Emission standards for light and heavy road vehicles

Environmental Factsheet No. 17 September 2004

See also related factsheets in this series:

No. 10, June 2002:
EU legislation on air pollution and acidification

No. 14, September 2003:
The LRTAP Convention

Available at www.acidrain.org/publications.htm

Produced by
The Swedish NGO Secretariat on Acid Rain
Box 7005
402 31 Göteborg
Sweden

Tel: +46-31-711 45 15
Fax: +46-31-711 46 20
E-mail: info@acidrain.org
Internet: www.acidrain.org

EMISSION REQUIREMENTS for light road vehicles have existed in the EU since the early 1970s, while the first requirements for heavy vehicles came in at the end of the 1980s. Compared with the US and some European countries (Sweden, Norway and Austria), the EU was late in introducing requirements that were strict enough to force the use of catalytic converters in petrol vehicles.

The current exhaust emission requirements regulate four groups of compounds: nitrogen oxides (NOx), hydrocarbons (HC), carbon monoxide (CO) and particulate matter (PM). Of these, carbon monoxide is less significant from the point of view of health and the environment. For light vehicles (under 3.5 tonnes) the emission standards differ depending on the engine type (petrol or diesel). Emissions of the greenhouse gas carbon dioxide are not currently regulated for any type of vehicle.

The way in which the emission standards for light and heavy road vehicles in the EU have been stiffened over the years is shown in tables 1 and 2. The standards for both light and heavy vehicles are designated "Euro" and followed by a number (usually Arabic numerals for light vehicles: Euro 1, 2, 3.., and Roman numerals for heavy vehicles: Euro I, II, III..).

Emission standards also exist for two and three-wheeled vehicles (motorcycles and mopeds) and for engines for non-road machinery, but these are not covered here.

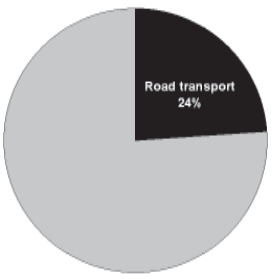
Test cycles

Emissions are measured using a standardized test cycle that is designed to simulate real driving. For light vehicles the entire vehicle is tested and emissions are measured in g/km. For heavy vehicles the engine is bench-tested and the results are expressed in relation to the engine power (g/kWh). A vehicle or engine that is tested and approved in one EU country may then be sold throughout the union without any requirement for further testing.

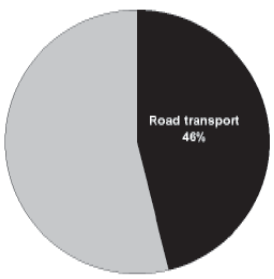
Light vehicles are subjected to a transient cycle in which the vehicle follows a prescribed driving pattern that includes accelerations, decelerations, changes of speed and load, etc.

In the case of heavy vehicles two different test cycles have been used in the EU since 2000: one transient (ETC, European Transient Cycle) and one stationary (ESC, European

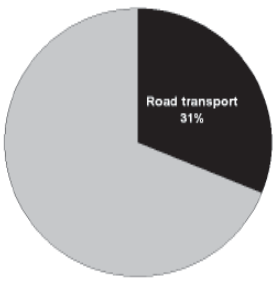
Road traffic's share of total emissions in the EU15 2001.



Carbon dioxide
Change in road transport emissions since 1990: +22%



Nitrogen oxides
Change in road transport emissions since 1990: -27%



Volatile Organic Comp.
Change in road transport emissions since 1990: -42%

Source: Energy and Transport in Figures. Statistical Pocket Book 2003. DG TREN, http://europa.eu.int/comm/dgs/energy_transport/figures/pocketbook/2003_en.htm

Stationary Cycle). The stationary cycle consists of a sequence of constant engine speed and load modes. Smoke opacity is measured on the ELR (European Load Response) test.

For the type approval of new heavy vehicles with diesel engines according to the Euro III standard (year 2000), manufacturers have the choice of using either of these tests. For type approval according to the Euro IV (year 2005) limit values the emissions have to be determined using both the ETC and the ESC/ELR tests. The latter also applies to the category Enhanced Environmentally friendly Vehicles (EEVs).

Outside the EU several other test cycles are used, so emission standards from different countries are not always directly comparable. In December 2003 however, the EU, US, Japan and China agreed to draw up a common scientific platform to measure and benchmark air pollution from traffic.

