Fuel quality and emissions

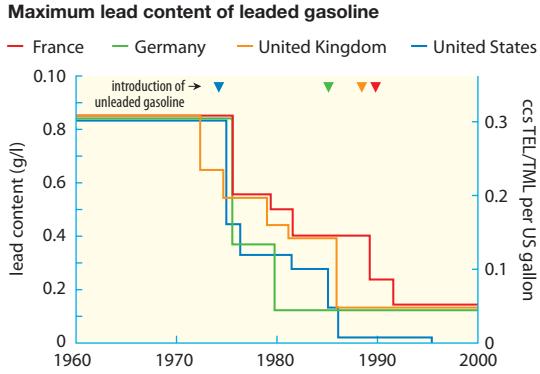
Rising to the challenges of increasingly demanding fuel specifications

CONCAWE first embarked on work on fuels quality in relation to automotive emissions in the late 1970s. Since that time, tremendous progress has been made in reducing emissions from road transport, with improvements in fuel quality contributing substantially to these reductions. Nevertheless, there are still challenges to be faced, one of the key current issues being the reduction in CO_2 emissions from road transport. CONCAWE continues in its endeavour to use a sound science-based approach to deal with the challenges ahead.

In the early years CONCAWE's work focused on issues such as the reduction of lead content of gasoline and the determination of the optimum octane for unleaded gasoline. When CONCAWE was first formed in 1963, the legal limit for lead content of European gasolines was 0.84 g/l max. As concerns over the health effects of lead mounted and air pollution became a major issue, advances in refining technologies made it possible to continue to reduce the lead content of gasoline. The advent of unleaded gasolines in the late 1980s enabled the introduction of the first generation of catalyst cars. Lead was finally eliminated from gasolines throughout the EU in 2000 (Figure 1).

The elimination of lead required the refineries to make gasoline with a higher 'natural' octane, implying additional investment, operating cost and energy. On the other hand higher octane enabled higher engine efficiency and the optimum octane debate was open. A comprehensive study was needed to address this issue and CONCAWE's 'Rational Use of Fuels In private Transport' (RUFIT) study provided the essential technical basis for the final selection of 95 RON as the main European gasoline grade (Figure 2).

Figure 1
Progress towards elimination of lead from gasoline by year 2000.



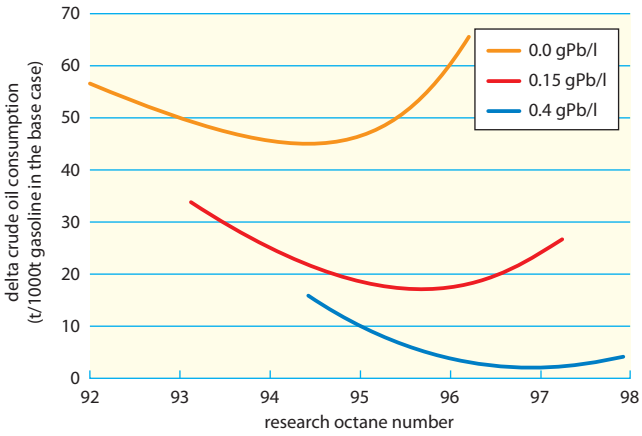
In the late 1980s, gasoline evaporative VOC emissions were the focus of much attention and several CONCAWE reports addressed this issue in relation to gasoline vapour pressure and evaporative emission control technologies. This work demonstrated that 'closing' the gasoline system through measures such as 'Stage 1' evaporative emissions controls at refineries, terminals and service stations and use of carbon canisters onboard cars was more cost-effective than reducing the vapour pressure of gasolines.

The relentless growth of the European diesel car population brought diesel fuel into environmental focus around the same time. CONCAWE carried out and reported its first work on fuel effects on emissions from diesel engines and vehicles in the mid 1980s.

