

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

Articles in previous editions of the CONCAWE *Review* have concentrated on petroleum products and their role in influencing emissions from mobile and stationary combustion sources and their contribution to possible adverse implications of emissions on human health and the environment. Besides summarizing the technical and scientific facts to substantiate CONCAWE's views on these issues, economic analyses about the consequences of any necessary petroleum product modifications have normally been an integral part of these *Review* articles. It appears though that we still owe our readers some insight into the methodologies used by CONCAWE and the associated complexities of these economic evaluations.

Whenever health or environment legislation aims at changing the properties of petroleum products, be it directly by fixing product specifications or indirectly by limiting emissions from oil-fired combustion sources, financial implications rest mainly on the refineries. Additionally, there are EU directives which impose restrictions on the handling, storage and distribution of petroleum products resulting in further costs to the petroleum industry.

In order to allow our readers a closer look at how CONCAWE assesses the costs of changing refineries to meet new product quality requirements, this *Review* contains three articles dealing with the work of the Refining Planning Advisory Group (RPAG). These articles supply detailed information in addition to the general aspects of RPAG's work as outlined in the April 1998 edition of the CONCAWE *Review*. They deal with a range of aspects and illustrate that the assessment of the refinery investments on an overall EU-15 basis is highly complex and needs agreement on a set of assumptions. CONCAWE considers it essential to state these assumptions clearly in any of its publications to make its work transparent. Enhancing transparency is another good reason to describe RPAG's work in this *Review*.

During recent years, the remit of RPAG has been extended to cover CO₂ emissions in addition to costs in order to evaluate the full consequences arising from direct/indirect petroleum product quality legislation. As outlined in one of the articles, CONCAWE is willing to offer its planning data, expertise and experiences to independent organizations. This offer reflects our conviction that CONCAWE's Linear Programme (LP) model calculations are providing valid results under the constraints of the current/future overall EU-15 supply and demand situation. CONCAWE would certainly appreciate receiving from its readers any positive but also critical comments on the RPAG articles.

In this context I want to welcome Jean-François Larivé as the new Technical Coordinator for RPAG who begins his work at the CONCAWE Secretariat on 2 May 2000.



Jochen Brandt
Secretary-General, CONCAWE

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The legislative maze

In how many different ways are refineries to be controlled?

A previous article (*CONCAWE Review* Vol. 8, No. 1) has described CONCAWE's involvement in the development of the BAT (Best Available Techniques) Reference Document (BREF) for refineries under the Integrated Pollution Prevention and Control Directive (IPPC). The first 'kick-off' meeting of the Technical Working Group (TWG) was held in Seville in May 1999. The European IPPC Bureau (EIPPCB) then collected information from members of the working group, and the initial draft of the BREF was produced. Refineries will also be affected by a number of so-called horizontal BREFs. These are for processes which are common to a number of industries and include monitoring, storage, cooling, waste water and gas treatment, and large combustion plants.

The outcome of the refinery study in particular will be of great importance to the European refining industry. As its title implies, it is intended to be a reference document for local regulators to use in granting permits to operate refineries when the IPPC Directive has to be applied by Member States to existing installations by 2007. The BREF will include information on the available technologies and achievable performance levels. It is likely that many refineries will have to upgrade their treatment processes to comply with the requirements for BAT.

The setting of BAT for refineries is a complicated process. Refineries are rather different from most other industrial sectors in that they manufacture a whole range of different products, with the range and relative quantities varying not only from refinery to refinery but also over time depending on product demand, type of crude processed, etc. Most processes produce mixtures of hydrocarbons which have to be separated before reblending with streams from other processes to produce the final sales products. The feed and products of these processes are integrated, as are energy saving measures and treatment of most of their emissions streams. There are also many common components such as furnaces.

For these reasons, CONCAWE is of the opinion that refineries should be treated as a whole, rather than process by process. Its submission to the TWG was structured on a media basis considering emissions to air, water and ground separately for the whole refinery. Cross media aspects were taken into account. The direct emissions from individual plants, notably emissions to air from the cat-cracker were considered separately. The EIPPCB, however, wish to cover refineries process by process. In CONCAWE's view, this will make the BREF unnecessarily repetitive and time consuming whilst adding little to the understanding of the issue.

The IPPC Directive is not the only European environmental legislation that impacts refinery operations. Perhaps the most fundamental is the directive controlling the quality of gasoline and diesel fuel. This will require new processes and changes in the way refinery processes are operated. Another directive limits the sulphur content of liquid fuels. Other directives that have an impact on refinery operations are regulating/controlling issues such as safety (Seveso Directive), the emissions from large combustion plants, VOC emissions, waste disposal and incineration, protection of groundwater, etc. There is also a decision by the Oslo and Paris Commissions (OSPARCOM), the body responsible for the protection of the North Sea and Eastern Atlantic,

controlling emissions from refineries directly to these seas and also to the rivers flowing into them. Similar bodies are responsible for the Baltic, Mediterranean and Black Seas.

An important set of directives covers the control of air quality, particularly the Air Quality Framework Directive and its daughter directives. These so far cover SO₂, NO_x, particulates, lead, CO and benzene with others such as ozone, PAHs and nickel still to follow. These directives set air quality standards (AQS) which have indirect impacts on refineries which are significant emitters of a number of these atmospheric pollutants. Their emissions have to be regulated together with the emissions from all other sources in the area, and even transboundary emissions, in order not to breach the overall AQS in that area. There is a mechanism through the IPPC Directive to tie AQS to specific industrial plants. Such sites have to use BAT (taking into account economic viability and local factors) to control their emissions. However, the AQS (and other environmental quality standards) must be complied with. If they are not, then more stringent measures must be taken.

Most of the above pieces of legislation involved at least some form of risk assessment (RA) in the development of their standards. However, a completely separate programme of risk assessments is being carried out as part of the EU programme for control of chemicals. Experts from one of the Member States carry out each RA. So far, progress has been slow and there has been no RA on any petroleum substance, although they are in progress for a number of chemical compounds contained in petroleum products such as benzene, toluene and MTBE.

CONCAWE is firmly committed to the principles of RA, indeed, the scientific assessment of environmental and health problems associated with oil and its use have been the cornerstone of its activities since it was founded more than thirty-five years ago. In this time, CONCAWE has collected a considerable quantity of information and scientific facts covering both the health effects of oil products and the exposure of workers and the public to the various products involved. Both aspects are fundamental parts of any RA. We are now reassessing these data to see what is missing and to fill the gaps. Thus when RA for petroleum substances is required, we will be in a position to cooperate effectively.

There are a number of problems associated with RA particularly where it impinges on existing legislation. RA is based largely on laboratory testing of individual substances on a variety of organisms followed by the application of generous margins of safety. It could well be that the RA of a substance which is present in refinery emissions could call for strenuous risk reduction measures based on inadequate and theoretical data, even though the refinery in question is already applying BAT and is situated in an area where the EQS are complied with.

For many years, the European oil refineries have taken a practical approach to assessing their emissions by monitoring the environmental impact on their surroundings. Some refineries (often in association with their regulatory bodies) have been doing this for more than thirty years. The results have generally shown very limited impacts. For example, in 1979 CONCAWE documented the environmental impact of refinery effluent water (Report 8/79). Since then, further CONCAWE reports have detailed the rapidly decreasing oil releases in refinery effluents. It is therefore difficult to see why extra measures for individual substances in such water should be called for when it has been demonstrated that the aggregated effect of the whole is minimal.