Light vehicles

The light category of vehicles covers road vehicles under 3.5 tonnes, i.e. both passenger cars and light commercial vehicles. The first exhaust emission requirements for these were specified in Directive 70/220/EEC, which has been stiffened several times.

The Euro 1 requirements (91/441/EEC), which came into force in 1992–93, forced the manufacturers to install three-way catalytic converters in petrol vehicles. Euro 2 was subsequently introduced in 1996–97 (94/12/EC), and in 1998 the standards for Euro 3 and 4 (98/69/EC) were agreed, to take effect in 2000 and 2005 respectively, see table 1. Standards also exist for light commercial vehicles. The limit values for these are generally slightly higher than for passenger cars and are dependent on the weight class – the heavier the vehicle, the higher the permissible emissions.

The requirement levels for 2000 and 2005 were agreed after several years of joint work between the Commission, the automotive industry and the oil industry – the so-called Auto-Oil Programme – on the basis of achieving good air quality in Europe by 2010 at the lowest cost.

Fuel quality standards were also stiffened as a consequence of the project, both to reduce emissions and to permit the introduction of new emission control technology, which in many cases requires a low sulphur content in order to work (see fact file). The highest permitted sulphur content for petrol was set at 150 ppm (parts per million) in 2000 and 50 ppm in 2005, and for diesel at 350 ppm in 2000 and 50 ppm in 2005. As the result of a new decision in 2003 (2003/17/EC) the limit for both fuels will be reduced to 10 ppm in 2009. 10 ppm fuel must be made generally available in the member countries by 2005.

Figure 1. Emission standards (NOx and PM) for heavy duty vehicles.

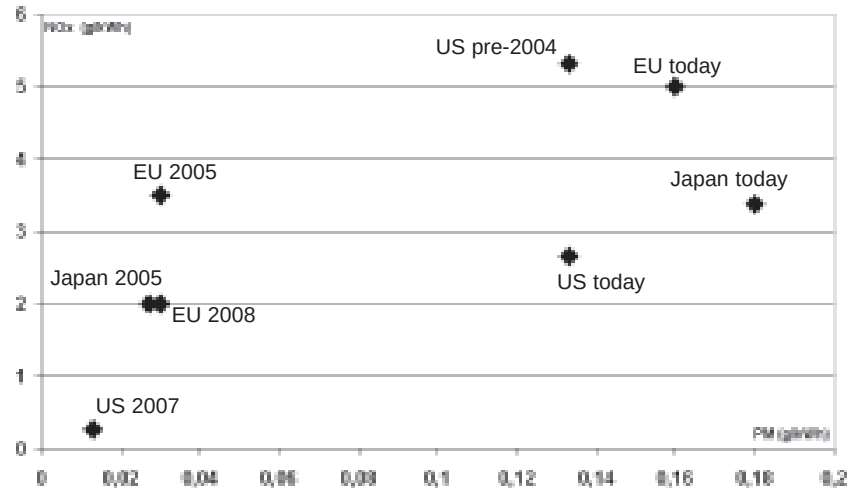
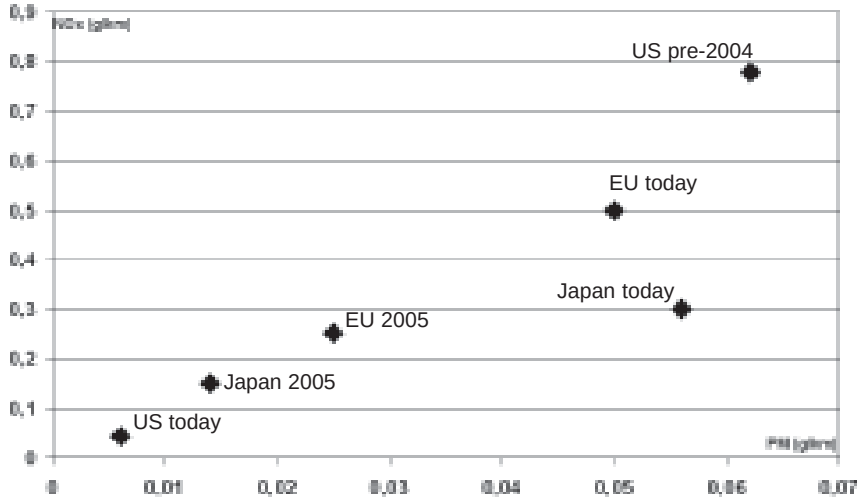


Figure 2. Emission standards (NOx and PM) for diesel-driven passenger cars.



