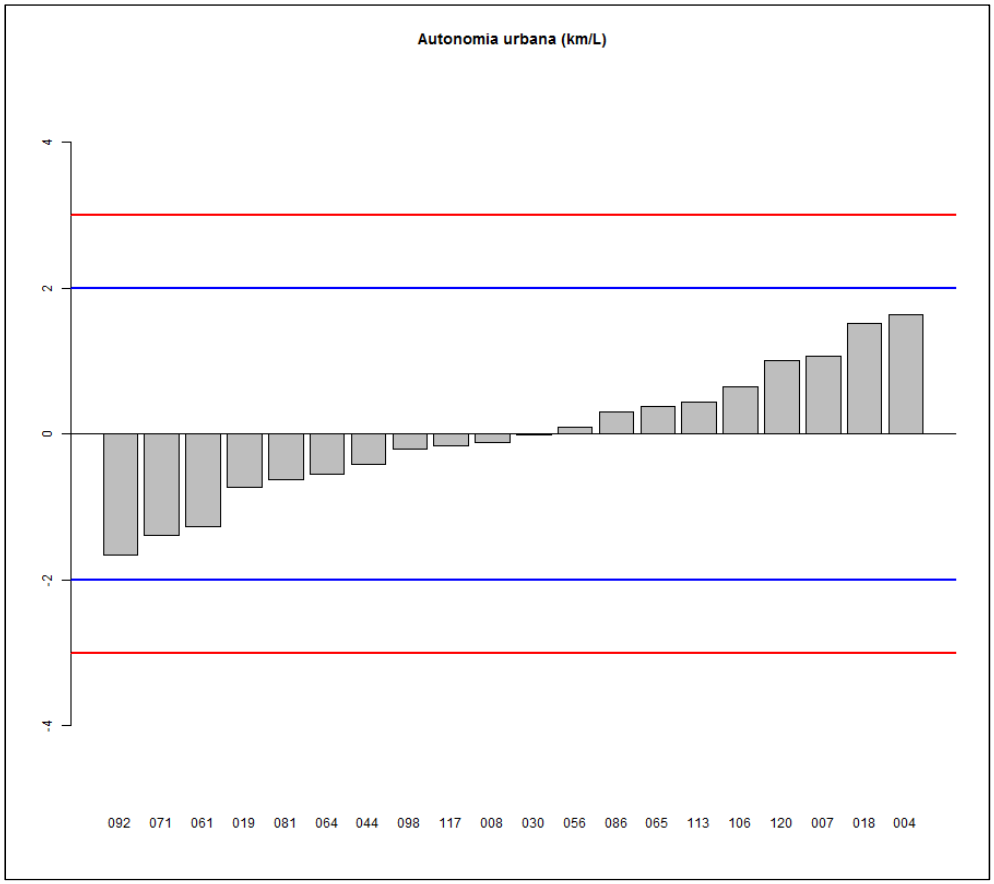

Figure 24 – z-score graph for urban autonomy measurement – urban cycle.

Through z-score graph analysis, it can be seen that:

CO (g/km): 20 participants presented satisfactory results;

CO_2 (g/km): 20 participants presented satisfactory results;

THC (g/km): 20 participants presented satisfactory results;

NO_x (g/km): 19 participants presented satisfactory results. Participant 064 presented unsatisfactory result;

NMHC (g/km): 20 participants presented satisfactory results;

Total aldehydes (g/km): 19 participants presented satisfactory results. Participant 113 presented unsatisfactory result;

Urban autonomy (km/L): 20 participants presented satisfactory results.

7.2. Evaporative Emissions

Table 8 presents the average and standard deviation of each participant, where the result is the mean value of the replicates.

Note:

Note: All decimal places were considered for calculations, but the values in the table 8 was rounded to the same number of decimal places as requested in the results form.

Table 8 – Average and standard deviation of participants for evaporative emissions parameter (g/test).

Code	Evaporative emissions		Code	Evaporative emissions	
	Average	Standard deviation		Average	Standard deviation
002	0.389	0.016	**063**	0.424	0.005
021	0.317	0.010	**080**	0.221	0.033
026	0.380	0.009	**082**	0.376	0.051
034	0.317	0.005	**094**	0.212	0.020
049	0.487	0.018	**115**	0.362	0.005
052	0.135	0.012	**116**	0.431	0.049
060	0.341	0.026	**-**	-	-

For the performance evaluation of the participants, z-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results for each parameter as assigned value and its standard deviation. Table 9 and figure 25 show these results.

Table 9 – z-score values for the evaporative emissions (g/teste) parameter.

Evaporative emissions			
Code	**z score**	**Code**	**z score**
002	0.36	**063**	0.75
021	-0.42	**080**	-1.49
026	0.30	**082**	0.22
034	-0.43	**094**	-1.59
049	1.45	**115**	0.07
052	**-2.44**	**116**	0.83
060	-0.15	-	-

