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Use of portable emissions measurement system (PEMS) for the development and validation of passenger car emission factors ☆

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HIGHLIGHTS

- ► Emissions from gasoline and diesel cars were studied using PEMS measurements.
- ► Important concerns raised about actual NO_x emissions of modern diesel vehicles.
- ► For gasoline vehicles emissions remained below regulated limits.
- ► COPERT emission factor in most cases reflect adequately real world performance.
- ► Need for additional data input in COPERT particularly for Euro 5 cars.

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ABSTRACT

This paper discusses the development and validation of passenger car emission factors, using real world operation data. In total, six passenger cars of different technologies were studied. The tested vehicles were operated under various driving conditions and over two different routes in the region of Lombardia, Italy. These routes were specifically defined in order to provide a range of driving conditions, including urban, rural and highway driving. Tailpipe emissions and exhaust gas flows were measured on-board the vehicle, using a portable emissions measurement system (PEMS). In addition, all vehicles were tested over the European type-approval driving cycle (NEDC) with the same PEMS equipment.

The testing of gasoline vehicles showed that emissions are well below the emission standards and do not raise any concern. However, the testing of diesel vehicles both under real-world driving conditions and over the NEDC brought to the surface important concerns regarding the actual NO_x emissions of modern diesel vehicles, since they seem to comply with the corresponding emission standard over the type-approval cycle, but they constantly exceed the specified limit when tested under real-world driving conditions. Results from real-world operation revealed that there is a significant deviation from the NO_x emission standard limit (especially for the newly introduced Euro 5 technology). These observations raise concerns regarding the actual NO_x emissions of modern vehicles and their impact on urban air-quality.

The emission factors originally measured on the road are also compared to the corresponding COPERT average speed emission factors. In general, emissions of CO_2, THC and CO correlate fairly well with COPERT, for all vehicles. In the case of NO_x emissions, emission levels of the two tested Euro 5 diesel passenger cars are consistently higher in urban, rural, and highway driving compared to the corresponding COPERT emission factor. Thus, leading to the conclusion that more experimental data are necessary, especially for post-Euro 4 compliant diesel vehicles of different engine capacities particularly when it comes to NO_x emissions from diesel vehicles.

1. Introduction

Road transport is an important source of air pollution worldwide and particularly in urban areas. Based on ETC/ACC (2009) data, road transport contributes about 42% of total NO_x emissions, 47% of total CO emissions and 18% of total PM emissions at EU25

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level. Monitoring and projecting the evolution of transport generated pollutant emissions is important for assessing both the environmental pressures and the possible effects on human health they may cause. In addition they constitute a necessary tool in assessing the effectiveness of regulatory measures (emissions standards). Thus, accurate emission factors and road transport emission inventories are essential for policy and decision making when addressing emission projections, air pollution, or climate change. Emission factors (EFs) usually describe the emitted mass (g) of a substance per driven distance (km or mile). EFs can be used for single vehicles as well as for an entire fleet or vehicle categories and they depend on many variables such as size, type, cylinder capacity, fuel mode of the vehicle (gasoline or diesel), model year, type of exhaust gas aftertreatment technology, driving pattern, road gradient and the maintenance of the vehicle. The diversity of these factors shows that an estimating the amount of air pollutants due to traffic is a complex task. Most national air emission inventories today are compiled by means of computerised emission models (Sjödin and Jerksjö, 2008; Smit et al., 2010). Air quality models require emission data of specific pollutants, which are calculated by detailed emission models which, in turn, are based on appropriately chosen road-traffic-related emission factors.

