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Traffic & Transport
Anna van Buerenplein 1
2595 DA Den Haag
P.O. Box 96800
2509 JE The Hague
The Netherlands

www.tno.nl

T +31 88 866 00 00

TNO report

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Emissions of six petrol vehicles with high mileages

Date	14 June 2018
Author(s)	Gerrit Kadijk Mitch Elstgeest Norbert E. Ligterink Peter J. van der Mark
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Samenvatting

Voor het onderbouwen van emissiefactoren heeft TNO in opdracht van het Ministerie van Infrastructuur en Waterstaat de emissies van zes oudere benzine voertuigen, bouwjaar na 2000, met driewegkatalysator gemeten.
Deze emissiefactoren worden gebruikt voor luchtkwaliteitsmodellen en nationale rapportageverplichtingen. Twee Euro 3, drie Euro 4 voertuigen en een Euro 5 personenvoertuig, met kilometerstanden van 155.000 tot 254.000 km zijn volgens een (CADC) ritcyclus getest op de rollenbank, met gewichten en rijweerstanden representatief voor de praktijk.

De resultaten laten een grote spreiding zien in het NO_x emissiegedrag van deze zes voertuigen. Gemeten NO_x emissies variëren tussen 17 en 1234 mg/km.
Drie voertuigen laten NO_x emissieniveaus zien die onder of in de buurt van de NEDC limietwaarde liggen, drie voertuigen met emissieniveaus tussen 254 en 1234 mg/km overschrijden deze limietwaarde in behoorlijke mate (tot ongeveer 15 x). Voor fijnstof emissies is er ook grote spreiding, maar zijn de niveaus laag.

In het verleden zijn benzinepersonenauto's gemeten, toen deze voertuigen een paar jaar oud waren, en beperkte kilometerstanden hadden. Op basis van deze gegevens zijn emissiefactoren vastgesteld voor de verschillende praktijksituaties op de weg. Met oplopende leeftijd en kilometerstanden, voor voertuigen in het Nederlandse wagenpark, is het de vraag of deze voertuigen nog steeds dezelfde emissieniveaus vertonen.

Uit dit onderzoek blijkt dat de NO_x emissies voor het huidige wagenpark in het verleden te laag zijn ingeschat. Maar voor de spreiding in de emissies in deze diverse groep getest voertuigen, qua kilometerstanden, leeftijd, en merken, is het aantal geteste voertuigen te klein om met zekerheid de gemiddelde emissies vast te stellen. Een vervolgonderzoek is daarom aanbevolen.
In een vervolgonderzoek kan ook in beeld worden gebracht of via aanscherping van de emissietest in de APK de voertuigen met sterk verhoogde emissies kunnen worden geïdentificeerd.

Kader
Om negatieve effecten van de uitstoot van luchtverontreinigende stoffen en het broeikasgas CO_2 door het wegverkeer te verminderen zijn er Europese normen voor de uitlaatgasemissies van wegvoertuigen. Daarnaast is er aanvullend Nederlands beleid om de toepassing van schone en zuinige voertuigtechnieken te stimuleren. Om de effectiviteit van dit beleid te kunnen beoordelen, voert TNO sinds 1987 in opdracht van het Nederlandse Ministerie van Infrastructuur en Waterstaat emissiemetingen uit aan wegvoertuigen. Daar waar in de beginjaren de aandacht vooral uitging naar controle van de emissies van nieuwe auto's tijdens de officiële typekeuringstest op de rollenbank, is de aandacht het laatste decennium verschoven naar het verzamelen van betrouwbare informatie over de emissies van voertuigen in de praktijk, in het kader van luchtkwaliteit.

De resultaten van deze metingen worden door het Ministerie van Infrastructuur en Waterstaat met de Tweede Kamer gedeeld. Sinds 2015 worden testresultaten van individuele voertuigen door TNO aan de RDW opgestuurd.

De RDW stuurt deze resultaten vervolgens ter informatie door naar de typekeuringsautoriteit van het land dat de emissiegoedkeuring voor het betreffende voertuig heeft afgegeven.

Daarnaast worden de meetresultaten verwerkt in emissiefactoren, die worden gebruikt voor het modelleren van de luchtkwaliteit ten behoeve van het Nationaal Samenwerkingsprogramma Luchtkwaliteit (NSL) en voor de nationale emissieregistratie. Emissiefactoren zijn op basis van meetgegevens berekende gemiddelde emissies voor specifieke voertuigcategorieën onder specifieke gemiddelde verkeerscondities.

De relevante gegevens worden gepubliceerd als onderdeel van de rapportage van de Taakgroep Verkeer en Vervoer, op www.emissieregistratie.nl.
Tot slot worden de uit de meetprogramma's verkregen inzichten gebruikt om in Brussel en Genève wetgeving en testprocedures met betrekking tot voertuigemissies te verbeteren. Op dit moment hoeven voertuigen boven 100.000 kilometer niet te voldoen aan duurzaamheidseisen.

Doordat benzineauto's hun hele levensduur op de Nederlandse wegen zijn (nauwelijks geëxporteerd worden), en daarvan een groeiend aandeel in de stad komt naarmate ze ouder worden, zijn ze relevant voor stedelijke luchtkwaliteit. Het is daarbij ook nog de grootste groep auto's: ze vormen meer dan 70% van al het stedelijke verkeer.

Van de geteste voertuigen variëren ook de fijnstof (PM) en koolwaterstof (THC) emissieniveaus in sterke mate. Gemeten PM emissieniveaus van 0.1 tot 3.9 mg/km liggen beneden de NEDC limietwaarde voor dieselauto's en directe injectie benzineauto's, en beneden de huidige emissiefactoren, ondanks het feit dat sommige voertuigen een fors olieverbruik hebben. Vijf voertuigen presteren goed op THC emissie, die varieert van 8 tot 138 mg/km.

Emissiefactoren
Vooral de twee voertuigen met de gemeten hoogste NO_x emissie zijn van groot belang voor de luchtkwaliteit. Eén voertuig vertoonde een NO_x emissie, die, als deze in slechts één op de zes voertuigen voorkomt, zoals in het testprogramma, bijna een verdubbeling van de gemiddelde emissies ten opzichte van het gemiddelde van de resterende vijf voertuigen zou betekenen. Zelfs het gemiddelde van de vijf schonere voertuigen zou echter een aanzienlijke toename zijn van de emissiefactoren van Euro 3 tot Euro 5 voertuigen met hoge kilometerstanden zoals die momenteel worden gebruikt. De spreiding in de steekproef en de beperkte informatie waarom hoge NO_x emissies optreden bij hoge kilometerstanden, betekent dat op basis van het huidige programma de NO_x emissiefactoren worden onderschat. Bovendien is de onzekerheid in de feitelijke toename.

Op basis van de eerste inzichten (na metingen aan drie voertuigen) in gemeten fijnstofemissies, die een uniform resultaat lieten zien, zijn de fijnstof emissiefactoren voor 2018 al naar beneden bijgesteld. De andere drie voertuigen bevestigen dit beeld. Voor fijnstofemissies uit de uitlaat zijn in de toekomst de grote aantallen benzineauto's de belangrijkste bron. Het is daarom van belang om deze emissies zo goed mogelijk in te schatten.

