# CONCAWE Review

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CONCAWE *is the oil companies' European organization for environment, health and safety. The emphasis of its work lies on technical and economic studies relevant to oil refining, distribution and marketing in Europe.*

CONCAWE *was established in 1963 in The Hague, and in 1990 its Secretariat was moved to Brussels.*

concawe

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# Foreword

As announced in the *Review* of November last year, I took over the responsibilities of Secretary General in CONCAWE on 1 December. First I take this opportunity to address our thanks to Jochen Brandt who retired at the end of last year. Through his long association with our organization, there is no doubt that Jochen has been one of the major contributors to its accomplishments and its image.

Our industry is undergoing major restructuring and we are operating in an environment where the authorities and the public at large question the potential health and environmental impact of all our activities and products. In this challenging environment, CONCAWE's mission of providing our stakeholders with a sound and objective scientific basis for the decisions they have to make is all the more essential.

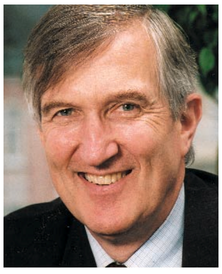
Air quality modelling has been the cornerstone of programmes such as Auto/Oil and we present an article showing that recent air quality measurement data confirm the validity of the models.

Polyaromatic hydrocarbons (PAH) are the focus of much attention. Following a literature survey of published data on automotive PAH emissions, CONCAWE ran a test program aimed at filling some of the gaps in our knowledge. While a full report will be published in due course, you will find the main results of this research in the following pages.

Many of our readers rely on our regular worldwide assessment of motor vehicle emission regulations and fuels specifications. I am glad to announce the publication of both the yearly update and the 1996–2000 historical review reports. There is growing concern that insufficient investments may be made to meet impending fuel specification changes; this could lead to supply shortfalls. We report on a study that considered the potential effects of drastic reductions of diesel density and boiling range.

CONCAWE has been involved in health management issues for more than twenty years and you will find in this issue a general overview of the related CONCAWE activities and achievements. We also report on a recent study of noise exposure levels for EU refinery workers and related hearing trends. The new Dangerous Preparation Directive has significant implications for the downstream petroleum sector and this issue includes an outline of the report on this topic published at the end of last year.

With a final article summarizing the latest statistics on the integrity of Western European pipelines, this issue of the *Review* illustrates once again the diversity of the subjects in which CONCAWE is active.



Jean Castelein
Secretary-General, CONCAWE

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# Air quality trends in London confirm predictions

In response to growing concern over urban air quality in the European Union, the 90s saw an unprecedented legislative focus on reducing emissions from road transport. The Consolidated Vehicles Directive (CVD) and its revision (Council Directives 91/441/EEC and 94/12/EC) set new emission limits for vehicles registered after 31 December 1992 with a further tightening of these limits for vehicles registered after 31 December 1995. The revised sulphur in gas oil Directive (Council Directive 93/12/EEC) was, in part, designed to ensure that the sulphur level in diesel fuel was suitable for the diesel vehicle technology anticipated to be required to meet the post '95 emission limits of the CVD.

The first European Auto/Oil Programme, with its 'air quality driven' rather than 'technology driven' approach, was designed to determine the least cost mix of further vehicle technology and fuel measures required to deliver the road transport contribution to the attainment of European Air Quality Targets. This programme resulted in the mandating of tougher fuel specifications and vehicle emission limits for 2000 and 2005 (Council Directives 98/70/EC and 98/69/EC).


Traffic remains with us—but is air quality improving?

Along with this focus on road transport, the EU Air Quality Framework Directive has resulted in a significant increase in the number of air quality monitoring stations in European cities during the 90s. As the Commission's Second European Auto/Oil Programme draws to a close and they embark on their wider CAFE initiative, are the predicted emission reductions resulting from mandated measures already resulting in noticeable improvements in actual air quality? Positive signals are surely crucial to maintain stakeholder's confidence in environmental quality driven approaches to future legislation inasmuch as it relies on emission forecasting and air quality modelling. In this article we seek to address this question by looking at the 'Example City' of London.

## ESTIMATING EMISSIONS AND AIR QUALITY TRENDS

CONCAWE used its in-house forecasting tool, *STEERS[1] for Europe,* to estimate emission trends for UK urban road transport. This incorporates the methodologies developed for the latest release of COPERT[2] together with the UK fleet composition, turnover data and driving characteristics used in Auto/Oil II. During the second Auto/Oil Programme, STEERS was extensively benchmarked against the FOREMOVE[3] and TREMOVE[4] tools used by the Commission. Given that all three tools utilize essentially the same methodology and databases, emission forecasts from all three emission models were predictably found to be in close agreement.

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[1] *Strategic Toolkit For Evaluating Emission Reduction Scenarios*

[2] *COmputer Programme to calculate Emissions from Road Transport, Version III*

[3] *Forecast of Emissions from Motor Vehicles, LAT, Aristotle University Thessaloniki*

[4] *TREMOVE, developed for the European Commission as part of Auto/Oil II, is a behavioural model designed to analyse the cost-effectiveness of a wide range of technical and non-technical measures aimed at reducing emissions from road transport.*

The emission trends from non-road transport sources were based on the data generated by SENCO[5] for the European Commission as part of the second Auto/Oil Programme.

The air quality data were obtained from the extensive UK National Air Quality Information Archive[6] web site. Hourly data were used to build the compliance picture from a 'bottom up' approach for each pollutant.

To relate predicted emission trends to air quality, a 'reference year' was first selected for each measuring station/pollutant combination. For this reference year, the relative contribution of road transport emissions to overall measured concentration was estimated. For road-side stations this was assumed to be 100%. For urban background stations it was estimated from published air quality modelling results such as Auto/Oil I. By setting the 'emissions-based air quality' equal to the measured air quality in the reference year, the relative change in air quality due to emission reductions could then be determined for the whole period. The results for the three pollutants: benzene, $PM_{10}$ and $NO_2$ are presented in this article.

## MEASURED AIR QUALITY TRENDS IN LONDON CONFIRM EMISSIONS-BASED MODEL PREDICTIONS

The modelling protocols described above have been used to predict air quality trends in the London area, in particular for specific spots where measuring stations are located. Examples of results for three pollutants, namely, benzene, $PM_{10}$ and $NO_2$ are discussed below. The analysis was undertaken for a number of measuring stations, all of which showed good agreement between modelled and measured air quality. However, this article focuses on two stations for each pollutant.

### *Benzene*

Figure 1 indicates that the measured benzene concentrations in two London locations are consistent with the substantial reductions in benzene emissions from road transport that were predicted to occur over the period. In particular, the effect of the mandatory introduction of a maximum content of benzene in gasoline from 1 January 2000, is clearly reflected in these data.

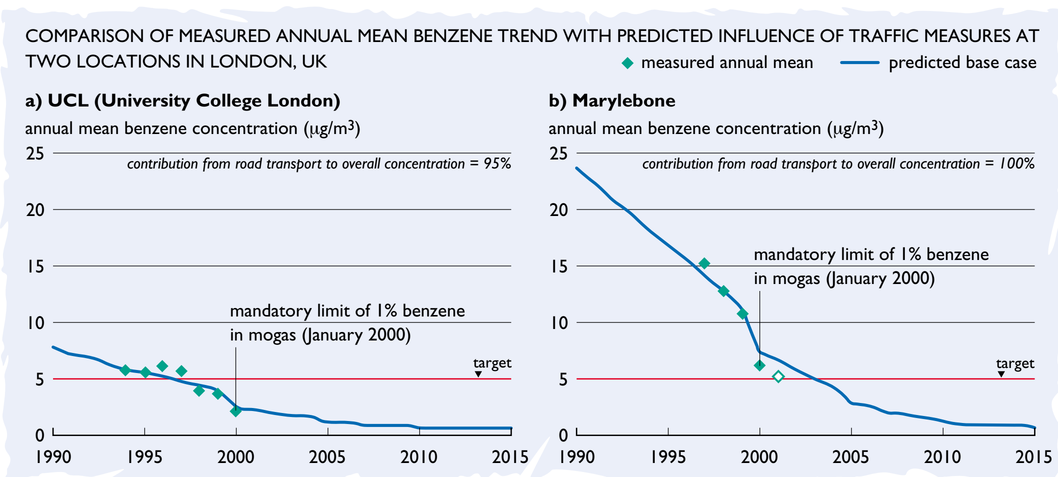



Figure 1a/b
Benzene air quality trends in London. The 2001 data point for Figure 1b is based on only two months of measurement data in 2001.

