Final Report of the Proficiency Testing in Vehicles Emissions 7th Round

Inmetro
Instituto Nacional de Metrologia, Qualidade e Tecnologia

PEP-Inmetro

Programa de Ensaios de Proficiência do Inmetro

PROFICIENCY TESTING IN VEHICLES EMISSIONS - 7TH ROUND

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FINAL REPORT N°006/15

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SUMÁRIO

1. Introduction

The problem of air pollution is a serious threat to human health, decreasing their quality of life. The 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, providing then 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 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 evaluated: (CO, CO_2, THC, NO_x, NMHC and Total aldehydes (formaldehyde + acetaldehyde)) in g/km, evaporative emissions hot phase in g/test and urban autonomy and road autonomy in km/L. Nine parameters were evaluated with participation of sixteen laboratories, the same number of 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 Toyota having the following characteristics: Model Corolla XEi year 2014, chassis 9BRBDWHE4F0200011, engine 2.0, CVT transmission, Flex Fuel, equivalent inertia of 1474 kg. The test vehicle was correlated with the purge system of the blow-by gas canister and exhaust, since there was, in this edition, evaporative emission measurement. Each participating laboratory should use its own fuel (Gasool A22 as standard ABNT NBR 8689).

2.2. Methodology

The standard methods used for emission measurements were ABNT NBR 6601, 7024, 12026 and 11481. The tests defined by these standard methods are complementary and were carried out simultaneously. The values of deceleration times (coast down) were provided by the CETESB emission laboratory to the participants in order to adjust their dynamometers and reproduce the deceleration times. The laboratories should replicate the deceleration times in the dynamometer informed of vehicular emission by CETESB.

The tests defined by ABNT NBR 11481 was performed only by laboratories that have appropriate equipment.

The laboratories were instructed to start testing at 25 ℃ temperature in order to minimize the effect s of the cold start results.

3. Test Item Conditions

The results of Toyota emission laboratory performed in the beginning, in the middle and in the end of the round were used to statistically evaluate the integrity of the test item. For the 09 analyzed parameters (CO, CO_2, THC, NO_x, NMHC, Total Aldehydes, evaporative emissions hot phase, Urban Autonomy and Road Autonomy), the results were the same, with *p-value* greater than 0.05. Therefore it can be stated that there is no statistically significant difference between the means at a confidence level of 95%, the sample data can be regarded as arising from the same population. Thus, the vehicle remained intact during the course of this Proficiency Test.

Due to the confidentiality of the results, as Toyota participates in the PT, these results are not shown.

4. Evaluation of Performance

4.1. *Z*-score

For performance evaluation of the individual participant results, one of the criteria described in ABNT NBR ISO/IEC 17043:2011 was carried out, the *z*-score (measure of the relative distance of the participant measurement result from the assigned value of the PT), that was calculated according to the equation 1.

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

Where:

x_i = is the average result of each participant

X = is the assigned value for this PT;

$\hat{\sigma}$ = is the standard deviation for the PT, which was calculated in this round based on ISO 13528:2005, a robust standard deviation based on the results of the participants.

The interpretations of the *z*-score are presented as follows:

|z| ≤ 2,0 - Indicates “satisfactory” performance and generates no signal;

2,0 < |z| <3,0 - Indicates “questionable” performance and generates a warning signal;

|z| ≥ 3,0 - Indicates “unsatisfactory” performance and generates an action signal.

5. Assigned Values

According to the available procedures, to establish assigned values in ABNT NBR ISO/IEC 17043:2011, the assigned values of this PT were calculated using statistical methods according to ISO 13528:2005, by consensus values of participants.

ISO 13528: 2005 describes the robust analysis involving the use of the “A” estimation algorithm for the calculation of the assigned value and the standard deviation. Robust statistical techniques are used to minimize the influence that extreme results can have on the average and standard deviation. Therefore, the coordination of this PT adopted the following approach: The assigned value derived from the calculation of robust statistics presented in section 5.6 of the ISO 13528: 2005, which is a specific standard statistical method for use in a PT by interlaboratory comparisons.

Initially, all objects analysis values (values sent by the participants) were placed in ascending order. The following, values of robust average and robust standard deviation of these data by (x^*) and (s^*) were denoted. The initial values of (x^*) and (s^*) were calculated according to the following equations:

$$x^* = median\ of\ x_i \tag{2}$$

$$s^* = 1{,}483 \times median\ \left|x_i - x^*\right| \tag{3}$$

The values of (x^*) e (s^*) were updated as follows:

$$\delta = 1{,}5 s^* \tag{4}$$

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

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

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

$$x^* = \sum x_i^* \ / \ p \tag{6}$$

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

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 table below presents the average values for robust average calculation (assigned value) and robust standard deviation for each parameter of the PT.

Table 01: Assigned Values and standard deviation of the PT.

Parameter	Assigned Value	Standard Deviation
CO (g/km)	0,312	0,068
CO2(g/km)	167,1	4,3
THC (g/km)	0,036	0,006
NOx (g/km)	0,010	0,002
NMHC (g/km)	0,033	0,005
Total aldehydes (g/km)	0,0012	0,0004
Urban autonomy (km/L)	12,96	0,35
Road autonomy (km/L)	17,63	0,55
Evaporative emissions hot phase (g/test)	0,21	0,08

6. Dispersion Results

Figures 01 to 09 presents graphically the means and standard deviations of the results reported by the laboratories for each analyzed parameter.

The assigned value is represented by a continuous line and each laboratory is identified only by the last number of its identification code. Dotted lines are representations of Ref ± 1s and ± 2s, where "ref" is the assigned value (robust average) and "s" is the robust standard deviation.