Summary

To substantiate emission factors and on behalf of the Ministry of Infrastructure and Water Management, TNO measured the emissions of six older petrol vehicles, model year after 2000, with three-way catalysts. The emission factors are used for air quality assessments and reporting on national emission inventories.
Two Euro 3, three Euro 4 vehicles and a Euro 5 passenger vehicle, with odometer readings of 155.000 to 254.000 km have been tested on the chassis dynamometer according to a (CADC) driving cycle, with representative road loads.

The results show a large spread in the emission behaviour of these six vehicles. Measured NO_x emissions vary between 17 and 1234 mg/km. Three vehicles show NO_x emission levels below or close to the NEDC limit value; three vehicles with emission levels between 254 and 1234 mg/km exceed this limit value to a considerable extent (up to approximately15 x). Particulates emissions of these vehicles vary as well, but these emission levels are low.

In order to determine whether the results are representative for the emissions from the entire group of older petrol vehicles of the above-mentioned classes within the Dutch vehicle fleet, a larger group of vehicles with different technologies and mileages has to be tested. In that follow-up research, it should become clear whether it is possible to test whether older petrol cars with a three-way catalyst exhibiting strongly increased emission levels can be identified by tightening the emissions test in the periodic technical inspection (PTI, or, in Dutch: APK).

Context
In order to reduce the negative impacts of the pollutant and greenhouse gas emissions of road transport, the European Commission has implemented emission regulations for the exhaust emissions of road vehicles which set limits for various pollutant components and CO_2 emission. In addition, Dutch policies are implemented with the aim to promote the application of clean and energy-efficient vehicle technologies. To enable evaluation of the effectiveness of these policies, the Dutch Ministry of Infrastructure and Water Management has commissioned TNO to carry out road vehicle emission tests. These test programmes have been executed since 1987. In the early years, the focus was on validation of the emissions of new road vehicles on the type approval test. In the last decades however, the focus has shifted towards obtaining reliable information on the emission performance of vehicles in real-world operation on the road.

The Ministry of Infrastructure and Water Management regularly shares results of these measurements with the Dutch Parliament. Since 2015 TNO also sends test results of individual vehicles to the Dutch type approval authority RDW (Rijksdienst voor het Wegverkeer). These test results are forwarded by the RDW to the granting type approval authority that is responsible for the Whole Vehicle Type Approval of that particular vehicle.

Furthermore, the results are used to determine national vehicle emission factors, that are used for air quality modelling for the National Cooperation Programme for Air Quality (NSL) and the national Pollutant Release and Transfer Register.

Emission factors are average emissions calculated on the basis of measurement data for specific vehicle categories under specific average traffic conditions.
The relevant data are published as part of the report of the Task Force on Traffic and Transport, at the website www.emissieregistratie.nl

Last but not least, the insights obtained in emission measurement projects serve as input for the activities of the Dutch government and the RDW in the context of regulation and legislative processes in Brussels (European Commission) and Geneva (GRPE) to improve emission legislation and the associated test procedures for emissions of vehicles. At this moment, vehicles with a mileage above 100,000 km do not have to meet sustainability requirements.

Petrol passenger cars have been measured in the past when these vehicles were a few years old and had limited odometer readings. On the basis of this data, emission factors have been determined for the different practical situations on the road. With increasing age and odometer readings, the question is whether these vehicles still have the same emission levels. Because petrol cars are their entire lifespan on the Dutch roads (they are hardly exported), and because they become a growing share of the total amount of vehicles within cities as they get older, they are relevant for urban air quality. It is also the largest group of cars: they constitute more than 70% of all urban traffic.

Of the tested vehicles, particulate matter (PM) and hydrocarbon (THC) emission levels also vary greatly. Measured PM emission levels of 0.1 to 3.9 mg/km are below the NEDC limit value for diesel cars and GDI vehicles, and the current estimate of the particulate mass emission of these vehicles, despite the fact that some vehicles have a substantial oil consumption. Five vehicles perform well on THC emission, ranging from 8 to 138 mg/km.

<u>Emission factors</u>
In particular the three vehicles with a high NO_x emission are of a major concern for air-quality. One vehicle showed NO_x emissions, which, if they occur in only one of every six vehicles, like in the test programme, would mean almost a doubling of the average emissions with respect to the average of the remaining five vehicles. Furthermore, even the average of the five cleaner vehicles would be a significant increase of the emission factors of Euro-3 to Euro-5 vehicles with high mileages than currently estimated. The spread in the sample, and the limited information why high NO_x emissions occur at high mileages, means that based on the current program the NO_x emission factors are underestimated. Moreover, the uncertainty in the actual increase is large.

For PM emissions, based on the first insights which show a uniform result, emission factors for 2018 have already been adjusted downwards. For PM emissions from the exhaust, petrol cars will be the most important source in the future. It is therefore important to estimate these emissions as good as possible.

Contents

1 Introduction

This report presents detailed results of emission tests carried out by TNO in the period autumn 2017- spring 2018. The tests focussed on emissions of in-use, older, petrol vehicles with three-way catalyst and high mileages. The emission tests were carried out as part of a project for the Dutch Ministry of Infrastructure and Water Management. This vehicle group has a significant impact on the total emissions after 2020, mainly due to the fact that it concerns several millions of vehicles in the Netherlands.

With this report TNO intends to provide clarity and understanding on the measured data and what the results do and do not imply. TNO and the Dutch Ministry of Infrastructure and Water Management aspire to provide maximum transparency on the information that feeds into policy decisions regarding air quality and emission legislation.

1.1 Context

Euro emission standards
To minimize air pollutant emissions of light-duty vehicles, in 1992 the European Commission introduced the Euro emission standards. In the course of time, these standards have become more stringent. Currently produced light duty vehicles of categories M and N must comply with the Euro 6b standard. The Euro 6c and 6d-Temp standards, that further limit the emissions, will become mandatory in the period of 2018 - 2020. The standards apply to vehicles with spark ignition engines and to vehicles with compression ignition engines and cover the following gaseous and particulate emissions:

- CO (carbon monoxide);
- THC (total hydrocarbons);
- NO_x (nitrogen oxides);
- PM (particulate mass),
- PN (particulate number, for direct injection only).

As a result of the Euro emission standards, the pollutant emissions of light-duty vehicles, passenger cars and vans, as observed in type approval tests have reduced significantly over the past decade. However, under real driving conditions some emissions substantially deviate from their type approval values. The real driving emissions of nitrogen oxides, or NO_x, from diesel vehicles are currently the most important issue with regard to pollutant emissions, as many cities fail to satisfy the NO_2 air-quality standards mainly through the poor real-world performance of diesel cars.[1] As NO_x represents the sum of NO and NO_2 emitted, and much of the NO is converted to NO_2 in ambient conditions, reducing NO_x emissions of vehicles is important for bringing down the ambient air NO_2 concentration in cities.
In the Netherlands, the ambient NO_2 concentration still exceeds European limits at numerous urban road-side locations[2].

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[1] http://www.platformparticipatie.nl/projecten/alle-projecten/projectenlijst/aanpassing-nationaal-samenwerkingsprogramma-luchtkwaliteit-2018/index.aspx
[2] http://www.atlasleefomgeving.nl/en/meer-weten/lucht/stikstofdioxide

For petrol vehicles, tested by TNO annually till 2008 and more intermittently after that time, limited deviations between the type-approval tests and the real-world tests were observed. The NEDC type-approval test, with the low test velocity, short distance, and the cold start, formed stringent requirements for petrol vehicle technology which ensured in real-world circumstances the emissions were typically lower than the emission limits in the type-approval test. Moreover, from monitoring programs, such as remote sensing studies, there was little concern on the real-world performance of petrol vehicles. However, given the size of the fleet and, for example, the impact on the total emissions after 2020, there are risks that minor deviations in the estimates will have considerable consequences for the total real-world emissions.