* Satisfactory result
* Questionable result
* Unsatisfactory result

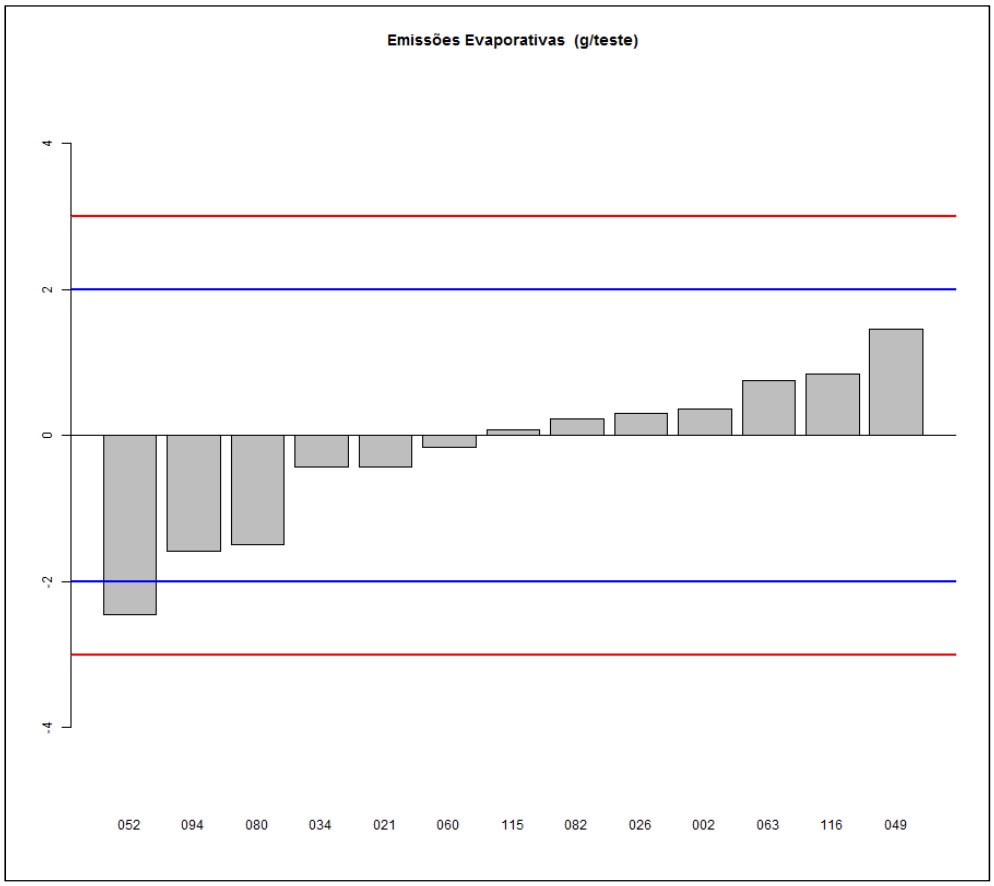

Figure 25– z-score graph for evaporative emissions (g/test) measurement.

Through z-score graph analysis, it can be seen that:

Evaporative emissions (g/test): the 12 participants presented satisfactory results. Participant 052 presented questionable result.

7.3. Road Cicle Emissions

Table 10 presents the average and standard deviations of each participant, where the result is the mean value of the replicates.

Note: All decimal places were considered for calculations, but the values in the tables 10, 11 and 12 were rounded to the same number of decimal places as requested in the results form.

Table 10 – Average and standard deviation of participants for CO, CO_2, THC, NO_x and NMHC (g/km) parameters– road cycle.

Code	CO (g/km)		CO_2 (g/km)		THC (g/km)		NO_x (g/km)		NMHC (g/km)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
001	0.559	0.096	184.3	1.3	0.013	0.000	0.038	0.002	0.011	0.000
006	0.388	0.073	184.5	3.2	0.014	0.001	0.039	0.003	0.012	0.001
009	0.530	0.043	171.4	0.4	0.010	0.000	0.030	0.005	0.010	0.000
011	0.401	0.017	181.5	0.2	0.017	0.000	0.038	0.005	0.014	0.000
013	0.533	0.118	181.0	0.6	0.012	0.000	0.027	0.000	0.010	0.000
015	0.550	0.009	192.4	2.7	0.020	0.004	0.025	0.005	0.018	0.004
020	0.389	0.036	185.4	2.2	0.011	0.001	0.018	0.002	0.009	0.001
022	0.613	0.071	182.1	0.8	0.011	0.000	0.034	0.004	0.009	0.001
031	0.361	0.040	182.0	0.6	0.012	0.000	0.027	0.005	0.010	0.000
045	0.499	0.138	196.2	0.8	0.014	0.001	0.043	0.010	0.011	0.001
047	0.437	0.017	182.8	0.3	0.015	0.003	0.037	0.007	0.012	0.002
070	0.425	0.072	184.6	0.9	0.013	0.001	0.024	0.003	0.010	0.000
073	0.564	0.084	182.7	0.6	0.011	0.001	0.028	0.002	0.010	0.001
079	0.476	0.052	186.2	0.6	0.017	0.001	0.030	0.002	0.013	0.000
084	0.537	0.024	183.2	0.5	0.013	0.000	0.033	0.004	0.011	0.001
091	0.605	0.177	185.2	5.3	0.017	0.002	0.042	0.006	0.014	0.001
095	0.467	0.128	181.5	0.9	0.013	0.000	0.027	0.002	0.011	0.000
099	0.520	0.090	180.5	0.8	0.011	0.001	0.030	0.001	0.009	0.000
103	0.486	0.081	177.8	1.2	0.013	0.001	0.024	0.003	0.011	0.001
112	0.395	0.049	183.0	0.5	0.012	0.001	0.024	0.001	0.010	0.000

Table 11 – Average and standard deviation of participants for urban autonomy (km/L), road autonomy (km/L) and combined autonomy (km/L) parameters – road cycle.

Code	Urban autonomy (km/L)		Road autonomy (km/L)		Combined autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
001	9.10	0.33	11.78	0.08	10.14	0.21
006	8.90	0.04	11.74	0.21	9.98	0.08
009	9.37	0.01	12.62	0.04	10.59	0.02
011	9.12	0.07	11.98	0.02	10.22	0.05

Code	Urban autonomy (km/L)		Road autonomy (km/L)		Combined autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
013	9.06	0.08	11.95	0.04	10.17	0.06
015	8.71	0.02	11.24	0.15	9.69	0.06
020	8.76	0.06	11.66	0.14	9.86	0.05
022	9.24	0.08	11.87	0.06	10.26	0.07
031	9.26	0.05	11.90	0.04	10.28	0.05
045	---	---	11.03	0.03	9.77	0.03
047	9.02	0.03	11.85	0.02	10.10	0.02
070	9.00	0.04	11.74	0.05	10.05	0.04
073	8.96	0.09	11.84	0.03	10.06	0.06
079	8.79	0.17	11.63	0.03	9.87	0.12
084	9.13	0.07	11.81	0.03	10.17	0.04
091	9.01	0.26	11.64	0.33	10.03	0.27
095	9.35	0.03	11.93	0.06	10.36	0.04
099	9.04	0.20	11.99	0.06	10.16	0.16
103	9.17	0.02	12.18	0.08	10.32	0.03
112	8.92	0.06	11.84	0.03	10.04	0.05

Participant 045 did not present result for urban autonomy parameter.