To conclude, refinery operators increasingly have to manage their compliance with all the environmental legislation, not just ensuring that their sites comply with the specific legislation controlling their activities (the IPPC Directive). They truly have a maze of legislation to contend with.

Carbon, sulphur and hydrogen in oil refineries

In order to meet new fuels specifications, refineries need to reduce carbon and sulphur contents of petroleum fuels and therefore use more hydrogen.

The net result is an increase in global CO₂ emissions.



CARBON CONTENT

Accurately calculating the global carbon balance in oil refinery and petroleum product end-use systems is a challenge of nightmare proportions. All except the lightest of the output streams are of uncertain and variable chemical composition. Oil refining deals with potentially millions of different chemical compounds all mixed up together. Matters are not too difficult up to the six carbons level, the light gasoline region. Beyond six, the number of possible combinations of carbon (linked by single and double bonds in rings and chains) and hydrogen increases exponentially. Then there are the myriad varieties of sulphur and nitrogen compounds commonly present in crude oils. The measurement and tracking of individual compounds through the refining processes, 'refining with tweezers' as it is jokingly called, is clearly impossible. To cap the complexities, where properties of complex pure hydrocarbon compounds have been measured, published data do not always all run in neatly predictable progressions.

Up to the present day, not even the species of the chemical compounds constituting the products have been measured routinely. Speciation is limited to determinations of the PONA (paraffins, olefins, naphthenes, and aromatics species) of some gasolines. There are also some uncertain measures of mono- and poly- aromatics species in some diesel fuels and their components where, depending on the test methods, the values recorded include more or less of the other species attached to the aromatic ring(s).

Physical/performance data on some examples of hydrocarbons in the diesel boiling range					
Hydrocarbon	C_xH_y	Type	Boiling point °C	Density kg/m³	Cetane Number
Acenaphthylene	$C_{12}H_8$	Diaromatic unsaturated mononaphthene	266	899	0
Acenaphthene	$C_{12}H_{10}$	Diaromatic saturated mononaphthene	279	1024	0
Tetradecyl benzene	$C_{20}H_{34}$	Monoaromatic mononaphthene	359	856	72
Cyclohexyl benzene	$C_{12}H_{16}$	Monoaromatic saturated	236	950	30
n-Octadecane	$C_{18}H_{38}$	Paraffin	316	792	110
n-Hexadecane (Cetane)	$C_{16}H_{34}$	Paraffin	287	773	100
n-Pentadecane	$C_{15}H_{32}$	Paraffin	270	768	95
n-Tridecane	$C_{13}H_{28}$	Paraffin	234	756	50

Source: CRC Handbook of Chemistry & Physics 75th Ann. Ed. 1988-89

Petroleum products are specified mainly by measurements of physical characteristics. The available data that define the heaviness of constituents of petroleum energy products are the measures of density and distillation cut points and boiling ranges, augmented by other physical measures that differ between products. The missing chemical measurements prevent the clear appreciation of carbon and hydrogen contents in each batch of product.

Density varies as a consequence both of changes in carbon/hydrogen (and some oxygen and sulphur) ratios, commonly referred to as aromaticity, and from changes in the number of carbon atoms bonded together in the constituent compounds. These physicochemical reasons for the changes in density are important but are unknown in detail in the models used to simulate refineries. The changes in the heating values of the road fuels can and should be accounted for. Fuel economy is generally talked of in terms of litres per 100 km, i.e. in the volumetric terms that the motorist sees. For study purposes though, it is best to work in mass units (so a mass balance can be assured) and adjust the product demands to allow for the mass-based lower heating value (LHV_m) of the fuel.

So is it not possible to do global carbon emission effects studies? Yes, not only is it possible—in fact it could hardly be simpler as long as the study is designed properly. The saviour is the mass balance fundamental that input and output are equal. The changes in input carbon can be calculated precisely. The only other requirement is that the carbon in the not-burned petroleum products does not change between cases. This happens to be true enough when the changes considered are road fuels qualities. What cannot yet be done with any great degree of accuracy is to apportion the carbon emissions between sectors such as refineries, vehicles, homes etc. CONCAWE intends to investigate doing some modelling work on the carbon outputs. Meanwhile, it is necessary to be content with the global CO_2 emission effect, which is actually what counts for sustainability and global warming considerations.

Most of the specifications being tightened, both for gasoline and diesel, tend towards more saturated and paraffinic molecules i.e. a higher hydrogen to carbon ratio. As this ratio deviates increasingly from that in the virgin crude oil fractions, hydrogen addition, and therefore manufacturing, needs to increase.

SULPHUR CONTENT

The physics and chemistry of sulphur compounds are important too. More study is needed before making confident pronouncements on the costs and carbon emissions effects of meeting universal diesel fuel sulphur contents in the region of 10 ppm and below. There is already plenty of experience of operating in this region but it is restricted to gas oils from hydrocrackers (HC), from hydrodesulphurization (HDS) and hydrodearomatization (HDA) units operating on virgin low-sulphur paraffinic gas oils that are undercut (300°C say). The EU diesel pool as a whole relies on the use of deeper virgin cuts, and high demand means high penalties for excluding the gas oils produced by visbreakers, cokers, residue hydrocrackers and cat crackers. Total exclusion of sulphurous and naphthenic crude types 'for ever' from all the EU refineries' crude oil diets also seems unlikely to be sustainable.

In the gas oil cuts, the ever-present sulphur is bonded to carbon atoms in both chains and rings. The sulphur in the chains is the most accessible to desulphurization catalysts but becomes more difficult to reach when in a ring, and much more so when two or possibly three rings are shielding the sulphur. So why not do away with the rings? HDA units add hydrogen and can virtually eliminate polycyclic aromatics and reduce monoaromatics to a point where equilibrium is reached but before hydrocracking of the rings starts to really take off. (Such hydrocracking removes the sulphur but makes products lighter than allowable in diesel.) Hence the rings do not go away but are changed to the saturated naphthene and polynaphthene types.

When treating a gas oil in a desulphurization unit, the most reactive sulphur species are removed first. It follows that the bulk of the sulphur species remaining in a gas oil treated to a level of say 350 ppm sulphur are all fairly refractory and comparatively more difficult to remove. A common option to bridge the gap between the 350 and 50 or 10 ppm level is to add a second HDS unit in series with the existing one. Attacking the least reactive species, necessary to reach such low sulphur levels requires a combination of higher temperature and residence time on the catalyst which must be reflected in the design of such new units. A crucial aspect in the design is catalyst stability i.e. ensure catalyst lives of a practical magnitude. Although process licensors and catalyst manufacturers are working hard on the problem, the outcome remains uncertain so that the precise capital costs associated to such new HDS units remain only a 'best guess'.

As the demand on the desulphurization hardware increases, flexibility and ability to cope with unforeseen technical problems within the refinery decrease. Many refineries may insure against that by 'cherry-picking' crudes and diesel components thereby becoming less consistent in the amounts of diesel they produce.

The practical responses decided on by EU refiners are not yet fully settled for the 350 ppm maximum level following the 1 January 2000 reduction from 500 ppm. Precisely what will be done to the processing hardware to meet the much more challenging reduction to 50 ppm is



Hydroprocessing removes sulphur and increases yields of road fuels, but consumes hydrogen and increases global CO₂ emissions.

shrouded in uncertainty. Any cost study done now on 10 ppm would apportion prospective costs between the 50 ppm measure and a 10 ppm measure before having sufficient knowledge of the hardware developments that is so crucial to assure the reliability of the results.

