concawe review

Volume 21, Number 2, Autumn 2012

The oil companies' European association for environment, health and safety in refining and distribution

Cover photograph courtesy of ©2012 Shutterstock.com

Editor: Ken Rose, CONCAWE

Design and production: Words and Publications • words@words.co.uk

Foreword

Michael Lane
Secretary General
CONCAWE

Welcome to the latest edition of the CONCAWE *Review*. As CONCAWE begins its 50th anniversary year in 2013, we continue to focus on high quality, scientifically objective research that is of value to our industry and to regulatory institutions. In this issue of the *Review*, we summarize some of this work which is of special importance.

The third phase of the European Emissions Trading Scheme (ETS) will come into force in 2013. To prepare for this, CONCAWE, collaborating with Solomon Associates, developed the CO_2 benchmarking scheme that has been adopted by the European Parliament. This scheme, first explained in CONCAWE *Review* Vol. 18, No. 2, is now the legal basis by which CO_2 allowances will be allocated to European refineries starting in 2013. Since that time, we have worked with the European Commission to clarify some key aspects of the methodology, which are explained in this article. These clarifications should make the scheme fairer and easier to operate when it comes into force.

Improvements in health care and environmental conditions, including air quality, have significantly improved the life expectancy of European citizens over the past 50 years. Air quality throughout most of Europe has improved considerably and the refining industry has made significant contributions to this improvement, mainly by improving the quality of transport fuels and by reducing refinery emissions. In order to ensure that future improvements in air quality are targeted at those steps that will produce the biggest benefits at the lowest cost to society, a sound basis is needed to evaluate future proposals for improving air quality. The second article in this *Review* describes some of the problems that are encountered with today's cost-benefit analysis (CBA) approaches and proposes some ways in which these can be improved.

Another factor that is often used by regulators to evaluate costly options for mitigating air pollution is the monetary value associated with an estimated reduction in human mortality risk due to air quality improvements. This factor is called the 'Value of a Life Year' (VOLY) and was explained in CONCAWE *Review* Vol. 15, No. 2. Although VOLY is a reasonable metric for this purpose, the way in which VOLY is calculated is fraught with difficulties and can easily be misinterpreted. The next article in this *Review* clarifies, through the use of statistical methods, some better ways to estimate such an important value for assessing the human health impact of environmental improvement options.

The cancer causing effects of the chemical benzene have been known and extensively studied for many years. This work has led to a substantial reduction in benzene exposures, for both petroleum industry workers and consumers. Our industry continues to study benzene to ensure that the potential health effects are fully understood, even at the very low exposure levels now encountered. To this end, CONCAWE has sponsored a major reanalysis of recent studies, resulting in a new benzene 'pooled' analysis. By 'pooling' and assessing the results from three smaller studies, conclusions can be drawn that were not possible when looking at each study individually. The results and conclusions of this new benzene study are summarized in this *Review* which will also help focus future work into the health effects of benzene.

We close this *Review* with an interview of CONCAWE's first ever Research Associate. In 2010, CONCAWE decided to complement its Secretariat staff with early career stage researchers to carry out studies in specific technology areas. Lucia Gonzales joined our air quality team in 2011 and, in this interview, describes her experiences as a CONCAWE Research Associate in Brussels.

Finally, I would like to acknowledge the important contributions of Bohdan Dmytrasz, Technical Coordinator for Petroleum Products, who retired at the end of 2012. After 14 years covering petroleum products and their uses for CONCAWE, Bo became a leading European expert on REACH and made a huge contribution to the successful implementation of REACH by the refining industry. While thanking Bo for his many contributions, I am also pleased to welcome Francisco del Castillo Roman, from CEPSA, who will lead us forward in the next phase of petroleum product stewardship.

I take this opportunity to wish you well for 2013 and hope you welcome this edition of the *Review* as part of your wintertime travel reading!

Contents

In the Autumn of 2009, a CONCAWE *Review* article (Vol. 18 No. 2) described the regulatory background to the development of CO_2 emissions benchmarks for EU industrial sectors, and the development of a specific benchmarking scheme for oil refineries. Three years later, this article revisits this subject and explains the process that led to the successful development and implementation of a CO_2 benchmarking methodology for the EU refining sector, and the subsequent allocation of CO_2 emissions permits to individual refineries under the rules of the EU Emissions Trading Scheme (ETS). A full report (CONCAWE Report 9/12) has also been published and is available on the CONCAWE website (www.concawe.org).

Enquiries to: alan.reid@concawe.org

Cost-benefit analyses (CBA) are often used to estimate the societal costs and benefits of environmental policies. In the air quality area, these analyses are used to evaluate the net societal benefits associated with different investments to reduce air pollution. Three recent CBA studies have been evaluated and shown to have two main deficiencies. First, they adopt an unrealistically high Value of a Life Year (VOLY) and, second, they do not account for important uncertainties in the modeling of air pollution. It is essential that Europe develops more robust CBA methods and information in order to ensure cost-effective investments to reduce air pollution and improve human health.

Enquiries to: pete.roberts@concawe.org

This article looks at how the Value of a Life Year (VOLY) is used in cost-benefit analyses and proposes an alternative approach for selecting a single VOLY from 'willingness to pay' survey assessments. This approach maximises the revenue to society that could be expected if actual financial payments were made to achieve air quality improvements. The resulting societal benefit is significantly less than the mean or median VOLY that is used today in European cost-benefit analyses.

Enquiries to: pete.roberts@concawe.org

Benchmarking CO_2 emissions from European refineries

A Complexity Weighted Tonne (CWT) approach is used to benchmark CO_2 emissions from European refineries.

The regulatory landscape

Under the European Union's Emissions Trading Scheme (ETS) Directive, industrial emitters of greenhouse gases (GHGs) must deliver emission permits or allowances every year that equal their actual GHG emissions for that year. In the first and second trading periods of the ETS Directive, the majority of these allowances were distributed free of charge using historical emissions as the distribution mechanism (so-called 'grandfathering') and with a common GHG reduction percentage.

In the third ETS trading period, starting in 2013, the distribution rule will change to auctioning, that is, emission allowances will be auctioned by governments and sold to the highest bidder. Trading of already-issued allowances on the open market will also be possible. While this auctioning process is relatively simple and provides strong market-related signals, it puts a potentially high and uncertain financial burden on industrial installations operating within the EU. This burden does not apply to equivalent installations operating outside the EU and would result in 'carbon leakage', i.e. where CO_2-emitting industries choose to move out of the EU to parts of the world where GHG emissions are not regulated.

Recognising this concern, sectors that are exposed to international competition, including the oil refining sector, will be granted a portion of their GHG emission allowances free of charge for the third ETS trading period. These free allowances will be granted on the basis of a 'best in class' benchmark developed for each industrial sector.

But, what exactly is a 'best in class' benchmark for the oil refining sector and how can it be determined?

The CO_2 benchmarking challenge

The objective of the ETS Directive is to encourage emission reductions through GHG-reducing investments and best practices. To achieve this, a refinery benchmarking scheme has to be accepted as fair and equitable, it must recognise early adopters, and it must establish differences in GHG emissions from industrial sites that are due strictly to each site's performance. This means that the evaluations driving a benchmarking scheme must assess 'how well things are done', rather than 'what is being done', due to differences in the level and type of activity from site to site.

In the refining sector, oil refineries process crude oil to manufacture a broadly similar range of products, such as petrol, diesel fuels and others. However, no two refineries are the same because of differences in their physical size, the number and types of process units, the range of crude oils that they can process, and the specific grades and volumes of products that they manufacture. Because of these differences, the energy consumption and CO_2 emissions vary from refinery to refinery and these parameters do not readily correlate with simple indicators such as the amount of crude oil processed or the volumes of refined products produced.

As an example, a simple refinery may distil crude oil into its various boiling fractions and perform a minimum level of treating (desulphurisation) and upgrading (octane improvement). The total energy consumption of such a simple refinery per tonne of crude oil will be quite low, perhaps only 3–4% of its total energy intake. Its CO_2 emissions relative to crude oil intake will also be quite low. However, such a simple refinery will not typically be able to produce the quantities and types of products that are demanded by the market.

A complex refinery, on the other hand, performs all of the same operations as the simple refinery and, in addition, converts higher-boiling molecules into lower-boiling ones. In doing so, it will make more of the products that the market demands. This extra versatility is not free, however, and a complex refinery will consume considerably more energy (at least 7–8% of its energy intake) and will have much higher CO_2 emissions per tonne of crude oil processed.

Just because one refinery uses more energy and produces more CO_2 emissions does not mean that the simple refinery is 'good' or 'higher performing' and the complex one is 'bad' or 'poorer performing'. Both types are essential parts of the entire refinery 'system' that is needed to supply Europe's demand for the volumes and types of refined products given the crude oils that are available on the global market. Thus, in order to benchmark different refineries, a common activity parameter must be used that accounts for differences in refinery complexity in a consistent way and allows the CO_2 emissions performance of refineries to be compared based on how efficiently they operate, rather than on how many operations they perform.

The CWT methodology

Working on behalf of the EU refining industry, CONCAWE collaborated with Solomon Associates, a consultant to the oil industry for more than 30 years, to develop a benchmarking scheme for EU refineries based on their 'Complexity-Weighted Tonne' (CWT) concept. A 2009 study completed for the EU Commission by the Ecofys consulting company confirmed that Solomon's CWT approach was an appropriate activity parameter that could be used to develop a refinery benchmarking scheme. With Solomon's support, CONCAWE was able to apply the CWT concept and develop a benchmarking methodology for EU ETS compliance.

The CWT approach was explained in CONCAWE *Review* Vol. 18, No. 2. This article also explained how the methodology was validated against historical refinery data. Although the CWT calculation has not changed since then, important changes were made to the total refinery emissions based on clarifications from the European Commission during the benchmark development process.