Source for both figures: **Future Diesel**, Umweltbundesamt, 2003. US standards for passenger cars: Tier 2: Bin 5.

As can be seen from table 1 the Euro 2–4 standards are different for diesel and petrol vehicles. Under the current Euro 3 and forthcoming Euro 4 standards diesel vehicles are allowed to emit around three times more NOx than petrol vehicles. Emissions of particulates from petrol vehicles are not regulated since these are very low compared to emissions from diesel engines. Some direct-injection petrol engines can however emit almost the same level of particulates as a diesel engine.

When the Euro 4 requirements were decided it was generally believed that they would compel the use of particulate filters on diesel vehicles. A number of manufacturers have however developed models that meet the requirements without further exhaust gas treatment, although particulate filters appear to be necessary on most larger engines.

New legislation on durability was introduced along with the Euro 3 and 4 standards, making manufacturers responsible for the emissions from light vehicles for a period of five years or 80,000 km (Euro 3) and five years or 100,000 km (Euro 4). The same directive included a decision to introduce on-board emission diagnostic systems (OBD) between 2000 and 2005 and a requirement for a low-temperature emission test (7°C) for petrol vehicles with effect from 2002. The member countries were also given the right to introduce tax incentives for early introduction of 2005-compliant vehicles.

From figure 1 it is apparent that the Euro 4 requirements (2005) permit much higher emissions of NOx and particulates than the requirements in the US and Japan at the corresponding time.

Heavy vehicles

The first EU directive to regulate emissions from heavy vehicles, i.e. road vehicles heavier than 3.5 tonnes, came in 1988 (88/77/EEC). Before that there had been a common standard within the UN Economic

Table 1. EU emission standards for passenger cars and UBA proposal (2008). There are also standards for carbon monoxide, but these are not included in the table.

Passenger Cars	PM (mg/km)		NOx (g/km)		HC (g/km)		HC+NOx (g/km)	
	diesel	petrol	diesel	petrol	diesel	petrol	diesel	petrol
Euro 1 (1992-93)	140	--	--	--	--	--	0.97	0.97
Euro 2 (1996)	80/100[1]	--	--	--	--	--	0.7/0.9[1]	0.5
Euro 3 (2000)	50	--	0.50	0.15	--	0.20	0.56	--
Euro 4 (2005)	25	--	0.25	0.08	--	0.10	0.30	--
Euro 5 - UBA proposal (2008)	*2.5*	*2.5*	*0.08*	*0.08*	*0.05*	*0.05*	--	--

[1] Indirect Injection (IDI) and Direct Injection (DI) engines respectively.

Table 2. EU emission standards for heavy vehicles, and UBA proposals for 2008 and 2010. There are also standards for carbon monoxide and special standards for methane for gas-driven vehicles, but these are not included in the table.

Heavy duty vehicles	NOx (g/kWh)	HC (g/kWh)	PM (mg/kWh)
Euro I (1992-93)	9.0	1.23	400
Euro II 1995-96)	7.0	1.1	150
Euro III (2000)	5.0[1]	0.66[2]	100/160[3]
Euro IV (2005)	3.5[1]	0.46[2]	20/30[3]
Euro V (2008)	2.0[1]	0.46[2]	20/30[3]
Euro V UBA proposal (2008)	*1.0[1]*	*0.46[2]*	*2/3[3]*
Euro VI UBA proposal (2010)	*0.5[1]*	*0.46[2]*	*2/3[3]*

[1] Both ESC and ETC test cycle. [2] ESC test cycle only. [3] ESC and ETC test cycle respectively.

Commission for Europe (ECE R49).

The Euro I standards for medium and heavy engines were introduced in 1992–93 (91/542/EC). The same directive also laid down standards for Euro II, which took effect in 1995–96.

On the basis of the Auto-Oil Programme (see Light vehicles above) a directive (1999/96/EC) was adopted in 1999 giving standards for Euro III (2000), IV (2005) and V (2008). See table 2.

Euro V differs from Euro IV in its stricter emission requirement for NOx. The Euro V requirements are still indicative, since many countries were unsure of the potential of emission control technology when the directive was adopted. According to the Commission's review in December 2003 it is however perfectly possible to achieve these requirements.

