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## **On-board emission measurement of high loaded light duty vehicles in Algeria**

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### **ABSTRACT**

*A sample of eight private gasoline and diesel conventional light-duty vehicles (LDVs) in use with various ages, carrying a load of 460 kg, were tested on a representative trip in the traffic flow of the city of Blida to obtain emission factors representing the actual use conditions of Algerian LDVs. The gas sampling system (mini-constant volume sampling) as well as the analyzers are carried on-board the vehicle. Around 55 tests were conducted during 3 months covering more than 480 km under various real driving conditions. The mean speed downtown is about 16.1 km/hr with a rather low acceleration, an average of 0.60 m/sec<sup>2</sup>. For each test, kinematics are recorded as well as the analysis of the four emitted pollutants carbon dioxide, carbon monoxide, oxides of nitrogen, and total hydrocarbons. Emission factors were evaluated according to speed for each category of gasoline and diesel engines. The influence of some parameters such as cold/hot start, age of vehicle and its state of maintenance are discussed. Results are compared with the European database ARTEMIS for comparable vehicles. These measurements contribute to the development of unit emission of the vehicles used in Algeria, which are necessary for the calculation of emission inventory of pollutants and greenhouse gases from the road transportation sector. The unit emissions constitute a tool of decision making aid regarding the conception of new regulations of vehicle control and inspection in Algeria and even in similar developing countries.*

### **INTRODUCTION**

All the Maghreb countries are sensitive to the air quality deterioration in urban cities and the side effects on human health and the environment due to road traffic emissions (Azri et al., 2002; Nejjari et al., 2003, Atek et al., 2004). As a result, many stations of air pollution measurement and control have been installed in Algeria, Tunisia, and Morocco (Ouldbba, 2002; Worldbank, 2004; Aoudia and Boukadoum, 2005). Vehicle pollutant emissions constitute not only a problem of air quality in big cities such as Algiers (Mayer, 1999; Kerbachi et al., 2003, 2006; Boughedaoui et al., 2004) but also a source of a constant growing greenhouse gases (GHG) particularly in developing countries (Schafer, 2000; Sausen et al., 1998; Metz, 2005, Corvalan and Urrutia, 2000; Badami, 2005). Thus unit emission factors of each vehicle category become crucial for all new policies of road transportation, traffic management and any use of air quality models.

The default emission factor of the various international databases like IPCC ([www.ipcc-nggip.iges.or.jp/EFDB](http://www.ipcc-nggip.iges.or.jp/EFDB)), CORINAIR ([www.air.sk/projects/corinair/e\\_reporter.html](http://www.air.sk/projects/corinair/e_reporter.html)), COPERT (<http://lat.eng.auth.gr/copert>), Artemis ([www.trl.co.uk/artemis](http://www.trl.co.uk/artemis)), MOBILE ([www.epa.gov/otaq](http://www.epa.gov/otaq))

are not realistic for developing countries and are the source of over or under estimate of pollutant emissions (Corvalan and Urrutia , 2000; Van Rymbeke, 1991). Emission factors coming from a given country could be representative on a regional scale when there are strong socio-economic, environmental, and car fleet similarities as it is for the three countries of the Maghreb: Algeria, Morocco and Tunisia. The development of specific emission factors based on national data is encouraged by the Intergovernmental Panel on Climate Change (IPCC, 2000) in order to reduce uncertainties on the GHG inventory to comply to the United nations framework convention on climate change (UNFCCC). After the Kyoto protocol entered into force in February 2005, potential GHG emission reduction is being sought where its estimation is based on the calculation of a baseline using the emission factors. The standardized methodology used to evaluate the vehicle emission factors is based on the Constant Volume Sampling (CVS) using the chassis dynamometer for measurement in a laboratory (Joumard, 1987) by reproducing driving cycles, legislated or representative of the real situations. On road remote sensing (Sjödin and Andréasson, 2000; Chan et al., 2004) is also carried out with vehicle identification by their license plate and access to central vehicle databases. This technique allows the measurement of a large number of vehicles but cannot evaluate the vehicle load rate with precision. Both of these two and similar methods are not adapted to many developing countries because of lack of equipped laboratories with CVS and chassis dynamometer which are expensive and database for vehicle identification is not easily accessible.

However several alternative measurement techniques with on-board instrumentation are developed for scientific purposes (Van Ruymbeke, 1993; Lenaers, 1996; Staab and Schuermann, 1987; Vojtisek-Lom and Cobb, 1997; Kvatch et al., 1998; Holmén and Niemeier, 1998; Frey et al., 2001; Miyazaki et al., 2003). Results obtained using on-board measurements in real circulation showed emission differences between realistic emission factors compared to CVS's in Europe and USA (Pierson et al., 1990; De Vlieger, 1997). It is possible with this methodology to measure vehicle emissions in sites whose specific conditions are not easily reproducible in a laboratory. It also eliminates the uncertainties caused by the reproduction of real conditions at a laboratory like the bench calibration, the engine cooling, the state of the roadway, the real environment of the vehicle, the ambient temperature, the sunning, and especially the driving behavior. However the method must be rigorous for a representative driving pattern which consequently requires a lot of experimentation time. Several studies showed the reliability of on-board measurement compared to tests in laboratories (Van Ruymbeke, 1991; Cadle et al., 2003). The mini CVS has been tested by three laboratories (WSL; UTAC, INRETS) using ECE-15 hot cycle showed an average deviation between mini-CVS and CVS of -3.4% for CO, -2.0 for NOx and -9.7% for HC and a variation for all pollutants and all tests range between -15% to +1%. Compare to CVS, the mini-CVS underestimate emissions by an average of -5%. These techniques are well adapted for developing countries and have a double advantage of being relatively cheap and not requiring a prerequisite driving cycle development which takes a long time to obtain.

