The Director General

Maisons-Alfort, France, 11 August 2009

OPINION

of the French Agency for Environmental and Occupational Health Safety (Afsset)

Relating to the "impact of after-treatment technologies on NO_2 emissions from diesel vehicles, and associated health issues"

Afsset Solicited Request No 2006-09

The mission of the French Agency for Environmental and Occupational Health Safety (Afsset) is to help ensure environmental and occupational health safety and assess potential health risks in these areas. It provides the competent authorities with all information required on these risks as well as the expertise and technical support needed to draft legislative and statutory provisions and implement risk management strategies.

Context

Various European regulations, especially the Euro regulations relating to emissions from personal vehicles and heavy-goods vehicles, determine limits restricting the emission of particles from diesel vehicles. These limits will probably lead to the widespread use of particle filters on such vehicles.

Particle filters (PF) will reduce the mass and levels of particle emissions.

Certain technologies available on the market combine oxidation catalysis (oxidation catalyst) with the particle filter; however, at present, the conclusions drawn by several European and Californian studies seem to indicate that technology using an oxidation catalyst significantly increases the nitrogen dioxide (NO_2) emissions (conveyed by a higher NO_2/NO_x ratio) without an observable effect on the total NO_x emissions. This, therefore, raises the issue of the impact of a widespread use of particle filters on diesel vehicles in terms of the NO_2 emissions and the health effects.

Presentation of the question

In this context, on 24 August 2006, the French ministries for the environment, health and work requested Afsset to "assess the health effects relating to the emission of particles and nitrogen dioxide from diesel vehicles". Following exchanges with the ministries, three areas of work were identified, with nitrogen oxides being considered a matter of priority:

- **Area 1:** Analysis of all the bibliographic data available and, more specifically:
  - an analysis of French and European pollution data (background and proximity situations) to obtain an idea of the nitrogen oxide concentrations (NO_x and NO_2);

- an analysis of the data published in the scientific literature relating to emissions from diesel vehicles, especially the changes in nitrogen dioxide (NO_2) emissions;
- a review of the existing bibliographic data relating to the conditions of measuring nitrogen dioxide (NO_2).

- **Area 2:** Identifying the varying impacts of the oxidative catalyst coupling and particle filter (PF) technologies on the NO_x emissions and on the NO_2/NO_x ratio.
- **Area 3:** This area of work focuses on health implications, broken down into two points:
  - identifying the toxicological issues linked to the NO_2 emissions combined with the different oxidative catalyst coupling and particle filter (PF) technologies. Identifying the different "typical exposure scenarios" (including "worker-type scenarios"), performing research on recent literature for exposure concentration data relating to such scenarios and, at the very least, providing a qualitative evaluation of the risk.
  - analysing the relationship between emissions of[1] NOx, NO_2 and particles and acute and/or chronic health indicators (mortality, cardiorespiratory diseases, for example) in relation to the elements analysed in Area 1. This point, therefore, can only be tackled if Area 1 reveals the existence of a specific signal relating to nitrogen oxides and the NO_2/NO_x ratio.

Organisation of the expert appraisal

The expert appraisal was carried out in compliance with French standard NF X 50-110 "Quality in Expert Appraisal Activities – General Requirements of Competence for Expert Appraisals (May 2003)" with the objective of respecting the following points: competence, independence, transparency and traceability.

Afsset called upon the Committee of Specialised Experts (CES) "Assessment of risks associated with air environments" to work on this solicited request. This committee appointed a working group to carry out the necessary appraisal activities.

The methodologies and scientific findings of the working group were regularly submitted to the CES. The working group met 12 times in full session and 4 times in dedicated subgroups between June 2007 and February 2009, and the CES discussed their findings during their meetings on 27 March 2008, and 21 January and 5 May 2009. The work of the working group was adopted during the final meeting.

These expert appraisal activities are therefore the result of the work of a group of experts with complementary competences.

On a scientific level, this opinion is based on the final report of the expert appraisal and was drafted by Afsset.

