

Catalogue of Concawe general interest reports

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INTRODUCTION

The term "current" as used in this catalogue denotes any published report considered to have some current relevance at the time this catalogue was compiled. When considering making a request for reports, readers are asked to bear in mind the date of publication of each individual report particularly with regard to some of the earlier works, and assess carefully whether the documents requested are likely to remain relevant to their needs.

Concawe reports are published only in English. All recent reports are available on the Concawe Website <http://www.concawe.eu> and may be downloaded free of charge. Copies of all Concawe reports are held in the Secretariat, including earlier reports, which are not necessarily listed in this catalogue. These may be ordered by sending an e-mail request to publications@concawe.eu.

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Concawe's Product Dossiers are currently unavailable pending update with the most recent information compiled for registration under REACH

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Impact of a potential reduction of the poly-aromatics content of diesel fuel on the EU refining industry 7/05

The impact of reducing sulphur to 10 ppm max in European automotive fuels - an update 8/05

Techno-economic analysis of the impact of the reduction of sulphur content of residual marine fuels in Europe 2/06

Oil Refining in the EU in 2015 1/07

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1.11. GENERAL

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CONCAWE Review Vol. 23 No. 1 Spring 2014

CONCAWE Review - Year of air 2014 (special issue)

CONCAWE Review Vol. 24 No.1 Spring 2015

CONCAWE Review Vol. 24 No.2 Winter 2015

CONCAWE Review Vol. 25 No.1 Spring 2016

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CONCAWE Review – Special Symposium Edition Spring 2017

CONCAWE Review Vol. 26 No.1 Summer 2017

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CONCAWE Review – Special Symposium Edition Spring 2019

CONCAWE Review Vol. 28 No.1 October 2019

CONCAWE Review Vol. 29 No.1 June 2020

CONCAWE Review Vol. 29 No.2 February 2021

CONCAWE Review Vol. 30 No.1 May 2021

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2. SUMMARIES OF CURRENT REPORTS (IN CHRONOLOGICAL ORDER)

<https://www.concawe.eu/publications/concawe-reports>

8/75 THE IDENTIFICATION AND MEASUREMENT OF REFINERY ODOURS

This report quotes current European regulations on odours, systems adopted for receiving odour complaints from the general public and summarizes the types of compounds giving rise to odours from oil refineries and identifying the possible sources. Instrumental and olfactory methods for the identification and measurement of odours are described, in particular chromatographic methods for the determination of hydrocarbons and sulphur compounds in the atmosphere. A novel method of presenting the data to highlight the compounds causing odour is given. The selection and the use of odour panels as a means of establishing good public relations and of monitoring public complaints are discussed.

5/79 THE ENVIRONMENTAL IMPACT OF REFINERY EFFLUENTS

This study was carried out by two internationally respected consultants at CONCAWE's request following the publication of EEC Directive 76/464 of 4 May 1976 on pollution caused by dangerous substances discharged into the aquatic environment. Dr. J. Baker, of the Field Studies Council (UK) reviews the ecological impact of refinery effluents in the marine and estuarine environment (Part III) and Dr. L. Huber of the State of Bavaria Institute for Water Research (W. Germany) the ecological effects of refinery effluents in inland waterways with particular reference to substances on List I of the EEC Guidelines for Water Protection (Part IV). The report is completed by an extended summary (Part I), a brief introduction to oil refining in Europe and to the sources, characteristics and methods of treatment applicable to refinery waste waters (Part II), the EEC Directive (Part V) and a glossary of technical terms (Part VI).

1/81 GUIDELINES FOR THE DETERMINATION OF ATMOSPHERIC CONCENTRATIONS OF OIL MIST

This report examines various methods currently in use for fixed position area sampling and for personal sampling and discusses the suitability of three methods of analysis (gravimetric, ultraviolet absorption and infra-red absorption) for determination of oil mist concentrations typically found in industrial situations. An Appendix gives guidance on the applicability of the methods.

4/81 THE PROPAGATION OF NOISE FROM PETROLEUM AND PETROCHEMICAL COMPLEXES TO NEIGHBOURING COMMUNITIES

The report describes the results of a research study designed to produce a new and comprehensive model for the assessment of noise propagation. The work itself was carried out by Acoustic Technology Ltd., of Southampton, England, in accordance with a programme defined by CONCAWE. Details are given of the development of an initial model, experimental measurements and the consequent refinement of the model to produce the final version and three simplified versions. The report also describes the establishment during the study of separate attenuation curves for six categories of weather conditions, for each of the usual octave bands, and the estimation of confidence intervals for the predictions through the application of statistical analysis. It concludes with a comparison between the new CONCAWE model and two other noise propagation models already in general use. Tables of atmospheric absorption values,

graphs and equations for calculating the attenuation parameters, and a brief description of the statistical analysis methods used, are also included.

3/82 PRECAUTIONARY ADVICE ON THE HANDLING OF USED ENGINE OILS

This brief paper spells out the advice to all persons who have contact with used engine oils, that they should exercise care to avoid prolonged skin contact and maintain good standards of personal hygiene. Lubricating oils, regardless of make or origin, can undergo a change when used in internal combustion engines. Substances produced by this change have caused skin cancer in mice. The risk to humans in normal circumstances, based on a assessment of the extent of normal human exposure to used engine oils, is considered to be slight. Nevertheless, CONCAWE considers it prudent to publish precautionary advice given in this report. The Appendices provide a warning notice in English, Dutch, French, German, Italian and Spanish.

7/82 HEALTH ASPECTS OF BITUMENS

The report provides an extensive review of health aspects in the handling and use of bitumen and bitumen derivatives, with the main emphasis on indicating potential health hazards and the precautions required to avoid them. Attention is drawn to the importance of distinguishing between bitumens and coaltar products, the latter not being covered in the report. An assessment of toxicity of bitumens based on a review of published toxicological information is included as an Appendix.

Main conclusions and recommendations are that: the major hazard is of skin burns; there is no evidence, from animal tests or human experience, of long-term effects in man during normal use of bitumens; precautions are required to avoid possible high exposure to fumes in confined situations, and there is a need for bitumen suppliers to advise on safe use of their products, particularly where any additional hazards may arise from the nature of the product or its application.

8/82 ECOLOGICAL MONITORING OF AQUEOUS EFFLUENTS FROM PETROLEUM REFINERIES

The report provides information which will allow the management of inland and coastal refineries to evaluate the need for appropriate ecological monitoring programmes to study the effect of aqueous discharges on the environment into which they are discharged. The stages in the development of a monitoring programme are reviewed and a description is given of some benefits that may arise from properly conducted studies. Other sections outline procedures for sampling, collection and analysis of data and describe several case histories at refinery sites in a variety of natural habitats. The report illustrates the practical contribution that an ecological monitoring programme can make to overall refinery management. It is emphasised that such a programme should be approached only in consultation with appropriate experts, who are unlikely to be part of normal refinery staff, and that such experts should be involved in subsequent review and updating.

10/82 METHODOLOGIES FOR HAZARD ANALYSIS AND RISK ASSESSMENT IN THE PETROLEUM REFINING AND STORAGE INDUSTRY

The report provides readers both within and outside the petroleum industry with an overview of the methodologies already in use or being developed, to assist and supplement risk management practices. The report briefly describes the consecutive steps in the identification, assessment and comparison of hazards and associated risk. These techniques can be helpful in setting the priorities for the decision on measures to reduce risk. When quantifying risk, e.g. for the comparison of alternative design

cases, the use of a consistent data base is stressed. It is pointed out that the risk assessment techniques described in the report, although potentially valuable tools for improving overall safety performance, have shortcomings particularly in dealing with human factors. In the Appendices examples are given of the techniques, ranging from checklists to the prediction of human error. A glossary is appended to define terms as they are used in this report and a list of recommended further reading is included.

3/83 HEALTH AND SAFETY DATA SHEETS FOR PETROLEUM PRODUCTS

This report presents first a survey of the current regulatory requirements and legislation for the supply of health and safety data on petroleum products in Western Europe in general and within the EEC in particular. It also covers petroleum companies procedures. From this analysis, in order to help develop a common oil industry approach and to minimize possible confusion due to misunderstanding in this critical area, guidelines for drafting Health and Safety Data Sheets for Petroleum Products are proposed. Two specimen Health and Safety Data Sheets are included as illustrations.

6/83 PRECAUTIONARY ADVICE ON THE HANDLING OF MOTOR GASOLINES

The report reviews the potential hazards associated with the handling of motor gasolines and the precautions necessary for their safe use. It begins by describing briefly the physical properties and composition of motor gasolines and then outlines the major safety and health hazards. A further section gives advice on the safe handling of gasoline and provides references to detailed codes of safe practice. The advice is presented in summary form in an Appendix.

8/83 CHARACTERISTICS OF PETROLEUM AND ITS BEHAVIOUR AT SEA

The report examines the various interrelated factors which can affect the behaviour of spilt oil in a marine environment and, consequently, influence the effectiveness of oil spill clean-up methods. These factors relate not only to the origin and nature of the oil itself, but also to such processes as spreading, evaporation, dispersion, emulsification, dissolution, sedimentation and degradation. The report first discusses the way in which each separate process will affect the rate of weathering of the spilt material, and uses mathematical models to estimate the corresponding changes in physicochemical properties. A further chapter considers how these processes interact and influence the ultimate fate of the spilt material and options for its treatment and/or collection. The report classifies different crude oils into groups which will behave in a similar way after spillage at sea and will therefore require similar treatment methods. A detailed compendium giving relevant properties of some 57 crude oils is included as an Appendix.

11/83R ASSESSMENT OF THE ENERGY BALANCES AND ECONOMIC CONSEQUENCES OF THE REDUCTION AND ELIMINATION OF LEAD IN GASOLINE

This report gives details of a study carried out at the request of the EEC Working Group: Evolution of Regulations - Global Approach (ERGA). The study assesses the impact of reducing or eliminating lead in gasoline and considers the ultimate situation, ten to fifteen years after the introduction of unleaded gasoline, when only unleaded gasolines are being manufactured. Computer models of refineries incorporating the latest refining technology are used to predict the optimum octane number for unleaded gasoline which will minimize total energy consumption. The report explores the variation of this optimum as the parameters of the base case are varied. The report also comments on the accompanying changes in gasoline composition and the way this will influence automotive exhaust emissions.

1/84 DETERMINATION OF HYDROCARBONS IN AQUEOUS EFFLUENTS FROM THE OIL INDUSTRY BY INFRA-RED ANALYSIS

The report indicates that analytical procedures based on infra-red spectroscopic techniques are the most suitable for the routine determination of hydrocarbons in effluents from petroleum refineries. From a review of some 15 published IR methods those technical elements are selected which CONCAWE considers to be essential for any method to yield satisfactory results. To improve the comparability of data from different sources, CONCAWE recommends that the key elements of the procedures be considered when a new analytical standard method is developed, or when a standard method is selected from those presently available.

2/84 EFFECTS OF THE INTRODUCTION OF UNLEADED GASOLINES ON THE GASOLINE STORAGE/DISTRIBUTION SYSTEM

The report reviews the factors to be taken into account when assessing the effects of superimposing one, or two, unleaded gasoline grades on the existing leaded gasoline storage/ distribution system. It also considers the consequences for both the oil industry and the motorist throughout the introductory and transitional phases until only unleaded gasoline is required.

7/84 COST OF CONTROL OF SULPHUR DIOXIDE, NITROGEN OXIDES AND PARTICULATES EMISSIONS FROM LARGE COMBUSTION PLANTS IN OIL REFINERIES

This report presents the results of a study on the cost of controlling emissions of SO₂, NO_x and particulates from oil refineries by flue gas treatment. Reductions of emissions have been chosen in accordance with those proposed by the European Commission's directive "Limitation of the emission of pollutants into the air from large combustion plants". The report calculates the retrofitting cost for the "average" CONCAWE refinery and the total cost for all EEC refineries. A short review of available emission reduction techniques is also included.

2/85 HEALTH ASPECTS OF PETROLEUM FUELS - GENERAL PRINCIPLES

The report reviews the health hazards which may arise from the handling and use of petroleum fuels, LPGs, gasolines, kerosines, gasoils and residual fuel oils. Health hazards arise from a combination of the properties of the fuel and the extent to which people are exposed to it and both aspects are covered in the report. It is concluded that, provided sensible precautions are taken, the risk in handling and using petroleum fuels is very small. Suitable precautions are outlined, and the importance of proper care emphasised.

5/85 STRATEGIES FOR THE ASSESSMENT OF THE BIOLOGICAL IMPACTS OF LARGE COASTAL OIL SPILLS - EUROPEAN COASTS

A full evaluation of the effects caused by a spill, involving quantification of the extent of the impact and assessment of the rate of recovery of the environment, should be based on carefully planned studies with well-defined objectives and should draw on the experience of the few large oil spills which have occurred. This paper provides an overview of the strategies recommended for such studies. Special attention is given to the following aspects:

- definition of the objectives of oil spill studies;

- selection of priority areas for study;
- selection of techniques and timing of the studies;
- scope and desirability of advance planning;
- organization and expertise required.

7/85 WORKPLACE NOISE AND HEARING CONSERVATION

Prolonged and repeated exposure to loud noise can lead to the development of noise-induced hearing loss (NIHL). This report addresses the subject of workplace noise in the petroleum industry and the role of hearing conservation programmes in preventing NIHL. It outlines the essential features of such programmes, including the evaluation and control of workplace noise, hearing surveillance, and worker education about NIHL and effective preventative measures, as well as indicating the management and employee responsibilities in their implementation.

2/86 VOLATILE ORGANIC COMPOUND EMISSIONS: AN INVENTORY FOR WESTERN EUROPE

CONCAWE has compiled this inventory of atmospheric emissions of volatile organic compounds (VOCs) using data available from oil industry internal studies interpreted together with published information. VOC emissions are given for the year 1983 for both OECD Europe and EEC-10. The data covers natural emissions, and man-made emissions under seven main headings: mobile sources, oil industry, solvents, manufacturing industry, natural gas, solid waste disposal and stationary combustion. By convention, all the figures shown exclude methane emissions. This is to ensure compatibility of the data and should not be taken to indicate that methane is inactive in atmospheric chemistry. The inventory demonstrates that the two biggest contributors to man-made, non-methane VOC emissions are road transport and solvents (each 38-40% of total) whereas oil industry operations contribute much smaller amounts (8% of total).

3/86 REVIEW OF EUROPEAN OIL INDUSTRY BENZENE EXPOSURE DATA

This review takes the available benzene exposure data for various types of oil industry jobs set against the critical requirements of a 1 ppm 8-hour time-weighted average (TWA) "Action Level" and a 5 ppm 8-hour TWA "Limit Value". It follows the publication of these requirements in the EEC's proposal for a Directive on the "Protection of workers from risks related to exposure to benzene at work". The review shows that with good work practices and use of appropriate control measures, most oil industry employees are well below the proposed 5 ppm "Limit Value". In particular, service station attendants are clearly normally below the 1 ppm "Action Level". In addition, road tanker driver and refinery unit operator exposures are normally below 1 ppm. The report also identifies jobs for which exposures may, under some conditions, exceed 1 ppm.

4/86 RESIDUE HYDRODESULPHURIZATION INVESTMENT AND OPERATING COSTS

Residue hydrodesulphurization (RDS) investment and annual operating costs have been updated to take into account the latest technological developments. More data is provided on RDS for high sulphur vacuum residues which is increasingly displacing atmospheric residue as potential RDS feedstock. RDS technology for cracked residues is still not yet available on a commercial scale. Investment costs are estimated in the range 150-215 \$US (1985) per ton/year of 1% sulphur fuel oil, depending on feedstock quality. Operation of RDS units would incur energy and loss requirements in the range

of 13-19% of 1% sulphur fuel oil. Allowing for the potential credits for conversion into lighter products as a side effect of RDS operation, total price increase to be paid for 1% sulphur over 3.5% sulphur fuel oil to balance RDS costs would lie between 30 and 52 \$US (1985) per ton. Such costs would make fuel oil uncompetitive with low sulphur coal and natural gas. Therefore, investments in RDS cannot be justified.

**5/86 SULPHUR EMISSIONS FROM COMBUSTION OF RESIDUAL FUEL OIL BASED ON
EEC ENERGY DEMAND AND SUPPLY, 1980-2000**

An assessment of the energy consumption and oil combustion related sulphur emissions for 1980-2000 is used as a basis to discuss the possibility of further sulphur emissions reductions and the implications to oil refiners. It is shown that sulphur emissions from inland fuel oil are reduced 57-68% in 2000 versus 1980 as a result of market forces alone. A reduction of inland fuel oil sulphur to (say) 1% would require massive investment (\$US 3-6 x 109) for residue desulphurization (RDS) units. To recover costs would require an average of 38 \$US/ton premium (55 \$US/ton for a refiner unable to take advantage of potential RDS conversion credits) for 1% sulphur fuel oil over 3.5% sulphur fuel oil. This would make fuel oil uncompetitive with low sulphur coal and natural gas, which taken together with the anyway shrinking fuel oil demand, makes large scale investment in RDS units highly unlikely. The more effective and cheaper means to reduce sulphur emissions from oil burning is the application of flue gas desulphurization to large power stations burning high sulphur fuel oil.

6/86 MEASURED DATA ON NO_x EMISSIONS IN EUROPEAN REFINERIES

Oil refineries are responsible for only a very small part of total man-related nitrogen oxides emissions in Europe. In fact recent measurement data provided by CONCAWE member companies has shown that only 1.4% and 1.2% of such emissions arising in OECD-Europe and EEC-10 countries respectively originate from oil refineries. This indicates that the post-1990 emission level reductions previously estimated by CONCAWE in Report No. 9/84 "Contribution of petroleum refineries to emissions of nitrogen oxides" have already been achieved. The conclusion already arrived at are therefore re-stressed, namely that the amount of nitrogen oxides emitted by European oil refineries represents such a small fraction of total man-related nitrogen oxides emissions that they cannot contribute more than a negligible extent to the contamination of the environment.