[5] *Sustainable Environment Consultants*

[6] *The UK National Air Quality Information Archive is sponsored by the Department of Environment, Transport and the Regions, the National Assembly for Wales and the Scottish Executive and maintained by the National Environment Technology Centre, NETCEN.*

This provides confidence in the validity of the emissions predictions that underlie the emissions-based air quality trends. Further, it provides justification for extrapolating these trends using the emission forecasting tool to obtain a robust view of future air quality. The anticipated further improvements, resulting from the tightening of VOC emission standards for vehicles and fuel specifications changes post 2000, are also shown on the charts. This indicates that, even for a roadside station such as Marylebone, the recently adopted EU benzene annual mean air quality standard of 5 µg/Nm$^3$ will be met before 2005.

This ability to relate emission trends to measured air quality also means that any potential further emissions changes e.g., due to a vehicle technology or fuel specification change, may be expressed in air quality terms. Such 'what if' analysis is explored in the air quality trends for $PM_{10}$ discussed below.

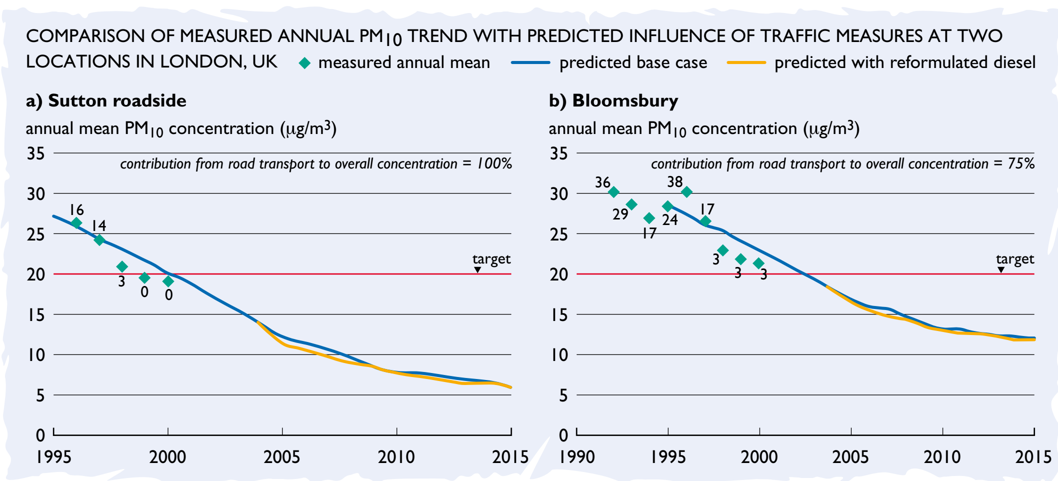
### ***$PM_{10}$***

Figure 2 shows that the measured concentrations of $PM_{10}$ are in good agreement with the emissions-based trend for two London measurement stations. This facilitates the extrapolation of the expected trend resulting from emission reductions from already mandated transport measures, the so-called 'Base Case'. For these stations this indicates compliance with both the annual mean air quality standard and the 24-hour air quality standard exceedance target, before 2005.

Confirmation of the robustness of using the emissions to provide a forecast of future air quality also permits a reliable assessment of the effect of further measures on this trend. Here one such case is shown. This is the introduction in 2005 of one of the reformulated diesel fuels examined under the second Auto/Oil programme[7]. As may be seen, this measure offers a very small further reduction on $PM_{10}$ levels. Indeed, since such a new fuel only benefits the existing fleet in 2005, with time, as these vehicles are replaced with new vehicles (which use the new fuel to conform to their emission standard), this small impact reduces to zero.

Figure 2 a/b
$PM_{10}$ trends in London

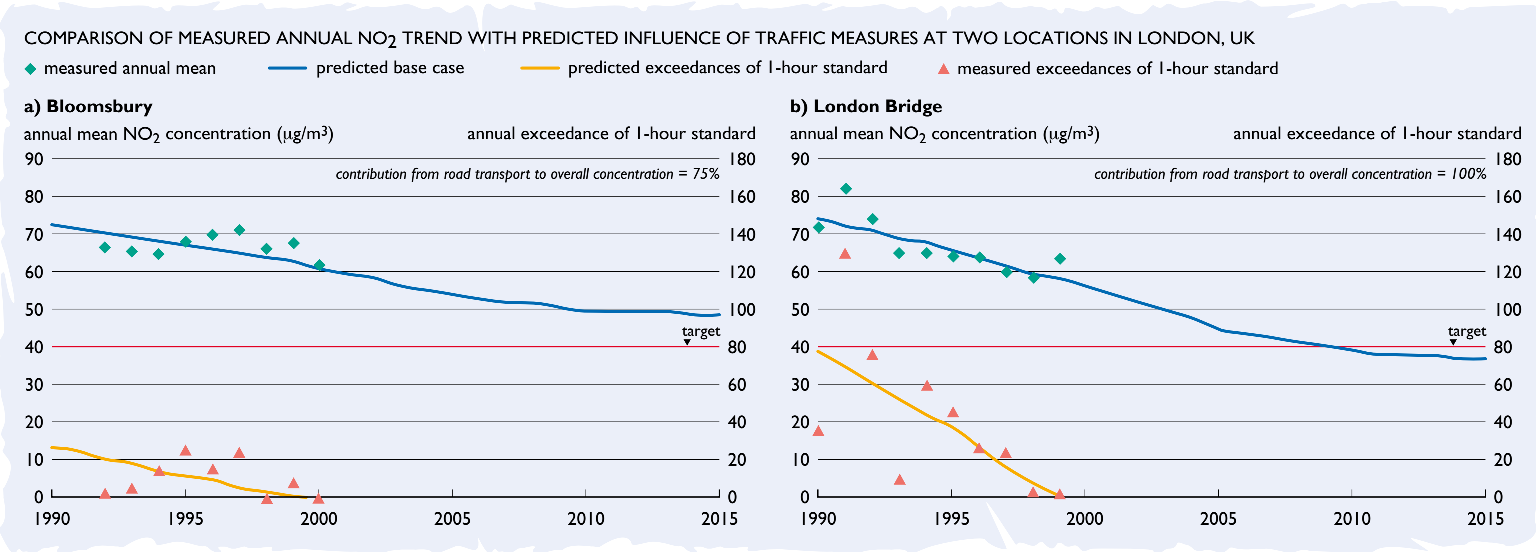
Note: The numerical value attached to each data point denotes the number of days for which the 24-hour average standard of 50 µg/m$^3$ has been exceeded. Measured data are shown for each measurement year.




### ***$NO_2$***

Figure 3 provides a comparison between measured annual mean concentrations of $NO_2$ and the emissions-based annual mean trend. The availability of measurement data on an hourly basis permitted the emissions-based annual mean air quality trend to be related to the exceedances of

[7] *The so-called DQ3 case: 'market-average' diesel fuel with a density of 825 kg/m$^3$, a T95 of 355°C and polyaromatic content of 3% m/m.*




the 200 μg/m$^3$ 1-hour standard. Again this shows close agreement with the exceedance trend based on measured data.

Figure 3 a/b
$NO_2$ trends in London

Note: $NO_x$ emitted from motor vehicles is almost all in the form of NO which reacts in the atmosphere with ozone to form $NO_2$. To account for this, the measurements of both NO and $NO_2$ were used to develop the emissions-based trends shown in the figure.

The trends show that the annual mean standard of 40 μg/m$^3$ is a more challenging target than the exceedance criteria for the 200 μg/m$^3$ target. This is especially so for the Bloomsbury measuring station where the emissions from non-transport sources play a more important role in overall measured levels, especially post 2000. The London Bridge Road site, being much more traffic-dominated, benefits from the significant transport emission reduction over the period. These different characteristic responses at the two sites are reflected in the exceedances of the short-term standard. Where traffic dominates, the exceedances are much higher but decline rapidly as transport emissions reduce.

