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

In May this year the CONCAWE Council elected me as the new Chairman of the organization. It is both a privilege and a challenge to take over this responsibility. A privilege to be in charge of leading CONCAWE's activities of developing sound scientific information in support of requirements in the fields of environmental protection, health and safety. But also a challenge to ensure continuity of CONCAWE's successful work during a time of extensive reorganization and rationalization within the organization's member companies. I would also like to take this opportunity to express our gratitude to the previous Chairman, Peter Gill, for his inspiring leadership over the last three years.

When CONCAWE was founded in 1963, the prevention of pollution and its resulting adverse effects on human health and ecosystems were still low on the agenda of governments and the public at large. Since then legislators, NGOs and industry have taken up public concerns about the state of the environment, which has resulted in massive reductions of emissions from all major sources and a proportional increase in environmental legislation.

On behalf of its member companies, CONCAWE is firmly committed to providing technical input into the development of legislation aimed at reducing the risks to man and the environment, arising from pollution, to 'acceptable' levels. The challenge is, of course, to define the term 'acceptable'. In this context CONCAWE has tried over recent years to contribute to the necessary technical elements that need to be evaluated for an 'acceptable risk' legislative approach. Examples of this are the previous *Review* articles on the 'precautionary principle', the cost-benefit and cost-effectiveness aspects and the process of the multi-risk characterization/multi-risk management.

During the time of my chairmanship I will be committed to continuing and refining CONCAWE's way of addressing issues on the basis of objective scientific/technical facts. There are currently a multitude of legislative initiatives which require technical input in support of legislative and business objectives (Auto/Oil-II, Air Quality Standards, National Emissions Ceilings, BAT notes (BREFs) under IPPC, legislation of chemical substances, to mention just a few). Setting priorities among these issues, and attempting to use synergies effectively among the CONCAWE interrelated activities will be an important function of my chairmanship.

Developing and analysing data for addressing certain topics is important and CONCAWE would like to know of any researchers or other interested parties, including authorities, who wish to cooperate in filling the many data gaps, to help avoid duplication of effort, and to work towards rational decisions. Even more important is the effective dissemination of such technical information to interested parties within and outside of the CONCAWE membership. For this purpose, we have decided to exhibit new CONCAWE reports on our website to give readers early access to the results of CONCAWE's work.

Bart van Holk
Chairman, CONCAWE.

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Health effects of ambient PM—an update

More research is needed to manage air quality effectively for PM.

INTRODUCTION

Directive 1999/30/EC was adopted in April of this year by the Council of the European Union. This is the first Daughter Directive established under the Air Quality Framework Directive. The Directive specifies limit values for a series of pollutants in ambient air, including particulate matter. The limit value for particulate matter is set for particles smaller than 10 micrometers in diameter or so-called PM_{10}. Stage 1 limit values are set at 40 and 50 microgrammes per cubic metre ($\mu g/m^3$) as annual and daily averages respectively, to be achieved in 2005. A maximum of 35 exceedances is allowed annually. A further possible Stage 2 reduction of the annual average to 20 $\mu g/m^3$ and reduction of the number of exceedances from 35 to 7 from 2010 onwards is also indicated, pending a review in 2003. The Directive also requires Member States to start measuring particles smaller than 2.5 micrometers or so-called $PM_{2.5}$, as this may in future be considered an even more relevant measurement for harmful particulate air pollution. At present, however, there are insufficient monitoring data available for use in health evaluations.

The current understanding of the health effects of particulate air pollution was discussed in past editions of the CONCAWE *Review* (e.g. Vol. 6, No. 1 and Vol. 7, No. 1). At that time, a Working Group of experts and the European Commission were developing a position paper that formed the basis for the Commission proposal for the limit values.

Data on current ambient levels of PM_{10} in Europe are not widely available because of the different parameters and measurement methodologies employed by the Member States. In fact, most of the European cities that participated in the APHEA project (cf. CONCAWE report 99/54 and CONCAWE *Review* Vol. 6, No. 1) reported some form of ambient PM monitoring, but none reported PM_{10}. It is commonly accepted that today's levels are lower than in the past, primarily as a result of the decline in the use of coal for heating and power generation.

CONCAWE believes there are many important questions still to be answered that could help determine the real potential for the new Directive to deliver increased health protection. These questions relate to:

- the lack of measured data and the limited accuracy of the methods used to estimate personal exposure, which ultimately determines the potential for health effects;
- the relative importance of ambient PM to an individual's overall exposure in view of other determining factors such as time spent in indoor environments, and PM originating from personal activities including smoking; and
- the need for mechanistic studies to validate the apparent associations between ambient PM and adverse health effects that are demonstrated by environmental epidemiology studies.

EPIDEMIOLOGICAL STUDIES AS INDICATORS FOR HAZARD

Messages in the media about thousands of people dying from exposure to particles (fine dust, PM_{10}, $PM_{2.5}$ etc.) in ambient air must give the impression that fine particles are public health enemy number one.

The current indications for possible adverse health effects are based on a relatively large number of short-term epidemiological studies which relate episodes of increased air pollution to increases in mortality (all causes, respiratory and cardiovascular). On average an increase of 10 µg/m^3 of PM_{10} would be associated with an increase of 0.4–0.7 per cent in mortality per period of increased air pollution.

Morbidity increases are also studied, with the numbers of hospital admissions for respiratory and cardiovascular conditions being used as indicators.

There are a few long-term studies which relate PM_{10} air concentrations to increased mortality by comparing populations in more polluted with less polluted cities or locations. On average, the results would indicate an increase in annual mortality of ± 5 per cent for each long-term increase in PM_{10} by 10 µg/m^3.

VALIDITY OF ASSOCIATIONS IS UNCERTAIN

It is uncertain that the associations between exposure to PM_{10} and adverse health effects, including mortality, are true and valid associations:

- there is no information about the personal exposure of the morbidity and mortality cases; exposure misclassification is therefore probable;
- it is unlikely that is has been possible to discriminate between the adverse health effects caused by particles and those caused by other air pollutants which can cause similar effects (ozone, SO_2, NO_2 and CO), and/or other factors such as changes in temperature and humidity, or social class. In other words, sufficient control of compounding factors is dubious.

It is highly probable that bias of exposure misclassification and lack of sufficient control of compounding factors have occurred in the short-term and long-term studies. Therefore, the associations are likely to be invalid as there is no certainty about the true identity of the elements from which the associations are constituted.

CAUSE-EFFECT RELATIONSHIP OF ASSOCIATIONS IS UNCERTAIN

In the 1960s Sir Lawrence Bradford Hill published nine criteria which have been proven to be of help if one wants to get an insight into the probability that an observed true and valid association is based on a direct cause-effect relationship and not just on coincidence or on a remote and indirect cause. These criteria have been applied in CONCAWE report 95/62 and it is clear that there is insufficient evidence for a cause-effect relationship. A similar analysis of both the short-term and long-term studies was published by Dr John Gamble (EBSI) in the prestigious journal *Environmental Health Perspectives* (August and September issues, 1998) and led to the same conclusion.

TOXICOLOGY STUDIES

Ambient airborne particulate matter is generally of unknown and variable composition. There is no agreed scientific explanation of the health effects of PM. It is unknown whether the total amount inhaled is what counts (i.e. mass inhaled), or the chemical composition (the effect of metals content has been investigated), the size (very small, so-called nano-particles, which are smaller than 0.1 micrometer, or fine particles, e.g. $PM_{2.5}$ or PM_{10}, i.e. particles smaller than 2.5 or 10 micrometers, respectively) or even other parameters such as acidity of the particles. Several experimental toxicology studies have reported big differences in toxicity between nano-particles and fine particles of the same chemical composition, making size the dominant parameter, although the materials studied were not representative of ambient PM.

PERSONAL EXPOSURE STUDIES

Scientists active in the PM field have recognized that the lack of comprehensive studies of personal exposure to PM is a major shortcoming in the present risk assessment for ambient PM, and have started to address this with experimental work. In particular, investigation reports are now starting to appear on how well personal exposures in a community can be estimated from the limited information gained from a single stationary outdoor air monitoring point. Some researchers conclude that the estimates are valid and, hence, further epidemiological studies may use this easily available information instead of having to put a major effort into generating detailed and individual exposure data. CONCAWE experts are reviewing these reports and have so far concluded that outdoor measurements are generally not representative for the measured personal exposures. It is obvious that more work is needed in this area to understand how well or how poorly personal exposure is estimated from limited outdoor measurements.