Commissioned by the Dutch Ministry of Infrastructure and Water Management, TNO regularly performs emission measurements within the "in-use compliance programme for light-duty vehicles". In the early years, i.e., in 1987 to 2000, the focus was on performing a number of standard type approval tests on a large number of vehicles in the lab. In recent years, however, the emphasis has shifted towards gathering emission data under conditions that are more representative for real-world driving, by using various non-standard, i.e., real-world, driving cycles in the lab and by increasingly testing cars on the road with mobile emission measurement equipment.

Emission factors

Table 1-1: Emission factors for Euro-2 to Euro-5 petrol vehicles for the Dutch air-quality assessments.

road type	g/km	Euro-2	Euro-3	Euro-4	Euro-5
urban	NOx	0.4684	0.1480	0.0539	0.0431
	HC	0.5132	0.4374	0.4197	0.3357
	PM	0.0046	0.0023	0.0023	0.0019
	CO	10.6833	6.6475	5.6150	4.4920
	Elemental Carbon	0.0012	0.0004	0.0004	0.0003
	real-world CO2	284.7	254.6	235.9	213.2
rural	NOx	0.2130	0.0594	0.0248	0.0199
	HC	0.2334	0.2153	0.2118	0.1694
	PM	0.0023	0.0012	0.0012	0.0009
	CO	4.3987	3.2906	2.8732	2.2985
	Elemental Carbon	0.0006	0.0002	0.0002	0.0001
	real-world CO2	143.3	152.6	149.2	134.9
motorway	NOx	0.1984	0.0360	0.0147	0.0117
	HC	0.0654	0.0216	0.0189	0.0151
	PM	0.0050	0.0025	0.0025	0.0025
	CO	3.4073	1.8849	1.6523	1.3218
	Elemental Carbon	0.0013	0.0004	0.0004	0.0004
	real-world CO2	203.0	203.6	194.8	176.1

The emission factors, or average emissions, for pollutant tailpipe emissions of this group of vehicles are typically below the type-approval limit. The current, 2018, emission factors are given in Table 1-1. The urban emissions are substantially higher than rural and motorway emissions.

This is the result of the cold start contribution. In the total emissions, the start of the cold engine typically dominates the emissions. In the first 300 metres of driving the same emissions are produced as in the next twenty or more kilometres. For urban driving it is estimated that for every 7 kilometres of driving one cold start occurs.[3]

TNO is one of the few institutes in Europe that perform independent emission tests. Based on the results of performed emission tests, TNO develops, and annually updates, Dutch vehicle emission factors that represent the average real-world emissions data for specific various vehicle types categories under different driving and traffic conditions.

Vehicle emission factors are used for emission inventories and air quality monitoring. The emission factors, and the underlying test results, are one of the few independent sources of evidence for the growing difference between legislative emission limits and real-world emission performance of cars. Furthermore, the insights obtained in emission measurement programs serve as input for the activities of the Dutch government and the RDW in the context of regulation and legislative processes in Brussels (European Commission) and Geneva (GRPE) to improve emission legislation and the associated test procedures for light duty vehicles, all with the aim to reduce real-world emissions and improve air quality.

Lack of data of older petrol vehicles
With the focus in recent years on diesel vehicles and NO_x emissions, the test programmes for petrol vehicles were limited. With Euro-5 a few incidental and specialized test programmes for petrol vehicles were executed. The last test programme in 2016, was intended to determine PM and EC emissions of the emerging GDI technology vehicles.

A lack of emission data of older petrol vehicles was identified: Petrol passenger cars have been measured in the past when these vehicles were only a few years old and had limited odometer readings. On the basis of this data, emission factors have been determined for the different practical situations on the road. With increasing age and mileages, the question is whether these vehicles still have the same emission levels.

Because petrol cars are their entire lifespan on the Dutch roads (they are hardly exported), and because, as they get older, they become a growing share of the total amount of vehicles within cities, they are relevant for urban air quality. It is also the largest group of cars: they constitute more than 70% of all urban traffic. Modern petrol cars reach on average 100,000 kilometres at after 7 years. A vehicle from 1990 and before had an average lifespan of 18 years or less and 150,000 kilometres. Vehicles from 2005 and earlier reach the 150,000 at 10 years, and likely drive more than 200,000 kilometre in total.

Therefore it was decided to perform an exploratory emission measurement program with six petrol passenger cars with high mileages. Also the fact that the Dutch petrol fleet has an increasing age, underlines the importance of this study. The results, presented in this report are important in order to check and update emission factors for air-quality and emission inventories.

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[3] See report: Methods for calculating emissions of transport in the Netherlands, 2017.

1.2 Aim and approach

The aim of the project was to assess the real-world emission performance of petrol passenger cars with three way catalyst and higher mileages and to provide input for generating emission factors for this vehicle category. This was done by performing emission measurements on the chassis dynamometer under real-world conditions. In particular, particulate emissions, such as particulate mass and particulate numbers, can only be measured with confidence in the laboratory. There are no indications the laboratory tests will not be representative for the real-world emissions, for these vehicles.

This study involves chassis dynamometer measurements on a total of six Euro 3, Euro 4 and Euro 5 passenger vehicles. This number of vehicles provides a basis to observe trends in their emission behaviour and to indicate average deterioration factors for the different road types.

1.3 TNO policy with respect to publication of data

TNO takes the care in generating data and in communication on the findings of its studies to the various stakeholders. It is beneficial to ensure no errors are made in the testing and problems are addressed early.

In the evaluation and interpretation of test results on individual vehicles the following considerations need to be taken into account:

- The tests performed by TNO are intended to determine the levels and trends of emissions of various categories of vehicles. The tests are not intended for enforcement, and they are not suitable for identifying or claiming fraud or other vehicle-related irregularities in a scientifically and legally watertight way.

- For each make or model, only a single vehicle or a small number of vehicles is/are tested a limited number of times. This means that the results correlate to the specific condition of the tested vehicles or to specific test conditions. The latter is especially the case in real-world testing on the road in which a large number of conditions, that have a strong influence on test results, vary from trip to trip.

In publications about the emission test results on light duty vehicles TNO has up to March 2016, for reasons as indicated above, chosen to present test results in a way that does not allow makes and models to be identified. In case results of individual vehicles were reported, these were always anonymized.

As part of TNO's constructive contribution to the on-going public debate about the real-world NO_x emissions of diesel cars, TNO has decided present test results with references to makes and models. This decision also meets a desire expressed by the Dutch Ministry of Infrastructure and Water Management.

By presenting results from the complete sample of vehicle models tested, covering a wide range of makes and models, and by providing the necessary background information on test procedures and test conditions as well as caveats with respect to what can be concluded from these data, the test results on individual vehicle models are presented in a context that allows a well-balanced interpretation of the meaning of the results.