**2/87 THE HEALTH EXPERIENCE OF WORKERS IN THE PETROLEUM
MANUFACTURING AND DISTRIBUTION INDUSTRY**

A review of health studies of petroleum workers finds lower than average death rates for all causes and all cancers.

As part of its ongoing assessments of health aspects related to European petroleum industry activities and in view of growing interest in the possible health effects of exposure to gasoline, CONCAWE considered it would be valuable to review published studies on the health experience of workers involved in manufacture and distribution of gasoline. An independent epidemiologist, Professor J.M. Harrington, University of Birmingham, UK, was commissioned to make the review which is presented in CONCAWE Report No. 2/87. The review embraced 105 published papers, many of which cover workers involved in manufacture and distribution of other petroleum products in addition to gasoline.

The review reveals inconsistent results which may in part be due to the variable quality of the epidemiological studies. However, there is the consistent finding of lower than average death rates from all causes and all cancers, thus implying that a widespread

serious health effect of gasoline exposure seems remote. The evidence for a link between occupation and health effects is weak but it cannot be ruled out that occupational causes may play a part in the development of brain cancer and renal disease. Further work of better quality is necessary to investigate those diseases where there remains a suspicion of a link.

4/87

A SURVEY OF EXPOSURES TO GASOLINE VAPOUR

During 1984-85 a CONCAWE industrial hygiene task force collected 540 personal gasoline exposure measurements in 13 European countries for workers involved in the manufacture and distribution of gasoline. A new method, developed by CONCAWE, for monitoring exposure to gasoline vapour in air enabled exposures to be quantified and characterised for up to 150 individual components of gasoline vapour for 15 different groups of jobs. The report describes these different jobs and the way in which vapour exposures can occur. Differences in composition between liquid gasoline and vapour are highlighted and the implications of these with respect to a realistic exposure limit for total hydrocarbons in gasoline vapour are discussed.

Establishment of a computer database of the measurements has assisted the preparation of summaries of exposures to total hydrocarbons and several individual components. The report reviews the exposure data for the various job groups and shows that, with the exception of filling drums in the absence of adequate local exhaust ventilation and possibly some marine loading operations (for which only limited data were obtained), 8-hour time-weighted average personal exposures to total hydrocarbons are well below a limit of 1700 mg/m³ calculated from an average gasoline vapour composition. This calculated exposure limit is considered more appropriate than established limits of 900 mg/m³ (ACGIH, USA) and 220 mg/m³ (Sweden); both of these are based on the composition of liquid gasolines which, as this report clearly shows, is very different from the vapour to which exposures occur and to which potential health risks are related.

Similar conclusions to those for total hydrocarbons apply to assessment of exposures to benzene, n-hexane and trimethylbenzenes against established individual limits. For toluene and xylenes, all exposures are well below established limits.

6/87

VOLATILE ORGANIC COMPOUND EMISSIONS IN WESTERN EUROPE: CONTROL OPTIONS AND THEIR COST-EFFECTIVENESS FOR GASOLINE VEHICLES, DISTRIBUTION AND REFINING

In view of the growing interest in Europe in emissions of volatile organic compounds (VOC) which include hydrocarbons, CONCAWE has completed a number of technical studies on the subject.

These studies cover emission inventories, assessment of available control technologies for motor gasoline use and oil industry operations and their cost and cost-effectiveness, i.e. cost per tonne of hydrocarbon reduction.

CONCAWE's inventory of all sources of (non-methane) VOC emissions in Western Europe shows that out of a total of 10 million t/yr man-made emissions, mobile sources and solvents account together for 81%, whereas the oil industry accounts for 6.5%. Natural gas (excluding methane) and a variety of other smaller sources account for the balance. Natural emissions (trees etc.) are about equal to man-made emissions.

With respect to the mobile sources (41% of man-made emissions), the gasoline sector is responsible for 37%. A comparison of controls shows that the greatest emission reduction is obtained by the application of catalysts to vehicle exhaust systems and by

enlarged on-board carbon canisters to collect both evaporative and refuelling emissions.

A reduction of gasoline vapour pressure is a less effective control and is more expensive than on-board devices. "Stage 2" control, i.e. service station vapour recovery for refuelling emissions, is the least effective of the controls studied. The combination of reduced gasoline vapour pressure and "Stage 2" controls still recovers less emissions (2.7%) than on-board vehicle canisters (10%) and is significantly less cost-effective. The equipment to effectively minimize emissions arising from evaporation and combustion of gasolines will create an essentially closed gasoline system. Most importantly, this will enable the gasoline to be geared towards optimum engine performance including fuel economy. Legislation affecting the gasoline specification e.g. in terms of the vapour pressure or the hydrocarbon composition would then be unnecessary.

The solvents sector although identified as a large source of VOC emissions lacks well-documented information on control measures and their costs. Additional efforts in this field are required.

In the Western European oil industry sector, emissions from refineries and distribution sectors represent some 5% of man-made emissions. These emissions can be reduced by a half by a combination of improved refinery maintenance and inspection measures and of "Stage 1" vapour recovery with a cost-effectiveness comparable to that of on-board canisters for reducing evaporative emissions.

10/87 DIESEL FUEL QUALITY AND ITS RELATIONSHIP WITH EMISSIONS FROM DIESEL ENGINES

CONCAWE predicts future (year 2000) diesel fuel properties to be essentially in the range of 43 to 54 cetane number (median value: 48.5) and 0.825 to 0.870 density (median value: 0.846). Compared with present average commercial European diesel fuels this means a drop in cetane number by 2 and an increase in density by 0.006, however the spread in quality remains similar.

Operating costs for the EEC oil industry to compensate for these changes would amount to some \$US 38 to 45 million per year if ignition improvers were employed and \$US 1.3 to 1.7 billion/year if hydrogenation processes were installed. The latter figure is based on capital costs of some \$US 3.5 to 4.5 billion. The ignition improver approach is clearly less expensive than the processing route but it will not change other parameters such as density/aromaticity.

The costs and energy requirements to compensate for the anticipated changes in diesel fuel quality are very high and any improvement in emissions performance of today's engines would be marginal. Updating the diesel engine homologation fuel specification to reflect changes in commercial fuel properties would reliably ensure that certified emissions standards will be met in the field, despite variations in fuel quality. In addition, advances in engine technology, which are already emerging in the USA, represent viable measures for improving the emissions performance of diesel engines.

11/87 EMERGENCY PLANNING GUIDANCE NOTES

These are three of a series of Guidance Notes to be issued by CONCAWE on the general subject of major hazards with specific reference to the implementation of the requirements of the Seveso Directive.

The overall purpose of these Notes is to provide guidance to CONCAWE contributing companies on aspects of the assessment and control of major hazards. The Notes may also assist national Regulatory Authorities in their contacts with the petroleum industry.

The first of the Guidance Notes is "Selecting the Incident Scenarios for Off-Site Emergency Planning". This recommends inclusion of a range of incidents which may occur based on a review of the design of the plant and audit of its operation and maintenance. The second Guidance Note is "Responsibilities of Petroleum Industry and Regulatory Authorities in Off-Site Emergency Planning". This clarifies that the petroleum industry is to provide the information to the authorities who develop the Off-site plan and ensure that it is ready for action. Both parties need to liaise closely. The third Guidance Note is "Information to the Public". This provides advice on the type of information that should be provided during and after an incident and makes recommendations on its dissemination. Additional Guidance Notes in this series are planned for future publication.

3/88 **REGENERATIVE FLUE GAS DESULPHURIZATION COSTS IN EUROPEAN OIL REFINERIES - COST ESTIMATES BASED ON A EUROPEAN APPLICATION**

CONCAWE has studied costs of applying regenerative flue gas desulphurization in European refineries based on actual experience from the Wellman-Lord process in one refinery. It has been necessary to relate the situation there to the more general European refinery situation in order to identify cost influencing items. It appears that the actual application has benefited from a number of favourable aspects such as a large flow of flue gas mainly from fuel oil combustion in a power station, availability of space for retrofitting, spare capacity in relevant process facilities/ utilities e.g. sulphur recovery facilities and the ability to burn available high sulphur refinery liquid fuel. In refineries without these advantages capital costs could be 25-30% higher.

The capital costs of Wellman-Lord FGD in refineries largely determine the total annual costs, 75% being due to the capital charge. The results are summarized in the following table:

Capacity (flue gas 1000 Nm ³ /h)	600		150	
Liquid fuel burnt (t/d)	980		245	
	(actual capacity)		(typical capacity)	
MW _{th} (approx.)	500		125	
Fuel oil sulphur content (% wt)	2.35	3.75	2.35	3.75
Cost \$/t sulphur removed	3300-4200	2100-2700	5600-7000	3500-4400
Cost \$/t liquid refinery fuel burnt	75-95	75-96	125-157	124-157

The cost-effectiveness of sulphur removal from flue gases is significantly better when 3.75% sulphur fuel is burnt instead of 2.35% sulphur fuel. A small plant size, more typical of what could be applied in European refineries, has a significant detrimental effect on sulphur removal cost-effectiveness. When expressing costs per ton liquid refinery fuel, sulphur content has little effect, but plant size has a large effect. The application of Wellman-Lord FGD can more than double the cost of liquid refinery fuel.

5/88 **EMERGENCY PLANNING GUIDANCE NOTES**

- Content of emergency plans
- Planning for mutual aid

The guidance note on "Content of emergency plans" has been prepared to assist refinery and marketing installations in defining those items which should be addressed in on-site emergency plans as well as outlining a recommended format for the emergency manual. In addition, some guidelines for the content of off-site emergency plans are described to help the dialogue with local authorities in making preparations to handle major incidents which may affect the local community;

The guidance note on "Planning for mutual aid" has been prepared to assist refinery and marketing installations in preparing plans for mutual aid in the event of a major accident. Mutual aid agreements are of value to all petroleum operations since they help to extend the reserve of fire fighting and rescue equipment available to any one site. They are especially useful to the operators of terminals and marketing depots where the availability of trained manpower is inevitably much lower than at refinery installations.

6/88 EMERGENCY PLANNING GUIDANCE NOTES- REFINERY EMERGENCY PLANNING

The Guidance Note "Refinery emergency planning" describes emergency organization specifically for oil refineries. The general principles also apply to smaller oil installations such as marketing terminals. A framework for emergency organization is outlined including descriptions of key responsibilities, and some typical actions are highlighted for various emergency cases. The need for training in emergency roles is emphasized and rehearsals of credible event exercises are recommended to ensure readiness.

7/88 IARC 1987 RE-EVALUATION OF CARCINOGENICITY OF MINERAL OILS AND BITUMENS - CONCAWE COMMENTS AND INTERPRETATION

Following the IARC response to CONCAWE comments on their 1987 re-evaluation of carcinogenicity of mineral oils and bitumens, CONCAWE decided that a revised version of Report No. 87/63 should be published in this report. The objective is to ensure that all who may be concerned with carcinogenicity classifications of these petroleum products, including national and international regulatory authorities, are aware of the reasons for the differences between the 1984 and 1987 IARC classifications and of CONCAWE's reservations concerning the revised classifications.

This document reviews important differences between the new and previous evaluations, which are summarized in tabular form, and also indicates how the differences have occurred. In addition, it provides CONCAWE's interpretation of the available evidence, taking into account points discussed with IARC.

2/89 EMERGENCY PLANNING GUIDANCE NOTES

- Training, exercises and rehearsal of emergency plans
- Communications during emergencies

These are two more guidance notes in the CONCAWE Emergency Response Planning series.

The first note is on training, exercises and rehearsal of emergency plans. For an installation's emergency plans to work effectively, the people involved need to be prepared through training, exercises and rehearsal. Also, feedback of information from these activities can be used to develop and improve the plans. This guidance note offers advice on the development of training, exercises and rehearsal for emergency response, and sets out how various aspects can be coordinated through an overall programme. Appendices suggest topics for emergency planning workshops, and

subjects for On-site emergency exercises and emergency response rehearsal (major exercises).

The second note is on communications during emergencies. Effective internal and external communications help ensure efficient marshalling of appropriate resources to the scene and assist the management and control of the emergency. Radio and telephone communications will be high priorities in designing a communications network for an emergency plan. Communication equipment chosen must be suitable for emergency conditions. The note also gives advice on effective ways in which information can be provided to the news media.

4/89 MANAGING SAFETY

Managing safety is an integral and essential part of the total management of a successful enterprise in the oil industry. Company safety policies set the objectives to achieve this, and this report includes an outline of the principles and provides typical aspects of the approach generally adopted. This document has been prepared to contribute to dialogue between industry and authorities on how the oil industry manages safety.

7/89 EMERGENCY PLANNING GUIDANCE NOTE

- Marketing installation emergency planning.

This guidance note highlights aspects that need to be considered when developing emergency plans for oil marketing installations in order to protect life, the environment and property. Whilst the note provides a framework, each operating location needs to make its own contingency plans suited to the local situation, legal requirements, and potential hazards.

Marketing installations vary greatly in size from large terminals to small distribution depots, so that the approach taken must be appropriate to the installation size and type, local resources and manning levels.

An emergency organization is shown, important company responsibilities described, and some typical actions for various emergency cases proposed. A description of potential events and consequences serves to illustrate possible courses of action.

Last, but not least, training is emphasized. For the plan to be effective, key personnel and professionals must be trained in their emergency roles, both individually and as members of a team. Regular simulations of credible events are recommended as the best way of testing the effectiveness of the plan and the readiness of all personnel involved in the plan.

10/89 COSTS TO REDUCE THE SULPHUR CONTENT OF DIESEL FUEL

This study examines the consequences to refineries of making step-wise reductions in the sulphur content of diesel fuel from 0.26 to 0.05% wt. The EC-12's 95 refineries have been grouped into four categories for the purposes of representing process configurations and studying changes using computer LP models.

With reduction of diesel fuel sulphur, increasing amounts of new high pressure (60+ bar) desulphurization capacity would be required. This would increase significantly in the region of 0.10% wt, although this break point differs for different countries and refineries.

To meet 0.05% wt sulphur in diesel fuel for EC-12 over the range of cases studied would require capital expenditure of 3000 to 4300 M\$ and lead to an increase in total manufacturing costs of 12 to 18 \$/t diesel fuel. Some 0.8 to 1 Mt/yr of additional refinery energy consumption would be required to meet the 0.05% rather than the 0.2% wt sulphur content level with a consequent increase in CO₂ emissions.

11/89 A US EXPERIENCE ON HYDROCARBON CONTROLS AT SERVICE STATIONS

This paper was presented by Lee M. Thomas, Chairman and CEO of Law Environmental and former Administrator of the US Environmental Protection Agency (EPA), at the international workshop on refuelling emissions, held in Berlin on 2nd November 1989.

The US government has had 20 years experience with legislation for control of VOC emissions from the gasoline distribution system and gasoline fuelled vehicles. The decision made by some US states in the early 1970s to require Stage I gasoline vapour controls at marketing terminals and service stations, and on-board vehicle evaporative emission controls using small carbon canisters, have proved highly effective. But extending controls at a later date to address vehicle running losses and refuelling emissions has the potential for duplication of effort or application of less effective controls. Only in recent years has the EPA discovered the significance of managing car evaporative emissions, including running losses, and refuelling losses together. The on-board strategy, using enlarged carbon canisters, is the most efficient and cost-effective pollution control option and is safe.

The European Community is at a cross-roads where evaluating the US experience is helpful in finalizing the approach so that advantage can be taken of the on-board system for the cause of environmental protection.

3/90 CLOSING THE GASOLINE SYSTEM - CONTROL OF GASOLINE EMISSIONS FROM THE DISTRIBUTION SYSTEM AND VEHICLES

This report shows that a series of measures effectively closing up the gasoline system of distribution and use in motor vehicles is the preferred strategy to control gasoline emissions. These emissions contribute about 40% to the volatile organic compound (VOC) element of photochemical ozone, and control is being given priority in the EC.

The European Commission is proposing to control gasoline evaporative emissions from cars in the draft directive which sets stringent exhaust

emission limits, requiring 3-way exhaust catalysts for all cars. A further draft directive is expected during 1990 to control emissions from distribution of gasoline from refineries and terminals to service stations.

The effectiveness of each of the main options to control gasoline emissions is examined. Carbon canisters are capable of 90% control of evaporative emissions from parked cars, but full effectiveness depends upon choice of test conditions which realistically represent road fuels and the more testing ambient conditions found.

This leads to the conclusion that the strategy being followed by the Commission should be followed through by taking the opportunity presented by the enlarged on-board carbon canister to control vehicle emissions, giving control of refuelling and evaporative emissions in one step, including running losses.

This strategy is more effective and energy efficient than the alternative of restricting the quality and composition of gasoline. The enlarged carbon canister is the most effective way of achieving the "closed gasoline system".

To underline this conclusion, the effectiveness of the closed system approach is assessed for the control of benzene emissions derived from gasoline. Limiting the benzene content of gasoline would be a much less effective approach.

3/92 THE ENVIRONMENTAL BENEFITS AND COST OF REDUCING SULPHUR IN GAS OILS

This report considers the impact on air quality and on product costs of a possible reduction in maximum sulphur content of heating and marine gas oils to 0.1% by 1999. It also documents a re-evaluation of an earlier CONCAWE study on the cost of reducing diesel fuel sulphur content to 0.05% maximum by 1996.

The environmental effect of reducing sulphur content of heating oil has been studied by CONCAWE in London and Köln. In both cases, the application of the Large Combustion Plant Directive has brought (Köln) or is sufficient to bring (London) the ambient SO₂ levels within the guide values of the EC Air Quality Directive (80/779/EEC). The impact of reducing heating oil sulphur from 0.2 to 0.1% would only contribute 1.5-2 µg/m³ reduction in ambient SO₂ levels, which represents 3-5% of the SO₂ guide value. The corresponding increase in the intensity of refinery processing generates over 20 tons CO₂ for every ton of sulphur removed from heating oil.