Results

The results of the expert appraisal highlighted that:

1 Immission: concentration of a chemical substance in the ambient air.

1) Regarding changes to the nitrogen oxide emissions (NO, NO_2 and NO_x) from diesel vehicles:

Preamble

Many chemical species are found in diesel engine emissions (particle matter (PM), nitrogen oxides –NO_x, unburned hydrocarbons - HC, carbon monoxide - CO, polycyclic aromatic hydrocarbons, aldehydes, etc.). Various types of technology are used to treat the emissions, including:

- The catalyst (without particle filter): mainly involved in treating CO and HC;
- The particle filter (PF): traps the PM. The trapped soot must be burnt to regenerate the particle filter and avoid a counter-pressure which is detrimental to the engine. As the PM combusts at approximately 550°C whereas the exhaust gas is at a much lower temperature, catalysts are used to lower the temperature required for combustion and to initiate the periodic regeneration of the PF. Two types of technology are currently used for this purpose:
  - catalysed particle filters: a particle filter uses an oxidation catalyst, installed above the PF; one of its functions is to increase the NO_2 concentrations, taking advantage of the oxidative ability for the combustion of the PM. The catalyst can also be integrated into the FP media;
  - additive particle filter: the catalyst is incorporated into the fuel system (e.g. cerium-based catalyst), and does not require increased NO_2 concentrations to combust the PM.

For emissions from light duty diesel vehicles

- On average, Euro 1 vehicles have lower NO_x emissions than Euro 2 vehicles. In fact, only total HC+NO_x is regulated for Euro 1 and Euro 2. The use of an oxidation catalyst, which was rendered compulsory by Euro 2, allows the limits relating to CO emissions to be reached and reduces HC. However, it significantly increases NO_2 emissions and may also increase NO_x, though without exceeding the statutory ceiling established by Euro 2 in relation to total HC + NO_x.
- The transfer from Euro 2 to Euro 3 indeed results in a 2 to 3 factor reduction in NO_x emissions from actual cycles, without a systematic reduction in NO_x emissions.
- Filtration itself does not generate excess emissions of NO_2. However, technologies combining enhanced oxidation catalysis with the particle filter to manage its regeneration (catalysed particle filters) lead to an increase in NO_2 emissions.
- The Euro 4 standard, which imposes a halving of NO_x emissions on the approval cycle, does not represent a major change for the actual cycles compared with Euro 3. The various configurations that enhance oxidation catalysis (to manage the regeneration of the particle filter in particular), whether installed above or on the FP, record the highest NO_2 emissions.
- For Euro 3 vehicles, it should be noted that the NO, NO_2 and NO_x emissions obtained with additive particle filters show relatively few differences when compared with the version without a PF; the additive particle filter does not require enhanced oxidation catalysis for regeneration.

For emissions from heavy duty diesel vehicles

Although the available data is less extensive for this type of vehicle, the following points have been identified:

- Strengthening of the first generation of Euro standards has not always resulted in a lowering of NO_x emissions under actual traffic conditions (a point also observed with light duty vehicles);
- The presence of a catalyst, with or without a particle filter, systematically results in an increase in NO_2 emissions;
- NO_x and NO_2 emissions strongly depend on a combination of many parameters, including engine performance (speed and load), the extent to which exhaust gases are recycled and the after-treatment technologies present.

■ Finally, with regard to the impact of these developments on emissions from light duty vehicles, according to the observations and modelling carried out (see Appendix) it appears that:

- The NO_2/NO_x emission ratio in light duty diesel vehicles has been rising since 1996, the date when oxidation catalysts were made compulsory on new vehicles by the Euro 2 standard; and this situation is set to continue.
- However, if the penetration rate for additive particle filters amongst all vehicles fitted with a particle filter exceeds approximately 30%, total NO_2 emissions from light duty vehicles should be minimised by 2014; the rate of the reduction will vary depending on the "favourable" or "moderate" scenario[2] retained by experts.
- Conversely, if this rate were lower than around 30%, an increase in NO_2 emissions from light duty vehicles would be observed.
- Since the beginning of the year 2000, NO_2 emissions from vehicles have mainly been attributable to catalysed diesel vehicles due to Euro 2 to 4 (and even due to Euro 5 with its "moderate" and "unfavourable" scenarios[3]).
- At present, due to low penetration levels, vehicles fitted with a particle filter combined with an oxidation catalyst contribute only extremely moderately to total NO_2 emissions. However, this contribution should increase in the future.

Comment: due to the lack of sufficient data in the scientific literature, it is currently impossible to carry out the same type of analysis for heavy duty vehicles.