Finally, we would like to emphasize that as an independent knowledge institute, TNO is, has been, and will be open to constructive dialogue with industry and governments. This is part of TNO's efforts to work together with relevant stakeholders in finding and supporting the implementation of effective solutions to reduce real-world emissions of harmful substances from vehicles, as well to determine and demonstrate the effects of implemented measures in an objective way.

1.4 Structure of the report

Information regarding the selection and the basic specifications of the selected vehicles can be found in Chapter 2. This chapter also provides detailed information about emission limit values, the used test cycles and the test equipment. Chapter 3 presents an overview of the test results for the six tested vehicles, followed by conclusions and discussion in Chapter 4. Chapter 5 gives recommendations for further research.

All test results of the individual vehicles as well as the specification of the chassis dynamometer as used during the tests are part of the Appendices.

2 Test programme

This chapter presents the most important characteristics of the test programme as performed. The measurement methods are described in more detail in the TNO methodology report [TNO 2016a]. The tests were performed on a chassis dynamometer mainly to have reliable particulate mass measurements. This is not yet possible in on-road testing.

2.1 Tested vehicles

2.1.1 Vehicle selection

Starting point for the selection of vehicles to be tested was the actual Dutch fleet composition of September 2017. The number of vehicles to be tested within this project was limited to six. Selection was done in such a way that the test vehicles represent the largest part of older vehicles. Most of the selected vehicles (see Table 2-1) belong to the group of highest sales vehicles.

2.1.2 Vehicle specifications

In Table 2-1 some basic data of the selected vehicles are specified. All selected vehicles have a registration data between 2001 and 2012 and mileages between 154,800 and 254,100 km.

Table 2-1: Six tested Euro 3, 4 and 5 passenger cars. All vehicles have a Three-Way Catalyst.

No	Brand	Model	Euro Class	Power [kW]	Registration Date	Odometer [km]	Empty Mass [kg]
1	Citroën	Xsara	3	80	14-10-2005	154,800	1,141
2	Toyota	Aygo	5	50	20-06-2012	193,500	780
3	Ford	Focus	3	74	12-07-2001	254,100	1,093
4	Volkswagen	Polo	4	44	30-01-2001	198,900	996
5	Opel	Corsa	4	55	30-03-2001	219,400	935
6	Fiat	Punto	4	59	23-05-2003	206,000	910

2.2 Emission limit values

In Table 2-2 the emission limit values of passenger vehicles and their durability and In Service Conformity mileages are shown. The limit values are based on a New European Driving Cycle (NEDC) with a cold start.

Table 2-2: Emission limit values of petrol passenger vehicles.

Emission limit values of M1 Class 1 petrol vehicles								
Emission	THC	NMHC	CO	NO_x	PM	PN	Durability	ISC
class	[mg/km]					[#/km]	[km]	[km]
Euro 3	200	-	2300	150	-	-	80000	-
Euro 4	100	-	1000	80	-	-	100000	tbr
Euro 5a	100	68	1000	60	5.0	-	160000	100000
Euro 5b	100	68	1000	60	4.5	-	160000	100000
Euro 6b	100	68	1000	60	4.5	6.0E+12	160000	100000
Euro 6c	100	68	1000	60	4.5	6.0E+11	160000	100000

2.3 Test cycle and chassis dynamometer settings

High particulates emissions of petrol vehicles are associated with poor air-fuel mixing, higher engine speeds, high engine loads and lubricant consumption of the engine. As the test programme is set up to assess the risks of high PM and PN emissions within the group of older petrol vehicles, the tests are conducted with engine loads that are at the higher end of the spectrum of normal vehicle use in the Netherlands. This means that the engine loads in the test are higher than what is common for the type-approval tests. This is achieved by setting the driving resistance and test mass on the high side of normal use. The applied values are comparable to carrying two passengers and, for example, the use of C- or D-energy label tyres.

Table 2-3: The settings of the chassis dynamometer for the test mass and driving resistance.

Trade mark	Type	Empty mass	Inertia	F0	F1	F2
		[kg]	[kg]	[N]	[N/(km/h)]	[N/(km^2/h^2)]
Citroën	Xsara	1141	1450	130	0.00	0.040
Ford	Focus	1093	1450	130	0.00	0.040
Toyota	Aygo	780	1130	130	0.00	0.040
VW	Polo	996	1350	130	0.00	0.040
Opel	Corsa	935	1350	130	0.00	0.040
Fiat	Punto	910	1350	130	0.00	0.040

For all tests the vehicles were soaked at 14 °C. All chassis dynamometer tests are carried out with a test cell temperature of 14 °C. This is close to the average Dutch temperature of 11 °C.

Vehicles are tested on the CADC-130 driving cycle[4] (Figure 2.1 and Table 2.4), which is considered representative of more aggressive driving within the spectrum of normal driving. The variant of the CADC-cycle used, has a maximum velocity of 130 km/h. Therefore, all in all the power demand on the vehicles is on the high side, and the emissions may be somewhat higher than can be expected from average driving. The need of this high demand lies in the fact that emissions may increase rapidly with engine demand and therefore average driving does not necessarily result in average emissions.

Table 2-4: The parameters of the CADC driving cycle.

	Distance [km]
Urban	4.4
Rural	16.4
Motorway	23.7
CADC total	44.5

[4] For more information on TNO test methods for laboratory and on-road testing see:
TNO 2016 R11178, "Assessment of road vehicle emissions: methodology of the Dutch in-service testing programme", V.A.M. Heijne et al., 2016

The Citroën, Toyota and Ford vehicles were subjected to three complete CADC tests (1 cold start and two warm starts) and the Volkswagen, Opel and Fiat were subjected to one complete CADC test start with an additional urban part (fourth phase).

Since particulate matter is collected on a filter, the tests of three cars have been repeated three times to collect sufficient particulate matter for an accurate filter particulate mass determination. Rather than collecting the emissions of a full CADC cycle on a single filter, the urban, rural and motorway part are collected on separate filters to have representative particulate mass results for each of these traffic situations.

Moreover, cold starts, when the engine itself is at the ambient temperature, may lead to additional particulates emissions. Cold starts occur mainly in urban driving situations. In the tests cold starts are included in the result of the urban test.
For all vehicles only a single cold start was performed.

The filters were of pure quartz. These filters can be used for elemental carbon determination using the SUNSET[5] method from the EUSAAR. In this method of determination the filters are heated up to 800 ˚C. Other types of filters cannot withstand such temperatures, and the filter material itself might contaminate the results.

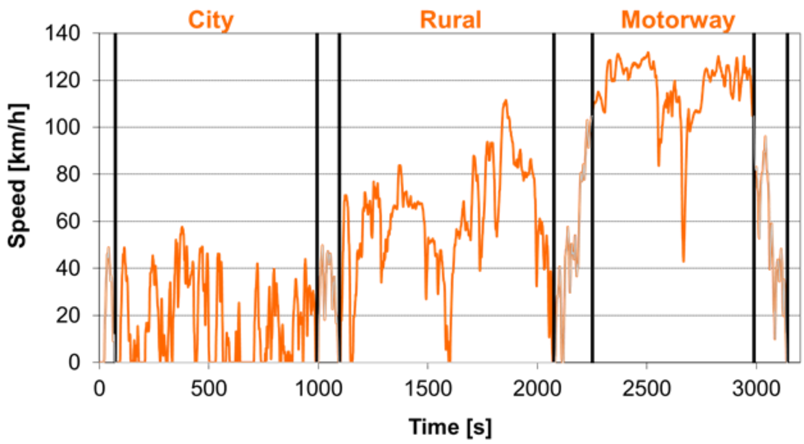

Figure 2.1: Common Artemis Driving Cycle (CADC).

