concawe review

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Foreword

Those old enough to remember the '70s may have a sense of *déjà vu* as energy conservation appears once more at the forefront. Today, however, in addition to depletion of natural resources and security of supply, a third issue, greenhouse gas emissions from burning fossil fuels, is on the agenda. While the world demands more and more energy, the promise of a clean and plentiful renewable source has so far proved elusive. Transport, in particular road transport, is in the limelight and the love affair between man and his automobile contrasts with the less pleasant effects of road traffic congestion.

In such a context, the search for alternative modes of transport and ways to power them is entirely legitimate. As the efficient provider of virtually all transport fuels, the oil industry must play its role in the debate and CONCAWE makes its own modest contribution to the process.

The lead article in this *Review* deals with a recent industry initiative, involving CONCAWE, to coordinate research efforts in road transport. Under the 'Activity update' section of this *Review*, a short highlight of the 'well-to-wheels' study of alternative fuels—a joint project between the auto industry and the EU Commission's research arm—is also featured.

The other main articles cut across CONCAWE's activities, dealing with the quality of fuels, health effects of air pollution, refinery sulphur emissions and our recent pipeline seminar. The 'Activity update' included in this issue aims to inform readers of developments in a number of areas of importance to the industry, and in which CONCAWE is actively involved.

Jean Castelein
Secretary-General, CONCAWE

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Gasoline risk assessment

The Existing Substances Regulation (ESR), implemented in the EU in 1993, provides a formal process for assessing the risks to man and the environment associated with the use of existing substances. The procedures for risk assessment of existing substances were specified in a technical guidance document (TGD) which was originally issued in 1995, was amalgamated with the TGD for new substances in 1996 and is now being updated. Since that time there have been a number of risk assessments of high priority substances, several of which are also gasoline constituents. The scope of those risk assessments have been limited to the specific substances and not extended to gasoline or other petroleum substances. Thus, potential risks associated with exposure as a consequence of gasoline manufacture and use have not been explicitly evaluated under the ESR programme.

To address the lack of a regulatory requirement to evaluate the risks associated with gasoline, CONCAWE has undertaken a risk assessment of gasoline and its blending streams on a voluntary basis. The objectives of this effort are to:

(1) compile and review hazard data on the substance gasoline;
(2) estimate the potential for human and environmental exposure at different points in the product life cycle; and
(3) characterize human and environmental risk as a consequence of gasoline exposure from manufacture and use in Western Europe.

This assessment will encompass risks to workers, consumers and the general public (via the environment) at both local, i.e., adjacent to refineries and/or service stations, and regional scales. The risks associated with key gasoline constituents will also be considered. The risk assessment for gasoline is scheduled to be completed in mid-2003.

This risk assessment for gasoline is the first in a series of 13 risk assessments for petroleum substances to be undertaken by CONCAWE over the next several years in anticipation of the requirements of the future EU chemicals control legislation. As risk assessments for complex substances have not previously been conducted, and the existing TGD guidance is not fully developed for complex substances, there will be a need to develop new methodologies. A paper outlining the methodology to be followed for the gasoline risk assessment has been developed and will be reviewed by an independent panel of experts to confirm the validity of the proposed approaches. It is intended that the methodologies developed for the gasoline risk assessment might also be used to assess the risks of other complex petroleum substances.

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Understanding fuel requirements of modern vehicles

Despite the dramatic reduction in emissions from road transport achieved in the last few years, the latest update to the EU Fuels Directive will require a review of fuel quality requirements to be completed by end 2005. Data on fuel effects in advanced engines is essential if future legislation is to be adopted on a technically sound basis. In this context, CONCAWE is currently running a number of programmes to investigate the influence of fuel qualities on emissions in modern/advanced vehicles.

Test work is in progress to evaluate the effects of sulphur content and other fuel properties (aromatics, olefins, volatility and final boiling point) on four gasoline vehicles covering stoichiometric and lean burn direct injection technologies as well as an advanced conventional port fuel injected engine.

With regard to diesel, two state-of-the-art, Euro-3 light-duty diesel vehicles are being tested: one small car with an oxidation catalyst and one larger car with a particulate filter system. In addition three heavy-duty diesel engines are being evaluated in cooperation with the firm of automotive engineers, AVL: these include a Euro-3, a prototype Euro-4 (using exhaust gas recycle plus particulate filter) and a prototype Euro-5 fitted with a urea/selective catalytic reduction after-treatment system. This work also forms part of CONCAWE's contribution to the DG TREN[1] Particulates Consortium, so detailed particle size and number data will be generated as well as the standard regulated emissions. In both the light- and heavy-duty diesel tests, fuel matrices will cover current fuel qualities versus 50- and 10-ppm sulphur fuels, and also more extreme fuels. The aim is to quantify the benefits of low sulphur fuels when used with advanced engines/after-treatment systems, as compared to the potential effects of other fuel properties.

Work is also in progress on a small vehicle fleet to study the influence of gasoline volatility and ethanol content on hot and cold weather driveability. The work is using the latest hot and cold weather test procedures developed by the Groupement Français de Coordination and aims to update understanding of driveability-related gasoline requirements for modern vehicles.

The above test work should be completed early in 2003 and aims to contribute to the technical knowledge needed as a basis for future debates on fuel quality requirements.

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CAFE—Clean Air For Europe

The CAFE Thematic Strategy, launched last year by the EU Commission, has the potential to significantly affect the oil industry. CONCAWE is closely following and, where appropriate, contributing to the programme. Several task forces have been set up within CONCAWE to shadow the Commission's work and the extensive parallel activity within the UN-ECE[2]. A number of important areas have already emerged.

The Integrated Assessment Modelling (IAM) that will be carried out in CAFE/UN-ECE will be underpinned by a common 'baseline' energy demand scenario similar to those used in previous programmes such as Auto/Oil, the National Emissions Ceiling Directive (NECD) and the Gothenburg Protocol. The design of this scenario will have a significant influence on both the CAFE and the UN-ECE processes, in terms of the additional legislative measures that might be recommended and of the burden-sharing between Member States.

One of CAFE's first aims is to extend the capability of the regional IAM to the 'city level'. In principle, this should facilitate the development of synergistic policies which address both regional and urban scale problems. The City-Delta project is aimed at developing the necessary functional relationships between emission reductions and air quality change at the urban level. In parallel, the EMEP[3] two-dimensional regional-level model used for the Gothenburg Protocol and the NECD is being replaced by a more sophisticated three-dimensional model which is in the final stages of development/testing.