2 Favourable and moderate scenarios: equivalent share of additive and catalysed particle filters; the Euro 5 unitary NO_2 emissions for light duty diesel vehicles are lower compared with Euro 4 in terms of the estimated percentage for NO_x as a result of statutory limits for the favourable scenario, and increased by 10% compared with Euro 4 for the moderate scenario.

3 Unfavourable scenario: 20% of additive particle filters and 80% of catalysed particle filters; unitary NO_2 emissions from light duty diesel vehicles (Euro 5) increased by 10% compared with Euro 4.

2) Regarding changes to nitrogen oxide concentrations (NO, NO_2, NO_x) in the ambient air linked to road traffic:

- A variable situation is observed near road traffic, as since the mid nineties there has been a tendency for the NO_2 levels to stagnate or increase, both in France and in other European countries. The annual limit value[4] of 40 µg/m^3 defined for nitrogen dioxide is exceeded at a number of these sites.
- Two factors can explain these tendencies observed near traffic:

  - the photochemical processes linked, among other aspects, to a rise in ozone levels, which may play a role by reacting with the primary NO emitted by traffic to form NO_2,

  - the rise in primary NO_2 emissions from traffic stemming from an increase in the number of diesel vehicles on the road and their technological developments.
- Finally, the NO_2 levels reported in the flow of traffic and inside the passenger compartment, in particular, significantly exceed the levels observed by near proximity monitoring stations. One of the main parameters influencing NO_2 levels in the passenger compartment are the emissions from vehicles close to the vehicle in question, especially from the one immediately in front. Concentrations in the vehicle's passenger compartment increase significantly when driving through tunnels. However, it cannot be excluded that other factors (type of road taken, traffic congestion, topography of the location, etc.) can also influence concentration levels inside the passenger compartment.

3) Regarding the health effects of NO_2:

- Toxicological data shows that NO_2 has a toxic effect on the respiratory system. These effects are described in experimental studies after exposures to NO_2 concentrations higher than the guide values.
- The epidemiological studies relating to NO_2 exposure are limited due to their inability to separate the effects of NO_2 from those of other pollutants emitted or formed with NO_2, although a number of methodological studies looking at this subject are currently underway. In particular, NO_2 has already been used as a marker for the pollution emitted by combustion, especially that emitted by road traffic.
- The contributions of an epidemiological approach seem to be fairly limited, both in terms of the information available on the health effects of NO_2 emitted by diesel vehicles and also in terms of evaluating the medical effects associated with the introduction of new after-treatment technologies for on-road vehicles.

With a special emphasis on studies targeting the effects of NO_2 contained in diesel emissions:

No publications were found on the impact of the after-treatment devices on the global toxicity of diesel emissions (gaseous and particle phases) which included NO_2 measurements. The only results available from experimental studies relate to studies carried out under the

4 Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe

framework of a Primequal/Predit research programme[5] and the MAAPHRI programme[6]; the data from these programmes were completely reanalysed. Finally:

- The exposures analysed corresponded to higher levels than those normally found in the ambient environment.
- Emissions from diesel engines, filtered and unfiltered, appear to induce greater biological effects in rats treated with oxidation catalysis (in particular, changes to the enzyme activity involved in the antioxidant defence and systemic inflammation).
- The NO_2 content of these emissions provides an indicator of how they are treated via the oxidation catalysis and also their oxidising potential.
- The epidemiological and toxicological data do not exclude the role of other oxidising species emitted simultaneously.

Taking these results into account, NO_2 exposure levels (current and forecast) were analysed alongside various reference values.

The following were taken into consideration:

– As exposure environment: inside the passenger compartment of light duty vehicles (outside tunnels in urban situations, and in tunnels);

– As population studied: the general population and an occupational population corresponding to drivers of light duty vehicles (4 and 8 hours a day);

– As reference values:

➢For the general population: 200 µg/m^3 over 1 hour[7]

➢For the occupational population: 110 µg/m^3 over 8 hours[8]
400 µg/m^3 over 8 hours[9]
1,000 µg/m^3 over 15 minutes[10]

– Exposure levels:

➢Current: 130 to 560 µg/m^3 in 2007 outside tunnels

➢Forecast: 100 to 550 µg/m^3 in 2014 outside tunnels[11]

It appears that in the majority of the envisaged situations, projected NO_2 exposure levels exceed the reference values retained. The limitations of this analysis do not detract from the conclusions that can be drawn.