For a given refinery and a given time period, the CWT is calculated by first multiplying the throughput of each refinery process unit by a factor that is characteristic of the typical CO_2 emissions for that unit. These products are then summed to give the overall CWT for the refinery. An additional term for 'off-site' operations is added to account for ancillary operations such as blending, storage and others. CWT accounts for all emissions that are related to the energy demand of the process units whether the energy is produced on-site or imported to the refinery in the form of heat or electricity.

After some debate, the Commission decided that the simplest and fairest way to deal with the transfer of heat energy was to allocate its GHG emissions to the consumer of the heat. This means that the actual GHG emissions from a refinery site must be corrected by excluding any emissions that are associated with the production of heat exported from the refinery and including any emissions associated with the production of imported heat.

Because no free allowances may be granted for electricity production under the ETS Directive, a refinery's actual emissions and its CWT must both be corrected. To do this in line with the Commission's guidelines, an 'electricity utilisation factor' (EUF) was defined. The EUF is calculated by first taking the refinery's emissions excluding those from all electricity production and exported heat and including those from imported heat (U). This value is then divided by the same refinery's emissions including any additional emissions from electricity consumption, assuming a standard emission factor (EC). The complete CWT algorithm, including the calculation of the final performance indicator (CO_2 emissions divided by the corrected CWT) is shown in Figure 1.

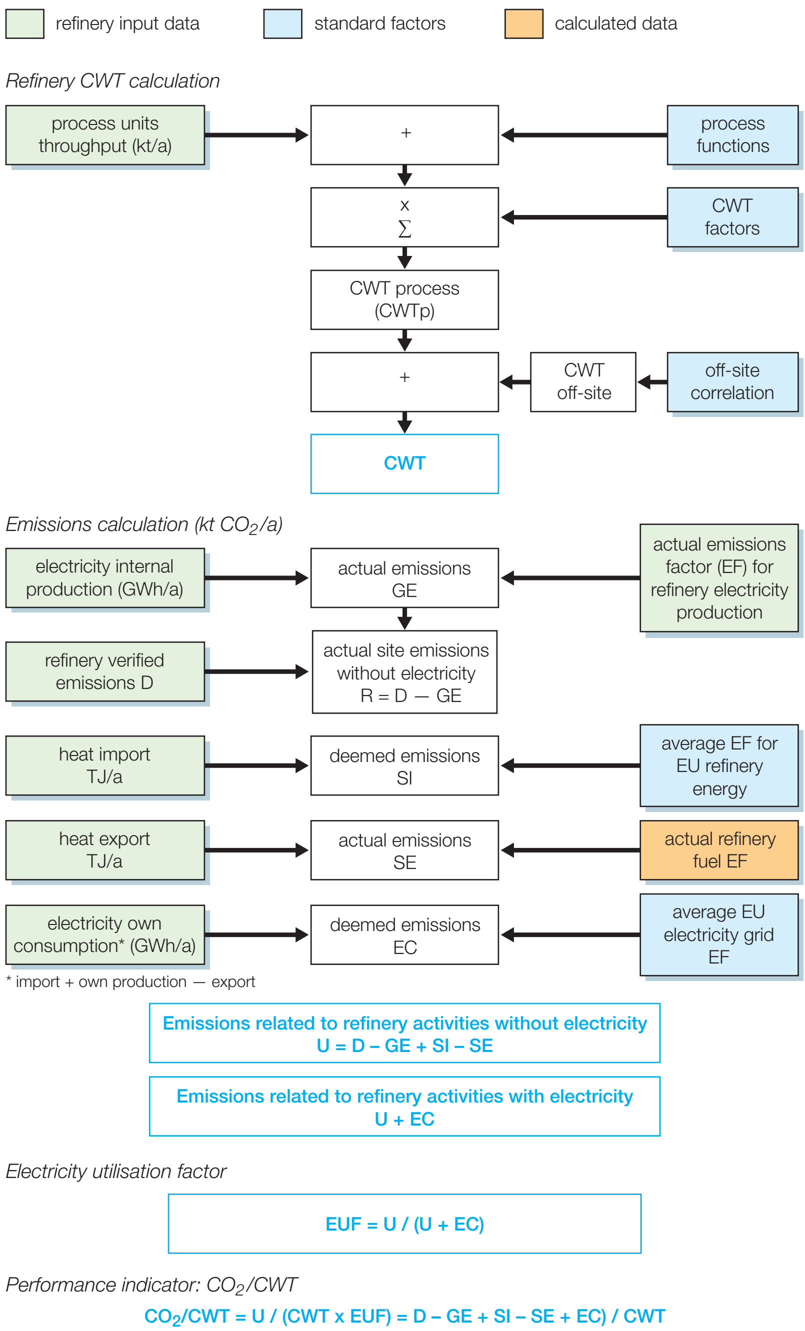
Determining the benchmark

The ETS Directive states that the benchmark must be based on 'the average performance of the 10% most efficient installations in a sector in the Community in the years 2007–2008'. Although this seems clear enough, the EU Commission further clarified that the benchmark must be the arithmetic average of the 10% best (that is, lowest) values of the performance indicator in the entire sector population.

To determine the benchmark, the first task was to collect data from refineries in order to calculate both the CWT and all appropriate emission terms from all refineries. CONCAWE undertook this task for the refining industry and developed a template to facilitate the data collection process. It became apparent that fairly detailed data were needed to ensure consistent reporting, and also fairness and credibility of the benchmarking scheme. Some issues arose with the systematic and consistent 'mapping' of real process units to the simplified CWT process unit functions, and with the consistency of data needed to estimate emissions from internally generated electricity.

The second task was to establish the refinery population. Primarily from information provided to CONCAWE

Figure 1 The complete CWT algorithm



by its members in 2010, 113 sites in the EU and Norway were classified as oil refineries. This number included some smaller sites that performed specialised tasks, such as bitumen and lube oil manufacturing. Applying the CWT methodology to these sites gave somewhat unpredictable results because the CWT database did not include installations of this sort. Including these 'atypical' sites in the benchmark population would distort the benchmarking process and result in unrealistic rankings and GHG allowances for some sites.

Of these 113 refineries, 98 'typical' refineries were identified that processed mainly crude oil to produce at least 40% light refined products, such as gasoline, diesel and heating oil. The other 15 'atypical' refineries were removed from the benchmark population and received their allowances based on their energy consumption over the baseline period using the energy benchmarks defined by the Commission.

Process unit data were collected from European refineries in the second half of 2009. These data were based on earlier years when the need for such detailed and high quality information had not been anticipated, which proved to be a data-reporting challenge for many refineries. In order to keep to the tight deadlines set by the Commission to finalise the refinery benchmark by May 2010, independent verification of data from the 20 best performing refineries was completed, that is, about twice the number of refineries that would set the benchmark. This exercise resulted in only small changes to the data originally submitted by the refineries to CONCAWE.

Figure 2 shows the performance curve for all 98 'typical' refineries, and the benchmark population of the 10% best performers on the left-hand side, yielding a benchmark value of 29.5 kg CO_2/CWT. This benchmark is about 20% lower than the average of 37.0 kg CO_2/CWT from all refineries. Taking into account GHG emissions associated with electricity production which do not qualify for free allowances, it is clear that the refining sector will receive a much smaller fraction of free allowances than would have been expected by the overall ETS objective of a 20% reduction by 2020.

As part of the benchmarking analysis, it was crucial to demonstrate that there was no fundamental bias towards a certain type of refinery and that the benchmark population was reasonably representative of the full range of refineries. No particular relationship between CWT and the performance index CO_2/CWT could be detected. This means that there are good and less good performers in all sizes of refineries, although the worst performing refineries were generally found to be among the smallest and simplest refineries. This was to be expected because these refineries usually have less opportunity for capital investments and efficiency improvements. In addition, the average fuel emission factors were found to be similar in both the total and best performing populations, as was the proportion of own electricity production. Finally there was no indication that the larger and more complex refineries were at a particular disadvantage using the benchmarking methodology, which was confirmed by Solomon in their own analysis of refinery performance parameters.

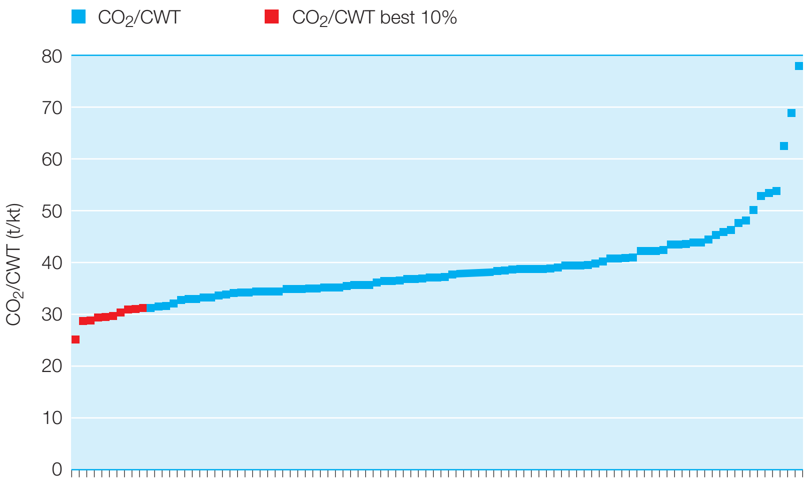
Many process units found in refineries can also be found in the petrochemical or gas production sectors. Such plants should receive a similar benchmarking treatment regardless of where they are operated. For example, a hydrogen plant, supplying a refinery, can be either inside or outside of the refinery perimeter depending on its ownership and historical permit. CONCAWE therefore established contact with other sectors to explore alternatives and arrive at the best solutions, which resulted in the adoption of the same CWT concept for all such process units.