As the regulations regarding vehicle emissions and fuel specifications were becoming more complex, CONCAWE identified the need for a document compiling the details of all such regulations in the world's main regions and countries. Thus CONCAWE's report on motor vehicle emissions legislation and fuel specifications was born in 1988. It has been updated almost every year ever since and has become a much appreciated and trusted source of information. The next edition is scheduled for publication in 2004.

In the 1990s it became increasingly clear that fuels and vehicles needed to be considered together rather than separately and the emphasis shifted towards the relation-

Optimum gasoline octane/energy use



Reductions in regulated emissions, 1985–2010

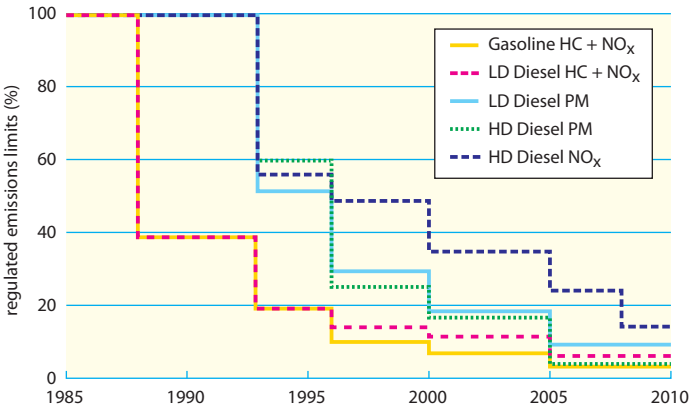


Figure 2 (above left) *CONCAWE's 'RUFIT' study provided the essential technical basis for the final selection of 95 RON as the main European gasoline grade.*

Figure 3 (above right) *Impressive reductions in regulated emissions limits have been achieved since the late 1980s.*

ship between vehicle technologies, fuels quality and emissions. The European Programme on Fuels, Engines and Emissions (EPEFE), carried out between 1993 and 1995, underpinned the Auto/Oil I programme. CONCAWE task forces shadowed the Auto/Oil I process, contributing much to the technical debates and assisting the EU Commission's consultants in various ways. During that period CONCAWE produced a series of reports on both gasoline and diesel fuel effects on emissions from that generation of engines and vehicles as well as on the economic consequences of changing fuel specifications on EU refineries. This pattern continued throughout the Auto/Oil II programme in the late 1990s and the related review of sulphur content of fuels in relation to advanced engines and exhaust after-treatment systems in 2000.

Around that time climate change issues and CO_2 emissions started to take over the environmental agenda and it was realised that, while more stringent fuel specifications have potential environmental benefits through reduced emissions, they also entail an environmental cost through the increase of refinery CO_2 emissions. CONCAWE contributed to the debate by pioneering the modelling of the impact that changing fuel specifications would have on refinery CO_2 emissions.

Figure 3 illustrates the impressive reduction of the regulated emissions limits of various pollutants for different vehicle types. Meeting these limits has presented a tremendous challenge to both the automotive and the fuel industries.

Fuels have played a major role, partly through direct effects such as the reduction of gasoline benzene content, and partly through enabling advanced automotive technologies to be applied. EU fuel specifications have been dramatically tightened over the past decade. The latest update of the ***EU Fuels Directive*** (2003/17/EC) published in March 2003 requires the introduction of sulphur-free gasolines and diesel fuels (10 mg/kg maximum sulphur content) on 'an appropriate balanced geographic basis' from 2005. Full market coverage of sulphur-free fuels is required from 2009, though the end date for diesel fuel remains subject to review.

Sulphur-free fuels will enable a range of advanced engines and exhaust after-treatment systems that will achieve the new Euro-4 and Euro-5 emissions standards with best fuel efficiency, assisting the motor industry to meet their voluntary CO_2 commitments (European passenger car fleet average 140 g/km CO_2 by 2008). The transition to sulphur-free fuels can be seen as a major step when one considers that the sulphur contents of both gasolines and diesel fuels were measured in % rather than ppm levels, well into the 1990s.