A reduction of sulphur content of heating and marine gas oils from 0.2% to 0.1% gives an insignificant improvement in ambient SO₂ levels, increases refinery CO₂ emissions by 1.1 million t/yr and requires investment in new hydrodesulphurization capacity of at least US \$1500 million in 1991 money.

The capital expenditure required to achieve a diesel fuel sulphur content of 0.05% (with heating and marine gas oils at 0.1%) is US \$3500-5000 million, essentially similar to the costs previously found.

1/93 THE EUROPEAN ENVIRONMENTAL AND REFINING IMPLICATIONS OF REDUCING THE SULPHUR CONTENT OF MARINE BUNKER FUELS

Proposals have been put forward within the International Maritime Organization to reduce the level of sulphur dioxide emissions from ships by lowering the limit on the sulphur content of marine bunker fuel. This report presents assessments of the environmental benefit and cost of such a requirement.

The assessment of the environmental contribution of ships to overall sulphur burdens is based on EMEP data provided under the UN-ECE Convention on Long Range Transboundary Air Pollution. Although the quantification of costs is confined to the residue desulphurization process option, the report discusses the alternative options of high sulphur residue conversion and fuel substitution, and loss of European competitiveness in supplying the bunkers market if lower bunker sulphur levels were required solely in Europe. The report also briefly examines the economics of on-board sea-water scrubbing as an alternative route of reducing airborne emissions of sulphur dioxide.

The study indicates that the contribution of SO_x emissions from ships to the total burden on a country is very small (2% or less). However, capital expenditure of between 5.6 and 8.2 billion dollars coupled with an implied price increase of between 46 and 68

dollars per tonne would be required for all European bunker fuel oil to meet a 1.5% sulphur requirement.

The contribution of ship emissions remains low even when considered at a regional level of 150 km x 150 km grid squares. However, capital expenditure of between 2.1 and 3.5 billion dollars coupled with an implied price increase of between 58 and 85 dollars per tonne would be required for captive European bunker fuel oil (some 30% of the total) to meet a 1% sulphur requirement.

2/94 THE CONTRIBUTION OF SULPHUR DIOXIDE EMISSIONS FROM SHIPS TO COASTAL DEPOSITION AND AIR QUALITY IN THE CHANNEL AND SOUTHERN NORTH SEA AREA

The purpose of this report is to present a detailed analysis of the impact of sulphur emissions from ships within the heavily trafficked southern North Sea and Channel as a contribution to the debate on the need to limit the sulphur content of bunker fuels.

The fuel consumed by all shipping in the study area was estimated at 4 Mt/year. This compares to a bunker production in Europe of some 25 Mt/year.

The study clearly identifies in-port emissions as a significant source of ship emissions in the study area with ships in port contributing some 26% of the total emissions from ships. As a consequence, the data presented show that in the major ports of Rotterdam, Europoort, Antwerp and Le Havre, ships make a significant contribution to atmospheric concentrations of sulphur dioxide. In the study area, the contribution of ships operating outside territorial waters was less than 5% of total deposition.

In areas where ship emissions contribute most significantly to overall deposition and air quality, the study indicates that emission reduction measures in just four of the major ports (of the 80 ports in the study area) would offer a greater benefit to the environment than the control of all at-sea ship emissions within the study area. Furthermore, the cost of achieving a unit reduction in deposition in such areas through in-port control is some 10-20% of the cost for control of ships operating outside the 12 mile territorial limit.

6/94 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES AND COMBUSTION OF OIL PRODUCTS IN WESTERN EUROPE (1992)

In a survey covering the year 1992, 84 European refineries, processing about 80% of Western European crude oil throughput, have provided to CONCAWE comprehensive data on sulphur in crude oil, petroleum products and sulphur emissions in air. This is compared with previous surveys covering the years 1979, 1982, 1985 and 1989.

The data for Western Europe as a whole illustrate the following trends:

- Total crude runs since 1979 having fallen back sharply, have been slowly recovering since 1985.
- The percentage of sulphur in crude oil has declined from about 1.4 percent to fractionally more than 1 percent - the lowest point was reached in 1985.
- Sulphur in oil products for combustion has decreased by some 60 percent since 1979.
- Over the period 1979-1992, sulphur recovery in the refineries has been improved from just over 1 Mt/yr (10 percent of the sulphur input) to nearly 1.9 Mt/yr more than 30 percent of input).

- Refinery SO₂ emissions have followed the crude runs pattern; however there has been a steady improvement in relative terms.

The 1992 data collection has been extended to a detailed analysis of sulphur levels in crude oil, groups of major products and the fuel used for refinery furnace firing.

Another important addition to the 1992 survey is the inclusion of data on the distributions of percent sulphur levels in crude oil and major products, with each set of data broken down to show sulphur levels in four selected European regions.

7/94 REVIEW OF EUROPEAN OIL INDUSTRY BENZENE EXPOSURE DATA (1986 - 1992)

This report summarizes over 2,000 occupational exposure data on benzene, measured in the period 1986-1992.

Exposures for the various types of jobs are reviewed against a number of time-weighted (TWA) criteria, including 1 ppm and 0.5 ppm.

Most of the 8-hour TWA exposures were below 1 ppm and 62-100% at, or less than, 0.5 ppm depending on the job being undertaken. The results are similar to those found in a survey conducted in 1977-85.

2/95 ALTERNATIVE FUELS IN THE AUTOMOTIVE MARKET

A review of the advantages and disadvantages of alternative fuels for road transport has been conducted. Based on numerous literature sources and in-house data, CONCAWE concludes that:

- Alternatives to conventional automotive transport fuels are unlikely to make a significant impact in the foreseeable future for either economic or environmental reasons.
- Gaseous fuels have some advantages and some growth can be expected. More specifically, compressed natural gas (CNG) and liquefied petroleum gas (LPG) may be employed as an alternative to diesel fuel in urban fleet applications.
- Bio-fuels remain marginal products and their use can only be justified if societal and/or agricultural policy outweigh market forces.
- Methanol has a number of disadvantages in terms of its acute toxicity and the emissions of "air toxics", notably formaldehyde. In addition, recent estimates suggest that methanol will remain uneconomic when compared with conventional fuels.

3/95 A SURVEY OF EUROPEAN DIESEL FUEL QUALITY

CONCAWE has conducted a survey of diesel fuel quality in fifteen European countries. Over 1300 samples were collected in the period 1991-1993 and analysed. This report summarizes the findings by country. Only limited data were available for fuel composition and are presented in a separate appendix.

6/95 EFFECT OF PRODUCT QUALITY CHANGES ON ENERGY CONSUMPTION AND CO₂ EMISSIONS FROM EUROPEAN REFINERIES

This report quantifies the impact of demand and product quality changes on refinery energy consumption, and therefore CO₂ emissions, covering the period from 1980 through to 2010.

Refinery energy consumption remained relatively constant during the period 1980 to 1990 as investment in conservation measures compensated for increases due to additional processing for product quality and demand changes. This situation will not be mirrored in the period 1990 to 2010. Refinery specific energy consumption is forecast to grow by 50% to 75% by the year 2010, from 5.8% to between 8.7% and 10.2% of refinery intake, to meet future product quality and demand changes with limited economic opportunities for further energy conservation.

Absolute CO₂ emissions are very dependent on the product demand projections and therefore refinery intake. In the two scenarios evaluated, CO₂ emissions by the year 2010 are forecast to range from 98 Mt/yr to 156 Mt/yr, an increase of between 4% and 65% on 1990 levels.

5/96 COLLECTION AND DISPOSAL OF USED LUBRICATING OIL

This report covers all aspects of used oil generation and disposal in Western Europe for the year 1993. From a study of the amounts of lubricating oil sold, the amount that is theoretically recoverable, and the records of the quantity of used oil collected, it concludes that the fate of some 1.1 million tonnes of used oil is unknown. This represents ca. 20% of the total virgin lubricating oils market.

The report considers the various ways of disposing of used oil and compares their environmental impacts. Both burning and re-refining options are considered and are compared from both the technical and economic aspects. It is concluded that a variety of burning and re-refining options can be technically acceptable and have similar health considerations as for the petroleum products that they would replace.

An economic assessment shows that none of the acceptable disposal options are economically self-sufficient when collection costs are included. An overall ranking of the options has not been made as this would require a full Life Cycle Analysis which is not the purpose of this report. However, the assessment shows that the differences between the various acceptable options are small in terms of both economic and energy efficiency and that the ranking may vary with local circumstances.

3/97 TASK RISK ASSESSMENT

Task Risk Assessment (TRA) is presented, what it is and how it is used in the petroleum industry. Typical techniques are covered with respect to the area of business (upstream/refining/marketing/retail) and the extent of risk exposure. The selection of the appropriate process is explained. The techniques described include verbal and written procedures, the written ranging from simple proformas to qualitative tabular and matrix methods. Examples are given.

This review of TRA has been prepared to publicize to a wider audience how the petroleum industry procedures are controlling the risk to their workers, also meeting the intent of the Framework Directive 89/391/EEC.

6/97 MOTOR VEHICLE EMISSION REGULATIONS AND FUEL SPECIFICATIONS PART 2 – DETAILED INFORMATION AND HISTORIC REVIEW (1970-1996)

This report details the development of world-wide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption from circa 1970 to 1996. It describes legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes and legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions, plus automotive fuel specifications and fuel characteristics.

This comprehensive work of reference should be read in conjunction with Part 1, which has been issued as a separate volume. Part 1 summarises the most important legislation, either in place or shortly to be enacted. It is therefore intended that Part 1 will be updated annually, whereas this report - which reviews the history of automotive emissions legislation - will be revised at appropriate, longer term intervals.

1/98 METHODS OF PREVENTION, DETECTION AND CONTROL OF SPILLAGES IN EUROPEAN OIL PIPELINES

This report gives information on the measures which are used to ensure safe operation of industry pipelines in Western Europe related to the causes of spillages. The result of the application of these measures has been a very low level of spillage over the 25 years that CONCAWE has collected statistics.

3/98 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES AND COMBUSTION OF OIL PRODUCTS IN WESTERN EUROPE AND HUNGARY (1995)

The CONCAWE survey for year 1995 examines the sulphur balances of European oil refineries and the sulphur contents of oil products. Comparisons are made with data from the 1992 CONCAWE survey.

Data are included on the distribution of sulphur levels in the major product groups to allow assessment of the impact of regulatory measures.

Compared with 1992, there was a significant decrease in sulphur in combustion products with a corresponding increase in sulphur recovered by refineries.

To provide further continuity with the 1992 report, some data are broken down to show the situation in four different European regions.

4/98 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE – STATISTICAL SUMMARY OF REPORTED INCIDENTS – 1997 AND OVERVIEW 1993 TO 1997

This report is the fourth by CONCAWE reviewing the safety performance of the downstream oil industry in Western Europe. It includes the results of 27 companies which together represent over 90% of the oil refining capacity in the region. Of the 27 companies, 18 gave data for both contractors and employees. It is therefore a representative sample of the industry. However, as the data for some companies is incomplete, the most important results are quoted as frequencies.

The data covers the year 1997 and is also aggregated for the five year period 1993 to 1997. Overall, the reported hours worked by company staff and contractors combined were about 440 million with an average Lost Workday Injury Frequency (LWIF) of 4.6 which is very similar to those reported in previous years which ranged from 4.0 to 4.7.

A range of other measures of safety performance are also reported. The responsible management of safety in the oil industry has resulted in a low level of accidents compared to other industries in Europe despite the intrinsic hazards of the materials handled and the operations carried out.

In general, the safety performance for the companies reporting was similar in 1997 to the performance reported previously for 1993 to 1996.

5/98 A SURVEY OF EUROPEAN GASOLINE QUALITIES – SUMMER 1996

CONCAWE has conducted a new survey of gasoline qualities in sixteen European countries. Over 1100 samples were collected in the summer period 1996 and analysed. This report summarises the findings by country.

7/98 THE SEVESO II DIRECTIVE AND THE OIL INDUSTRY (TO BE PUBLISHED SHORTLY)

This report has been prepared in order to give guidance to the management of sites in the oil industry on the interpretation of the Seveso II (or COMAH) Directive. Emphasis has been put on differences with the Seveso I Directive. A number of items were selected and worked out in more detail, and in some cases completed with examples. This guidance is based on the provisions of the Directive itself. As the Directive is implemented in the member states (due in February 1999), more information will become available in the different member states from other kinds of industries, professional organisations, competent authorities, etc. which might also be helpful in the interpretation and final implementation of this Directive.

1/99 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE – STATISTICAL SUMMARY OF REPORTED INCIDENTS – 1998

This report is the fifth by CONCAWE reviewing the safety performance of the downstream oil industry in Europe. The area of coverage is primarily the EU, EEA and Hungary, but for some companies the data for other European countries such as Poland, Czech Republic, Turkey, etc. is included. The report includes the results of 27 companies which together represent over 90% of the oil refining capacity in the region. This is the same number as last year but includes one company reporting for the first time. This was compensated by the merger of two companies who this year returned a combined report. Of the 27 companies, 21 gave data for both contractors and employees. It is therefore a representative sample of the industry. However, as the data for some companies is incomplete, all results are quoted as frequencies.

The data covers the year 1998 and is compared with the averages for the five year period 1993 to 1997. Overall, the reported hours worked by company staff and contractors combined were about 470 million with an average Lost Workday Injury Frequency (LWIF) of 4.5 which is very similar to those reported in previous years which ranged from 4.0 to 4.7, and with the average for the years 1993 to 1997 of 4.5. However, it is lower than for any of the previous year's figures apart from 1994 when only 17 companies reported.

A range of other measures of safety performance are also reported. The responsible management of safety in the oil industry has resulted in a low level of accidents compared to other industries in Europe despite the intrinsic hazards of the materials handled and the operations carried out. In addition, nearly all the fatalities reported were unconnected with these hazardous properties and mainly resulted from road accidents and criminal actions.

In general, the safety performance for the companies reporting was similar (and if anything, slightly better) in 1998 to the performance reported previously for 1993 to 1997.

2/99 ENVIRONMENTAL EXPOSURE TO BENZENE

A review is provided of the health risks from environmental exposure to benzene. Sources and levels of benzene exposure of the general public have been identified from literature. Model calculations are presented of the daily absorbed dose of benzene for different activity patterns. The possible influence of changing benzene levels due to legislative measures on the daily absorbed dose is estimated.

1/00 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE - STATISTICAL SUMMARY OF REPORTED INCIDENTS - 1999

This report is the sixth by CONCAWE reviewing the safety performance of the downstream oil industry in Europe. The area of coverage is primarily the EU, EEA and Hungary, but for some companies the data for other European countries such as Poland, Czech Republic, Turkey, etc. are included. The report includes the results of 21 companies which together represent a large majority of the oil refining capacity in the region. This is six less companies than last year and results from five companies not being able to supply usable data and the merger of two others. Of the 21 companies, 17 gave data for both contractors and employees. It is therefore a representative sample of the industry. However, as the data for some companies is incomplete, all results are quoted as frequencies.

The data covers the year 1999 and is compared with the averages for the previous five year period 1994 to 1998. Overall, the reported hours worked by company staff and contractors combined were about 450 million with an average Lost Workday Injury Frequency (LWIF) of 4.3. This is slightly lower than the average for the years 1994 to 1998 which was 4.5. It is also lower than for any of the figures reported for previous years apart from 1994 when only 17 companies reported.

A range of other measures of safety performance are also reported. The responsible management of safety in the oil industry has resulted in a low level of accidents compared to other industries in Europe despite the intrinsic hazards of the materials handled and the operations carried out. In addition, all the fatalities reported were unconnected with these hazardous properties and resulted from road accidents or construction and maintenance activities.

In general, the safety performance for the companies reporting was slightly better in 1999 than the performance reported previously for 1993 to 1998. In particular, the number of fatalities reported was at the all time low of eight.

2/00 A REVIEW OF EUROPEAN GASOLINE EXPOSURE DATA FOR THE PERIOD 1993-1998

This report presents data on over 5000 personal gasoline exposure measurements taken in European countries in the period 1993-1998. The majority of the data were generated by CONCAWE member companies as part of routine occupational hygiene programmes, but relevant literature data are also included. The exposure measurements covered both airborne breathing zone concentrations and biological monitoring of gasoline components. The data are presented as arithmetic means and ranges for full work shift and short-term (< 1 hour) exposures for a range of jobs in the production, distribution, retail and use of gasoline. Changes in exposures over time are evaluated.

This report updates information provided in CONCAWE Report 4/87.

**3/01 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE
STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2000**

The seventh such report by CONCAWE, this issue includes own employees as well as contractor data for the year 2000 from 20 companies (representing some 90% of the European refining capacity) and primarily covers the EU, EEA and Hungary. The data is reported in terms of Lost Workday Injury Frequency (LWIF) as well as a range of other metrics. It is compared with the averages for the previous five-year period 1995 to 1999 and also to similar statistics from related industries as well as general EU figures. The improvement trend continues as illustrated by the 2000 Lost Workday Injury Frequency (LWIF) which at 4.2 is slightly lower than the average for the years 1995 to 1999 (4.5). The responsible management of safety in the oil industry has resulted in a low level of accidents compared to other industries in Europe despite the intrinsic hazards of the materials handled and the operations carried out. In addition, all the fatalities reported were unconnected with these hazardous properties and resulted from road accidents or construction and maintenance activities.