CONCAWE RESEARCH STRATEGY

Following the logical sequence of the key steps in risk assessment (i.e. hazard identification, exposure assessment, risk characterization and recommendations for risk management), CONCAWE's Management Groups for Air Quality, Automotive Emissions and Health have developed a research strategy which identifies the need for additional research in these areas and which indicates specific areas of interest for CONCAWE. Several actions have already been taken (see box below: CONCAWE reports), other projects are progressing or being discussed.

The intention is to use the results of the research work and desk studies, carried out or sponsored by CONCAWE, in the discussion during the 2003 review, and also as contributions to the workshops that will be held in preparation for the review. Key areas for CONCAWE are: source apportionment, fuel characteristics and particle emissions, health hazard identification, personal exposure assessment and risk characterization.

CONCAWE reports on particulate matter

92/51	The chemical composition of diesel particulate emissions
95/62	Air quality standard for particulate matter
96/56	The measurement of the size range and number distribution of airborne particles related to automotive sources—a literature study
96/61	Review and critique of the APHEA project
99/55	Polycyclic aromatic hydrocarbons in automotive exhaust emissions and fuels
99/54	Overview and critique of the air pollution and health: a European approach (APHEA) project

CONCAWE *Review* articles on particulate matter

Vol. 2, No. 1, April 1993	The influence of diesel fuel characteristics on emissions. Fuel density, sulphur content and cetane number affect the particulate emissions of diesel fuels
Vol. 6, No. 1, April 1997	An introduction to particulate matter issues. Particulate matter: sources and presence in air. APHEA—a pan European study on the effect of air pollution. Analysis of reported data
Vol. 7, No. 1, April 1998	Automotive particulate matter. From mass to number—an exploration into the unknown

Ambient particulate matter: sources and apportioning

Both current and predicted levels of PM emissions are subject to great uncertainty; hence the development of meaningful air quality strategies is complicated.

INTRODUCTION

The quality of the air we breathe has become an increasingly important and emotive issue over the past few years. To date, the regulation of air quality has focused mainly on outdoor air (even though for particular pollutants, indoor concentrations may be greater and exposures are often more significant—on average we may spend up to 90 per cent of our lives indoors). Ambient air quality standards have been established for many different pollutants, including standards for particulate matter in various countries.

Unlike many air pollutants, ambient particulate matter is not well characterized; it encompasses a range of different sizes and has variable chemical composition depending on where, when and how it is sampled. This variation depends both on the nature of the original sources and on subsequent physical and chemical transformations. At a particular location, the quantity and composition may vary throughout the day, and will be subject to seasonal variation, impacts of the weather and proximity to local sources.

So what is ambient particulate matter? It is a complex mixture of varying composition emitted from a variety of sources, formed in the atmosphere by gas-to-particle conversion, or re-suspended by the action of the wind or mechanical processes.

Why are we interested? Over recent years, a large number of epidemiological studies have suggested an association between exposure to ambient particulate matter at current concentrations and adverse health effects. The establishment of national air quality standards in many countries has increased pressure to improve air quality and reduce the concentration of ambient particulate matter. It is essential to understand the relative contributions of the different sources to total particulate matter so that cost-effective abatement strategies can be devised to reduce emissions and, hence, improve air quality. With this in mind, we need to understand not just the concentrations of particulate matter in the ambient air, but the contribution made by different sources to the total.

AMBIENT PARTICULATE/AEROSOL

Ambient particulate matter is a complex mix of liquid and solid particles existing in dynamic equilibrium with gases in the surrounding air. It arises from a wide range of sources, both natural and related to human activity (anthropogenic), and can be divided into three main categories (APEG[1], 1999): primary particles (emitted to atmosphere directly from source); secondary particles (formed in the atmosphere from gas to particle conversion) and re-suspended particles (by wind or mechanical action). Particulate matter originating from different sources may have specific size ranges and chemical characteristics (useful for identifying sources i.e. 'fingerprinting'),

[1] *Airborne Particulates Expert Group*

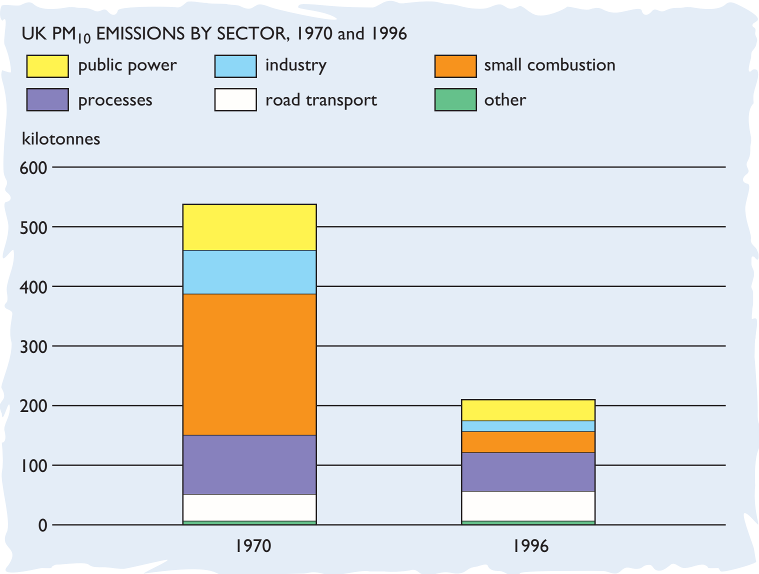
but these characteristics tend to be lost as particles from different sources mix and 'age' in the atmosphere. These ageing processes include both physical interactions and chemical transformations, such as coagulation, adsorption of gaseous pollutants and oxidation.

Routine measurements of the concentration of ambient particulate matter are taken at fixed-point measuring sites using either gravimetric filter methods or electronic equipment such as the TEOM (tapering element oscillating micro-balance). These measurement techniques focus on size-selected particles (usually PM_{10}, although measurements of $PM_{2.5}$ are now becoming more common). Historically other parameters such as total suspended particulate (TSP) and black smoke (BS) have been used. The various methods collect and measure different types of particulate matter and it is difficult to calibrate these methods against each other or the 'true' ambient concentrations. As PM from different sources also varies, the choice of collection method will influence the assessment of the predominant contributing sources (i.e. the main sources of black smoke, PM_{10} and $PM_{2.5}$ will be different). It is also recognized that underestimation of total mass (in particular, secondary particulate contribution) may result from evaporative losses of more volatile particulate matter, such as ammonium nitrate, during collection (Hering and Cass, 1999).

ASSESSMENT OF SOURCE CONTRIBUTIONS

Taking these issues into consideration, it is impossible to assess the contribution of individual sources to total ambient particulate matter from simple air quality monitoring, or indeed to derive the contribution of secondary, re-suspended or transboundary particulate without more detailed chemical analysis. Historically, source contributions to total primary emissions have been developed from information on emission factors estimated for particular processes or technologies. From the emission factor, for example, for a furnace of particular design, knowledge of fuel throughput allows the contribution to total emissions to be estimated. These contributions can then be aggregated to develop an overall source inventory. CORINAIR (CORe INventory AIR) is probably the most extensive source inventory available for European gaseous emissions to air. However, emissions of primary particulate matter are not included in CORINAIR. The most widely cited inventory of European primary particulate matter emissions has been developed by the Dutch scientific research organization, TNO, and includes information on PM_{10}, $PM_{2.5}$ and $PM_{0.1}$ emissions (TNO, 1997). A key issue for source inventories is verification of the estimates by reference to real world measurements. Validation of the inventory for the different PM size fractions is currently hampered by the lack of reliable data on ambient particulate matter characterization and source attribution.

In compiling the European PM inventory, TNO acknowledged the limited availability of information on emission factors and their variability, especially in relation to $PM_{0.1}$; TNO describe reliable data on $PM_{0.1}$ emissions as 'scarce'. Even for PM_{10} emission factors, there is generally no information available on what emissions control technologies were in place when the factors were estimated for each type of plant. The significance of uncertainty about the source contributions to total ambient small particles becomes increasingly important as the health effects focus moves to smaller and smaller particulate matter. For the UK, 25 per cent of PM_{10} and 60 per cent of $PM_{0.1}$ emissions are reported to come from road transport (APEG, 1999); these estimates were developed from information from USA data (US EPA, 1995) and the TNO inventory. However, a recent source apportionment study in the US has suggested that 80–90 per cent of primary particulate emissions are fugitive dusts, with only a 3–9 per cent contribution to total PM_{10} from automotive exhaust emissions (Chow *et al*., 1999). Similarly, a study in Australia has suggested that automotive sources account for only 13 per cent of PM_{10} and 6 per cent of primary $PM_{2.5}$ aerosol mass (Chan *et al.,* 1999).