Regional and urban inventories are key inputs to both the air quality and integrated assessment modelling steps. Regional-scale inventories are available from the ongoing work within the EMEP (broken down into 50x50 km grids) and urban-scale inventories from the City-Delta project (broken down into 10x10 km grids or less). These emission data are currently being reviewed to ensure they are robust enough to support the modelling work.

Within the IAM process, the costs of various control options are represented by so-called 'cost curves'. As part of the UN-ECE process, the existing set of cost curves, originally developed in connection with the NECD and the Gothenburg Protocol, are being updated and extended to include control options for fine particulates (PM_{10} and $PM_{2.5}$).

[1] *The EU Commission's Directorate General for Transport and Energy*

[2] *The United Nations Economic Commission for Europe*

[3] *UN-ECE's cooperative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe*

Activity update

CONCAWE's ongoing involvement in key development areas

The Commission has requested the WHO's European Centre for Environment and Health (ECEH) to prepare updates of their health effects assessments for the CAFE priority pollutants, i.e. ozone, nitrogen dioxide and particulate matter. Earlier versions of WHO assessments were extensively used in the preparation of the position papers for air quality limit values proposed by the Commission under the Air Quality Framework Directive.

The WHO review is structured around a series of questions formulated about each pollutant by the CAFE Steering Group (Commission, Member States and stakeholder organizations). The review is expected to provide new interpretations of the rapidly growing scientific literature in this area. In particular it will address no-effect thresholds and dose-response relationships (to be used in integrated assessment modelling to estimate health impacts). CONCAWE health scientists remain sceptical about some of the approaches used to produce evidence for the assumed causal relationships between pollution levels and observed health effects, and are working with other industries through the European industrial organization UNICE to provide technical comments on the WHO review papers.

The WHO-ECEH is scheduled to report back to the CAFE steering group by end of first quarter 2003.

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IPPC—Integrated Pollution Prevention and Control

The IPPC Directive foresees the development of Best Available Technique (BAT) Reference documents, known as BREFs, to cover the activities of all major industry sectors. These documents are developed in close cooperation with the industries concerned. CONCAWE has made contributions through its membership of the Technical Working Group for the Refinery BREF. This was completed in December 2001 and CONCAWE will publish a guidance note for IPPC implementation in the fourth quarter of this year.

In addition to the industry specific 'vertical' BREFs, a number of 'horizontal' BREFs, covering several sectors, are also being developed. Some of these cross-sector BREFs are relevant to the oil industry, for example those covering Monitoring, Storage, Environmental Management Systems (EMS), and Economics and Cross Media.

The Monitoring BREF[4] provides guidance for IPPC permit writers and operators on monitoring of industrial emissions at source. It has been finalized and will be presented to the Information Exchange Forum[5] (IEF) in November 2002.

The Storage BREF[6], is concerned with oil product storage installations. It is scheduled to be completed next year.

The purpose of the EMS BREF is to provide a standard text for all vertical BREFs. This activity was initiated by the IEF and CONCAWE participates in the task force which has just reviewed the second draft.

The Economics and Cross Media BREF looks at methodologies for costing, assessment of cross media effects and economic viability. The first draft has yet to be issued.

The IPPC Directive has a requirement for Member States to report emissions, which is now embodied in the European Pollution Emissions Register (EPER) regulations. CONCAWE has reviewed these regulations with a view to producing, in the course of 2003, a toolkit to help refineries complete their returns for the Pollution Emissions Register.

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[4] *Full title: 'Reference Document on the General Principles of Monitoring'*

[5] *The body that recommends the BREFs and their updates to the EU Commission*

[6] *Full title: 'Reference Document on the Best Available Techniques for Storage of Bulk or Dangerous Materials'*

'Well-to-wheels' evaluation of alternative road fuels and powertrains

In Europe, the objectives of reduction of greenhouse gas (GHG) emissions and diversification of energy supply drive the quest for new fuels and powertrains. These could provide credible alternatives to oil-based fuels and internal combustion engines. New fuels and powertrain concepts may involve many new processes and consequent changes to infrastructure. Only by evaluating the complete chain, from the primary energy resource to the exhaust of the vehicle, can a credible assessment be made of the potential impact of new fuel/vehicle combinations.

Many well-to-wheel studies have been, and are still being carried out in this area. However, these often concentrate on a particular country, or on a type or class of alternative fuel. They also frequently lack transparency in terms of the specific assumptions and data sources considered.

Recognizing the need for uncontroversial answers to legitimate questions on the potential of alternative road fuels and powertrains, EUCAR (the European Council for Automotive Research and Development), CONCAWE and the EU Commission's Joint Research Centre (JRC) have pooled their resources to carry out a wide-ranging study, whose main objectives are to:

- establish the energy and GHG balance for a number of different fuel/powertrain options in the context of plausible European scenarios;
- estimate the scale at which such schemes could be developed and the associated investments and operating costs;
- take into account data from all relevant reliable and authoritative sources; and
- report results in a fully transparent way, including the publication of the database and methodology.

The energy resources considered are crude oil, coal, natural gas, biomass and wind. From these, a variety of fuels can be produced, including conventional road fuels, compressed natural gas, hydrogen, methanol, di-methyl ester, fuels from Fischer-Tropsch synthesis, ethanol and biodiesel. The powertrains include port-injected gasoline, direct injection gasoline and diesel, dedicated natural gas and fuel cells (with and without reformer), with hybridization as an option.

The 'well-to-tank' section of the study is led by CONCAWE assisted by the firm of consultants LBST[7]. The 'tank-to-wheels' section is led by EUCAR assisted by the Institut Français du Pétrole. JRC's Institute for Environment and Sustainability at Ispra provides overall coordination and integration as well as data on specific issues, particularly biofuels.

The current study presents a challenging workload, but aims for completion by the end of 2002 to match the timetable set by DG TREN, who have expressed great interest through their Contact Group on Alternative Fuels.

At a later stage, as new information emerges, it will be possible to use the database and methodology to analyse additional pathways or to revisit those already in existence.

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[7] *Ludwig Bolkow SystemTechnik, a Stuttgart-based consultancy with long experience in alternative fuels, particularly hydrogen.*

Future road transport and associated fuels

Will conventional fuels remain the dominant component of road fuels supply over the next two decades?