**1/02 WESTERN EUROPEAN CROSS-COUNTRY OIL PIPELINES 30-YEAR
PERFORMANCE STATISTICS**

CONCAWE has collected 30 years of performance data on Western European cross-country oil pipelines, which currently comprise 30.8 thousand km transporting 672 million m³ per year of crude oil and oil products. This report shows how the pipeline system reported on has developed. The data on safety-related incidents are reported and the levels and trends of spillage incidence, gross and net spillage volumes and the significant features of individual cause categories: mechanical failure, operational, corrosion, natural hazard and third party. The pipeline system has always been considered to be a safe and reliable way of transporting oil in bulk. Most European pipeline spillages are small and effects are generally localised and temporary. Moreover, integrity is on an improving trend with spillage frequency over the period reduced from 1.2 to 0.25 spillages per 1000 km of pipeline. Subject to continuing performance monitoring and the use of improved and new techniques such as internal inspection using intelligence pigs, safe and reliable operation of the pipelines should remain possible for the foreseeable future.

**2/02 ENERGY AND GREENHOUSE GAS BALANCE OF BIOFUELS FOR EUROPE - AN
UPDATE**

Recent literature publications have been used to estimate the energy and greenhouse gas balance of the most relevant biofuels in Europe, i.e. ethanol and Rapeseed Methyl Ester (RME). The potential for biofuels to substitute conventional fuels on the basis of available land is also discussed.

**4/02 EVALUATION OF DIESEL FUEL CETANE AND AROMATICS EFFECTS ON
EMISSIONS FROM EURO-3 ENGINES**

Following EPEFE, the influence of two important diesel fuel quality parameters on emissions remained under debate. These were the difference (if any) between natural and additive-derived cetane and the influence of aromatics content. Another key issue was how emissions from more modern engines would be influenced by fuel quality. CONCAWE has therefore conducted a rigorous test programme to examine exhaust emissions from 3 light-duty vehicles and 2 heavy-duty engines representing Euro-3 technology levels. Two fuel matrices were tested to evaluate the influence of cetane (natural and improved) and aromatics (mono- versus poly-).

Fuel effects were generally small compared to engine technology effects and test variability. Despite the rigorous test design, statistically significant fuel effects were difficult to identify. Increasing cetane number had no significant effect on NO_x or PM, but directionally reduced emissions of HC and CO. Cetane trends did not differentiate between natural and additive-derived cetane. Aromatics effects were small and showed variation between vehicles.

5/02 AMENDED SAFETY DATA SHEET DIRECTIVE (2001/58/EC)

This report outlines the requirements of the amended EU Safety Data Sheet Directive and reviews the implications for the oil industry. A copy of the amended Safety Data Sheet Directive is included as an appendix.

6/02 VOC EMISSIONS FROM LOADING GASOLINE ONTO SEA-GOING TANKERS IN EU-15: CONTROL TECHNOLOGY AND COST-EFFECTIVENESS

This report updates the earlier CONCAWE report 92/52. It provides revised estimates for the cost and cost-effectiveness of sea-going tanker gasoline loading VOC emission controls. These measures comprise both modifications to the ships to permit vapour collection and installation of VOC emission control systems at the loading terminals.

About 45 Mt of gasoline are loaded at 60 marine terminals in the EU-15. It is estimated that the fleet of tankers comprises 1250 vessels. VOC emissions from these loading operations are estimated to be 12,575 t/a, equivalent to approximately 0.13% of the total man-made VOC emissions in 2000.

Total costs to control VOC emissions during gasoline loading of sea-going tankers are estimated at 575 MEUR. These costs comprise 282 MEUR to install vapour emission controls at the 60 terminals and 293 MEUR conversion costs for the tanker fleet.

The overall cost-effectiveness of VOC emission controls would be in the range of 4840 EUR/t emissions abated to over 30,000 EUR/t abated as the terminal throughput decreases. Marine gasoline loading VOC emission controls would not be justified on cost-effectiveness grounds even for the very largest throughput terminals.

7/02 ASSESSMENT OF PERSONAL INHALATION EXPOSURE TO BITUMEN FUME - GUIDANCE FOR MONITORING BENZENE-SOLUBLE INHALABLE PARTICULATE MATTER

This report discusses practical issues in relation to the assessment of occupational exposure to bitumen fume as benzene-soluble inhalable particulate matter. A detailed sampling and analytical method is presented. This report supersedes guidance given previously by CONCAWE in report 6/84.

8/02 METHOD FOR MONITORING EXPOSURE TO GASOLINE VAPOUR IN AIR - REVISION 2002

An overview is provided of practical issues in relation to the assessment of occupational exposure to gasoline vapour, determined via complete compositional analysis. A detailed sampling and analytical method is presented. This report replaces guidance given previously by CONCAWE in report 8/86.

9/02 A SURVEY OF EUROPEAN GASOLINE EXPOSURES FOR THE PERIOD 1999-2001

This report presents data on measured occupational exposures to gasoline vapour in European Union countries in the period 1999-2001. The exposure measurements were taken in order to complement an earlier review of recent exposure data for the period of 1993-1998, published as report 2/00. The surveyed operations were selected on the basis of past high exposures, newly implemented vapour recovery measures, or a general lack of information. In addition to inhalation exposures, analytical data are presented on composition of the gasolines handled during the monitored work activities. Most of the surveyed operations covered gasoline according to product specifications in force after 1 January 2000, when the maximum content of benzene in gasoline was reduced to 1% by volume.

10/02 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES AND COMBUSTION OF OIL PRODUCTS IN WESTERN EUROPE AND HUNGARY (1998)

This report examines the sulphur balances of European oil refineries and the sulphur contents of oil products based on a CONCAWE survey of 1998 actual data. Comparisons are made with data from the previous CONCAWE surveys of 1992 and 1995. The distribution of sulphur content between the major oil products groups is highlighted to allow assessment of the impact of regulatory sulphur reduction measures.

Confirming the trend observed since 1992, there is a continuous significant decrease in the sulphur content of petroleum fuels and with a corresponding increase in the quantity of sulphur recovered by refineries.

To provide further continuity with the previous reports, some data are broken down to show the situation in four different European regions.

1/03 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES STATISTICAL SUMMARY OF REPORTED SPILLAGES - 2001

The performance in 2001 of 35,545 km of on-shore oil pipelines in Europe is reported with regards to hydrocarbon spillage. Incidents are analysed by cause and the effectiveness of the clean up is recorded. The inventory of European oil pipelines covered by this annual report has been increased by 4800 km with the inclusion of data for Czech Republic, Hungary and Slovakia. Direct repair and clean-up costs are reported. Performance in 2001 was again better than the long-term average. Third party activities remain the main cause of spillage incidents. The report also gives the annual intelligence pig inspection statistics.

2/03 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2001

The eighth such report by CONCAWE, this issue includes own employees as well as contractor data for the year 2001 from 19 companies (representing some 90% of the European refining capacity) and primarily covers the EU, European Economic Area (EEA) and Hungary. The data is reported in terms of Lost Workday Injury Frequency (LWIF) as well as a range of other metrics. It is compared with the averages for the previous five-year period 1996 to 2000 and also to similar statistics from related industries as well as general EU figures. The improvement trend continues as illustrated by the 2001 Lost Workday Injury Frequency (LWIF) which at 4.3 is slightly lower than the average for the years 1996-2000 (4.5). The responsible management of safety in the oil industry has resulted in a low level of accidents compared to other industries in Europe despite the intrinsic hazards of the materials handled and the operations carried

out. There were 14 fatalities reported this year, one more than for 2000. However, none of these fatalities were caused by fire and hence related to the flammable properties of the materials handled.

3/03 EUROPEAN OIL INDUSTRY GUIDELINE FOR RISK-BASED ASSESSMENT OF CONTAMINATED SITES (REVISED)

This report proposes a three-tiered approach to assessing the nature and extent of the contamination of soil and groundwater at oil industry sites and implementing corrective action. Such sites range from complex refineries down to retail service stations. The nature and extent of contamination range from major to insignificant while the potential for exposure of own workers or third parties also varies enormously. The principle of the approach is to tailor corrective action to site-specific conditions and hazards (risk-based corrective action). This leads to more cost-effective solutions, and allows the greatest effort to be targeted to where it is most beneficial.

This report updates and expands CONCAWE report 2/97. In particular it includes appendices including a number of discussion papers on technical and policy issues which should be of interest and value to regulators and their technical staff developing or reviewing risk-based strategies for the remediation of contaminated land and water.

4/03 THE IPPC DIRECTIVE, REFINERY BREF, AND EUROPEAN REFINERIES - A GUIDANCE MANUAL

This report has been prepared as a guidance manual for refining environmental and planning personnel who must prepare for the permitting and operational implications of the IPPC regulations which become applicable to existing operations in October 2007. New operations must already comply. The IPPC regulations have to be interpreted and enacted into national legislation and detailed compliance will vary from country to country. A common resource for relevant technical information will be the series of Reference documents for Best Available Techniques (BREF documents) prepared by the European Integrated Pollution Prevention and Control Bureau (EIPPCB) in Seville.

This guidance manual introduces the IPPC Directive and BREF document relevant to mineral oil and gas refineries. It aims to clarify critical points and to provide checklists of actions and debating points that those responsible for advocacy, refinery operations, permitting, and/or planning can use in preparing to most effectively manage the IPPC permitting process in their country and at their site.

5/03 FUEL EFFECTS ON EMISSIONS FROM MODERN GASOLINE VEHICLES PART 1 - SULPHUR EFFECTS

The influence of gasoline quality on exhaust emissions has been evaluated using four modern European gasoline cars with advanced technologies designed to reduce fuel consumption and CO₂ emissions, including stoichiometric direct injection, lean-burn direct injection and variable valve actuation. This report (part 1) describes the short-term sensitivity of the four cars to gasoline sulphur content. Part 2 of this report will describe the influence of other fuel effects (aromatics, olefins, volatility and FBP).

All four cars achieved very low emissions levels, with some clear differences between the vehicle technologies. Even at these low emissions levels, all four cars showed very little sensitivity to gasoline sulphur content. The results were also compared with other studies that had suggested higher sensitivity at low emissions levels. Overall it is concluded that low emissions can be achieved without significant short-term sensitivity to fuel sulphur and that sulphur sensitivity is principally influenced by catalyst system design rather than emissions level.

6/03 A GUIDE FOR REDUCTION AND DISPOSAL OF WASTE FROM OIL REFINERIES AND MARKETING INSTALLATIONS

This guide has been written primarily for those in the oil refining and marketing industry who have responsibility for the management of waste and its disposal. It should also provide useful information to the authorities who exercise legal control over these activities.

The guide lists the types of wastes commonly encountered in the industry and highlights techniques for minimising the quantities generated. Guidance is given on the methods of pre-treatment and disposal, together with information on how to select and monitor waste facilities and contractors, to ensure a high quality and safe disposal operation.

Information is also provided on documentation and labelling of waste cargoes and reference is made to legislation and sources of additional information.

While use of the guide cannot guarantee a problem-free operation, it will minimise the risks involved in disposal of waste materials from oil industry installations.

1/04 CHRONIC TOXICITY STUDIES ON WHITE OILS

This report summarises the results of experimental studies undertaken to investigate the chronic toxicity and carcinogenic potential of two highly refined mineral white oils of medium and high viscosity. The studies were commissioned to support regulatory submissions on the safe use of mineral hydrocarbons in direct food and food contact applications.

Results are presented and discussed and a proposal is made for a No Observed Adverse Effect Level.

2/04 FUEL EFFECTS ON EMISSIONS FROM MODERN GASOLINE VEHICLES PART 2 - AROMATICS, OLEFINS AND VOLATILITY EFFECTS

The influence of gasoline quality on exhaust emissions has been evaluated using four modern European gasoline cars with advanced engine technologies/after-treatment systems. Part 1 of this report described the short-term sensitivity of these four cars to gasoline sulphur content. This report describes the influence of other fuel effects: aromatics, olefins, volatility and final boiling point.

Emissions from the test vehicles were all very low, in compliance with the appropriate Euro-3 or Euro-4 emission limits. The measured effects of fuel changes on the regulated emissions: NO_x, HC and CO, were small and often conflicting, with differing directional responses for different vehicles and emissions.

The three direct injection cars emitted higher levels of particulate mass (PM) than the advanced MPI car, although much lower than the Euro-4 diesel PM emission limit. Response to fuel effects was similar in the three direct injection cars. PM emissions from the advanced MPI car, which is more representative of the current fleet, were very low on all fuels tested and insensitive to fuel changes.

3/04 GASOLINE VOLATILITY AND ETHANOL EFFECTS ON HOT AND COLD WEATHER DRIVEABILITY OF MODERN EUROPEAN VEHICLES

A joint test programme has been carried out by CONCAWE and GFC to evaluate the impact of gasoline volatility and ethanol on the driveability performance of modern

European vehicles. Eight vehicles, three with DISI fuel systems and five with MPI, were tested for hot driveability performance. The same eight vehicles were tested for cold driveability, although only a subset of four vehicles was tested in depth. The latest test procedures developed by GFC were used for both hot (20, 30 and 40°C) and cold (+5 and -10°C, representative of moderate winter conditions) weather testing on climate controlled chassis dynamometers. A matrix of four hydrocarbon test fuels at two levels of DVPE and E70 was blended for the hot weather testing, and three fuels with varying E100 but essentially parallel distillation curves for the cold weather tests. For each hydrocarbon fuel, two other fuels containing 10% ethanol were tested, one splash blend and one with matched volatility. Some tests were also carried out using 5% ethanol fuels made by blending the hydrocarbon and 10% ethanol fuels.

This report describes the results obtained for both hot and cold weather driveability.

5/04 OCCUPATIONAL HEALTH AUDITING

This document describes an approach to occupational health auditing, intended to meet the needs of CONCAWE member companies. It includes examples of typical questions and model answers on which an appropriate questionnaire for any location or activity may be based. It incorporates the slightly revised material of report 99/58 (Occupational health auditing (1): occupational hygiene) and has been extended to include occupational medicine elements. This report replaces report 99/58.

6/04 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2002

The ninth such report by CONCAWE, this issue includes statistical work accident data for the downstream oil industry's own employees as well as contractors for the year 2002. Data was received from 17 companies representing around 80% of the European refining capacity and essentially covering the EU, European Economic Area (EEA), and Hungary. Trends over the last ten years are highlighted and the data is also compared to similar statistics from related industries as well as general EU figures.

7/04 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES STATISTICAL SUMMARY OF REPORTED SPILLAGES - 2002

This annual report covers the performance with regards to hydrocarbon spillage of 35,592 km of on-shore oil pipelines in Europe in 2002. Incidents are analysed by cause and the effectiveness of the clean up is recorded. Direct repair and clean-up costs are reported. The inventory of European oil pipelines covered by this annual report is essentially the same as for the 2001 exercise. Performance in 2002 was marginally better than the long-term average. Third party activities remain one of the main causes of spillage incidents, although this year, corrosion caused a slightly larger number of incidents. The report also gives the annual intelligence pig inspection statistics.

8/04 EUROPEAN EPIDEMIOLOGY STUDIES OF ASPHALT WORKERS - A REVIEW OF THE COHORT STUDY AND ITS RESULTS

An overview is provided of the first set of results of an epidemiology study program on asphalt workers in selected European countries. This report contains a brief description of the study, its methodology and results.

10/04 GUIDANCE DOCUMENT FOR APPLICATION OF THE EU COMMISSION'S GUIDELINES FOR MONITORING AND REPORTING OF GHG EMISSIONS

This document was prepared by a CONCAWE ad hoc group to address concerns from a number of member companies with regards to the level of uncertainty implied by the EU Commission's Guidelines for monitoring and reporting of GHG emissions.

It is intended for use by member companies and their national associations in order to assist them in their negotiations with national and local Authorities on this matter.

11/04 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2003

The tenth such report by CONCAWE, this issue includes statistical work accident data for the downstream oil industry's own employees as well as contractors for the year 2003. Data was received from 18 companies representing over 80% of the European refining capacity. Trends over the last eleven years are highlighted and the data is also compared to similar statistics from related industries as well as general EU figures.

12/04 METHOD FOR MONITORING EXPOSURE TO LPG CONTAINING SMALL AMOUNTS OF 1,3-BUTADIENE

The validation of a sampling and analytical methodology is described for occupational exposure monitoring of liquefied petroleum gas (LPG) and its components including trace amounts of 1,3-butadiene. A detailed sampling and analytical method is included.

1/05 FUEL EFFECTS ON THE CHARACTERISTICS OF PARTICLE EMISSIONS FROM ADVANCED ENGINES AND VEHICLES

To update understanding on emissions from road transport, CONCAWE is continuing to assess fuel effects on emissions from new engine/vehicle technologies as they approach the market. In this work, two advanced light-duty diesel vehicles, two direct injection gasoline vehicles, and three heavy-duty diesel engines covering Euro-3 to Euro-5 technologies were tested on a range of fuels.

This report concentrates on the fuel and engine technology effects observed on a range of individual characteristics of the particulate emissions, measured as part of CONCAWE's contribution to the larger DG TREN 'Particulates' Consortium. In addition to regulated mass, the total number, surface area and size distribution of the particulate emissions have also been measured.

Results for regulated emissions and fuel consumption for the diesel engines and vehicles are described in the companion CONCAWE report 2/05.

2/05 FUEL EFFECTS ON EMISSIONS FROM ADVANCED DIESEL ENGINES AND VEHICLES

To update understanding on emissions from road transport, CONCAWE is continuing to assess fuel effects on emissions from new engine / vehicle technologies as they approach the market. In this work, two advanced light-duty diesel vehicles and three heavy-duty diesel engines covering Euro-3 to Euro-5 technologies were tested on a wide range of fuels.

This report describes the results for the regulated emissions, HC, CO, NO_x and PM, as well as CO₂ and fuel consumption. The detailed particulates characterisation (size and number measurements) is covered in the companion CONCAWE report 1/05.