2.4 Test equipment

The specifications of the chassis dynamometer and test equipment are reported in Appendix G.

[5] F. Cavalli et al., *Toward a standardised thermal-optical protocol for measuring atmospheric organic and elemental carbon: the EUSAAR protoco*l, Atmos. Meas. Tech. (2010) 3 p.79-89.

3 Emission test results

The emission tests were performed between October 2017 and March 2018. The overall results for all tested vehicles are reported in the following sections. Detailed reports of the test results per vehicle can be found in Appendices A to F of this report.

3.1 On Board Diagnostic data

In Table 3-1 the OBD and MIL status of the six vehicles are reported. These readings are taken before the actual start of the dynamometer emission test programme. There is one vehicle with an OBD failure code which is related to the exhaust emissions. The dealer did not advise the owner of this vehicle to have the error repaired. The emission test of this vehicle will show the possible effect on emissions, while having an OBD failure code.

Table 3-1: OBD and MIL status of the tested vehicles

		Euro class	Odometer	Calibration ID	MIL	OBD failure codes
			[km]			
Citroën	Xsara	3	154,800	9656393499	Off	No
Toyota	Aygo	5	193,500	Unknown	Off	No
Ford	Focus	3	254,100	KP AL 0A 4 HEX	Off	No
Volkswagen	Polo	4	198,900	Unknown	Off	No
Opel	Corsa	4	219,400	Unknown	On	Yes (PO1405)
Fiat	Punto	4	206,000	1037363518001000	Off	No

3.2 Overview test results of all vehicles

Table 3-2 shows CADC test results of the six tested vehicles. These results are compared with the type approval limits of the NEDC test. A conformity factor (CF) of 1 means that the test result is equal to the NEDC type approval limit value. For PM there are no requirements for these vehicles, the emission limit for GDI's is taken as standard.

Table 3-2: Test results and Conformity Factors (CF) of six tested vehicles on the basis of CADC test results with a cold start and NEDC type approval limit values. Note: Euro 3 and 4 PM conformity factors are based on a limit value of 5 mg/km.

	Euro Class	CO		THC		NO_x		PM	
		[mg/km]	CF	[mg/km]	CF	[mg/km]	CF	[mg/km]	CF
Citroën Xsara	3	719	0.3	8	0.0	39	0.3	0.1	0.0
Toyota Aygo	5	4135	4.1	25	0.3	17	0.3	1.1	0.2
Ford Focus	3	2476	1.1	97	0.5	254	1.7	2.3	0.5
VW Polo	4	2500	2.5	53	0.5	96	1.2	1.5	0.3
Opel Corsa	4	724	0.7	23	0.2	375	4.7	3.9	0.8
Fiat Punto	4	5133	5.1	138	1.4	1234	15.4	3.7	0.7

For each emission component the table shows a large spread in emission performance per vehicle. The elevated CO emissions are related to the test conditions (relatively high load). Three out of six vehicles have a high or very high NO_x emission (254 – 1234 mg/km), one vehicle had an active malfunction (EGR valve failure). Only one vehicle exceeds CO, THC and NO_x limit values.

3.3 Overview test results of standard PTI four gas tests

Knowing the test results of the CADC test, it was decided to perform an additional standard PTI four gas test with the vehicles that showed the highest NO_x emissions. In Table 3-3 the emissions at low idle speed in the CADC tests and in PTI tests are reported. The CO, CO_2 and O_2 volumetric concentrations of the two test methods are similar. The measured HC emissions of the two test methods are very different, this is probably caused by the test set up (with or without sample conditioning at 180 °C).

All three vehicles pass the PTI emission test because CO emissions are below the Dutch PTI limit values and lambda is between 0,97 and 1,03.

The measured NOx emission at low idle speed in the CADC test is very low (0 to 11) ppm, this indicates a proper working three-way catalyst and lambda control at these conditions.

Table 3-3: Exhaust emissions at low idle speed in the CADC and PTI tests.

	Ford Focus		Fiat Punto		Opel Corsa	
	CADC	*PTI*	*CADC*	*PTI*	*CADC*	*PTI*
CO [vol%]	0.12	0.02	0.11	0.10-0.18	0.02	0.01-0.03
CO_2 [vol%]	15.1	14.8-14.9	14.7	14.7-14.9	15.3	15.1
O_2 [vol%]	0.04	0.04-0.09	0.90	0.17-0.19	0.22	0.02-0.08
THC(C1) [ppm]	59	54-372	34	510-672	1	36-120
NOx [ppm]	0.44	-	10.81	-	2.50	-
Lambda [-]	-	1.001	-	1.001	-	1.001

4 Conclusions and discussion

4.1 Conclusions on basis of the chassis dynamometer and four gas test results

The chassis dynamometer results show a large spread in the emission performance of the six tested vehicles in the CADC tests:

- The CO emissions are in the range of 719 – 5133 mg/km. Due to the relative high applied load, the engines can run with rich mixtures and the high CO emissions are common in these cases.

- The PM emissions are in the range of 0.1 – 3.9 mg/km. However, all PM emissions are below the tightest type approval limit value of 4.5 mg/km for GDI.

- The THC emissions are in the range of 8 - 138 mg/km. Only one Euro 4 vehicle exceeds its type approval limit value of 100 mg/km.

- NOx emission levels, as measured in the CADC tests, vary between 17 to 1234 mg/km. Three vehicles have NOx emissions below or near their NEDC limit value and three vehicles with a NOx emission in the range of 254 to 1234 mg/km exceed these limit values (very) significantly.

- In particular the three vehicles with a high NO_x emission are of a major concern for air-quality. One vehicle showed NO_x emissions, which, if they occur in only one of every six vehicles, like in the test programme, would mean almost a doubling of the average emissions with respect to the average of the remaining five vehicles. However, even the average of the five cleaner vehicles would be a significant increase of the emission factors of Euro-3 to Euro-5 vehicles with high mileages than currently used.
  The spread in the sample, and the limited information why high NO_x emissions occur at high mileages, means that based on the current program the NO_x emission factors are underestimated. Moreover, the uncertainty in the actual increase is large. In order to create more profound revised NO_x emission factors for these type of vehicles, more vehicles with different ages and mileages need to be tested.

- Three vehicles with increased CADC NO_x emission were also subject to a PTI emission test. This test is based on the CO, CO_2, O_2 and HC tail pipe emission and a lambda value at idle speed. The vehicles passed the PTI emission test without faults.

- The Dutch PTI emission test as performed on three petrol vehicles is not suited to detect vehicles with high real world NO_x emissions.

- One Euro 4 vehicle with a high NOx emission of 375 mg/km has been running with a Malfunction Indication Light (MIL) on. The OBD failure code PO1405 is related to a failure of the position sensor of the EGR valve. The dealer advised the vehicle owner not to repair this malfunction because according to Dutch PTI rules the vehicle passes the PTI test.

- The vehicle with the highest emissions (Fiat Punto with 205,000 km) was fairly good maintained. No special issues were registered in the CADC test. It seems that the measured high emissions are a result of standard vehicle use with a standard maintenance servicing.