Although 2007–2008 was the reference period for establishing the benchmark, major changes in refinery capacity that occurred after this reference period must also be taken into account. Fortunately, the CWT methodology is a simple and effective solution to this problem because plant capacity changes translate simply into a change of the CWT activity level.

Collecting baseline activity data

The benchmark established the level of performance that would be the basis for granting allowances in the third ETS trading period. The activity level to which this benchmark would be applied for the entire 2013–2020 trading period was to be based on a so-called 'baseline' period, eventually defined by the Commission as the median annual activity from either 2005–2008 or 2009–2010. Significant capacity changes during the period were to be taken into account, for which a specific methodology and significance threshold were developed by the Commission.

Figure 2 Performance curve for all 98 'typical' refineries plus the 10% best performing benchmark refineries



To facilitate reporting, a generic, cross-sectoral template was developed by the Commission and used by most Member States while CONCAWE adapted its original template to include capacity change calculations and provide refineries with a simpler and more effective tool. The generic formula for calculating the preliminary free allocations to each EU refinery is:

$$A = CWT \times EUF \times B$$

where:

- A is the refinery's annual free allocations (in kt CO_2/a);
- CWT is the median of the refinery's annual actual CWT values for the baseline period including adjustments for capacity changes (in kt/a);
- EUF is the refinery's electricity utilisation factor, averaged over the baseline period; and
- B is the EU refining CO_2/CWT benchmark value of 29.5 kg CO_2/CWT.

A further adjustment to free allowances may have to be brought in to allow for the so-called 'cross-sectoral' correction. When sectoral benchmarks have been defined and free allocations calculated for individual installations across the EU, the sum of all free allocations will be compared to the total emissions allowed by the ETS Directive reduction path. This may result in a correction that is uniformly applied to all sectors and all installations.

Cost-benefit analysis and air quality policy

Cost-benefit analysis (CBA) is an important tool for estimating societal costs and benefits.

The place for CBA studies

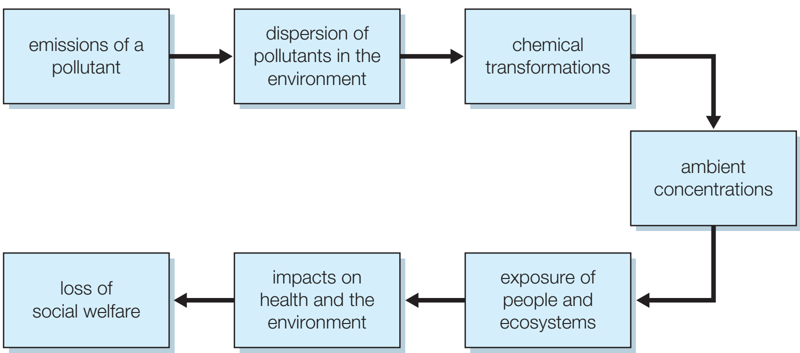
Air quality policy measures implemented in the past decades have successfully reduced national pollutant emissions in all European countries. Not surprisingly, it now becomes more difficult to identify additional measures that will lead to meaningful emission reductions and air quality improvements, and costs associated with such measures tend to escalate. CBA is used to evaluate whether the societal benefits of a particular policy option will exceed its societal costs, but does not explore alternatives to this option. To ensure that policy development is robust, it is important therefore to take a broader view and consider whether money spent to address one societal 'risk' may provide greater societal benefits if used elsewhere.

Although this article focuses on CBA as one of the tools used to compare the societal costs and benefits of air quality policy, this tool is focused, by its very nature, on single issues. It does not lead directly to an assessment of whether better outcomes could be achieved by using the same expenditure to address other societal risks.

Air pollution is a consequence of many types of economic activity, including industrial production, transport, agriculture, energy production, and so on. There is now a long history of developing cleaner production techniques and clean technology options to reduce pollution from these and other sectors. The widespread use of these technologies has led to considerable improvements in European air quality in recent decades.

Nevertheless, ambient air pollution remains a societal concern due to remaining emissions. In some areas, especially within cities where emissions from transport, industries, and other commercial and domestic sources are concentrated, pollutant levels too frequently exceed air quality standards. The pollutants most often associated with adverse health impacts include NO_x, SO_x, ozone and particulate matter (PM). Based on measurement practicalities, PM is most frequently defined by particle size, with the fraction having an aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) considered to be the most harmful to human health. However, $PM_{2.5}$ can originate from many sources and can have different chemical compositions with a varying degree of risk to human health, as was discussed in CONCAWE *Review* Vol. 21, No. 1.

Figure 1 Causal chain for modelling the societal costs of air pollution



Analysing the costs of air pollution

Analysing the societal costs of air pollution involves a number of steps, as shown in Figure 1. First, the way in which emissions are dispersed from their primary sources and subsequently transformed in the atmosphere must be modelled. Every pollutant has specific chemical characteristics and will follow a different pathway as a function of its emission source, prevailing wind conditions, temperature and other pollutants. The exposure of people to these pollutants will depend on individual behaviour, for example the time that a person spends indoors and outdoors, the time spent commuting, and so on. Similarly, the environmental impacts of pollutants will depend on local characteristics. For example, different ecosystems have different capacities to absorb pollutants from the atmosphere.

Next, societal impacts must be understood and quantified. Human health impacts will depend on the exposure to pollution as well as on the health and lifestyle of each person. Environmental impacts will depend on the type of ecosystems involved and how these ecosystems are used by people (often expressed as 'ecosystem services'). Finally, changes in health and environmental quality are usefully expressed in monetary terms in order to assess the societal benefits of various emission reduction measures.

To model the causal chain shown in Figure 1, two steps are particularly important. First, sophisticated models, such as RAINS/GAINS, are used to relate the emission, dispersion, transformation and resulting concentrations of different air pollutants to their health and environmental impacts. In this step, the effectiveness and cost of different emission reduction measures are also evaluated. Second, a monetary evaluation of the health and environmental benefits is carried out by using statistical relationships between the concentrations and effects of air pollutants and by attributing specific costs to each effect. Expressing human health and mortality impacts in terms of an economic cost is controversial because it involves making assumptions about society's willingness to pay for a reduction in mortality risk, a statistical quantity which is not easily explained.

CBA studies on European air pollution

Three CBAs that evaluated European air pollution policies were completed in 2011 by AEA Technology, the European Environment Agency (EEA), and the EU-funded research project EC4MACS (European Consortium for Modelling of Air Pollution and Climate Strategies). It is useful to examine some of the important uncertainties in these studies, especially those related to the analysis of the costs of air pollution, and consequently the benefits from reducing pollution.

The AEA report (AEA, 2011) estimated the net economic benefits of a series of scenarios for pollution control. These scenarios were developed by IIASA in the context of the Gothenburg Protocol to the UNECE Convention on Long Range Transboundary Air Pollution (CIAM, 2011). The EEA report (EEA, 2011) was based on a technical paper prepared by the EEA's Topic Centre on Air Pollution and Climate Change Mitigation. This report assessed the costs to health and the environment resulting from pollutants emitted from European industrial facilities including power plants and other major industrial sites reporting via the European Pollutant Release and Transfer Register (E-PRTR).

Only an interim report was available from the EC4MACS project that presented an outlook of the likely development of air pollutant emissions and their economic costs to 2030 based on forecasts of economic development and the implementation of existing legislation on EU air pollution control measures.

These three assessments, in particular the AEA and EC4MACS reports, acknowledge that a significant reduction in ambient air pollution concentrations has been achieved for almost all air pollutants in the past decades as a consequence of environmental policies and changes in energy use and economic activity. Nevertheless, these assessments also signalled to policy makers that further emission reductions would result in net economic benefits on a societal basis. As analysed below, however, there is a high degree of uncertainty in these CBAs, especially regarding the analysis of the economic costs of air pollution.

Methodology gaps and uncertainties

Recent analyses of the costs of air pollution in Europe are extensions of the Clean Air for Europe (CAFE) methodologies that were developed in the 1990s and are now part of the EC4MACS toolkit. Although there is a statistical association between air pollution and health, such as cardiovascular and respiratory problems, there is still uncertainty on three main issues: (i) the appropriate relationship between ambient air pollution and health effects; (ii) the economic costs of pollution-related health impacts; and (iii) the magnitude and costs of environmental impacts. These points are discussed below.

Ambient air pollution and health effects

Some key assumptions from the CAFE methodology have been incorporated into the recent CBAs. These include: (i) equal health impacts are assumed for all types of PM that originate from human activity while no health impacts are assumed for PM from natural sources, such as sea salt; (ii) there is no threshold level below which PM is not harmful to health; and (iii) there is a 6% increase in human mortality risk for every 10 µg/m^3 increase in long-term $PM_{2.5}$ concentration exposure.

The association between PM concentration and mortality risk and other health impacts is based on statistical analysis (Künzli *et al.*, 2000). One aspect that is generally acknowledged to lead to additional uncertainty is how the age distribution of the exposed population influences health risks. It is also uncertain how the chemical composition of the $PM_{2.5}$ fraction influences health impacts. For example, all particles in the

$PM_{2.5}$ fraction may not be equally harmful to human health (see also CONCAWE *Review* Vol. 21, No. 1). These sources of uncertainties should be reflected in sensitivity analyses of the cost and benefit assessments, and this has not been done in the three CBA studies cited above.

Economic costs of health impacts

In the monetisation of health impacts, the most critical issue is the value of health benefits that are attributed to better air quality. In the CAFE programme, the costs of premature mortality were assessed to be about 70% of the total costs of air pollution in Europe as a result of the monetary value assigned to a Year of Life Lost (YOLL)[1]. It was recognised at the time that the interpretation of health benefits based on avoided mortality (monetised using the Value of a Statistical Life or VSL) was inappropriate but the CAFE CBA included this as an alternative measure.