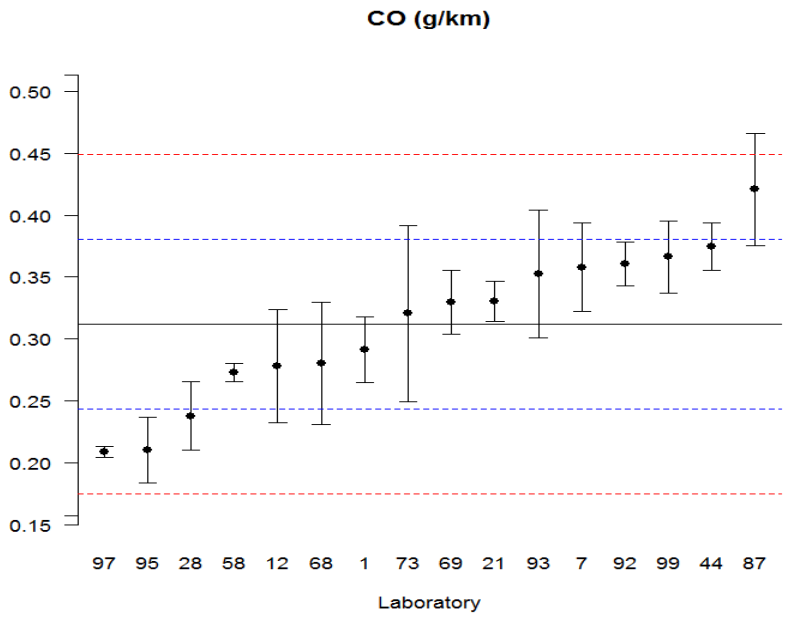

Figure 01 – Scatter plot of the results for CO determination

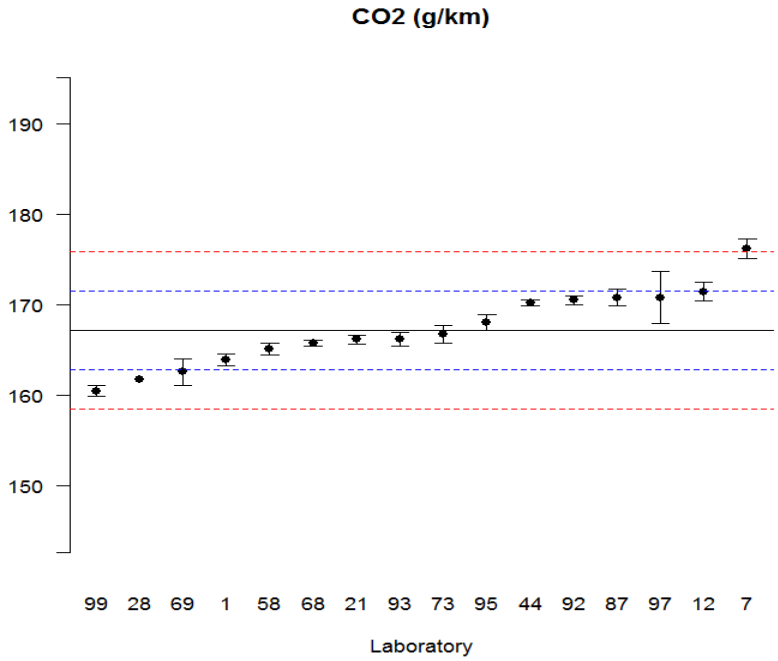

Figure 02 – Scatter plot of the results for CO_2 determination

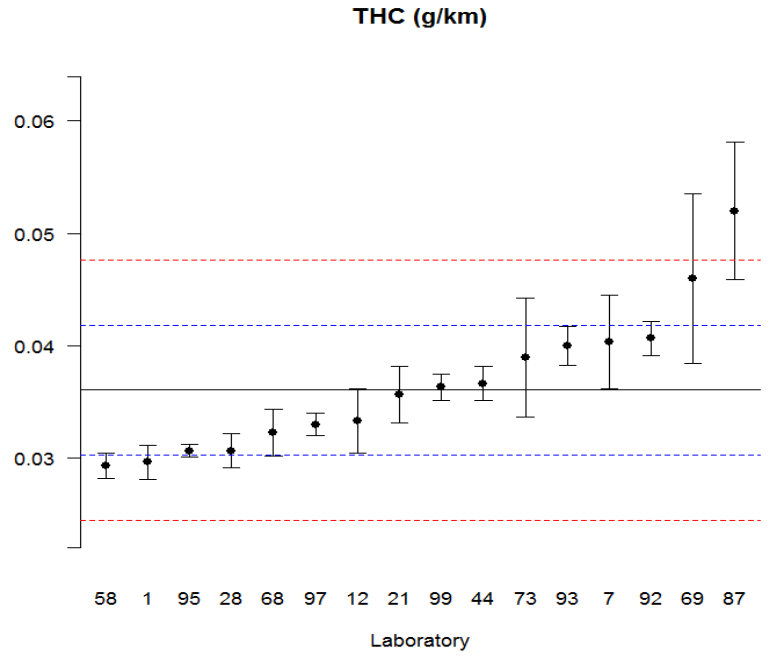

Figure 03 – Scatter plot of the results for THC determination

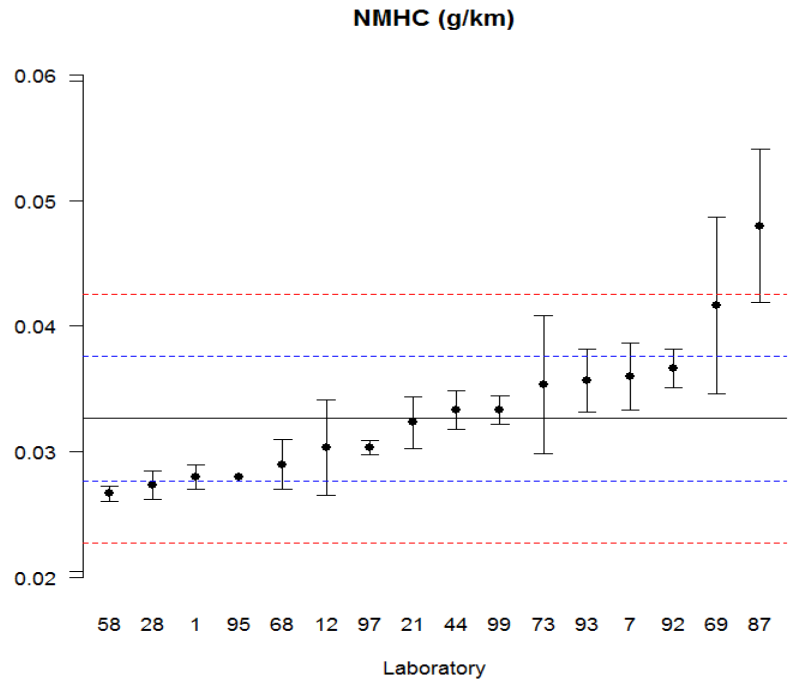

Figure 04 – Scatter plot of the results for NMHC determination

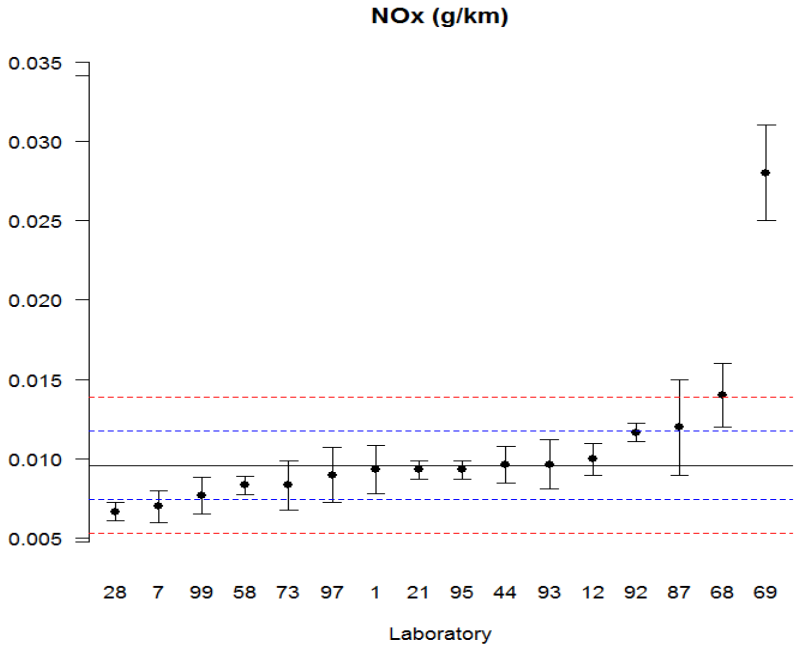

Figure 05 – Scatter plot of the results for NO_x determination

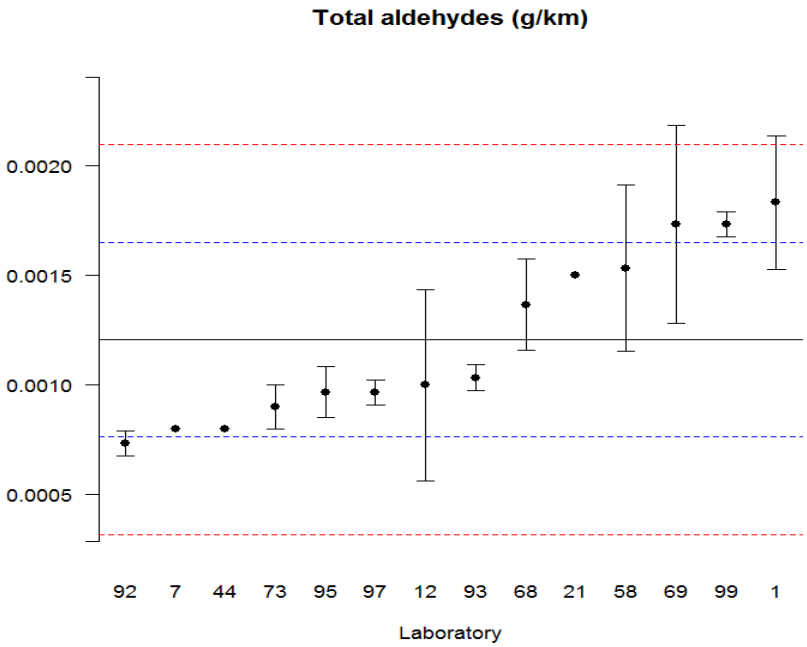

Figure 06 – Scatter plot of the results for Total Aldehydes determination

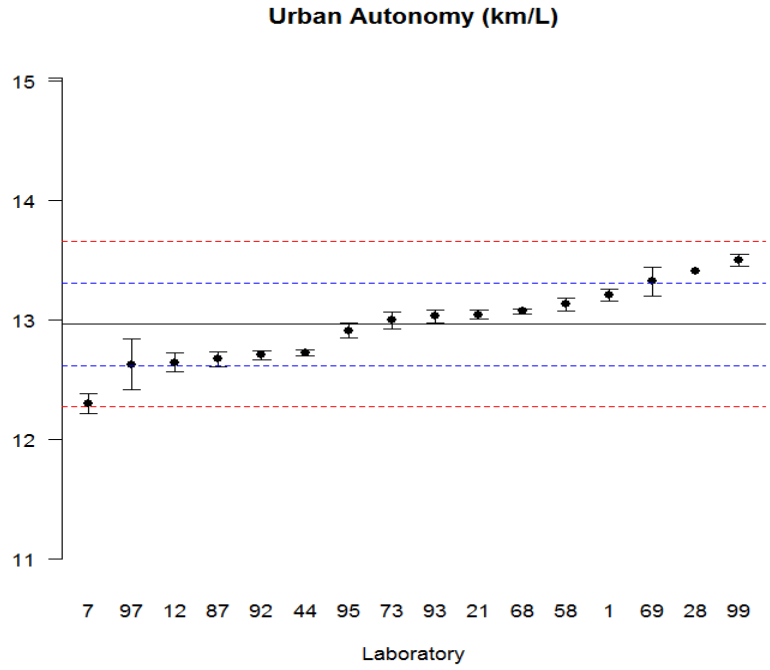

Figure 07 – Scatter plot of the results for Urban Autonomy determination

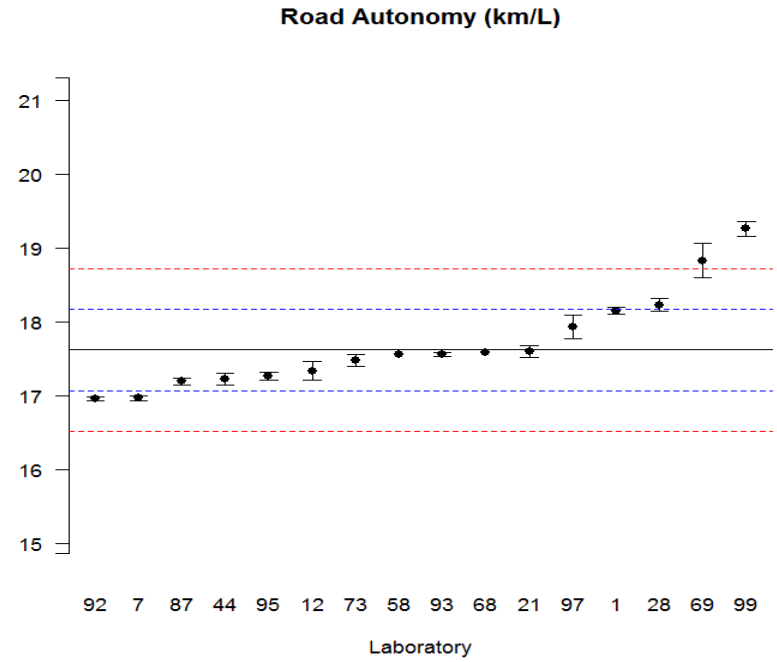

Figure 08 – Scatter plot of the results for Road Autonomy determination

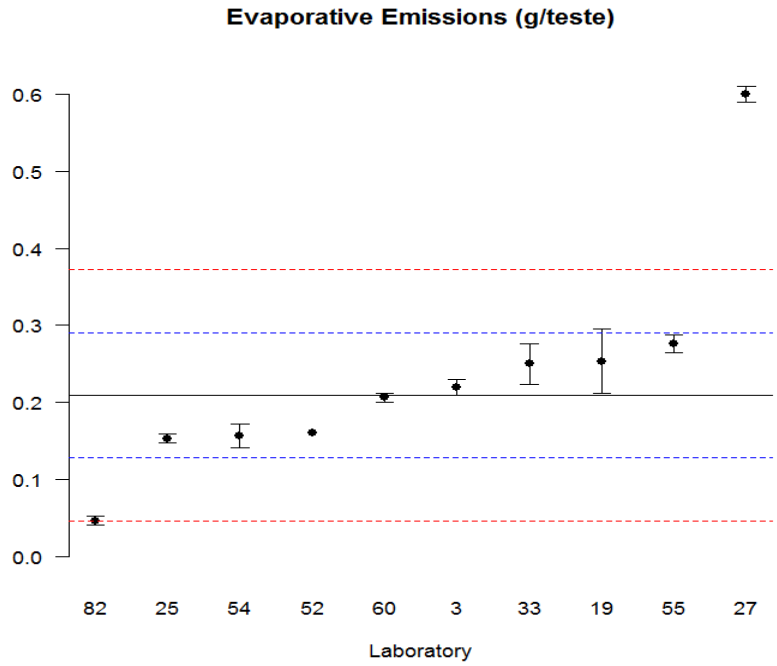

Figura 09 – Scatter plot of the results for Evaporative emissions hot phase

Through the graphs, it can be seen that:

- CO (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 97, 95, 28 and 87 presented results between the range of Ref ± 2*s.* The participant 73 had the highest standard deviation for this parameter.
- CO_2 (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 99, 28, and 69 presented results between the range of Ref ± 2*s.* Only the participant 7 had a result outside the range of Ref ± 2*s* and had the highest average for this parameter.

- THC (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 58, 01, and 69 presented results between the range of Ref ± 2*s.* Only the participant 87 had a result outside the range Ref ± 2*s.*