CHANGES REQUIRE HYDROGEN

Increasing the hydrogen content of fuels beyond what is available in virgin crude fractions inevitably requires hydrogen that therefore has to be manufactured. The standard way of doing this is by partial combustion of hydrocarbons to form a mixture of carbon monoxide and hydrogen followed by the so-called CO-shift reaction with steam where CO is turned into CO₂ while hydrogen is released from the water. In this process the original hydrocarbons act both as feedstock and fuel and all carbon is turned into CO₂.

From a global perspective and assuming that the balance of alternative fuels (such as natural gas) is not affected, additional hydrogen must be made from additional crude oil. Assuming a typical carbon content of 86 per cent mass, each ton of hydrogen manufactured produces 11.5 tons of CO₂.

If this hydrogen is now added to e.g. diesel fuel via hydrotreatment, the CO₂ emissions resulting from usage of this improved fuel decrease both because of its intrinsically higher hydrogen content and its higher heating value.

The net balance is still negative though, reflecting amongst other factors the limited efficiency of the processes involved. We have calculated that a requirement of 0.5 Mt/a additional hydrogen (EU refineries for Auto/Oil I) would result in an additional consumption of 0.41 Mt/a of crude oil for a net global increase of 1.3 Mt/a CO₂ emissions.

Statements that address only a part of the issue, for example, comparisons of the carbon dioxide emissions from vehicles that run on different fuels, can be very misleading. With fuel carbon/hydrogen ratios, as with sulphur removal, there is no such thing as a free lunch in terms of global carbon dioxide emissions.

Estimating the implications of road fuels quality changes on the EU refining industry

CONCAWE has developed the tools and techniques to guide oil refinery cost and CO₂ emission studies.



Calculations of the cost and global CO₂ emission implications to European refining arising as a consequence of required measures such as the Auto/Oil I and potential future Auto/Oil II legislation need to be done in a very particular way using long-range regional industry-wide refinery planning basis and techniques. The methodology used to determine future costs needs to address the effects that will arise over a lifetime and must avoid technically unsound approaches. Pitfalls include making assumptions on non-forecastable factors such as future product prices, or adding together individual refinery solutions that leave a gap (e.g. between demand and supply) to be covered somehow by some unknown outsider.

Following on from the poor profit margins experienced over many years, the EU refining sector tends towards caution when considering whether to undertake any refinery project that requires significant capital expenditure. Hence, to maximize the credibility of their cost study findings, analysts are tempted to calculate costs that include a minimum of investment solutions and instead use crude oil and product supply/demand alternative responses. After all, these are usually the effects that become visible in the short-term after a measure is first implemented.

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Figure 1
Platts marketscan is daily news on yesterday's prices and margins but unusable for events that lie in the future.

investments in appropriate new process units. By using LP models, analysts can ensure these processes are available if required to optimize the base case as well as to solve the quality cases. Meeting a fixed slate of products and using a single marginal crude ensures that all of the effects across all the products are taken into account and no gaps are left that have to be guessed at. It is necessary to ensure that no free spare capacity is available to fix quality issues for nothing. Any real long-term refining spare capacity is eventually closed down and apparent spare is actually in use covering daily variations/and profit opportunities. Finally, it is necessary to ensure that a sufficiently wide range of process options is included appropriate to the changes at issue both in nature and size to avoid an over-constrained cost model and unreasonable answers. Taking a difference between an optimized base case and the quality at issue case ensures that answers are minimally affected by forecasting errors in basic assumptions. Any under-forecasting of technical progress in quality change process technology generally produces only second order cost effect changes.

To make the cost model suitable for assessing the global CO₂ effects of fuels quality changes, it is necessary to ensure that the more carbon efficient energies such as natural gas are not allowed in as variables into solutions to help provide the quality improvements at issue. The maximum available/sustainable use of carbon efficient fuels is already implicit in the base case allocations between non-fossil energies, gas, oil and coal. On the other hand, any significant transport fuel heat value effects as a consequence of quality-changes should be accounted for in the fuel consumption levels on a basis that provides constant kilometres of transportation.

CONCAWE has developed its model of EU oil refining comprising an LP optimized supply/demand and refinery capacity, energy consumption and operating cost data generator and a sepa-

rate investment cost allocation model. These have been tailor-made for determining the ongoing costs of oil product quality changes and to provide quantified global CO₂ emissions effects. All models make compromises in details of their representation of the real world and this special sort of refinery planning is thus something of an art form. At CONCAWE, the required development/response-testing time has been taken and the technical analysis of refinery experts is incorporated. Sound advice is available on the science behind the art that is adopted for serious studies of the implications of EU-wide and Member State initiatives.

The difficulty is that it requires knowledge of future price margins between various crude oils and products. These prices are driven up by quality premia that are dynamic and responsive to the levels of demands and to the magnitude of the quality changes at issue. Assuming a price margin is, in effect, setting the answer to the cost effect.

To avoid such ‘not cost-able’ variable supply/demand solutions, planners can instead evaluate variable refinery solutions that utilize

Figure 2
The difference
between two LP model
solutions of cases
without and with the
potential change
quantifies the effects

The impact of Auto/Oil I and II on refinery costs and global CO₂ emissions.

The EU Commission's independent consultants recently published their results on the consequences of Auto/Oil II in terms of refinery costs. In addition CONCAWE has estimated the associated changes in global CO₂ emissions.

AUTO/OIL I

Under the Auto/Oil I (AO I) study work in 1996, the EU commission contracted A.D. Little associated with Touche Ross to provide the basis for the cost effects of changes to gasoline and diesel fuels characteristics. The AO I programme finally resulted in a full set of specifications for application in 2000 with a limited number of properties to be further tightened by 2005. The calculated cost of the 2005 package for the then 12 EU Member States was estimated at US\$ 34 billions (G\$34) in terms of Net Present Value (NPV) of the combined investment and annual operating costs over a period of 15 years.

With hindsight, it is now apparent that the benzene control up-front investment costs were overestimated and the accelerated progress in gas oil desulphurization technology (an increase in attainable desulphurization rates from about 97 per cent to 99.5 per cent for virgin gas oils) was unforeseen back in 1994 when the studies started. Even so the real costs over 15 years still to come may very well fall within the +/-30 per cent claimed as study accuracy limits. Any under-run is far from assured.

AO I mandated 'environmental quality' changes, year 2000 and 2005 road fuels)					
	Unit	Pre 2000 average	01/01/2000 spec.	01/01/2000 average*	01/01/2005 spec.**
Gasoline					
RVP (summer)	kPa	68	60	58	
Aromatics	%v/v	40	42**		35
Benzene	%v/v	2.3	1.0**		0.8
Olefins	%v/v	11	18	11	11.5
Sulphur	mg/kg	300	150**		50
Oxygen	%m/m	0.6	2.7	1.0	0.6
Diesel Fuel					
Cetane Number		51	51	53	53
Density	kg/m ³	843	845	835	835
PAH	%m/m	9	11	6	5.7
Sulphur	mg/kg	450	350	300	50
T95	°C	355	360	350	355

* Agreed in technical phase of AO I study. ** Amended by AO I political processes. *** Forecast in AO II Bechtel study

Although some flexibility still exists to avoid or at least defer investment costs beyond implementation of the new specifications, this is not expected to significantly reduce the global costs to the refining industry. Additional measures may further limit the scope of alternatives based on product exchanges and component selection. For example, the octane loss associated with benzene control in gasoline is commonly compensated for by MTBE import rather than refinery investment. Any ban on MTBE (see relevant article page 22) would require a fundamental reassessment of the benzene control options in many refineries. Market imbalances caused by the new limits may trigger large differential costs in the early years after their introduction and therefore have a comparatively large effect on the NPV. This may be the case for gas oils. Demand for heating oil (the traditional sink for lesser quality components) is steadily declining under, amongst other things, the pressure to reduce CO₂ emissions. At the same time demand for diesel is growing.