The assessment of road-traffic-related pollutant emission factors is usually based on exhaust gas measurements of vehicles on chassis dynamometers over various driving cycles. However, dynamometer tests do not necessarily reflect the real on-road driving conditions and the level of maintenance of the actual vehicle fleet (Palmgren et al., 2001). Therefore, there is a need for on-road emission estimates of air pollutants from actual vehicles under real driving conditions. To this aim the most common approaches are (a) road–tunnel studies (Staehelin et al., 1997; Gofa et al., 1998; Jamriska et al., 2004), (b) remote sensing studies (Guenther et al., 1994; Chan et al., 2004; Guo et al., 2007), and (c) portable emission measuring systems (PEMS) (Gierczak et al., 1994; Kihara and Tsukamoto, 2001; Frey and Kim, 2005; Weiss et al., 2011a, Weiss et al., 2011b). Regarding the latter, it is a desirable approach for measuring emissions from vehicles, since data are collected under real-world conditions in the driving environment. PEMS are reliable/accurate relatively simple and inexpensive and can be installed on a wide variety of vehicles. Extensive official programs have confirmed the ability of the most advanced PEMS to provide a measurement quality in line with the emissions certification labs (Johnson et al., 2009; Sharp et al., 2009; EPA, 2008) These systems are designed for measuring in-use emissions during real-world on-road operation under a wide range of ambient conditions, traffic conditions, and operational/duty cycles.

Today, several emission monitoring and inventorying tools are being used, such as: COPERT, MOVES, MOBILE, HBEFA, ARTEMIS (Andre and Rapone, 2008), VERSIT (Smit et al., 2007), GLOBEMI (Jöchlinger and Hausberger, 1996), EMV (Hammarström and Karlsson, 1998).

Only a few attempts have been made to check the validity of European emission models (Ekström et al., 2004; Colberg et al., 2005; Berkowicz et al., 2006; Mellios et al., 2006; Sjödin and Jerksjö, 2008; Smit et al., 2010), despite the importance of the road transport sector for European air pollution and climate change policy. Most validation work has been based on the comparison of model results with "real-world" emission data, for example using data from tunnel studies, in which real-world emission factors are derived from simultaneous measurements. Remote sensing studies have also been used for the same purpose (Ekström et al., 2004; Sjödin and Jerksjö, 2008).

In the present study, on-road emissions measurement have been carried out for six passenger cars of different engine/after-treatment technologies in order to estimate their actual emission factors and identify any significant deviations from the corresponding emission standards. Particular emphasis was given on the recently introduced Euro 5 gasoline and diesel vehicles. In addition, these emissions data are compared with the values derived from the COPERT 4 model and correction factors are proposed where needed. Results from on-road testing were also compared to those derived from chassis dyno tests using the European certification test procedure. The European certification procedure uses the New European Driving Cycle (NEDC) as the reference cycle for emissions and fuel consumption quantification. The NEDC was developed to assure comparability and reproducibility of emission measurements in the type-approval of light-duty vehicles. Given this objective, the NEDC inherits limitations regarding its ability to reproduce real on-road emissions. It is hence possible that vehicles comply with applicable emission limits during the certification emissions testing although they might show substantially different emissions levels on the road (Weiss et al., 2011a). The European Commission and Member States alike have recently put a lot of effort in identifying possible shortfalls between certification and real world emission values in order to properly amend existing regulation and update current emission factors. This effort forms the basis for the present PEMS analysis of on-road emissions of light-duty vehicles (Perujo et al., 2012).

2. Methodology

2.1. Vehicles

In total, six passenger cars were used during the PEMS experimental campaign. The fleet consisted of three diesel and three gasoline vehicles, from Euro 3 to Euro 5 compliant (Table 1).

2.2. Testing and PEMS equipment

For the PEMS measurements the regulated test protocol for Europe was used (Regulation 582/2011,1). The regulation contains detailed guidelines regarding the specifications of the instrumentation to be used, the preparation of the vehicle, the installation of the measuring equipment, pre-testing procedures, test runs and verification of results. The PEMS instrumentation used was a Semtech DS from Sensors Inc., able to measure the exhaust gas

Table 1
Vehicle fleet characteristics.

	Diesel vehicles			Gasoline vehicles		
Engine capacity [litre]	2	1.6	1.5	1.6	1.2	1.8
After-treatment system	Diesel Oxidation Catalyst + DPF		Oxidation catalyst only – No DPF	Three way catalyst		
Emissions standard	EURO 5	EURO 5	EURO 4	EURO 5	EURO 4	EURO 3
Mileage [km]	4667	3408	800	7285	16,996	13,831
Code Name during the experimental campaign	Veh1_D_U5	Veh2_D_U5	Veh3_D_U4	Veh4_G_U5	Veh5_G_U4	Veh6_G_U3