Section VI

Guidance/guidelines by source category: Source categories in Part III of Annex C

Part III Source category (h):
Motor vehicles, particularly those burning leaded gasoline

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VI.H Motor vehicles, particularly those burning leaded gasoline

Summary

The major fuels used in motor vehicle transportation are gasoline and diesel. Liquefied petroleum gas, vegetable oil-based and other biofuels, and alcohol-oil mixtures are gaining importance.

PCDD and PCDF have been found in the emissions from motor vehicles fuelled with gasoline or diesel. The higher concentrations identified in emissions from vehicles run on leaded gasoline are due to the presence of chlorinated and brominated scavengers in the fuel.

As alternatives to leaded gasoline, the following fuels may be considered: unleaded gasoline (best when equipped with catalyst); diesel (best when equipped with diesel oxidation catalyst and particulate filter); liquefied petroleum gas; compressed natural gas; propane/butane gas; biofuels; and alcohol-oil mixtures.

Best available techniques include banning of halogenated scavengers, and fitting motor vehicles with an oxidation catalyst or particulate filter.

There are no measured data available for biofuels, alcohol-oil mixtures or liquefied petroleum gas, and no data for 2-stroke engines.

1. Introduction

1.1 Process description

For motor vehicles, the process description is relatively straightforward. The gasoline engine derives its power from the explosion of a mixture of air and gasoline, whereas in the diesel engine the fuel burns rather than explodes. The air-fuel mixture, when ignited, expands rapidly in a cylinder, forcing a piston from the top of the cylinder to the bottom. After its release from a vehicle, the exhaust gas is diluted approximately a thousandfold in the first few seconds and cooled down very rapidly (DEH 2004).

1.2 Fuels, engine types and emissions

The major fuels used in transportation are gasoline, diesel and liquefied petroleum gas. Most gasoline-powered internal combustion engines used today in cars, light trucks, motorcycles and other vehicles are 4-stroke engines. Like many combustion processes, internal combustion engines generate polychlorinated dibenzo-*p*-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) as unwanted byproducts (UNEP 2005).

Most small gasoline-powered internal combustion engines used today in boats, jet skis, mopeds, small motorcycles, tuk-tuks, lawnmowers, chainsaws and other vehicles and appliances are 2-stroke engines. These engines follow the same thermodynamic combustion cycle as the 4-stroke engine; however, it consists of only two strokes, namely the combined exhaust and intake stroke, and the compression, ignition and combustion stroke. The most striking difference from the 4-stroke engine is the fact that all strokes occur during only one full revolution of the crankshaft. Lubrication is usually by oil added to the fuel. Therefore, higher amounts of pollutants may be released and efficiency may be lower compared to 4-stroke engines. However, the simplicity and low production cost of the 2-stroke engine make it an ideal motor for small-scale applications.

Diesel engines are used in heavy trucks, light trucks, passenger cars, heavy construction equipment, boats, generators, pumps and farm equipment, including tractors and other large equipment. They usually use diesel (light oil) and a 4-stroke cycle. Compression is used for ignition rather than a spark. Air is taken into the cylinder and compressed. Diesel fuel is added at high pressure and burnt. This results in a more efficient use of fuel and lower specific emissions. However, particle emissions in the form of soot are associated with the operation of diesel engines due to incomplete combustion, especially during start-up, warming and load changes. Particulate emissions from diesel engines are well known to contain high concentrations of polycyclic aromatic hydrocarbons.

Since PCDD/PCDF were detected for the first time in used motor oil (Ballschmiter et al. 1986), evidence has mounted that PCDD/PCDF are formed and emitted by the combustion processes in gasoline- and diesel-fuelled engines. Incomplete combustion and the presence of chlorine in the fuel , lubricant and air lead to the formation of PCDD/PCDF, chemicals listed in Annex C of the Stockholm Convention (Marklund et al. 1987, 1990; Schwind et al. 1991; Hutzinger et al. 1992; Gullett and Ryan 1997). Whereas for gasoline-powered engines the only relevant release vector for PCDD/PCDF is to air, diesel engines generate considerable amounts of deposits (soot). However, no measured data are available for PCDD/PCDF concentrations in diesel soot (UNEP 2005).

2. PCDD/PCDF formation and release

2.1 Studies of PCDD/PCDF emissions

Several European studies and one study in the United States of America evaluated PCDD/PCDF emissions from vehicles by measuring the presence of PCDD/PCDF in tunnel air. This approach has the advantage that it allows random sampling of large numbers of cars, including a range of ages and maintenance levels. The disadvantage of this approach is that it relies on indirect measurements, which may introduce unknown uncertainties and make interpretation of the findings difficult. Concerns have been raised that in tunnel studies resuspended particulates and absorbed PCDD/PCDF that have accumulated over time may lead to overestimates of emissions. This approach was therefore not deemed appropriate and the results of these studies were not considered in detail in the compilation of these guidelines. For further reading refer to the publications on tunnel and ambient air studies at the end of this section.

The first tailpipe emission study was performed by Marklund et al. (1987) on Swedish cars. Since then several studies either on running engines (passenger cars or trucks) or on motor stands or chassis dynamometers have been performed. Different fuels have been tested under varying conditions (simulating different traffic situations or varying loads). The results of the studies that report emissions based on fuel consumption are summarized in Table 1.