At present, NO_2 levels to which users of light duty vehicles are exposed - general and occupational populations - can have toxic effects on the respiratory system, especially for sensitive populations (particularly asthmatics). Until 2014 (the date

5 Report published online on the Primequal/Predit website (http://www.primequal.fr/files/doc/899185bb1ea1e50e.pdf)

6 Morin J-P, et al. Prevalidation of in vitro continuous flow exposure systems as alternatives to in vivo inhalation safety evaluation experimentations: Outcome from MAAPHRI-PCRD5 research programme. Exp Toxicol Pathol (2008), doi: 10.1016/j.etp.2008.01.007

7 Medical value: Guide value of the WHO

8 Medical value: Value obtained by adjusting the WHO guide value of 200 µg/m^3 over one hour for an 8-hour exposure. This adjustment was carried out using the general concentration-response-time ratio derived from Haber's Law.

9 Management value: OEL of SCOEL (Scientific Committee on Occupational Exposure Limits) established by the European Commission Decision 95/320/EC).

10 Management value: OEL of SCOEL (Scientific Committee on Occupational Exposure Limits) established by the European Commission Decision 95/320/EC).

11 Three scenarios (reducing, average, maximising) were retained to lower the average levels of NO_2 in the passenger compartment of light duty vehicles according to the global NO_2 emissions from vehicles on the road between 2007 and 2014. They are partly based on the distribution of NO_2 concentrations measured in 2007 in the passenger compartments of light duty vehicles in the urban communities of Rouen and Paris, and on scenarios implying a change to the emissions from road traffic.

when the Euro 6 standard comes into force), any changes to this situation will depend on the use on vehicles of current anti-pollution technologies and management measures relating to vehicle emissions.

Other points of interest on an international level

Two approaches were investigated in greater depth:

1) the role of emission-treatment technologies (particle filters, oxidation catalysts, etc.) in changing the NO_2 and particle concentrations in the air;

2) the management measures aimed at reducing particle emissions whilst still limiting NO_2 emissions from road vehicles fitted with emission-treatment technology.

1) Two English studies carried out by the Institute for Transport Studies[12/13] and an expert appraisal of the Air Quality Expert Group (AQEG)[14] investigated the role of primary NO_2 emissions from traffic in the increase in NO_2 concentrations measured in the air. Specifically these studies showed that:

- concentrations of NO_2 in the air and especially the NO_2/NO_x ratio had statistically significantly increased in London;
- fitting catalysed filters (CRT, Continuously Regenerating Trap) on London buses was the main reason for these results: the percentage had changed from 39% to 79% between 2002 and 2004, with a drop in the numbers of personal cars;
- there was an extremely significant decrease in the concentration of PM 2.5 (fine particles < 2.5 µm) and a lower decrease in the concentration of gross particles, in common with the previous observations[13];
- the assumption that it was responsible for an increase in the background concentration of ozone should be discounted[13].

2) In France, no procedures taking NO_2 into account have been identified to test the quality of the particle filtering systems for road vehicles. However, this type of procedure exists elsewhere (Switzerland, Germany, Austria, United States, etc.):

- VERT quality tests[15]
  - Based on the effectiveness of the particle filter systems in retaining ultrafine particles and limiting secondary emissions (e.g. NO_2) and the durability.
  - No significant increase of reaction products potentially harmful to the environment or to health compared with the initial state of the engine is admissible in the purified exhaust gases below the filter[16]. This also applies to NO_2. Moreover, the

12 Evidence of an increasing NO_2/NO_x emissions ratio from road traffic emissions. (D.C.Carslaw, 2005)

13 Detecting and characterising small changes in urban nitrogen dioxide concentrations (D C Carslaw, N Carslaw, 2007)

14 DEFRA draft report - Trends in Primary Nitrogen Dioxide in the UK (Air Quality Expert Group, 2006)

15 VERT: Verminderung der Emissionen von Realmaschinen im Tunnelbau (reducing emissions from machines used for tunnelling), a programme to study of the technical feasibility of reducing to a minimum the diesel particles emitted from engines (1994-1999). Joint project of the Swiss National Accident Insurance Fund (Suva), the Österreichisches Unfallversicherungsanstalt (AUVA), the Deutsche Tiefbauberufsgenossenschaft (TBG), of the Swiss Federal Office for the Environment (FOEN) and the German Umweltbundesamtes (UBA), and a large group supporting the industry (www.suva.ch).