Several works were conducted on Light Duty Vehicles (LDVs) to characterize their emissions and the influence of many parameters like load rate (Samaras and Ntziachristos, 1998; Joumard et al., 2001, 2003; Behrentz et al., 2004; Markewitz and Joumard, 2005, 2006; El Shawarby et al., 2005). Zallinger and Hausberger (2004) studied the effect of the load on personal cars with a maximum loading of 450 kg for an engine capacity between 1.2 to 2.1 L for gasoline and diesel. The effect of load was highlighted only for the diesel vehicles and only for NOx and particles. The emission variation of the other pollutants due to the load is of the same order as their standard deviation. Corvalan and Vargas (2003) showed that degradation of pollutant emission is related to vehicle global mileage and speed which depend on local traffic conditions. Total hydrocarbons (THC) emission measurements of 3-way catalyst equipped vehicles in Santiago (Chile) depict degradation factors 2 to 2.8 times higher than models such as COPERT and US EPA AP-42. This result points out the local measurement importance to develop national

emission factors. Artemis is an European database which gathers data of European vehicle emission measurements from various laboratories, including the majority of the LDV make and models used in Algeria. However, Algerian vehicles do not comply with the European standards and are not driven in similar conditions. This permits access to carry out comparison studies on vehicles of the same origin but subjected to different use and environmental factors.

This work aims to measure the emission factor of loaded LDVs of more than 50% which are largely used in Algeria and in the Maghreb (Boughedaoui et al., 2006). It contributes to enrich the knowledge on vehicle emissions and give decision makers the real data for this highly loaded category of vehicles.

## **TRAFFIC CHARACTERISTICS**

Facing a low supply at high cost of goods transportation in Algeria and given their flexibility and compactness, individuals and professionals prefer investing in LDVs. They are often equipped with back folding seats and have a double use, private and commercial, making this type of vehicle run an important mileage with an average load of 20 - 30% of the maximum according to surveys carried out. LDV average annual mileage is 38,000 km for vehicles less than 5 years according to our survey carried out in 2001 in Algiers and Blida on a sample of 935 vehicles. This annual mileage decreases according to age and remains higher than the European mileage for all ages as shown in figure 1 (Hickman et al., 1999; André et al., 1999; Adra and André, 2004). The LDV life is longer than in Europe with an average age of 10 years and a weak level of maintenance. The Algerian fleet counts more than 3 millions vehicles, the LDVs account for 21%, where 79% are European make and only 17% from Asia. According to the 2005 statistics office (ONS, 2006), the mean life of the LDV administrative fleet, which include all the recorded vehicles based on their license, is 17.8 and 15.4 years respectively for Blida and Algiers. A vehicle survey on road was carried out during 2005 by visual observation of more than 65,000 vehicles during one week including weekends in eight selected places in the cities of Blida and Algiers. In Algeria, the year of the first setting of a vehicle is indicated on the license plate, where the identification of its age is made easy. The results show the LDVs account for 11% and 15% of the vehicle flow with an average age of 9.3 and 10.2 years in the two cities respectively. This highlights the existing difference between the ONS administrative fleet and the running one which one can have an image on the road at a given time.

## **METHODOLOGY**

On-board emission measurements are performed with the mini-CVS on a sample of 8 vehicles where kinematics and 4 pollutant ( $\text{CO}_2$ , CO, HCT,  $\text{NO}_x$ ) measurements are recorded. The mini-CVS is a simplified system similar to the CVS for sampling the vehicles gas exhaust which has been developed by TRL, UK, for which the reliability has been tested and validated by TRL and INRETS (Potter, 1987; Van Ruymbeke, 1993). The device used in this study has been modified by adding analyzers to measure instantaneous emissions. The sampling system is on-board the vehicle and connected to the tailpipe. The exhaust gases emitted by the vehicle pass in a cone attached to the muffler; the end is made of 112 small parallel tubes. Only the gases of one tube are brought to the dilution chamber, the other beams are being rejected outside. The fraction of gas taken is proportional to the number of tubes. At this stage, the admitted assumption is that the primary flow is supposed to be equally divided into 112 flows. Figures 2 show the experimental apparatus with all the equipment aboard.

Using six pumps assembled parallel to one another; the exhaust gas is sampled and diluted in a mixing tube. Dilution air is taken from the ambient air at the same height from the ground as the tailpipe but symmetrically opposite with the axis of the vehicle, in order to avoid high polluted air and any disturbance due to the difference of pressure or turbulence at the back of the vehicle. The dilution air flow varies and is not measured; only the diluted gas mixture flow is measured

and maintained constant at 300 l/min. A fraction of the diluted mixture is taken by a seventh independent pump with an adjustable flow and divided again in three flows equivalent of 85 l/min each, by a three way distributor, which are directed towards analyzers of CO/CO<sub>2</sub>, HCT and NO<sub>x</sub>. An eighth independent pump is used for taking a sample of the used dilution air in a Tedlar bag of 70 liters at a flow of 1 l/min to be analyzed.