For the performance evaluation of the participants, z-score values were calculated, after the exclusion of the outlier results, using the robust average and robust standard deviation of the results for each parameter as assigned value and its standard deviation. Table 12 and figures 26 to 33 show these results.

Table 12 – z-score values for CO, CO_2, THC, NO_x and NMHC parameters – road cycle.

Code	CO (g/km)	CO_2 (g/km)	THC (g/km)	NO_x (g/km)	NMHC (g/km)
	z score	z score	z score	z score	z score
001	0.83	0.65	0.19	0.92	0.46
006	1.14	0.76	0.73	1.09	0.66
009	0.53	**-5.64**	-0.35	-0.71	-0.77
011	0.99	-0.71	**2.19**	0.96	**2.31**
013	0.53	-0.93	-0.49	-0.43	-0.54
015	0.72	**4.62**	**3.83**	-0.76	**4.58**
020	1.13	1.21	-1.26	-1.58	-1.18

Code	CO (g/km)	CO_2 (g/km)	THC (g/km)	NO_x (g/km)	NMHC (g/km)
	z score	z score	z score	z score	z score
022	1.45	-0.41	-0.89	0.40	-1.18
031	1.45	-0.45	-0.71	-0.46	-0.56
045	0.14	**6.49**	0.37	1.65	0.05
047	-0.57	-0.07	0.92	0.79	0.87
070	0.71	0.76	-0.35	-0.89	-0.35
073	0.88	-0.11	-0.89	-0.33	-0.56
079	0.12	1.56	**2.01**	-0.11	1.69
084	0.57	0.11	0.01	0.31	0.05
091	1.36	1.07	**2.01**	1.52	**2.11**
095	0.22	-0.71	0.19	-0.41	0.25
099	0.37	-1.18	-0.89	-0.07	-0.97
103	0.01	**-2.55**	-0.35	-0.89	-0.15
112	1.06	0.00	-0.71	-0.89	-0.56

* Satisfactory result
* Questionable result
* Unsatisfactory result

Table 13 – z-score values for urban autonomy (km/L), road autonomy (km/L) and combined autonomy (km/L) parameters – road cycle.

Code	Urban autonomy (km/L)	Road autonomy (km/L)	Combined autonomy (km/L)
	z score	z score	z score
001	0.26	-0.36	0.17
006	-0.73	-0.67	-0.71
009	1.56	**5.54**	**2.78**
011	0.34	1.06	0.64
013	0.05	0.81	0.34
015	-1.64	**-4.22**	**-2.41**
020	-1.38	-1.23	-1.40
022	0.94	0.22	0.90
031	1.01	0.43	1.01
045	---	**-5.66**	-1.93
047	-0.13	0.08	-0.02
070	-0.23	-0.67	-0.30
073	-0.43	0.01	-0.27
079	-1.27	-1.44	-1.34

Code	Urban autonomy (km/L)	Road autonomy (km/L)	Combined autonomy (km/L)
	z score	z score	z score
084	0.39	-0.15	0.36
091	-0.18	-1.37	-0.44
095	1.44	0.64	1.43
099	-0.04	1.07	0.32
103	0.60	**2.41**	1.20
112	-0.64	0.05	-0.40

* Satisfactory result
* Questionable result
* Unsatisfactory result

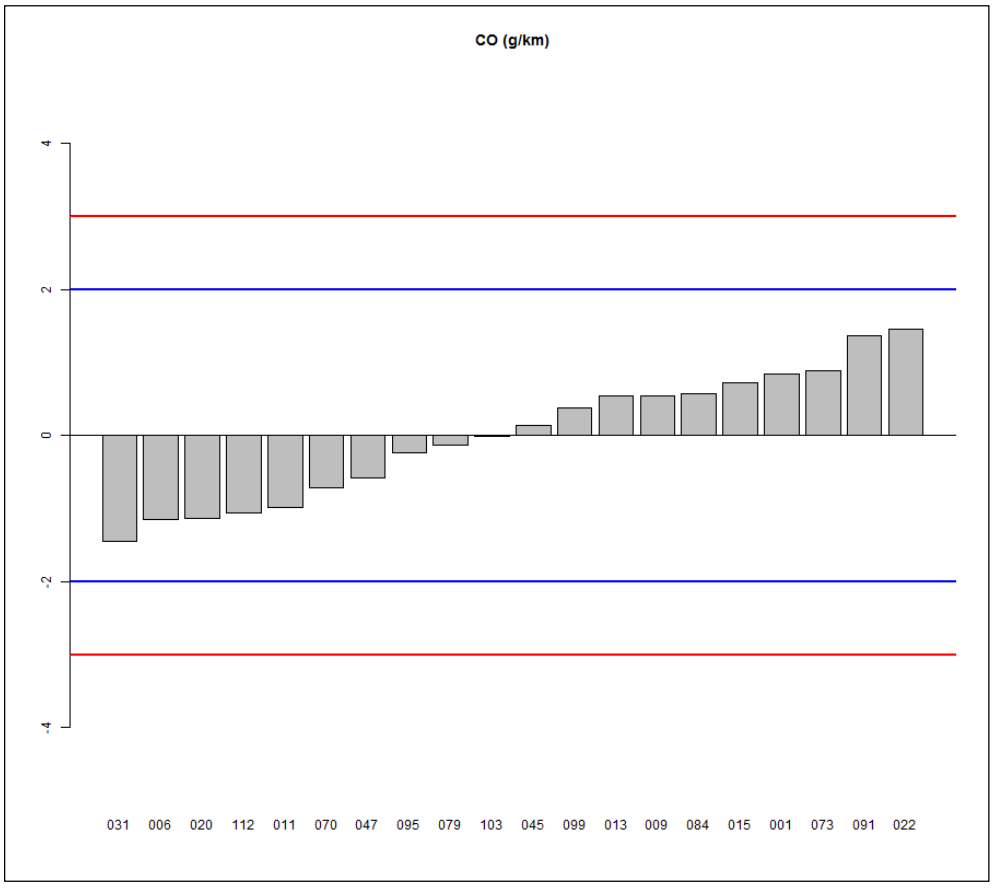

Figure 26 – z-score graph for CO measurement – road cycle.