AUTO/OIL II

The consultant chosen by the Commission for Auto/Oil II (AO II) refinery cost evaluations is Bechtel Ltd. The fuels matrix and the costs are set out in a final report on conventional fuels dated December 1999.

The AO II study is based on the Commission's pre-Kyoto scenario which shows gasoline growth nearly as strong as diesel with modest overall growth in transport fuels offsetting a modest and steady decline in heating fuels. CONCAWE, on the other hand, expects that the growth in road fuels will be predominantly diesel unless the countries that currently weight much more tax onto gasoline than diesel change policies.

AO II fuels packages and cost effects (excludes combined gasoline and diesel cases)											
Gasoline		MS1	MQ1	MS2	MQ2	MS3	MQ3	MS4	MQ4		
E150	%v	77	88	79	90	77	88	79	90		
Oxygen	%m	2.7	0.6	2.7	0.6	2.7	1.1	2.7	0.6		
Olefins	%v	18	11.5	18	11.5	18	11.5	14	10		
Capital cost	G\$		2.0		3.7		0.7		4.6		
Annual cost*	G\$/a		0.16		0.35		0.40		0.46		
NPV**	G\$		3.6		7.2		4.6		9.1		
Global CO ₂	Mt/a		1.1***		1.4***		1.9*		1.2*		
Diesel		DS1	DQ1	DS2	DQ2	DS3	DQ3	DS4	DQ4	DS5	DQ5
Density	kg/m ³	840	830	840	830	830	825	840	830	840	830
PAH	%m	11	5.1	6	3.0	6	2.8	6	3.0	6	3.0
Cetane		51	53	51	53	51	53	53	55	51	53
T95	°C	360	352	360	355	360	351	360	353	345	335
Capital cost	G\$		2.2		4.5		6.7		4.5		5.6
Annual cost*	G\$/a		0.2		0.25		0.46		0.22		0.56
NPV**	G\$		4.2		6.9		11.1		6.7		11.1
Global CO ₂	Mt/a		2.6*		N/A		6.7*		4.4*		7.4*

MS and DS are the gasoline and diesel specification cases respectively. MQ and DQ are the anticipated average qualities in the Bechtel study.

*Arabian Light US\$20/barrel FOB price basis. Global CO₂ calculated by CONCAWE. **Calculated as per AO I using: capital cost + 9.75 x annual cost. ***Calculated from Bechtel figures. N/A: Not Available. CONCAWE cannot accurately model PAH, and global CO₂ is not calculable from Bechtel figures.

The results of the Bechtel study in terms of refinery costs are presented in the table on page 12. The NPV calculation methodology is the same as in AO I. CONCAWE estimates of the associated **global** CO₂ emissions changes (by global is meant integrating all effects from refineries, hydrogen and other components, e.g. MTBE, production and petroleum fuels usage) are also included in the table.

The gasoline cases use additions of various combinations of isomerization, alklylation and TAME processing. The diesel cases require major configuration changes adding hydrocrackers as well as hydrodearomatization processes and additions to the associated hydrogen production and sulphur recovery infrastructures.

For inland heating gas oil and fuel oil, the Commission is now advising a 'Kyoto -6 per cent' scenario that shows significant and early reductions in consumption of these products. Post 2005, when the diesel supply/demand balance is expected to be already under strain following the AO I measures, any diesel density or T95 reductions will seriously widen the structural EU diesel fuel/gas oil supply demand and quality imbalances. In particular, DQ3, DQ4 and DQ5 involve diesel production shortfalls or/and capital expenditure on projects that not all EU refining companies may be prepared to withstand. Supplies of such fuels would be less reliable than the market is accustomed to. The implications of such occurrences will fall into the area of diesel price instability, supply disruption and possibly shortfalls. The consequences would be likely to ripple through various countries with different intensities. The disturbances to economies and lifestyles are not the sorts of things that can be calculated beforehand.

The air quality implications of these potential AO II conventional fuels measures are being quantified, but are expected to be so small that they would not even be discernible in the emissions projections illustrated in the next article. In engineering planning circles, there is a well-regarded offshoot of Murphy's Law, known as the Law of Unintended Consequences, that lurks within complex, difficult to define systems. It is generally considered wise to ensure the benefits of proceeding with a serious change are really well worth having before 'bungee jumping' into the unknown. When the conditions cannot all be calculated, it becomes vital to ensure that a good strong safety net is present in case the elastic snaps.



Could this start happening here?

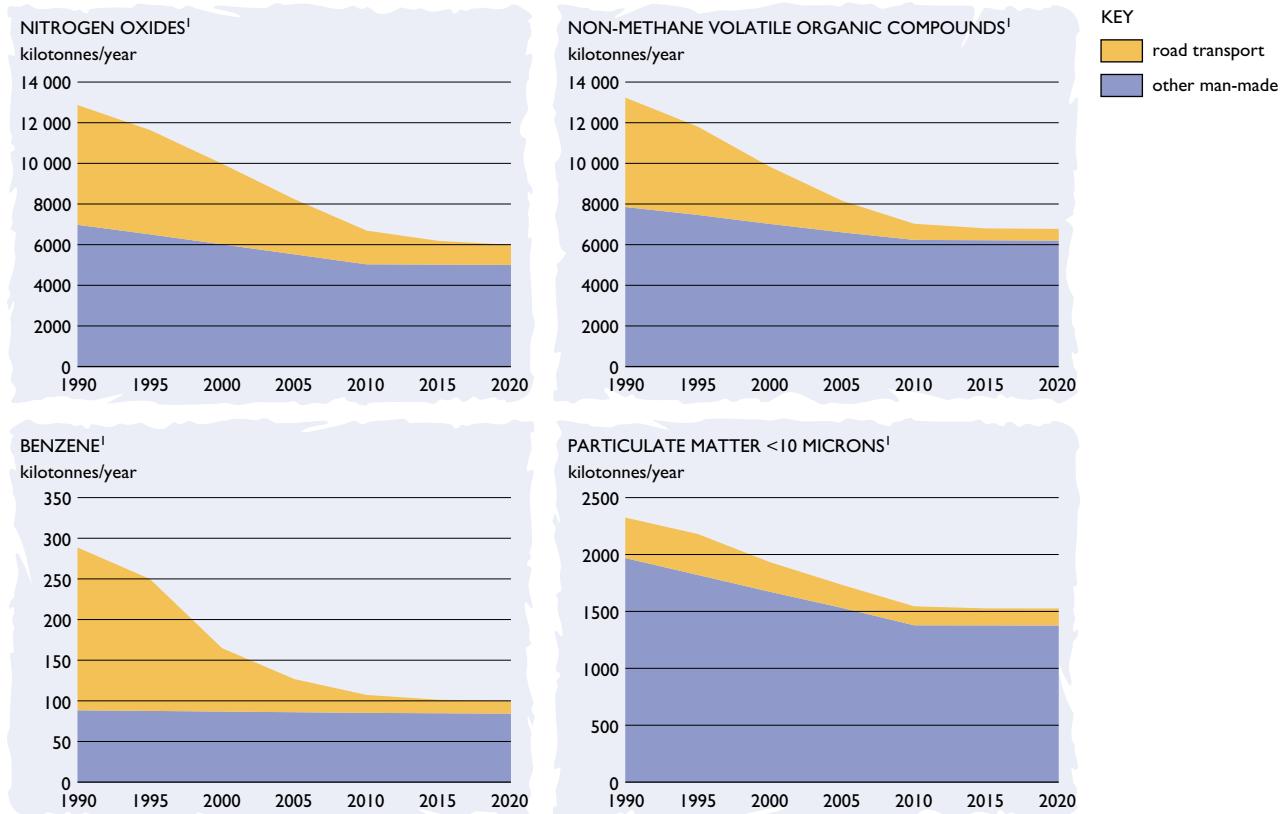
European air quality: changing priorities?