Table 1 summarises the history of the key gasoline and diesel fuel specification changes over the period 1993–2009, i.e. since the introduction of the first European (EN) standards. The continuing challenge for the oil industry is to supply the required market volumes reliably at the specified quality. Apart from the issue of sulphur reduction, diesel fuel volumes are limited by

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Table 1 Summary of European gasoline and diesel fuel specification developments

Year			1993	1995	1996	2000	2005	2009
Gasoline Unleaded 95/85 – EN228								
Sulphur	ppm m/m	max	1000	500		150	50/10	10
Benzene	% v/v	max	5			1		
Aromatics	% v/v	max				42	35	
Olefins	% v/v	max				18		
Oxygen	% m/m	max	2.5 (1)			2.7		
RVP (summer)	kPa	max	up to 80			60 (2)		
E100	% v/v	min	40(s)/43(w)			46		
FBP	°C	max	215			210		
Diesel (standard grade) – EN590								
CI		min	46					
CN		min	49			51		
Sulphur	ppm m/m	max	2000		500	350	50/10	10 (3)
Density	kg/m^3	min	820					
		max	860			845		
T95	°C	max	370			360		
PAH	% m/m	max				11		
Lubricity	µm @ 60 °C	max			460			

[1] *Up to 3.7% at Member State discretion. Individual limits apply to specific compounds*
[2] *70 kPa max allowed in Member States with arctic or severe winter conditions*
[3] *End date for full introduction of 10mg/kg S max diesel remains subject to further review*

constraints on density and back-end distillation points, while demand increases steadily. For gasoline the challenge is to satisfy the octane and distillation requirements, while the reduction in aromatics content from 2005 continues to decrease the choice of molecules available to the blending pool.

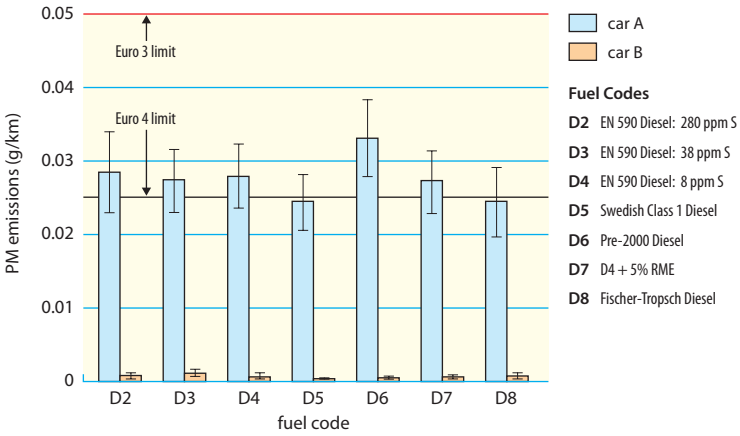
Despite the progress made, pressures for further improvements remain. The Clean Air For Europe (CAFE) programme provides an integrated approach on air pollution, human health and the environment, taking into account emissions from all sources. CONCAWE supports this approach which should be the framework within which any additional measures are evaluated for overall cost-effectiveness towards meeting environmental and health targets.

There are nevertheless other initiatives that run parallel to CAFE which may result in additional legislation on fuels. The 2003 ***EU Fuels Directive update*** already requires a review of the road fuel specifications to be completed by end 2005. In parallel, a new initiative to develop the next generation of engine/vehicle emissions standards, Euro-5 for light-duty vehicles and Euro-6 for heavy-duty engines, has just been formally launched by the EU Commission, with its primary focus on particulate and NO_x emissions from diesel engines.