**3/05 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES
STATISTICAL SUMMARY OF REPORTED SPILLAGES - 2003**

This annual report covers the performance with regards to hydrocarbon spillage of 36,422 km of on-shore oil pipelines in Europe in 2003. Incidents are analysed by cause and the effectiveness of the clean up is recorded. Direct repair and clean-up costs are reported. The inventory of European oil pipelines covered by this annual report is similar to that for the 2002 exercise with the addition of product pipelines in Slovakia. Performance in 2003 was better than the long-term average. Third party activities remain one of the main causes of spillage incidents, with all but one of the spillages this year resulting from this cause. The report also gives the annual intelligence pig inspection statistics.

**4/05 EVALUATION OF AUTOMOTIVE POLYCYCLIC AROMATIC HYDROCARBON
EMISSIONS**

CONCAWE has measured PAH emissions from a range of vehicles and fuels. For diesel vehicles, the relationship between fuel poly-aromatics content and PAH in exhaust emissions has been examined. The programme focused on the US EPA's Priority Pollutant list of 16 polycyclic aromatic hydrocarbons (PAH) and both particulate-bound and vapour phase PAH were measured.

In older technology diesel vehicles, reducing fuel poly-aromatics content gave lower PAH emissions, although reducing fuel poly-aromatics content even to zero would not eliminate PAH emissions, as a significant proportion of the total PAH emissions is combustion derived.

The improvements with advanced emissions control systems were impressive. Modern three-way catalyst (TWC) gasoline cars all gave very low PAH emissions. In the newer technology diesel vehicles with effective exhaust after-treatment, either oxidation catalysts or diesel particulate filters, PAH emissions were so low that there was no longer any sensitivity to fuel poly-aromatics content. The advances in exhaust after-treatment, which are being implemented for the control of total hydrocarbon and particulate emissions, are clearly effective in also controlling PAH emissions.

**5/05 FACTORS POTENTIALLY AFFECTING THE HEARING OF PETROLEUM
INDUSTRY WORKERS**

This report aims at giving an overview of the various factors that may influence the hearing of petroleum industry workers, including the issue of 'ototoxic' chemical exposure. It also provides guidance for occupational physicians on factors that need to be considered as part of health management programmes.

**7/05 IMPACT OF A POTENTIAL REDUCTION OF THE POLY-AROMATICS CONTENT
OF DIESEL FUEL ON THE EU REFINING INDUSTRY**

The cost and CO₂ emissions associated with the reduction of poly-aromatics (PAH) in the EU diesel fuel have been evaluated using the CONCAWE EU refining model.

A reduction of the diesel fuel PAH specification below 8% m/m would require investment in EU refineries up to nearly 9 G€ at 1% m/m. This would also cause

refineries to emit additional CO₂, up to 15.9 Mt/a for a 1% m/m limit corresponding to an increase of over 10% of the total refinery emissions in the reference case.

8/05 THE IMPACT OF REDUCING SULPHUR TO 10 PPM MAX IN EUROPEAN AUTOMOTIVE FUELS - AN UPDATE

The cost and CO₂ emissions associated with the reduction of sulphur in EU road fuels have been evaluated using the CONCAWE EU refining model. The results are compared to those of a similar study carried out in 2000.

In order to reduce sulphur in road fuels to less than 10 ppm, the EU refining industry is set to invest some 7 G€ while increasing its CO₂ emissions by 7.3 to 9.2 Mt/a. This is in addition to about the same investment and a CO₂ emissions increase of 13Mt/a to meet demand evolution.

10/05 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2004

The eleventh such report by CONCAWE, this issue includes statistics on work-related personal injuries for the downstream oil industry's own employees as well as contractors for the year 2004. Data was received from 18 companies representing over 80% of the European refining capacity. Trends over the last twelve years are highlighted and the data is also compared to similar statistics from related industries.

1/06 HUMAN EXPOSURE INFORMATION FOR EU SUBSTANCE RISK ASSESSMENT OF GAS OILS

Information is presented on inhalation and dermal exposures to gas oils for workers in European manufacturing and distribution operations and for consumers, for use in substance risk assessment according to EU regulations. Similar, but more limited, information is also presented for exposures resulting from the use of gas oils by workers outside the oil industry.

2/06 TECHNO-ECONOMIC ANALYSIS OF THE IMPACT OF THE REDUCTION OF SULPHUR CONTENT OF RESIDUAL MARINE FUELS IN EUROPE

Annex VI of the IMO's MARPOL convention is coming into force in 2006 for the Baltic Sea and 2007 for the North Sea, imposing a 1.5% m/m sulphur cap on residual marine fuel (RMF) burned in these areas. At the same time EU Directive 2005/33/EC will further extend the 1.5% cap to ferries operating from and to an EU port. These provisions are subject to further review in the near future, opening the possibility of further sulphur reductions. In this context CONCAWE undertook a study to evaluate the impact of these measures on EU refineries and the consequences for RMF cost. The study concludes that, faced with the prospect of desulphurising residual streams, refiners would have a clear incentive for full conversion. This would push the price of low sulphur RMF well beyond the costs related to desulphurisation, close to the price of gasoil.

3/06 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES STATISTICAL SUMMARY OF REPORTED SPILLAGES - 2004

This annual report covers the performance with regards to hydrocarbon spillage of 35,383 km of on-shore oil pipelines in Europe in 2004. Incidents are analysed by cause and the effectiveness of the clean up is recorded. Direct repair and clean-up costs are reported. The inventory of European oil pipelines covered by this annual report is similar to that covered in 2003. Performance in 2004 was significantly better than both the

2003 performance and the long-term average performance. This year, mechanical failure caused more accidents than third party activities although the latter caused the highest spillage volume. The report also gives the annual intelligence pig inspection statistics.

4/06 ANALYSIS OF THE CAFE COST BENEFIT ANALYSIS

This report discusses a few aspects of the Cost Benefits Analysis that was developed within the context of the Clean Air For Europe (CAFE) programme of the European Commission. The aspects considered are the monetisation of impacts of air pollution on human health and the results of a statistical uncertainty analysis.

The CAFE programme has resulted in the publication of the so-named Thematic Strategy on Air Pollution (TSAP) and this TSAP is also considered in the report.

5/06 MOTOR VEHICLE EMISSION REGULATIONS AND FUEL SPECIFICATIONS - PART 1 2004/2005 UPDATE

This report summarises changes in worldwide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption. Specifically it details current and proposed legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes plus legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions. It also includes information on fuel specifications and characteristics.

The report should be read in conjunction with the Appendix to Part 1 and Part 2, which was originally issued as a separate volume in 1997 (Report No. 6/97). There are now two editions of Part 2:

- Report No. 6/97, detailing the development of worldwide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption from 1970 to 1996.
- Report No 6/06, providing the same material for the period from 1996 to 2005.

These two editions of Part 2 provide similar information on an historical basis. It is intended that Part 1 will be updated regularly, whereas Part 2 - a comprehensive reference document - will be revised at appropriate, longer term intervals. The Appendix to Part 1 and Part 2 (Report 6/06) replace an earlier edition of Part 2 (Report No 2/01).

6/06 MOTOR VEHICLE EMISSION REGULATIONS AND FUEL SPECIFICATIONS - PART 2 HISTORIC REVIEW (1996-2005)

This report details the development of world-wide legislation and regulations governing motor vehicle emissions, fuel specifications and fuel consumption from 1996 to 2005. It describes outdated legislation on emissions limits and emissions testing, vehicle inspection and maintenance programmes and legislation aimed at controlling in-service emissions performance, fuel consumption and carbon dioxide emissions. Automotive fuel specifications (including reference or certification fuels) and fuel characteristics are also documented.

This comprehensive work of reference is a companion to CONCAWE Report 6/97 which provided similar details for the period 1970 to 1996. It should also be read in conjunction with Part 1 (and the Appendix to Part 1 – report no. 5/06), which have been

issued as separate volumes. Part 1, and its Appendix, summarise the most important legislation, either in place or shortly to be enacted. Part 1 is updated annually, whereas this report - which reviews the history of automotive emissions legislation – will be revised at appropriate, longer term intervals.

**7/06 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE
STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2005**

The twelfth such report by CONCAWE, this issue includes statistics on work-related personal injuries for the European downstream oil industry's own employees as well as contractors for the year 2005. Data was received from 18 companies representing over 80% of the European refining capacity. Trends over the last thirteen years are highlighted and the data is also compared to similar statistics from related industries.

1/07 OIL REFINING IN THE EU IN 2015

In the next decade, the EU refining industry will be facing significant changes in demand both in absolute terms and with regard to the relative calls for its main products. Notably the imbalance between the demand for gasoline and middle distillates is likely to continue to increase. This report explores the possible consequences of these changes on the investment requirement of the EU refining sector as well as the evolution of its energy consumption and CO₂ emissions.

**2/07 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES AND COMBUSTION OF
OIL PRODUCTS IN WESTERN EUROPE AND HUNGARY (2002)**

This report examines the sulphur balances of European oil refineries and the sulphur contents of oil products based on a CONCAWE survey of 2002 actual data. Comparisons are made with data from the previous CONCAWE survey of 1998 and also in some cases with 1995 sulphur survey data. The distribution of sulphur content between the major oil products groups is highlighted to allow assessment of the impact of regulatory sulphur reduction measures.

Confirming the trend observed since 1992 as reported in earlier CONCAWE reports, there is a continuous significant decrease in the sulphur content of petroleum fuels and with a corresponding increase in the quantity of sulphur recovered by refineries.

To provide further continuity with the previous reports, some data are broken down to show the situation in four different European regions.

**5/07 REPORT OF A WORKSHOP ON ENVIRONMENT AND HEALTH: AIR QUALITY
RESEARCH NEEDS IN THE EU 7TH FRAMEWORK PROGRAMME OF RESEARCH,
15-16 JANUARY 2007**

An open international workshop was convened to debate research needs for the EU in the field of health effects of ambient air pollution in the wider context of environmental factors and public health. The workshop provided scientific updates in a number of key areas including toxicology, epidemiology and exposure assessment. Facilitated discussions amongst participants resulted in a series of recommendations which are summarised in the present report.

6/07 HUMAN EXPOSURE INFORMATION FOR EU SUBSTANCE RISK ASSESSMENT OF KEROSENE

Information is presented on inhalation and dermal exposures to kerosene for workers in European manufacturing, distribution and aviation refuelling operations, for use in substance risk assessment according to EU regulations.

1/08 IMPACT ON THE EU OF SO_x, NO_x AND PRIMARY PM_{2.5} EMISSIONS FROM SHIPPING IN THE MEDITERRANEAN SEA: SUMMARY OF THE FINDINGS OF THE EURO DELTA PROJECT

This report discusses the outcome of modelling scenarios comparing the impact of emissions from ships in different areas of the Mediterranean with those from land based emissions. The modelling uses the results of a recent emission inventory for the Mediterranean Sea and the modelling structure developed for the wider "Euro Delta" project.

For the Mediterranean Sea as a whole, the emission potencies for exposure of EU populations to fine particulates are found to be significantly lower (by a factor of about five or more) than emissions from land based sources. Only for "adjacent to shore" Mediterranean Sea scenarios do the emission reduction potencies approach those of land based measures. This has important implications for the development of cost-effective abatement strategies.

These results are in good agreement with data from the RAINS/GAINS model used in the integrated assessment modelling of EU air quality. Comparison of the two sets demonstrates that the situation in the Mediterranean is very different to that of the North Sea or Baltic where emission potencies are often similar to those of land based sources (e.g. for Germany and the UK). They further confirm that for other impacts (e.g. ozone impacts on human health; acidification and eutrophication), the potency of contributing emissions from the Mediterranean Sea is also extremely low (a factor of about ten) compared to land based sources and the emissions from shipping in the North Sea and Baltic.

2/08 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2006

The thirteenth such report by CONCAWE, this issue includes statistics on work-related personal injuries for the European downstream oil industry's own employees as well as contractors for the year 2006. Data was received from 20 companies representing over 80% of the European refining capacity. Trends over the last thirteen years are highlighted and the data is also compared to similar statistics from related industries.

3/08 GUIDELINES FOR BLENDING AND HANDLING MOTOR GASOLINE CONTAINING UP TO 10% V/V ETHANOL

This report provides guidance on handling and blending ethanol at up to 10% v/v concentrations in motor gasoline. The major challenges associated with ethanol-containing gasolines are discussed as they relate to the conformity of the finished fuel to typical specifications, especially those in the European unleaded motor gasoline specification (EN228). This report focuses on the production, distribution, and supply of motor gasoline containing up to 10% v/v ethanol and does not address issues related to higher ethanol blends, specifically E85 fuels (up to 85% v/v ethanol in gasoline).

For the purposes of this report, the terms motor gasoline and unleaded petrol (as defined in European Standard EN228) are considered to be synonymous.

4/08 ADVANCED COMBUSTION FOR LOW EMISSIONS AND HIGH EFFICIENCY: A LITERATURE REVIEW OF HCCI COMBUSTION CONCEPTS

This report reviews an extensive published literature covering a class of advanced combustion concepts for low emissions and high efficiency in internal combustion engines. For diesel engines, these combustion concepts are generically called Homogeneous Charge Compression Ignition (HCCI) and, for gasoline engines, Controlled Auto-Ignition (CAI). The market drivers for exploring these advanced concepts as well as the fundamentals of how they work to enhance performance and reduce engine-out emissions are described using examples from recent literature. Following this introduction, various engine hardware options are reviewed that have been reported to enhance performance and extend the practical speed and load range for advanced combustion modes. Finally, the impact of fuel properties are described for enabling advanced combustion, including the impact of the fuel's ignition resistance (cetane number), volatility, and fuel composition on engine performance, emissions, and noise.

5/08 REPORT OF A TOXICOLOGY FORUM SYMPOSIUM ON AIR QUALITY AND CARDIOVASCULAR HEALTH EFFECTS: WHAT'S THE IMPACT - OCTOBER 24, 2007

CONCAWE sponsored a special session at the ToxForum meeting (October 2007) on Air Quality and Cardiovascular health effects. The session provided an opportunity to bring together leading scientists and have a debate on the state of knowledge in this field. The discussion amongst participants resulted in a series of recommendations for future research.

6/08 OPTICAL METHODS FOR REMOTE MEASUREMENT OF DIFFUSE VOCs: THEIR ROLE IN THE QUANTIFICATION OF ANNUAL REFINERY EMISSIONS

This report provides a review of the techniques which are currently commercially available for remotely monitoring VOCs from both point and area diffuse emission sources.

The use of recently developed optical gas imaging (OGI) equipment is a relatively simple and cost-effective method to identify fugitive point emission sources. An OGI camera can scan all potential sources on a process plant, which is not possible using conventional hydrocarbon leak detection instruments. Emission factors have been developed to permit quantification of annual emissions using OGI techniques.

For refinery area diffuse emission sources, the use of emission factor methodologies is concluded to be very effective in combination with a procedure to detect any 'significant emitters'.

Complex remote sensing techniques can only provide short-term emission measurements. Extrapolation of these can lead to very large errors in the projected annual inventory values due to the temporal variability of refinery emissions.

The OGI technique permits the cost-effective identification of any tank equipment components causing significant emissions. The complex techniques at best allow the identification of tanks with significant emissions but do not have the capability of pinpointing the equipment components in need of maintenance.

8/08 IMPACT OF PRODUCT QUALITY AND DEMAND EVOLUTION ON EU REFINERIES AT THE 2020 HORIZON - CO₂ EMISSIONS TREND AND MITIGATION OPTIONS

This report presents an integrated assessment of the impact of product quality and demand changes on EU refineries between 2000 and 2020 in terms of investment requirements, energy consumption and CO₂ emissions. It further explores the potential of various mitigating options available to EU refiners to curb the inevitable increase of their CO₂ emissions.

1/09 AIR POLLUTANT EMISSION ESTIMATION METHODS FOR E-PRTR REPORTING BY REFINERIES – 2009 EDITION

This report is the first revision of CONCAWE Report 3/07, which itself replaced Report No. 9/05R *Air Pollutant Emission Estimation Methods for EPER and PRTR Reporting by Refineries*. It provides algorithms to permit emission estimates to be made by refineries to meet the reporting requirements of the European Pollutant Release and Transfer Register (E-PRTR) regarding pollutant emissions to air.

2/09 COMPARISON OF PARTICLE EMISSIONS FROM ADVANCED VEHICLES USING DG TREN AND PMP MEASUREMENT PROTOCOLS

CONCAWE has developed extensive data on particle emissions from light-duty and heavy-duty vehicles through its previous experimental programmes. In this study, four light-duty vehicles, two diesel and two gasoline direct injection (GDI), were tested for particulate mass and particle number emissions under regulated (NEDC) and transient (Artemis) driving cycles. One of the two diesel vehicles was equipped with a Diesel Particulate Filter. Particle number emissions were compared using procedures that had been developed in two different studies: the procedure previously used in the DG TREN “Particulates” Consortium Study (2001) and a second that has been adopted for Euro 5b certification of new light-duty diesel vehicles based on results from the Particle Measurement Programme (PMP).

The particulate mass and particle number measurements compared favourably between the two studies on comparable vehicles, fuels, and driving cycles. A broad correlation was observed between particulate mass and particle number for all vehicles (both diesel and gasoline) over the NEDC. The particle number emissions from the two gasoline vehicles were about the same order of magnitude as those from the diesel vehicle equipped with a particulate filter. The particle number results showed no apparent dependence on fuel properties even with significant variations in fuel sulphur level and other properties.

3/09 IMPACT OF MARINE FUELS QUALITY LEGISLATION ON EU REFINERIES AT THE 2020 HORIZON

Legislative measures recently adopted by the International Maritime Organisation (IMO) pave the way for a dramatic reduction of the sulphur content of international marine fuels. Based on a 2020 reference scenario taking into account all expected product quality changes and demand change forecast, this report analyses the specific impact of marine fuel quality changes on EU refineries focussing on configuration, investments, energy consumption and CO₂ emissions.