Some insights from the second European Auto/Oil Programme.

The second European Auto/Oil Programme (AO II) mentioned in the preceding articles has involved the European Commission, together with Member States, industry¹ and the NGO community, over the past three years. A major goal of this programme has been to assess the impact of already mandated emission control measures on air quality in the European Union. Where air quality targets are predicted not to be attained, the programme has also been designed to assess the efficacy of further transport fuel/local measures in making progress towards the target. As the technical phase of the programme draws to a close, what key policy-related messages are emerging? What important conclusions can be drawn in determining priorities as the Commission launches its follow-up initiative of **Cleaner Air For Europe (CAFE)**? In this brief article we shall seek to answer these questions.

To begin we need to look at the anticipated trends in emissions. Figure 1 shows those for NO_x, VOCs, benzene and PM₁₀ as developed by the Commission's consultant.² NO_x is the key target for NO₂ attainment and, together with VOCs, a key target for the attainment of ozone. Benzene and PM₁₀ emissions are key targets for attaining the air quality objectives for these high concern pollutants.

Figure 1
EU-15 emissions
projections for NO_x,
VOCs, benzene and
PM₁₀.



¹ The auto and oil industry sectors

² SENCO (Sustainable Environmental Consultants) and DRI (Data Resources Inc.)

Correspondingly there are significant improvements in air quality for NO₂, VOCs, benzene and PM particularly between 1995 and 2010.

The trends are based on an assessment of the impact of already mandated control measures and account for the significant anticipated growth in transport over the period. The figures clearly illustrate why, over the past decade, there has been such a strong focus within the European Union on introducing road transport related measures as a means of improving air quality. They also clearly illustrate the efficacy of such a focus in dramatically reducing emissions from the road transport sector. The impact of this on air quality in our cities can be seen from the work undertaken by the European Environment Agency (EEA) in parallel to the Commission's programme. This 'top down' assessment³ of the impact on 2010 urban air quality in some two hundred cities utilized the same detailed emission trends that underpin those given above. However, in this case individual sector/individual country level data for 1995 were used to properly account for national trends and the composition of emission inventories in each of the cities. For reasons of space we have only been able to include results for NO₂, benzene and PM₁₀.

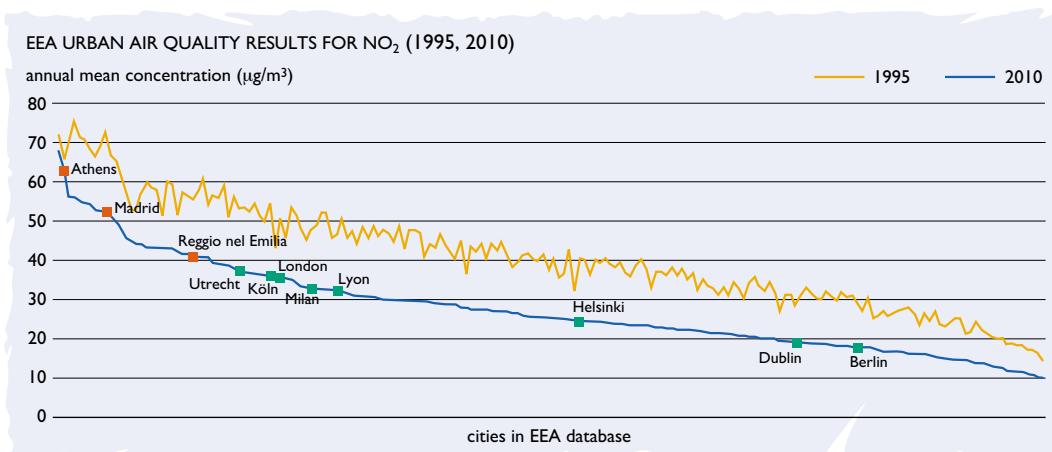


Figure 2
Auto/Oil II: plots of
EEA urban air quality
results, 1995/2010,
for NO₂

For NO₂ the annual mean air quality target set in the air Quality Daughter Directive is 40 µg/m³. This is recognized to be more difficult to achieve than the one-hour standard set in the same Directive. The EEA's assessment shows that already agreed measures will deliver the annual mean target in most cities by 2010. This is confirmed by the more detailed, but limited, individual city modelling carried out by the Commission.⁴ In the Commission's view, the strategy for delivering the NO₂ target in the residual 'non-attainment' cities is likely to be best achieved through local targeted measures.

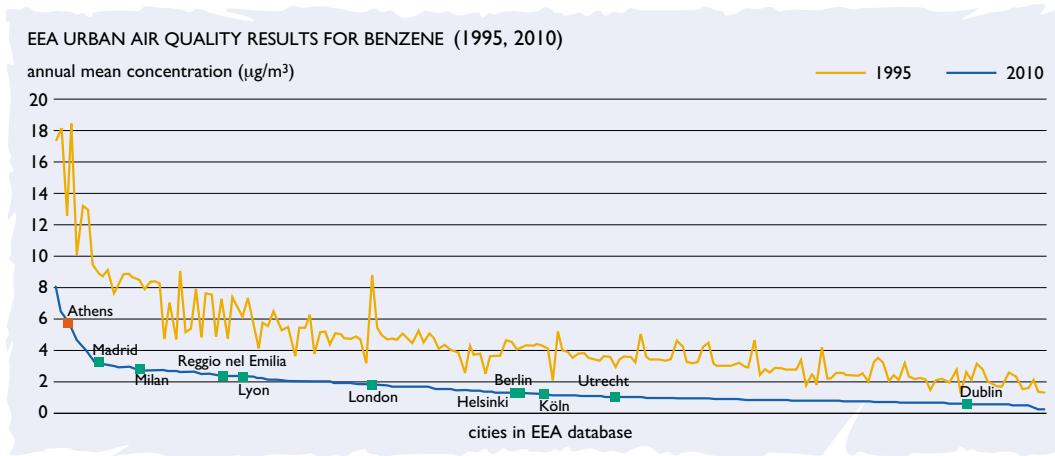
Since, in the case of benzene, long-term exposure is the concern, only an annual mean target is proposed by the Daughter Directive. As this draft Directive moves toward adoption, it appears that a target of 5 µg/m³ will be mandated. The EEA's analysis together with the individual city analysis shows almost all cities will be brought into compliance with this target. Here, again, it is the Commission's view that further measures to achieve compliance in the few remaining 'non-attainment' cities is likely to be best achieved through local targeted measures.