Carbon dioxide (CO<sub>2</sub>) and monoxide (CO) are measured by an Infrared absorption (Cristal 300), nitrogen oxides (NO<sub>x</sub>) are analyzed by a chemiluminescence (Topaze 3010) mono room, and a heated flame ionization detector (Graphite 750) is used for the total hydrocarbons (THC). All the apparatuses are supplied by Cosma - Environnement SA (France). Calibration of all analyzers is made every day preceding the first measurement with 99.5% pure calibrated gases supplied by Air Liquide Company (France). Vehicle speed is recorded during the trip with a precision of 0.1 km/h using a calibrated Doppler speed sensor DRS-6/1aa supplied by BS2 Multidata GmbH (Germany). Electricity is provided to analyzers by a power generator unit (2.2 kVA). A 12 Volt battery (200 Ah) supplies continuous current to minis-CVS. To avoid any influence on the engine load, no electric connection is used on the vehicle battery. Tests are conducted with all material on-board for final calibration: to find the ranges of instantaneous emissions, to check the stability of different flows of gas circuit on road in real circulation, and to check the analyzers stability by the injection of calibrated gases. The total load of the equipment and accessories aboard the vehicle is 460 kg.

### **Vehicle sample**

A sample of 8 LDVs, less than 1.2 tons of category NI-1, is selected within the private Algerian running fleet, including 2 gasoline vehicles of 1.4 L and 6 diesel vehicles between 1.6 and 1.9 l. The 2 vehicles from the years 1993 and 1996 underwent repairs of their engine by their owner right before the measurement campaign. The 2 gasoline vehicles are rather old because the new LDVs are rarely powered by gasoline and a small number is put in the market; there has been a strong tendency towards their dieselization during the last decade. This is due to the low cost of gas oil of 13.70 DA/l (US\$ 0.19/l) compared to gasoline which costs 23 DA/l (US\$ 0.32/l). The size of our sample is comparable to the sample size of the Artemis database which gathers 30 vehicles of category NI-1 emission tests of different European laboratories. The global load of 460 kg including the driver corresponds to loads of 60 and 43 % respectively for the tested gasoline and diesel vehicles. These loads are relatively high compared to the published literature of emission measurements. There is no exhaust emission homologation procedure for new vehicles sold in Algeria. As there are no regulations to comply with any kind of standards, vehicle suppliers do not reveal the standards (Car manufacturers escape from this question and do not reveal this information to date). This raises a real problem for any emission evaluation or data comparison. The only available reference is the year of setting in traffic which does not inform the standard. In any case, gasoline tested vehicles are not equipped with 3-way catalyst and diesel are not equipped with oxidation catalyst nor with a particle filter.

### **Measurement campaign**

The measurement campaign occurred at Blida between September and November 2005. The wilaya of Blida accounts for 780,000 inhabitants and is located 50 km south of Algiers the capital. The car fleet of Blida is the second most important in the country after the Algiers' with 6.4% from the national fleet and 7.7% of the LDVs (ONS, 2006). Blida constitutes an important agricultural, commercial and industrial zone. It is also a passing area from north to south and from east to west. The topography of the city presents an average slope of 1.5%. The trip is selected to represent the arteries and the streets that are most used in Blida. The trip length is about 6.4 km selected on the basis of more than 1000 km of recorded kinematics carried out by a shadowed vehicle and is drowned in city traffic flow (Boughedaoui et al., 1999). Each vehicle is submitted to 5 to 13 urban tests at the same period of the day, which gives a total number of 55

urban tests for all the measurements corresponding to more than 480 km (table 1). Moreover, each vehicle is also tested on suburban road and highway, where the speed limit is 80 km/h on trips of length up to 15 km. The average ambient temperature of all the tests is 22.8°C close to Artemis's average of 23°C. Without any preliminary maintenance, the first test of each vehicle stopped all night constitutes a cold measurement which is conducted under the same conditions as the hot tests. The vehicle is drowned in the traffic flow of the selected trip and is driven by only one driver in order to eliminate variability associated to driver behavior which can be significant according to Holmèn and Niemeier (1998). Instructions are given to the driver to reproduce the shadowed vehicle kinematics as accurate as possible while in the flow avoiding extreme behaviors.

## RESULTS

For each vehicle test, mean values correspond to the average of test results (table 2). These averages are thus representative of the tests carried out and could be higher considering the underestimation of the gas sampling technique used by around -5% compared to CVS. The relative standard deviation is about 33% for all tests and pollutants. These standard deviations are probably due to the kinematics differences between tests. Facing the lack of emission standards and former data of vehicle emissions in Algeria, we seek to compare our results with the emission levels of the European vehicles of the Artemis model for equivalent vehicles (Markewitz and Joumard, 2005, 2006). For these vehicles, the average fuel consumption of Artemis is calculated using consumption data of their base while their emissions are calculated using for the same speed and load as in our tests.

### Hot emissions

The comparison with the emissions of the Artemis model highlights that:

- Our gasoline vehicles are close to the European vehicles pre-Euro. We thus qualify them pseudo Pre-Euro.
- The diesel vehicles from the years 1993 and 1996 have emissions close to those of the European vehicles meeting the standard Euro I (figure 3); the other diesel vehicles have emissions close to the standard Euro II. We thus qualify them respectively pseudo Euro I and pseudo Euro II which enables us to distribute our diesel vehicles sample in two groups.

Our sample of vehicles tested can thus be divided into three subsamples: 2 gasoline LDVs pseudo Pre-Euro, 2 diesel LDVs pseudo Euro I, and 4 diesel LDVs pseudo Euro II. The average emission factors rise for these subsamples respectively to 123.4, 143.5 and 167.4 g/km for CO<sub>2</sub>, 11.99, 0.68 and 0.49 g/km for CO, 1.42, 0.08 and 0.05 g/km for the THC and of 1.14, 0.59 and 0.48 g/km for NO<sub>x</sub> (table 2). The results of the CO unit emissions according to the average speed tests are presented in figures 4 - 6 for the gasoline and the diesel vehicles. The NO<sub>x</sub> emissions vary from 0.19 to 1.6 g/km for all vehicles, gasoline and diesel, but remain low in front of Artemis emissions Euro I and Euro II. These low emissions are probably due to the low acceleration observed during the tests because of the road environment and the high load which does not facilitate high acceleration. Osses et al. (2002) showed NO<sub>x</sub> are better correlated with positive acceleration rather than speed for non catalyzed vehicles when the work of Joumard et al. (2006) demonstrated that NO<sub>x</sub> and CO<sub>2</sub> emissions for LDVs are very sensitive to the acceleration frequency and high acceleration.