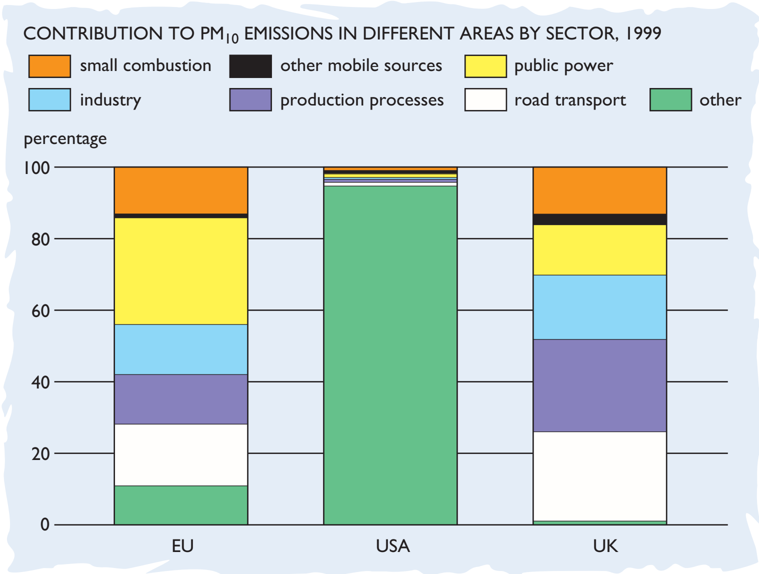


Figure 1
Total PM_{10} emissions and source contributions have changed markedly from 1970–96.

Figure 2
Percentage contributions to PM_{10} by different sectors vary considerably between Europe and the USA.

Figure 1 shows how both total PM_{10} emissions and the source contributions have changed during the period 1970–96 in the UK (APEG, 1999). Figure 2 gives a wider overview of the percentage contributions of different sectors to total primary PM_{10} emissions in different regions, based on existing inventories (from Holman, 1999).

It is clear from these data that the relative contributions to ambient primary particulate matter vary enormously between Europe as a whole and the UK, and even more so between Europe and the USA. The US inventory indicates that most PM_{10} emissions come from 'other' sources, which include fugitive dusts from paved and unpaved roads, agriculture and forestry, whilst in the UK these contributions are very small. Certainly, some of the variations between regions reflect real differences in the relative importance of particular sources. However, they do also serve to prompt questions about the robustness of the methodologies employed in different locations to arrive at the estimates. Methodologies must be consistent if comparisons between inventories are undertaken and aggregated inventories are to be meaningful.

On a worldwide basis, estimates of the overall contribution of natural, primary and secondary contributions to ambient particulate matter have been published (IPCC, 1996); the total anthropogenic contribution is estimated to be approximately 11 per cent (see Table 1).

A weakness of all of these inventories is their focus on primary emissions, whilst it is clear that secondary and re-suspended particulate makes a significant contribution to total ambient PM mass. For $PM_{2.5}$, Holman suggests that the secondary particulate contribution may be four times greater than the primary (Holman, 1999). Similarly, the inventories do not account for the contribution made by transboundary long-range transport of particulate matter, which is increasingly recognized as representing a significant proportion of the total particulate matter load under appropriate meteorological conditions (APEG, 1999).

In order to be useful, emission factors must be updated to keep abreast of developments in combustion technology and abatement methods. The positive impact of developing legislation on emissions is easily underestimated when inventories are not updated. This results in increasing uncertainty in emissions estimates (and air quality predictions) for future scenarios, the further we look ahead. Incomplete or inaccurate information on emissions source contributions based on outdated emission factors risks the establishment of the wrong priorities for legislation.

As an alternative to this form of 'bottom-up' analysis, several groups of investigators have reported on extensive chemical characterization of particulate matter produced by different sources, which they have used to define profiles or 'fingerprints' for particular types of particulate matter in the ambient mix. From this form of detailed analysis, it has been possible to begin to investigate real world source-receptor relationships for different sorts of ambient particulate matter (e.g. Cass, 1998; Kleeman and Cass, 1999; Spindler *et al.,* 1999). Such approaches are especially valuable in estimating the primary source contributions of fugitive dust sources, such as wind-blown dust, re-suspended road dust and sea spray, for which emission factors are not meaningful.

Sources of worldwide particulate matter

Source	*Type*	*Emissions (Mt/y)*	*Percentage of total emissions (%)*
Natural			
Primary	Soil dust (mineral)	1500	44
	Sea salt	1300	38
	Volcanic dust	33	1
	Biological debris	50	1
Secondary	Sulphates from natural precursors (as ammonium salt)	102	3
	Organic matter from biogenic VOC	55	2
	Nitrates from NO_x	22	1
	Total (Natural)	*3060*	*89*
Anthropogenic			
Primary	Industrial dust, etc.	100	3
	Soot (elemental carbon) from all fossil fuels	8	<1
	Soot from biomass combustion	5	<1
Secondary	Sulphates from SO_x (as ammonium salt)	140	4
	Biomass burning	80	2
	Nitrates from NO_x	36	1
	Total (Anthropogenic)	*370*	*11*
TOTAL		3430	100

Table 1
Total anthropogenic contribution to ambient PM worldwide is estimated to be 11 per cent.
(Source: IPCC, 1996)

Emissions inventories are not available for all countries and, therefore, there is an incomplete representation of the overall picture. Different emissions inventories often employ different source categories, which makes inter-comparison and aggregation very difficult. They are often limited in their spatial coverage, and extrapolation to larger domains requires validation of the underlying assumptions. However, the available inventories do allow a 'first order' estimate of the source contributions of the major sectors to the overall primary emission.

SUMMARY

Limited availability of particulate matter emissions data (in particular for the smaller size fractions), means that, for Europe as a whole, current estimates are subject to significant uncertainty and error. Consequently, the basis for forward projection of PM emissions is subject to great uncertainty.

The contributions made by automotive and different stationary emission sources (primary PM) and the significance of secondary and transboundary PM are currently uncertain. Knowledge of the source contributions to ambient PM in the size ranges of particular interest from a health perspective ($PM_{2.5}$, $PM_{0.1}$ and smaller) is essential, but currently weakest.

The development of meaningful and cost-effective strategies to improve air quality by reducing emissions of particulate matter (and precursors of secondary PM) is currently hampered by this uncertainty. As a consequence, there is a real risk that costly legislation will be enacted that will fail to produce the anticipated benefits.

Note: The full list of references cited in this article may be found on page 26 of this PDF version of the Review.

Particulates and policy— the role of models

Much work on the development of reliable models still needs to be done to address concerns over particulate emissions.

INTRODUCTION

In the companion article in this *Review* (pp. 6–9) we examine the current state of understanding on the sources of particulate matter (emission inventories) and their contribution to ambient levels in the air we breathe (source apportionment). This serves to highlight the high degree of uncertainty in both areas. When it comes to the development and use of models that attempt to link emissions with air quality and to evaluate the efficacy of various emission reduction measures on current air quality, reliable emission inventories and source attribution are vital. In this article we will review the implications of these current uncertainties on particulate modelling with a particular focus on their implications for robust policy making. The purpose is not to focus on any particular models but rather to address the key question 'what policy questions can/can't current 'state of art' models help to us to answer?'.

EMISSIONS/EMISSIONS TRENDS

The two figures below help to illustrate that our understanding of emissions and emission trends is subject to change and also to highlight something of the uncertainty in current understanding. Figure 1 provides a forecast of anthropogenic primary PM_{10} emissions in EU-15 as developed by the Commission's Consultants for Auto/Oil-II early in 1999; Figure 2 shows the updated figure provided in June 1999. These data are largely based on the TNO inventory and forecast, but with road transport adjusted to reflect the Commission's Auto/Oil-II.

While it is obvious that both the absolute levels and trends for some sources have changed significantly, there are at least two clear policy messages which are unaffected by such changes.

