Assessment of NOx concentration levels during periodic technical inspection idle test of SCR-equipped Diesel vehicles

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Supplementary Information

1. Figures

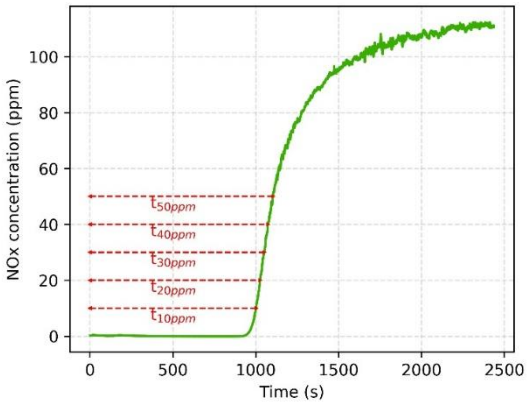


Figure S1. Schematic representation of the approach used during an idling test of a light-duty vehicle to determine the time required for the NOx concentration at tailpipe to reach 10, 20, 30, 40 and 50 ppm

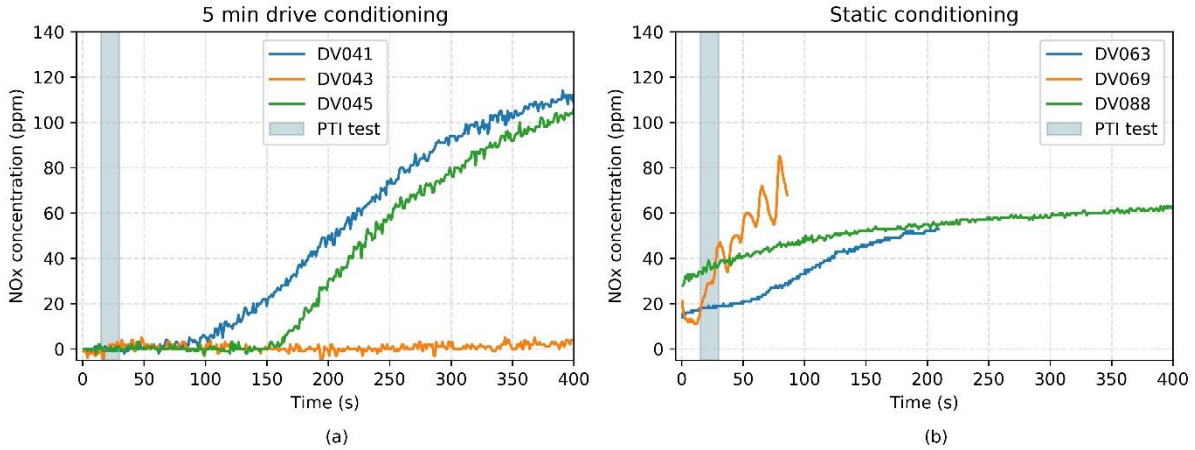
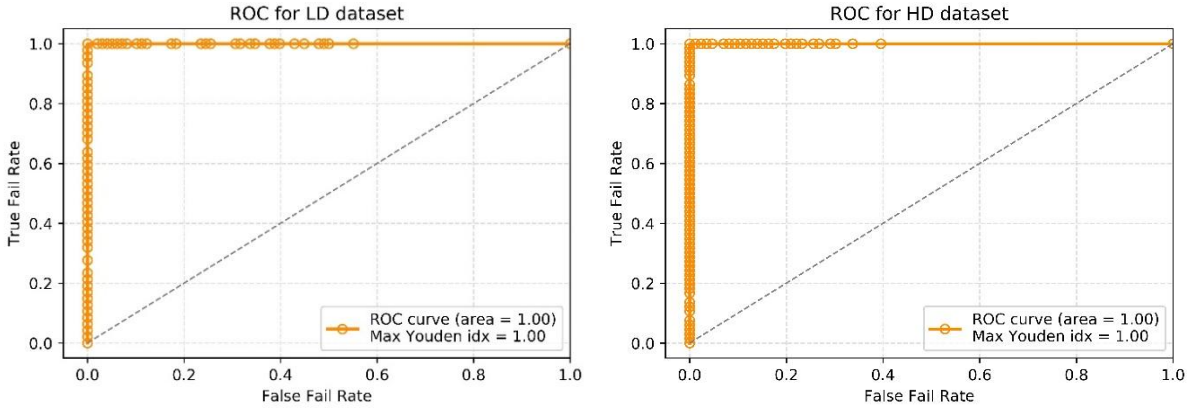