*Gasoline vehicles,* The CO<sub>2</sub> emissions for gasoline vehicles are lower than 125 g/km with an average of 123.4 g/km which remain lower than Artemis Pre-Euro which is characterized by levels higher than 180 g/km for all speeds. The CO emissions have an average of 12 g/km, which decrease quickly with speed to a minimum of 6.5 g/km at the speed of 55 km/h. The variation of these emissions according to the average speed is similar to that of Artemis which has an average

level of 10.4 g/km. The THC average emissions rise to 1.4 g/km and remain close to the Artemis emissions. The NOx emissions grow proportionally with speed and vary from 0.55 to 1.6 g/km with a mean level of 1.1 g/km, but remain lower than the Artemis values which vary from 1 to 3.2 g/km according to the speed. This variation is undoubtedly due to the weak accelerations practiced with a maximum in the urban environment of 0.60 m/s<sup>2</sup>. The positive average acceleration of urban cycles of loaded LDVs of Artemis is 0.76 m/s<sup>2</sup> (André, 2004) and thus rather higher. Recorded accelerations are weak because of not only the strong load but of the traffic congestion and urban conditions as well. The emission factors obtained on the tested sample show that CO and THC emissions of the gasoline LDVs are comparable with the Artemis Pre-Euro emissions but there is a difference between the NOx emissions.

*Diesel vehicles,* The CO<sub>2</sub> diesel emission average is 155.4 g/km which is much lower than Artemis Euro I and Euro II. The low emission levels of the pseudo Euro I group vehicles is undoubtedly due to the recent replacement of engine parts made on these vehicles. The emissions of the pseudo Euro II group remain close to Artemis Euro II. These last vehicles did not undergo modification of their engine. The average CO emission is 0.58 g/km which lies between the Artemis Euro I and Euro II values. The group pseudo Euro I shows emission levels appreciably lower than Artemis Euro I levels while those of the group pseudo Euro II coincide with Artemis Euro II. The THC are emitted with an average of 0.06 g/km for the entire sample and remain included between Artemis Euro I and Euro II. The average of the group pseudo Euro I is 0.08 g/km and that of the group pseudo Euro II is 0.05 g/km. The average NOx emission is 0.53 g/km with tendencies similar to the variations of the Artemis emissions for the two groups pseudo Euro I and pseudo Euro II. Broadly the diesel vehicle emissions are comparable with the Artemis emission which supports the assumption formulated with respect to the standards of the vehicles tested. The existing differences can be due to the environment and conditions of use in which these vehicles evolve.

*Ratios,* The ratio CO/CO<sub>2</sub> and HCT/CO<sub>2</sub> indicate the state of the maintenance of vehicles (Pierson et al., 1996), low ratio reveals good maintenance of the vehicle. The ratio comparison with Artemis (table 3) shows wider intervals for the same vehicles measured in Europe. The vehicle from the year 1996 has been repaired thereafter presents a ratio (HCT/CO<sub>2</sub>) of 0.016% close to the ratio of the vehicle from 2004 which is 0.013%. This highlights the importance of maintenance for the reduction of the pollutant emissions.

### **Cold overemissions**

The mass difference of pollutant emitted by cold and hot tests for the same trip with a close mean speed represents absolute cold overemission (table 4). Rated by the unit hot emission, this absolute emission is expressed in an equivalent distance run with a hot engine. In other words, it is the distance necessary for a hot engine to emit the same mass of pollutant as the cold overemission. This distance does not have any relation with the cold distance, rather this explains the distance necessary to reach a hot engine. On the other hand it expresses the weight of cold emission compared to hot emission. This equivalent distance is variable according to the pollutant and the vehicle: the maximum value reached is 83 and 90 km for the cold emission of CO and THC for a diesel vehicle respectively. The CO<sub>2</sub> emission is equivalent to 6.2 km for gasoline vehicles and to 4.5 km for diesel. For CO, it is respectively 28.2 and 23.7 km, for the THC it is 22.7 and 27.7 km, and for the NOx it is – 1.7 km for the gasoline, and of 4.1 km for the diesel. A negative distance means that we are in the presence of an under-emission. The cold emission is thus particularly important for CO and THC, moderate for CO<sub>2</sub>, and low for NOx. On average for all pollutants, the cold emission represents the equivalent of 13.8 km for gasoline vehicles and 15.4 km for the diesel which is thus of comparable relative importance for the two fuels.

## Fuel consumption

The average fuel consumption of gasoline and diesel vehicles pseudo Euro I and pseudo Euro II are reported on table 2. The consumption of gasoline vehicles remains lower than that Artemis which is 68.9 g/km. On the other hand the consumption of the diesels pseudo Euro I is comparable with Artemis which is 54.5 g/km whereas the group pseudo Euro II has a higher consumption. These consumption variations can be due to weak acceleration but also to the repair of the vehicles pseudo Euro I. The driving conditions and high load could also play a role which will be studied in future work.