[1] See CONCAWE *Review* Vol. 21 No.1 for a discussion on YOLL.

Several economic valuation methods have been developed to estimate both VSL and the Value of a Life Year (VOLY) on the basis of price effects observed in the market, for example in the form of additional compensation for professions that experience a relatively high mortality risk. These methods are not applicable to air pollution risk mitigation, however, and the most common approach today is to estimate VOLY based on 'stated preferences'. This means that opinion surveys are used to ask a large number of people to state their 'willingness to pay' (WTP) for a risk reduction leading to a possibly longer life expectancy.

This method has two important drawbacks (e.g. Cummings and Harrison, 1995). First, as with any survey, the 'stated preferences' approach is sensitive to how the question is formulated. Second, the WTP survey is hypothetical because those surveyed don't actually have to pay anything and they know that they will not be asked to pay. Therefore, there is a risk that the WTP expressed will be too high, either for strategic reasons or because there is not enough consideration given to the actual ability to pay. In addition, the amount of money that most people would be prepared to pay to achieve a small increase in life expectancy is relatively more than they would pay for a longer increase, and more than they would pay for a short increase if they are in poor rather than good health. Thus, even within a survey, there are variations in the derived VOLY value based on the risk reduction choice. These uncertainties are expressed through the sometimes widely varying VOLY estimates that have been found in both European assessments and in the scientific literature.

A notable step forward on the understanding of VOLY was made in a recent scientific study (Desaigues *et al.*, 2011) as part of the NEEDs project. This study analysed theoretical aspects of VOLY and reported on the outcome of a recent WTP survey that determined VOLY in nine European countries. Desaigues *et al*. argued that the mean value from a WTP survey, and not the median, should be used as a VOLY. On this basis the recommended VOLY was €41,000 for the EU15 countries + Switzerland and €33,000 for new EU member countries. These differences in WTP reflect the role of population selection when conducting a WTP study.

The question about the most appropriate single value from a WTP survey to use for VOLY is not yet resolved. CONCAWE believes that neither the mean nor the median value is appropriate. The problem associated with choosing a single value from a WTP study is discussed in the following article in this *Review* and a novel approach is proposed.

The VOLY value proposed by Desaigues *et al*. (the mean from the WTP survey responses) is much lower than those used in the three cited CBAs. In these three studies, the mean WTP values were almost four times higher. In addition, the three cited CBA studies are seriously flawed in their use of premature mortality and VSL as alternatives to YOLL and VOLY to represent an uncertainty range for monetised health impacts. A proper analysis of the uncertainty in VOLY values should be completed in order to more realistically assess the monetised benefits of air pollution control measures.

Environmental impacts

The recent CBA studies have also quantified the costs of environmental damage, including both damage to the 'built' environment (buildings and infrastructure) and damage to the natural environment (ecosystems and crops). In general, estimated damages to the built environment are small compared to those in the natural environment.

There are several important uncertainties when analysing the costs of air pollution damage in the natural environment. First, ecosystems are under stress from many factors. Some of these are naturally occurring such as temperature extremes, excess or limited water, and limited availability of nutrients. Other stress factors include overgrazing or harvesting of wood and other resources. The relationship between different stress factors and ecosystem responses will be different for each species, so untangling the impact of air pollution in such complex systems is difficult (Grimm *et al.*, 2008). Interactions between pollutants and the environment are further complicated because ecosystem biotic and abiotic factors change significantly over time due to ecological processes. In addition to temperature variations on a daily and seasonal basis, there are also longer-term developments that affect the ecosystem over many years or decades. These time-dependent variations affect both polluted and pristine ecosystems so that no single point in time or space can be defined as being truly representative of the environment as a whole.

In natural ecosystems, the costs of air pollutants can be related to a decrease in the economic benefits supplied by ecosystems due to air pollution-related changes. However, the relationship between the state of the ecosystem and the economic benefits that can be expected from these ecosystems is not well understood (Daily *et al*., 2009). Furthermore, ecosystems are complex and dynamic systems and the response of an ecosystem to a change in air pollutants is difficult to predict. Costs could potentially arise from impacts on timber production, carbon sequestration, production of non-timber forest products, and so on. Better estimates for such costs may be revealed when more complete assessment methodologies are available. These complications are well recognised in the cited CBA studies, which only partially analysed environmental impacts. As is also the case for environmental impacts, the absence of a robust analysis of uncertainties in these CBA studies limits their relevance for policy decisions.

Conclusions

The three CBA studies cited in this article have two main deficiencies. First, they adopt a single and very high value for VOLY, which is not in line with recent scientific literature. Second, they do not conduct a rigorous analysis to account for important uncertainties in the cost-benefit analysis process. It is essential, therefore, for the CBA used in policy development to reflect up-to-date scientific insights and to include a rigorous analysis of uncertainties and their implications. Studies of this sort will guide a cost-effective reduction in health and environmental impacts while maintaining the global competitiveness of European industry.

References

AEA, 2011. *Cost Benefit Analysis for the Revision of the National Emission Ceilings Directive: Policy Options for Revisions to the Gothenburg Protocol to the UNECE Convention on Long-range Transboundary Air Pollution*. European Commission framework contract ENV.C.5/FRA/2006/0071.

CIAM, 2011. *Cost-effective Emission Reductions to Improve Air Quality in Europe in 2020: Scenarios for the Negotiations on the Revision of the Gothenburg Protocol under the Convention on Long-range Transboundary Air Pollution.* Background paper for the 48th Session of the Working Group on Strategies and Review. Geneva, April 11–14, 2011. Version 2.1—March 31, 2011. Centre for Integrated Assessment Modelling (CIAM) and International Institute for Applied Systems Analysis (IIASA).

Cummings, R.G. and G.W. Harrison (1995), The measurement and decomposition of nonuse values: a critical review. *Environmental and Resource Economics*, 5: 225–47.

Daily, G.C., S. Polasky, J. Goldstein, P.M. Kareiva, H.A. Mooney, L. Pejchar, T.H. Ricketts, J. Salzman, and R. Shallenberger. 2009. Ecosystem services in decision making: time to deliver. *Frontiers in Ecology and the Environment*, 7: 21—28.

Desaigues, B., Ami, D., Bartczak, B., Braun-Kohlová, M., Chilton, S., Czajkowski, M., Farreras, V., Hunt, A., Hutchison, M., Jeanrenaud, C., Kaderjak, P., Máca, V., Markiewicz, O., Markowska, A., Metcalf, H., Navrud, S., Nielsen, J.S., Ortiz, R., Pellegrini, S., Rabl, A., Riera, R., Scasny, M., Stoeckel, M.-E., Szánto, R. and Urban, J., 2011. Economic valuation of air pollution mortality: A 9-country contingent valuation survey of value of a life year (VOLY). *Ecological Indicators*, 11 (3): 902–910.

EC4MACS, 2011. *Greenhouse gases and air pollutants in the European Union: Baseline projections up to 2030*. EC4MACS Interim Assessment. European Consortium for Modelling of Air Pollution and Climate Strategies.

EEA, 2011. *Revealing the costs of air pollution from industrial facilities in Europe*. European Environment Agency, Copenhagen, 2011.

Grimm, N.B., Foster, D., Groffman, P., Grove, J.M., Hopkinson, C.S., Nadelhoffer, K.J., Pataki, D.E. and Peters, D.P.C., 2008. The changing landscape: ecosystem responses to urbanization and pollution across climatic and societal gradients. *Frontiers in Ecology and Environment* 2008; 6(5): 264–272.

Künzli, N., Kaiser, R., Medina, S., Studnicka, M., Chanel, O., Filliger, P., Herry, M., Horak, F. Jr., Puybonnieux-Texier, V., Quénel, P., Schneider, J., Seethaler, R., Vergnaud, J-C., Sommer, H., 2000. Public-health impact of outdoor and traffic-related air pollution: a European assessment. *Lancet* 356: 795–801.

See also the following CONCAWE *Review* articles:

Cost Benefit Analyses: some basic concepts and issues (CONCAWE *Review* Vol. 13, No. 2)

Evaluation of health impacts in an environmental cost benefit analysis: the challenge of allocating a monetary value to changes in human health due to air pollution (CONCAWE *Review* Vol. 15, No. 2)

Cost Benefit Analysis for air quality policies: an update and an IPPC Directive case study
(CONCAWE *Review* Vol. 17, No.1)

Reducing the concentration of fine particulates in ambient air (CONCAWE *Review* Vol. 21, No.1)

Evaluating the Value of a Life Year (VOLY)

Air quality policies depend on realistic values for both societal costs and societal benefits.

Today's European air quality policy uses cost-benefit analysis (CBA) to assess the effectiveness of different measures to mitigate air pollution. This involves comparing the cost of achieving emission reductions with the benefits of reducing the concentrations and/or the deposition of different air pollutants. Because benefits can take many forms, converting them to a monetary basis (monetisation) is an important step. This article discusses monetisation of the health benefits associated with reducing concentrations of fine particulate matter (PM).

$PM_{2.5}$, that is particles that are smaller in diameter than 2.5 µm, is a key pollutant from a health perspective[1]. Data from epidemiological studies suggest that long-term exposure to $PM_{2.5}$ can increase human mortality risk. It follows that reducing $PM_{2.5}$ concentrations should reduce mortality risk and consequently result in a small increase in statistical life expectancy. The parameter that is chosen to describe this benefit is population life years, which is conventionally expressed as Years of Life Lost (YOLL) associated with the incremental risk. To monetise the health benefit associated with a given reduction in $PM_{2.5}$, it is therefore necessary to calculate the potential YOLL that would result and multiply it by the Value of a Life Year (VOLY). The determination of VOLY and its use in CBAs were discussed in CONCAWE Report 4/06. In this article, we discuss the appropriateness of VOLY values that are used today in air quality policy and present an alternative approach to deriving these values from the same base data.