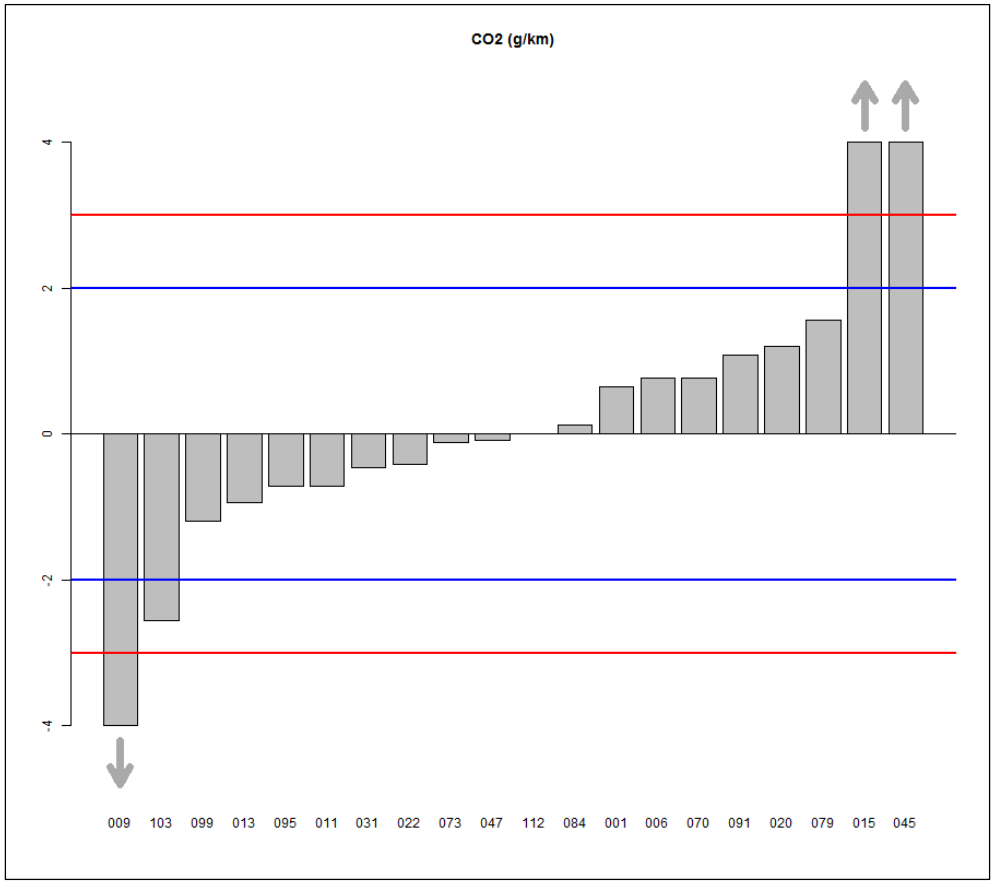

Figure 27 – z-score graph for CO_2 measurement – road cycle.

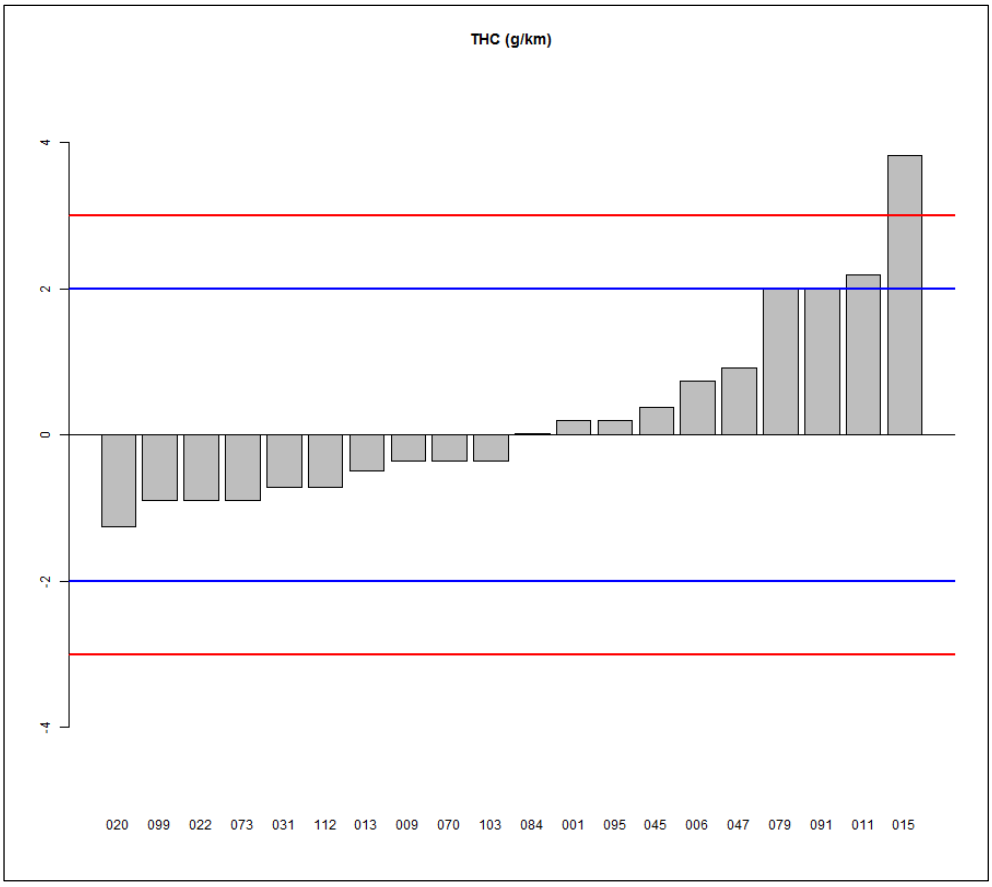

Figure 28 – z-score graph for THC measurement – road cycle.