Over the past year, many new initiatives have been launched in the area of sustainable transport. The EU Commission's 'White Paper' on European Transport Policy was issued in 2001, followed by initiatives on biofuels, other 'renewable' fuels and diversification of energy supply. Both DG TREN and DG Environment currently have work programmes under way aimed at new policy development, with specific emphasis on compressed natural gas (CNG) and hydrogen, while DG Research's proposed 6th Research Framework Programme aims to develop longer-term knowledge on sustainable transport, including alternative and renewable energy supplies. There are also a number of individual Member State initiatives in this area.

The collaborative 'well-to-wheels' study between the Commission's Joint Research Centre (ISPRA), EUCAR (the European Council for Automotive Research and Development) and CONCAWE (see the 'Activity update' section of this *Review*) will provide valuable information for this debate.

Road Transport Research Advisory Council (RTRAC)

Looking to the longer term, there is a need for more efficient coordination of European research on road transport and to this end, EUCAR recently launched the Road Transport Research Advisory Council (RTRAC). This follows similar initiatives in the rail, aviation and shipping sectors and responds to the EU Commission's wishes to establish a similar body for road transport. RTRAC has been set up as an industry committee with high-level representatives from the automotive sector, energy and component suppliers, independent research organizations and road infrastructure builders. Its objectives are to:

- develop a vision of the year 2020 road transport system;
- identify the research agenda required to realize the vision;
- advise industry, the EU Commission and Member States on the required research and priorities; and
- identify and promote areas of collaboration between the European and National Research Programmes.

The oil industry has two seats on RTRAC and in order to coordinate input, CONCAWE has set up its own RTRAC shadow group.

Oil industry view of road transport in 2020

As a first input into the RTRAC process, CONCAWE's shadow group has developed its own view of the evolution of road transport, and particularly of transport fuels, over the next two decades. This view (see box) represents what the industry sees as the most likely scenario, where conventional fuels remain the dominant component of the road fuels supply while alternative fuels and powertrains assume a significant but still relatively minor role. It is also consistent with the car industry's forecast for vehicle sales.

At this point in time the major breakthroughs in key technologies, such as harnessing of renewable energy or

Road transport as we know it has a bright future

improved fuel cells, which would be required for a step change in penetration, are not expected to occur early enough to materially affect the 2020 scenario. A large-scale shift away from crude oil-based fuels is more likely to occur later in the century. The future is of course uncertain and unexpected technology developments or extreme regulatory initiatives cannot be ruled out.

Avoid 'picking winners' too early

RTRAC offers an opportunity for improving coordination of European research on road transport and for debating the key research needs with the EU Commission and Member States. The oil industry view will be taken forward into the development of the formal RTRAC vision and a high-level research plan should then be developed.

From a CONCAWE perspective, it is important that potential future fuel/powertrain options are assessed against advances in conventional systems on an integrated 'well-to-wheels' basis, taking account also of practicality and cost-effectiveness. Understanding the fuel requirements of future internal combustion engines continues to be important, as these systems will still form the bulk of the vehicle population in 2020. It is even more important that attempts should not be made to 'pick winners' too early. Potential future technology options are at an early stage and further research is needed prior to legislative action. Time is available for the necessary research.

CONCAWE's view of European road transport in 2020

1. **Road transport remains the main means of goods transportation and personal mobility**
    - Demand for road transport and mobility has increased over the past 20 years
    - Personal vehicles are still the major means for personal mobility
    - Road remains the primary instrument of goods transportation, despite contributions from rail and water
    - The impact of road transport on air quality is minimal
    - Progress has been made on greenhouse gases, but a technology breakthrough is still sought

2. **Oil and gas remain major sources of energy for Europe for the foreseeable future**
    - Oil and gas are in sufficient supply
    - Diversification of energy sources is taking place where economically viable

3. **Internal combustion engines, including hybrid concepts, powered by conventional fuels provide the major part of road transport demand**
    - Internal combustion systems supported by low sulphur fuels have continued to improve
    - The shift from gasoline to diesel has continued, driven by pressure on CO_2 reduction together with road haulage growth
    - Hybrid concepts have shown their potential to deliver GHG savings and see increasing market penetration as technology improves and costs are reduced

4. **Fuel cell vehicles are achieving a small market share, but no route to large-scale sustainable hydrogen production yet exists**
    - Fuel cell vehicle options are still actively researched in terms of performance, reliability, durability and cost because of their inherent energy efficiency and perceived environmental benefits
    - Emissions benefits are very small compared to the new generation internal combustion engines
    - Development of stationary applications and auxiliary power units have facilitated progress in automotive fuel cell technologies
    - Reforming of hydrocarbon fuels is providing the hydrogen for the first generation of fuel cell vehicles
    - Non-fossil electricity is still limited and is not available for large-scale hydrogen production as it contributes more to CO_2 savings via other routes
    - Hydrogen use in internal combustion engines remains marginal

5. **Other alternative fuels and vehicle systems that have proven benefits are penetrating the market**
    - Local priorities drive limited markets for alternative systems
    - Environmental benefits are insufficient to justify large investments in production, transport and distribution infrastructure for compressed natural gas
    - The objective to diversify energy supply sources drives a steady growth of other natural gas based fuels such as GTL ('gas to liquids')
    - LPG has a limited role
    - Fuels from biomass are available in limited quantities and are mainly used as blending components
    - Alternative uses of land have been found more beneficial than production of ethanol and FAME (biodiesel)

The focus on aromatics in automotive fuels specifications

Can further reductions in aromatic hydrocarbons be environmentally justified?

Over the years, and particularly in the past decade, European motor fuel specifications have changed dramatically. This has followed a general trend, supported mainly by concerns about the effect of road traffic on urban air quality. The USA, and more specifically California, have led the world with regard to gasoline, while diesel has attracted considerable attention in Europe due to its much larger share of the personal car market.

Beside sulphur reduction, these changes have been mainly targeted towards aromatic hydrocarbons, with an initial focus on benzene in gasoline. Exposure of workers and the public at large to benzene, an acknowledged category 1 carcinogen, has caused particular concern and justified drastic reduction measures. Benzene can be released into the atmosphere through evaporative emissions from gasoline storage (fixed or mobile) or through vehicle tailpipe emissions. The former are directly related to the benzene content of the fuel while the latter are also influenced by the total aromatics content of the fuel.

The reduction of the benzene content of gasoline to below 1% in 2000, together with the introduction of increasingly efficient catalytic emissions control systems on vehicles, has essentially solved the exhaust emissions problem. Other measures, including vapour recovery systems and reduction of the vapour pressure of gasolines, particularly in summer, have curtailed emissions of benzene and, more generally, of volatile hydrocarbons from both bulk and on-board storage.