4/09 REFINING BREF REVIEW – AIR EMISSIONS

A review of emission and abatement technologies has been carried out to inform the review of the Reference Document for Best Available Techniques for the Mineral Oil

and Gas Refining Industries (the BREF) which acts as a guidance to permit authorities when implementing the Industrial Pollution Prevention Control Directive.

This report extends and supplements CONCAWE Report no. 99/01 - Best Available techniques to Reduce Emissions from Refineries. Focus is on providing additional information on emissions to air, with new information on NO_x emissions from combustion, emissions from FCC units, sulphur removal and recovery and vapour recovery systems.

Recommendations are made as to how to improve the BREF and update the Associated Emission Levels (AELs) ascribed to each technique. It is suggested that the BREF be clearer in its definition of AEL values associated with the Best Available Technique by enumerating each component technique.

This work did not set out to gather detailed information on costs of abatement techniques because a substantial element of cost is in the local implementation and this is extremely difficult to quantify. However, where cost information has become available in the course of the work on techniques, it has been included.

5/09 ADDITIONAL HUMAN EXPOSURE INFORMATION FOR GASOLINE SUBSTANCE RISK ASSESSMENT (PERIOD 2002-2007)

This report provides an update on human exposure information for gasoline-related activities for which previous assessments had suggested that exposure was either elevated or highly variable or available data were considered out-of-date. In addition data are presented for several activities for which no information had been available previously.

The occupational exposures activities described in this report include railcar loading, refinery maintenance, laboratory operations, aviation gasoline refuelling, gasoline pump maintenance and repair, gasoline pump calibration, and the operation of gasoline-powered gardening equipment. In addition, general public exposure levels are described, particularly relating to residency near service stations.

6/09 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2007

The fourteenth such report by CONCAWE, this issue includes statistics on work-related personal injuries for the European downstream oil industry's own employees as well as contractors for the year 2007. Data was received from 30 companies representing over 97% of the European refining capacity. Trends over the last fourteen years are highlighted and the data is also compared to similar statistics from related industries.

7/09 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2008

The fifteenth such report by CONCAWE, this issue includes statistics on work-related personal injuries for the European downstream oil industry's own employees as well as contractors for the year 2008. Data was received from 31 companies representing 97% of the European refining capacity. Trends over the last fifteen years are highlighted and the data is also compared to similar statistics from related industries.

8/09 VOLATILITY AND VEHICLE DRIVEABILITY PERFORMANCE OF ETHANOL/GASOLINE BLENDS: A LITERATURE REVIEW

The effect of blending ethanol (up to 20% v/v) into gasoline on the volatility of the ethanol/gasoline blend and on the hot and cold weather vehicle driveability performance of these blends has been assessed from published literature. This literature review covers major fuel blending and vehicle driveability studies that have been completed over the past 20 years.

Volatility of Ethanol/Gasoline Blends

The percentage of an ethanol/gasoline blend that evaporates at 70°C (E70) substantially increases when ethanol is blended into gasoline. The corresponding E100 (the percent of the blend that evaporates at 100°C) also increases but less substantially than the E70 value. The increase in these two volatility parameters with ethanol addition is usually smaller as the volatility of the gasoline increases. Interestingly, “Blending E70” values for ethanol tend to decrease with increasing ethanol content while “Blending E100” values increase. This difference is due to the formation of an azeotrope that affects the volatility behaviour of the ethanol/gasoline blend at different temperatures. Simple predictive models have been developed based on analytical data from the published studies that describe the change in Blending E70 and Blending E100 values with the base gasoline’s E70 and E100 and with ethanol contents in the range of 5 to 20% v/v.

Vehicle Driveability Performance of Ethanol/Gasoline Blends

Published studies on the impact of ethanol and gasoline volatility on vehicle driveability performance have also been evaluated. These included seven studies on Hot Weather Driveability (HWD) and eleven studies on Cold Weather Driveability (CWD). These studies show that modern vehicles are much less susceptible to HWD performance problems than are older vehicles. Some early model Direct Injection Spark Ignition vehicles tested by CONCAWE/GFC (2003) showed some HWD problems but only on high volatility fuels. Current specification properties appear to be adequate to control HWD but some increases in the E70 maximum limits allowed by the European EN228 gasoline specification may be needed in order to allow ethanol blending into gasoline at 10% v/v and higher.

CWD vehicle performance is affected by mid-range gasoline volatility (E100) and is an issue for modern vehicles because it is linked to exhaust emissions performance under cold starting conditions. CWD is degraded by the use of ethanol/gasoline blends at the same volatility level as hydrocarbon-only gasolines. To reduce the impact of ethanol, new Driveability Indices (DI) have been developed and applied in some extensive US studies. These DIs generally include ethanol offset terms in order to control the impact of volatility on CWD performance. Although current E100 volatility class limits are fixed in the European EN288 gasoline specification, the published literature indicates that the minimum E100 limits should ideally vary with ambient temperature and should include an ethanol offset term in order to control CWD performance. Based on these results, a European DI including an ethanol offset term should be considered in order to account for the performance of European vehicles under European climatic conditions.

9/09 GUIDELINES FOR HANDLING AND BLENDING FAME

This report provides guidance on the handling and blending of Fatty Acid Methyl Esters (FAME), as a neat product and at concentrations up to 10% v/v in diesel fuel. The major challenges associated with diesel fuels containing FAME are discussed as they relate to the conformity of the finished fuel to typical specifications, especially those in the European standard for automotive diesel (EN 590). This report focuses on the production, blending, distribution, and supply of diesel containing up to 10% v/v FAME as well as the storage and handling of neat FAME but does not address vehicle-related issues with the use of diesel fuels containing FAME. The potential future production and use of Fatty Acid Ethyl Esters (FAEE) in diesel fuel is also discussed.

1/10 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES IN EUROPE (2006)

This report describes the results of the 2006 year survey into the sulphur pathways in European refining. This includes the distribution of sulphur in products, the capture and recovery of sulphur in refineries and the emission of sulphur oxides as part of the refining process. The archived results of surveys carried out for the years 1998 and 2002 have also been reanalysed to ensure use of consistent methodology when establishing trends and to better understand caveats made in the 2002 survey report. This survey covered a limited dataset and as a consequence, it was not known if it was fully representative.

In 2006 67 surveys representing a crude throughput equivalent to 68% of the Organisation for Economic Co-operation and Development (OECD) European refining capacity were analysed. The results confirm a downward trend in the sulphur content of major product streams and a reduction of sulphur emitted from refinery operations to ~3.7% of total sulphur intake. This is a factor 2 lower than in 1998. About 45% of all sulphur taken into refineries as crude and other products was recovered as elemental sulphur in 2006.

The results of the reanalysis of earlier surveys were consistent with previous reports. Importantly we were able to establish that, despite concerns over the small survey size, the 2002 survey was generally representative. An important exception was the sulphur content of Marine Bunker Fuels. The 2002 survey suggested a decrease in the sulphur content of marine fuels. However the 2006 and 1998 data were very similar. It therefore seems unlikely that the 2002 survey was representative of all of the European marine bunker production.

2/10 REFINERY BREF RELATED ENVIRONMENTAL PARAMETERS FOR AQUEOUS DISCHARGES FROM REFINERIES IN EUROPE

This report is prepared as part of the Industry input to the revision process for the Refinery Best Available Technique (BAT) Reference Document (BREF) that is being undertaken by the European IPPC Bureau.

Five effluent parameters were selected for consideration on the basis that these are addressed in the current refinery BREF. These are Total Hydrocarbon Content (THC), Total Nitrogen (TN), Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Suspended Solids (TSS). The data are presented in this report document as cumulative frequency plots of the measured concentrations (mg/l), as reported and where possible the associated determined loads in grammes per tonne of Crude oil processed.

The analysis reveals that there is no obvious correlation between concentrations and loads of these five parameters and type of wastewater treatment process. Further analysis indicates that the level of complexity of a refinery (as characterised by the

industry standard Nelson Complexity Index) have no bearing on the quality of the final effluent.

It is, therefore, concluded that it is not possible, from this set of data, to specify a level of effluent quality that can be achieved or be expected from these two aspects of refinery technology. It is more likely that effluent quality is determined by a complex combination of operational process and waste-stream management parameters and that management of these on a site-specific basis is likely to present the most effective way of meeting effluent quality objectives.

3/10**CONCAWE EFFLUENT SPECIATION PROJECT**

In preparation for the implementation of the EU REACH regulation, a project was undertaken to transfer the high-resolution analytical method for determining hydrocarbon blocks in petroleum products by comprehensive two-dimensional gas chromatography (GCxGC) to a laboratory external to the petroleum industry (Institute for Environmental Studies (IVM) of the VU University of Amsterdam). The method was validated and used for the analysis of petroleum hydrocarbons extracted from refinery effluents.

The report describes the technology transfer and the approaches used to demonstrate the successful transfer and application of the GCxGC methodology from analysing petroleum products to the quantitative determination of hydrocarbon blocks in refinery effluents.

The report describes all the methods used for all the determinations on the effluent samples along with an overview of the results obtained which are presented in summary tables and graphs. These data have significantly improved CONCAWE's knowledge of what refineries emit in their effluents.

A total of 111 Effluent Discharge Samples from 105 CONCAWE refineries in Europe were obtained in the period June 2008 to March 2009. These effluents were analysed for metals, standard effluent parameters (including COD, BOD), oil in water, BTEX and volatile organic compounds. The hydrocarbon speciation determinations and other hydrocarbon analyses are also reported. The individual refinery analytical results are included into this report, coded as per the CONCAWE system. These data will be, individually, communicated to companies and refineries.

The report demonstrates that it is feasible to conduct a research programme to investigate the fate and effects of hydrocarbon blocks present in discharged refinery effluents.

5/10**REVIEW OF DERMAL EFFECTS AND UPTAKE OF PETROLEUM HYDROCARBONS**

This report serves as an update to and an extension of a previous CONCAWE report on dermal absorption of petroleum hydrocarbons (Petroleum hydrocarbons: their absorption through and effects on the skin, CONCAWE Report 84/54, 1984).

To contribute to health risk assessments associated with dermal exposure, this report evaluates experimental data to determine the extent to which petroleum hydrocarbons pass through the skin. These data strongly suggest that dermal exposure to petroleum hydrocarbons, even following long-term exposures such as in occupational settings, will not cause systemic toxicity under normal working conditions and assuming an intact skin barrier. Skin contact with some petroleum products may cause skin irritation, leading to dermatitis, particularly after repeated or prolonged exposure. In addition to

these irritating effects, the skin barrier function may be affected following repeated contact with petroleum hydrocarbons, making the skin potentially more susceptible to other irritants, sensitizing agents, and bacteria. In addition, the impaired skin barrier may lead to increased dermal penetration of hydrocarbons and other substances. To avoid this there is a need to minimise skin contact.

6/10 CONCAWE COMPILATION OF SELECTED PHYSICAL-CHEMICAL PROPERTIES OF PETROLEUM SUBSTANCES AND SULFUR

For the purpose of REACH registration, CONCAWE has collected physical-chemical data from its member companies on petroleum substances and sulfur produced at their sites. Substances were identified using CAS Registry Numbers and / or EINECS / EC numbers. Some 1400 measured data points for physical-chemical properties, mainly for boiling range, melting point/pour point, density, vapour pressure, flash point, self-ignition temperature and kinematic viscosity, have been grouped into substance categories. All data points have been validated and the laboratory test reports archived by CONCAWE.

7/10 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2009

The sixteenth such report by CONCAWE, this issue includes statistics on work-related personal injuries for the European downstream oil industry's own employees as well as contractors for the year 2009. Data were received from 33 companies representing more than 97% of the European refining capacity. Trends over the last sixteen years are highlighted and the data are also compared to similar statistics from related industries. In addition, this report presents the results of the first Process Safety Performance Indicator data gathering exercise amongst the CONCAWE membership.

8/10 REPORT OF A WORKSHOP ON ENVIRONMENT AND HEALTH: EVALUATING EUROPEAN AIR QUALITY RESEARCH AND TRANSLATING PRIORITIES INTO ACTIONS, 19-20 JANUARY 2009

Scientists, academics, regulators, and representatives of industry and non-governmental organizations from some 18 countries around the world convened at the Bedford Hotel and Congress Centre, Brussels, Belgium on January 19-20, 2009 to participate in a *Workshop on Environment and Health: Evaluating European Air Quality Research and Translating Priorities into Actions*. The Workshop was organized by CONCAWE with contributions from the European Commission's DG Research, Session Chairpersons and other distinguished presenters. The workshop provided scientific updates in a number of key areas including toxicology, epidemiology and exposure assessment of airborne pollutants. Invited platform presentations and submitted posters followed by facilitated discussions amongst participants resulted in a series of recommendations which are summarized in the present report.

9/10 ADVANCED COMBUSTION FOR LOW EMISSIONS AND HIGH EFFICIENCY PART 1: IMPACT OF ENGINE HARDWARE ON HCCI COMBUSTION

Two single-cylinder diesel engines were optimised for advanced combustion performance by means of practical and cumulative hardware enhancements that are likely to be used to meet Euro 6 emissions limits and beyond. These enhancements included high fuel injection pressures, high exhaust gas recirculation levels and charge cooling, increased in-cylinder swirl, and a fixed combustion phasing. These enhancements achieved low engine-out emissions of NO_x and particulate matter emissions with engine efficiencies equivalent to today's diesel engines. These

combustion conditions approach those of Homogeneous Charge Compression Ignition, especially at the lower part-load operating points.

Four fuels exhibiting a range of ignition quality, volatility, and aromatics contents were used to evaluate the performance of these hardware enhancements on engine-out emissions, performance, and noise levels.

10/10 ADVANCED COMBUSTION FOR LOW EMISSIONS AND HIGH EFFICIENCY PART 2: IMPACT OF FUEL PROPERTIES ON HCCI COMBUSTION

A broad range of diesel, kerosene, and gasoline-like fuels has been tested in a single-cylinder diesel engine optimized for advanced combustion performance. These fuels were selected in order to better understand the effects of ignition quality, volatility, and molecular composition on engine-out emissions, performance, and noise levels. Low-level biofuel blends, both biodiesel and ethanol, were included in the fuel set in order to test for short-term advantages or disadvantages.

The diesel engine optimized in Part 1 of this study included practical and cumulative engine hardware enhancements that are likely to be used to meet Euro 6 emissions limits and beyond, in part by operating under conditions of Homogeneous Charge Compression Ignition, at least over some portions of the speed and load map.

The centre of combustion was matched for each fuel by adjusting the fuel injection timing. This simulates the performance of a future advanced engine operating with closed loop combustion control using an in-cylinder pressure sensor. The warmed-up engine could be run successfully on a wide range of diesel, kerosene, and gasoline-like fuels, including part-load and full-load operation, with diesel-like efficiency.

NO_x emissions at or below Euro 6 emissions limits were achieved without the use of a NO_x aftertreatment system. PM emissions were also low but a diesel particulate filter would be needed to reach Euro 6 limits and below. HC and CO emissions increased but were within the range that could be treated with a diesel oxidation catalyst.

Fuel properties had a substantial effect on PM emissions, consistent with the wide range of fuels investigated. In general, PM emissions decreased with increasing ignition delay, higher volatility, and lower aromatics levels of the fuel but the relative effects varied depending upon the engine operating conditions.

This study has investigated engine performance and emissions for a warmed-up single-cylinder bench engine only. Additional work would be needed to investigate engine performance under transient and cold start conditions.

1/11 ENVIRONMENTAL SENSITIVITY ASSESSMENT OF RETAIL FILLING STATIONS IN SELECTED EUROPEAN COUNTRIES

The environmental sensitivity of approximately 86,000 retail filling stations in 13 European countries has been assessed with regard to groundwater, surface water and ecological receptors using a source-pathway-receptor and Geographical Information System (GIS) based methodology. The information is stored in a CONCAWE database.

Across all thirteen countries the results demonstrate that, based on their location alone (i.e. irrespective of containment engineering standards which can reduce environmental risk), the percentage of retail filling stations with the potential to pose a risk to the receptors in question is small: 5% with respect to potable water (groundwater and surface water) abstractions, 8% with respect to the ecology of surface water bodies

and 3% with respect to designated Natura 2000 sites (protected habitats and ecosystems).

Information in the database can be used to:

- Support a site-specific, risk-based approach to the implementation of environmental regulations and the management of groundwater contamination.
- Develop pro-active environmental risk management strategies for networks of retail filling station sites appropriate to their environmental risk profile.

Inform decisions regarding the environmental liability potential of sites during acquisitions, divestments and site swaps.

1/11 APP ENVIRONMENTAL SENSITIVITY ASSESSMENT OF RETAIL FILLING STATIONS IN SELECTED EUROPEAN COUNTRIES - APPENDICES

The report 1/11 '**Environmental sensitivity assessment of retail filling stations in selected European countries**' is appended with separate country specific reports for the following 13 European countries:

- Appendix 4: Austria
- Appendix 5: Belgium
- Appendix 6: Czech Republic
- Appendix 7: Denmark
- Appendix 8: Finland
- Appendix 9: France
- Appendix 10: Germany
- Appendix 11: Italy
- Appendix 12: The Netherlands
- Appendix 13: Norway
- Appendix 14: Poland
- Appendix 15: Spain
- Appendix 16: UK

2/11 TRENDS IN OIL DISCHARGED WITH AQUEOUS EFFLUENTS FROM OIL REFINERIES IN EUROPE - 2005 AND 2008 SURVEY DATA

This report summarises data gathered by CONCAWE in surveys of effluent water quantity, oil content and treatment processes for refinery locations situated in the EU-27 countries and those in Norway and Switzerland for the years 2005 and 2008. Data obtained in previous surveys are included for comparison.