- NMHC (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 58, 28, and 69 presented results between the range of Ref ± 2*s.* Only the participant 87 had a result outside the range of Ref ± 2*s.*
- NO_x (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 28, 07, and 87 presented results between the range of Ref ± 2*s.* The participants 68 e 69 presented results outside the range of Ref ± 2*s.* The participant 69 presented the dispersed average measurements comparing to the other participants.
- Total Aldehydes (g/km): The most participants presented results between the range of Ref ± 1*s* and the participants 92, 69, 99 and 01 presented results between the range of Ref ± 2*s.*
- Urban Autonomy (km/L): The most participants presented results between the range of Ref ± 1*s* and the participants 07, 69, 28 and 99 presented results between the range of Ref ± 2*s.* The participant 97 presented the dispersed standard deviation comparing to the other participants.
- Road Autonomy (km/L): The most participants presented results between the range of Ref ± 1*s* and the participants 92, 07, and 28 presented results between the range of Ref ± 2*s.* The participants 69 and 99 had a result outside the range of Ref ± 2*s.*
- Evaporative emissions hot phase (g/test): The most participants presented results between the range of Ref ± 1*s.* Only the participant 82 had a result between the range of Ref ± 2*s* and the participant 27 had a result outside the range of Ref ± 2*s* had the highest average for this parameter.

7. Laboratories' Results

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

The tables 02 to 04 show the averages and standard deviations for each participant, where the result is the average value of the replicates.