Other aromatic compounds, such as toluene, xylenes or ethylbenzene are not such a direct concern, but their effect on vehicle emissions of benzene and other pollutants has been the focus of attention. Increasingly effective exhaust after-treatment systems and the introduction of lower sulphur fuels have already dramatically reduced these effects and are set to further do so. Nevertheless a 42% v/v total aromatics limit in gasoline was introduced in 2000 and a further reduction to 35% from 2005 is already foreseen in the legislation.

In the case of automotive diesel, early work in the USA suggested a link between regulated emissions and total aromatics content of the fuel. Later work, however, showed the importance of density and demonstrated that polyaromatics have more effect than monoaromatics. Polyaromatics have also come under scrutiny because of the carcinogenic nature of some of these compounds, leading to a polyaromatics limit of 11% m/m in European automotive diesel from 2000. Recent CONCAWE work[1] showed that, for older technology vehicles, the quality of the fuel has a discernible effect on exhaust emissions of a marker polyaromatic compound, but that this virtually disappears with more modern technology engines and/or when an oxidation catalyst is installed.

Also from 2000 the minimum cetane number of automotive diesel was increased from 49 to 51 while the maximum density was reduced to 845 kg/m^3. These two new limits indirectly control the level of total aromatics in the fuel.

Consequences for the refiners and beyond

Aromatic hydrocarbons are an integral part of motor fuels. The problem of reducing their concentration in the commercial blends is of a different nature for gasoline and diesel.

Aromatics are desirable to meet the performance criteria of gasolines, where they provide the bulk of the octane rating, the fundamental quality for a spark-ignited engine. Aromatics are actually 'made' by refineries in order to meet their octane target.

[1] *CONCAWE Review Volume 10, Number 1 (April 2001)*

In diesel, aromatics are part of the package of molecules found in the relevant virgin crude oil cuts and are also produced in catalytic and thermal cracking of heavier cuts. They are not particularly needed and have, in fact, a detrimental effect on cetane quality. Removing them is a question of cost but also of energy consumption with the corollary increase in CO_2 emissions.

Aromatics in gasoline: the quest for octane

The octane quality of the fuel is the property that allows a spark-ignited engine to run efficiently by permitting a high compression ratio[2]. The demand for octane has increased over the years particularly in Europe where more power was sought from smaller engines and a higher emphasis was placed on fuel economy. The current European standard grade has a minimum requirement of 95 RON, 85 MON.

Octane is related to the molecular composition of the fuel. Straight chain paraffins and naphthenes (saturated cyclic hydrocarbons) have poor octane ratings whereas aromatics, branched paraffins and olefins, have high octane values. Oxygenated compounds such as alcohols and ethers generally have very high blending octanes. MON is generally lower than RON and the difference (called sensitivity) is highest with unsaturated and oxygenated molecules.

Addition of an organic lead compound was, in the past, an alternative way to boost the octane rating by typically 3–4 points. The elimination of lead, both on health grounds and to enable the use of 3-way exhaust catalysts, has removed this option. The use of alternative metal-based additives such as MMT (methylcyclopentadienyl manganese tricarbonyl) or Ferrocene is not widespread in Europe and there is continued controversy on their possible effects on engines and after-treatment systems. The whole of the octane requirement therefore has to stem from the molecular composition of the gasoline.

The molecular 'cocktail' of virgin gasolines (known as 'naphthas') is such that their octane rating is generally very low, typically 65–75. The traditional solution has been to 'reform' the naphthas, a process whereby paraffins are cyclized and cyclic molecules are dehydrogenated to aromatics. Reforming is therefore an essential source of hydrogen (and in many refineries the only one), a commodity in increasing demand for hydrotreating of various streams, particularly gasoils. Most reformates are produced with RON values between 98 and 102 and contain between 60% and 75% aromatics. This includes the benzene present in the virgin streams and that formed from 'precursor' molecules such as cyclohexane. The lighter naphtha fractions can also be improved by isomerization, turning straight chains into branched paraffins.

Large volumes of the world's gasoline are produced via catalytic cracking of heavier cuts such as vacuum distillates and atmospheric residues. These 'cracked gasolines' are strongly unsaturated, containing aromatics (including some benzene) and large amounts of olefins. Their octane rating is relatively high, typically 91–93 RON, although not high enough for the modern European premium grades especially in view of their high sensitivity. Catalytic crackers also produce significant quantities of mixed C3 and C4 hydrocarbons. These, and particularly the C4 fraction, can be combined by alkylation to form C7 and C8 hydrocarbons.

In terms of volumes, only reformates and cracked naphthas have the potential to provide the bulk of the demand at the required octane level. The sources of isoparaffins are limited and such components as isomerates and alkylates, although important, can only play a supporting role when it comes to producing the large volumes of gasoline required by the market. Oxygenates such as alcohols or ethers generally have favourable octane properties and have, in recent years, assumed an important role in gasoline manufacture, principally in the form of MTBE (methyl tertiary butyl ether).

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[2] *Octane rating is a performance property measured by comparison of the self-ignition tendency of a fuel with that of two reference compounds in a standard test engine. Two different sets of testing conditions are used resulting in a RON (Research Octane Number) and a MON (Motor Octane Number) rating, with MON generally lower than RON. The 'road octane number', (RON+MON)/2, is used as a single specification in the USA whereas both numbers are specified separately in Europe.*

The focus on aromatics in automotive fuels specifications

Can further reductions in aromatic hydrocarbons be environmentally justified?

The elimination of most of the benzene had a relatively limited impact on octane because the benzene concentrations were relatively low to start with (about 3% v/v average for Europe) and because benzene could be at least partially replaced by heavier aromatics. The reduction was achieved by a combination of measures involving not making the benzene by eliminating the precursors from the reformer feed and/or changing the crude diet. Where this was not sufficient or not desirable, benzene was physically separated from the bulk of the reformate and either sold to the petrochemical industry or hydrogenated. It must be noted that the initial concerns over benzene overproduction never materialized as most of the benzene originally found in gasolines is now not made in the first place.

The residual benzene now comes more or less in equal parts from reformate and from cracked gasolines. Any further reduction of the benzene specification would require addressing the problem of removing benzene from both streams. At this level the options are limited. Solvent extraction of reformates, although applied on a limited scale for the production of individual aromatics, has not been used specifically for the purpose of removing benzene from gasoline. This could be envisaged but would be very capital- and energy-intensive. The full-range cracked gasoline is often split into two or three cuts to provide optimum blending flexibility and, more recently, sulphur removal. Benzene can be concentrated in the 'heart-cut', a stream that is sometimes hydrotreated and reformed because of its comparatively low octane. In this way the bulk of the benzene can be concentrated in the reformate and dealt with accordingly. Directionally though, this entails replacing olefinic by aromatic octane and is therefore limited by the total aromatics specification.