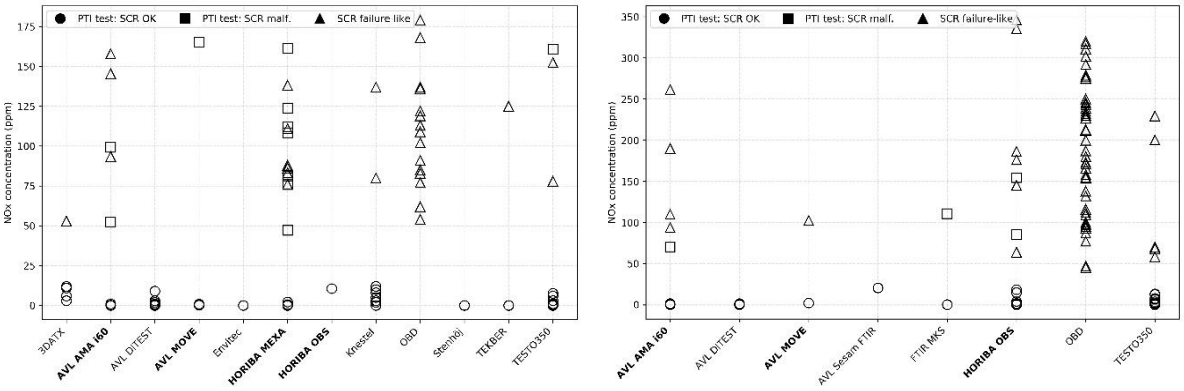
Figure S2. NOx concentration during idle test of six different vehicles assessed in LD campaign-2. Each vehicle is identified with a unique code DVXXX. In (a) the three vehicles were warmed-up before the test with a five minutes' drive, while in (b)

the vehicles were conditioned statically, i.e. using stand still free acceleration or high idling at constant engine speed. Time scale starts at the beginning of the idle. Time span 15–30 s is highlighted to show the NOx-PTI measurement period



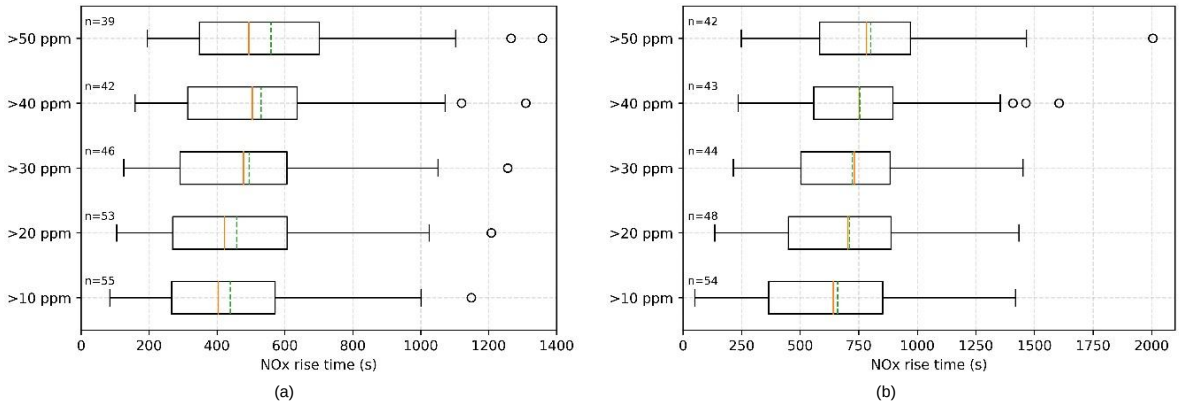
(a) (b)

Figure S3. ROC curve for (a) LD and (b) HD vehicle datasets. The area under the ROC curve (AUC) is also reported. The AUC value ranges from 0 to 1, where 1 indicates perfect classification. Additionally, the Youden index, which measures the maximum potential effectiveness of a diagnostic test, is also considered, with a maximum value of 1 indicating optimal balance between sensitivity and specificity



(a) (b)

Figure S4. NOx concentration measurement per equipment at NOx-PTI idle test of (a) light-duty and (b) heavy-duty vehicles. Each point represents a measurement and the measurement classification per group is highlighted with different markers, according to Sect."NOx–PTI idle test" of the main text. Laboratory-grade and PEMS equipment are reported in bold



(a) (b)