- The root cause of the elevated NO_x emission of the three vehicles is not investigated. The common causes are the EGR system, the deteriorated threeway catalyst, and the lambda control. The tailpipe emission at low idle speed of these vehicles is very low, this indicates a well-functioning catalyst and lambda control. If further research of the root cause of these vehicles will be started, it is recommended to check the EGR-system and possible deposit formations.

4.2 Possible effects of emissions of older vehicles on air quality

In particular the two vehicles with a high NO_x emission are of a major concern for air-quality. The Fiat Punto showed NO_x emissions, which, if they occur in only one of every six vehicles, like in the test programme, would mean almost a doubling of the average emissions with respect to the average of the remaining five vehicles. However, even the average of the five cleaner vehicles would be a significant increase of the emission factors of Euro-3 to Euro-5 vehicles with high mileages than currently used. The spread in the sample, and the limited information why high NO_x emissions occur at high mileages, means that based on the current program the NO_x emission factors are underestimated. Moreover, the uncertainty in the actual increase is large.

For PM emissions from the exhaust, petrol cars will be the most important source in the future. It is therefore important to estimate these emissions as good as possible. For PM emissions, based on the first insights which show a uniform result, emission factors for 2018 have already been adjusted downwards.

4.3 General caveats regarding interpretation of the test results

- The tests performed by TNO are not intended nor suitable for enforcement purposes and are not suitable for identifying or claiming fraud or other vehicle-related irregularities in a technically and legally watertight way. The observed high emissions under real-world test conditions can and should therefore not be interpreted as an indication for the use of so-called “defeat devices”, “cycle beating” or other strategies that are prohibited by European vehicle emission legislation. Instead the test programme has been designed to generate insight in the overall real-world emission behaviour of vehicles, required for environmental policy making and evaluation, as well as inputs for the activities of the Dutch government in the context of decision making processes for improving vehicle emission legislation and the associated test procedures.

- For each make or model, only a single vehicle or a small number of vehicles are tested, which means that it cannot be ruled out that the results correlate to the specific condition of the tested vehicles.

- The results for individual vehicle models cannot be interpreted or used as emission factors. Emission factors are estimates of the overall average emissions of a specific vehicle category, or of the average emissions of a specific vehicle category under specific average driving conditions on a specified road type.

- Because of the myriad of factors that determine the outcome of a real-world emission test, the values reported cannot easily be used to rank vehicles with respect to their emission performance. The influence of differences in the tests executed on two vehicles may be larger than the difference in actual performance of engine, exhaust after treatment and control systems.

5 Recommendation

The test results of three of the six tested, older, vehicles show substantial NO_x deterioration effects. These vehicles have relatively high mileages (206,000 to 254,100 km) and their NO_x emission level show a potential risk for air quality. Despite the fact that the test vehicles were carefully selected from the most common vehicle models, only 6 vehicles are tested in this research which does not necessarily represent the average vehicle condition of the whole Dutch petrol fleet with high mileages. Therefore it is recommended to further investigate the status quo for older petrol vehicles.

On basis of the test results it is recommended to investigate the possibilities for a simple NO_x PTI screening test, to detect the highest emitters.

6 References

[TNO 2016a] Heijne et al., *Assessment of road vehicle emissions: methodology of the Dutch in-service testing programme*, TNO report 2016 R11178

[TNO 2016b] Ligterink, N.E., *Emissions of three common GDI vehicles*, TNO report 2016, R11247

[PBL 2017] Kleijn et al., *Methods for calculating the emissions of transport in the Netherlands*, Task Force on Transportation of the Dutch Pollutant Release and Transfer Register, 2017

7 Abbreviations

CADC	Common Artemis Driving Cycle
CF	Conformity Factor
NEDC	New European Driving Cycle
MIL	Malfunction Indication Light
OBD	On Board Diagnosis
PTI	Periodic Technical Inspection

8 Signature

The Hague, 14 June 2018	TNO
Peter J. van der Mark Project leader	Gerrit Kadijk Author

A Test results Citroën Xsara, Euro 3

In Table A-1 the specifications of the tested Citroën Xsara are reported.

Table A-1: Vehicle specifications of the Citroën Xsara.

Trade Mark	[-]	Citroën
Type	[-]	Xsara
Body	[-]	Station wagon
Vehicle Class	[-]	M1
Fuel	[-]	Petrol
Vehicle Identification Number	[-]	VF7N2NFU173920273
Engine Calibration ID	[-]	9656393499
Swept Volume	[cm^3]	1587
Max. Power	[kW]	80
Euro Class	[-]	Euro 3
Vehicle Empty Mass	[kg]	1141
Odometer	[km]	154,711
Registration Date	[dd-mm-yy]	14-10-05

Test results of the Citroën Xsara are presented in Table A-2.

Table A-2: Test results of the Citroën Xsara

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100 km]
CADC cold1	8	719	182.0	39	25	6	***0.1***	2.7E+11	7.75
CADC hot1	4	575	176.4	51	33	2	***0.1***	8.2E+10	7.50
CADC hot2	3	522	178.5	48	31	2	***0.1***	1.0E+11	7.58
Urban cold 1	49	1342	291.8	46	25	41	0.2	2.4E+12	12.44
Urban hot 1	9	184	262.9	124	80	5	0.2	2.7E+11	11.13
Urban hot 2	6	318	267.9	70	42	3	0.2	3.5E+11	11.35
Rural cold 1	2	182	152.9	22	9	1	0.2	7.0E+10	6.48
Rural hot 1	1	81	147.9	27	17	1	0.2	4.4E+10	6.26
Rural hot 2	2	378	150.0	32	20	1	0.2	1.2E+11	6.37
Motorway cold 1	6	973	181.7	50	32	3	0.0	8.1E+10	7.75
Motorway hot 1	4	987	180.2	55	34	3	0.0	9.7E+10	7.69
Motorway hot 2	4	660	181.4	56	35	3	0.0	7.3E+10	7.71

Overall emission image of the Citroën Xsara:

The measured CO, THC, NOx and PM CADC emissions of the Euro 3 Citroën Xsara with 155,000 km are below the Euro 3 NEDC limit values and even pass the Euro 6c limit values. From this vehicle no oil consumption data are available.

On the basis of the overall emission performance of this Citroën Xsara no deterioration effects can be identified.

Cold start emissions of the Citroën Xsara:

In the CADC test with cold start the measured CO and THC emissions are elevated in the urban and rural part. This emission behaviour can be marked as normal because after the cold start, the engine runs some time with a rich air-fuel mixture and the three way catalyst is not active because it operates below the light-off temperature

B Test results Toyota Aygo, Euro 5

In Table B-1 the specifications of the tested Toyota Aygo are reported.

Table B-1: Vehicle specifications of the Toyota Aygo

Trade Mark	[-]	Toyota
Type	[-]	Aygo
Body	[-]	Hatchback
Vehicle Class	[-]	M1
Fuel	[-]	petrol
Vehicle Identification Number	[-]	JTDKG12C80N629817
Swept Volume	[cm^3]	998
Max. Power	[kW]	50
Euro Class	[-]	Euro 5
Vehicle Empty Mass	[kg]	780
Odometer	[km]	192,515
Registration Date	[dd-mm-yy]	20-06-12

Test results of the Toyota Aygo are presented in Table B-2.