Reduction of total aromatics in gasoline is a particularly thorny problem for a refiner as it requires a strategy for replacing the octane deficit by using other suitable molecules. The above short inventory of possible options shows that the number of candidates is limited. When the other limits on olefins, sulphur, oxygen content are factored in, the feeling is increasingly that we may 'run out of molecules' to formulate our gasolines.

Branched paraffins are the preferred compounds but their availability is very limited and they cannot play much more than a supporting role when it comes to producing the large volumes required by the market. Oxygenates are widely available but supply would in no way be sufficient to make up a major aromatics shortfall. In any case their use is currently limited by a maximum allowable oxygen content of 2.7% m/m. Ethers, particularly MTBE, have also caused concern in relation to potential contamination of underground water.

At the 35% aromatics level, the combined pressures of benzene reduction, virtually complete sulphur removal and olefins limitation will stretch the octane producing capability of the refineries to the limit. Any further reduction of the total aromatics, besides having no environmental justification, would require a complete rethink of the way gasoline is manufactured and require massive investments.

It is also worth noting that the growing demand for isoparaffins for gasoline manufacture is having an effect on the availability of light naphtha, the traditional bulk feedstock for light olefins production. A CONCAWE study on the consequences of reducing total aromatics from 42% to 35% suggested an increase of the density of petrochemical naphtha from 690 to 710 kg/m^3. Such a change can have far-reaching consequences. Higher feed density generally equates to lower olefin yields and proportionally higher production of pyrolysis gasoline i.e. mainly aromatics that may not match the demand. Portions of these heavier streams also traditionally find their way back into the refinery blends where they are increasingly unwanted. The increased value of C4 olefins as alkylation feed also introduces an extra 'front' in the competition of fuels and petrochemicals for appropriate feedstocks.

Aromatics in diesel

Although there is no total aromatics limit as such in EU diesel, the amount is effectively constrained through the combination of the density, distillation and cetane specifications. Currently at 51 the European cetane number specification is the world's highest. Tightening of tail-end distillation limits as well as the need for ultra-deep desulphurization also pushes refiners towards selecting lighter fractions for the diesel pool.

In practice the current specifications allow the use of only small amounts of simply desulphurized cracked gasoils in diesel blends. This is even more the case at the 10 ppm sulphur level, as ultra-deep desulphurization of cracked stocks is difficult to achieve in standard or modified hydrodesulphurization plants. Turning cracked gasoil into suitable diesel components requires deep hydrogenation either in a purpose-built plant or as part of the feed stream to a hydrocracker. As a consequence EU diesel is, already today, largely blended from virgin and deeply hydrogenated streams. This is set to become even more so in the future. This constrains the production volumes in a context of increasing demand for diesel and jet fuel. While development of a sizeable distillate deficit for the whole region is likely, it will be mostly filled from outside sources such as Russia and the Middle East. European refiners are unlikely to enjoy sufficient margins to justify massive yield investments but they will have a strong incentive to maximize diesel and jet production from their existing facilities. As a result the relatively light, low aromatic distillate fractions favoured as petrochemical feed, are likely to become more desirable to the refiners for their fuel business.

In addition to the implicit limit on total aromatics discussed above, the content of di+ aromatics in European diesel has also been limited to 11% m/m since January 2000. The polyaromatics content of a virgin gasoil is highly dependent on the origin of the crude. Cracked stocks generally have high levels of polyaromatics but this is also very variable. Hydrotreating converts part of the polyaromatic content to monoaromatics, the conversion rate depending on the operating conditions (modern plants operating at higher pressure and lower temperature achieve higher conversion rates). The current European market average is around 5% m/m but this conceals a large disparity between individual situations. Further sulphur reductions will somewhat reduce this number but a significant reduction would require specific processing steps involving deep hydrogenation.

The bottom line

The European refining industry has achieved great improvements in the quality of road fuels and is actively working towards meeting the 2005 specifications and towards the virtual elimination of sulphur by the end of the decade. This has already required, and will require further large investments, while resulting in additional CO_2 emissions.

As long as the spark ignition engine has a sizeable share of the vehicle market, aromatics will play a vital role in providing both the quantity and high-octane quality of the required fuel. Any further reduction of the aromatics content of motor fuels would require further in-depth changes in the way streams are processed and selected in the refinery. This would invariably translate into extra costs and extra energy use, i.e. extra CO_2 emissions from the refinery.

The indications are that, at the level already legislated and with the advent of advanced engines and after-treatment technologies, further reductions of the aromatics content of road fuels would afford minimal benefits in terms of emissions reduction and air quality improvement.

AIRNET

A thematic network to interpret research into health effects from air pollution

AIRNET is the acronym for the Thematic Network on Air Pollution and Health. The Network has been funded by the Commission's DG Research to help with the interpretation of results of European research into health effects from air pollution.

Although the Commission has already been funding research on health effects from air pollution for several years, there was until now no proper interpretation framework. AIRNET has been set up to to fill this gap. Its purpose is to develop a general and widely supported framework for interpreting the results of air pollution and health studies, so as to provide a foundation for developing future policy in these areas. This will be achieved by linking findings from exposure assessment, epidemiology and toxicology to risk and health impact assessment, and then to policy issues (standard setting, source control etc.). The main result will be a transparent link between research findings in these areas on the one hand, and policy implications on the other hand.

AIRNET will also produce inventories of research projects by discipline, organize annual conferences, write summary reports on the findings of the research, and draw up recommendations for future policy.