## CONCLUSIONS

This analysis of air quality measurement data in the London area shows that forecast air quality trends are already reflected in measured data. This reinforces confidence in the current forecasting methodologies both for emissions and resultant air quality. It also upholds the validity of the technical analysis of the second European Auto/Oil Programme for which such forecasts are the cornerstone. This should provide further assurance regarding the robustness of underlying technical analysis to those involved in finalizing the conclusions of the Programme. Finally it vindicates concepts such as Integrated Assessment Modelling that depend on emissions forecasting and will be at the heart of the technical input to the development of future programmes such as CAFE and future air quality policies.

# Keeping abreast of emission regulations and fuel specifications

For many years now, CONCAWE has produced a regular update to their report on 'motor vehicle emission regulations and fuel specifications'. Over the years, this has become a key compilation and ready reference manual for many readers. A comprehensive update has recently been prepared.

This report details the development of worldwide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption. It describes legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes, and legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions. Automotive fuel specifications (including reference or certification fuels) and fuel characteristics are also documented.

Due to the increasing number and complexity of developments in motor vehicle emission regulations and fuel specifications, the two-part format introduced in 1997 was also adopted for the new update:

Part 1: motor vehicle emission regulations and fuel specifications—summary and annual update 1999/2000

Part 2: motor vehicle emission regulations and fuel specifications—detailed information and historic review 1996–2000

Part 1 provides the annual summary and update on current and future automotive emissions legislation and fuel quality regulations. All the major oil-consuming countries from which information is available are included. To make the document easy to use, the amount of detail and background information contained in Part 1 is limited and for further details, the reader is directed to the more comprehensive information contained in Part 2.

The first edition of Part 2 was published as CONCAWE Report No 6/97 and covered the years 1970–96. Part 1 has continued to be issued annually, growing in size and complexity. It was therefore considered opportune to publish a new edition of Part 2, covering the period 1996–2000. The complete history of the development of automotive emissions and fuel specifications is thus now covered by the new Part 2 and the earlier edition, Report No. 6/97.

CONCAWE, as a European organization, has focused on providing detailed information for Europe. Much attention has also been paid to the United States and Japan as their legislation also influences worldwide trends. Every effort has been made to document information from other countries—however, the data obtained are not as detailed as that for Europe and input from readers of this report is always welcomed. Readers with information which they feel could usefully be incorporated into the next revision of this report are encouraged to contact CONCAWE's Secretariat.

# Automotive emissions of polycyclic aromatic hydrocarbons

The International Agency for Research on Cancer (IARC) has classified certain individual polycyclic aromatic hydrocarbons (PAH) as carcinogenic to animals and probably carcinogenic to humans. Current PAH concentrations in European ambient air are the lowest ever measured, largely as a result of the reduced use of coal in domestic and other heating. Nevertheless, in 1999 the European Commission created a Working Group to review the knowledge on PAH in ambient air and to consider the need for, and implications of, regulations on the concentrations of PAH under the Air Quality Framework Directive (96/62/EC).

Amongst the EU Member States, only Italy currently has legally enforceable ambient air standards for PAH but five others have issued guidance for planning and policy purposes, all based on the use of benzo(a)pyrene (B[a]P) as a marker for PAH. Road transport is a relatively small contributor to B[a]P emissions. By 2010, domestic combustion of solid fuels, in particular wood, is expected to be by far the largest contributor to total European B[a]P emissions.

In order to understand the contribution from road transport, CONCAWE carried out a literature review of PAH levels in automotive exhaust emissions and fuels. The results of this review (CONCAWE report 98/55) clarified some of the complexities in the area of automotive exhaust PAH emissions but also identified some key knowledge gaps. Although the literature on diesel PAH emissions is extensive, there is a striking lack of definitive investigations into the link between diesel fuel PAH content and PAH exhaust emissions.

CONCAWE has now studied the relationship between fuel PAH and exhaust PAH emissions from a range of vehicles and fuels in a rigorous test programme. Both particulate-bound and vapour phase PAH emissions were measured for the 16 PAH species targeted by the US EPA.

The total measured exhaust PAH represented less than 1% of the total emitted hydrocarbons, with the majority found to be in the vapour phase, dominated by naphthalene. Reducing diesel fuel polyaromatic content from 12% to near zero had a relatively small effect on B[a]P emissions, although effects on 2+ and 3+ ring species were larger. A significant portion of B[a]P emissions was shown to originate from combustion. Newer technology diesel vehicles with effective after-treatment showed reduced PAH emissions and lower sensitivity to fuel polyaromatics content. As expected, a modern three-way catalyst (TWC) gasoline car gave very low PAH exhaust emissions, even with the extreme fuel qualities investigated.

## OBJECTIVES OF THE PROGRAMME

The objectives of this programme were set in view of the conclusions and knowledge gaps identified in the literature survey and were:

- to evaluate the relationship between diesel fuel polyaromatics content and exhaust PAH emissions;

- to clarify the proportion of combustion-derived versus unburned hydrocarbon PAH emissions in diesel engines; and
- to verify that a modern TWC gasoline car gives very low PAH emissions and is insensitive to extreme variations of fuel quality.

## DEFINITION AND SELECTION OF PAH TO MEASURE

The term 'total' PAH is used extensively throughout the literature but has no firm definition. It usually refers to the sum of the species that a particular researcher has analysed, may or may not include both particulate-bound and vapour phase emissions and generally only includes parent PAH, omitting any alkylated species. In this programme the US EPA's 'Priority Pollutants' list of 16 PAH was used as the selection criteria.

## TEST PROTOCOL

There is no standardized sampling protocol for PAH from automotive exhaust emissions streams or standard analytical procedure. In order to address both particulate-bound and vapour phase PAH, a common analytical system was required. A sampling system was developed in conjunction with Ricardo Consulting Engineers, which sampled both particulate-bound and vapour phase PAH from a standard dilution system. Sampling was carried out over the relevant test cycle (MVEG cycle for light duty and ECE R49 for heavy duty). In order to identify potentially small effects, each fuel was tested a total of six times over the appropriate legislated test cycle in a statistically designed pattern. System blanks were run on a regular basis.

Although vapour phase and particulate-bound PAH were measured separately, only the sum of the PAHs are reported because there is always some transfer of PAH between the vapour and the particulate phase.

## SELECTION OF VEHICLES, ENGINE AND FUELS

Four light-duty vehicles (three diesel and one gasoline) and one heavy-duty diesel engine were used in the programme. Three Euro 2 diesel passenger cars were tested in order to cover a range of light-duty vehicle technologies with and without exhaust after-treatment. One of the cars was tested both with and without an oxidation catalyst. The heavy-duty engine was a nominal Euro 2 engine typical of the bulk of the current European HD diesel fleet.

A matrix of five diesel fuels was tested. Three fuels were blended to cover a wide range of polyaromatics content (1%, 6% and 12% by IP 391), with other key parameters (sulphur, density, cetane number, T95) held constant. The other fuels were included to separate the effects of polyaromatics and total aromatics.

The gasoline car had a typical Euro 2 engine using a conventional TWC. The gasoline programme was intended only as a demonstration of the extremely low PAH emissions from conventional vehicles equipped with TWC. Hence, only two fuels were used, covering a wide range of PAH, aromatic and sulphur contents.

## IMPROVING UNDERSTANDING OF PAH EMISSIONS

As a result of the careful design and preparation of the programme, it has been possible to detect small fuel effects. Although data are available for all individual 16 EPA PAH species, the report has grouped the species for comparative purposes as follows:

1. Benzo(a)pyrene (B[a]P); selected on the basis of its potential use as a 'marker' in air quality developments.
2. Sum of PAH with 3 or more rings (referred to as '3+ ring PAH'); these reflect the targeted PAH which are predominantly emitted bound to particulates.
3. Sum of all 16 species ('2+ ring PAH'); these emissions are dominated by naphthalene and this category reflects the behaviour of the targeted di-aromatics which are predominantly emitted in the vapour phase.