Table B-2: Test results of the Toyota Aygo

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100 km]
CADC cold1	25	4135	139.4	17	11	20	***1.1***	9.7E+11	6.31
CADC hot1	19	3423	137.6	17	11	15	***1.1***	7.0E+11	6.18
CADC hot2	18	3404	138.2	17	11	14	***1.1***	6.9E+11	6.21
Urban cold 1	48	719	183.4	42	27	45	0.1	9.9E+11	7.99
Urban hot 1	14	204	170.9	42	27	12	0.1	6.6E+11	7.41
Urban hot 2	11	238	170.6	53	34	9	0.1	5.7E+11	7.40
Rural cold 1	8	862	107.4	11	7	7	0.1	4.2E+11	4.70
Rural hot 1	7	759	106.6	11	7	6	0.1	3.9E+11	4.66
Rural hot 2	8	851	107.6	11	7	7	0.1	4.3E+11	4.71
Motorway cold 1	33	7053	153.4	17	11	24	2.1	1.6E+12	7.12
Motorway hot 1	28	5867	152.9	17	11	21	2.1	1.1E+12	7.02
Motorway hot 2	27	5776	153.3	14	9	20	2.1	1.1E+12	7.03

Overall emission image of the Toyota Aygo:

The measured THC, NOx and PM CADC emissions of the Euro 5 Toyota Aygo with 192,515 km are below the Euro 5 NEDC limit values.
The measured CO emission on the highway is 5867 – 7053 mg/km which is caused by the high applied engine load. The measured CO emission of 204 to 862 mg/km in the urban and rural parts are at regular levels. For this vehicle no oil consumption data are available.

On the basis of the overall emission performance of this Toyota Aygo no deterioration effects can be identified.

Cold start emissions of the Toyota Aygo:

In the CADC test with cold start the measured CO and THC emissions are elevated in the urban part. This emission behaviour can be marked as normal because after the cold start the engine runs some time with a rich air-fuel mixture and the three way catalyst is not active because it operates below the light-off temperature.

C Test results Ford Focus, Euro 3

The specifications of the tested Ford Focus are given in table C-1.

Table C-1: Vehicle specifications of the Ford Focus.

Trade Mark	[-]	Ford
Type	[-]	Focus
Body	[-]	Stationwagon
Vehicle Class	[-]	M1
Fuel	[-]	Petrol
Vehicle Identification Number	[-]	WF0NXXGCDN1M28182
Engine Calibration ID	[-]	KP AL 0A 4 HEX
Swept Volume	[cm^3]	1596
Max. Power	[kW]	74
Euro Class	[-]	Euro 3
Vehicle Empty Mass	[kg]	1093
Odometer	[km]	253,425
Registration Date	[dd-mm-yy]	12-07-01

The test results of the Ford Focus are presented in Table C-2.

Table C-2: Test results of the Ford Focus.

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100 km]
CADC cold1	97	2476	173.9	254	165	79	**2.3**	6.1E+12	7.53
CADC hot1	92	2290	171.0	225	146	74	**2.3**	5.1E+12	7.39
CADC hot2	98	2122	173.1	282	184	79	**2.3**	1.0E+13	7.47
Urban cold 1	272	2489	281.5	676	435	230	3.7	3.3E+12	12.11
Urban hot 1	280	2509	255.7	617	392	240	3.7	4.6E+12	11.02
Urban hot 2	344	2638	254.3	818	527	304	3.7	5.5E+12	10.98
Rural cold 1	46	1074	143.2	222	144	33	1.1	4.0E+12	6.13
Rural hot 1	60	1725	142.1	174	112	45	1.1	3.7E+12	6.13
Rural hot 2	50	1203	139.8	192	124	36	1.1	4.3E+12	6.00
Motorway cold 1	100	3442	175.1	196	127	83	2.8	9.6E+12	7.65
Motorway hot 1	79	2640	175.1	188	121	64	2.8	7.6E+12	7.59
Motorway hot 2	85	2657	180.9	244	157	66	2.8	1.8E+13	7.84

Overall emission image of the Ford Focus:

The measured THC CADC emissions of the Euro 3 Ford Focus with 253,425 km is 92-98 mg/km and below the Euro 3 NEDC limit value of 200 mg/km.
The measured CO emission in the CADC tests with a cold start is 2476 mg/km which is just above the NEDC limit value of 2300 mg/km. The PM emissions vary from 1.1 to 3.7 mg/km and are probably mainly caused by the substantial oil consumption of the engine which is 1 litre per 3200 km (281 mg/km).
The NO_x emission in the cold CADC test is 254 mg/km and is more than 1,7 times of the NEDC limit value of 150 mg/km. On the basis of the overall emission performance of this Ford Focus significant NO_x deterioration effects can be identified.

Cold start emissions of the Ford Focus:

The CADC tests with cold and warm start show similar emissions.

D Test results Volkswagen Polo, Euro 4

The specifications of the tested Volkswagen Polo are given in table D-1.

Table D-1: Vehicle specifications of the Volkswagen Polo.

Trade Mark	[-]	Volkswagen
Type	[-]	Polo
Body	[-]	Hatchback
Vehicle Class	[-]	M1
Fuel	[-]	Petrol
Vehicle Identification Number	[-]	WVWZZZ6NZ1Y1163422
Swept Volume	[cm^3]	1390
Max. Power	[kW]	44
Euro Class	[-]	Euro 4
Vehicle Empty Mass	[kg]	996
Odometer	[km]	198,900
Registration Date	[dd-mm-yy]	30-01-2001

The test results of the Volkswagen Polo are presented in table D-2.

Table D-2: Test results of the Volkswagen Polo.

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100km]
CADC cold	53	2500	168	96	60	35	1.5	2.6E+12	7.27
CADC hot	43	2411	165	88	55	26	-	2.6E+12	7.15
Urban cold	131	1525	261.1	133	81	109	2.3	1.25E+12	11.16
Urban hot	27	627	234.3	52	30	12	-	1.2E+12	9.95
Rural	19	992	136.7	33	21	12	0.1	1.5E+12	5.85
Motorway	62	3725	172.1	132	83	38	2.3	3.57E+12	7.53

Overall emission image of the Volkswagen Polo:

The measured THC CADC emissions of the Euro 4 VW Polo with 198,900 km is 53 mg/km and below the Euro 4 NEDC limit value of 100 mg/km.
The measured CO emission of 2500 mg/km in the cold CADC test exceeds the Euro 4 NEDC limit of 1000 mg/km. The measured CO emission on the highway is 3725 mg/km which is caused by the applied high engine load. The measured NO_x emission of 96 mg/km in the CADC test exceeds slightly the Euro 4 NEDC limit of 80 mg/km. The overall PM emission is 1,5 mg/km which can be marked as low. The measured oil consumption of the Volkswagen Polo is around1 litre per 5000 km (180 mg/km).

On the basis of the overall emission performance of this VW Polo, no significant deterioration effects can be identified.

Cold start emissions of the Volkswagen Polo:

In the CADC test with cold start the measured CO and THC emissions are elevated in the urban part. This emission behaviour can be marked as normal because after the cold start the engine runs some time with a rich fuel-air mixture and the catalyst is not active because it operates below the light-off temperature.

E Test results Opel Corsa, Euro 4

The specifications of the tested Opel Corsa are given in table E-1.