[1] See CONCAWE *Review* Vol. 21, No. 1 for more information on $PM_{2.5}$ and Years of Life Lost (YOLL).

'Willingness to pay' surveys

Estimating the monetary value of a life year in a given population is not an easy thing to do. The accepted method is to survey people for their 'willingness to pay' (WTP) to achieve a small increase in statistical life expectancy (see the previous article in this *Review*). For example, if each person in a surveyed population is asked to pay for some treatment option that might result in a few months longer life expectancy on average in the population, how much would they be willing to pay? Such studies are very hard to conduct without bias, while ensuring that the participants understand there is no guarantee that they may actually benefit from the treatment.

The outcomes of these WTP surveys reveal the following:

- Different surveys return different results based on the questions that are asked and the population of people that are surveyed.
- Survey responses are quite varied and provide a distribution of monetary values, ranging from zero up to very high values.
- Most respondents to a WTP survey will say that they are willing to pay only a small amount for a particular treatment option while fewer respondents say that they are willing to pay much larger amounts. As a result of this skewed distribution of responses, the mean value of a WTP survey distribution is much larger than the median value. It is important, therefore, to know what results from the WTP survey best describe the preferences of the surveyed population.
- The monetary value for a full life year improvement is obtained by scaling the responses to a 12-month basis. However, for a short increase in life expectancy, WTP is relatively higher than for a longer increase, that is, the surveys indicate that a longer increase in life expectancy is considered to be less valuable than a short one.
- The WTP also depends on the future state of health. That is, the willingness to pay to increase life expectancy is typically lower if poor health is assumed rather than good health.

These outcomes indicate that considerable care is needed to properly interpret WTP survey results into monetary values for a life year.

In CONCAWE Report 4/06, several cost-benefit studies were compared including one (NewExt) that was used for the Thematic Strategy on Air Pollution (TSAP). This report concluded that the full distribution of VOLY should be used in CBAs and should not be simplified to a single value such as the distribution's mean or median result. In fact, the CBA methodology used in the Clean Air for Europe (CAFE) programme acknowledged that more robust results could be obtained by using the full distribution of WTP survey results, but the simplicity of using a single VOLY value continues to be the easy option for developing air quality policy.

The difference between the median and mean VOLY values (in Euros) from the NewExt and NEEDS studies

Table 1 Comparison of the median and mean values from NewExt and one version of the NEEDS study

Study	Median VOLY	Mean VOLY
NewExt Study (2005)	€52,000	€118,000
NEEDS Study with an assumed increase in life expectancy of three months (2009)	€19,000	€42,000

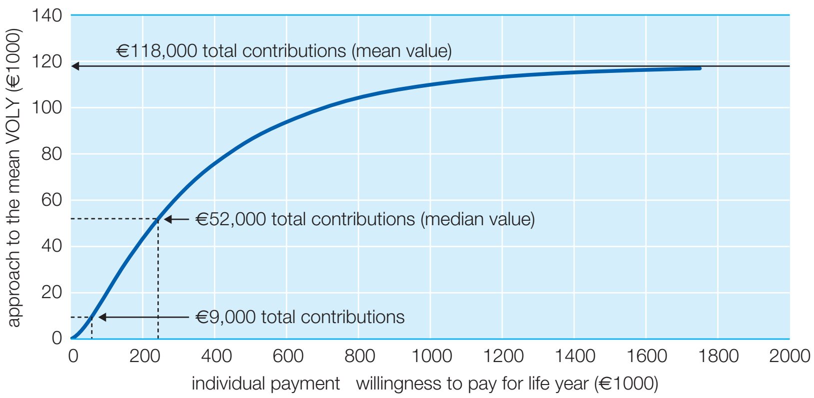
are shown in Table 1. The NEEDS study included more countries and improved the survey technique compared to the NewExt study, so the NEEDS study is widely considered to be the better of these two studies.

The VOLY used in CAFE was €52,000[2] which was the median value from the NewExt study. It would be consistent therefore to use the median value of €19,000 from the better NEEDS study. However, the current policy round assumes a VOLY value of €57,000, which is the CAFE value adjusted for inflation.

[2] AEA, 2007. *Analysis of the Costs and Benefits of Proposed Revisions to the National Emission Ceilings Directive. NEC CBA Report 2. CBA of TSAP and EP target optimisation model runs*. AEA Technology, London, UK.

So which property of the WTP distribution is best for this purpose: the mean, median or mode? It can be argued that the mean value of the WTP distribution is the statistically correct single value with which to represent the survey results. It can also be argued that the median value is the most appropriate parameter because it represents the WTP that divides the sample population equally by choice of paying a higher or lower value. Further, it can be argued that the modal value is most appropriate because it represents the most popular choice.

Figure 1 Integration of the 'willingness to pay' responses of survey respondents using the NewExt study data



If the WTP distribution were symmetrical, as is a normal distribution, all three values describing the distribution would be equivalent. This is not the case for WTP surveys, however, because the distribution of responses is skewed to lower values and approximate a Weibull distribution. In the following calculations, the survey results from previous studies are described using a Weibull distribution defined by the reported mean and median WTP values.

We can illustrate a key weakness in using either the mean or median values when using WTP study results to evaluate benefits. The NewExt results are used to illustrate the case.

Consider how the mean of such a distribution is calculated. All the responses to the WTP survey are added together and the sum is divided by the total number of respondents. Figure 1 shows this process using the Weibull fit to the NewExt study results. Increasing WTP responses are ranked along the x-axis while the running total of contributions, always divided by the total number of survey respondents, is plotted on the y-axis. When the responses from all of the respondents have been counted, the total approaches a mean value of €118,000.

Figure 1 clearly shows just how asymmetric the WTP distribution is. Consider the argument for using a median VOLY, representing the view of exactly half of the survey population. While the median VOLY in the NewExt study was found to be €52,000, the running total of contributions up to this WTP amounts to just €9,000, as shown in Figure 1. When the running total has reached €52,000, individuals who have pledged €240,000 are contributing. Applying the same analysis to the NEEDS survey data, the running total for contributions up to the median WTP of €19,000 would be just €3,000.

These results suggest that even the 'democratic' choice of the median value from a WTP survey is questionable as an estimate of VOLY.

Are there other approaches that would represent a fairer way to determine VOLY?

'Maximised Societal Revenue' approach

CONCAWE proposes that a simple flat fee analysis would be a better way to determine VOLY from a WTP survey. In this approach, a fee would only be paid by those who express a WTP that is higher than or equal to the fee. The flat fee value is chosen to maximise the revenue from the survey population, normalised by the total population. This revenue becomes the 'VOLY' in place of the fee. The attractiveness of this flat fee approach is that it reflects the full distribution of expressed WTP values, is less sensitive to the very highest choices and is fairer to the highest bidders.

Figure 2 shows how this approach would change as the flat fee increases. Results are compared for three studies: NewExt and two versions of the NEEDS study where risk reductions leading to an increase in life expectancy of either three or six months are assumed.

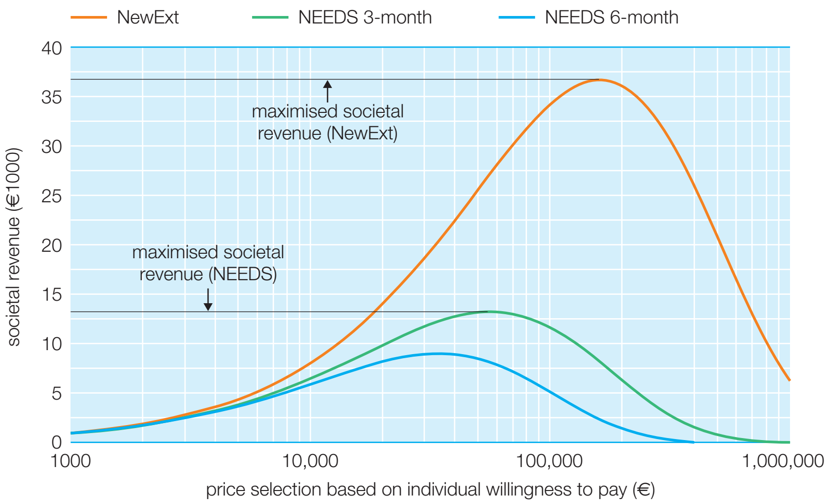
When the flat fee is low, more people would be expected to pay but the total amount of money raised would also be small. As the flat fee increases, fewer people would be expected to pay but the payments are larger so that the revenue increases more rapidly. Eventually, a maximum revenue is reached after which the number of people paying decreases faster than the fee increases. We call the point at which the revenue is maximised the 'Maximised Societal Revenue', expressed on a per capita basis.

The corresponding values of the 'Maximised Societal Revenue' are shown in Table 2 for the NewExt and NEEDS data as well as for the earlier UK DEFRA studies. The values range between €9,000 and €13,000 for the NEEDS study and between €3,400 and €13,000 for the UK DEFRA study.

Conclusions

Using a single value from a WTP survey, such as the mean or median, to characterise the VOLY in policy-oriented CBAs is not a robust approach. As shown here and in CONCAWE Report 4/06, the full distribution of survey results should be used because the skewed shape of the WTP distribution is not properly captured by a single value.

Figure 2 Societal revenue versus the 'willingness to pay' for three different studies



It has been shown that VOLY, and hence monetary benefits, depends disproportionately on the choices of a small fraction of the surveyed population. If a single value must be used to describe such WTP surveys, then a simple flat fee analysis is a better approach which takes the contributions from those willing to pay most but caps their exposure. We believe that this 'Maximised Societal Revenue' approach reflects the full distribution of WTP survey results and reduces the dominance of more extreme values. This approach gives VOLY values in the range €9,000 to €13,000, based on the NEEDS WTP study, which is considerably less than the €57,000 used in current policy development.