16 This type of secondary emission is "significant" when the concentration of pollutants measured in the waste gases downstream from the filter are three times higher than the emissions from an engine that has not been fitted with a particle filter.

increase in the NO_2/NO_x ratio, measured according to the SNR 277205 standard, should not exceed 30% (valid since 1 January 2008).
  - Particle filtering systems that have successfully passed these tests are published and recommended by the Swiss Federal Office for the Environment and by Suva for later devices for diesel engines. AKPF[17] supplies a "VERT filter" label.
  - Contrary to the situation with construction site equipment (building work, tunnels), the application of VERT quality tests on road vehicles is currently not a statutory obligation in Switzerland.
  - The evaluation of particle filtering systems by virtue of the VERT quality tests is applied by several organisations (OFEV, Suva, OFROU - Switzerland; AUVA, TIROL, Vienna - Austria; TBG, UBA, TRGS - Germany; CARB, MSHA - USA; VROM - The Netherlands; SÜDTIROL – Italy; CONAMA - Chile; DTI - Denmark; DEEP - Canada; LEZ London - UK).
- Checking procedure for *retrofit* technologies (i.e. installed on an existing engine) implemented by US EPA[18]
  - Protocols established to check the catalysts, the particle filters, modifications to engines, and SCR technologies.
  - Based specifically on the effectiveness of the systems in reducing particles, CO, NO_x and HC and on the durability.
  - The increase in NO_2 emissions resulting from the technologies that were checked is limited to 20% of the basic level of engine NO_2 emissions (valid since 1 January 2009).
  - The verified and approved *retrofit* technologies are published in the list of "Verified Technologies".
- Checking procedures for the strategies to control diesel emissions implemented by the CARB[19]
  - Procedure established to inspect the oxidation catalysts, the particle filters, the "flow-through" filters"[20](hybrid after-treatment method that reduces particles using an oxidation catalyst and filtering process), the technologies to control the NO_x (EGR, SCR technologies, "lean-NO_x" catalyst technologies) on diesel engines in service.
  - Based, in particular, on the effectiveness of the systems used to reduce particles and NO_x, and on the durability.
  - The increase in NO_2 emissions resulting from the technologies that were checked is limited to 20% of the basic level of engine NO_2 emissions (valid since 1 January 2009, previously limited at 30% since 1 January 2007).
  - The verified strategies for inspecting diesel emissions are published in the "Currently Verified" list.

In principle, all toxic substances not found, or found at much lower concentrations, in the exhaust gas of an engine that has not been fitted with a particle filter are considered as secondary emissions.

17 AKPF: A working group founded by manufacturers and distributors of diesel particle filters (Arbeitskreis des Partikelfilter-System-Hersteller)

18 US EPA: American Environmental Protection Agency

19 CARB: Californian Air Resources Board, a board issued from the California Environment Protection Agency (Cal EPA)

20 "Flow-through" filters: a hybrid method of after-treatment that reduces particles by means of oxidation catalysis and filtration.

- Procedure included in the Californian regulations (California Code of Regulations, Title 13, Division 3) and constituting a statutory obligation for compliance. The 20% limit for the NO_2 increase (see above) is a statutory limit.

The effectiveness of these three procedures used by foreign manufacturers has been demonstrated.

Opinion

➔Firstly, Afsset reiterates that atmospheric pollution remains a major concern for public health. Nitrogen dioxide (NO_2) and fine particles are known to be indicators of atmospheric pollution. They are particularly associated with road traffic in urban communities. Short- and long-term effects have been reported for these two pollutants; for particles, the long-term impact on health predominates over the short-term impact.

These two pollutants should be considered jointly in policies on managing atmospheric pollution due to their health effects and their ability to act as a precursor of equally harmful secondary pollutants (NO_2 is, in fact, a precursor of ozone, of secondary particles, and so on).