Figure S5. NOx rise time at different thresholds during NOx-PTI idle test of (a) light-duty and (b) heavy-duty vehicles. The box represents the interquartile range (IQR), the orange line inside the box shows the median while the dashed green line the mean, and the whiskers extend to the minimum and maximum values excluding outliers. N.B. not all boxplots contain the same number of tests (reported on the left), as for some vehicles the measurement time was not enough to reach NOx concentration above a certain value

2. Tables

Table S1. Summary of the measurement equipment used per campaign. Equipment are listed in alphabetical order

Analyser	Compound	Range (ppm)	Accuracy	LD camp.	HD camp.
3DATX - parSYNC® FLEX	NO	0 - 5000	± 15 ppm or ± 2% rel.	2	
	NO_2	0 - 300	± 5 ppm or ± 2% rel.		
AVL AMA i60	NO/NOx	0 - 10000	±2% rel.[a]	1	1
AVL DiTEST Gas 2301	NO	0 - 5000	± 50 ppm (<500 ppm)	2	4
			± 10 % rel. (≥500 ppm)		
AVL MOVE PEMS	NO	0 - 5000	±0.2% FS or ±2% rel.	1	1
	NO_2	0 - 2500	±0.2% FS or ±2% rel.		
AVL Sesam FTIR	NO	0 - 10000	N.A.[b]		1
	NO_2	0 - 1000			
Envitec - NOXO 100	NO	0 - 5000	± 4% or 25 ppm (0 - 4000 ppm)	2	
			± 8% rel. (4000 - 5000 ppm)		
HORIBA MEXA	NO/NOx	0 - 5000	±2% rel.[a]	1	
HORIBA OBS ONE	NOx	0 - 3000	±0.3% FS or ±2% rel.	1	1, 2, 3
	NO	0 - 3000	±0.3% FS or ±2% rel.		
MKS FTIR	NO	0 - 10000	N.A.[c]		1
	NO_2	0 - 2000			
Knestel - CLD mini[d]	NO	0 - 2500	± 1%	2	
Stenhöj - SGA 400	NOx	0 - 5000	N.A.	2	
TEKBER/Centralauto®-SPEKTRA 3011	NOx	0 - 5000	±4% or ±25 ppm (0 - 4000 ppm)	2	
			±5% rel. (4001 - 5000 ppm)		
Testo350	NO	0 - 4000	±5 ppm (0 - 99 ppm)	3	1, 2, 3
			±5 % rel. (100 - 1999 ppm)		
			±10 % rel. (2000 - 4000 ppm)		
	NO_2	0 - 500	±5 ppm (0 - 99,9 ppm)		
			±5 % rel. (100 - 500 ppm)		

[a] According to Regulation (EU) 2017/1151.

[b] Limit of Detection: 0.6 ppm for NO, 0.3 ppm for NO_2.

[c] Limit of Detection: 0.5 ppm for NO, 0.2 ppm for NO_2.

[d] Not possible to know whether the model employed featured a NOx-converter to measure NOx.

Table S2. Binary classification metrics for all possible thresholds for LD vehicles: true fail (TF), false fail (FF), true pass (TP), false pass (FP), 'sensitivity' or true fail rate, 'specificity' or true pass rate and 'accuracy' or fraction of correct classifications

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
185.00	0	0	98	47	0.000	1.000	0.676
184.00	1	0	98	46	0.021	1.000	0.683