## DISCUSSION AND CONCLUSION

For the first time in Algeria, emission factor measurements are undertaken on high loaded LDVs with diesel and gasoline fuels. Hot emission factors are compared with emissions of equivalent vehicles tested in Europe using the European model Artemis. One of the difficulties that appeared during this comparison is the absence of the emission standards for the vehicles put on the Algerian vehicle market. The comparison enables us to evaluate the European standard to which emissions of each vehicle correspond. When compared to Algerian vehicles at equal age, Algerian vehicles would thus show a delay of zero standards for vehicles before 2001 and to one the standards for those after 2000. Measurements also enable us to evaluate cold overemissions which are compared to hot emissions, and cold behavior of gasoline vehicles which hardly differs from the diesel's. The small sample of 8 vehicles tested is comparable with samples of European laboratories. Nevertheless, interpretation thus remains limited, in particular the comparison with the vehicles used in Europe, because the load is more important than those used in Artemis and the average mileage of the tested vehicles of our sample is high at 696 and 163 Mm respectively for the gasoline and diesel vehicles. LDVs from the Algerian fleet run important annual mileage exceeding 38 Mm and have an average lifespan of 10 years. The effect of the load can be highlighted only when compared with unloaded vehicle measurements, which could not be done in this case because of the important weight of all the equipment embarked on-board. We thus plan in future works to sample gases in Tedlar bags but not to analyze them on-board, which will reduce the minimal load considerably, and thus to study the intrinsic effect of load on LDV emissions. These evaluations are necessary to improve the inventories of emissions of GHG and pollutants from road transport sector, which constitutes an essential input data for air quality models. Because of many differences of developing countries regarding the use of vehicles (lack of standard, age and condition of the vehicle use, transportation system, etc.) inventory models designed in developed countries are often inaccurate for them. Future research tasks should use an extended vehicle sample more representative of the Algerian fleet and evaluate the emission degradation with age and load, as well as the emission of the various LDV classes.

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Table 1: kinematics of the urban trips

Parameters	Speed average (km/h)	V <sub>max</sub> (km/h)	Stop Time (% total time trip duration)	Stops Number	Average positive acceleration (m/s <sup>-2</sup> )	Trip duration (s)	Average trip length (m)
Average (standard deviation)	16.1 (3.5)	50.5 (6.4)	20 (9)	20.5 (15.3)	0.60 (0.04)	1339 (233)	6370 (0.17)

Table 2: Average and standard deviation emissions of tested vehicles

Fuel	Vehicle year	Average emission (g/km)					Relative standard deviation (%)					
		CO <sub>2</sub>	CO	HCT	NO <sub>x</sub>	Consumption	CO <sub>2</sub>	CO	HCT	NO <sub>x</sub>	Average for all pollutants	Consumption
Gasoline	Average pseudo Pre-Euro	123,4	11,99	1,42	1,14	57,4	16	32	25	31	26	24
Gas oil	Average pseudo Euro I	143,5	0,68	0,08	0,59	55,0	18	59	65	19	40	21
	average pseudo Euro II	167,4	0,49	0,05	0,48	62,3	11	25	39	30	26	23

Table 3: Pollutant emission ratios comparison between measurements and Artemis (%)

Fuel	Measurement			Artemis		
	Pseudo standards	CO/CO <sub>2</sub>	HCT/CO <sub>2</sub>	CO/CO <sub>2</sub>	HCT/CO <sub>2</sub>	EU standards
Gasoline	Pseudo Pre-Euro	4,7 – 17,8	0,9 - 2,6	1,7 - 20	0,28 - 1,2	Pre-Euro
Gas oil	Pseudo Euro I	0,28 - 1,23	0,016 - 0,302	0,14 - 0,4	0,005 - 0,087	Euro I
	Pseudo Euro II	0,04 – 2,6	0,007 - 1,195	0,10 - 0,5	0,016 - 0,2	Euro II

Table 4: Average cold (g/test), hot (g/km) and equivalent distance (km) emissions on urban trip.  
The hot equivalent distance is the corresponding distance of the ratio of absolute cold emission (g) to unit hot emission (g/km).

Fuel	Average speed (Standard deviation)	Average load rate	CO <sub>2</sub>		CO		THC		NO <sub>x</sub>	
			Cold	Hot equivalent	Cold	Hot equivalent	Cold	Hot equivalent	Cold	Hot equivalent
	(km/h)	(%)	(g/test)	(km)	(g/test)	(km)	(g/test)	(km)	(g/test)	(km)
Gasoline	12.14 (0.76)	60	1532.2	6,18	415.43	28,18	40.51	22,67	5.41	-1,67
Gas oil	13.81 (0.96)	48.7	1742.9	4,46	14.57	23,73	2.18	27,68	5.43	4,08