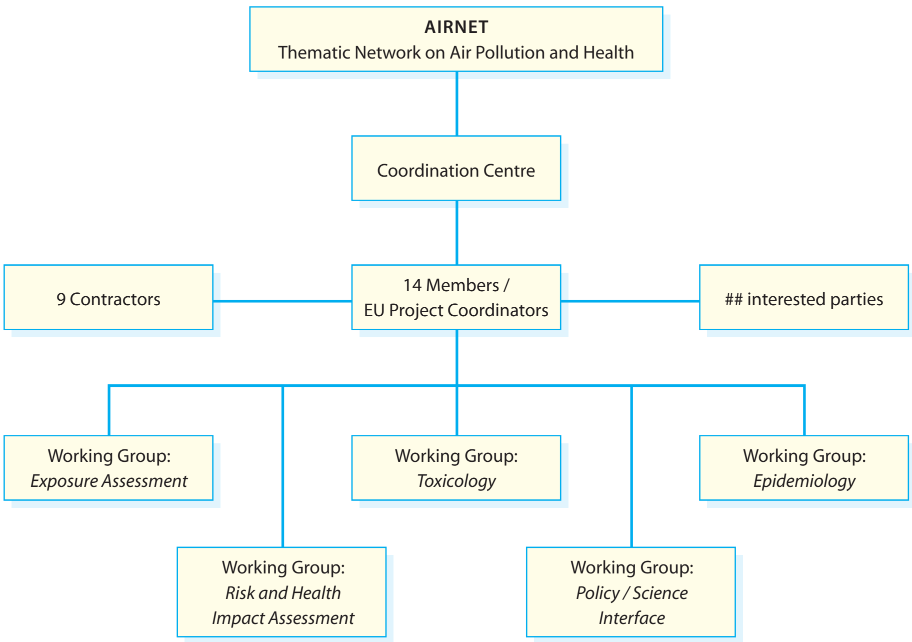
The network is coordinated by the University of Utrecht and the RIVM[1]. The organizational chart, including several working groups, is shown below.

AIRNET brings together scientists from the various disciplines involved in health research of air pollution, such as exposure assessors, toxicologists and epidemiologists, as well as people with interests in health impact assessment and in the science/policy interface.

[1] *Rijksinstituut voor Volksgezondheid en Milieu— the Dutch national institute of public health and the environment*

Figure 1

AIRNET organization structure



Participants include:

- coordinators and additional key investigators of EU-funded projects that were (or are being) conducted within the 4th and 5th Framework Programmes;
- key investigators of non-EU funded major studies (recent or ongoing) on air pollution and health;
- WHO representatives, especially from the Rome and Bonn centres on Environment and Health;
- UN-ECE and related bodies involved in environmental health impact evaluations;
- policy makers from the EU and from some selected national governments;
- representatives of the automobile industry, the oil and/or gas industry (through CONCAWE), and other interested industrial partners;
- representatives of some key consumer organizations; and
- representatives of some key environmental NGOs.

Several international agencies and research centres focusing on air pollution and its adverse impact on human health have expressed an interest in AIRNET and intend to use its output for guiding and structuring their integrated assessments and policy development. These include:

- the European Topic Centre for Air and Climate Change;
- the UN-ECE Convention on Long-Range Transboundary Air Pollution; and
- The European Center for Environment and Health of the World Health Organization.

The network is now half way through its first year of existence and is intended to remain active for a total of three years. Although it was not specifically timed to coincide with the CAFE programme, the Commission's DG Environment nevertheless expects AIRNET to make an important contribution to CAFE.

Five out of six AIRNET working groups have recently held their inaugural meetings. CONCAWE was represented at each of them and took the opportunity to put forward its expectations for sound scientific practices. The first annual conference is scheduled for 11–12 December 2002 in London.

The network maintains a web site at
http://airnet.iras.uu.nl

Refinery sulphur emission reductions reflect the different regional needs

SO_2 emissions legislation and the north/south divide

Since the late '70s, CONCAWE has conducted three-yearly surveys of its Member Companies to provide detailed data on sulphur in crude oil and petroleum products, and sulphur emissions to air. The most recent survey, covering the year 1998, includes data from 79 European refineries processing about 87% of the Western European crude oil. The results, soon to be published in a CONCAWE report, show continued decrease of refinery SO_2 emissions and increase of global sulphur recovery as the European refining system has responded to legislation on emissions and product quality. It establishes a new baseline for comparisons with future performance as further legislation affecting refineries and their products is enacted.

In this brief article we focus on the sulphur emissions to air from the reporting refineries and compare the results of the 1998 survey with those of 1992 and 1995. In particular, we examine the trends in refinery 'combustion bubble concentration'[1] of SO_2 in the light of concerns over acidification in the EU.

In Europe there is continued pressure for environmental legislation to reduce SO_2 emissions. The main drivers for such legislation are air quality improvement and control of acidification. Given the general attainment within Europe of the air quality standards for SO_2 designed to protect public health, acidification has become the more important of these two issues.

Partly in response to these concerns over acidification, the European Union recently adopted the National Emission Ceilings Directive (NECD) and the The United Nations Economic Commission for Europe (UN-ECE) promulgated the multi-pollutant/multi effects Protocol known as the Gothenburg Protocol.

[1] *The combustion bubble concentration of SO_2 is defined as the total amount of sulphur dioxide emissions (mass) from all the combustion plants in a given refining site divided by the total amount of flue gas emitted (Normal cubic metres) by those combustion plants, assuming an excess oxygen content (dry basis) of 3%.*

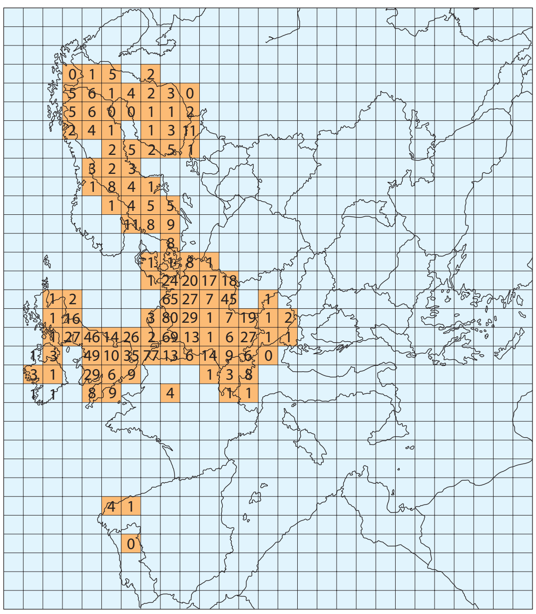
The technical work underpinning both the NECD and the Gothenburg Protocol highlighted the significant differences in the severity of acidification problems across Europe. In particular this showed that northern Europe experiences much more severe problems than southern Europe due to its more vulnerable ecosystems. This is clear from Figure 1 which shows the percent of ecosystems that are foreseen to be exceeding their acid critical loads in 2010 assuming that the measures legislated prior to the NECD and the Gothenburg Protocol are implemented.

This 'north-south' divide is reflected in the more demanding SO_2 emission ceilings for northern European countries in both the NECD and the Gothenburg Protocol. This is mirrored in the regional differences in SO_2 bubble concentrations as well as in the differing regional trends in bubble concentration since 1995.