The number of refinery locations reporting in 2008 has increased to 125. The results of the surveys show that the trend for lower volumes of effluent discharge relative to refinery capacity and throughput has continued. Changes in the total amounts of discharged oil, ammonia, total nitrogen (TN), phenols, BOD, COD and TOC are related to the increase in the number of refineries reporting in these years. The associated slight increases in the ratios of oil, TN, phenol, BOD and COD discharged relative to refining capacity and/or throughput may reflect the inclusion of additional refineries in countries that joined the EU in that period and whose performance may not have been at the same level as those previously surveyed.

The results show that 89% of the refineries surveyed in 2005 had at least one stage of biological treatment in their wastewater treatment facilities. For 2008, this number rose to 94% for the reporting refineries.

A different system of refinery complexity classification has been adopted for the 2005 and 2008 surveys. The Nelson Complexity Index (NCI) is an industry standard measure that takes account of each piece of refinery equipment on a refinery site. The 2005 and 2008 NCI scores show that the trend towards more complex refineries that was evident in the data set for the years 1969 to 2000 continues.

4/11 A COMPREHENSIVE REVIEW OF EUROPEAN EPIDEMIOLOGICAL STUDIES ON PARTICULATE MATTER EXPOSURE AND HEALTH

In 2006/2007 CONCAWE's Health Management Group (through H/STF-27) commissioned a literature survey and review with the primary aim of summarising the current state of science on particulate matter in ambient air and its possible effects on health. The survey and review were undertaken by the Department of Epidemiology, Mario Negri Institute, Milan, Italy¹, the International Agency for Research on Cancer, Lyon, France², the International Epidemiology Institute, Rockville, MD, USA³ and the Institute of Medical Statistics and Biometry, University of Milan, Italy⁴. The authors of the study are Eva Negri¹, Silvano Gallus¹, Paolo Boffetta², Joseph K. McLaughlin³ and Carlo La Vecchia^{1,4}

The body of this report consists of a brief overview of the findings written by H/STF-27, followed by the detailed information in Appendix developed by the mentioned experts.

5/11 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2010

In this seventeenth annual report on European downstream oil industry safety performance, 2010 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Data were received from 34 CONCAWE Member Companies representing approximately 93% of the European refining capacity. Trends over the last seventeen years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the second year of results for Process Safety Performance Indicators from CONCAWE members.

6/11 COST EFFECTIVENESS OF EMISSIONS ABATEMENT OPTIONS IN EUROPEAN REFINERIES

This report explores the cost-effectiveness of emission reductions in European refineries associated with Best Available Techniques (BAT) and illustrates how Associated Emission Level (AEL) ranges might be derived using a "shadow price". This methodology is consistent with the Economics and Cross-Media BAT Reference

Document (BREF) and closely parallels the technical process underpinning the choice of National Emission Ceilings (NEC).

This report first summarises information gathered by CONCAWE in 2010 concerning the costs of applying candidate Best Available Techniques to reduce emissions from refineries in Europe. Importantly, these costs do account for the retrofitting of equipment to units in existing refineries. The focus is on NO_x and SO₂ emissions from major refinery sources.

Cost data has been expressed as a capital cost, an annualised cost and, with reference to unabated emissions, as a marginal cost. The marginal cost (€/tonne abated) depends on the effectiveness of the technology to be applied and the existing emission. Using the 2006 CONCAWE Sulphur Survey data, the distribution of the incremental marginal cost of different technology applications across the refinery pool has been estimated.

The use of an incremental marginal cost per technology step is central to the GAINS Integrated Assessment Model in deriving cost-effective National Emissions Ceilings for priority pollutants. The Thematic Strategy on Air Pollution (TSAP) set environmental (and consequential emission reduction) targets for 2020 using this methodology and the European Member States accepted the cost of these measures. The average EU cost per tonne of pollutant to be removed has been used as an illustrative "shadow price". Comparing this "shadow price" and the marginal cost curve indicates which abatement techniques could be considered cost-effective and by what proportion of the industry.

7/11 THE POTENTIAL FOR APPLICATION OF CO₂ CAPTURE AND STORAGE IN EU OIL REFINERIES

CO₂ Capture and Storage (CCS) is a potential route to large scale reduction of CO₂ emissions to the atmosphere from large power generation and manufacturing facilities. It does, however, raise a number of technological, economic and legal challenges. This report reviews the state of knowledge in the areas of transport and storage of CO₂, to focus mainly on CO₂ capture in oil refineries. Sources of refinery CO₂ emissions, the capture technologies that can potentially be deployed in that environment and the particular issues facing refiners in the application of CCS are discussed from both a technological and an economic point of view. One important conclusion is that the volumes and unit locations for CO₂ production in refineries are not conducive to CCS projects in individual refineries and will require alliances with other large CO₂ producers, particularly the power industry, in order to be commercially justified.

9/11 ACUTE AQUATIC TOXICITY OF HEAVY FUEL OILS - SUMMARY OF RELEVANT TEST DATA

This report describes the experimental procedures and results obtained in acute ecotoxicity tests on several heavy fuel oil (HFO) samples. Water accommodated fractions (WAFs) of these samples were tested for toxicity to the rainbow trout (*Oncorhynchus mykiss*), the crustacean zooplankter (*Daphnia magna*) and green algae (*Selenastrum capricornutum*). These results assist in determining the environmental hazard from heavy fuel oil.

1/12 ASSESSMENT OF REFINERY EFFLUENTS AND RECEIVING WATERS USING BIOLOGICALLY-BASED EFFECT METHODS

Within the EU it is apparent that the regulatory focus on the use of biologically-based effects methods in the assessment of refinery effluents and receiving waters has

increased in the past decade. This has been reflected in a recent refinery survey which revealed an increased use of such methods for assessing the quality of refinery effluents and their receiving waters. This report provides an overview of recent techniques used for this purpose. Several case studies provided by CONCAWE member companies describe the application of biological methods to effluent discharge assessment and surface water monitoring.

The case studies show that when biological methods are applied to refinery effluents and receiving waters they raise different questions compared with those obtained using physical and chemical methods. Although direct measurement of the toxicity of effluent and receiving to aquatic organisms is the most cited technique, more recent efforts include tests that also address the persistence of effluent toxicity once discharged into the receiving water.

Similarly, ecological monitoring of receiving waters can identify effects of effluent inputs arising from species interactions and other secondary effects that would not always be apparent from the results of biological tests conducted on single aquatic organisms.

In light of recent and proposed regulatory developments the objectives of this report are therefore to:

- Discuss the application of biologically-based effects methods (including ecological monitoring) to refinery discharges and receiving waters,
- Assess the implications of such methods for future regulation of refinery discharges and
 - Provide guidance on good practice that can be used by refineries and the downstream oil industry to carry out and interpret data obtained using biologically-based effects methods.

While the emphasis is on the toxic effects of effluents, other properties will also be covered because of their interdependency in determining potential effects in the environment. In particular, the properties of effluent constituents that determine their persistence and potential to accumulate within organisms will also be considered.

2/12

GASOLINE VOLATILITY AND VEHICLE PERFORMANCE

A six vehicle study has been completed to investigate the impact of changes in the volatility characteristics of unleaded gasoline containing 10% v/v ethanol on regulated exhaust and evaporative emissions and on hot and cold weather vehicle driveability performance. The vehicles selected for this study were representative of the current EU fleet, met or exceeded Euro 4 emissions certification, spanned the range from upper medium to small vehicle classes, were compatible with 10% v/v ethanol according to the manufacturer's warranty information, and included two modern gasoline Direct Injection Spark Ignition engine types. Results included regulated emissions measured over the New European Driving Cycle (NEDC) at +23°C and -7°C, evaporative emissions according to the European regulatory procedure, cold engine starting and idling at -20°C, and Hot Weather Driveability performance at +40°C.

Unleaded gasolines containing 10% v/v ethanol (E10 gasolines) were specially blended for this study to investigate changes in volatility, specifically in the E70¹ and E100² distillation values. The Dry Vapour Pressure Equivalent (DVPE) of all test fuels targeted

¹ E70 is the percentage of the gasoline sample that evaporates at 70°C

² E100 is the percentage of the gasoline sample that evaporates at 100°C

either summer (60kPa) or winter (100kPa) grade maximum values. The DVPE of the test fuel was selected to be consistent with the type of vehicle test that was completed.

To investigate the impact of volatility changes on vehicle emissions and performance, 'Baseline' E10 gasolines were evaluated having E70 and E100 distillation values at the current maximum limits allowed by the EN 228 gasoline specification. Results on these 'Baseline' gasolines were then compared to fuels having relaxed volatility, that is, where the E70 and E100 values were higher than the maximum limits allowed by the EN 228 specification. These volatility values were selected based on a proposal that CONCAWE has made to the European Committee for Standardisation to relax the volatility specifications for future E10 gasoline blends.

For most vehicle tests, results on the 'Baseline' gasoline were compared to those on a 'Step 2' gasoline in which the E70_{max} and E100_{max} specifications were relaxed by +10% v/v and +4% v/v, respectively. Some tests were also conducted on 'Step 1' gasolines in which the E70_{max} and E100_{max} specifications were relaxed by +4% v/v and +2% v/v, respectively. The 'Step 1' gasolines were consistent with CONCAWE's proposal to CEN for relaxed volatility specifications while tests on the 'Step 2' gasolines represented a more severe test for vehicle emissions and driveability performance.

All six vehicles were able to complete the required driving cycles on all of the test fuels with no false starts, no misfires, no stalls, no failures, and no faults recorded by the On-Board Diagnostics (OBD) systems. Overall, the impacts of gasoline volatility on emissions and driveability performance were small compared to vehicle-to-vehicle differences.

3/12 EU REFINERY ENERGY SYSTEMS AND EFFICIENCY

The consumption of energy within EU refineries plays a crucial role in determining refinery operating costs and emissions and has therefore long been a focus of attention by refinery operators. Improvements in refinery energy efficiency have resulted in net energy savings which have helped to offset the increases in energy intensity associated with increasing product demand and increasingly stringent quality requirements. This report provides data on the progress made in improving the energy efficiency of EU refineries over the past 18 years and discusses the factors which have contributed to this achievement.

4/12 GASOLINE ETHER OXYGENATE OCCURRENCE IN EUROPE, AND A REVIEW OF THEIR FATE AND TRANSPORT CHARACTERISTICS IN THE ENVIRONMENT

Ether oxygenates are added to certain gasoline (petrol) formulations to improve combustion efficiency and to increase the octane rating. In this report the term gasoline ether oxygenates (GEO) refers collectively to methyl tertiary butyl ether (MTBE), ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), di-isopropyl ether (DIPE), tertiary amyl ethyl ether (TAEE), tertiary hexyl methyl ether (THxME), and tertiary hexyl ethyl ether (THxEE), as well as the associated tertiary butyl alcohol (TBA).

This report presents newly collated data on the production capacities and use of MTBE, ETBE, TAME, DIPE and TBA in 30 countries (27 EU countries and Croatia, Norway and Switzerland) to inform continued and effective environmental management practices for GEO by CONCAWE members. The report comprises data on gasoline use in Europe that were provided by CONCAWE and obtained from the European Commission. Furthermore Société Générale de Surveillance (SGS) provided detailed analytical data (more than 1,200 sampling campaigns) on the GEO composition of gasoline in European countries in the period 2000-2010.

Another major aspect of this report is the investigation of GEO distribution in groundwater, drinking water, surface water, runoff water, precipitation (rain/snow) and air in the European environment. Apart from the general sources of literature for the study, local environmental authorities and institutes in the 30 European countries have been contacted for additional information.

Finally, a review of the international literature on GEO natural attenuation processes was undertaken with a focus on international reports and peer-reviewed scientific publications to give an overview on the known fate, transport and degradation mechanisms of GEO in the subsurface, to inform risk-management strategies that may rely on natural attenuation processes. The literature reveals that all GEO compounds used in fuels are highly water soluble and weakly retarded by aquifer materials, but are biodegradable under favourable environmental conditions, and volatilise from liquid (gasoline or water) to vapour phase. Consequently natural attenuation processes are expected to decrease GEO concentrations in the environment and, with appropriate site-specific evidence, may be incorporated into risk assessment / management strategies at GEO release sites.

5/12 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE – STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2011

In this eighteenth annual report on European downstream oil industry safety performance, 2011 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Data were received from 34 CONCAWE Member Companies representing approximately 96% of the European refining capacity. Trends over the last eighteen years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the third year of results for Process Safety Performance Indicators from CONCAWE members.

6/12 TRENDS IN OIL DISCHARGED WITH AQUEOUS EFFLUENTS FROM OIL REFINERIES IN EUROPE - 2010 SURVEY DATA

This report summarises data gathered by CONCAWE in a 2010 survey of effluent water quantity, oil content and treatment processes for refinery installations situated in the EU-27 countries and those in Croatia Norway and Switzerland. Data obtained in previous surveys are included for comparison.

Operators of 100 installations completed questionnaires, of which two of these only reported data for water intake and discharge.

The number of 100 reporting locations is lower than the 125 locations that reported in 2008. There are several reasons for this. Since the last data gathering exercise several refinery installations have been closed or moth-balled, turning these into fuels depots without any production. Another four sites that are still operating today informed CONCAWE that these would not be in a position to complete the questionnaire for 2010. Finally, the ownership of some installations changed since 2008, leading to CONCAWE being unable to identify an appropriate contact person for timely completion of the questionnaire.

The data provided through the completion of the questionnaire have been extracted into an MS-ACCESS Database. This enabled sorting, extraction, analyses and presentation of the information in a range of formats. The information presented in this report relates to a selected range of parameters that have been covered by previous surveys carried out since 1969. Two further reports will cover the results of the complete survey in more detail; one concerning final discharge quality parameters and the other focussing on water use and consumption.

The results reported herein show that the volume of process water that was being discharged from EU-27+3 (Norway, Croatia and Switzerland) - located refineries decreased between 2008 and 2010 while the overall volume of aqueous discharges remained about the same or slightly increased over the same period. When expressed relative to refinery capacities and throughputs there is a slight increase in 2010 in the amount of effluent discharged from all sources per tonne of capacity and throughput compared with 2008.

The amount of oil discharged in effluents from reporting installations continued to decrease both in terms of the absolute amount discharged and the amount expressed relative to the volume of feedstock processed (throughput) and the refining capacity of the installations.

The amounts of ammonia, total nitrogen (TN) and phenols also appear to have continued to decrease but the figures are more difficult to interpret because the number of refineries that reported data was, particularly in the case of ammonia, lower. However, when expressed relative to feedstock throughput, the decrease is still evident. Similar trends are evident in the data for Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and Total Organic Carbon (TOC) content. It should be noted, however, that the 2010 figure also includes data for non-process related effluent streams if reported.

The majority of the reporting installations have on-site waste water treatment plant (WWTP) and the total emission loads for ammonia, total nitrogen, phenols, BOD, COD and TOC are reported as associated with their discharges. For installations that transfer their effluents to an off-site WWTP for treatment prior to discharge, these are reported separately.

The distribution of the 2010 Nelson Complexity Index (NCI) scores is very similar to that derived for 2005 and 2008. It shows a slightly increasing trend of operation complexity of the refinery installations operated by CONCAWE members.

The trend series available in CONCAWE demonstrate that the refining sector has reduced its oil and TPH releases into the aquatic environment significantly over the past 40 years. Overall a reduction of more than 99.5%-mass is demonstrated.

7/12 REACH – ANALYTICAL CHARACTERISATION OF PETROLEUM UVCB SUBSTANCES

The purpose of this report is to summarise the findings of the scientific and technical work undertaken by CONCAWE to assess the feasibility and potential benefit of characterising petroleum UVCB substances beyond the recommendations issued by CONCAWE for the substance identification of petroleum substances under REACH.

9/12 DEVELOPING A METHODOLOGY FOR AN EU REFINING INDUSTRY CO₂ EMISSIONS BENCHMARK

In the third trading period under the EU Emission Trading Scheme (EU ETS), refineries and other eligible industrial installations may be granted free CO₂ emission allowances according to a benchmark based on the 10% most efficient installations in the sector. This report describes the process whereby CONCAWE, on behalf of the refining industry, proposed a benchmark for oil refineries under the EU ETS based on the CWT (complexity weighted tonne) concept developed by Solomon Associates. This benchmark defines the basis on which free allowances are to be allocated to refineries between 2013 and 2020.

10/12 PRIMARY BIODEGRADATION OF PETROLEUM HYDROCARBONS IN SEAWATER

This report describes primary biodegradation experiments performed to determine the persistence of higher molecular weight petroleum hydrocarbons in seawater. Results from the biodegradation experiments show that the majority of tested petroleum hydrocarbons have half-lives in seawater less than 60 days.

11/12 DEVELOPING HUMAN HEALTH EXPOSURE SCENARIOS FOR PETROLEUM SUBSTANCES UNDER REACH

This report describes the approaches that were adopted by CONCAWE to prepare the human exposure estimates in the chemical safety assessments of the REACH registration dossiers for petroleum substances based on all applicable regulatory guidance. Separate exposure estimates were developed for workers and for consumers and included inhalation and dermal routes. The complex nature of petroleum substances required various scientifically justified refinements of the regulatory guidance.

12/12 USE OF THE MODIFIED AMES TEST AS AN INDICATOR OF THE CARCINOGENICITY OF RESIDUAL AROMATIC EXTRACTS

Existing data demonstrate that residual aromatic extracts (RAEs) can be either carcinogenic or non-carcinogenic. CONCAWE had previously concluded that “Although limited data available indicate that some RAEs are weakly carcinogenic, it is not possible to provide a general recommendation. Classify on a case-by-case basis” (CONCAWE 2005) [11]. Therefore CONCAWE’s Health/Toxicology Subgroup (H/TSG) has developed a proposal for the use of the modified Ames test as a short-term predictive screening tool for decisions on the classification of RAEs for carcinogenicity.