In the case of PM₁₀ it is also recognized that the annual mean target of 20 µg/m³ is tougher than the 24-hour mean target set forth in the Daughter Directive. Both the EEA analysis and the

³ EEA 'top down' analysis using their c-Q model

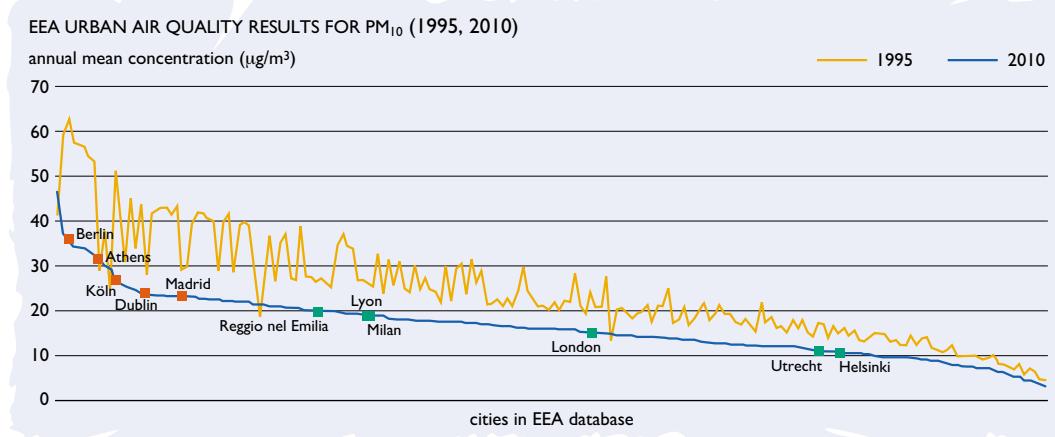
⁴ Joint Research Centre of the European Commission, Ispra

Figure 3
Auto/Oil II: plots of
EEA urban air quality
results, 1995/2010,
for benzene



limited detailed city modelling confirm that a significant number of cities will not attain compliance with the annual mean target with already mandated control measures. In looking at the possible options for further measures aimed at moving towards a greater level of compliance, the emission trends given above provide a crucial perspective. While road transport related emissions are set to fall significantly, these reductions are not matched by any of the other major sectors. Indeed, by 2010, transport exhaust emissions are anticipated to make up only some 5–7 per cent of the total primary PM₁₀ emissions. If secondary PM₁₀ are included, this drops to less than 4 per cent! Given that PM₁₀ is increasingly recognized as a long-range transportable pollutant, the need to address the non-road transport sector as ‘the new priority’ in future programmes like CAFE is obvious from this emission trend.

Figure 4
Auto/Oil II: plots of
EEA urban air quality
results, 1995/2010,
for PM₁₀



If it be said that, in the future, the focus will move to PM_{2.5} rather than PM₁₀, then again the emissions trend shown above suggests an urgent need for the research community to fill the enormous gap in understanding on the contribution of non-transport sectors to such emissions. Much research is under way to characterize the nature of road transport particulates; corresponding work on other sectors is conspicuous by its absence. If science is to inform wise policy, such gaps must surely be addressed urgently.

Finally a brief word about ozone. Whatever the outcome of the target-setting process for a new ozone target, it is again clear from the emission trends for NO_x and VOCs that, in a ‘beyond 2010’ Europe, road transport will have become a significantly reduced contributor. This too provides an important perspective for the setting of policy priorities for CAFE.

Personal exposure to air pollutants

There is increased complexity of personal exposures when compared with exposures to ambient outdoor air concentrations alone.



The air quality limit values which the European Commission has been working on for the last couple of years apply to ambient air. In this sense, 'ambient air' is defined as outdoor air in the troposphere, excluding workplaces. The purpose of the air quality limit values is to help attain a high level of protection of human health and the environment in the European Community. The averaging time for the air quality measurements varies with the pollutant, depending on the targeted health effect, and is typically 1 hour, 24 hours or the calendar year. Health effects, however, are caused by pollutants in air that people actually breathe. CONCAWE has long argued that knowledge of personal exposures to airborne pollutants is essential to understand the associations of health effects and ambient air quality. Personal exposures are the result of all polluting sources of breathing air, of which ambient air is only one. Internationally, researchers have started to act on this acknowledged shortcoming in the epidemiological database. Several studies have now been published on this subject, with more likely to follow, especially in the USA but also in Europe. Some of these studies are looking at subgroups of the population, such as young children, or elderly people living at retirement homes, both considered to be particularly sensitive to some of the air pollutants.

The picture emerging from the exposure studies is that of increased complexity when compared with the concentration patterns of regulated ambient air pollutants. In many cases the personal exposures are higher and much more variable than the corresponding ambient air measurement

results. A variety of factors can be responsible for that. Climatic conditions contribute because they determine the general standard of housing, especially the degree to which ambient air is allowed to penetrate. Personal preferences contribute, e.g. the degree to which a house is ventilated. Pollutant characteristics contribute, such as for ozone which, due to its high reactivity, decays rapidly in the indoor environment. Social factors contribute, especially being exposed to environmental tobacco smoke which has been estimated to contribute 3.5 µg/m³ to a person's daily exposure to benzene (Commission proposal for ambient air: 5 µg/m³) and 20–30 µg/m³ for particulate matter (Council directive: 40 µg/m³ as an annual limit value).

People's time spent in traffic and public transport are significant for PM exposures. Also for PM, a so-called personal cloud has been detected which has not yet been fully explained, although it is now thought to be caused at least in part by clothing. Use of consumer products may contribute to exposure to volatile compounds. Wood fires and barbecues are other, potentially significant, sources of personal exposures to toxic air pollutants.

Several exposure studies have been conducted recently in Europe, with the support of the European Commission. Personal exposure to benzene was studied in the project Monitoring of Atmospheric Concentrations of Benzene in European Towns and Homes or MACBETH. Cities involved were Copenhagen, Antwerp, Rouen, Padova, Murcia and Athens. Ambient levels of benzene, as well as personal exposures were generally found to increase from north to south. Personal exposures of study participants, as well as indoor levels, were higher than outdoor levels in four of the cities, pointing to contributing sources in the indoor environment.

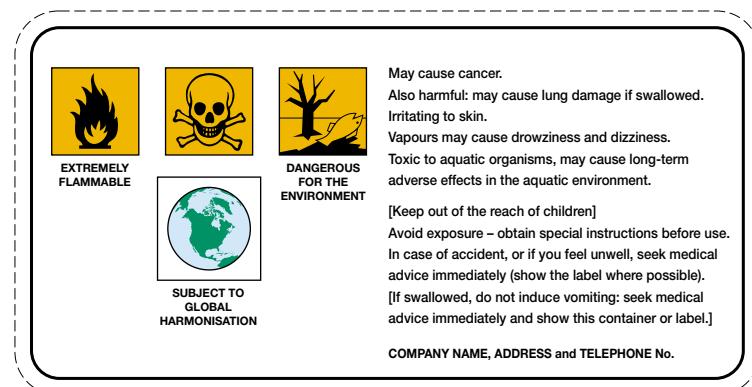
A similar exposure study was conducted under the name of EXPOLIS, for adult urban populations. The cities included Helsinki, Basel, Prague, Grenoble, Milan and Athens. Personal exposures to fine particulates, carbon monoxide and 30 volatile organic compounds including benzene were assessed, in combination with stationary measurements of outdoor air for the same pollutants. Again the personal exposures to benzene were higher than the concentrations in outdoor air, this time in all cities, indicating the contribution from personal or indoor sources. A similar geographic spread of personal exposures to fine particulate matter was found, with indications of contributions from non-outdoor sources. EXPOLIS researchers also looked at time-activity patterns of European adult population. On average, people were found to spend more than 20 hours per day in indoor situations (home, work, commute).