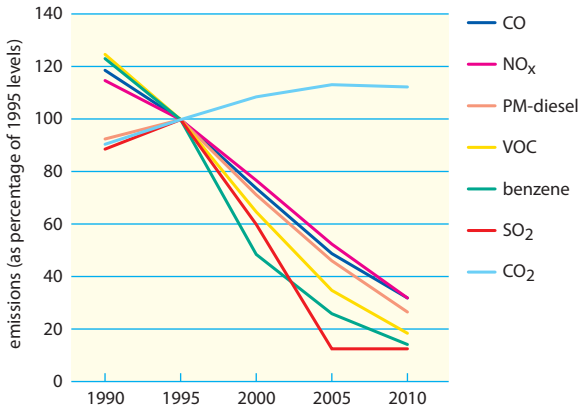
In order to be prepared to contribute to the ensuing debates, CONCAWE has continued to test fuel effects on emissions from advanced engine/after-treatment technologies as they enter or approach the market. Recent work comparing low sulphur/sulphur-free conventional diesel fuels with more extreme fuel compositions has shown that advanced engine technologies such as particulate traps are much more effective in controlling emissions than further changes to fuel properties. Figure 4 provides an example for PM emissions from two diesel cars, one with and one without a particulate filter, tested on a series of fuels, D2 to D8, encompassing a wide compositional range (see Table 1). The costs associated with the introduction of sulphur-free fuels must now be compensated by harnessing the ability of these fuels to enable advanced vehicle technologies.

The particulate emissions debate has moved on from simple measurements of particulate mass to measurements of other properties of particles, especially size and

PM emissions from two diesel cars (with and without a particulate filter)



Trends in regulated emissions, 1990–2010



number. CONCAWE has been active in this area with a number of reports, SAE papers and collaborations such as the UK DETR/SMMT/CONCAWE programme reported by Ricardo in May 2001, and the DG TREN Particulates Consortium currently approaching completion.

The EU Commission's study for Auto/Oil II highlighted the inadequacy of measures to tackle CO_2 emissions (Figure 5). Indeed the latest trends emerging from the CAFE programme confirm that attention should now focus on reducing CO_2 emissions while maintaining or even further reducing air pollutant emission levels.

The car industry's commitment to achieving an average CO_2 emissions level of 140 g/km by 2008 for the European passenger car fleet is a first step in addressing the issue of fuel efficiency. As road transport continues to grow, further measures to reduce CO_2 emissions from vehicles can be expected.

In addition, the potential contribution from 'renewable' fuels such as RME, ethanol, other biomass-derived fuels and hydrogen are increasingly in focus. CONCAWE's first report on alternative fuels was published in 1995. In the context of the EU Commission's Biofuels Directive proposal[1], CONCAWE published in 2002 the results of a literature review on the overall energy and greenhouse gas balance of ethanol and RME (report no. 2/02).

[1] *Directive 2003/30/EC on the promotion of the use biofuels or other renewable fuels for transport.*

Unlike other air quality issues that tend to play at local or regional level, the greenhouse gas (GHG) issue is global and needs to be addressed as such. In order to contribute to the understanding of the complex interactions between fuel production and fuel usage, CONCAWE is collaborating with EUCAR and the EU Commission's Joint Research Centre (JRC) in a comprehensive well-to-wheels study on alternative fuels and powertrains. The full study results are due to be released at the end of this year.

Outlook

Tremendous progress has been made in controlling emissions from road transport. Further benefits can be expected as the new generation of low emission vehicle technologies enters the market, enabled by the new generation of sulphur-free fuels. Nevertheless, major challenges remain, in particular with regard to GHG emissions, where it is critical that considerations of future fuel/powertrain technologies are taken into account on a realistic well-to-wheels basis. After 25 years of CONCAWE's involvement in road fuels and emissions issues, there is no let up in the challenges for the industry; testing and exciting times continue to lie ahead. In striving for further improvements in environmental performance other aspects such as vehicle driveability, security of supply and European competitiveness should not be forgotten. More than ever there is a need to bring sound scientific evidence to support cost-effective regulatory decisions.

Figure 4 (above left)
Particulate filters are much more effective than further fuel changes in reducing PM emissions.

Figure 5 (above right)
The current challenge is to reduce greenhouse gas emissions while also achieving very low regulated emissions.