Table 1 shows the ranges of these identified groups and the comparison of the targeted PAH with the regulated total hydrocarbon emissions (HC). The range of results reflects the range of vehicles and fuels tested as well as the variability of the test measurements. Some effects are already clear from the table:

- The total PAH exhaust emission measured is a very small percentage of the total emitted hydrocarbons.
- The total is dominated by 2 ring PAH vapour phase emissions, principally naphthalene.
- The absolute levels of B[a]P emissions are extremely small.
- PAH emissions from the TWC gasoline vehicle are an order of magnitude lower than diesel.

Table 1
Total PAH emissions are significantly less than measured emissions of hydrocarbons.

Comparison of targeted PAH with regulated total hydrocarbon emissions

| | *B[a]P* | *'3+ ring PAH'* | *'2+ ring PAH'* | *HC* |
|---|---|---|---|---|
| Heavy-duty diesel (μg/kWh) | 0.11–0.24 | 61–165 | 443–2220 | 264–294 x $10^3$ |
| Light-duty diesel (μg/km) | 0.14–1.53 | 46–296 | 189–2240 | 65–295 x $10^3$ |
| Light-duty gasoline (μg/km) | 0.03–0.09 | 11.1–11.6 | 103–230 | 116–128 x $10^3$ |

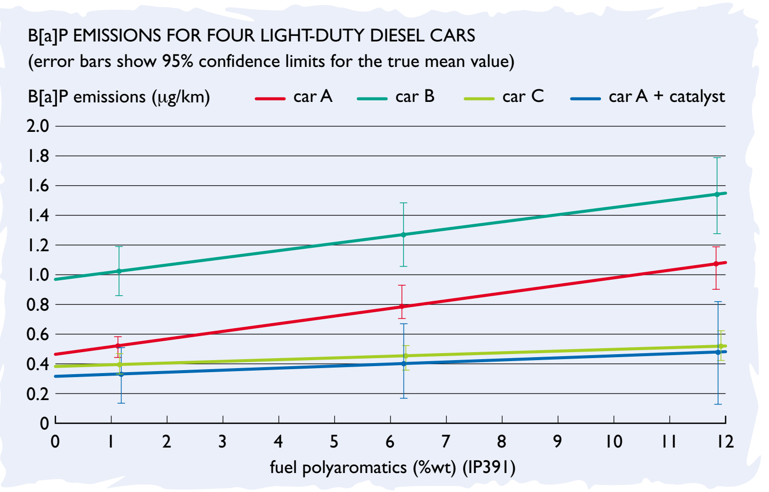
## BENZO(A)PYRENE (B[A]P)

The report addresses the PAH emissions in detail based on the three groups, as described above. In view of the use of B[a]P as a marker for PAH in the current air quality debates, we focus here on the B[a]P emissions data. Figure 1 shows the data for the light-duty diesel fleet (cars A,B,C and A+ oxidation catalyst), demonstrating that:

- Reducing fuel polyaromatic content from 12% to near zero has a relatively small effect on B[a]P emissions especially for advanced technology vehicles.
- Even though B[a]P is not detectable in any of the test fuels, it is formed during the combustion process.
- Vehicle technology effects are substantial:
  - the more advanced technology vehicles produce the lowest absolute PAH emissions and have the lowest sensitivity to fuel polyaromatics content; and
  - the oxidation catalyst technology has a key influence.

Similar trends were observed in the heavy-duty engine data, though in this case, only one engine without an oxidation catalyst was tested.

Figure 1
Vehicle technology, in particular the oxidation catalyst, are key factors in influencing B[a]P emissions.



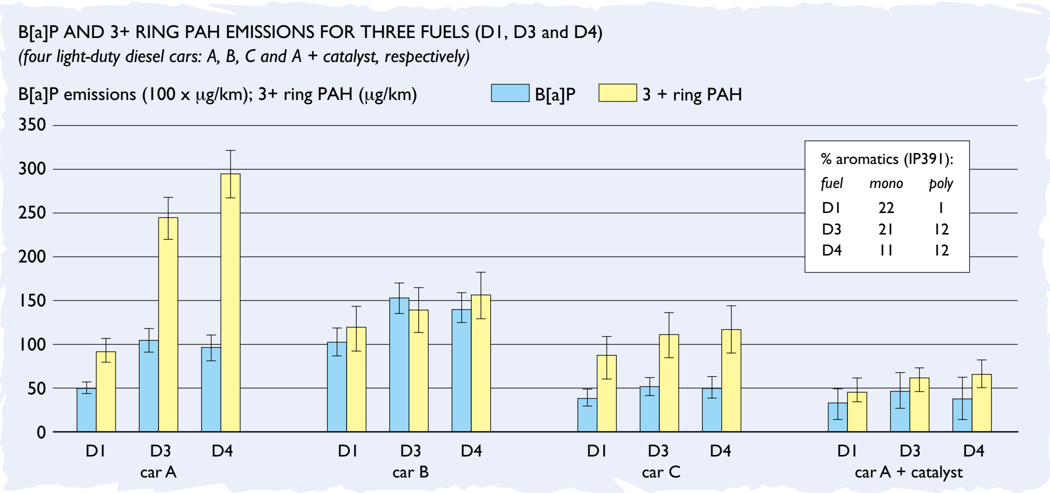



Figure 2
New vehicle technologies have a greater effect on PAH emissions than reductions in fuel PAH content.

The fuel matrix enabled the separation of the effects of poly-, mono- and total aromatics content. The data shown in Figure 2 demonstrate that:

- Fuel effects on B[a]P and 3+ ring PAH emissions correlate with polyaromatics and not with mono- or total aromatics content.
- However, PAH emissions were reduced more effectively by newer vehicle technologies, e.g., with oxidation catalyst, than by reductions in fuel PAH content

## CONCLUSIONS

- The total targeted automotive PAH exhaust emissions (EPA 16; particulate-bound plus vapour phase) is a very small percentage of the total emitted hydrocarbons.
- There is no correlation between exhaust PAH and fuel total aromatics content.
- Without exhaust after-treatment, diesel fuel polyaromatics content does influence PAH emissions but a significant portion of PAH emissions is combustion-derived.
- Exhaust after-treatment is the most effective means to reduce PAH emissions and substantially reduces the sensitivity to diesel fuel polyaromatics content.
- Results from the gasoline car equipped with a TWC confirm expectations from the literature survey that PAH emissions are very low. Changes in gasoline quality over a wide range of parameters made no significant difference to B[a]P and 3+ ring PAH emissions.

Current or planned emissions abatement measures for currently legislated pollutants will contribute significantly to the reduction of exhaust PAH emissions. The key role that fuels can play in future emission control and air quality improvement is to enable the application of more efficient engine technologies, in particular exhaust after-treatment systems. In this regard, fuel sulphur content is currently the only generally recognized enabling fuel property. Reductions in fuel PAH content would have only a small and diminishing effect on ambient PAH levels.

# Could tougher specifications affect diesel supply?

The evaluation of the impact of various measures on the EU refining industry is generally based on the assumption that refiners will invest in order to meet both future demand and product specifications. Reality may be less clear-cut. While some refiners will indeed invest, others may resort to solutions such as changes to the crude diet, import/export of components or changes to the production pattern. In any business, the decision to invest has to be based on the judgement that a return can be made on the proposed investment and, if there are viable alternatives to investment, these decisions could be avoided or deferred.

In the face of a major change to product specifications, some refiners may consider the option of a volume reduction if it allows the new quality requirements to be met without investments. This is not always possible, but many specification changes offer that opportunity. Diesel density or T95 are such specifications, and new limits could be met by reducing production of diesel and jet fuel. In the context of the Auto/Oil II process, CONCAWE investigated the potential diesel volumes reduction that could be associated to a tightening of these two specifications.

## DENSITY

The base case represented the 2005 Auto/Oil I scenario with the diesel density specification set at 845 kg/m$^3$ maximum. The specification was then reduced, first to 835, then to 830. For each density specification level the refinery blending target was reduced by 5 kg/m$^3$ in order to allow for the blending margin.