Finally, Afsset reiterates that diesel engine emissions are classified by the International Agency for Research on Cancer (IARC) as potentially carcinogenic for humans (Group 2A).

In this context, taking into account the results of this work and any possible changes to light duty vehicles over the coming years, Afsset considers that:

➔The implementation of anti-pollution devices incorporating a particle filter on diesel vehicles should have beneficial health effects, mainly due to a significant drop in the emission of particles with a recognised health effect. However, when the use of anti-pollution devices with a particle filter leads to excess production of NO_2, results from current studies have shown that the situation with regard to this specific pollutant remains a concern, especially for the occupants of light duty vehicles in urban communities. From a health perspective, the NO_2 levels to which they are already exposed seem to indicate, in relation to the reference values, a health effect is possible.

➔These elements demonstrate the usefulness of systematically measuring NO_2 emissions during approval cycles, in addition to measuring NO_x emissions, and to make the measurement results public. In fact, the Euro VI standard (heavy duty vehicles) imposes the measurement of NO_2 emissions and offers an option to determine a limit value for such emissions at a later date. This, however, is not the case for the Euro 6 (light duty vehicles) standard.

➔The most appropriate method for measuring NO and NO_2 emissions seems to be heated on-line chemiluminescence with a dehumidifier, to prevent the NO converting into NO_2, condensation and the formation of non-measured HNO_3.

➔The management measures aimed at promoting the use of particle filters, for instance on dedicated fleets of vehicles (buses, commercial vehicles, taxis, etc.), must limit as far as possible the generation of additional pollutants, especially nitrogen dioxide (NO_2).

➔Based on available knowledge, it is not currently possible to evaluate the health effects of NO_2 emissions and the particles resulting from the various technologies used for the after-treatment of diesel emissions. In fact, the current exposure-risk relationship established by epidemiological studies is not capable of identifying the health effects of a specific pollutant in relation to the other pollutants emitted or formed with the pollutant; however, a number of methodological studies looking at the subject are currently underway.

Recommendations

Regarding the standards relating to diesel engine emissions:

➔With regard to systematising the rules on emissions, Afsset recommends that NO_2 is specifically taken into account, in addition to the standards relating to total NO_x emissions. Without waiting for a review of the rules, Afsset is encouraging the establishment of official recommendations in this area.

In addition, and taking into consideration:

- the results of this collective expert appraisal,
- the particularly high dieselisation rate of the French rolling stock,
- the expected widespread use of particle filters, which can sometimes be combined with oxidation catalysts,
- and the existence of procedures testing the quality of particle filters used on road vehicles, which take NO_2 into account (used in particular in the United States, Switzerland, Germany and Austria),

➔Afsset recommends the implementation of a system to evaluate the efficiency of the technologies used to control diesel emissions (including particle filters, oxidation catalysts, and the technologies used to control NO_x), based on the experiences of Switzerland, Germany, Austria and the United States. The system will take into account the reduction in particles, the reduction of NO_x, the limitation on NO_2 emissions and the durability of the technologies.

Regarding an improvement in the state of knowledge, Afsset recommends:

➔Improving documentation of the levels of pollutants emitted by car traffic[21] in its immediate surroundings and their determining factors (for instance, the influence of the position of the

21 Immediate proximity to road traffic: this notion includes all the air areas located the closest to the road traffic (closer than the location of fixed stations, known as "traffic proximity stations", which monitor air quality and are managed by approved associations for monitoring air quality), where the air is likely to be breathed in (e.g. in the passenger compartment of a vehicle stuck in traffic, behind a vehicle stuck in traffic, etc.).

exhaust on the levels measured in the slipstream), taking into account the scale of the populations concerned and, in the work currently underway, identifying the relevance of these environments.