The general picture that emerges from these studies, and similar studies conducted elsewhere in the world, is that of increased complexity of personal exposures when compared with ambient concentrations. This is not surprising in view of the many sources and factors that may contribute to, or modify, personal exposures. It confirms the notion that benefits from improvement of outdoor air quality should not be assessed in isolation from people's real exposures. Any claims made about proportional health benefits from reduction of pollutants in ambient air simply cannot tell the whole story. The costs of implementing stringent air quality limit values should be balanced against their predicted real benefits.

Global harmonized system of hazard communication for chemicals

Non-harmonized classification and labelling lists can be a nightmare when products are traded 'out of region'.

Classification and Hazard Communication (labels and safety data sheets) for hazardous chemicals including some oil products are currently driven by national legislation for supply, and by UN harmonized agreements for international transport. Moves are under way towards a global harmonized system (GHS) for both, although probably not fast enough for the globalization of many supply arrangements. Agreement could bring cost savings for industry and enhanced protection for workers and consumers, if the established systems in the major trading blocks, particularly the USA and Europe, can be brought together and a harmonized framework established. Much of the debate, hitherto, has been technical discussion of classifications, but the critical phase concerning hazard communication is now under way. A group of representatives from twelve nations, together with four industry representatives and four worker representatives, under the chairmanship of Ireland, is currently attempting to shape the future direction of chemical hazard communication.



The process stems from one of the commitments under the Agenda 21 (for the 21st century) section of the 1992 UN Conference on Environment and Development held in Rio de Janeiro. The process has been divided into two stages. The first, under the direction of the OECD, has been concerned with the harmonization of hazard classification. This process is almost complete for substances but continues for mixtures. The second stage, under the ILO, started more recently and is concerned with the labelling and hazard communication.

The GHS proposal was to be ready by 2000, although it is clear that this will not be met. The GHS will not be binding, but may become the de facto (minimum) standard. It should be of help to those many countries that have no system at present, and do not have the resources to develop one of their own. In contrast, systems in a number of countries such as Europe, the USA, Canada, and Australia are well developed, but different. In addition, a system for the classification of dangerous goods for international carriage has developed over the past 30 years or so. (For gasoline, the designation UN1203, Hazard Class 3 may be familiar to many.) This system is updated and developed through the UN Committee of Experts on the Transport of Dangerous Goods (UNCETDG) and cascaded through the various international and regional

committees for road, rail, sea and air transport, such as the International Maritime Organization (IMO) and International Civil Aviation Organization (ICAO) on a two-yearly cycle.

Given the existence of the UNCETDG, and the wish by the UN and member nations for no increase in resources, it is proposed that the future operation of the GHS be managed through a reorganized UNCETDG. This will continue to operate under the UN Economic and Social Committee (UN ECOSOC) of which IPIECA is the oil industry corresponding member. For the present, CONCAWE will represent IPIECA at UNCETDG and follow developments.

The aim of the GHS is to harmonize the classification and hazard communication for both transport and supply, indeed throughout the supply chain. Clearly this is neither a simple, nor a quick task, particularly given the resources currently employed.

Correct classification of materials (substances and preparations) is the foundation of any system, and much time has been devoted to establishing criteria for hazards and their severity. This process has been carried out by separate OECD expert working groups, with industry represented by BIAC (Business and Industry Advisory Committee to the OECD). BIAC ensured that it could represent industry's views by holding separate meetings of industry experts to comment on and critique OECD proposals. The European oil industry was represented by CONCAWE. In this way, industry has been a part of the GHS process. The intent of this process has been to develop an internally harmonized system without compromising the safe working practices of any existing system.

The process is in three stages. Stage 1 is to establish what systems currently exist and what they consist of. Stage 2 is to identify areas of similarity and difference, and areas for improvement. Stage 3 is to make proposals for a harmonized system.

Good progress has been made in harmonizing health hazard criteria for substances. For example OECD has agreed harmonized criteria for acute toxicity, skin sensitization, genotoxicity, cancer and reproductive effects, and those for organ toxicity are expected to be agreed within the next few months. Environmental hazard criteria are yet to be agreed. The process with mixtures started only 18 months ago and is already at Stage 2, with proposals for harmonized criteria for classifying mixtures currently being discussed in BIAC and at OECD level. It is anticipated that this process will be completed towards the end of 2000. OECD currently has agreed on the use of cut-off concentrations in mixtures and is currently struggling with issues such as how to classify mixtures that contain untested components and what cut-off concentrations should be used for different hazard classes.

The process for hazard communication is currently at Stage 2, and the major area of discussion is the hazard label. Supply hazard labels, in Europe at least, have evolved into a complicated combination of hazard symbols (flame, skull and crossbones, St Andrews cross, etc.), indications of danger (flammable, toxic etc), and risk and safety phrases, based on the assessed hazards. Comprehensibility studies both in Europe and the USA indicate most of the detail is incomprehensible. Transport labelling is much simpler and better understood by those who need it, for example the emergency services after an incident, but mainly because of training and a clear communication escalation process. Their process relies on a four-stage ladder:

- the primary hazard warning label and any coded information;
- the product code as defined by the UN number (e.g. UN1223 for kerosine) which can be checked in a look-up list advising an appropriate response (e.g. IMDG guide for marine transport);
- the safety data sheet; and
- experts at the product manufacturers or suppliers or equivalent.

Despite similar elements, a parallel scheme is not even being considered for supply, where labelling has been driven by a wish to summarize all the hazards, indicate precautionary measures and, in the case of the USA, avoid litigation. Little thought has been given to whether such information is comprehensible, and more importantly, acted upon in an appropriate manner. Given the propensity of most people to equate hazard with risk, the current approach helps no-one, except perhaps the lawyer. The group has acknowledged the need to consider risk as opposed to hazard in labelling, particularly for end consumers where the use is well determined, but the current habit is proving hard to cure. The very fact that the work is on hazard communication and not risk communication, and that it was decided to delay the work until after work on hazard classification was almost complete, is a strong indication of the direction anticipated.

European Chemical Industry representatives have put forward a proposal that hazard labels should avoid the use of words and rely entirely on symbols both for hazard indication and for precautionary measures. This is based on a desire to avoid multiple or wrong language labels, which are even more incomprehensible, or those which cannot be read.

The question of a global harmonized list along the lines of that established for transport has not even been considered, yet would provide a powerful means of harmonizing classifications and labelling. Non-harmonized lists, particularly between the US Toxic Substances Control Act (TSCA) and European Inventory of Existing Chemical Substances (EINECS) lists, are of concern for companies selling globally, and can be a nightmare when products are traded on beyond the area for which they were intended.

This work may not be seen as a high priority by many at present, but decisions made now may affect how our products are dealt with for many years into the future. Representation at the relevant UN bodies such as the revamped UNCETDG or its GHS subcommittee will help steer things in future, but the direction is being set now. Is this a topic we should be taking more seriously, or can we live with the consequences? Chemical hazard labelling may seem a somewhat arcane subject for the oil industry, but all our products are seen as chemicals by legislators. Eventually the public will see them in that light too, and if hazard labelling is seen as indicating risk, the oil industry could be fighting on an unnecessary front.

MTBE in gasoline

MTBE faces a ban in the USA—can its use in Europe still be justified?

The abbreviation MTBE refers to methyl tertiary butyl ether—a volatile, water-soluble, oxygen-containing, colourless liquid with an ethereal odour. In Europe, it is used mainly to boost octane rating, especially in unleaded and lead-replacement grades. It is being used in increasing amounts to compensate for octane rating lost with the reduction of benzene, aromatics and olefin contents of gasoline and the phase-out of leaded gasoline which are required by new EU fuels legislation.