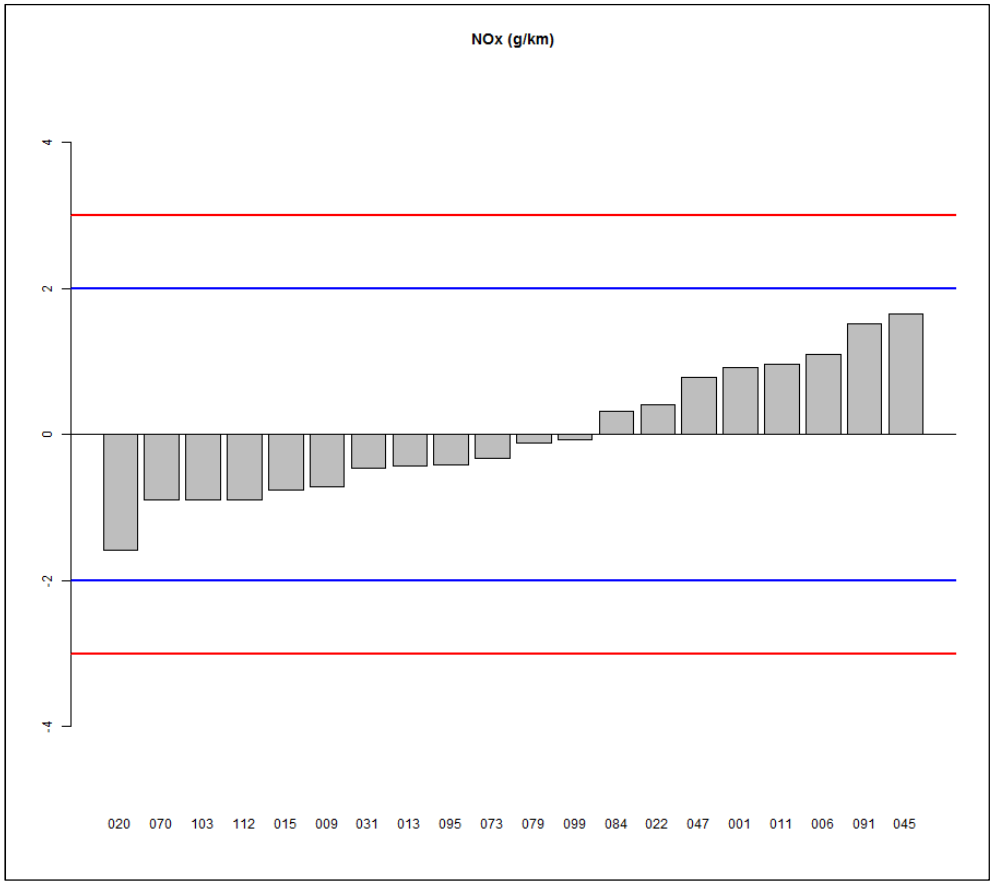

Figure 29 – z-score graph for NO_x measurement – road cycle.

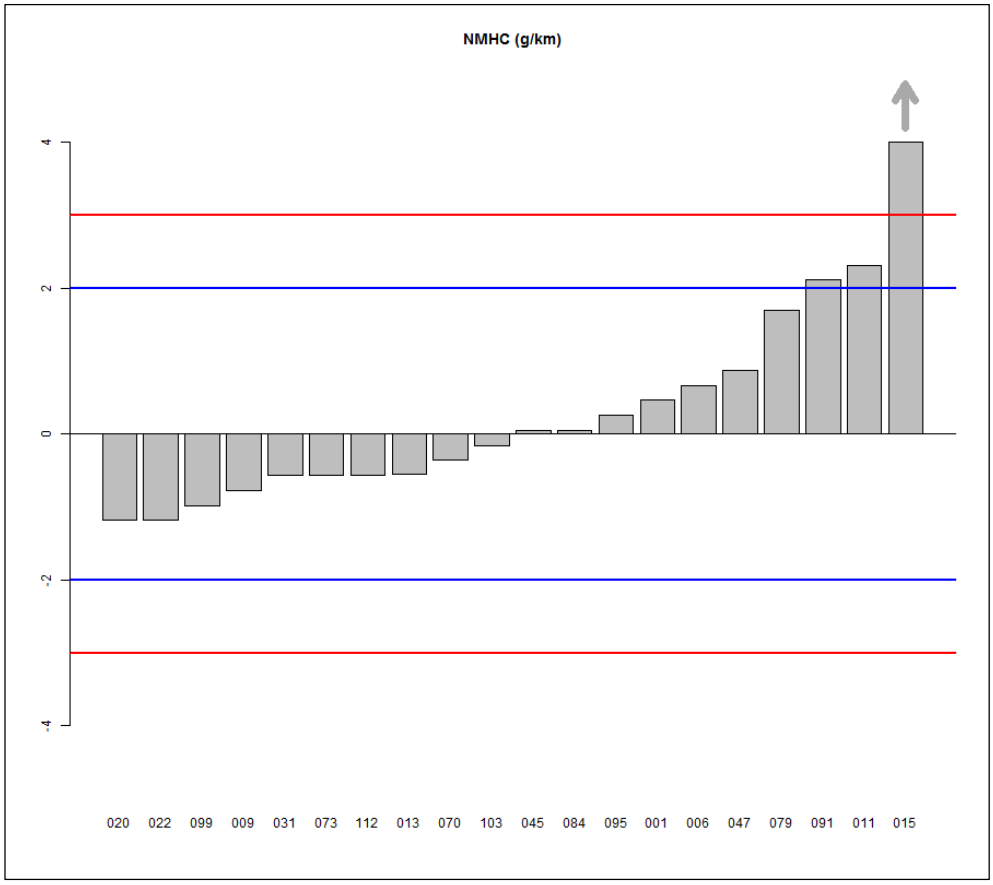

Figure 30 – z-score graph for NMHC measurement – road cycle.