In the usual CONCAWE cost-modelling mode, all base case demands and crude supply are kept constant with the exception of one marginal crude (Kuwait) that provides the required degree of freedom. In this case, the diesel and jet fuel demands were allowed to fluctuate.

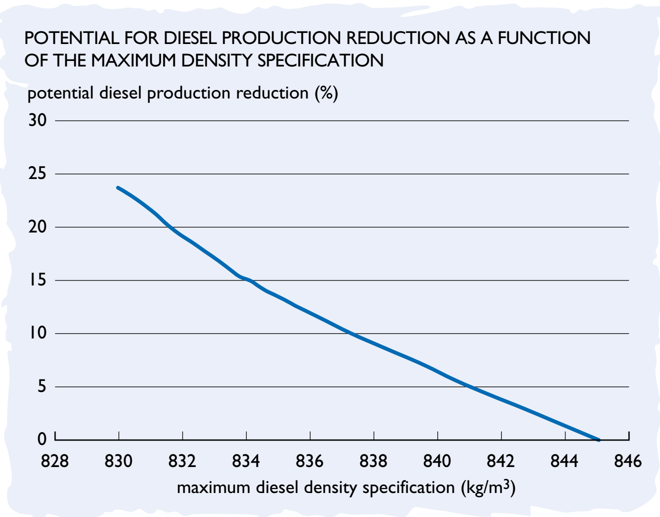
Table 1:
Dealing with diesel density reduction

Results of the CONCAWE investigation into potential diesel volumes reduction (global EU refining system)

| | *Base case* | *no investment (worst case scenario)* | | *normal investment* |
|---|---|---|---|---|
| Diesel density (kg/m$^3$) | | | | |
| Specification | 845 | 835 | 830 | |
| LP maximum | 840 | 830 | 825 | |
| Present value of new plants (GEUR) | Base | None | None | 7.8 |
| Crude intake (Mt/a) | 616 | 590 | 565 | 617 |
| Main products (Mt/a) | | | | |
| **Gasolines** | **143** | **143** | **143** | **143** |
| **Jet/Kero** | **47** | **31** | **35** | **47** |
| Diesel | 146 | 136 | 112 | 146 |
| IGO | 76 | 76 | 76 | 76 |
| HFOs | 33 | 33 | 33 | 33 |
| Worst case potential reduction Jet+Diesel | | 13% | 24% | |

The results pertaining to the global EU refining system are shown in Figure 1 and Table 1. The last column in the table represents the 'normal' investment case and shows that investing for a density of 830 kg/m$^3$ maximum would correspond to a present value of 7.8 GEUR for the EU-15 industry. The second and third columns represent scenarios where no investments are allowed, i.e. a 'worst case' scenario where all refiners decide against investment.

Figure 1
The potential effect of changes in density on production is not a linear function, mainly because the 845 specification is not universally constraining.




Low-density diesel production would therefore be possible without investment albeit at the cost of a diesel + jet fuel volume reduction of nearly 25% in the most severe scenario. The production volumes of all other products would be maintained.

Figure 1 shows that the effect is not completely linear. This is mainly due to the fact that the 845 specification is not universally constraining.

There would of course be some flexibility to swap between jet fuel and diesel although it must be noted that increasing jet volumes would increase the density of the diesel pool and therefore reduce the global volume even further. Similarly some gasoline reduction could be accepted in order to boost jet production. This is a likely scenario inasmuch as the base case includes gasoline exports out of the EU area. The scope is limited though, as short-cutting the straight-run naphthas is limited by hydrogen requirements (i.e. reformer intake) while kerosene flash point soon becomes a limit as EU refineries are not normally designed for maximum kerosene modes. Use of heavy FCC gasoline in diesel is extremely limited (if at all possible) because of the unfavourable properties of this stream.

The 25% reduction figure is an average. Local reductions would depend on specific conditions such as crude flexibility, refinery configuration and demand barrel. From a global point of view there appears to be little scope to improve on the average figure by varying the crude diet (within plausible boundaries).

## T95

T95 stands for the temperature at which 95% of the diesel is evaporated (in the standard ASTM distillation procedure). It is a measure of the 'heavy ends' present in the fuel. The current specification for EU diesel fuel is 360°C.

Based on a recent CONCAWE internal survey, the current T95 market average is in the region of 350°C. This was our assumption for the base case, which was otherwise the same as for the density study. With the specification reduced to 340°C, the constraint would be much more significant and the give-away would decrease to maybe 5°C. Our assumption is therefore that the average would have to be reduced by 15°C (to 335°C) to meet a 340°C specification.

T95, like all ASTM distillation points, is difficult to represent accurately in a typical model that is invariably based on true boiling point (TBP) cuts. The relationship between the TBP cut-point and the ASTM T95 of a fraction is complex. Based on actual data, we considered here that a 10°C reduction of T95 would require a 13°C reduction of the cut point. For a 340°C T95 specification a cut-point reduction of about 15 x 13 /10 = 20°C would therefore be required.

In a no-investment scenario, all components removed from the diesel pool would have to find their way into IGO (industrial gasoil/heating oil) and HFO (heavy fuel oil). As the markets for both products are limited a reduction of crude intake to keep the IGO + HFO volume constant would be required (this is particularly true for inland refineries for which the bunker market for heavy fuel is not a practical option). The results are shown in the figure below where we have allowed both distillates and gasoline production to vary from the base case

The potential reductions exceed 25% for diesel and are about 11% for both gasoline and jet fuel. Again there would be some possibility of swaps between the pools. Blending additional kerosene into diesel would relieve the T95 constraint thereby somewhat increasing the total distillate pool. Whether it would be economic to do so would depend on the relative value of jet and diesel. Although such scenarios were not explored in this limited study, we do not believe the overall figures would be much affected. As illustrated in the graph, the T95 reduction also has impact on density.

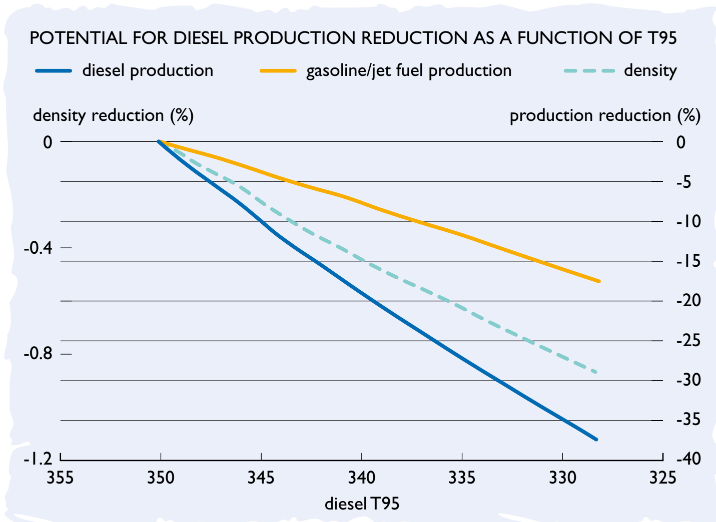



Figure 2
Potential yield reductions exceed 25% for diesel and are about 11% for both gasoline and jet fuel. Note that a reduction in T95 also has an impact on density.

## SUPPLY IMPLICATIONS

Reductions in the diesel density and/or T95 specification, such as envisaged in the Auto/Oil II programme could be achieved by foregoing volumes rather than investing in new plants. At the level envisaged in the Auto/Oil II programme, the shortfall 'worst-case' potential is as much as 30% for diesel and, as a knock-on effect, about 10% for gasoline and jet fuel.

Although a shortfall of such magnitude is unlikely to develop in reality, these calculations highlight the potential for supply disruptions. In an expanding distillate market, the conclusion by some refiners that investment might not be economically viable could be sufficient to create a small but significant shortage. Other refiners, already stretching their production capabilities, would find it difficult to cover the deficit. The scope for imports is likely to be limited especially in a very low sulphur specification scenario. This was recently illustrated in the USA, where even marginal shortages (or the perception thereof) seems to have had disproportionate effects on the markets with severe price implications.