MTBE is one of a number of oxygenated compounds (including other ethers and alcohols) which can be used in gasoline. EU Directive 98/70/EC permits gasoline to contain up to 15% v/v MTBE. In fact, although the use of MTBE is widespread, the concentrations used in Europe are nearly always much lower than this, on average approximately 2–3% v/v.

Although MTBE has been used in gasoline for some years, its use was first publicized widely when reformulated gasoline, designed to reduce carbon monoxide (CO) emissions, was mandated over large areas of the USA. Subsequently, MTBE has been found in drinking water supplies and in groundwater wells. This, together with the contamination of Lake Tahoe (also a drinking water resource) by watercraft using 2-stroke fuel, led the Governor of California to announce a year ago a phase out of the use of MTBE by end 2002. The concerns over the use of MTBE have been largely supported by a Blue Ribbon Panel set up by the US EPA who, on 20 March, took the first steps towards restricting its use. It is expected that these decisions will prompt public debate in Europe over the use of MTBE in gasoline, and CONCAWE member companies will participate constructively in dialogue with interested parties in order to determine the best way forward.

Extensive studies have been carried out to determine the health effects of MTBE. Reviews of these studies include a CONCAWE report (no. 97/54) which concludes that ‘MTBE has a low order of acute toxicity, and is not teratogenic, mutagenic, neurotoxic, nor a reproductive toxicant.’ Subsequently, the International Agency for Research on Cancer (IARC) has reviewed the carcinogenicity data on MTBE and concluded that there was a lack of evidence to justify any classification as a human carcinogen.¹

Concerns about water supplies arise because the odour and taste thresholds of MTBE are low. In December 1997, the US EPA Office of Water released the document *Drinking Water Advisory: Consumer Acceptability Advice and Health Effects Analysis on MTBE*, which recommends that MTBE concentrations less than 20 to 40 microgrammes per litre ($\mu\text{g/l}$ or ppb) would not normally give rise to unpleasant taste and odour effects for a large majority of people. It also concludes that there is little likelihood that these MTBE concentrations would cause adverse health effects because they are tens of thousands of times lower than the range of exposure levels that caused observable health effects in animals.

The most common ways that MTBE enters the environment are by accidental releases of gasoline containing MTBE and use of gasoline two-stroke-powered watercraft. Spills can occur at all

¹ Carcinogenicity data include disputed cancer claims based on non-standard animal tests and partly published work.

stages of the manufacturing/distribution system but leaks from underground storage tanks at retail sites, storage tanks and operations at distribution depots, and product pipelines give rise to the most concern. Two-stroke engines emit unburned fuel from their exhausts, which in the case of watercraft results in MTBE dissolving in the water.

In the case of filling stations, standards for storage tanks, site design, and leak monitoring continue to improve, with many sites rebuilt in recent years. Double-skinned tanks, leak detection, leak-proof pavements and reconciliation of volumes are being used to improve containment and monitor for leaks. Nevertheless, the volumes of MTBE that could give rise to problems are very small—perhaps a single overfill—and total containment is unlikely to be achievable without radical redesign.

MTBE is much more soluble in water (43 g/l) than gasoline hydrocarbons (e.g. benzene at 1.8 g/l is one of the most soluble); biodegrades only slowly (and perhaps not at all in the absence of air); and is only weakly adsorbed on soil particles. MTBE therefore tends to persist in groundwater, to travel further and faster through the ground than hydrocarbons and is likely to be present in higher concentrations. The properties of MTBE also make it more difficult to treat if it contaminates soil or water. The difference is mainly one of degree—contamination has been remediated using similar techniques to those used in normal gasoline clean-up, but it is more costly.

Although MTBE is resistant to biodegradation, it does slowly degrade given sufficient air, nutrients and suitable bacteria. If necessary, naturally-isolated bacteria can be grown in the laboratory and introduced to the contaminated site or used in a biotreater. Given the appropriate conditions, MTBE can be degraded. Biodegradation in the absence of air has not been confirmed, although in an eight-year experiment 90 per cent disappeared. Many authorities now accept natural remediation of spills and leaks of gasoline containing the aromatics benzene, toluene, ethylbenzene and xylene (BTEX) as appropriate, but not in the case of MTBE.

As MTBE is volatile, some will evaporate into the atmosphere during distribution and use. Small amounts are also emitted from four-stroke vehicle exhausts. Any MTBE emitted degrades in the air, so concentrations in the atmosphere remain low. But, because of its solubility in water, some MTBE will be washed out by rain and enter surface and shallow ground waters. As a result, MTBE can often be detected in shallow ground waters at concentrations of less than 1 µg/l.

To sum up, MTBE in gasoline can pose problems, but given its low toxicity it does not pose a direct health threat. It will be found at low concentrations in many environmental compartments, but will not accumulate if sufficient air is available. Where higher levels exist from accidental spills, methods are available to treat them. The question is whether the benefits of continuing to use MTBE in gasoline outweigh the odour and taste effects on water resources, or whether a phase out, as seems likely in the USA, is justified. The oil industry cannot answer these questions alone, not least because no short-term alternative appears to be acceptable to all parties. A constructive dialogue is therefore required between the key parties concerned in order to determine the best way forward.

CONCAWE news

MAILING OF CONCAWE DOCUMENTATION

The last issue of the CONCAWE *Review* included a questionnaire on readership and we should like to thank all those who responded. As a result of this survey, we have carried out a fairly drastic pruning of our *Review* mailing list. We hope that we have not removed the name of anyone who would still wish to be on the distribution list, but who somehow omitted to return the questionnaire. For this reason, and given the current level of reorganization in our industry, it will help us if recipients of the *Review* would check with colleagues who may benefit from receiving it, and ask them to contact us with their details, if required (CONCAWE's e-mail and fax details may be found overleaf).

We are also increasingly issuing CONCAWE questionnaires by e-mail, and continuing to add new CONCAWE reports to the CONCAWE Internet website at www.concawe.be, building up the inventory of reports that can be downloaded.

These measures are helping us to make significant cost savings and to reduce the volume of paper that we produce and send out by courier/'snail' mail. We trust that this is also to the benefit of those interacting with us, and that everyone continues to receive our information where it is needed.

SECRETARIAT

We are pleased to welcome Jean-François Larivé who joins the Secretariat on 2 May as Technical Coordinator for publications and refining planning. Our thanks go to Denis Lyons, for stepping into this position at short notice following the untimely death of Kees van Leeuwen in November last year.

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CONCAWE PUBLICATIONS, 1999 TO DATE

General circulation (yellow cover) reports:

- 1/99 European downstream oil industry safety performance—statistical summary of reported incidents—1998
- 2/99 Environmental exposure to benzene
- 3/99 Performance of cross-country oil pipelines in western Europe—statistical summary of reported spillages 1998
- 4/99* Motor vehicle emission regulations and fuel specifications—part I summary and annual 1998/99 update

Special interest (white cover) reports

- 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 (I): occupational hygiene
- 99/59* A test method to assess the 'inherent' biodegradability of oil products
- 99/60 The health effects of PM_{2.5} (including ultrafine particles)
- 99/61 The European Union legislative process
- 99/62 Potential of exhaust after treatment and engine technologies to meet future emissions limits
- 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

Product dossiers

- 99/110 Petroleum waxes and related products

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.

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CONCAWE
Madouplein 1
B-1210 Brussel
Belgium

Telephone: 32-2-220 3111

Telefax: 32-2-219 4646

E-mail: info@concawe.be

World Wide Web: <http://www.concawe.be>



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