Table 1. PCDD/PCDF emissions from motor vehicles

Fuel	Vehicle type	Emission (pg TEQ/L)	Reference
Leaded gasoline, 4-stroke	Passenger car, old: before muffler/in tailpipe	60/10	Marklund et al. 1990
	Passenger car, new: before muffler/in tailpipe	21/23	Marklund et al. 1990
	Passenger car	0.55–1.66	Schwind et al. 1991
Diesel	Truck	291	Geueke et al. 1999
	Heavy duty vehicles	29.3–47.7	Gullett and Ryan 1997
	Passenger car	2–141	Schwind et al. 1991
	Truck	4–88	Schwind et al. 1991
	No information	0.5, 0.6, 2.0	Kim et al. 2003
	Truck	1.20–103	Government of Japan 2003

Fuel	Vehicle type	Emission (pg TEQ/L)	Reference
	Passenger car	1.47–121	Government of Japan 2003
	Passenger car (chlorine: 12, 131, 259 ppm)	3–49	Dyke 2005
Unleaded gasoline, 4-stroke	Passenger car, old and new: before muffler or in tailpipe	3.5	Marklund et al. 1990
	Passenger car	5–22	Schwind et al. 1991
	Truck	0.42, 0.99	Government of Japan 2003
	Passenger car	0.34–16.42	Government of Japan 2003
Unleaded gasoline with catalyst, 4-stroke	Passenger car	2–3	Schwind et al. 1991

In 1994, Hagenmaier and co-workers analysed the emissions of a diesel-fuelled bus (Hagenmaier 1994; Hagenmaier et al. 1995). PCDD/PCDF concentrations were around 1 pg/L for individual 2,3,7,8-substituted congeners, resulting in an I-TEQ of 0.01 ng I-TEQ/L. Thus, the 1994 results were much lower than the results obtained in 1990 (Hagenmaier et al. 1990). Whereas in 1990, mixed-halogenated dibenzo-*p*-dioxins (PXDD) and dibenzofurans (PXDF) (X = Br, Cl) could be quantified, the 1994 emissions did not contain detectable PXDD/PXDF. Similarly, PCDD/PCDF concentrations were below the limit of quantification in an extract from a gasoline-powered motor vehicle (Hagenmaier et al. 1995). These results indicate that with the ban on the use of halogenated scavengers (in Germany: see BImSchV 1992), the main source of PCDD/PCDF (and PXDD/PXDF) was eliminated. The results also showed that cross-contamination did occur since the same containers were used for the transport of diesel, leaded and unleaded gasolines. In a test programme to determine the emission of PCDD/PCDF and polychlorinated biphenyls (PCB) from internal combustion diesel engines, in some runs PCB were detected at levels of 3.6 to 8.0 pg WHO-TEQ/L, which was low compared to the dioxin levels (Dyke 2005). There may have been some uncontrolled effect from insufficient engine conditioning that influenced the early test runs.

2.2 Summary of findings

The literature documenting results of European, Japanese (see also Miyabara et al. 1999), Korean, and United States studies gives evidence that:

- PCDD/PCDF emissions from vehicles burning unleaded fuels are lower than the emissions from vehicles burning leaded gasoline;
- The higher emissions from vehicles run on leaded fuels are due to the presence of brominated scavengers added to the fuels;
- Catalyst-equipped cars – running on unleaded gasoline – have lowest emissions;
- Limited testing shows that diesel oxidation catalysts are effective in reducing emissions of PCDD/PCDF;
- Diesel particulate filters are efficient in reducing PCDD/PCDF emissions from diesel-fuelled vehicles;
- Diesel-fuelled vehicles have lower emissions than leaded-gasoline-fuelled vehicles and slightly higher emissions than vehicles running on unleaded gasoline and equipped with catalytic converters;

- Use of motor oils with low chlorine content (in the diesel experiments) did not result in lower PCDD/PCDF emissions.

The situation is not clear as to the influence of the age of the vehicles. Whereas Marklund et al. (1990) found higher emissions in older vehicles, the German study (Schwind et al. 1991; Hutzinger et al. 1992) did not find such dependence.

There are no measured data available for the following vehicle engine types:

- 2-stroke engines;
- Utilizing liquefied petroleum gas;
- Utilizing alcohol-oil mixtures;
- Utilizing biofuels (canola, etc.)

3. Best available techniques and best environmental practices

Best available techniques to reduce PCDD/PCDF emissions from motor vehicles may include the following:

- Prohibition of halogenated scavengers;
- Prohibition of the use of leaded gasoline;
- Installation of diesel oxidation catalysts, particulate filters and catalytic converters;
- Alternatives to gasoline engine (electricity, solar light and fuel cell).

Best environmental practices may include:

- Avoidance policies such as greater fuel efficiency should be encouraged. Alternative modes of transport, including cycling, rail and other public transportation, should be promoted;
- Separation of transport containers according to the fuel (for example, do not transport leaded gasoline containing halogenated scavengers in containers that are also being used for the transport of diesel or unleaded gasoline);
- Prohibition of the use of leaded gasoline;
- Promotion of vehicles with low fuel consumption;
- Education to identify driving conditions that have low pollutant formation and release;
- Good maintenance of the vehicle.

4. Regulations addressed to reduction of PCDD/PCDF emissions

In Japan, the Special Measures Law on Dioxins (enforced in 1999) regulates concentrations of PCDD/PCDF emissions from specific sources, in which emission gases from motor vehicles are not included. With regard to motor vehicle fuel, 100% lead-free gasoline was achieved in the 1980s and sales of leaded gasoline were prohibited by the law on lead, benzene and sulphur. In Tokyo metropolitan area, diesel vehicles have to be equipped with diesel particulate filters.

In Germany, the 19th BImSchV prohibits the use of halogenated scavengers in motor vehicles as a measure to reduce PCDD/PCDF emissions from motor vehicles fuelled with leaded gasoline (BImSchV 1992).

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