Table E-1: Vehicle specifications of the Opel Corsa.

Trade Mark	[-]	Opel
Type	[-]	Corsa
Body	[-]	Hatchback
Vehicle Class	[-]	M1
Fuel	[-]	Petrol
Vehicle Identification Number	[-]	W0L0XCF6818088435
Swept Volume	[cm^3]	1199
Max. Power	[kW]	55
Euro Class	[-]	Euro 4
Vehicle Empty Mass	[kg]	935
Odometer	[km]	219,400
Registration Date	[dd-mm-yy]	30-3-2001

The test results of the Opel Corsa are presented in Table E-2.

Table E-2: Test results of the Opel Corsa.

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100km]
CADC cold	23	724	173.4	375	240	20	3.9	7.3E+12	7.38
CADC hot	16	572	171.6	369	237	14	-	7.3E+12	7.30
Urban cold	79	2383	254.1	341	214	70	10.9	4.4E+12	10.913
Urban hot	12	861	236.1	283	191	9	-	4.7E+12	10.044
Rural	11	523	137.8	170	110	10	3.8	4.2E+12	5.863
Motorway	20	551	182.8	522	334	18	2.6	1.0E+13	7.769

Overall emission image of the Opel Corsa:

The measured THC and CO CADC emissions of the Euro 4 Opel Corsa with 219,400 km are below the Euro 4 NEDC limit values. However the NO_x emission of 375 mg/km is more than 4 times higher than the limit value of 80mg/km. This is probably caused by the EGR (Exhaust Gas Recirculation) valve failure which is indicated by the OBD. The overall PM emission of 3,9 mg/km and in urban traffic 10.9 mg/km which is fairly high. From this vehicle no oil consumption data are available.

On the basis of the overall emission performance of this Opel Corsa clear NO_x deterioration effects can be identified. In daily operation this vehicle was running with the EGR valve failure malfunction. Apparently the dealer did not advise the customer to repair the EGR valve failure. The error had no effect on the driveability of the vehicle.

Cold start emissions of the Opel Corsa:

In the CADC test with cold start the measured CO and THC emissions are elevated in the urban part. This emission behaviour can be marked as normal because after the cold start the engine runs some time with a rich fuel-air mixture and the three way catalyst is not active because it operates below the light-off temperature.

F Test results Fiat Punto, Euro 4

The specifications of the tested Fiat Punto are given in table F-1.

Table F-1: Vehicle specifications of the Fiat Punto.

Trade Mark	[-]	Fiat
Type	[-]	Punto
Body	[-]	Hatchback
Vehicle Class	[-]	M1
Fuel	[-]	Petrol
Vehicle Identification Number	[-]	ZFA18800000586797
Engine Calibration ID	[-]	1037363518001000
Swept Volume	[cm^3]	1242
Max. Power	[kW]	59
Euro Class	[-]	Euro 4
Vehicle Empty Mass	[kg]	910
Odometer	[km]	206,000
Registration Date	[dd-mm-yy]	23-5-2003

The test results of the Fiat Punto are presented in table F-2.

Table F-2: Test results of the Fiat Punto.

	THC	CO	CO2	NOx	NO	NMHC	PM	PN	FC
	[mg/km]		[g/km]	[mg/km]				[#/km]	[l/100km]
CADC cold	138	5133	164.1	1234	800	138	3.7	5.2E+12	7.30
CADC hot	116	5247	162.2	1203	784	116	-	5.2E+12	7.23
Urban cold	541	6695	249.3	1480	962	541	17.8	9.7E+12	11.06
Urban hot	315	7848	229.8	1165	797	315	-	9.6E+12	10.29
Rural	79	3035	134.0	794	519	79	2.7	2.1E+12	5.88
Motorway	104	6292	169.1	1493	964	104	1.8	6.6E+12	7.59

Overall emission image of the Fiat Punto:

The measured THC CADC emission of 138 mg/km of the Euro 4 Fiat Punto with 206,000 km is higher than the Euro 4 NEDC limit value of 100 mg/km. Especially the THC emission of 541 mg/km in the urban part is relatively high. The measured CO emission in the CADC tests with a cold start is 5133 mg/km and is probably mainly caused by the relative high applied load of the chassis dynamometer.
The NOx emission in the cold CADC test is 1234 mg/km and is more than 15 times higher than the NEDC limit value of 80 mg/km. The PM emission over the CADC parts varies from 1.8 to 17.8 mg/km. The high urban PM emission of 17.8 mg/km is possibly caused by the relative high oil consumption of the engine which is around 1 litre per 4000 km (225 mg/km). The maintenance file of the vehicle was available and up to an odometer reading of 190,000 km the vehicle was maintained well.

On the basis of the overall emission performance of this Fiat Punto significant NO_x, THC and PM deterioration effects can be identified.

Cold start emissions of the Fiat Punto:

The CADC test with cold and warm start have similar CO, NO_x and PN emissions, The THC emission of the urban test with cold start is 40% higher than this emission with a warm start.

G Specification of the chassis dynometer

The laboratory performs accredited emission tests according to ISO 17025 standards.

The following measuring equipment is installed on the chassis dynamo test bench:

Chassis Test Cell

Air conditioning
Weiss Umwelttechnik
cooling perfomance 150 kW
air circulation 30.000 m³/h
fresh air 2.000 m³/h
CVS-dilution air 1.200 m³/h
waist air 2.000 –
4.000 m³/h

Chassis Dynamometer
VULCAN II EMS-CD48L 4WD
max. speed 200 km/h
max. capacity/power 2 x 155 kW
wheel base 1800 – 3400 mm
max. axle load 2.500 kg
Fan LTG VQF 500/1250

Exhaust Measurement Equipment
MEXA ONE D1-EGR
Exhaust gas analyser,
Undiluted (direct) for:
O_2, CO, CO_2, NO_x/NO, THC and CH4,
separate EGR-Analyser

MEXA ONE C2-OV
Exhaust gas analyser,
dilute bag & continuous measurement
for: O_2, CO, CO_2, NO_x/NO, THC, CH4.

Heated Bag Cabinet
with 3 x 4 emission bags for
ambient air-, gasoline– and
diesel measuring.

MEXA 2100 SPCS
Measures solid particle number concentration
in raw engine exhaust gas in real time, within a
specified particle size range (UN/ECE Regulation.

- **Horiba MEXA ONE D1-EGR**, Exhaust Gas Analysing System for direct measurement
  (1-line) with following analysers: O_2, CO, CO_2, NO_x/NO, THC, CH4 and separate EGR-Analyser.
- **Horiba MEXA ONE C2-OV**, Exhaust Gas Analysing System for dilute bag & continuous measurement with following analysers: O_2, CO, CO_2, NO_x/NO, THC, CH4.
- **Horiba MEXA 2100 SPCS**, Solid Particle Counting System.
- **Horiba MEXA ONE CVS**, Constant Volume Sampler System, 6 m^3/min to 18 m^3/h.
- **Horiba DLS 7000**, Particulate Measuring System with Dilution Tunnel DLT 18.
- Different temperature and pressure regulators (according to the test application), max. 16 temperature inputs (Type K) and 8 voltage- and current analog inputs.
- **Horiba VETS One**,Host Computer and evaluation of measuring data with DIVA.
- **Horiba PWS-ONE**, Particle measurement and conditioning chamber with micro balance and robot.