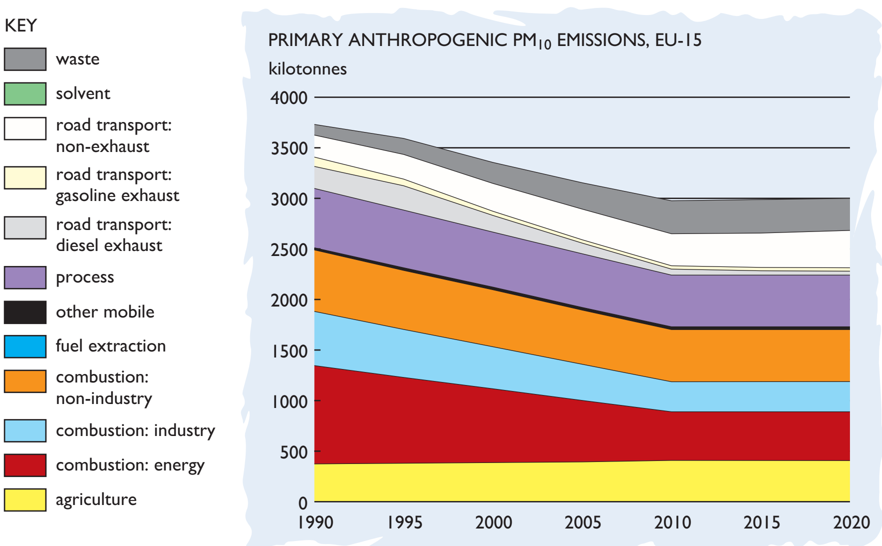


Figure 1
Predicted trends in PM_{10} emissions (EU-15) provided early in 1999.
(Source: European Commission Version 4)

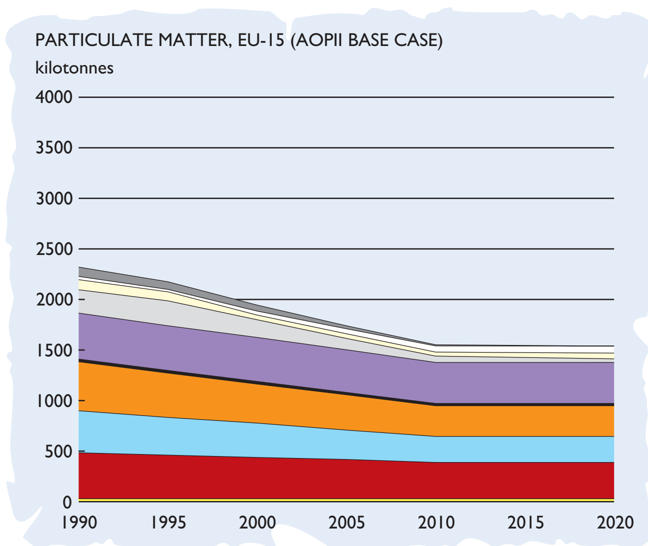


Figure 2
Revised prediction of PM_{10} emissions (EU-15), provided in June 1999.
(Source: European Commission Version 5)

The first message is the large predicted decline in the contribution from the tailpipe of road transport. This stands in contrast to the much more modest decreases (or in some cases increases) anticipated from other sources and reflects the impact of the policy priority that has been given to controlling tailpipe emissions over the last decade. Despite an anticipated growth of some 40 per cent in total vehicle kilometres from 1995 to 2015, the contribution of tailpipe emissions is seen to decline from about 14 per cent to 5 per cent. This clearly has implications for policy priorities not just for the current Auto/Oil-II programme but for broader based follow-up programmes such as the Commission's recently announced 'Cleaner Air for Europe.'

The second message is closely related. This is the need for comprehensive data to be developed and made available on the magnitude and nature of particulate emissions from sources other than road transport. Much research has been, and continues to be, undertaken to characterize the nature and fate of particulate emissions from road transport. However this is not currently matched by research programmes aimed at generating similar data from other sources. For policy makers to be in a position to respond to concerns over meeting air quality targets for particulates in the coming decade, such an imbalance needs urgently to be corrected.

AIR QUALITY/AIR QUALITY MODELLING

Understanding the relationship between air quality and emissions is the key to sound policy development aimed at delivering a given air quality target. A whole range of robust models are available for this purpose in the case of gaseous pollutants. However, in the case of particulate modelling, we encounter a serious problem since this requires the availability of air quality models that are able to represent adequately the physical and chemical processes involved, as well as the availability of reliable emission inventories. To date no such model is available. As discussed in the companion article in this *Review*, physical transformation processes, e.g. agglomeration of particles, and chemical transformation processes, e.g. secondary particulate formation, are to date poorly defined, at least in terms of what would be required to represent such processes adequately in a model. Both are very important, particularly if in future the focus of concern moves to $PM_{2.5}$ or $PM_{1.0}$. Furthermore, the lack of comprehensive data on what sources constitute current measured concentrations (source attribution) makes model validation very difficult.

Helsinki, one of the Auto/Oil-II cities in the EEA c-Q air quality model.

So where does this leave us in terms of policy guidance? The EEA with their semi-empirical 'c-Q model' have attempted to provide some understanding of particulate air quality trends. Their approach utilizes measured air quality data, empirically-derived relationships for the relative contribution from low and elevated emission sources and emissions forecasts. Such an approach is limited by the specific locations of the measuring stations on which future forecasts are based, by the robustness of the empirical relationship and, of course, by the robustness of the forecast on how individual emission sources change over time. The EEA have recently posted the results of their c-Q model for some 200 European cities which provided input to their recently published report 'Environment in the European Union at the turn of the century'.

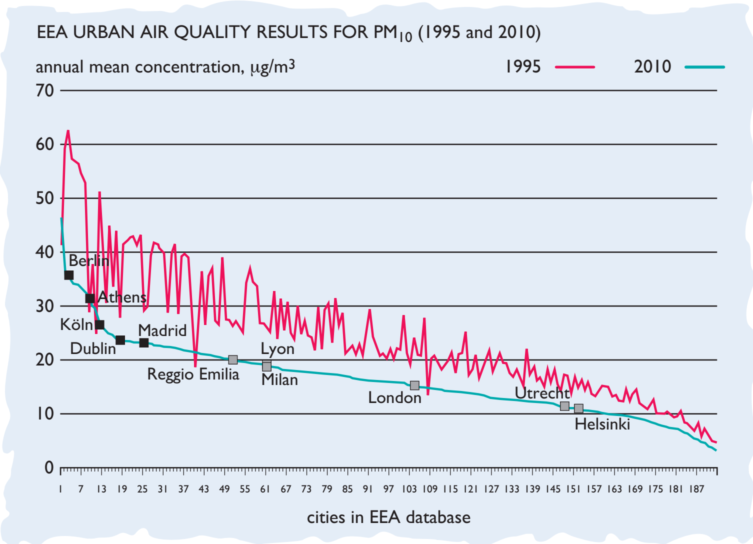


Figure 3
Currently mandated measures are expected to deliver a significant improvement in PM_{10} air quality over the next decade.
(Source: EEA c-Q Modelling June 1999)

The emissions inventory and emissions forecast for this analysis is consistent with the data shown in Figure 2 for EU-15. The results are shown in Figure 3.

The Auto/Oil-II cities have been identified on this figure given the importance of this current programme. Unlike the EEA, no accounting has been given here to the varying population in each of the cities. To provide a clear perspective, the cities have been ranked from highest to lowest predicted 2010 concentration. The 1995 plot has not been similarly ranked since it would not enable the change from 1995 to 2010 to be visible for a given city.

Although subject to all the uncertainties discussed above, what is clear from this chart is that currently mandated measures are expected to deliver a significant improvement in PM_{10} air quality in Europe over the next decade. However, the chart also shows that a significant number of cities are not expected to attain the annual mean target of 20 µg/m^3.* When weighted for population, the EEA quotes some 60 per cent of EU-15 population being exposed to levels above 20 even in 2010.

When it comes to addressing the key question of what further cost-effective measures can be introduced to deliver the objective in the non-compliance cities, these data from the EEA present a problem. This is the lack of detailed spatial coverage and the lack of source attribution data inherent in the c-Q modelling approach. The need to generate such data was recognized in Auto/Oil-II and formed part of the detailed Eularian modelling of the ten cities. However, the detailed results of this work were not available at the time of writing.

Despite the limitations of the c-Q model, the emissions projection given in Figure 2 would suggest that one interesting 'what if' scenario would be to run the model assuming zero road transport tailpipe emissions in 2010. Such a scenario would, potentially, provide an important perspective for developing any proposals within the context of the second Auto/Oil programme. For example, is continued emphasis on policy aimed at reducing tailpipe emissions from road transport appropriate in seeking to deliver the particulate air quality objective?

CONCAWE, along with others, recognizes the need for much more work to be done in developing the necessary understanding as a basis for building reliable models to guide further policy on dealing with the concerns over particulate emissions. This is especially true as the emphasis shifts to finer and finer particles. However, such work will require significant commitment to appropriate research programmes which recognize the need to balance the current high activity on emissions from road transport with similar activity on other sources. However, such work cannot be completed overnight and, in the meantime, work like that of the EEA and the city modelling within Auto/Oil-II should be used in the most effective way to inform policy makers and avoid the mandating of ineffective and high-cost measures.