Note: It was considered all the decimal places for calculations, but the values in the tables below were rounded to the same number of decimal places as requested results form.

Table 02 – Average and standard deviation of the participants for the parameters CO, CO_2, THC, NMHC and NO_X (g/km)

Labs' Code	CO (g/km)		CO_2 (g/km)		THC (g/km)		NMHC (g/km)		NO_X (g/km)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
01	0,292	0,027	163,9	0,6	0,030	0,002	0,028	0,001	0,009	0,002
07	0,358	0,036	176,2	1,1	0,040	0,004	0,036	0,003	0,007	0,001
12	0,278	0,045	171,4	1,0	0,033	0,003	0,030	0,004	0,010	0,001
21	0,331	0,016	166,1	0,5	0,036	0,003	0,032	0,002	0,009	0,001
28	0,238	0,028	161,7	0,1	0,031	0,002	0,027	0,001	0,007	0,001

Labs' Code	CO (g/km)		CO_2 (g/km)		THC (g/km)		NMHC (g/km)		NO_X (g/km)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
44	0,375	0,019	170,2	0,4	0,037	0,002	0,033	0,002	0,010	0,001
58	0,273	0,008	165,1	0,7	0,029	0,001	0,027	0,001	0,008	0,001
68	0,280	0,049	165,7	0,3	0,032	0,002	0,029	0,002	0,014	0,002
69	0,330	0,026	162,6	1,5	0,046	0,008	0,042	0,007	0,028	0,003
73	0,321	0,071	166,7	1,0	0,039	0,005	0,035	0,006	0,008	0,002
87	0,421	0,045	170,8	0,9	0,052	0,006	0,048	0,006	0,012	0,003
92	0,361	0,018	170,5	0,5	0,041	0,002	0,037	0,002	0,012	0,001
93	0,353	0,052	166,2	0,8	0,040	0,002	0,036	0,003	0,010	0,002
95	0,211	0,027	168,0	0,9	0,031	0,001	0,028	0,000	0,009	0,001
97	0,209	0,004	170,8	2,9	0,033	0,001	0,030	0,001	0,009	0,002
99	0,366	0,029	160,5	0,6	0,036	0,001	0,033	0,001	0,008	0,001

Table 03 – Average and standard deviation of the participants for the parameters Total Aldehydes (g/km) and Urban Autonomy (km/L) and Road Autonomy (km/L)