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
179.00	2	0	98	45	0.043	1.000	0.690
168.00	3	0	98	44	0.064	1.000	0.697
165.15	4	0	98	43	0.085	1.000	0.703
161.30	5	0	98	42	0.106	1.000	0.710
160.80	6	0	98	41	0.128	1.000	0.717
157.89	7	0	98	40	0.149	1.000	0.724
152.30	8	0	98	39	0.170	1.000	0.731
145.40	9	0	98	38	0.191	1.000	0.738
140.00	10	0	98	37	0.213	1.000	0.745
138.14	11	0	98	36	0.234	1.000	0.752
137.00	13	0	98	34	0.277	1.000	0.766
136.00	15	0	98	32	0.319	1.000	0.779
124.97	16	0	98	31	0.340	1.000	0.786
123.90	17	0	98	30	0.362	1.000	0.793
122.00	18	0	98	29	0.383	1.000	0.800
119.00	19	0	98	28	0.404	1.000	0.807
113.00	20	0	98	27	0.426	1.000	0.814
112.10	21	0	98	26	0.447	1.000	0.821
110.89	22	0	98	25	0.468	1.000	0.828
109.00	23	0	98	24	0.489	1.000	0.834
108.40	24	0	98	23	0.511	1.000	0.841
102.00	25	0	98	22	0.532	1.000	0.848
99.50	26	0	98	21	0.553	1.000	0.855
93.40	27	0	98	20	0.574	1.000	0.862
91.00	28	0	98	19	0.596	1.000	0.869
88.00	29	0	98	18	0.617	1.000	0.876
86.30	30	0	98	17	0.638	1.000	0.883
85.00	32	0	98	15	0.681	1.000	0.897
83.10	33	0	98	14	0.702	1.000	0.903
83.00	34	0	98	13	0.723	1.000	0.910
81.29	35	0	98	12	0.745	1.000	0.917
80.00	36	0	98	11	0.766	1.000	0.924
78.00	37	0	98	10	0.787	1.000	0.931
77.00	38	0	98	9	0.809	1.000	0.938
76.00	39	0	98	8	0.830	1.000	0.945
75.90	40	0	98	7	0.851	1.000	0.952
62.00	41	0	98	6	0.872	1.000	0.959
57.00	42	0	98	5	0.894	1.000	0.966
54.00	44	0	98	3	0.936	1.000	0.979
53.00	45	0	98	2	0.957	1.000	0.986
52.46	46	0	98	1	0.979	1.000	0.993
47.10	47	0	98	0	1.000	1.000	1.000
12.00	47	2	96	0	1.000	0.980	0.986
11.00	47	3	95	0	1.000	0.969	0.979

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
10.60	47	4	94	0	1.000	0.959	0.972
10.00	47	5	93	0	1.000	0.949	0.966
9.00	47	6	92	0	1.000	0.939	0.959
8.00	47	7	91	0	1.000	0.929	0.952
7.60	47	8	90	0	1.000	0.918	0.945
6.00	47	10	88	0	1.000	0.898	0.931
5.00	47	11	87	0	1.000	0.888	0.924
3.10	47	12	86	0	1.000	0.878	0.917
3.00	47	17	81	0	1.000	0.827	0.883
2.23	47	18	80	0	1.000	0.816	0.876
2.00	47	23	75	0	1.000	0.765	0.841
1.10	47	24	74	0	1.000	0.755	0.834
1.03	47	25	73	0	1.000	0.745	0.828
1.00	47	30	68	0	1.000	0.694	0.793
0.81	47	31	67	0	1.000	0.684	0.786
0.70	47	33	65	0	1.000	0.663	0.772
0.61	47	34	64	0	1.000	0.653	0.766
0.60	47	37	61	0	1.000	0.622	0.745
0.50	47	38	60	0	1.000	0.612	0.738
0.47	47	39	59	0	1.000	0.602	0.731
0.40	47	42	56	0	1.000	0.571	0.710
0.30	47	44	54	0	1.000	0.551	0.697
0.20	47	47	51	0	1.000	0.520	0.676
0.18	47	48	50	0	1.000	0.510	0.669
0.15	47	49	49	0	1.000	0.500	0.662
0.10	47	54	44	0	1.000	0.449	0.628
0.00	47	98	0	0	1.000	0.000	0.324

Table S3. Binary classification metrics for all possible thresholds for HD vehicles: true fail (TF), false fail (FF), true pass (TP), false pass (FP), 'sensitivity' or true fail rate, 'specificity' or true pass rate and 'accuracy' or fraction of correct classifications

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
347.10	0	0	86	66	0.000	1.000	0.566
346.10	1	0	86	65	0.015	1.000	0.572
335.60	2	0	86	64	0.030	1.000	0.579
320.00	3	0	86	63	0.045	1.000	0.586
317.00	4	0	86	62	0.061	1.000	0.592
311.00	5	0	86	61	0.076	1.000	0.599
302.00	7	0	86	59	0.106	1.000	0.612
292.00	8	0	86	58	0.121	1.000	0.618
279.00	9	0	86	57	0.136	1.000	0.625
277.00	11	0	86	55	0.167	1.000	0.638
275.00	12	0	86	54	0.182	1.000	0.645
261.50	13	0	86	53	0.197	1.000	0.651