Table 2 Maximised Societal Revenue, median and mean values of the 'willingness to pay' for VOLY (in Euros per life year increase in life expectancy) from several studies

Study	Maximised Societal Revenue	Median VOLY	Mean VOLY
NewExt	€37,000	€52,000	€118,000
NEEDS 3-month	€13,000	€19,000	€42,000
NEEDS 6-month	€9,100	€14,000	€27,000
DEFRA 1-month	€13,000	€15,000	€45,000
DEFRA 3-month	€5,500	€2,200	€23,000
DEFRA 6-month	€3,400	€2,700	€13,000

Note: '1-month', '3-month' and '6-month' refer to the different risk-reduction choices in these WTP studies.

A new 'pooled' analysis of benzene effects on human health

A 'pooled' analysis of three human health studies sheds new light on low-level benzene exposure.

[1] See CONCAWE *Review* Vol. 15, No. 2 (2006).

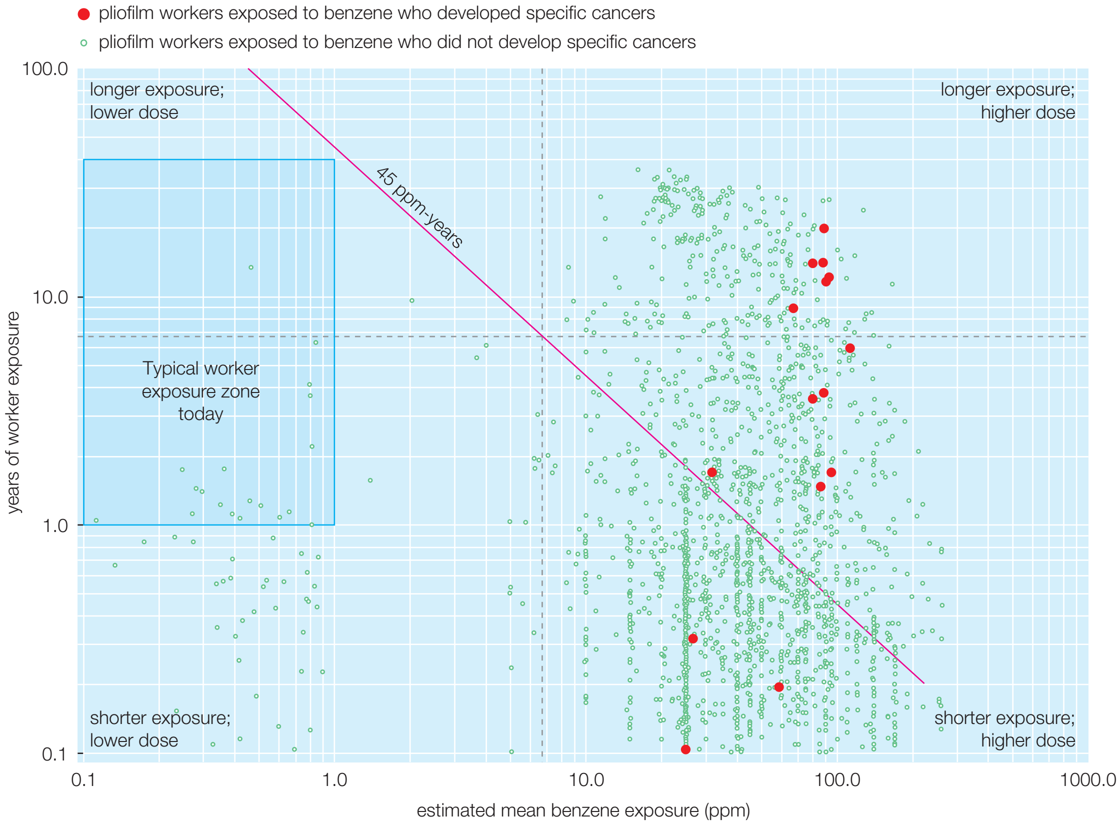
For many years, the effects of benzene on human health have been a concern of health experts and air quality regulators. Because of these concerns, regulatory limits and technological developments have resulted in progressive reductions in benzene concentrations in transport fuels and in ambient air. For example, the maximum amount of benzene in petrol was reduced to 1 wt% in 2000 while advanced vapour recovery systems at service stations were introduced to reduce exposure by employees and consumers to benzene emissions and other evaporative emissions[1]. Workplace limits on benzene and other priority pollutants in ambient air have also been reduced over the same time period resulting in significantly lower exposure to workers and the general public.

The basis for today's worker and environmental benzene regulations in Europe and in the USA were driven by an epidemiological study completed in the 1980s. This study, called the 'pliofilm study', evaluated benzene-induced leukaemia in workers exposed to benzene vapour through the manufacturing of pliofilm polymers, mainly in the 1950s and 1960s.

Most of the workers in this study were exposed to relatively high amounts of benzene, generally over only a few years. Figure 1 shows the average benzene exposure for workers evaluated in the pliofilm study compared to that typically experienced by workers today. The x-axis shows the mean benzene exposure concentration over a working career, while the y-axis shows the duration of benzene exposure in years. In this study, benzene-induced leukaemias were largely associated with higher benzene concentrations over longer exposure durations, which increased the health risk for these workers.

However, most workers in this pliofilm study were exposed to benzene concentrations that are much higher than they are today, typically much less than 10 ppm. Consequently, the pliofilm study has a number

Figure 1 Average benzene exposures for workers evaluated in the 1950–60s 'pliofilm study' compared to typical worker exposures today



of important limitations when considering today’s exposure levels, notably the small number of exposed workers, the lack of actual benzene exposure measurements, and the relevance of these historically high exposure levels, which were 50 to 100 times higher than current workplace exposures. While the pliofilm study focused primarily on benzene-induced leukaemias, other scientific studies have reported a consistent picture between high benzene exposures and acute myeloid leukaemia (AML), but there is a much less clear relationship with other blood cancers such as non-Hodgkins lymphoma (NHL) and chronic lymphoid leukaemia (CLL).

To fill in some of the gaps from the pliofilm study, the petroleum industry sponsored three independent epidemiological studies in the 1990s on the health experiences of Australian, Canadian and British petroleum workers exposed to benzene. These studies did not find any relationship between benzene exposures and some types of leukaemia (e.g. chronic myeloid leukaemia (CML) and acute lymphatic leukaemia (ALL)) but a higher incidence of other forms of leukaemia, including AML and CLL, was observed in some of the studies. However, the findings were not consistent across the three studies and were therefore difficult to interpret. For example, in the Australian study, a higher incidence of AML in workers was observed at significantly lower concentrations of benzene (~1.0 ppm) than was found in the other two studies.

The ‘pooled analysis’

In order to better understand these important studies, a ‘pooled analysis’ of the three epidemiology studies was initiated in 2006 to combine (‘pool’) and update the three previous worker populations. These populations were identified in an EU-funded study (ECNIS in 2006 and 2008) as likely to represent the highest quality epidemiological datasets upon which future benzene limits might be based. Pooling the existing studies in this way was also intended to clarify the significance of the previous inconsistent observations on AML and CLL. This recently-published pooled analysis is now the largest study of its type and its findings are expected to play a major role in future regulatory discussions on controlling workplace exposure to benzene.

By analysing together the results from many more workers, the design of the pooled study also allowed an examination of the relationships between benzene exposure and leukaemia types that may not have been apparent in the three independent studies. From a health sciences perspective, a larger number of exposed workers covering a broader range of benzene exposure concentrations provides more statistical certainty where more definitive conclusions can be reached. An add-on to the pooled study was to look at blood diseases that can be grouped according to the latest World Health Organization (WHO) classifications. This means that the association between benzene exposure and two new blood disease groups, myelodysplastic syndrome (MDS) and myeloproliferative disease (MPD), could be investigated in the new study.

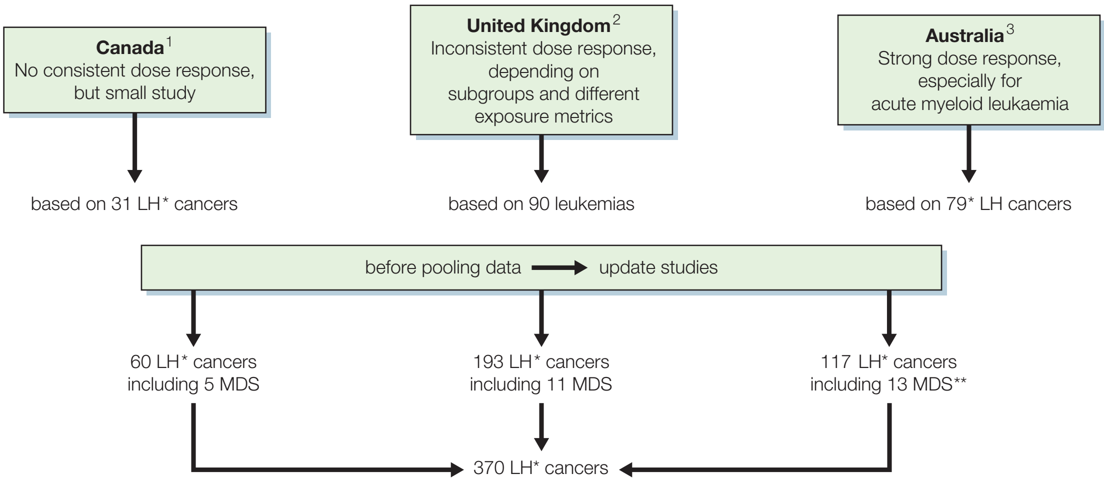
Methodology

The first step in conducting this benzene pooled analysis was to determine whether the three epidemiology studies could in fact be pooled, that is, whether the exposure conditions and measurements used in the studies were compatible. Clearly, this first step did indeed support a combined data analysis resulting in a study having much higher statistical power than any of the three individual studies.