For the total of the surveyed refineries, the average sulphur content of the refinery fuel oil burned decreased from

Figure 1

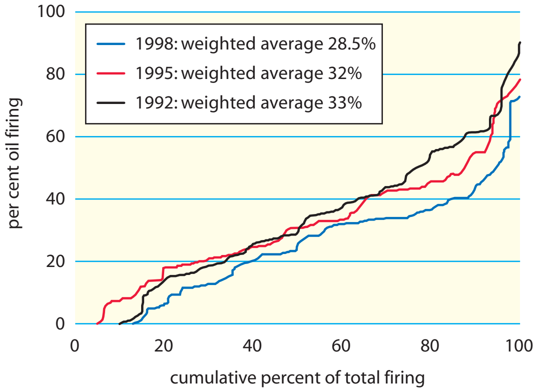
Percent of ecosystems exceeding their acid critical load in 2010



Refinery sulphur emission reductions reflect the different regional needs

SO_2 emissions legislation and the north/south divide

Percent of all oil firing in refineries
(all reporting refineries)



Sulphur content of refinery fuel oil
(all reporting refineries)

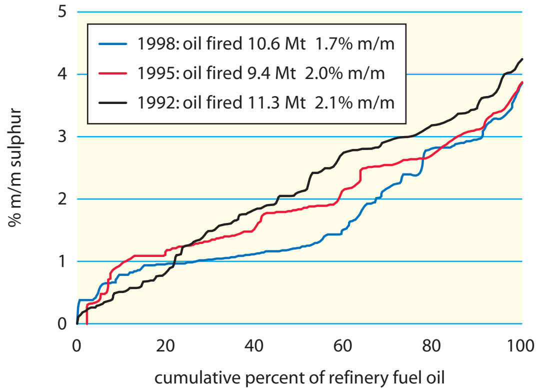
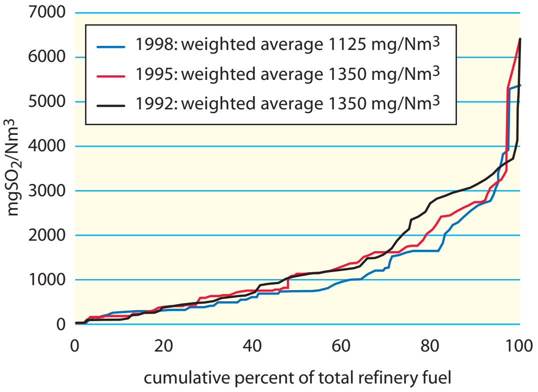


Figure 2 (left)
The percentage of fuel oil burned dropped from 32% in 1995 to 28.5% in1998.

Figure 3 (right)
The average sulphur content of refinery fuel oil burned decreased from 2.0% in 1995 to 1.7% in 1998.

SO_2 bubble concentrations from oil/gas firing
(all reporting refineries)



SO_2 bubble concentrations from oil/gas firing
(by region for 1998)

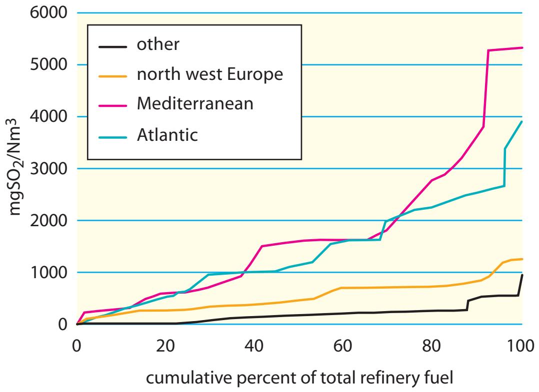


Figure 4 (left)
The average refinery SO_2 combustion bubble decreased from 1350 mg/Nm^3 in 1995 to 1125 mg/Nm^3 in 1998.

Figure 5 (right)
The 1998 data from Figure 4 is presented here by region, and reflects the tougher SO_2 ceilings for northern European countries.

2.0% in 1995 to 1.7% in 1998 while the percentage of fuel oil burned dropped from 32% in 1995 to 28.5% in 1998. The distribution across all reporting refineries is shown in Figures 2 and 3.

This resulted in a significant decrease in the average refinery SO_2 combustion bubble, from 1350 mg/Nm^3 in 1995 to 1125 mg/Nm^3 in 1998. The distribution of bubble concentrations across the surveyed refineries is given in Figure 4. In order to visualize the regional differences, the data are shown by region in Figure 5[2]. This clearly highlights the impact of the more severe acidification problems in northern Europe. This is perhaps even more clearly seen in the regional changes in refinery bubble concentration since 1995.

In north west Europe the average refinery SO_2 bubble concentration of about 860 mg/Nm^3 in 1995 dropped to 550 mg/Nm^3 in 1998, a 36% reduction. In contrast, the Mediterranean region average was much higher at 2060 mg/Nm^3 in 1995 and reduced by a more modest 9% to 1870 mg/Nm^3 in 1998. As discussed above, such regional differences are consistent with the more severe acidification problems in northern Europe compared to southern Europe and are reflected in the tougher SO_2 ceilings for northern European countries in the recently adopted EU National Emission Ceilings Directive and the UN-ECE Gothenburg Protocol.

[2] *The four regions used in the report have been defined to be representative of areas and countries which are similar in terms of crude supply and product demand pattern. They are: north west Europe (Belgium, The Netherlands, Germany and Denmark); Atlantic (Ireland, United Kingdom, Portugal and the Atlantic coasts of France and Spain); Mediterranean (the Mediterranean coasts of Spain and France, Italy and Greece); 'Others', namely the former EFTA countries (Norway, Sweden, Finland, Austria and Switzerland) and Hungary.*

6th CONCAWE pipeline seminar

COPEX 2002: a focus on pipeline management

In April 2002, CONCAWE hosted its 6th Oil Pipeline Operators Experience Exchange seminar 'COPEX 2002' in Brussels. The event, which is held approximately every four years, attracted an enthusiastic audience of nearly 100 representatives from pipeline operating companies from all over Europe. This year, the delegates heard a range of contributions covering a variety of topics related to pipeline safety management, particularly covering risk assessment, leak detection and the latest developments in intelligence pigging.

The keynote paper described the conclusions from the results of CONCAWE's collection of statistics on pipeline leaks. These statistics now cover 30 years and demonstrate a continuing reduction in the amount of oil spilled per year. This is now down to very low levels despite the fact that the average age of pipelines in Europe is increasing. These results were described in the last issue of the CONCAWE *Review* and the detailed analysis is available in CONCAWE report 1/02. In the next paragraphs we give a short summary of the content of the technical papers presented. Readers interested in obtaining copies of the full papers are invited to contact CONCAWE.