Some engine manufacturers are now able to meet Euro IV requirements without further exhaust gas treatment, but for many this is likely to require the use of both particulate filters and NOx reduction (see fact file). Euro V is very likely to require special NOx reduction.

The 1999 directive also contains special voluntary standards for enhanced environmentally friendly vehicles (EEVs), as well as requirements for on-board diagnostic systems (OBD) and provisions regarding the durability of emission control devices from 2005.

The directive has since been revised on a couple of occasions, partly to prevent manufacturers from adapting engines to give low emissions solely at the speeds used in the test cycle for certification.

Figure 2 permits comparison between the requirements that apply to emissions of NOx and particulates from heavy diesel vehicles in the EU, US and Japan.

Future emission standards

A review of emission standards for road vehicles in the EU began in autumn 2003. This work is being carried out by a subgroup of the Commission's Motor Vehicle Emissions Group (MVEG), with the participation of the member countries and various stakeholders. On the basis of this work the Commission will present a consultation document followed by proposed directives containing new standards. The proposed directives for light and heavy vehicles are expected to be issued in spring and autumn 2005 respectively, and the requirement levels will probably begin to apply in 2010. Among the questions the sub-group will consider are the access to emission control technologies, their performance and costs, and whether changes need to be made to the fuel standards.

The development of new technology in recent years, combined with new findings regarding harmful health effects, especially of particulates, makes it likely that the Commission will propose significant reductions in emission limits, primarily for diesel vehicles. In 2003, the German Environment Agency (UBA) published a proposal for new emission standards for motor vehicles, see tables 1 and 2.

For passenger cars the UBA proposals include the following:

❑ Emission requirements should be fuel-neutral, i.e. the same for all fuels.

❑ Particulate requirements should be strengthened by a factor of ten. The requirements of Euro 4 can be met without emission control equipment, at least for small cars, and a particulate filter removes 90 per cent or more of particulates in the entire size range.

❑ The NOx requirement for diesel cars should be strengthened by a factor of three, down to the same level as for petrol vehicles.

❑ The summation value for NOx + HC for diesel cars should be replaced with an HC limit value regardless of engine type.

If petrol vehicles are also covered by the proposed new particulate requirement it may mean that direct injection engines will have to be fitted with particulate filters.

The proposal for heavy vehicles means:

❑ Fuel-neutral requirements.

❑ The agreed but as yet indicative particulate standards for 2008 are lowered by a factor of ten, for the same reason as above.

❑ The agreed but as yet indicative NOx requirements for 2008 are halved, and then halved again in 2010.

In its report, the UBA discusses whether emissions of particulates should also be counted by number, or whether it would suffice merely to regulate the weight. It concludes that confining the limit to weight could lead to the engine makers concentrating primarily on eliminating the largest and heaviest particles, which have relatively little effect on health. It would therefore like to supplement the current weight-based standards with limits on the

maximum number of particles within the size range that is inimical to health.

The extra cost of the UBA Euro 5 proposals for a diesel car, compared with Euro 4, is estimated to run to 200–400 euros.

It would cost practically nothing, on the other hand, for a heavy vehicle to switch from Euro V to Euro VI, since it would suffice in that case to improve the emission control equipment that is already needed to meet Euro V requirements.

The need to reach a relatively quick agreement on the exhaust emission requirements that will apply from 2010 is not just important so that the industry has time to prepare for the production of cleaner vehicles. It also gives the member countries the right to bring in tax incentives to favour those vehicles that comply with the requirements early, such as diesel cars fitted with particulate filters.

Further information

The European Commission's Motor Vehicle Emissions Group: http://europa.eu.int/comm/enterprise/automotive/mveg_meetings/index.htm

The report of the German Environment Agency (Umweltbundesamt): *Future Diesel*. July 2003. Can be downloaded from www.umweltdaten.de/uba-info-presse/hintergrund/FutureDiesel_e.pdf

Articles on this topic from Acid News are gathered on the secretariat's website under the heading "Policy initiatives".

Emission standards, test methods, emission data for all models of car, etc., can be found at www.vcacarfueldata.org.uk (Vehicle Certification Agency, UK).