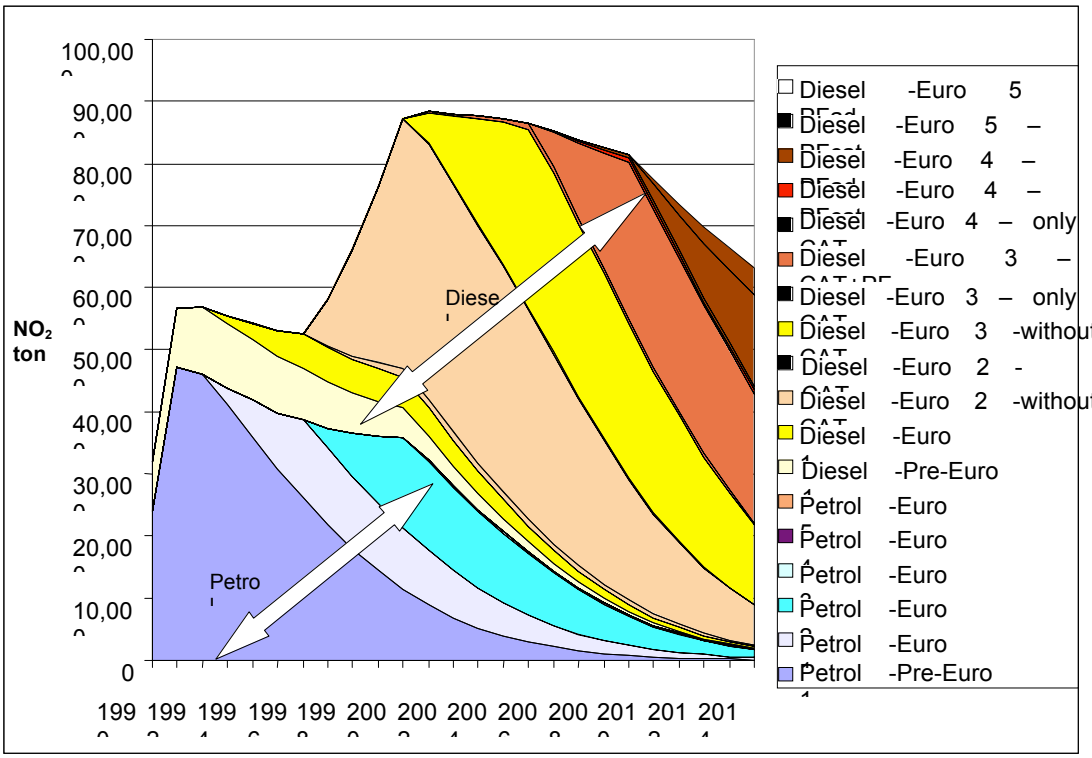
➔Gathering more information on vehicle NO_2 emissions, especially for vehicles already on the road and particularly heavy duty vehicles, to obtain more information on technology's influence on emissions, which are to be measured during test cycles and under real conditions.

➔Improving knowledge with regard to the toxicology of emissions from diesel vehicles fitted with after-treatment devices. During the work, Afsset noted that there is little available data relating to the toxicology of emissions from diesel vehicles fitted with after-treatment devices. In particular, it is recommended that additional work be carried out on the toxicity of emissions as a whole (aerosols emitted, including the gaseous and particular phases).