The development of technical standards for pipelines and pipeline fittings in the International Standards Organization, and the efforts of major pipeline companies to 'benchmark' their performance against other similar pipelines, are topical issues that were covered by a number of papers. This has reached the stage where a first pilot round has been completed and the process is now open for other pipeline companies to join.

An example of how risk-based methods can be used to identify which parts of a pipeline require attention was the subject of another paper. The risk factors were calculated using statistics from the US Department of Transport in preference to those produced by CONCAWE. Compared to Europe, the pipeline system in the USA is much larger and there have been more than ten times as many incidents recorded there. The statistical sample population is therefore larger, whereas the incidents recorded in Europe are too few for a statistically significant analysis of all the factors involved. A pipeline is broken down into 50 m lengths and the risks for each segment calculated in relation to factors such as road or rail crossings, proximity to houses, geological factors, etc. It is then possible to see whether preventive risk reduction measures or emergency response measures are required.

Supervisory Control and Data Acquisition systems are in almost universal use for the operational control of pipelines, and one paper covered the experience of a particular operator in upgrading his system. Although the existing system was working well and was well understood by the pipeline operator, the hardware was becoming outdated and not suitable for further expansion. The decision was taken to replace the hardware and continue to use the software, even though the hardware had not been designed with this particular software in mind. This gave the opportunity for a discussion on the doubtful merits of frequent 'improvements' to established software.

A series of papers was dedicated to the analysis of pipeline failure mechanisms and the preventive methods to detect them before failure actually occurs:

- Stress Corrosion Cracking was identified in 1997 in a refined product pipeline in France. Since then, research carried out by the whole French pipeline industry has resulted in a much better understanding of the phenomenon and of ways to detect it. This research has been used to develop routine management techniques so that affected pipelines can be operated safely.
- AC current-induced corrosion is a little-known or understood source of corrosion which can occur when buried pipelines run close to high voltage cables and can result in serious corrosion rates of more than 1 mm per year. It can easily be confused with other corrosion mechanisms.
- Metal fatigue is caused by the swings in pressure on the pipeline. A paper described a method of determining the risk of failure for a pipeline and identifying those sections most at risk.
- Theft or attempted theft from pipelines has been a consistent feature of operations, particulary in Eastern Europe, over a number of years and a major cause of incidents. A recent case in Italy unfortunately led to the death of the perpetrator. One presentation described the measures being taken in Hungary to address this problem. Between 1992 and 1999, the Hungarian system was attacked more than 100 times. Although not all of these attempts were successful, the value of fuel lost was substantial. Even more expensive was the cost of clearing up the spilt oil. To counter this threat, a sophisticated leak detection system has been installed. This not only detects leaks, but also pin-points the position of the leak which facilitates rapid intervention. As a result, the number of attempted thefts has now decreased dramatically.

Intelligence pigging is becoming more common. One paper described its application to a major crude oil pipeline over some 15 years. The large quantity of pipeline data collected is stored in a 'Pipe Data System' which has an entry for every section of pipe (currently totalling 67,400), fitting, etc. in the system. As well as the intelligence pig results, this includes data on the materials used in the construction of the pipe, weld inspections, etc. Over the years, some 25 intelligence pig runs have been conducted. These have revealed some 7500 'defects' of which 32 were identified as potentially critical. Of these, the 10 most serious have been investigated by excavating the pipeline. Comparison of the real findings with the results of the intelligence pigging allowed the company to agree with the authorities that a hydrotest was not necessary, that there was no need to carry out verification digs at river crossings and that the throughput of the pipeline could be increased.

26-inch pig trap with intelligence pig for crack detection measurement

A second paper described the development of a transverse magnetic flux leakage intelligence pig. Axial cracks in pipes are important as the pipeline tends to be stressed in this direction. Unfortunately, conventional pigs work best in the longitudinal direction and are not good at identifying such cracks. This 'transverse' pig overcomes this problem and has been used successfully on a French pipeline system.

Another paper described an acoustic method for detecting leaks which has been applied to an ethylene system. Finally, there was a paper on the development of reliability-based design methodologies, which is a new method for determining the wall thickness and steel strength required for new pipelines.

The seminar provided a day and a half of focus on many aspects of pipeline management as well as an opportunity for delegates to network and exchange information informally. All who attended felt that the seminar was a great success and looked forward to the next seminar in 2006.

CONCAWE news

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Sandrine Faucq is currently on maternity leave and during her absence is being replaced by Nathalie Rommel.

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CONCAWE publications

Reports published by CONCAWE from 2001 to date

General circulation (yellow cover) reports:	
1/01	Motor vehicle emission regulations and fuel specifications—part 1 summary and annual 1999/2000 update
2/01	Motor vehicle emission regulations and fuel specifications—part 2 detailed information and historic review (1996–2000)
3/01	European downstream oil industry safety performance—statistical summary of reported incidents—2000
4/01	Performance of cross-country oil pipelines in western Europe—statistical summary of reported spillages—2000
1/02	Western European cross-country oil pipelines 30-year performance statistics
2/02	Energy and greenhouse gases balance of biofuels for Europe—an update
3/02	Motor vehicle emission regulations and fuel specifications—part 1 summary and annual 2000/2001 update*
4/02	Evaluation of diesel fuel cetane and aromatics effects on emissions from euro-3 engines
5/02	Amended safety data sheet directive (2001/58/EC)
6/02	VOC emissions from loading gasoline onto sea-going tankers in EU-15: control technology and cost-effectiveness
7/02	Assessment of personal inhalation exposure to bitumen fume—guidance for monitoring benzene-soluble inhalable particulate matter*

Special interest (white cover) reports:	
01/51	Measurement of the number and mass weighted size distributions of exhaust particles emitted from European heavy duty engines
01/52	A noise exposure threshold value for hearing conservation
01/53	Classification and labelling of petroleum substances according to the EU dangerous substances directive (CONCAWE recommendations—August 2001)
01/54	Environmental classification of petroleum substances—summary data and rationale
01/56	An assessment of occupational exposure to noise in the European oil industry (1989–99)

* Available shortly

Since the beginning of 2002 all CONCAWE reports are published as 'yellow cover' reports.

Up-to-date catalogues of CONCAWE reports are available via the Internet site: www.concawe.be

New reports are generally also published on the website.

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