This benzene pooled analysis is based on a case control design. This means that the exposure experiences of individuals who contracted leukaemia or other blood conditions (‘cases’) were compared to the exposure experiences of randomly selected workers of the same age who did not (‘controls’). From a total combined study population in excess of 41,000 workers, the pooled population included 370 potential blood disorder cases and more than 1,500 suitable controls. This can be compared to only 15 blood disorder cases from a total of 1,700 exposed individuals in the pliofilm study.

In addition to the greater statistical confidence that the analysis of a larger exposure population provided, the pooled analysis used a standardized approach to characterize historic benzene exposures across all three studies. This was combined with a rigorous evaluation of how blood diseases, including cancers have been assessed and classified. Importantly, the pooled study assessed diseases using the recently revised WHO def-

Figure 2 Pooled data from three previous studies



*LH: lymphohematopoietic **MDS: myelodysplastic syndrome

1. Schnatter *et al*., 1996. Lymphohaematopoietic malignancies and quantitative estimates of exposure to benzene in Canadian petroleum distribution workers. *Occupational and Environmental Medicine* (*OEM*); 53: 773-781

2. Rushton *et al*., 1997. A case-control study to investigate the risk of leukaemia associated with exposure to benzene in petroleum marketing and distribution workers in the United Kingdom. *OEM*; 54:152-166

3. Glass *et al*., 2003. Leukemia risk associated with low-level benzene exposure. *Epidemiology* 14: 569-577

initions of tumours of the blood and lymph systems, and the clinical diagnoses of individuals in the pooled study were reviewed and confirmed by independent medical professionals.

Results

There were three major findings from the pooled analysis of the three separate benzene studies.

Firstly, no consistent relationship was identified between benzene exposure and AML. Because AML was the type of leukaemia that had previously been associated with exposure to higher benzene concentrations, this finding may indicate that benzene exposures higher than those experienced in the pooled study populations may be necessary for a significant risk of AML to occur.

Secondly, for today's more typical benzene exposure levels (i.e. those less than about 1 ppm on average) no relationship was identified with other blood-forming tumour sub-types, e.g. CML, CLL and MPD. These sub-types have been hypothesized as being associated with higher benzene exposure levels, which would be consistent with the finding from the pooled study.

Thirdly, MDS, a blood condition that can develop into leukaemia and which has previously been associated with exposure to benzene, was found to be related to benzene exposure but at lower benzene levels than had previously been reported. In this study, a regular peak exposure was defined as a short-term (15–60 minutes) exposure to more than 3 ppm benzene at least once per week for at least one year. Workers who experienced this regular peak exposure seemed to be most closely associated with the MDS blood condition. A number of other exposure metrics were also associated with MDS, but with lower levels of statistical significance. MDS was not identified in the earlier studies of petroleum workers, largely because it was not a reported condition until the 2001 WHO publication on the classification of blood and lymphatic tumours specified clearer criteria for MDS diagnosis.

Conclusions

Importantly, the pooled study did not find a clear relationship between various blood leukaemias and today’s typical benzene exposure levels. This is an important finding because the incidence of leukaemia has been used as the basis for current benzene workplace and environmental regulatory standards for many years. This conclusion suggests that existing regulatory standards for benzene, such as occupational exposure limits, are already sufficient to protect worker health for benzene-related leukaemias. The new finding concerning MDS-type blood conditions requires more research to determine whether this is a robust finding and whether there are implications for today’s benzene exposure control strategies.

This benzene pooled study has now been published in a peer-reviewed journal (Schnatter *et al.*, 2012)[2]. With these new and important results in hand, CONCAWE is now fulfilling its REACH obligations by updating the petroleum substance registration dossiers with this new epidemiology information.

[2] Schnatter, R.A., Glass, D.C., Tang, G., Irons, R.D., Rushton, L., 2012. Myelodysplastic Syndrome and Benzene Exposure Among Petroleum Workers: An International Pooled Analysis. *Journal of the National Cancer Institute*: DOI 10.1093/jnci/djs411. Available at: jnci.oxfordjournals.org/content/104/22/1724.full.pdf+html (Accessed 3 December 2012)

Epidemiology

Epidemiology is the study of the complex patterns and determining factors that have an impact on human health in defined populations. There are three important components to a well-designed epidemiology study: the test protocol, the selection and collection of data, and the statistical analysis of the results. Each component plays an important role in providing a well-reasoned blueprint for collecting, analysing and interpreting the data. A properly conducted study can provide health professionals with the information needed to assess a worker’s risk of experiencing a specific health impact from exposure to petroleum products in the workplace.

Due to major advances in health science over the past two decades, there has been a dramatic shift in how different blood diseases are classified. Today, the origin of the blood disease is used instead of the anatomy of the cancer cells and provides a much better link to the cause of the health effect:

- Traditional approach based on the anatomy of the cancer cells:
  - Leukaemias (cancer in peripheral blood)
  - Lymphomas (cancer in lymph system)

- New approach based on the origin of the cancer cells:
  - Myeloid tumours, such as:
    - Myeloproliferative disease (MPD)
    - Myelodysplastic syndrome (MDS)
    - Acute myeloid leukaemias (AML)
  - Lymphoid tumours, such as:
    - B-cells and T-cells (leukaemias and lymphomas)

Several blood-related diseases are now examined closely for potential links between human health and exposure of workers to substances like benzene. These diseases can include:

- Acute myeloid leukaemia (AML)
- Chronic myeloid leukaemia (CML)
- Chronic lymphoid leukaemia (CLL)
- Myelodysplastic syndrome (MDS)
- Myeloproliferative disease (MPD)

Interview with CONCAWE's first Research Associate

Lucia Gonzalez Bajos talks about her experience as CONCAWE's first Research Associate.

Lucia Gonzalez Bajos, seconded from Repsol, became CONCAWE's first Research Associate in October 2011 to advance air quality studies using remote sensing techniques. The CONCAWE *Review* departs from its usual format to interview Lucia about her experiences at CONCAWE and in Brussels so far.

Q: Lucia, before we talk about your work at CONCAWE, please tell us a little about yourself, including your experience living in Brussels.

A: *I am a chemist by training and worked for five years in Repsol's Technology Centre in Madrid. My initial assignment at Repsol was in the R&D department and focused on the optimization of several refining processes, including sulphur recovery, fluidized catalytic cracking, and catalytic reforming. In the three years before I came to CONCAWE in 2011, my work changed to focus more on biofuels and environmental issues.*

I have always enjoyed travelling and experiencing other cultures, so living outside of Spain was very appealing. Because Brussels is a smaller city than Madrid, I have found that it is also an easier city to live in and has an extraordinary range of cultural and sporting activities. I have been to the theatre more often this year than in my whole life and even bought a bicycle so that I can cycle to the office every day. This is something I would never have thought to do in Madrid!

Most importantly, I would like to thank all of the CONCAWE Secretariat staff for making me feel at home from the very first moment after my arrival!

Q: Why did CONCAWE decide to create the 'Research Associate' position?

A: *The Research Associate concept originated from a study that CONCAWE completed in 2010. This study looked at ways to improve the overall efficiency of the Secretariat operation, including staffing, procurement, project tracking, and so on. In some technical areas, there were special activities that seemed to be ideally suited for a 'Research Associate', that is, someone who could work closely with the Secretariat's Technical Coordinators and take responsibility for specific projects. CONCAWE's management team decided that this approach was a good way to complement the Secretariat staff and should be tested to see how well it would work.*

Q: Why were you interested in taking this position?

A: *Since 2008, I had been involved in CONCAWE activities by participating in the Air Quality Management Group and several other task forces. Because I was already quite familiar with many air quality projects, I decided that working with experts from different member companies was a perfect opportunity to further develop my professional career. Fortunately, my home company, Repsol, agreed and I was lucky enough to be selected as CONCAWE's first Research Associate.*

Q: What projects have you been working on during your time at CONCAWE?

A: *In my first year, I focused primarily on two projects related to the estimation of diffuse emissions of volatile organic compounds (VOCs). My main project focuses on the application of a remote sensing technique, called Differential Absorption Light Detection and Ranging, or DIAL for short, to estimate diffuse VOC emissions that can originate from petroleum storage tanks. In the past few years, remote sensing studies have been published that reported higher VOC emissions than those estimated using current emission factors. Attempts to explain the big discrepancies focused mostly on the accuracy of the emission factors that were being used. However, much less research had been done regarding uncertainties associated with the determination of the emitted VOC flow rates using remote sensing methods.*

So, in 2010, before I began my current assignment, CONCAWE started a research project to explore these uncertainties in more detail. The first stage of this project was completed in 2011 and included wind tunnel measurements and computational fluid dynamic modelling of the results. This part of the study examined, under controlled conditions, the flow and dispersion of diffuse VOC emissions from scale models of storage tanks.

From these results, we concluded that previous remote sensing studies had probably over-estimated tank emissions because the measurements were made too close to the tank. VOC concentra-

tion measurements should ideally be made at a distance of a few tank heights away from storage tanks in order to reduce uncertainties that arise in estimates of the emitted flow due to variations in the tank's shape and the source of the emissions compared to the prevailing wind field.

In 2012, we went one step further by completing a field trial on an outside storage tank to test the conclusions from the wind tunnel studies and look at other possible sources of uncertainty. We are still analysing the results of this trial and expect to publish a report on the results in 2013. We believe that these results will contribute to the development of a robust testing protocol for the application of remote sensing techniques to the determination of diffuse VOC emission flows, possibly even a CEN standard method.

My other main project is also related to the estimation of VOC diffuse emissions but is focused on emissions from primary oil/water separators in refinery waste water treatment plants. This study has reviewed different methods that can estimate these emissions and applied some of these in two field trials carried out in European refineries in 2011. Average VOC emission estimates during the trial periods have been obtained using four published emission factors, three different models and an empirical algorithm. The DIAL technique was also used to derive estimates of short-term emission fluxes from remote measurements of VOC concentrations. An assessment of the strengths and weaknesses of each method has also been carried out and the report on this work will be published in 2013.