# Understanding the health issues of oil industry operations and products

CONCAWE's Health Management Group (HMG) has been in existence for more than twenty years and recently held its 100th meeting. To mark the occasion we look at some of the contributions made by HMG towards improving the understanding and management of health issues related to European oil industry operations and products as well as the future contribution and role of the Group.

The members of HMG are senior occupational physicians, toxicologists, industrial hygienists and product stewards from CONCAWE's member companies. The emphasis of the group's work programme has gradually shifted since it was founded. Initially the focus was on producing guidance for effective occupational health management in member companies' operations. Latterly, the emphasis has evolved to include addressing environmental legislative initiatives in the fields of product classification and risk assessment, automotive emissions regulation and air quality limit values. In all these areas, whilst the legislative initiatives are targeted at improving environmental health protection, many of the underlying scientific issues are still unresolved and assumptions must be made when determining actions. In order to ascertain that any assumptions made by the regulators are as valid as possible it is necessary to understand several issues, i.e. the precise biological effects of harmful materials, the actual or assessed levels of exposure to the substances involved, the differences in susceptibility within the human population as well as methodology issues for population-based health research and epidemiology. There is also often a need to follow initiatives from several legislative jurisdictions. An example of this is addressing the potential health effects of occupational and environmental exposure to benzene.

An important data source for human health experience is the wide range of epidemiological investigations of oil and other industry employee groups from around the world. The current European and many national occupational exposure limits have been derived from this body of data. These data have also been used by the EU to estimate the risk associated with exposure to ambient benzene, resulting in the recently established Air Quality Limit Value. The epidemiological data available were all retrospective, by their very nature imprecise and thus necessarily subject to interpretative analysis. Assumptions critical to the resulting occupational risk estimates had therefore to be made, especially in relation to exposure levels and extrapolation of inferences. These assumptions were also essential when assessing the benefits of the ambient air quality limit value and the actions necessary to achieve them. HMG was active in helping to ensure a thorough understanding of the uncertainties in these assessments and members actively supported the industry representation in the European Commission's Working Group charged with the development of a proposed benzene air quality limit value. The same basic knowledge of benzene exposure and toxicity is currently used to work with Member States' authorities in the development of the Risk Assessment Report under European Regulation 793/93, for which benzene has been identified as one of the priority substances.

## SOME MILESTONES

HMG has contributed more than 65 reports to CONCAWE's extensive inventory. Many of these reports were written by individual HMG members. Other reports, commissioned from university-based experts, were the product of the three subgroups (Industrial Hygiene, Medical, and Toxicology) or of one of HMG's Special Task Forces. An example of this is the guide on first aid and medical advice for petroleum products (latest issue 1/97). This report was written with the purpose of informing poison control centres as well as to serve as a basis for member companies' material safety data sheets. It strongly supported the case that it was unnecessary for each oil company individually to provide highly detailed compositional information to each of the many European Poison Centres advising them on accidental over-exposure to petroleum products. It was accepted that the generic guidance of the 1/97 report was sufficient to ensure they could provide effective advice.

The production of generic Petroleum Product Dossiers was another example of CONCAWE reports and documents being an effective alternative to each oil company individually submitting product data to regulators. The production of such joint reports represents a considerable saving in overall effort and resources for the industry and ensures consistency of data provided to third parties.

HMG facilitated an important step in the reduction of reliance on animal testing to ensure safe human usage of petroleum products with the introduction of a simple analytical procedure (IP 346). Through this procedure the potential carcinogenic properties of base oils can be established and used for classification and labelling purposes without having to conduct two-year animal experiments. This development was in accord with industry's objectives and the expressed desire of both the European Parliament and the Council to reduce animal testing.

## WORKING WITH INTERNATIONAL BODIES

As a technical and scientific organization CONCAWE has established the credentials necessary to be accepted as a participant or an observer in working groups of many international organizations. HMG's representatives are, as a consequence, able to participate and collaborate with the European Commission services in the fields of occupational health (DG Employment and Social Affairs) and environmental health, e.g. product classification (DG Environment). HMG has also established cooperation with various institutions of the United Nations' World Health Organization. This includes the European Centre for Environment and Health on air quality guidelines and the International Agency for Research on Cancer for the preparation of their monographs on crude oils, base oils and bitumen and participation in a European study of asphalt workers.

## FUTURE DIRECTION

Further legislative initiatives to improve occupational and public health protection will continue and CONCAWE fully supports such objectives. HMG will continue to play a vital role in discussions and developments on CONCAWE's behalf. The product knowledge, hands-on experience, and professional qualifications available in the oil industry provide the basis for fulfilling that role. This expertise will continue to be used to interpret scientific and legal developments and to provide practical information on products as well as on the impact of the oil industry's operations on the health of its workers and that of the public at large.

# Hearing trends in noise-exposed oil refinery workers

Prolonged exposure to excessive noise may cause damage to an individual's hearing ability or a so-called 'Noise-Induced Hearing Loss' (NIHL). In EU Member States, occupational exposure to noise is controlled by legislation based on the requirements of European Council Directive 86/188/EEC of 12 May 1986[1].

According to the current legal requirements, workers exposed to daily personal noise levels above 85 decibels A-weighted (dB(A)) must be provided with hearing protection equipment and given the opportunity of having their hearing checked to allow early diagnosis of any hearing impairment. CONCAWE had previously evaluated the daily personal noise exposures of refinery workers and is currently preparing an update of these data. It appears that the 85 dB(A) criterion is regularly exceeded in oil refineries when process or maintenance work is carried out during prolonged periods in noisy areas. Many noisy areas have been identified and demarcated, and the use of personal hearing protection (muffs, plugs) has been made mandatory. As a consequence, actual exposure to noise is in most cases lower than the measured levels, which are normally measured with a microphone attached to the collar of the worker for the duration of the work-shift. Hearing checks, known as audiograms, are now carried out routinely in many oil refineries.

Directive 86/188/EEC contained a provision for a future review of the specified daily personal noise exposures levels (85 and 90 dB(A)) that requires control measures to be taken. As part of an amended proposal for a new EC directive on physical agents published in 1994, a threshold level for daily noise exposure of 75 dB(A) was specified. A previous article published in volume 8.1 of the CONCAWE Review (April 98) assessed the scientific data available and suggested that

[1] *Directive 86/188/EEC deals with the protection of workers from the risks related to exposure to noise at work. It required European Member States to bring into force legislation and provisions for the evaluation of occupational noise exposures and the protection of workers' hearing capability*

the daily exposure threshold level may be set at a level higher than 75 dB(A) (for instance 80 dB(A)) and still prevent noise-induced hearing loss.

In order to evaluate the impact of national regulations based on Directive 86/188/EEC and the implementation of the guidelines for hearing conservation programmes, CONCAWE's Medical Subgroup analysed the hearing trends of noise-exposed oil refinery workers in Europe. The study was carried out with the assistance of the Institute for Sound and Vibration Research of the University of Southampton (UK) and the Epidemiology Unit of the School of Public Health of the Université Catholique de Louvain (Belgium).

Audiometric data covering a period of approximately twelve years (from the mid-eighties to the late nineties) were retrieved from the occupational health departments of ten refineries in seven European countries. The change of the hearing thresholds over the period was assessed in a study population of over 1000 oil refinery workers regularly exposed to noise (this was defined as exposure to a noise level above 85 dB(A) for at least 1 hour per working day or more than 200 hours per year for the duration of the study period).

Hearing thresholds are known to increase with age, particularly at the higher frequencies, even without illness or exposure to noise. A correction is therefore needed if the influence of workplace noise exposure is to be evaluated in isolation. Normal hearing threshold data for people not exposed to noise are available from international guidelines as averages and standard deviations for various age groups. These data were used in this study.

The data were screened for non-noise related hearing deficiencies using established procedures and then corrected for age according to the international guidelines. Statistical analysis was undertaken to identify any time trends and differences between subgroups of younger and older workers.

