EMISSION FACTORS OF PCDD AND PCDF FOR ROAD VEHICLES OBTAINED BY A TUNNEL EXPERIMENT

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INTRODUCTION

In recent years different studies have been carried out to estimate the emission factors of polychlorinated dibenzo-p-dioxins (PCDD) and dibenzofurans (PCDF) using measurements performed in car exhaust test laboratories [1]. However, such results can always be questioned due to the following reasons. The small number of cars tested can never truly represent the average emission from an entire car fleet and the employed driving cycle may not necessarily represent real driving conditions.

Road tunnels represent an opportunity to obtain exhaust emission factors which are representative for the car population and the various traffic conditions that prevail in the tunnel. Especially in longitudinally ventilated tunnels the parameters necessary to calculate emission factors can be fairly accurately determined. Based on the measurements in a road tunnel in Oslo, Norway the emission factors for PCDD/PCDF were calculated for different traffic situations based on an average daily traffic of 8'000-14'000 cars.

EXPERIMENTAL

The methodology for the calculation of the PCDD/PCDF emission factors was as follows: PCDD/PCDF concentrations were measured at the inlet and outlet of each tunnel tube. Simultaneous measurements of traffic parameters such as traffic density, speed and vehicle composition (light duty and heavy duty) as well as the average air flux through the tunnel were also carried out. This allowed the calculation of emission factors using the following equation:

cross section near the outlet. The average air velocity was calculated according to the equation:

$$V = \frac{Q_{SF_6}}{C_{SF_6} A}$$

where: V: average air velocity (m/s) between the release and measurement cross sections.
A: cross sectional area of the tunnel (m^2).
Q_{SF_6}: tracer gas release rate (g/s).
C_{SF_6}: average tracer gas concentration (g/m^3) at the measurement cross section.

RESULTS AND DISCUSSION

As can be seen from Table I and II, the collected samples allowed the calculation of 2,3,7,8-TEQ emission factors for different traffic situations. The largest emission factors were obtained during workdays in the inclining tunnel tube with a free flowing traffic at about 60 km/h. The tetra- and pentachloro-CDF/CDD as well as the hexachloro-CDF isomers contributed most to the observed differences. The PCDD/PCDF level at the inlet of the tubes was little influenced by the traffic situation and was in the order of 0.1 pg/m^3 2,3,7,8-TEQ.

Table I: Traffic data and calculated 2,3,7,8-TEQ emission factors obtained by the tunnel measurements. The average values are determined on basis of the given data. 2,3,7,8-TEQ values according to the Nordic model.

Parameter	Northbound tube Inlet	Northbound tube Outlet	Southbound tube Inlet	Southbound tube Outlet
Daily average no. of cars [% of HDDT in ()]				
Workdays	14'170 (14.8)		11'930 (19.0)	
Saturdays	10'310 (3.7)		8'370 (5.7)	
Sundays	12'680 (6.2)		11'150 (8.2)	
Average speed [km/h]	59		68	
Measured traffic density [veh./s], % HDDT in ()				
Workdays	0.28 (15)		0.176 (18)	
Saturday/Sundays	0.175 (3.5)		0.070 (5.5)	
2,3,7,8-TEQ levels [pg/m^3]				
Workdays	0.1	1.0	0.13	0.23
Saturday/Sundays	0.09	0.55	0.10	0.13
2,3,7,8-TEQ emission factors [ng/km]				
Workdays	1.9		0.16	
Saturday/Sundays	0.88		0.075	

Compared to the weekends the percentage of HDDT was a factor of 3-4 higher on workdays which also resulted in a substantially increased emission of PCDD/-PCDF. This difference allowed the estimation of the 2,3,7,8-TEQ emissions factors for light duty (LDV, about 95% gasoline powered) and heavy duty diesel vehicles (HDDT) by extrapolating the results to 0 and 100% HDDT respectively. As a control measure the emission factors for CO and NO_x were calculated as well. The obtained CO and NO_x factors shown in Table II for both vehicle categories are reasonable compared to literature values representative for the current Norwegian car fleet [4]. The 2,3,7,8-TEQ emission factors for LDV were within the same range as reported earlier for single car experiments [1]. A rather large difference was found for the two traffic situations in the tunnel. The values obtained for HDDT which exceeded those for LDV by a factor of 20-30 were quite surprising. Very little is known about the PCDD/-PCDF emission from diesel engines.