Q: These sound like interesting projects. What else have you been working on?

A: *Yes, in my 'spare time', I have been working on an analysis of the refining sector data included in the European Pollutant Release and Transfer Register database (for more information on the E-PRTR, see CONCAWE* Review *Vol. 19, No. 1). This work is developing a standardised reporting methodology based on the publicly-available E-PRTR data for refining. Most of our readers are also aware that we are currently in the review process for the Best Available Techniques Reference (BREF) document for refining so I am helping CONCAWE's Technical Coordinators prepare for the next commenting phase.*

Q: How has your experience at CONCAWE helped you in your career?

A: *Working at CONCAWE and living in Brussels has been an extraordinary experience for me and I feel very privileged to have been selected for this position. By leading the storage tanks project, I have developed special expertise in remote sensing techniques and their application to the refining industry and, of course, have developed my project management skills at the same time. I have had the opportunity to work closely with many contractors and professionals including the chair and member company experts on my CONCAWE research team. This has allowed me to develop valuable contacts and gain a much broader perspective of the refining industry. Finally, living in Brussels, besides being a lot of fun, has enabled me to improve my language skills in both English and French and I have even started taking German lessons!*

Q: Will the 'Research Associate' position continue at CONCAWE?

A: *Well, I'm very happy to say that my own assignment has been extended for an additional year so that I can continue to develop the DIAL protocol. We have also started a new project on optical gas imaging techniques so I will be quite busy.*

Based on my own positive experience, CONCAWE is already looking for another Research Associate who will be brought in to extend our in-house capabilities in refinery, vehicle and fuel demand modelling. I am looking forward to helping the next CONCAWE Research Associate get off to a good start in 2013!

Abbreviations and terms

ALL	Acute Lymphatic Leukaemia
AML	Acute Myeloid Leukaemia
BREF	Best Available Techniques Reference Document
CAFE	Clean Air For Europe
CBA	Cost-Benefit Analysis
CLL	Chronic Lymphoid Leukaemia
CML	Chronic Myeloid Leukaemia
CO_2	Carbon Dioxide
CWT	Complexity Weighted Tonne
DEFRA	The UK Department for Environment, Food, and Rural Affairs
EC	European Commission
EC4MACS	European Consortium for Modelling of Air Pollution and Climate Strategies (An EU funded research project aimed at helping decision makers in the field of climate and air quality)
ECNIS	Environmental Cancer Risk, Nutrition and Individual Susceptibility (An EU-funded programme of research into cancer causation and prevention)
EEA	European Environment Agency
EF	Emissions Factor
E-PRTR	European Pollutant Release and Transfer Register
ETS	Emissions Trading Scheme
EU	European Union
EUF	Electricity Utilisation Factor
GAINS	Greenhouse gas - Air pollution Interactions and Synergies model (An extension of the RAINS model—see below)
GHG	GreenHouse Gas
Gothenberg Protocol	Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (The eighth Protocol to take effect under the Convention on Long-range Transboundary Air Pollution of the United Nations Economic Commission for Europe (UNECE))
IIASA	International Institute for Applied Systems Analysis
IPPC	Integrated Pollution Prevention and Control (EU Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control)
LH	Lymphohematopoietic, i.e. relating to, or involved in, the production of lymphocytes and blood cells
MDS	Myelodysplastic Syndrome
MPD	Myeloproliferative Disease
NEEDS	New Energy Externalities Developments for Sustainability (A study of the monetary valuation of mortality and morbidity risks from air pollution, commissioned by the European Commission)
NewExt	New Elements for the Assessment of External Costs from Energy Technologies (A study commissioned by the European Commission to assess the impacts of energy supply and use on human health, including a monetary valuation of mortality impacts from air pollution)
NHL	Non-Hodgkins Lymphoma
PM	Particulate Matter or Mass
$PM_{2.5}$	Particulate Matter with an aerodynamic diameter of 2.5 micrometres or less
PPM	Parts Per Million
RAINS	Regional Air Pollution Information and Simulation model (A tool developed by IIASA for analysing alternative strategies to reduce acidification, eutrophication and ground-level ozone in Europe)
REACH	Registration, Evaluation, Authorisation and restriction of Chemicals
TSAP	Thematic Strategy on Air Pollution
UNECE	United Nations Economic Commission for Europe
VOC	Volatile Organic Compound
VOLY	Value Of a Life Year
VSL	Value of a Statistical Life
WHO	World Health Organization
WTP	Willingness To Pay
YOLL	Years Of Life Lost

CONCAWE contacts

Secretary General

Michael Lane
Tel: +32-2 566 91 61 Mobile: +32-496 27 37 23
E-mail: michael.lane@concawe.org

Office management and support

Finance, Administration & HR Manager
Didier De Vidts
Tel: +32-2 566 91 18 Mobile: +32-474 06 84 66
E-mail: didier.devidts@concawe.org

REACH Implementation Officer
Sophie Bornstein
Tel: +32-2 566 91 68 Mobile: +32-497 26 08 05
E-mail: sophie.bornstein@concawe.org

Marleen Eggerickx
Tel: +32-2 566 91 76
E-mail: marleen.eggerickx@concawe.org

Sandrine Faucq
Tel: +32-2 566 91 75
E-mail: sandrine.faucq@concawe.org

Anja Mannaerts
Tel: +32-2 566 91 73
E-mail: anja.mannaerts@concawe.org

Barbara Salter
Tel: +32-2 566 91 74
E-mail: barbara.salter@concawe.org

Julie Tornero
Tel: +32-2 566 91 73
E-mail: julie.tornero@concawe.org

Technical Coordinators and Associates

Air quality
Pete Roberts
Tel: +32-2 566 91 71 Mobile: +32-494 52 04 49
E-mail: pete.roberts@concawe.org

Air quality—Research Associate
Lucia Gonzalez Bajos
Tel: +32-2 566 91 64 Mobile: +32-490 11 04 71
E-mail: lucia.gonzalez@concawe.org

Fuels quality and emissions
Ken Rose
Tel: +32-2 566 91 69 Mobile: +32-499 97 53 25
E-mail: ken.rose@concawe.org

Health
Arlean Rohde
Tel: +32-2 566 91 63 Mobile: +32-495 26 14 35
E-mail: arlean.rohde@concawe.org

Petroleum products • Risk assessment
Bo Dmytrasz
Retired December 2012

Petroleum products • Risk assessment
Francisco del Castillo Roman
Tel: +32-2 566 91 66 Mobile: +32-490 56 84 83
E-mail: francisco.delcastillo@concawe.org

Refinery technology
Alan Reid
Tel: +32-2 566 91 67 Mobile: +32-492 72 91 76
E-mail: alan.reid@concawe.org

Water, soil and waste • Safety • Oil pipelines
Klaas den Haan
Tel: +32-2 566 91 83 Mobile: +32-498 19 97 48
E-mail: klaas.denhaan@concawe.org

CONCAWE publications

Reports published by CONCAWE from 2011 to date

2011

1/11	Environmental sensitivity assessment of retail filling stations in selected European countries
2/11	Trends in oil discharged with aqueous effluents from oil refineries in Europe—2005 and 2008 survey data
3/11	Performance of European cross-country oil pipelines: Statistical summary of reported spillages in 2009 and since 1971
4/11	A comprehensive review of European epidemiological studies on particulate matter exposure and health
5/11	European downstream oil industry safety performance—statistical summary of reported incidents—2010
6/11	Cost effectiveness of emissions abatement options in European refineries
7/11	The potential for application of CO_2 capture and storage in EU oil refineries
8/11	Performance of European cross-country oil pipelines—statistical summary of reported spillages in 2010 and since 1971
9/11	Acute aquatic toxicity of heavy fuel oils—summary of relevant test data

2012

1/12	Assessment of refinery effluents and receiving waters using biologically-based effect methods
2/12	Gasoline volatility and vehicle performance
3/12	EU refinery energy systems and efficiency
4/12	Gasoline ether oxygenate occurrence in Europe, and a review of their fate and transport characteristics in the environment
5/12	European downstream oil industry safety performance—statistical summary of reported incidents—2011
6/12	Trends in oil discharged with aqueous effluents from oil refineries in Europe—2010 survey data
7/12	REACH—Analytical characterisation of petroleum UVCB substances
8/12	Hazard classification and labelling of petroleum substances in the European Economic Area—2012
9/12	Developing a methodology for an EU refining industry CO_2 emissions benchmark
10/12	Primary biodegradation of petroleum hydrocarbons in seawater
11/12	Developing human health exposure scenarios for petroleum substances under REACH
12/12	Use of the modified Ames test as an indicator of the carcinogenicity of residual aromatic extracts

Other recent reports co-authored by CONCAWE

2011	JRC/EUCAR/CONCAWE Biofuels Programme
2011	JRC/EUCAR/CONCAWE Well-to-Wheels Study
2012	A global and historical perspective on the exposure characteristics of traditional and new technology diesel exhaust
2012	A global and historical perspective on traditional and new technology gasoline engines and aftertreatment systems
2012	Effect of in vehicle storage on B10 diesel quality

Adobe PDF files of virtually all current reports, as well as up-to-date catalogues, can be downloaded from CONCAWE's website at: www.concawe.org/content/default.asp?PageID=569.

Readers can receive notification when a new report is published by subscribing to the relevant RSS feeds: www.concawe.org/content/default.asp?PageID=636.

CONCAWE

Boulevard du Souverain 165, B–1160 Brussels, Belgium

Telephone: +32-2 566 91 60 • Telefax: +32-2 566 91 81

info@concawe.org • www.concawe.org