Labs' Code	Total Aldehydes (g/km)		Urban Autonomy (km/L)		Road Autonomy (km/L)	
	Average	Standard deviation	Average	Standard deviation	Average	Standard deviation
01	0,0018	0,0003	13,21	0,05	18,16	0,05
07	0,0008	0,0000	12,30	0,08	16,97	0,04
12	0,0010	0,0004	12,64	0,08	17,34	0,13
21	0,0015	0,0000	13,04	0,04	17,60	0,08
28	NM	-	13,41	0,01	18,24	0,08
44	0,0008	0,0000	12,72	0,03	17,23	0,08
58	0,0015	0,0004	13,13	0,06	17,56	0,02
68	0,0014	0,0002	13,07	0,02	17,59	0,02
69	0,0017	0,0005	13,32	0,12	18,84	0,23
73	0,0009	0,0001	13,00	0,07	17,49	0,08
87	NM	-	12,67	0,06	17,20	0,05
92	0,0007	0,0001	12,70	0,04	16,97	0,02
93	0,0010	0,0001	13,03	0,06	17,56	0,03
95	0,0010	0,0001	12,91	0,07	17,27	0,06
97	0,0010	0,0001	12,63	0,21	17,93	0,16
99	0,0017	0,0001	13,50	0,05	19,27	0,10

NM - Not Measured

Table 04 – Average and standard deviation of the participants for the parameter Evaporative Emissions (g/test) hot phase

Labs' Code	Evaporative emissions (g/test)	
	Average	Standard deviation
03	0,22	0,01
19	0,25	0,04
25	0,15	0,01
27	0,60	0,01
33	0,25	0,03

Labs' Code	Evaporative emissions (g/test)	
	Average	Standard deviation
52	0,16	0,00
54	0,16	0,02
55	0,28	0,01
60	0,21	0,01
82	0,05	0,01

For the performance evaluation of the participants, *z*-score values were calculated, using the robust average and robust standard deviation of the results for each parameter as assigned value and its standard deviation. Tables 05 and 06 and figures 10 to 18 show these results.

Table 05 – *z*-score values for the parameter CO, CO_2, THC, NMHC and NO_X

CO (g/km)		CO_2 (g/km)		THC (g/km)		NMHC (g/km)		NO_X (g/km)	
Lab	***z* scores**	**Lab**	***z* scores**	**Lab**	***z* scores**	**Lab**	***z* scores**	**Lab**	***z* scores**
01	-0,29	**01**	-0,74	**01**	-1,11	**01**	-0,94	**01**	-0,13
07	0,67	**07**	**2,08**	**07**	0,74	**07**	0,67	**07**	-1,21
12	-0,49	**12**	0,99	**12**	-0,47	**12**	-0,47	**12**	0,18
21	0,28	**21**	-0,23	**21**	-0,07	**21**	-0,07	**21**	-0,13
28	-1,08	**28**	-1,25	**28**	-0,94	**28**	-1,07	**28**	-1,37
44	0,92	**44**	0,70	**44**	0,10	**44**	0,14	**44**	0,03
58	-0,57	**58**	-0,47	**58**	-1,17	**58**	-1,21	**58**	-0,59
68	-0,46	**68**	-0,32	**68**	-0,65	**68**	-0,74	**68**	**2,05**
69	0,27	**69**	-1,05	**69**	1,72	**69**	1,82	**69**	**8,56**
73	0,13	**73**	-0,10	**73**	0,51	**73**	0,54	**73**	-0,59
87	1,59	**87**	0,84	**87**	**2,76**	**87**	**3,10**	**87**	1,12
92	0,71	**92**	0,78	**92**	0,80	**92**	0,81	**92**	0,96
93	0,60	**93**	-0,22	**93**	0,68	**93**	0,61	**93**	0,03
95	-1,48	**95**	0,21	**95**	-0,94	**95**	-0,94	**95**	-0,13
97	-1,50	**97**	0,84	**97**	-0,53	**97**	-0,47	**97**	-0,28
99	0,80	**99**	-1,53	**99**	0,05	**99**	0,14	**99**	-0,90
Are highlighted in blue questionable values and in red unsatisfactory values.									

Table 06 – *z*-score values for the parameter total aldehydes, urban autonomy, road autonomy and evaporative emissions

Total Aldehydes (g/km)		Urban Autonomy (km/L)		Road Autonomy (km/L)		Evaporative Emissions (g/test)	
Lab	**Índice *z***	**Lab**	**Índice *z***	**Lab**	**Índice *z***	**Lab**	**Índice *z***
01	1,40	**01**	0,70	**01**	0,96	**03**	0,13
07	-0,92	**07**	-1,91	**07**	-1,19	**19**	0,54
12	-0,47	**12**	-0,92	**12**	-0,52	**25**	-0,69
21	0,66	**21**	0,23	**21**	-0,04	**27**	**4,80**
28	NM	**28**	1,28	**28**	1,10	**33**	0,50
44	-0,92	**44**	-0,69	**44**	-0,71	**52**	-0,61
58	0,73	**58**	0,48	**58**	-0,12	**54**	-0,65
68	0,36	**68**	0,31	**68**	-0,06	**55**	0,82
69	1,18	**69**	1,03	**69**	**2,19**	**60**	-0,04
73	-0,69	**73**	0,10	**73**	-0,25	**82**	-2,00
87	NM	**87**	-0,84	**87**	-0,77		

Total Aldehydes (g/km)		Urban Autonomy (km/L)		Road Autonomy (km/L)		Evaporative Emissions (g/test)
92	-1,07	**92**	-0,75	**92**	-1,20	
93	-0,39	**93**	0,19	**93**	-0,12	
95	-0,54	**95**	-0,15	**95**	-0,64	
97	-0,54	**97**	-0,97	**97**	0,55	
99	1,18	**99**	1,54	**99**	**2,98**	
Are highlighted in blue questionable values and in red unsatisfactory values. NM = Not Measured						