Emission control technology for vehicles

Petrol-driven passenger cars

A petrol engine without emission control produces large emissions of nitrogen oxides and unburnt hydrocarbons. The technology that manufacturers have used to meet stiffer emission requirements is the three-way catalytic converter. This consists of a ceramic material with microscopically small channels, coated with a very thin film of precious metals. As the exhaust gases pass through the converter the hydrocarbons and carbon monoxide are oxidized by the oxygen that is released when the nitrogen oxides are reduced to nitrogen (N_2).

The three-way catalytic converter has been fitted to all petrol passenger cars sold in the EU since the start of the 1990s and has become increasingly efficient as emission requirements have become stricter. The biggest problem is during cold starts, since a certain temperature (300-400°C) has to be reached before the catalytic process starts to work.

In the case of petrol engines that use an excess of air (known as lean burn technology) the three-way catalytic converter has no effect on emissions of NOx. Some manufacturers use an NOx storage catalytic converter (see Diesel vehicles below) to meet the standards.

Petrol vehicles with direct injection (GDI, FSI, SCi, etc.) produce relatively high emissions of particulates, which means that these may require special particulate reduction if emission requirements are stiffened (see Diesel vehicles below).

Diesel-driven passenger cars

The biggest environmental and health problems associated with diesel vehicles are emissions of nitrogen oxides and particulates, both of which are higher than for petrol vehicles.

NITROGEN OXIDES. Because a diesel engine works with an excess of air the three-way catalytic converter cannot be used to reduce emissions of NOx. Exhaust Gas Recirculation (EGR) technology, in which some of the exhaust gases are recirculated through the combustion chamber, can reduce NOx formation by lowering the temperature. The reduction potential is limited however, which means that further treatment of exhaust gases is likely to be necessary in order to meet future requirements.

One further treatment method is to use an NOx catalytic converter. This works by trapping and storing nitrogen oxides chemically in an NOx trap, and then reducing them periodically to nitrogen by injecting additional fuel and by using a catalytic converter. This method requires low-sulphur fuel (10 ppm), since sulphur is captured more easily than nitrogen in the NOx trap, as well as being more difficult to remove.

Another method – although mainly applied to heavy vehicles – is selective catalytic reduction (SCR). This involves reducing the nitrogen oxides to nitrogen gas in a catalytic converter with the aid of ammonia (injected as urea). The reduction efficiency approaches 80–90 per cent. Disadvantages include the added operating cost of using urea, the possibility of increased ammonia emissions and the loss of effect when the urea tank is empty. Some questions also exist regarding the durability of the technology. One advantage is that higher levels of NOx can be permitted during the combustion process, which can consequently be better optimized for low fuel consumption.

PARTICULATES. The formation of particulates can be reduced to some extent by modifying the combustion process. Smaller engines can meet Euro 4 requirements in this way. Particulate filters are however required for larger engines and when emission requirements are stiffened. They consist of a ceramic matrix of silicon carbide, perforated with microscopic channels. As the exhaust gases pass through, a large proportion of particulates (90–99 per cent) stick to the walls of these channels.

The trapping of particulates means that the channels become blocked, and the filter therefore has to be raised to a high temperature at regular intervals to burn off the particulates. Various methods have been developed to achieve this combustion, including a brief additional injection of fuel and a catalytic substance that reduces the temperature required. One requirement for low particulate emissions is a fuel with a low sulphur content.

COMBINED METHODS. Toyota is the only manufacturer so far to succeed in developing a catalytic converter that reduces emissions of both particulates and nitrogen oxides – particulates by 90 per cent and nitrogen oxides to the level that applies for petrol vehicles in 2005. The system is based on EGR (see above), NOx storage and an integrated catalytic converter and particulate trap.

Heavy vehicles

Practically all heavy road vehicles have diesel engines. In common with diesel cars, the emissions that are most important to reduce are NOx and particulates.

In the case of NOx the Euro V requirement for 2008 (max. 2 g/kWh) is expected to compel the use of SCR (see above) on all new heavy vehicles, while Euro IV (3.5 g/kWh) can be met by some manufacturers using EGR technology without the need for further treatment of exhaust gases.

Particulate reduction by means of filters is easier to solve for heavy diesel vehicles than for light ones, since heavier vehicles have a higher exhaust temperature. This makes the critical phase – burning off particulates from the filter – easier to achieve.

A particulate filter is often combined with an oxidation catalytic converter that reduces the content of carbon monoxide and hydrocarbons in the exhaust gases.