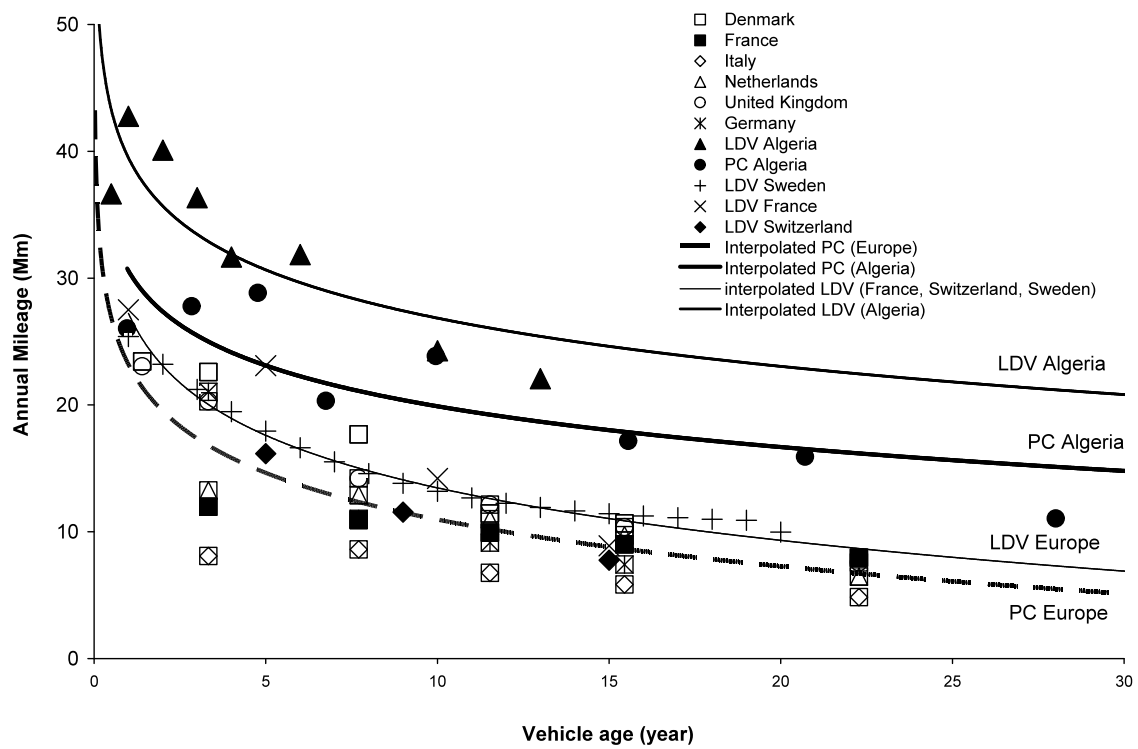


Figure 1: Comparison of annual mileage between LDV and PC in Algeria and Europe

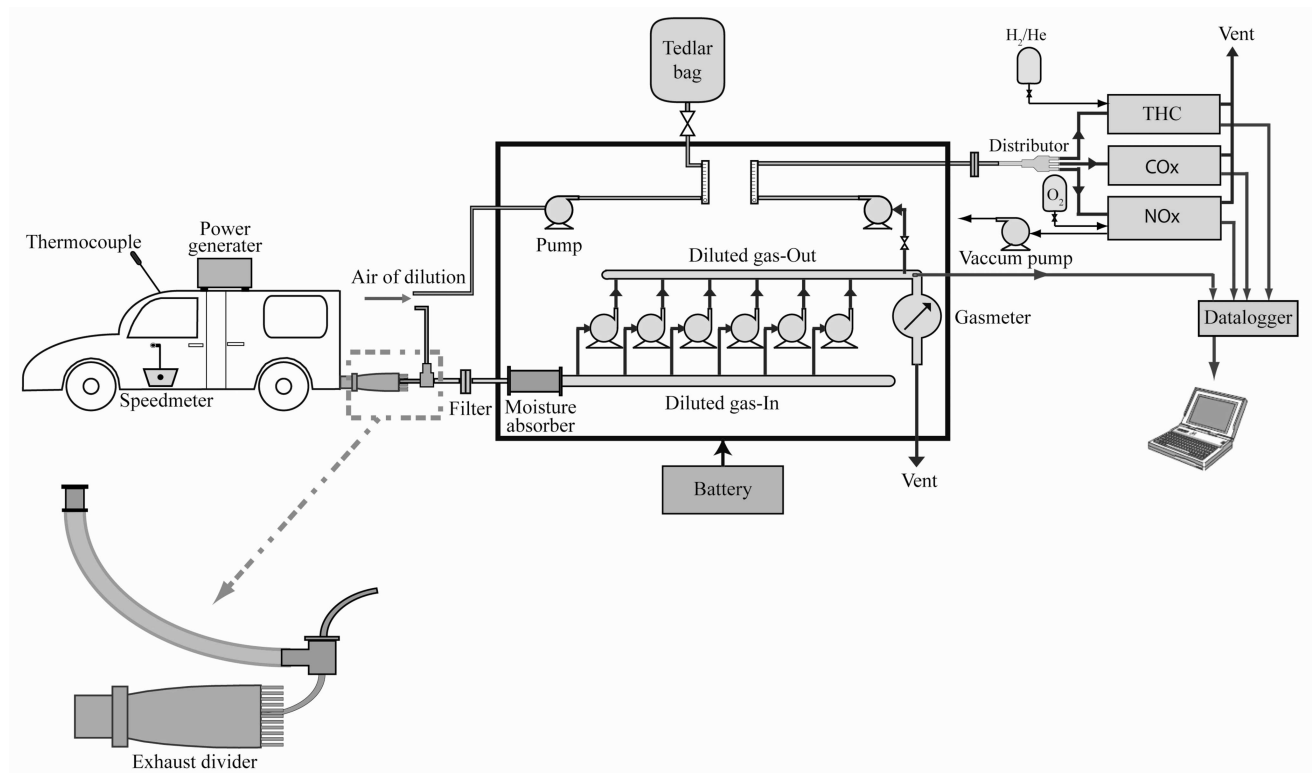


Figure 2 a: On-board sampling and measurement system scheme



Figure 2 b: A photo of the on-board instrumentation system