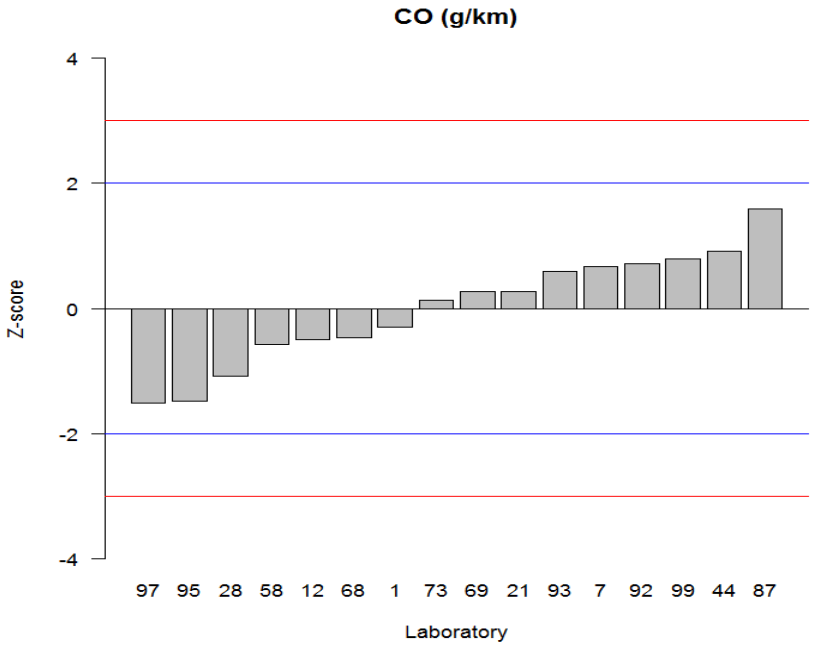

Figure 10 – *z*-score graph for CO measurement

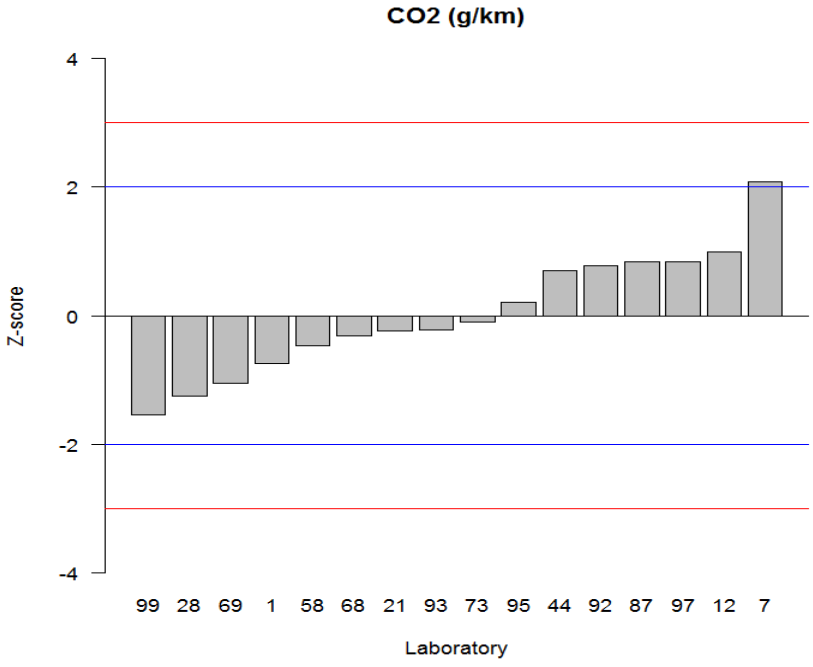

Figure 11 – *z*-score graph for CO_2 measurement

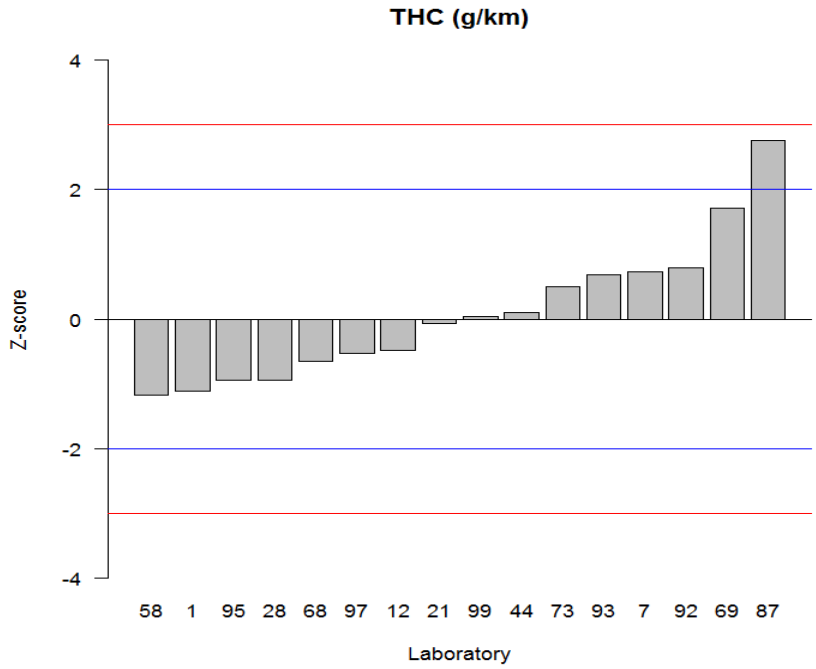

Figure 12 – *z*-score graph for THC measurement

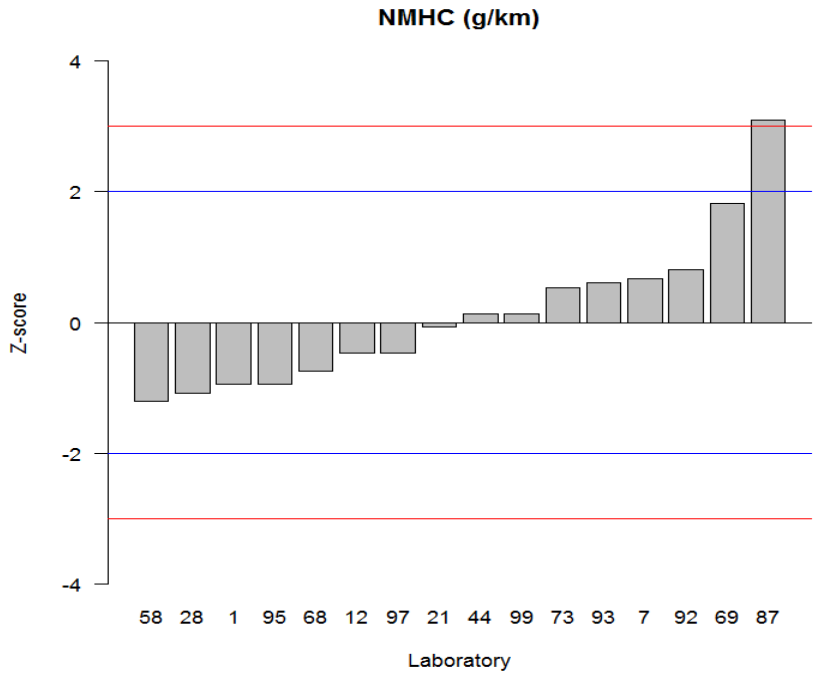

Figure 13 – *z*-score graph for NMHC measurement

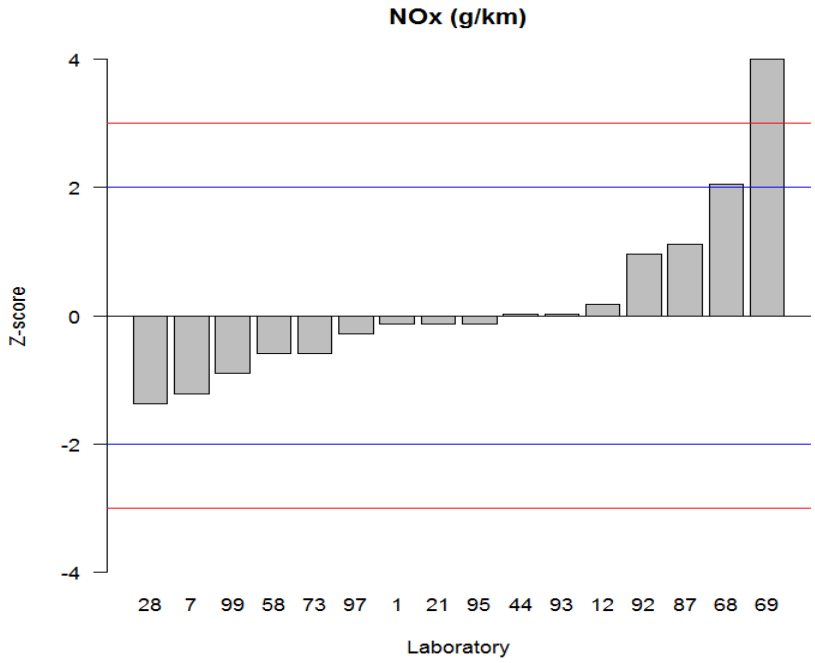

Figure 14 – *z*-score graph of for NO_x measurement

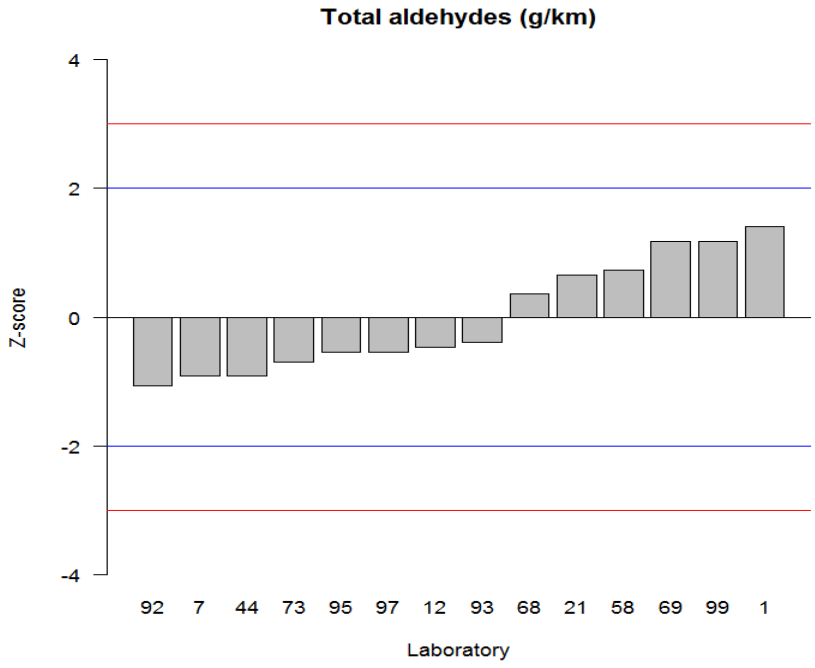

Figure 15 – *z*-score graph for Total Aldheydes measurement

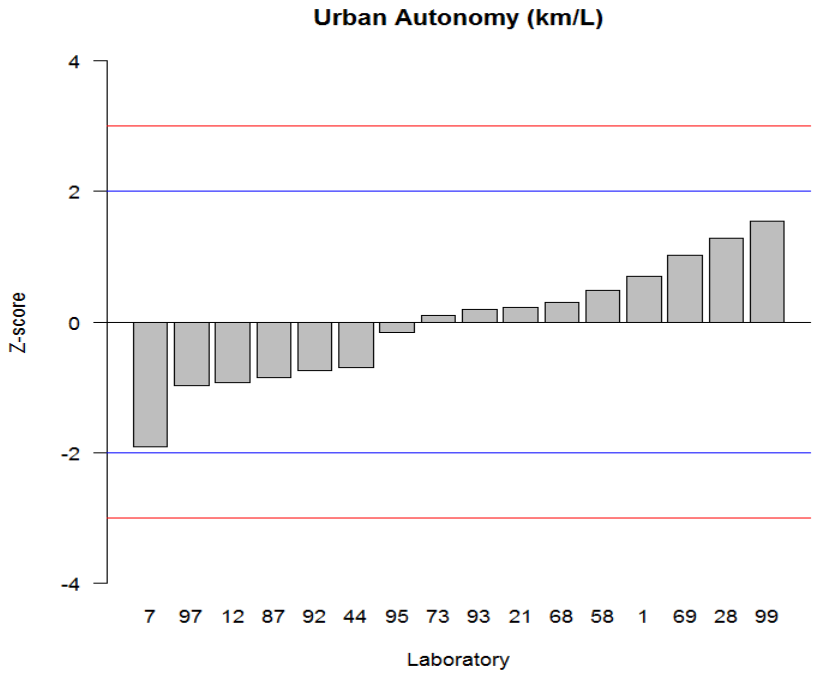

Figure 16 – *z*-score graph for Urban Autonomy measurement

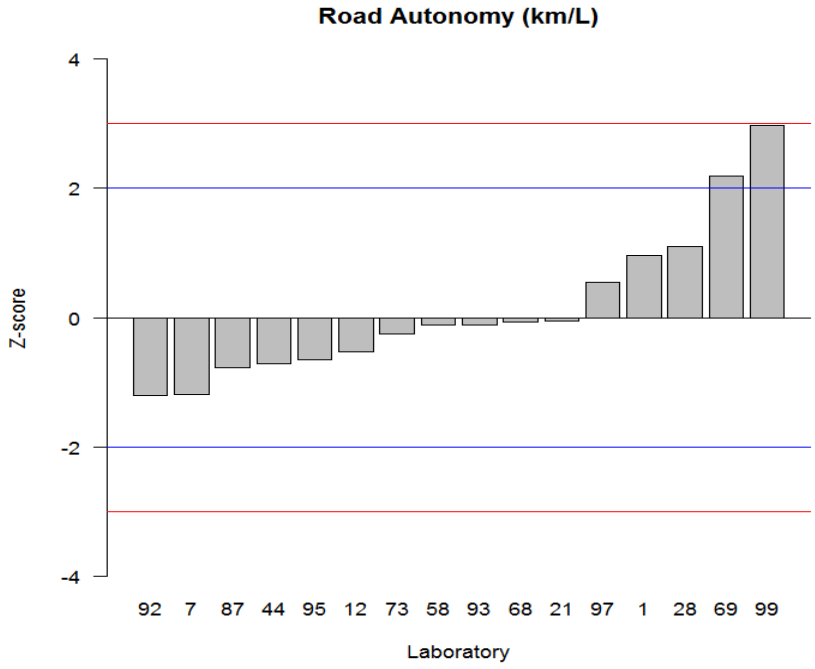

Figure 17 – *z*-score graph of for Road Autonomy measurement

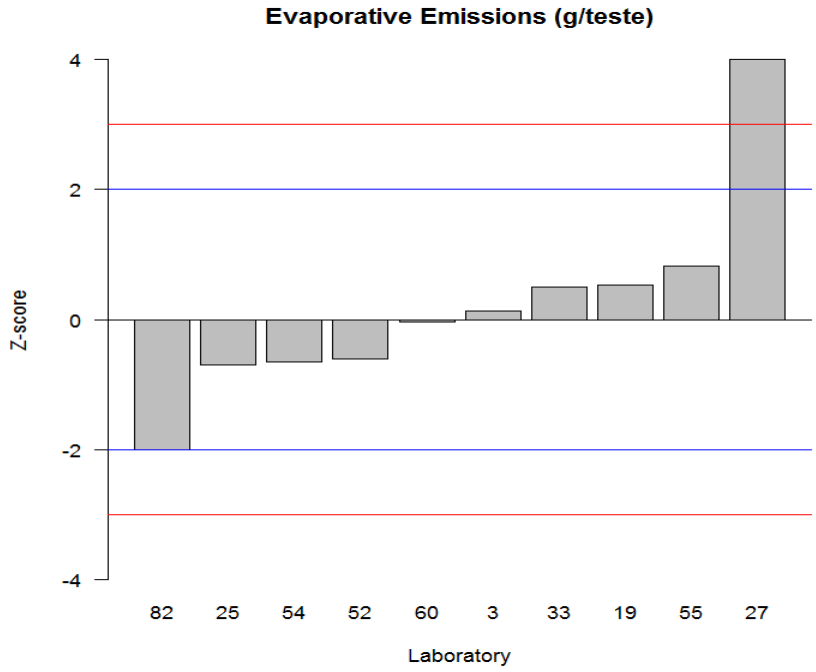

Figure 18 – *z*-score graph of for Road Evaporative Emissions.

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

- CO (g/km): all participants presented satisfactory results.
- CO_2 (g/km): only the participant 07 showed questionable result.
- THC (g/km): only the participant 87 showed questionable result.
- NMHC (g/km): only the participant 87 showed unsatisfactory result.
- NO_x (g/km): the participant 68 presented questionable result and the participant 69 showed unsatisfactory result.
- Total Aldehydes (g/km): all participants presented satisfactory results.
- Urban Autonomy (km/L): all participants presented satisfactory results.
- Road Autonomy (km/L): the participants 69 and 99 presented questionable results.