At the start of the study period, the average hearing thresholds of the refinery worker population were higher than those of the general population. This in itself was not an unexpected finding for a population of industrial workers. However, when the increase of the average hearing of the refinery workers over the 12-year study period was compared with the increase that one would expect to see in the general population caused simply by the ageing process, there was no indication of additional hearing loss due to noise exposure. In fact, the average refinery worker's hearing at the end of the study period was closer to the average general population hearing than at the start of the study period. This gives a strong indication that, although there is potential for noise exposure to reach hazardous levels in some oil refinery workplaces, the level of protection is such that it prevents the development of more hearing loss than can be attributed to ageing alone. A comparison of the age-corrected data for the two subgroups showed that less hearing loss had occurred in younger workers than in older workers. This is a further encouraging sign that standards of protection have improved.

# Dangerous Preparations Directive

Directive 1999/45/EC, the revised Dangerous Preparation Directive (DPD), has recently replaced the original Directive 88/379/EEC. The scope of the DPD has been expanded to include environmental classification and labelling criteria for preparations, revised disclosure requirements, Safety Data Sheets and implications for distance selling. The new Directive requires Member States to adopt and publish laws, regulations and administrative provisions necessary to comply with the Directive before 30 July 2002.

This article briefly highlights and explains the significance of the changes regarding the classification and labelling of preparations. More detailed information on the new Dangerous Preparations Directive may be found in CONCAWE report 00/56, *Revised Dangerous Preparations Directive (1999/45/EC)—implications for petroleum products.*

## ENVIRONMENTAL CLASSIFICATION

The major change is the introduction, for the first time, of the requirement for suppliers of finished products to evaluate preparations for environmental hazards and to classify and label them if appropriate. This is also applicable to producers of additives and additive packages.

Recommendations for the environmental classifications of petroleum substances can be found in CONCAWE report number 98/54 titled *Classification and labelling of petroleum substances according to the EU Dangerous Substances Directive* and its subsequent updates.

## GENERIC NAMES—DISCLOSURE REQUIREMENTS

The provision to use generic chemical names for confidentiality reasons when disclosing dangerous components on labels and data sheets is now restricted to substances with certain harmful and irritant classifications. It now applies only to components classified as Xn R20, R21, R22, Xn R65 and Xi R36, R37, R38. Further, generic chemical names may not be used for substances for which an EU occupational exposure limit (OEL) has been imposed.

Previously a supplier was permitted to use generic names, where applicable, the only requirement being to inform the competent authority in the Member State where the preparation was first put on the market. No provisions were made to define acceptable generic names.

According to the new Directive a supplier who wishes to use a generic name, must now request permission from the competent authority in the Member State where the preparation was first put on the market. The specific procedure includes a list of information that must be provided (Annex VI part A). The supplier must forward a copy of this permission to each of the Member States where the product is to be subsequently marketed.

## SAFETY DATA SHEETS (SDSs)

Under Directive 88/379/EEC, Member States were required to ensure that a system be set up for the mandatory supply of SDSs to professional users for all preparations classified as dangerous.

This still applies, but Article 14 now extends the requirement to give professional users the right to be supplied, on request, with SDSs containing 'proportionate' information for certain non-dangerous preparations. This extension applies to those preparations, not classified as dangerous by the DPD, but containing at least one substance:

- that poses health or environmental hazards; or
- for which Community OELs are imposed,

  and

where the concentration of any such individual component is 1% w/w or greater for non-gaseous preparations, or 0.2% v/v or greater for gaseous preparations.

As a consequence, CONCAWE member companies will need to have SDSs available for all products which meet the criteria specified above, so that sheets can be provided on request.

For the petroleum industry, the provision of safety data sheets for non-dangerous preparations has significant implications. For example, several different lubricant formulations may be sold under a single product name, all of which are non-hazardous according to the DPD, but each contains different hazardous components at the 1% w/w concentration level or above. Provision of separate SDSs for each formulation may not be practicable and could even be confusing. Generic SDSs may be more suitable particularly if coupled with formulation-specific information on the label such as the sensitizers present (if above 0.1% w/w), batch number, or date and place of manufacture.

The appropriate annex to Directive 91/155/EEC covering the format of SDSs is to be amended by 30 July 2002 to include the provision of SDSs for non-dangerous preparations. An ad-hoc Commission group is currently examining what proposal should be made.

## DISTANCE SELLING

Any advertisement for a preparation within the scope of the DPD which enables a member of the general public to conclude a contract for purchase of such preparation without first having sight of the label for that preparation must make mention of the type(s) of hazard indicated on the label. The key words of the text are 'advertisement', 'preparation', 'enables', 'member of the general public' and 'conclude'.

On the basis of a legal opinion provided to CONCAWE, it would appear that, where an advertisement for a preparation enables a member of the general public to order that preparation by telephone, fax, e-commerce, mail, etc., the seller would be required to inform the buyer, in advance of concluding a contract for purchase, of the type(s) of hazard on the product label. An example of this would be a website (which, it is commonly held, is an advertisement) which allows for on-line purchasing of a preparation.

In contrast, where an advertisement for a preparation does not enable a member of the general public to conclude a purchase contract, product label disclosure is not necessary. Examples of this would include billboards, pole signs, as well as magazine and television advertisements, which do not include, for example, an order form or an order line telephone number.

This interpretation could vary from country to country based on Member State transposition of the distance selling provision into national regulation. CONCAWE member companies will therefore have to clarify the applicable interpretation in the countries where they conduct retail operations.

# Integrity of oil pipelines in Western Europe

CONCAWE has been undertaking surveys of the number of spillage incidents from oil industry cross-country pipelines for nearly thirty years. The results have been presented in a series of annual reports, the most recent being CONCAWE report 3/00. Additionally, CONCAWE report 2/98 reviewed the first twenty-five years' data up to 1995.

The CONCAWE pipeline statistics now includes data from 72 companies and other bodies operating oil pipelines in Western Europe. These organizations operate some 250 different service pipelines which, at the end of 1999, had a combined length of 30 720 km; this length has remained fairly constant for a number of years. The volume transported in 1999 was 674 million cubic metres of crude oil and refined products, again similar to recent years. The total traffic volume (i.e. volume x distance transported) in 1999 amounted to 125 x $10^9$ $m^3$ x km.

There were eleven oil spillage incidents during 1999, nine from pipelines themselves and two from associated pump stations. None of these incidents led to associated fires but there was one fatality associated with an attempted theft. This number is less than the long-term average of 12.9 spillages per year since 1971. It must be remembered that in the earlier years of the survey, the length of pipelines included was much lower so that the improvement is better than it appears at first sight. This is shown by Figure 1 which plots the frequency of spills per year per 1000 km of pipeline. Generally the performance has improved since the 1970s although the curve may have flattened out over recent years.

Although the frequency of spillage has levelled off, the volume of oil spilled has decreased over the last five years. In 1999, this was only 516 $m^3$, a very small volume which represents only 0.00008% (or 0.8 parts per million) of the volume of oil transported. What is more, some 67% of this oil was recovered so that the net oil loss into the environment amounted to only 171 $m^3$, equivalent to 0.00002% (or 0.2 parts per million) of the total volume transported. Put another way, this only amounted to 6 $m^3$ lost per 1000 km of pipeline. These figures are significantly better than the long-term annual averages of 101 $m^3$ and 46 $m^3$ per 1000 km, respectively for gross and

Figure 1
Although the frequency of pipeline spillage has levelled off in recent years, performance has improved since the 1970s.