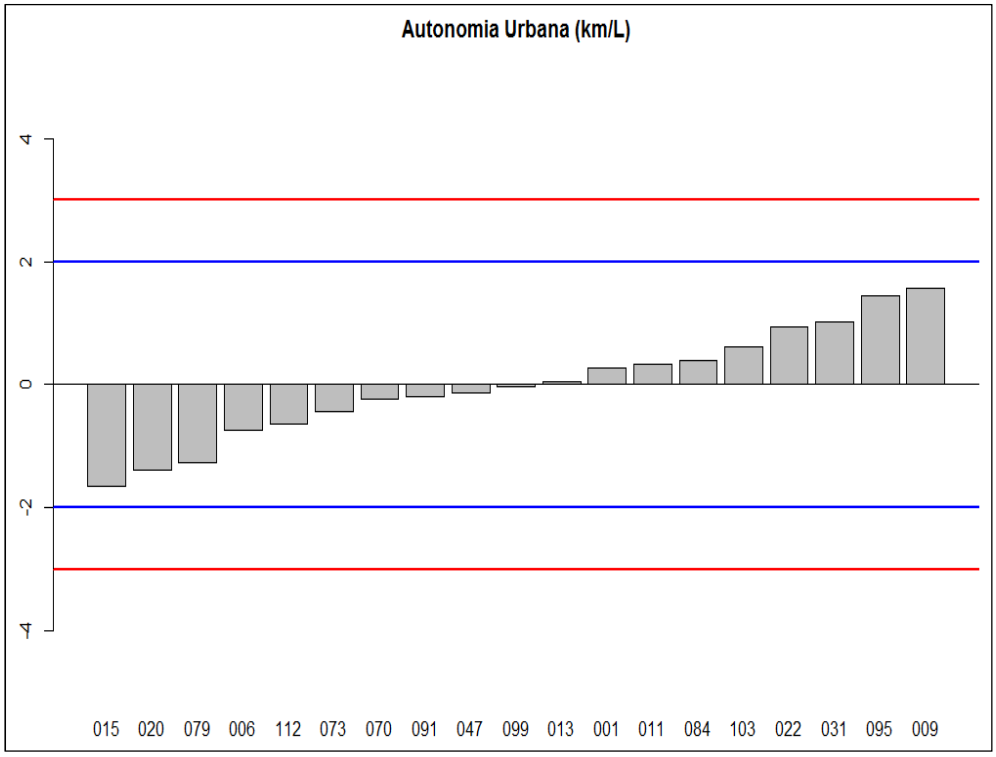

Figure 31 – z-score graph for urban autonomy measurement – road cycle.

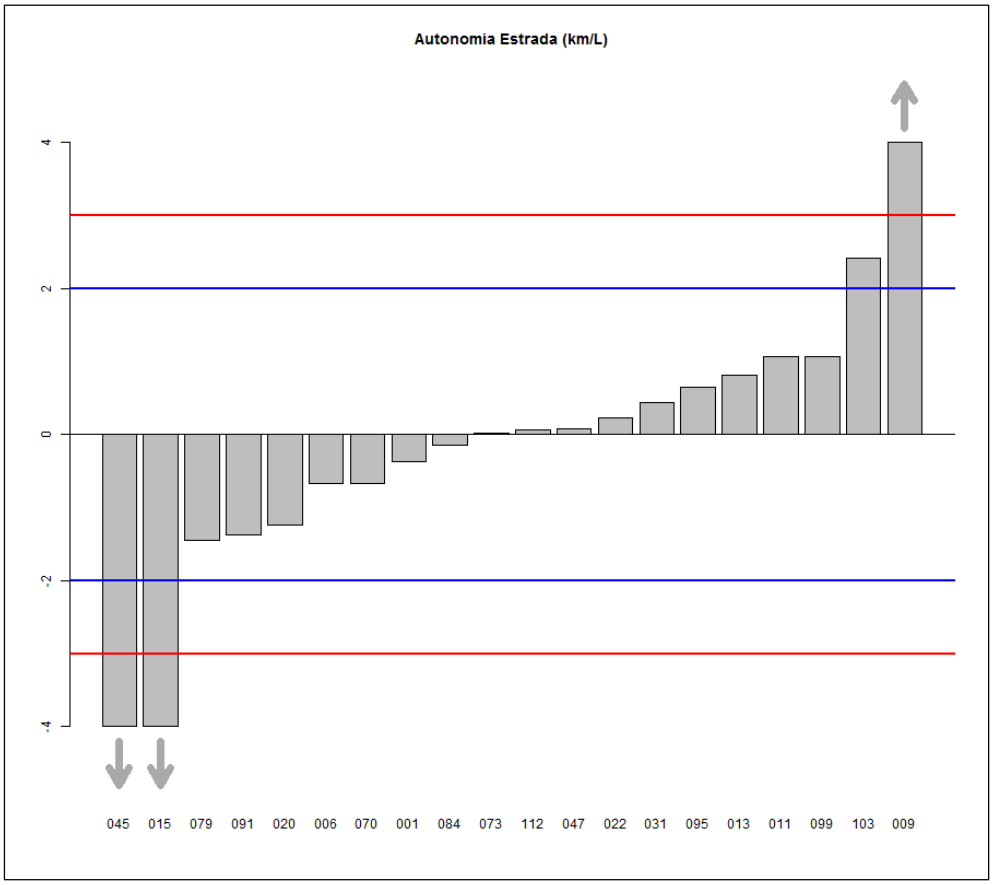

Figura 32 – z-score graph for road autonomy measurement – road cycle.