* *Indicative limit value to be reviewed before 31.12.2003.*

Fuels and engines need to be developed together

An essential, but difficult objective to meet.

Much discussion has taken place in Auto/Oil-I, Auto/Oil-II and many other forums on how to achieve air quality targets in a scientific and cost-effective way. The basis is sound science, starting with a thorough understanding of the adverse health effects of air pollution and the establishment of robust air quality standards. Reliable modelling of future air quality—taking account of already agreed abatement measures—can then identify the remaining gaps and the pollutants to be addressed. With this approach, the possible ways of solving the problems can be determined by combining available measures in an optimum manner.

Auto/Oil-I has been a good example of how to achieve the scientific basis for defining measures to meet air quality targets. Road transport has been the major area of possible improvements and engine/vehicle emission standards and fuel qualities were subsequently defined. With regard to fuel quality, the conclusions were based on an emissions test programme studying advanced engine technology and fuel properties. The programme not only showed the importance of vehicle technology and fuel quality on their own, but also demonstrated the importance of their interactions. A major outcome for current and future debate on both engine technology and fuel quality was that fuels and vehicle technology need to be developed together as a single system.

FUELS AND ENGINES—A COMMON SYSTEM

This very important message seems to have been lost over recent years. While vehicle and engine developments progress rapidly to meet the very stringent future emission levels of the next decade, the idea that both engine/vehicle technology and fuel quality have to be addressed as one design system and therefore developed together has not yet been adequately recognized. For example, worldwide fuel charters have been published by the automotive manufacturers' organizations tabling fuel properties for various technology categories. However, the oil industry was not involved in this exercise and no cooperative test programmes were conducted to generate information on interactions between fuels and advanced engines.

THE NEED FOR A COMMON APPROACH

CONCAWE felt the need to throw some light on the many aspects of importance when developing fuel specifications. Such aspects include vehicle emissions reduction, customer acceptance (e.g. driveability performance), fuel consumption, CO_2 and durability. It is essential that these issues should be well understood and adequately addressed. In order to complement the database, CONCAWE published a report on 'fuel quality, vehicle technology and their interactions' (report 99/55) to provide an understanding of the complexity of the task involved and an improved basis for developing fuel specifications. This is even more important since worldwide fuel specifications are suggested in an attempt at harmonization. The aspects of fuel and vehicle interaction reviewed in the report are illustrated in Table 1. In addition the report summarizes CONCAWE's information on the potential of vehicle technology to reduce emissions and the interaction with fuel consumption.

Aspects of fuel and vehicle interaction

- Vehicle technology trends
- Vehicle and fuel effects on emissions of NO_x, particulates, HC, CO, unregulated emissions
- Engine and fuel effects on CO_2 and fuel economy
- Customer acceptability: driveability, diesel cold operability, noise, odour, smoke
- Vehicle durability: after-treatment systems, engine deposits, diesel fuel pump wear
- Implications of fuel changes for refineries

Table 1
Fuel and vehicle technology have many interactions to be addressed.

Since both the automotive and the oil industries have the common aims of reducing environmental impact whilst satisfying the same customers in the most cost effective way, there is a need to develop vehicle technology together with fuel quality as one system. Thus the report is intended to stimulate a discussion with the automotive industry and the legislator on the best way to make progress in the debate on fuel quality and emissions. Any later decisions should be based on scientific programmes.

MANY ASPECTS NEED ATTENTION, PRIORITIES CAN BE DIFFERENT

Since fuel changes alone have relatively small effects, any real benefits would come from synergy between fuel and vehicle technology, i.e. 'enabling fuels' which allow new technology to work effectively. Good examples are the introduction of unleaded gasoline to allow the use of catalyst equipped cars, and of low-sulphur diesel fuel (with lubricity additives where needed) to enable Euro 2 diesel engines to meet emission limits. Fuel quality and vehicle technology should therefore be treated as a design system and developed in cooperation.

Environmental needs depend on local circumstances. The goal is the achievement of good air quality, rather than the reduction of all emissions without regard to costs. The most critical pollutants and the degree of control required will vary depending on the local situation.

HARMONIZATION, A DIFFICULT TASK

Given the interactive nature of engine technology, engine calibration and fuels, a worldwide approach to harmonization needs, by definition, to consider many aspects and is a complex task.

While an initiative is progressing to harmonize heavy-duty engine emissions cycles worldwide, harmonization of vehicle test cycles will be required as well. Worldwide fuel specifications could be a beneficial contribution, but only in conjunction with simultaneous harmonization of reference fuels and emission limits. In this context, the question of whether common worldwide advanced emission control requirements could be based on a common technology strategy would have to be investigated.

The expectations of the vehicle owner/driver need also to be taken into account, e.g. smooth and reliable operation under all operating conditions. Changes to reduce emissions may conflict with this objective. Customers around the world may place quite different values upon fuel economy, specific performance features and overall vehicle/operation costs.

AIR QUALITY INFLUENCED BY LOCAL NEEDS

It is vital to consider the underlying causes of the air quality problem: in individual situations, different technical/non-technical approaches will give the most cost-effective and practical solutions. Climatic or geographical conditions, customer driving patterns and expectations, the profile of the vehicle parc (size, diesel/gasoline, LD/HD, age), social demographics, public transport infrastructure, the impact of stationary emission sources and the scale of the problem (e.g. inner city versus regional) can be extremely varied.

ECONOMICAL USE OF FUEL PARAMETERS

Fuel properties should only be specified to control specific critical aspects of vehicle performance or emissions, where clear fuel effects are demonstrated and the specification parameters should be linked directly to vehicle effects. Long-term, unnecessary limits on fuel composition will restrict the ability of refineries to produce sufficient quantities of future fuels. This restriction in flexibility will translate into increased processing requirements and energy use.

CO_2 ISSUES MOVE TO THE FRONT (A 'WELL-TO-WHEELS' APPROACH)

CO_2 reduction is a further challenging objective for vehicle design. The extent to which moves to improve fuel economy align with customer expectations will vary across the regions.

Possible options to reduce CO_2 emissions/fuel consumption include vehicle size and/or weight reduction, gasoline direct injection, lean-burn technology, increasing the proportion of the diesel share, optimized (linked) engine-transmissions systems and hybrid vehicles.

To extend diesel and gasoline lean-burn applications to their full potential, breakthroughs are still required in development of exhaust gas de-NO_x technology. For such technology very low sulphur fuels are seen as enablers, but this has not yet been demonstrated. Cooperation in this area of complex and rapidly developing technology should be a priority for the industries involved, since only technically mature and cost-effective solutions can be the basis for a sound approach in meeting both air quality objectives and the customers' needs.

Changes to fuel specifications in order to reduce exhaust emissions inevitably require more processing in the refinery and hence generate more CO_2. As a consequence, CO_2 emissions must always be evaluated on a 'well-to-wheels' basis. Overlooking this principle may lead to incorrect conclusions. Any further reduction in fuel sulphur is such an example. Therefore a joint approach would have to take this into account, since increased refinery emissions could outweigh any benefits of supplying the new fuels to the vehicle fleet.

CONCLUSION—WORK IN COOPERATION

In CONCAWE report no. 99/55 the principles and the specific issues which are key to the development of fuel specifications are outlined. Cooperation between the industries involved is essential in such developments, since fuel and vehicle technology need to be developed together as a common technical system.

The US AQIRP[1], the European Auto/Oil/EPEFE[2] and JCAP[3] programmes demonstrate how the oil and auto industries can work together towards a common goal. Such programmes develop sound technical information, but more work is needed to expand the knowledge gained from these programmes to cover new technologies.

CONCAWE has, on various occasions, stated their willingness to join programmes contributing to a better understanding of future vehicle and fuel requirements for customer satisfaction and environmental needs.

[1] *US Auto/Air Quality Improvement Research Programme*
[2] *European Programme on Emissions, Fuels and Engine technologies*
[3] *Japanese Clean Air Programme*

EU—ambient air standard for benzene

The first EU limit value for a carcinogenic air pollutant.

On 2 December 1998 the European Commission accepted a proposal[1] for a Council directive on the establishment of limit values for concentrations of benzene and carbon monoxide in ambient air. In an earlier phase the Commission proposed limit values for SO_2, NO_2, lead and PM_{10}. However, benzene is the first air pollutant in the Commission's programme which is a proven human carcinogen. The risk characterization of carcinogens at very low exposure levels is technically difficult. The Working Group which prepared the proposal for the limit value (and the monitoring and analytical procedures, etc.) lacked the necessary expertise to make an evaluation of health risks, and therefore sought the advice of an ad hoc group of experts which had previously reviewed a number of risk assessments. A range of 0.2–20 $\mu g/m^3$ was accepted, wherein, in the view of the ad hoc group, the risk of one additional case of leukaemia per one million persons, exposed during life, would not be exceeded.