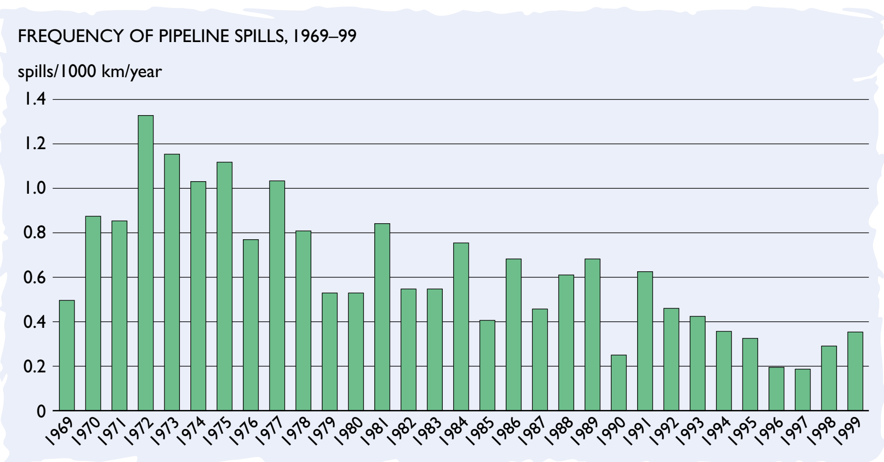
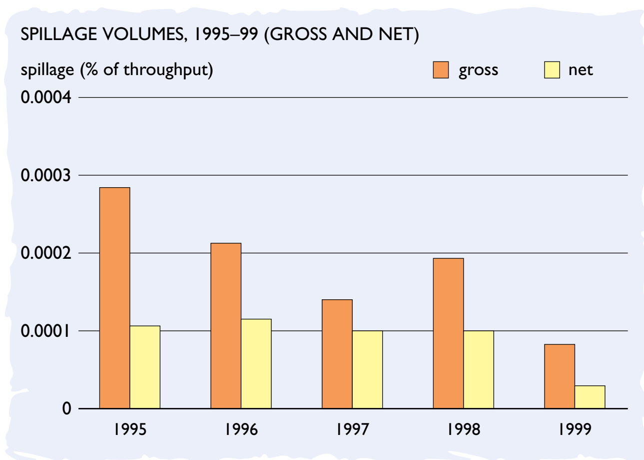



Figure 2
In 1999, only 8 parts per million of oil was spilled, with 67% recovered—a significant improvement over the long-term average.



net spillage, in fact, they are only about 17% and 12%, respectively, of the long-term averages. The 1999 volumes are compared with those for the last five years in Figure 2. This shows a significant reduction in the volume of oil spilt over the period.

CONCAWE also collects information on the intelligence pig inspection activity. This is a method for detecting defects in a pipeline before failure occurs. It is a highly specialized activity, the results of which must be interpreted with care. Not all types of defects can be detected and not all parts of the system can be accessed. It is also obviously of no assistance in stopping many of the incidents caused by third parties (such as attempted theft or external penetration by e.g. mechanical excavation). To date, 70% of the current pipeline inventory in Western Europe has been inspected at least once using intelligence pig techniques and this has undoubtedly contributed to the continuously improving safety record.

Of the 11 incidents that occurred in 1999, nine were either small or otherwise straightforward to clean up. Two spillages required extensive clean-up programmes and one of these was categorized as causing severe soil pollution. None affected watercourses or potable water supplies so that the overall environmental impact of these incidents was limited.

The causes were fairly typical. There were no spillages categorized as mechanical failure and only one in the operational category resulting from an error carrying out a manual valve operation. Four spillages were due to external corrosion, one of which was from a hot fuel oil pipeline. Such pipelines used to be a major cause of spillages in the past, but because of their poor record, and changes in the fuel oil market, most such pipelines have been shut down. In 1999, there were no spillages due to the effects of a natural hazard event.

As usual, third-party activity was the main cause of spillages from oil pipelines in 1999 with six incidents. The depressingly familiar cause of four of these was uncontrolled excavations. Immediate spillage resulted in three of the cases, whereas in the fourth case, spillage ensued from damage sometime in the past that had not been detected then. Unusually for Western Europe, two incidents were caused by attempted theft, one of which resulted in a spillage of 36 $m^3$ gross, for which the resulting repair and clean-up cost 24 000 Euro and took 35 days. The second had more serious consequences. Thieves attempted to steal the product by digging a steep-sided pit to get to a pipeline with 1.5 metres of ground cover and drilling into the pipeline. The release filled the pit with 80 $m^3$ of product. When the emergency response squad pumped this out, they found a dead body. Although such incidents have been very rare in Western Europe, they have been more common in Central and Eastern Europe, but fortunately (as far as we know) without fatalities.

CONCAWE started collecting data for Central and Eastern Europe a few years ago, with more systems being added to the database from year to year. Reporting from the companies involved is steadily improving but more time will be needed before the reported data reach the required standard. For this reason Central and Eastern European data have not been incorporated into the CONCAWE database used to produce the oil pipeline integrity report as yet. The companies concerned are working hard to improve pipeline environmental performance. Although incidence of leaks is higher than in the West, this is mainly due to theft and attempted theft related incidents. However, the incidence of theft seems to be declining as monitoring of the systems improves.

# CONCAWE news

CONCAWE's new home in the Boulevard du Souverain, Brussels

After more than ten years in the lofty heights of the 24th floor of the Madou Plaza, we have 'come back to earth' and are now installed in the somewhat less central but leafier surroundings of the Boulevard du Souverain. The move was rendered necessary by a combination of factors ranging from fire safety to lapsing lease. Although we did endure the almost inevitable teething problems with our various communication systems, these are now resolved and we hope that all interested parties can contact us without hindrance. We would certainly appreciate being informed if anyone still has difficulties in this area. Our website is still at the same address—www.concawe.be—and we invite you to visit it and to browse through the *Review* as well as our most recent reports, which can be downloaded free of charge.

## SECRETARIAT STAFF

| | | Telephone | e-mail |
|---|---|---|---|
| General | http://www.concawe.be | +32-2 566 91 60 | info@concawe.be |
| Secretary-General | Jean Castelein | +32-2 566 91 61 | jean.castelein@concawe.be |
| *Technical Coordinators:* | | | |
| Petroleum products | Bo Dmytrasz | +32-2 566 91 65 | bo.dmytrasz@concawe.be |
| Automotive emissions | Neville Thompson | +32-2 566 91 69 | neville.thompson@concawe.be |
| Safety management, water and soil protection and waste management, oil pipelines | Eric Martin | +32-2 566 91 83 or +44-1372 45 23 53 | eric.martin@concawe.be |
| Air quality | Henk Schipper | +32-2 566 91 71 | henk.schipper@concawe.be |
| Health | Jan Urbanus | +32-2 566 91 63 | jan.urbanus@concawe.be |
| Refinery planning and publications | Jean-François Larivé | +32-2 566 91 67 | jeanfrancois.larive@concawe.be |
| Documentation and library | Annemie Hermans | +32-2 566 91 80 | annemie.hermans@concawe.be |
| Secretariat | Laurence Evrard | +32-2 566 91 73 | laurence.evrard@concawe.be |
| | Sandrine Faucq | +32-2 566 91 75 | sandrine.faucq@concawe.be |
| | Elfriede Geuns | +32-2 566 91 76 | elfriede.geuns@concawe.be |
| | Barbara Salter | +32-2 566 91 74 | barbara.salter@concawe.be |

## CONCAWE PUBLICATIONS, RECENT REPORTS

General circulation (yellow cover) reports:

| | |
|---|---|
| 1/00 | European downstream oil industry safety performance—statistical summary of reported incidents—1999 |
| 2/00 | A review of European gasoline exposure data for the period 1993–1998 |
| 3/00 | Performance of cross-country oil pipelines in Western Europe—statistical summary of reported spillages—1999 |
| 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) |

Special interest (white cover) reports

| | |
|---|---|
| 00/51 | The occurrence of selected hydrocarbons in food on sale at petrol station shops and comparison with food from other shops—a literature survey |
| 00/52 | Management of occupational health risks during refinery turnarounds |
| 00/53 | An assessment of the reproductive toxicity of gasoline vapour |
| 00/54 | Impact of a 10 ppm sulphur specification for transport fuels on the EU refining industry |
| 00/55 | A review of trends in hearing thresholds of European oil refinery workers |
| 00/56 | Revised dangerous preparations directive (1999/45/EC)—implications for petroleum products |
| 01/51 | Measurement of the number and mass weighted size distributions of exhaust particles emitted from European heavy-duty engines |

Up-to-date catalogues of CONCAWE reports are available via the CONCAWE website at www.concawe.be

New reports are generally also published on the website.

* *available shortly*

CONCAWE
Boulevard du Souverain 165
B–1160 Brussels
Belgium

Telephone: +32-2 566 91 60
Telefax: +32-2 566 91 81
E-mail: info@concawe.be
World Wide Web: http://www.concawe.be