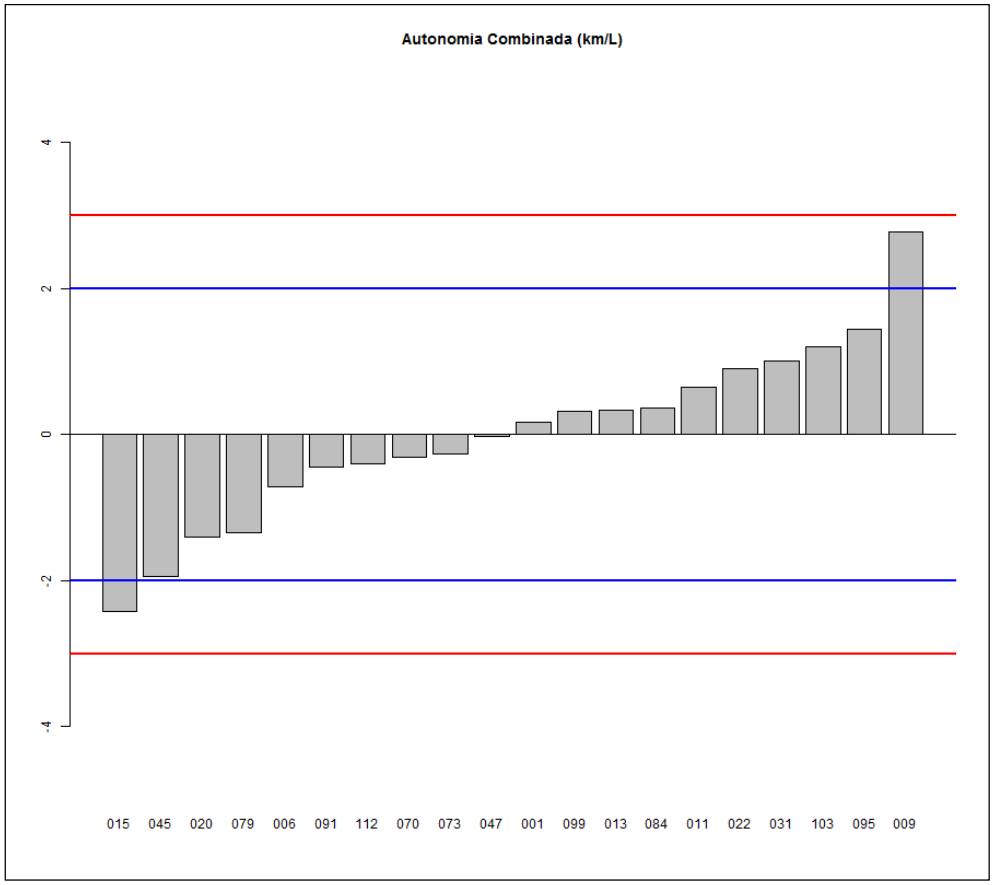

Figure 33 – z-score graph for combined autonomy measurement – road cycle.

Through z-score graph analysis, it can be seen that:

CO (g/km): 20 participants presented satisfactory results;

CO_2 (g/km): 16 participants presented satisfactory results. Participant 103 presented questionable result and participants 009, 015 and 045 presented unsatisfactory results;

THC (g/km): 16 participants presented satisfactory results. Participants 011, 079 and 091 presented questionable results and participant 015 presented unsatisfactory result;

NO_x (g/km): 20 participants presented satisfactory results;

NMHC (g/km): 17 participants presented satisfactory results. Participants 011 e 091 presented questionable results and participant 015 presented unsatisfactory result;

Urban autonomy (km/L): 19 participants presented satisfactory results.

Road autonomy (km/L): 16 participants presented satisfactory results. Participant 103 presented questionable result and participants 009, 015 and 045 presented unsatisfactory results;

Combined autonomy (km/L): 18 participants presented satisfactory results. Participants 009 and 015 presented questionable results.

8. Analysis Testimony

As established in the proficiency testing protocol, CETESB representative witnessed one of the PT three measurements at each laboratory participant and sent the results to the PT coordination. After finishing the tests, each participant sent their results to the coordination for statistical treatment.

Tables 14 to 16 show the comparison between the results sent by CETESB and those sent by the participants to PT coordination for all measurement cycles performed at the testimony day. It is worth saying that all values sent by CETESB were previously discussed with each one of the participants after the testimony.

8.1. Urban Cicle Emissions

Discrepancies were found in 3 of 400 results sent (0.75 %) for the urban cycle. Three among 20 participants of this PT round showed some discrepancy between the values sent by CETESB and those informed by the participants to the PT coordination. These discrepancies are mainly due to rounding or digitation errors by the participant when sending the results to PT coordination.

Table 14– Comparison between testimony results sent by CETESB to PT coordination and those sent by the PT participants for the urban cycle parameter.

Code	NMHC (g/km)		Total aldehydes (g/km)	
	CETESB	Lab	CETESB	Lab
030	-	-	0.00116	0.00120
106	-	-	0.00061	0.00059
065	-	-	0.00090	0.00091

8.2. Evaporative Emissions

Discrepancy was found in 1 of 39 results sent (2.5 %) for evaporative emissions. One of the 13 participants of this PT round showed some discrepancy between the values sent by CETESB and those informed by the participants to the PT coordination.

Table 15 – Comparison between testimony results sent by CETESB to PT coordination and those sent by the PT participants for the evaporative emissions parameter.

Code	Evaporative emissions	
	CETESB	Lab
082	0.315	0.320

8.3. Road Cicle Emissions

Discrepancy was found in 1 of 480 results sent (0.2 %) for road cycle. One of the 20 participants of this PT round showed only one discrepancy between the values sent by CETESB and those informed by the participant to the PT coordination, but this participant did not report any discrepant result and the discrepancy was due to the non-forwarding of the result by CETESB.

Table 16 – Comparison between testimony results sent by CETESB to PT coordination and those sent by the PT participants for the road cycle parameter.