In view of the uncertainty about the exact concentration of benzene in ambient air which does not exceed the accepted risk, the Commission opted for a cautious approach and proposed a limit value of 5 $\mu g/m^3$ (annual average) to be achieved in 2010. In view of the current and future air concentrations in 'hot-spots', this proposal—if eventually accepted by the Council—can be described as extremely ambitious, particularly for the southern Member States. These states will certainly invoke the derogation clause, which has become part of the proposal as a result of pressure applied by other Directorates-General.

Benzene is a proven human carcinogen which, in high doses, has caused fatal acute myeloblastic leukaemia (AML) in occupationally exposed persons. Certain researchers believe that benzene has also induced lymphatic leukaemia, but the epidemiological data are not convincing and the recent results of mechanistic toxicological research only point in the direction of AML and other non-lymphatic forms of acute leukaemia. Benzene is a weak carcinogen: hundreds of thousands of persons have been exposed, either occupationally or during their studies, sometimes to high air concentrations (hundreds of ppms) and/or have washed their hands in benzene. Nevertheless, the number of victims known from the literature is limited (some hundreds).

The development of a proposal for a limit value for the ambient air concentration of benzene was a challenge for the Commission's DG-XI and for the assisting working group, because there was no precedent for a carcinogenic air pollutant. Nevertheless, an agreement was reached recently by the Council and the European Parliament in the framework of the Drinking Water Directive on the starting point for the development of limit values for carcinogenic substances. That starting point is one additional case of cancer in one million persons exposed for life. This is in line with the *'de minimis'* principle used in the United States, that

[1] *Commission of the European Communities, 1998. Proposal for a Council Directive relating to limit values for benzene and carbon monoxide in ambient air. (1999/c 53/07) Off. J. Europ. Comm. 24.2.99.*

considers risks less than 1 x 10^{-6} (lifelong exposure) as not relevant for the legislator (*de minimis non curat lex:* the law does not deal with trivia).

The starting point for the Commission was the evaluation carried out in 1996 by the World Health Organization—European Region (WHO-EUR), in particular because the Commission had sponsored this work[2]. There were, however, at least two other relevant and recent evaluations with concrete recommendations for a limit value. The three evaluations, which are described in the boxes below, played an important role in the discussions of the ad hoc group of experts.

The WHO-EUR evaluation[2]

The Pliofilm* cohort was the basis for the risk evaluation by the WHO-EUR[2] in 1996. In the first publication of this cohort study with 1717 workers, there were nine cases of leukaemia. In later studies the number increased to fifteen. Apart from updates of the health status of the workers, three separately published studies were carried out on the exposures. The initial exposure estimates, which appeared to be too low, were later corrected, with the result that the risk estimate decreased (because of assumptions of higher exposures).

In the WHO-EUR document no less than 18 published risk evaluations using the Pliofilm–cohort are included. The risks expressed in 'unit risk' (the additional risk at lifelong exposure to 1 µg/m^3) vary from about 5.5 x 10^{-6} to 5.3 x 10^{-11}, depending on the method of extrapolation from the relatively high exposures experienced by the workers to the very low concentration of 1 µg/m^3 and are also influenced by the evaluation of the exposure of the workers for which two of the three published exposure studies were used. As a basis for the development of a standard, WHO-EUR chose to average the two linear unit risk evaluations which relate to the two exposure studies and arrived at 6 x 10^{-6} at 1 µg/m^3, lifelong exposure, or, in other words, one additional case per million, subjected to lifelong exposure to 0.17 µg/m^3. This concentration cannot be implemented as Limit Value because it is lower than the background concentration in rural areas.

** Pliofilm, a special kind of rubber produced in two plants in Akron, Ohio and in one plant in St Mary's, Ohio*

PROPOSAL BY THE AD HOC GROUP

The ad hoc group was composed of experts who have been particularly concerned with benzene, for example from Germany (rapporteur for the risk-assessment of benzene as existing chemical), WHO-EUR, the European Chemicals Bureau, the Joint Research Centre, industry and the Commission. The evaluations described in the boxes were discussed and the chosen approaches assessed. The group decided to identify the risk evaluations with the highest and the lowest plausible risk, in line with the precedent set by the risk-evaluation as required by the Drinking Water Directive, 5 x 10^{-6} and 5 x 10^{-8} respectively for lifelong exposure to 1 µg/m^3. Calculated as unit risk, this corresponds to benzene in air concentrations of 0.2 µg/m^3 and 20 µg/m^3. The 'correct' unit risk would lie within this range. UNICE has interpreted this pronouncement in the sense that each and every concentration within the range would be acceptable because the risk criterion of 1 x 10^{-6} would not be exceeded, but that preference should be given to the lowest possible concentration which is reasonably practicable.

COST/BENEFIT ANALYSIS

According to the Framework Directive on ambient air quality, a cost/benefit analysis has to be carried out in addition to the health risk analysis. The cost/benefit analysis has been prepared by a consultant to the Commission, who reported to the Working Group. Although much information is available on benzene in ambient air there are limitations that create uncertainties. The largest uncertainty however lies in the way of expressing early mortality in monetary terms and thus calculating the financial benefits of avoided mortality cases. In the consultant's

[2] *World Health Organization, 1996. Air Quality Guidelines for Europe 1996. Benzene. Edited final draft.*

report[3], the 'Value of Statistical Life' (VOSL) method is used, which takes into account the willingness of people to pay for reducing the risks of dying early. A VOSL of 3.1 million Euros was assigned for each mortality case and compared with the costs of reducing benzene in ambient air, on top of the costs of regulations already existing or in preparation.

In summary, for an annual average of 10 µg/m^3 in 2010, costs and benefits of measures in 'hot spots' (locations with the highest concentrations and where people are exposed for periods of time which are biologically relevant) are only more or less in balance in the most favourable scenario. However, if one strives for a standard of 5 µg/m^3, applicable also in 'hot spots', the costs greatly exceed the benefits.

The above assessment of costs and benefits was available in draft at the time when the Commission's proposal was finalized. In July 1999, however, the final Economic Evaluation of Air Quality Targets for CO and Benzene[4] was made available. The table in the summary to that document states that by the year 2010 with the in-the-pipeline measures implemented throughout the whole EU, there will hardly be any exceedances of a 10 µg/m^3 limit value (annual average) and that no leukaemia cases can be avoided by applying additional measures. For a limit value of 5 µg/m^3 some exceedances are predicted, which, when avoided through additional measures would result in the avoidance of 0–1.9 cases (depending on the unit risk used). The costs of the additional measures to meet 5 µg/m^3 and so avoid the 1.9 cases per year would equate to about 230 million Euros per case. For a limit value of 2 µg/m^3 many more exceedances are predicted and consequently more cases of leukaemia would be avoided if additional measures were taken to reduce benzene in ambient air to meet the limit value. Depending on the unit risk used, 0–17 cases could be avoided at an average cost per case of about 2 billion Euros.

PROPOSAL BY THE EUROPEAN COMMISSION

The Working Group members could not reach an unanimous position and, similarly, neither could the Steering Group, which comprises representatives of all Member States. The European Commission has carefully reviewed the differing views and eventually opted for a

The CONCAWE proposal

CONCAWE issued a report[5] in 1996 that discussed the scientific basis for an air quality standard for benzene in ambient air. The scientific considerations and the procedure are in line with those outlined in the report issued by the European Chemical and Oil Industry and submitted to the Rapporteur for benzene (Germany) on the occasion of the risk assessment of benzene as existing chemical. Fundamental in this evaluation is the view that the 'one-hit' hypothesis is not valid for benzene. There are many indications from mechanistic toxicological research for the existence of a threshold for the adverse effects of benzene on the bone marrow. A linear extrapolation of effects occurring with relatively high dosages to very low dosages is therefore too conservative. In the absence of any data points for effects in the very low dose area, the choice was made to use extrapolation factors which are argued one by one.

AML and other acute non-lymphatic forms of leukaemia (ANLL) are identified as critical effect. An empirically established no-effect level of 1 ppm—the result of an analysis of the Pliofilm cohort and three more recent studies—is the starting point for the extrapolation. This resulted in a health-based standard of 128 µg/m^3 (annual average).