- Evaporative Emissions (g/test): only the participant 27 showed unsatisfactory result.

9. Confidentiality

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

The 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 very satisfactory and this initiative is very important to the industry and society along these seven rounds held in collaboration between Inmetro and AEA.

The test vehicles emission involves a large number of variables that influence the results, so it is recommended that participants who had questionable performance make a critical analysis of their measurement methods.

In general, the results obtained by the participants showed good performance measurements, where 94% of the results were satisfactory, five questionable results (7%) and three unsatisfactory result (2%).

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

It is up to each PT participant to carry out a critical analysis of the results, as well consider the entire process and laboratory experience. Therefore, the participation in a proficiency test, can assure information to the laboratory about the measurement capability and it is very important to validate the routine analysis.

11. Participating Laboratories

Seventeen laboratories were registered in the seventh round of the Car Emissions Proficiency Test and sixteen attended because one had equipment problems and informed the coordination. A list of laboratories that sent the results to this PT coordination of is presented in Table 07. It's important to note that the numeration of the laboratories in the table only indicates the number of participants in the PT, not their identification.

Table 07 – Participating Laboratories

	Institution
1.	AVL South America Ltda
2.	Companhia Ambiental do Estado de São Paulo Setor de Laboratório de Emissão Veicular
3.	Continental Brasil Indústria Automotiva Ltda Laboratório de Emissões Veiculares – Centro Tecnológico "Geraldo Negri Rangel"
4.	Delphi Automotive Systems do Brasil Ltda
5.	FCA Fiat Chrysler Automóveis Brasil Ltda Laboratório de Emissões e Consumo

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.	Honda Automóveis do Brasil Ltda Laboratório de Emissões Honda Automóveis
9.	Instituto de Tecnologia para o Desenvolvimento – Institutos LACTEC LEME – Laboratório de Emissões Veiculares
10.	Magneti Marelli Sistemas Automotivos Indústria e Comércio Ltda
11.	Petróleo Brasileiro S.A. Laboratório de Ensaios Veiculares - CENPES
12.	Renault do Brasil S/A LEV – Laboratório de Emissões Veiculares
13.	Robert Bosch Ltda Laboratório de emissões veiculares – Robert Bosch
14.	Toyota do Brasil Ltda Laboratório de Emissões Indaiatuba
15.	Umicore Brasil Ltda Laboratório de Emissões Veiculares - Umicore
16.	Volkswagen do Brasil Ltda Laboratório de Emissões Veiculares da Volkswagen do Brasil Ltda

Total participants: 16 laboratories.

12. References

- ABNT NBR ISO/IEC 17025:2005: General requirements for the competence of testing and calibration laboratories.
- ABNT NBR ISO/IEC 17043:2011: Conformity assessment – General requirements for proficiency testing.
- ISO 13528:2005 (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.

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