Table II: Emission factors of 2,3,7,8-TEQ, CO and NO_x for LDV and HDDT in the northbound (3.5% incline, 60 km/h) and southbound tube (3.5% decline, 70 km/h).

Parameter		Northbound		Southbound	
		LDV	HDDT	LDV	HDDT
2,3,7,8-TEQ	ng/km	0.5	9.5	0.04	1.3
CO	g/km	10	10	5	5
NO_x	g/km	3.5	36	0.5	1.3

In 1985, the total traffic in Norway corresponded to about 19.4 10^9 km/year for LDV and 1.7 10^9 km/year for HDDT. Using as a first estimate the average emissions factors given in Table II, the annual 2,3,7,8-TEQ emissions from car traffic in Norway were assessed to 5.2 g from LDV and 9.2 g from HDDT.

REFERENCES

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$$q = \frac{\Delta C \; V \; A}{t \; L}$$

where:
- q: average emission factor (g/km) representing the traffic between the two sampling points.
- ΔC: concentration difference (g/m^3) between the two sampling points.
- V: average air flux (m/s) between the two sampling points.
- A: average cross sectional area of the tube (m^2).
- t: traffic density (units/s).
- L: distance between the two sampling points (km).

By performing measurements at times with different heavy duty diesel truck (HDDT) percentage of the total traffic (e.g workdays vs. weekend), it is possible to calculate the emission factors for light duty (gasoline) vehicles (LDV) and HDDT separately.

All measurements were carried out during the period 20 April to 7 May, 1989 in the Vålerenga tunnel in Oslo, Norway, which consists of two parallel tubes, one for each traffic direction. The north bound tunnel has an average incline of ca 3.5%, a cross-sectional area of 78 m^2 and 3 lanes (southbound: 3.5% decline, 69 m^2, 2 lanes). Further details about traffic density, average speed and percentage of HDDT traffic are given in Table I. PCDD/PCDF were collected by a high volume sampler equipped with a glass fibre filter of 142 mm ∅ and two polyurethane foam plugs in series. More details about the sampling method are given in [2]. Sampling was carried out during daytime traffic (0800-2000 hrs) for totally 14-24 hrs spread over two working days or saturday and sunday. Samples were simultaneously collected at the tube in- and outlets. The total sample volume varied between 300-500 m^3 and the particle load between 130-413 mg. In addition to PCDD/PCDF, continuous monitoring of CO, NO_x, NO_2 was carried out. The traffic volume, speed and vehicle length were detected continuously by means of inductive detectors installed in each traffic lane. Vehicles over 7 m length were classified as HDDT.

Quantification of PCDD/PCDF was carried out according to the method described in [2] using the following modifications. ^{13}C-marked 2,3,7,8-chlorine substituted isomers were used as recovery and quantification standards for sampling and analysis. An upscale of the clean-up columns by a factor of 3 was employed. Recovery of the added isotope-marked congeners was in average 50-70%. The detection limits were 0.02 pg/m^3 or better included 2,3,7,8-TCDD. The determined PCDD/PCDF levels were calculated as 2,3,7,8-tetrachlorodibenzo-p-dioxin equivalents according to the Nordic model [3].

The air flux through the tunnel was measured by a tracer gas technique. Sulfur hexafluoride (SF_6) was released at a controlled and measured rate at the tunnel inlet and the tracer gas concentration determined over the tunnel