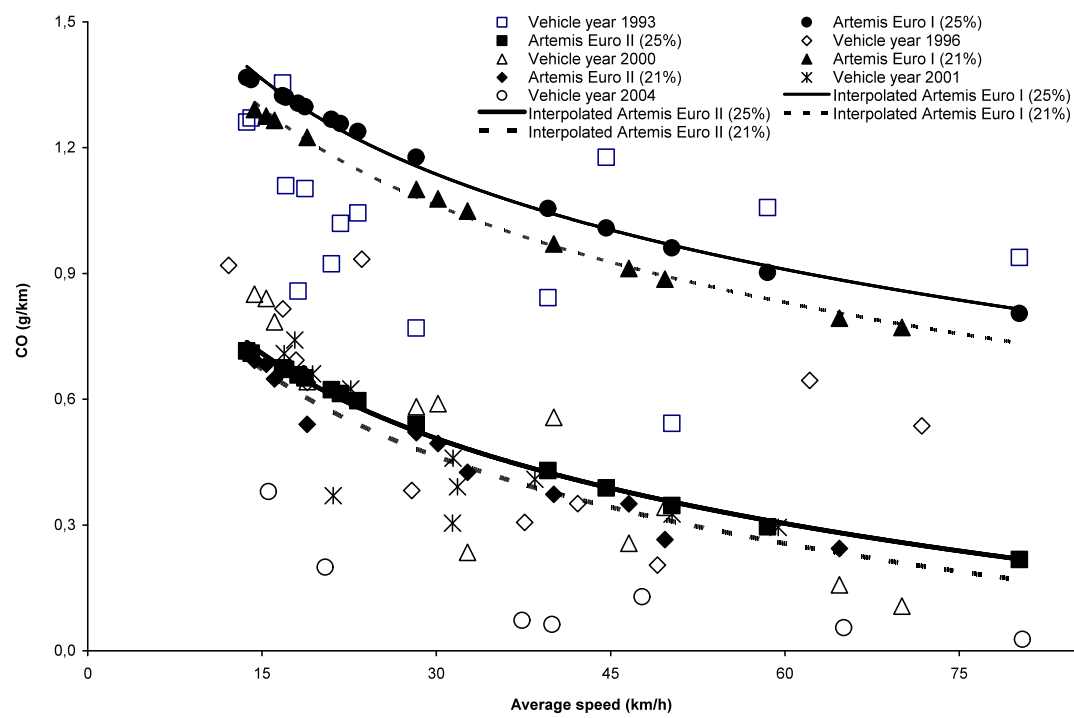


Figure 3: CO unit emissions of diesel loaded LDV compared to Artemis emissions for all tested vehicles

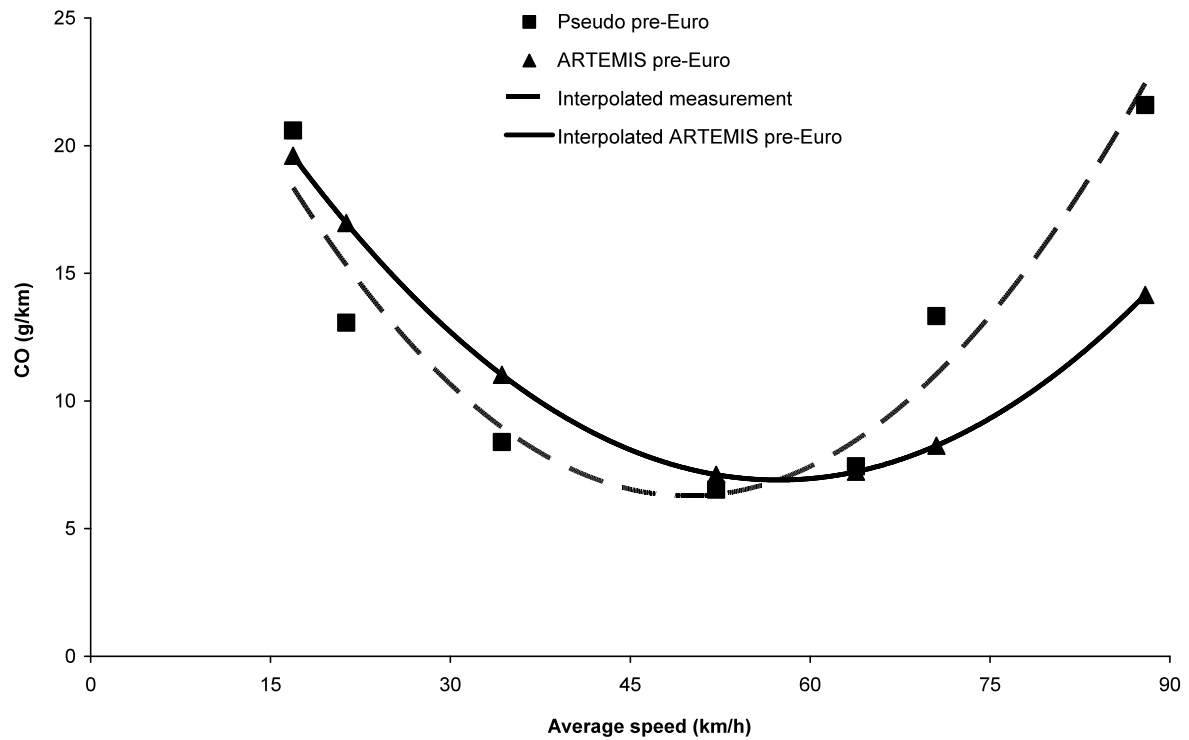


Figure 4: CO unit emissions of pseudo Pre-Euro gasoline loaded LDV compared to Artemis emissions