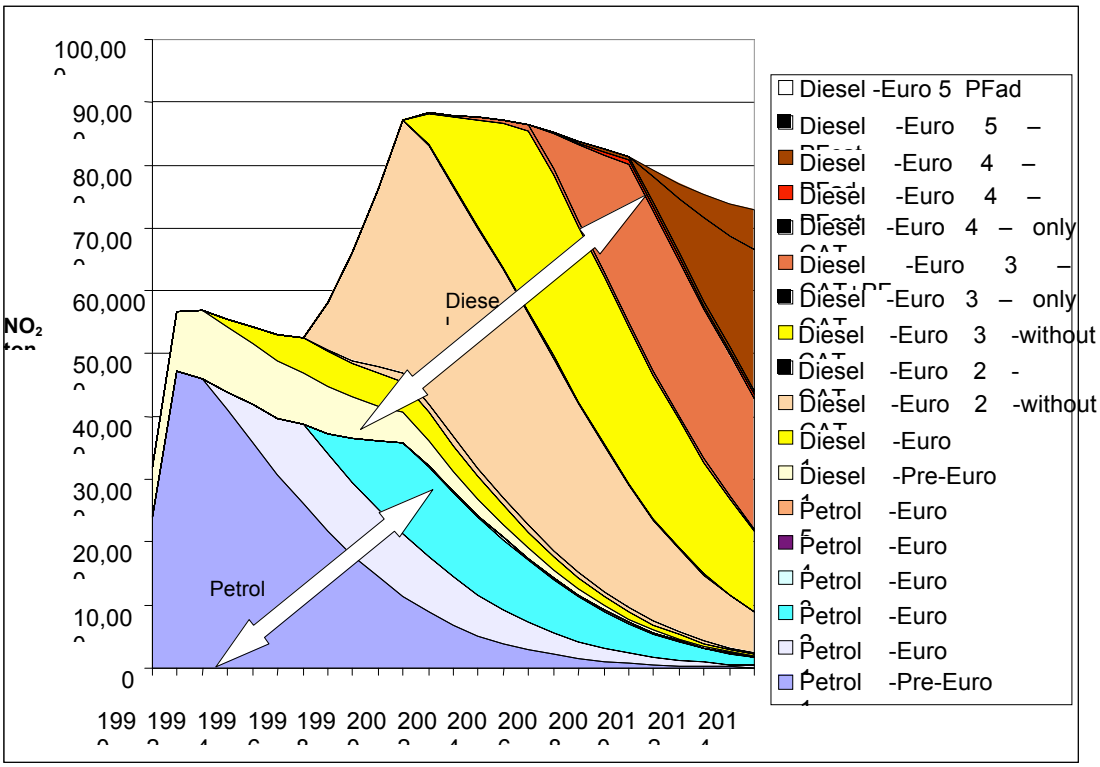
The Director General

Martin GUESPEREAU

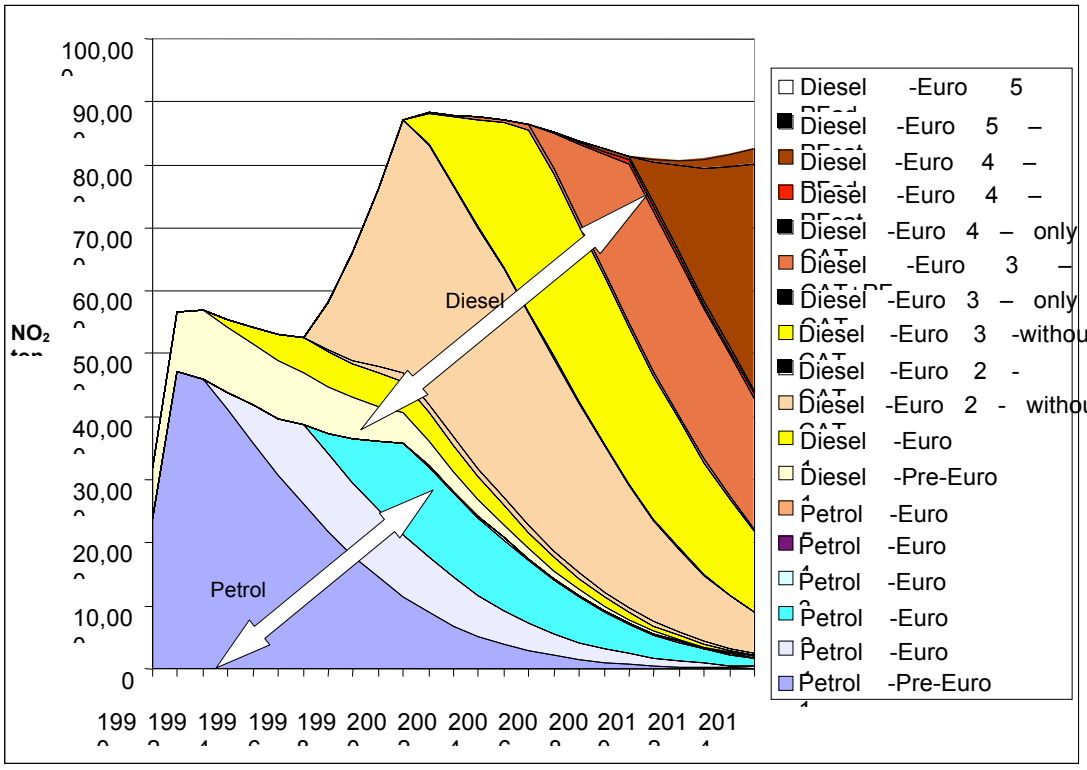
Appendix: NO_2 emissions from the national fleet of light duty vehicles



"Favourable" scenario



"Moderate" scenario



"Unfavourable" scenario