Code	Combined autonomy (km/L)	
	CETESB	Lab
073	-	9,99

*Cetesb did not send this testimony.

9. Confidenciality

Each participant was identified by an individual code which is only known by the participant and the PT coordination. As stated on the registration form, the identification of accredited laboratories and laboratories in stage of accreditation will be forwarded for information of the General Accreditation Coordination (Cgcre). The participant received, by email, his own identification code corresponding to the participation in this PT. This code was used to identify the participant in the results registration form. The results may be used in studies and publications by Inmetro respecting the confidentiality of each participant.

As established in section 4.10.4 of ABNT ISO/IEC 17043:2011, in exceptional circumstances, a regulatory authority may require the results and the identification of the participants to the PT provider. If this occurs, the provider will notify the PT participants about this action.

10. Conclusions

Proficiency Testing Schemes in vehicle emissions is a type of study carried out only in Brazil and, considering the particular features of such study, we can conclude that the results are quite satisfactory and this initiative is very important to the industry and society along these nine rounds held in collaboration between Inmetro and AEA.

This PT round involved a large number of variables and the testimony of a regulation body (CETESB). This large numbers of variables in the vehicle emissions PT certainly have influence in the reported results. Therefore it is recommended that participants that showed questionable performance to critically evaluate their measurement methods.

Some discrepancies between the reported results during CETESB testimony and those sent to PT coordination were observed. They were digitation or round errors that did not influence the quality of the results, but these discrepancies denote a checking problem before sending the results to PT coordination. It is an opportunity to improve the data checking procedures after the analysis.

It is worth saying that the established acceptance limits were lowered in the 8th round, as those results out of Ref ± 2s limits were considered outliers. In other rounds, these results could be considered as satisfactory and they became questionable or unsatisfactory due to the new criteria. In general, the results in this 9th round continue to improve compared to the results of the previous round.

In consequence, there was an improvement in the performance of participants, considering that urban cycle had 97.8 % of satisfactory results, 0.71 % of non-correctly reported or non-measured results, 0.71 % questionable results and other 0.71 % unsatisfactory results.

For the evaporative emissions cycle 92.4 % of the reported results were considered satisfactory and 7.6 % were considered unsatisfactory.

For road cycle, 89.3 % were considered satisfactory, 5.6 % were considered questionable and 5.0 % were considered unsatisfactory.

It should be emphasized the importance of different laboratory participation in a proficiency test scheme, since it constitutes an useful tool to monitor the procedures in routine analysis and to evaluate the laboratory measurement results, enabling the improvement of the results quality and ensuring greater reliability of the measurements.

It is up to PT participant to carry out a critical analysis of the results, where the entire process and laboratory experience must be considered. Therefore, the continuous participation in a proficiency test can assure information to the laboratory about the measurement capability and it is of great importance for monitoring the validity of the results.

11. Participants

Twenty-two laboratories were registered in the 9th round of the Proficiency Testing in Vehicles Emissions, but two participants did not send their results report because of equipment problems and informed it to the PT coordination. Thus, 20 participants remained.

The list of laboratories that sent results to this PT coordination is presented in Table 17. It is important to note that the numbering of laboratories in the table only indicates the number of PT participants, under no circumstances it is associated to laboratory identification in presenting their results.

Table 17– Participants.

	Instituição
1.	AVL SOUTH AMERICA LTDA
2.	CAOA Montadora de Veículos Centro de Pesquisas e Eficiência Energética
3.	Continental Brasil Indústria Automotiva Ltda. Laboratório de Emissões Veiculares – Centro Tecnológico “Geraldo Negri Rangel”
4.	FCA Fiat Chrysler Automóveis Brasil Ltda. Laboratório de Emissões e Consumo
5.	FEV America Latina Ltda.
6.	Ford Motor Company Brasil Ltda. Laboratório de Emissões do Campo de Provas de Tatuí
7.	General Motors do Brasil Ltda. Laboratório de Emissões do Campo de Provas de Cruz Alta
8.	General Motors do Brasil Ltda. Laboratório de Emissões Veiculares – Global Propulsion Systems
9.	Honda Automóveis do Brasil Ltda. Laboratório de Emissões Honda Automóveis
10.	Hyundai Motor Brasil Montadora de Automóveis Ltda. Centro de Pesquisa e Desenvolvimento HMB
11.	Instituto de Tecnologia para o Desenvolvimento – Institutos LACTEC LEME – Laboratório de Emissões Veiculares
12.	Magneti Marelli Sistemas Automotivos Indústria e Comércio Ltda.
13.	Petróleo Brasileiro S.A. Laboratório de Ensaios Veiculares - CENPES
14.	Peugeot Citroen do Brasil Automóveis Ltda.
15.	Renault do Brasil S/A LEV – Laboratório de Emissões Veiculares
16.	Robert Bosch Ltda. Laboratório de emissões veiculares – Robert Bosch
17	SENAI – Serviço Nacional de Aprendizagem Industrial LEV – CIT SENAI FIEMG Campus CETEC
18	Toyota do Brasil Ltda. Laboratório de Emissões Indaiatuba

	Instituição
19	Umicore Brasil Ltda. Laboratório de Emissões Veiculares - Umicore
20	Volkswagen do Brasil Ltda. Laboratório de Emissões Veiculares da Volkswagen do Brasil Ltda.

Total participants: 20 laboratories.

12. References

- ABNT NBR ISO/IEC 17025:2005: Requisitos gerais para a competência de laboratórios de ensaio e calibração.
- ABNT NBR ISO/IEC 17043:2011: Avaliação de Conformidade – Requisitos Gerais para ensaios de proficiência.
- ISO 13528:2015 (E), *"Statistical methods for use in proficiency testing by interlaboratory comparisons"*.
- Vocabulário Internacional de Metrologia: conceitos fundamentais e gerais e termos associados (VIM 2012). 1ª Edição Luso–Brasileira.

13. Review History

Corrections due to results of urban autonomy parameter in road cycle not sent by participant 045.

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