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
250.20	14	0	86	52	0.212	1.000	0.658
246.00	15	0	86	51	0.227	1.000	0.664
245.00	16	0	86	50	0.242	1.000	0.671
243.00	17	0	86	49	0.258	1.000	0.678
239.00	18	0	86	48	0.273	1.000	0.684
235.00	19	0	86	47	0.288	1.000	0.691
232.00	20	0	86	46	0.303	1.000	0.697
230.00	21	0	86	45	0.318	1.000	0.704
229.40	22	0	86	44	0.333	1.000	0.711
227.00	23	0	86	43	0.348	1.000	0.717
213.00	24	0	86	42	0.364	1.000	0.724
212.00	25	0	86	41	0.379	1.000	0.730
210.00	26	0	86	40	0.394	1.000	0.737
200.10	27	0	86	39	0.409	1.000	0.743
200.00	28	0	86	38	0.424	1.000	0.750
189.80	29	0	86	37	0.439	1.000	0.757
187.00	30	0	86	36	0.455	1.000	0.763
186.30	31	0	86	35	0.470	1.000	0.770
180.00	32	0	86	34	0.485	1.000	0.776
176.20	33	0	86	33	0.500	1.000	0.783
173.00	34	0	86	32	0.515	1.000	0.789
171.00	35	0	86	31	0.530	1.000	0.796
166.00	36	0	86	30	0.545	1.000	0.803
158.00	37	0	86	29	0.561	1.000	0.809
155.00	38	0	86	28	0.576	1.000	0.816
154.30	39	0	86	27	0.591	1.000	0.822
154.00	40	0	86	26	0.606	1.000	0.829
145.10	41	0	86	25	0.621	1.000	0.836
138.00	42	0	86	24	0.636	1.000	0.842
132.00	43	0	86	23	0.652	1.000	0.849
116.00	44	0	86	22	0.667	1.000	0.855
112.00	45	0	86	21	0.682	1.000	0.862
110.70	46	0	86	20	0.697	1.000	0.868
109.80	47	0	86	19	0.712	1.000	0.875
109.00	48	0	86	18	0.727	1.000	0.882
102.20	49	0	86	17	0.742	1.000	0.888
100.00	50	0	86	16	0.758	1.000	0.895
98.00	51	0	86	15	0.773	1.000	0.901
97.00	52	0	86	14	0.788	1.000	0.908
95.00	53	0	86	13	0.803	1.000	0.914
93.70	54	0	86	12	0.818	1.000	0.921
93.00	55	0	86	11	0.833	1.000	0.928
87.00	56	0	86	10	0.848	1.000	0.934
85.50	57	0	86	9	0.864	1.000	0.941

Threshold (ppm)	TF (#)	FF (#)	TP (#)	FP (#)	Sensitivity (-)	Specificity (-)	Accuracy (-)
77.00	59	0	86	7	0.894	1.000	0.954
70.35	60	0	86	6	0.909	1.000	0.961
70.20	61	0	86	5	0.924	1.000	0.967
68.00	62	0	86	4	0.939	1.000	0.974
63.80	63	0	86	3	0.955	1.000	0.980
58.20	64	0	86	2	0.970	1.000	0.987
47.00	65	0	86	1	0.985	1.000	0.993
45.00	66	0	86	0	1.000	1.000	1.000
30.00	66	1	85	0	1.000	0.988	0.993
20.30	66	2	84	0	1.000	0.977	0.987
18.20	66	3	83	0	1.000	0.965	0.980
14.70	66	4	82	0	1.000	0.953	0.974
13.00	66	6	80	0	1.000	0.930	0.961
12.30	66	7	79	0	1.000	0.919	0.954
7.60	66	8	78	0	1.000	0.907	0.947
6.30	66	9	77	0	1.000	0.895	0.941
3.80	66	10	76	0	1.000	0.884	0.934
3.40	66	11	75	0	1.000	0.872	0.928
2.00	66	12	74	0	1.000	0.860	0.921
1.80	66	13	73	0	1.000	0.849	0.914
1.70	66	14	72	0	1.000	0.837	0.908
1.60	66	15	71	0	1.000	0.826	0.901
1.40	66	17	69	0	1.000	0.802	0.888
1.30	66	18	68	0	1.000	0.791	0.882
1.20	66	19	67	0	1.000	0.779	0.875
1.16	66	20	66	0	1.000	0.767	0.868
1.10	66	22	64	0	1.000	0.744	0.855
0.60	66	23	63	0	1.000	0.733	0.849
0.40	66	25	61	0	1.000	0.709	0.836
0.29	66	26	60	0	1.000	0.698	0.829
0.20	66	29	57	0	1.000	0.663	0.809
0.10	66	34	52	0	1.000	0.605	0.776
0.00	66	86	0	0	1.000	0.000	0.434