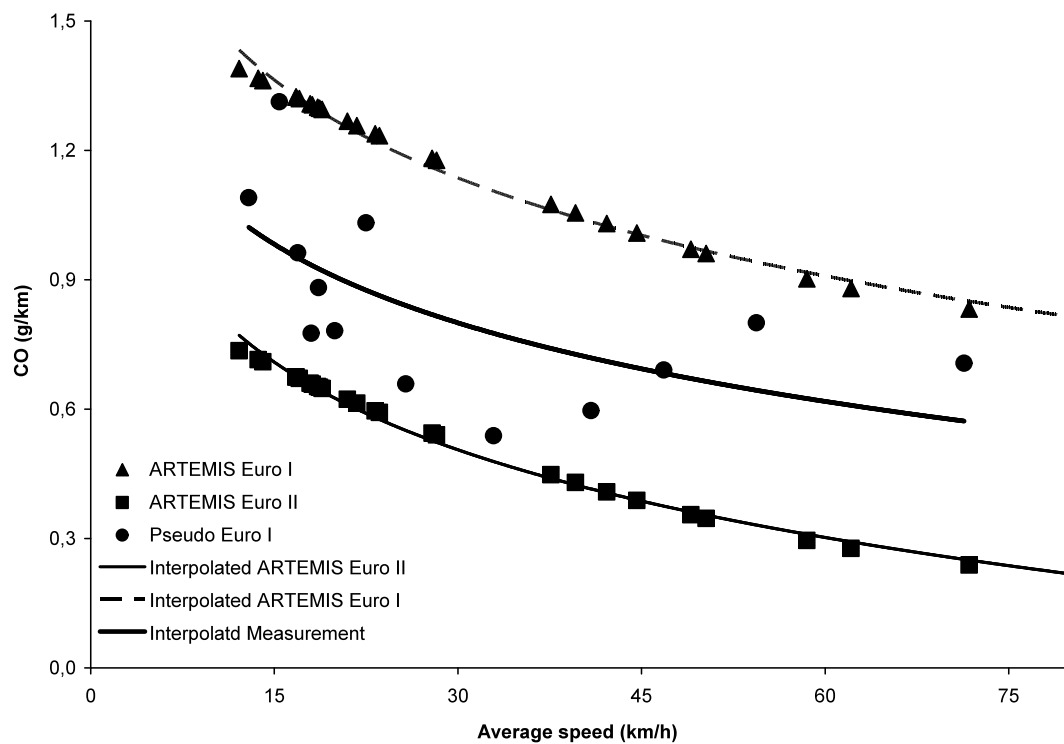


Figure 5: CO unit emissions of pseudo Euro I diesel loaded LDV compared to Artemis emissions



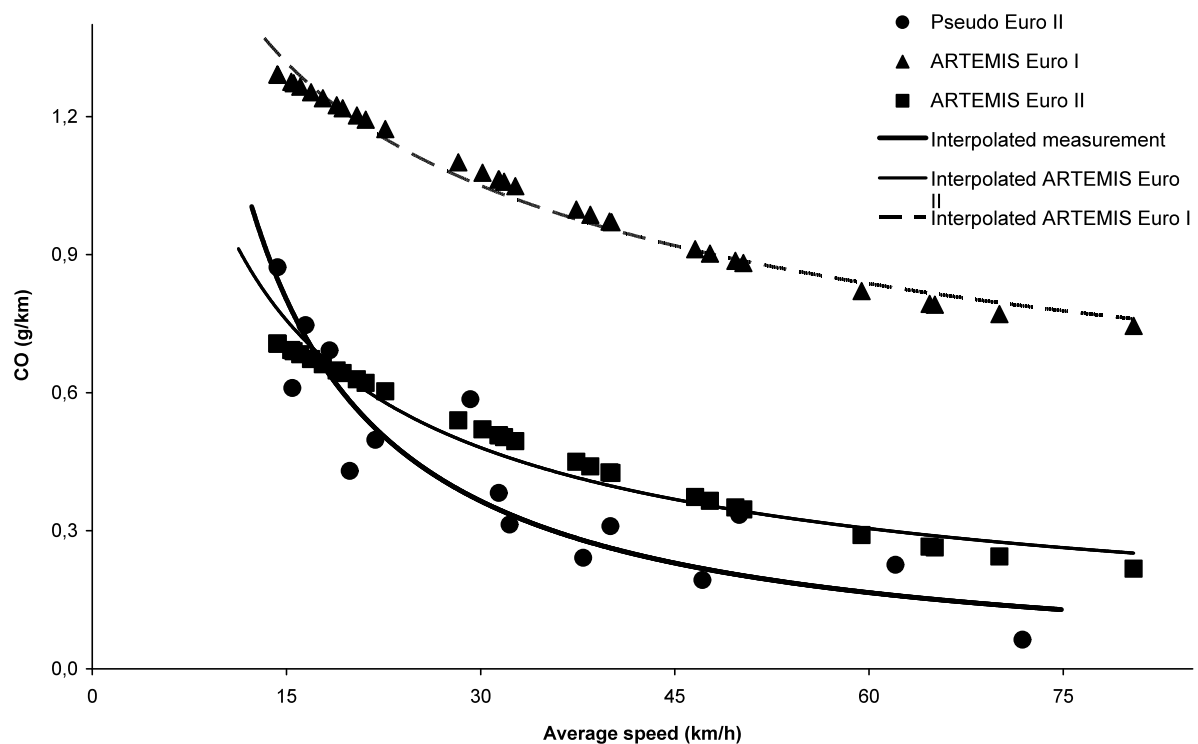


Figure 6: CO unit emissions of pseudo Euro II diesel loaded LDV compared to Artemis emissions

### Abbreviations

IPCC: Intergovernmental Panel of Climate Change

ONS: Office National de Statistiques, Algiers

Mini-CVS: A reduced system for constant volume sampling

UTAC: Union Technique de l'Automobile du Motorcycle et du Cycle, Paris, France

WSL : Warren Spring Laboratory, UK

INRETS: Intitut National de Recherche sur les Transports et leur Sécurité, France

TRL: Transport Research Laboratory, UK

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