[3] *AEA Technology, 1998. Economic evaluation of air quality targets for CO and benzene. Prepared for European commission. DG-XI. Draft final report.*

[4] *AEA Technology, April 1999. Economic Evaluation of Air Quality Targets for CO and Benzene. Final Report.*

[5] *CONCAWE, 1996. Scientific basis for an air quality standard on benzene. Report no. 96/63. Brussels.*

The evaluation of the Netherlands Health Council

Shortly before the meeting of the ad hoc group of experts, the Netherlands Health Council issued their (second) report on benzene[6] December 1997, in which toxicological advice given previously on a standard for benzene in ambient air was confirmed. The Health Council had already concluded in 1987 that linear extrapolation, which resulted in a concentration of 0.12 $\mu g/m^3$, was far too conservative and led to an overestimation of the risk by a factor of 100. This resulted in a toxicological advice value of 12 $\mu g/m^3$.

In the second report, the 'Committee for the evaluation of the carcinogenicity of chemical substances' had much new data available on the mechanisms of the toxicity of benzene. The Committee did not go as far in their conclusions as CONCAWE ('one-hit' hypothesis not applicable), but did establish that benzene, as a genotoxic substance, demonstrates an 'unusual' toxicity profile and that linear extrapolation results in an overestimation of the risk at low concentrations.

In line with CONCAWE, the Committee considered ANLL as the critical effect upon which the risk assessment should be focused.

The risk assessment was carried out using a cohort, constituted from a large number of studies, of 208 000 workers who had been exposed in the USA and Europe during many years at an average benzene concentration of 0.70 mg/m^3. In this cohort an excess risk for ANLL was not found. Using a simple formula, extrapolation from the occupational exposure, with an assumed average exposure duration of 10 years, to lifelong exposure of the general public, results in a concentration of 35 $\mu g/m^3$. This result was the reason for the Health Council to confirm their previous advice of 12 $\mu g/m^3$. (It is now known that the average exposure duration was close to 20 years; the number of 35 could therefore be multiplied with a factor of nearly 2, which results in a value not far away from the one that CONCAWE derived).

limit value of 5 $\mu g/m^3$ (annual average) to be reached in 2010. A minority of the Member States and UNICE preferred 10 $\mu g/m^3$ (annual average) with a review in 2005 or 2007[1]. This review of the air quality and the progress of the toxicological research into a threshold for effect has become a part of the proposal and will take place in 2004. Following pressure from other Directorates-General, a derogation clause has been built in, which allows for delayed implementation until 2015. However, the Commission proposal still has a long way to go before the Council will vote on it.

PROCEDURE

The current working procedure for the development of air quality standards by a working group, with a need to present information on ambient concentrations (and trends), measurement and assessment techniques, is laborious and inefficient. Guidance on the composition of Working Groups is limited to assuring an adequate representation from Member States, the Joint Research Centre, the European Environment Agency, the Topic Centre on Air Quality, non-governmental organizations, industry and the Commission, with the consequence that the experts come predominantly from the measurement and analytical circuit and the expertise on health effects is under-represented. This then leads to emergency measures, such as the appointment of an ad hoc group mandated to deliver a proposal in one day, while the working group needed several two-day meetings over a period of 18 months to develop the Position Paper. It would be much more efficient if the Commission were to give a contract, in an adequate time-frame, to a team of consultants to prepare a draft Position Paper which would subsequently be finalized in a Working Group in which all stakeholders are represented, as is now the case.

[6] *Gezondheidsraad, 1997. Benzene. No. 1997/29E, Rijswijk.*

Exposure profiles

Publication of exposure profile for kerosines/jet fuels.

The risk assessment of chemical substances is based on a comparison of the potential adverse effects of a substance at given concentrations with the known or foreseeable exposure for man and the environment. Identification of the intrinsic hazards of a substance together with data on the extent to which man and the environment are exposed are the two key sets of information in the risk assessment process.

Hazard assessment procedures are well developed and are based on the principles laid down in the Dangerous Substances Directive. For petroleum substances, comprehensive information on the human and environmental toxicological characteristics has been extensively reviewed. These are published in CONCAWE Report 98/54 and the CONCAWE product dossiers.

However, the collection of the corresponding exposure data for petroleum substances is less advanced, and in consequence, a CONCAWE Task Force has been established to assess available data from member companies and from the published literature to document the available exposure data in the form of exposure profiles for the main petroleum substance groups. These profiles will eventually form companion documents to the product dossiers and will be available for use by member companies and by the risk assessors.

The objective of the work of the Task Force has been to identify exposed populations for each of the main petroleum substance groups and to quantify the level of exposure for each population group and for the environment. Generally, there are three groups of people that, potentially, may be exposed to petroleum substances. These are: workers, through exposure in the work place (occupational exposure); consumers, during the normal use of the substance; and the general population, through exposure to contaminated air, soil and water, and via the food chain. Exposure to the environment is assessed in the form of the potential exposure of aquatic systems, sediments, soil and air.

CONCAWE has recently published the exposure profile for kerosines/jet fuels (report no. 99/52). This exposure profile is a review of exposure to kerosines and jet fuels based on available data from member companies and from the published literature. It considers human exposure data for workers in the petroleum industry and kerosine fuel distribution, and consumers; and indirect exposure to the general public via the food chain and through inhalation of air. Environmental exposure covers releases to air, water, soil and groundwater, where such information is available. In addition, the report gives a summary of the uses, compositions, hazards, occupational exposure limits, and supply and consumption figures for kerosines and jet fuels.

CONCAWE safety statistics

The oil industry is a safe place to work compared to other industries but there is still room for improvement.

CONCAWE has now been collecting data on the safety performance of the downstream oil industry in Europe for six years. For the first time, the 1998 survey included results from all the CONCAWE members who together represent more than 90 per cent of the oil refining capacity in the region. These surveys were last described in the CONCAWE *Review* two years ago (October 1997). Since then, two reports have been published covering 1997 and 1998 (CONCAWE reports nos. 4/98 and 1/99 respectively). Report 4/98 also includes an overview of the first five years of these surveys.

In previous years, the CONCAWE statistics were compared with those produced by the API for the US downstream oil industry and with those reported by E&P Forum for the upstream oil industry (exploration and production). This was not done this year as the report was finalized before these other statistics were available. However, there is no reason to doubt that as in previous years, the general level of safety performance in these three areas of the oil industry was of the same order.

Comparison of oil industry accident statistics with EU statistics

	*European incidence**		*Oil industry incidence**	
Industrial sector	*LWI*	*Fatalities*	*LWI*	*Fatalities*
Manufacturing	5054	5.0	921	5.6
Construction	9885	17.0		
Wholesale and retail	2868	3.3	77	8.6
Financial intermediation etc.	1827	3.5		
Combined**	4505	6.1	830	7.5

** Incidence = number of incidents/fatalities per 100,000 employees*
*** Combined = sum of all above sectors*

Table 1
Lost work injuries in the downstream oil industry are only about one-fifth of the frequency for the EU industry as a whole.

A new departure in the 1997 report was that it was possible to compare the CONCAWE statistics with limited statistics collected by the EU for general industry in Europe. These statistics are not complete in that they do not cover all areas of economic activity (agriculture and transport were excluded) and in a number of EU Member States they are estimated from partial reporting. Nevertheless, they are considered to be representative, covering as they do 122.4 million employees and more than 4 million accidents. These data are compared with the CONCAWE data in Table 1. The aggregated oil industry results for the five years 1993 to 1997 are shown in order to smooth out any annual differences. The criteria for an incident in the European figures is an accident leading to a lost time of three days or more, rather than the one shift or more used by most companies for the CONCAWE data. It therefore ignores some less serious incidents included in the oil industry statistics. However, given that the average number of lost days per incident in the European oil industry is more than 20 days, the effect of this is unlikely to be great.

The EU statistics are reported as incidents per 100 000 employees, rather than per million man-hours. The oil industry figures in the table have been converted to the same basis assuming that an average year's work consists of 1840 hours. The figures for the manufacturing and marketing sectors of the oil industry correspond approximately to, and are compared to, the manufacturing and wholesale and retail sectors in the EU figures. However, it is probably safer to compare the combined figures (bottom row of table). These reveal that lost work injuries (LWI) at 830 per 100 000 employees in the downstream oil industry are only about one-fifth of the frequency for the EU industry as a whole (4505 per 100 000 employees). Oil industry workers are therefore much less likely to be injured at work than other workers. However, the incidence of fatalities is similar between the two sets of data, possibly because the EU figures exclude transport activities.

Causes of fatalities in 1997 and 1998	*Manufacturing*	*Marketing*	*Combined*	*Percentage*
Road accident		11	11	41
Criminal action		4	4	15
Construction/ maintenance		3	3	11
Shipping accident		2	2	7
Shipping maintenance		1	1	4
Fire	4	2	6	22
TOTAL	4	23	27	100

Table 2
The relatively few fatalities in the manufacturing sector indicate that oil refineries are a relatively safe place of work.

A new development for the latest two CONCAWE surveys was to ask companies for a brief description of the circumstances of any fatalities so that they could be categorized. The results are shown in Table 2 and may be surprising. The first point to note is that most fatalities (41 per cent) were due to road accidents and this was true for both years. Criminal action on service station staff was also a major cause of death. There were very few (only 4 in 2 years) fatalities in the manufacturing sector, indicating that oil refineries are a safe place to work. In fact, only 6 fatalities (22 per cent) involved fire which most people might imagine to be the major hazard for workers in the oil industry.

Comparing the results for the two years with the average for the five years 1993 to 1997 (Figure 1), the performance in 1997 and 1998 was similar to the average. There were improvements in the Lost Workday Injury Severity (LWIS), the Fatal Accident Rate (FAR) and the Road Accident Rate (RAR). However, the Lost Workday Injury Frequency (LWIF) is almost unchanged. It had been hoped that the amount of effort being devoted in CONCAWE Member Companies to improving safety would have led to a greater improvement in this statistic which is considered to be the most reliable measure.

When the surveys were first started (for years 1993/4), only 17 Member Companies submitted data. It could be that these companies were those whose safety culture was most advanced at that time. We therefore decided to look at the performance of just these companies across the whole period. The results (Figure 2) show that indeed there is evidence that the performance of these seventeen companies has improved over the years as the LWIF, FAR, and RAR have all decreased. The All Incident Frequency (AIF) figures are more complicated and show an initial rise followed by a steady decrease. A possible explanation for this is that one of the first steps to improving safety performance is to ensure that all incidents are reported, so that they can be studied to identify weaknesses that can be corrected. In the first years of the survey, the companies concerned were making great efforts to improve the internal reporting of minor accidents and it is believed that this explains the initial rise. Since then, a real improvement in safety has led to an actual reduction in incidents and hence a corresponding decrease in the AIF.

Safety can be seen to be improving in many companies. As the same factors take effect in the other companies, the safety record of the industry as a whole should improve further.

Figure 1
Safety performance in 1997 and 1998 was similar to the average over the 5-year period 1993–97.

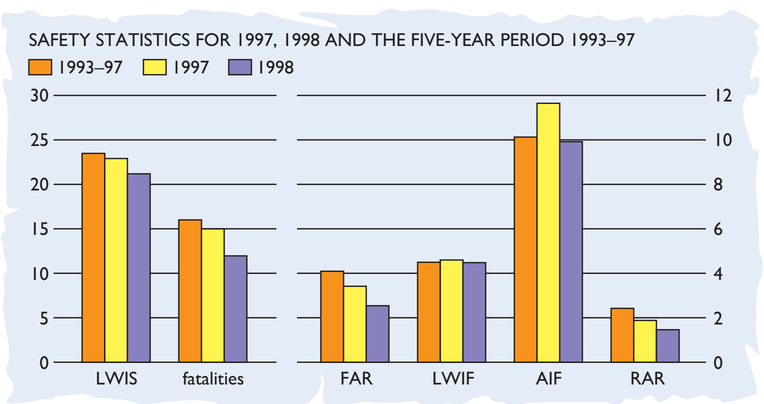
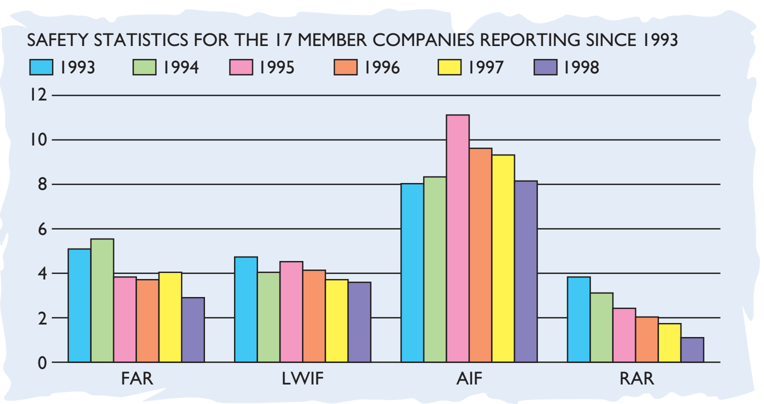


Figure 2
Safety performance of the 17 member companies submitting data since the start of the survey has continued to improve since then.



Mobile phones

Are they a hazard to more than your sanity?

Mobile phones have rapidly become one of the necessities of modern life, allowing people to keep in touch with each other at all times. As we all know, they can also be annoying when they ring at inappropriate times; even CONCAWE meetings now suffer from this problem! This may be fairly trivial, but can they be a fire hazard as well?

Recently, there have been a number of press articles highlighting the dangers of the use of mobile phones at service stations. Also, in a number of countries (for example the UK) there are signs displayed at service stations banning the use of such phones. However, the lists of dos and don'ts at service stations is now so long that they are losing their impact on the public.

Are such bans necessary? There have been reports of serious fires caused by mobile phones used during vehicle refuelling. However, it has proved very difficult to track down any reliable information on these fires; various sources have identified different companies in different countries, mostly in South-east Asia. It is therefore by no means certain that there have even been any such fires and, to our knowledge, none have been reported in Europe. Therefore, in the absence of hard evidence we have to revert to theory.

The refuelling of vehicles with gasoline is a good example of the difference between hazard and risk. Gasoline is a highly flammable liquid and therefore, by definition, its use presents a significant hazard. However, it is used in very large quantities, and millions of vehicles are refuelled with it in Europe every year. Experience shows that the numbers of fires which occur during this operation are very few, and most of these are not serious enough to cause personal injury. The observed risk is therefore very low. What is important is whether the use of mobile phones increases this risk.

Gasoline vapour in air is only flammable over a narrow composition range. In the vehicle tank, the vapour is too rich and it will not burn. As soon as the vapour is forced out of the tank by the incoming fuel it dissipates in the air and soon falls below the lower flammability limit. The fuel vapour can therefore only be ignited over a short distance from the car. Even though there are many ignition sources at a service station they are not usually present in the area of most hazard. Hence, fires are rare.

In theory, a mobile phone (like almost any other piece of electrical equipment) can generate a spark powerful enough to ignite gasoline vapour. In refineries they are classified as 'naked lights' and their use is only allowed (if at all) under permit when it has been established that flammable gas mixtures are not present. The many other possible ignition sources at service stations include smoking, static electricity and, not least, the car engines themselves. The additional risk from mobile phones is therefore likely to be small. There is, however, one exception. Many people carry phones attached to their belts. In this position, if the phone were to ring (which is perhaps the most likely time for a spark) it could well be in the right position to ignite the flammable vapour cloud.

Perhaps a greater risk when using a mobile phone while filling is the distraction from a task that should have one's full attention if spills and other accidents are to be avoided. All in all, perhaps the safest solution is to leave the phone in the car.

CONCAWE news

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In order to make CONCAWE reports more readily available, the CONCAWE Internet site is being extended. Up-to-date CONCAWE report catalogues and recent reports are available via the website at www.concawe.be.

SEASON'S GREETINGS

CONCAWE will not be sending its traditional Christmas greetings cards this year, but will instead make a donation to charity. The Secretariat staff would, therefore, like to take this opportunity of wishing all readers a very happy Christmas and a prosperous New Year.

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8/98	Trends in oil discharged with aqueous effluents from oil refineries in Europe—1997 survey
9/98	Motor vehicle emission regulations and fuel specifications—part 1, summary and annual 1997/98 update
1/99	European downstream oil industry safety performance—statistical summary of reported incidents—1998
2/99	Environmental exposure to benzene

Special interest (white cover) reports

98/55	Polycyclic aromatic hydrocarbons in automotive exhaust emissions and fuels
99/51	Proposal for revision of volatility classes in EN 228 specification in light of EU fuels directive
99/52	Exposure profile: kerosines/jet fuels
99/53	Scientific basis for an air quality standard for nickel
99/54	Overview and critique of the air pollution and health: a European approach (APHEA) project
99/55	Fuel quality, vehicle technology and their interactions
99/56	EU oil refining industry costs of changing gasoline and diesel fuel characteristics
99/57	Environmental levels of benzene at the boundaries of three European refineries
99/58	Occupational health auditing (1): occupational hygiene
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* *available shortly*

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The following references relate to the article *Ambient particulate matter: sources and apportioning* on pages 6–9 of the *Review*:

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