The relationship between RAE chemistry and carcinogenic potential is not as well understood as it is for some other categories of substances, e.g. Other Lubricant Base Oils (OLBO). However, a correlation has been found between the results of the skin carcinogenicity bioassay and the mutagenicity index (MI) obtained from the modified Ames test. Data supporting this correlation are summarised in this report. The H/TSG confirmed that the modified Ames test can be used as a predictive screening tool and that a cut-off value can be established to make a distinction between carcinogenic and non-carcinogenic products. RAEs with a MI > 0.4 demonstrated carcinogenic potential upon dermal application to mouse skin with chronic exposure. RAEs with a MI < 0.4 did not demonstrate a carcinogenic potential.

To justify the use of the modified Ames test with RAEs, additional analysis of the repeatability of the test with RAEs was required. With this objective, CONCAWE sponsored a round robin study with different samples of RAEs from member companies, at three different laboratories. The repeatability demonstrated in the round robin study with RAEs support the proposed use of the modified Ames test.

As part of the tools available for use by member companies, the H/TSG proposed a standard operating procedure (SOP) (included as an Appendix to this report) on the conduct of the modified Ames test with RAEs. The H/TSG also prepared two special Oil Industry Notes (OINs) for use in cancer hazard classification. One OIN based on Dangerous Substances Directive (DSD) (OIN 9) and one based on Classification, Labelling and Packaging (CLP) regulation (OIN 10) have been adopted.

1/13R OIL REFINING IN THE EU IN 2020, WITH PERSPECTIVES TO 2030

In the two decades to 2030, the EU refining industry will face significant changes in product demand, both in absolute terms and with regard to the relative demand for gasoline and diesel. The introduction of increasingly stringent product quality specifications, notably regarding the sulphur content of marine fuels, will impose additional challenges on the ability of the industry to satisfy both demand and quality requirements. This report assesses the possible impact of these changes on EU refining, focusing on the estimated capital investment requirements in the sector as well as the expected trends in energy consumption and CO₂ emissions through to 2030. Sensitivity cases are included to explore potential alternative scenarios for product demand and quality around the 2020 base scenario.

2/13 PREDICTING REFINERY EFFLUENT TOXICITY ON THE BASIS OF HYDROCARBON COMPOSITION DETERMINED BY GCXGC ANALYSIS

A high resolution analytical method for determining hydrocarbon blocks in petroleum products by comprehensive two-dimensional gas chromatography (GCxGC) was used for the analysis of petroleum hydrocarbons extracted from refinery effluents. From 105 CONCAWE refineries in Europe 111 refinery effluents were collected in the period June 2008 to March 2009 (CONCAWE, 2010). The effluents were analysed for metals, standard effluent parameters (including Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), oil in water (OiW), GCxGC speciated hydrocarbons, BTEX (Benzene, Toluene, Ethylbenzene, and Xylenes) and volatile organic compounds.

This report describes the subsequent analysis of the GCxGC data, as described in hydrocarbon blocks, and uses the PETROTOX model, to predict the environmental toxicity (i.e. ecotoxicity) of the discharged effluents. A further analysis was undertaken to address the potential environmental impact of these predicted effects initially using default dilution factors and then, when necessary site specific factors.

The report describes all the methods used to arrive at the predictions, and shows that for the majority of refinery effluents direct toxicity effects in the effluents are not anticipated.

Furthermore, when applying either the EU Risk Assessment Technical Guidance Document (TGD) default dilution factors or site specific dilution factors, none of the refineries are predicted to exerting either acute or chronic toxicity to organisms in the receiving aquatic environment, based on their hydrocarbon composition present in the effluent samples.

4/13 REFINERY EFFLUENT ANALYSIS METHODOLOGIES FOR RELEVANT PARAMETERS FROM EU - REGULATORY REGIMES

This report provides guidance to CONCAWE members on the analytical methods that might be used to monitor oil refinery effluents for those refinery-specific parameters covered by relevant European legislation and a comparison of the methods that are used today, as reported in the last Effluent Survey.

A method assessment programme is presented whereby the performance of methods of analysis (used to monitor oil refinery effluents) can be compared and prioritised in order of their analytical performance capabilities. Methods for a specific parameter, which is clearly and unambiguously defined, are compared with each other and then prioritised in terms of their overall quality. The quality of these methods is based on an assessment of a combination of characteristic features, namely, precision, bias or

recovery, limit of detection (where appropriate), indicative costs, and ease of use. Ranking scores for each feature are assigned to various ranges of each feature, and then added together to give an overall ranking value. The method exhibiting the lowest overall ranking value is deemed the most appropriate method for analysing that parameter.

Within this report, several recommendations are made in terms of comparing results of analyses or their associated uses. Where data are to be compared for a particular parameter, then, all CONCAWE members involved in this comparison should agree common objectives, in advance. These include defining a common definition for the:

- i) Parameter being analysed and compared;
- ii) Limit of detection, and how this concentration value should be calculated;
- iii) Limit of quantification, and how this concentration value should be calculated and how it is to be applied for selective reporting purposes; and
- iv) Uncertainty of measurement and how it should be calculated.

It is further recommended these involved members should agree on the range of values and ranking scores chosen to reflect the performance characteristic features used in the method assessment programme, or establish and agree alternative values.

In addition, CONCAWE members should agree to provide details of the methods they use and the performance data obtained on their own specific effluents, so that appropriate and realistic method assessment comparisons can be undertaken. CONCAWE desires to collate this appropriate information relevant to their specific sector from its members in a way that the assessment programme can be regularly updated with new data, enabling methods to be compared in a way that is more directly applicable to the refinery sector.

5/13 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE. STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2012

In this nineteenth annual report on European downstream oil industry safety performance, 2012 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Data were received from 38 CONCAWE Member Companies representing approximately 98% of the European refining capacity. Trends over the last nineteen years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the fourth year of results for Process Safety Performance Indicators from CONCAWE members.

6/13 ACUTE AND CHRONIC AQUATIC TOXICITY OF AROMATIC EXTRACTS-SUMMARY OF RELEVANT TEST DATA

This report describes the experimental procedures and the results obtained in acute and chronic ecotoxicity tests on several aromatic extracts samples. The samples were tested for toxicity to the rainbow trout, *Oncorhynchus mykiss*, the crustacean zooplankter, *Daphnia magna* and the algae, *Selenastrum capricornutum* using water accommodated fractions. These results assist in determining the environmental hazard posed by aromatic extracts.

7/13 **AQUATIC ECOTOXICITY AND BIODEGRADABILITY OF CRACKED GAS OILS - SUMMARY OF RELEVANT TEST DATA**

This report describes the experimental procedures and the results obtained in acute and chronic ecotoxicity tests as well as a biodegradation study on cracked gas oil samples. In a CONCAWE study, three samples were tested for toxicity to the crustacean zooplankter, *Daphnia magna* and the algae, *Pseudokirchneriella subcapitata* (alternatively known as *Selenastrum capricornutum*) using water accommodated fractions. In addition, another sample was tested in a separate API study for toxicity to the fish, *Oncorhynchus mykiss*, the crustacean zooplankter, *Daphnia magna* (acute and chronic) and the algae, *Pseudokirchneriella subcapitata* using water accommodated fractions. The API sample was also tested for ready biodegradability in a manometric respirometry test. All these results assist in determining the environmental hazard posed by cracked gas oils.

8/13 **MARINE FUELS AND HYDROGEN SULPHIDE**

The safe handling of petroleum cargoes and refined products that may contain hydrogen sulphide (H₂S) is an important issue for the marine and inland fuel industries. Attention has refocused recently on H₂S due to the revision of the ISO 8217:2012 specification for marine fuels which limited the maximum content of H₂S in the liquid fuel to 2.00 mg H₂S/kg fuel (2.00 ppmw).

This report summarizes issues associated with the presence of H₂S in residual marine fuels including:

- Sources of H₂S in petroleum products;
- Exposure levels for H₂S in the vapour phase and the effects of exposure;
- Relationship between the H₂S concentration in liquid fuel and in the vapour phase;
- Measurement methods for H₂S in marine fuel and in the vapour phase;
- Interpretation of results and guidance on maximum H₂S levels; and
- Guidelines for the safe handling of liquid petroleum products that may contain H₂S.

Importantly, the report reinforces the need for safe handling procedures, training, and personnel protection when transferring or storing fuels that may contain H₂S, rather than relying only on a measured H₂S level in the liquid product.

9/13 **CHALLENGES IN ADDRESSING PHOTOTOXICITY AND PHOTODEGRADATION IN THE ENVIRONMENTAL RISK ASSESSMENT OF POLYCYCLIC AROMATIC HYDROCARBONS IN THE AQUATIC COMPARTMENT**

This report summarises how light might interact with Polycyclic Aromatic Hydrocarbons (PAHs) to alter both their environmental fate and their potential to cause adverse effects. The quantification of these changes is complicated due to the difficulties in measuring these changes in the laboratory and subsequently, in relating these to how PAHs behave in the real environment. The consequences of attempting to account for these interactions within the framework of a generic environmental risk assessment are discussed and the conclusion reached that the impact of light on the behaviour of PAHs is best accounted for using a site-specific rather than a generic regional or generic local petroleum product risk assessment. The key elements of such an approach are described.

10/13 LABORATORY OXIDATION STABILITY STUDY ON B10 BIODIESEL BLENDS

A laboratory oxidation stability study has been completed jointly by CONCAWE and DGMK (Deutsche Wissenschaftliche Gesellschaft für Erdöl, Erdgas und Kohle e.V. - German Society for Petroleum, Gas and Coal Science and Technology) on three biodiesel blends containing 10% v/v (B10) Fatty Acid Methyl Ester (FAME). The results of the study are compared to measurements from an in-vehicle storage stability study on similar B10 diesel fuels that had been conducted previously in a Joint Industry Study ("Effect of in vehicle storage on B10 diesel quality, a Joint Industry Study sponsored by the petroleum industry, automotive, and fuel injection system industries").

This laboratory study monitored the oxidation stability of the three B10 blends during six weeks of laboratory storage under ambient (25°C) and elevated temperature (43°C) conditions. Various test methods were used to monitor oxidation stability changes in the B10 diesel fuel blends including electrical conductivity, viscosity, Rancimat oxidation stability (EN 15751), PetroOxy oxidation stability (EN 16091), acid number (EN 14104), Delta Total Acid Number (Delta TAN), and peroxide number (ISO 3960). Elemental analyses by ICP were also completed on the FAME and B10 blends at the start and end of the laboratory study. The concentrations of dissolved metals were very low in all cases except for silicon which was found to be between about 600-700ppb in the B10 blends. A limited study was also conducted on one neat FAME sample (B100) to investigate the effect of air/oxygen exposure on the rate of decrease in oxidation stability.

11/13 SUPPLEMENTARY GUIDANCE FOR THE INVESTIGATION AND RISK-ASSESSMENT OF POTENTIALLY CONTAMINATED SEDIMENTS: A COMPANION VOLUME TO ENERGY INSTITUTE / CONCAWE REPORT E1001

This report provides guidance on the investigation and assessment of potentially contaminated sediments, focusing on the inland, estuarine and coastal environments. It is designed as a complementary, technical companion document to Energy Institute & CONCAWE (2013) report '*Guidance on characterising, assessing and managing risks associated with potentially contaminated sediments*' (Report E1001). It highlights a number of significant challenges associated with assessing the aquatic and water bottom environment, which means that a sediment assessment should not be undertaken lightly.

Where a decision is taken to undertake a site assessment, this report promotes the use of an iterative process of Conceptual Site Model (CSM) development, data collection, data evaluation and a continuous CSM refinement, taking into account the results obtained.

Risk-based assessment is described throughout the report, entailing four tiers of assessment, which progress from a qualitative assessment (Tier 0) through to a detailed cause-attribution assessment (Tier 3), in which the decrease in uncertainty in the assessment process is balanced against the increased costs and timescales with progress to a higher tier assessment. The application of this evidence-driven risk-based approach to sediment site management, including remedial control measures, should help to overcome at least some of the challenges associated with contaminants in sediment sites in Europe, and promote a sustainable approach to sediment management on a case-by-case basis.

12/13 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES - STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2012 AND SINCE 1971

CONCAWE has collected 42 years of spillage data on European cross-country oil pipelines. At over 36,000 km the inventory covered currently includes the vast majority of such pipelines in Europe, transporting close to 700 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2012 and a full historical perspective since 1971. The performance over the whole 42 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (inspection pigs) is also reported. 12 spillage incidents were reported in 2012, corresponding to 0.33 spillages per 1000 km of line, above the 5-year average of 0.22 and below the long-term running average of 0.51, which has been steadily decreasing over the years from a value of 1.2 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. 1 incident was due to mechanical failure, 3 to corrosion, and 8 were connected to third party activities, 2 of which malicious. Over the long term, third party activities remain the main cause of spillage incidents although mechanical failures have increased in recent years, a trend that needs to be scrutinised in years to come.

13/13 ASSESSMENT OF THE IMPACT OF ETHANOL CONTENT IN GASOLINE ON FUEL CONSUMPTION, INCLUDING A LITERATURE REVIEW UP TO 2006

Ethanol, at low concentrations in motor gasoline, is known to impact both the fuel consumption and emissions from vehicles. Because ethanol has a lower energy content per litre compared to conventional hydrocarbon gasoline, a vehicle's volumetric fuel consumption generally increases when running on ethanol/gasoline blends. In principle, factors such as the higher octane number and high latent heat of vaporisation for ethanol could allow better engine efficiency which could mitigate this effect to some extent. The degree to which modern vehicles can compensate for the lower energy content of ethanol compared to conventional gasoline is not reliably known, however. This is an important question because it impacts the interpretation of Well-to-Wheels results for biofuel blends used in conventional vehicles. For this reason, an assessment of published literature up to 2006 was completed in order to evaluate the impact of ethanol content on fuel consumption.

The scope of this literature assessment was on the use of low-level ethanol/gasoline blends, specifically 5% (E5) and 10% (E10) v/v ethanol in gasoline. These blends are the most common ethanol levels in Europe today and have been formalised in the CEN EN 228 standard for motor gasoline. This literature review did not evaluate the impact of other oxygenate types that are also allowed in the EN 228 standard.

Although many publications were evaluated, the number of studies containing relevant data was limited primarily because the experimental variability in fuel consumption results was relatively large. From this analysis, the following conclusions could be made from the evaluated publications:

- There is a relatively high incidence of incorrectly derived fuel consumption data, usually resulting in an underestimate of the increase in fuel consumption from ethanol-containing gasolines.
- For some studies on gasoline blends containing up to E20, the increase in mass fuel consumption (FC) was typically only about 50% of the expected value, based on simply the loss in calorific value from ethanol addition. In the most extreme case, fuels with almost identical energy contents showed a fuel consumption difference of more than 4%, although for the majority of vehicles, the difference was generally less than 2%. For the largest data set (7 vehicles using up to 10 test

fuels), the overall trend showed a 3.97% increase in fuel consumption with a 3.4% reduction in fuel energy content.

- It is not clear that this variation in FC results was related to variations in fuel parameters other than the ethanol content. Rather, it is assumed that the variability in FC was primarily a consequence of experimental variation and poorly controlled test procedures. The variability found in these published studies limits the firm conclusions that can be drawn about the influence of low levels of ethanol on vehicle fuel consumption.

These conclusions suggested that a more definitive vehicle study was warranted to determine whether modern vehicles can or cannot compensate for the lower energy content of ethanol-containing gasoline through better engine efficiency. Such a study has now been completed by the JEC Consortium and is reported elsewhere.

1/14 **APPLICATION OF THE TARGET LIPID AND EQUILIBRIUM PARTITIONING MODELS TO NON-POLAR ORGANIC CHEMICALS IN SOILS AND SEDIMENTS**

The Target Lipid Model (TLM) provides a framework for deriving predicted no effect concentrations (PNEC) for nonpolar organic chemicals to organisms in the environment. This approach has been used to perform environmental risk assessment of individual hydrocarbons as well as complex petroleum substances. The TLM is based primarily on data for aquatic test organisms and this work evaluates the potential for extending the TLM to soil and sediment using Equilibrium Partitioning (EqP) theory.

Literature data for other nonpolar organics were compiled for acute and chronic exposures to invertebrates in soils and sediments. New data were generated according to OECD guidelines (CONCAWE, 2011 and 2012) to evaluate soil and sediment dwelling organisms and to test potential toxicity cut-offs for high log K_{ow} compounds. The default TLM was applied to these data using EqP to develop critical target lipid body burdens (CTLBB) including associated uncertainty in the model application.

Comparison of the CTLBBs for soil and sediment species to CTLBBs from the larger TLM database for aquatic organisms showed little difference in the relative sensitivity between these two groups of species within the uncertainty of the model and experimental data. Furthermore, the acute to chronic ratios (ACRs) for soil and sediment tests were within the range of ACRs for aquatic organisms exposed to nonpolar organic chemicals.

The TLM-derived PNEC applied to these data, also, demonstrated sufficient level of protection approximately 95% of data above PNEC, even for chemicals up to log K_{ow} 6. For chemicals with log K_{ow} >6 an increasing incidence of no observed toxicity consistent with the dataset for aquatic organisms was observed. The duration of the pre-equilibration step was important for some chemicals. For example, toxicity was observed for these chemicals following short pre-equilibration times (<2 days), whereas no toxicity was observed for spiked soils that had been aged up to 7 weeks prior to exposure.

In conclusion, the work shows that the TLM can be extended to the soil and sediment compartments using the EqP for the purposes of a tier 1 risk assessment.

2/14 **PROCEEDINGS OF THE MINERAL OIL CROSS INDUSTRY ISSUES (MOCRINIS) WORKSHOP - SEPTEMBER 2013**

CONCAWE organised a 2-day Mineral Oil Cross Industry Issues (MOCRINIS) Workshop in Bologna, Italy in September 2013. The objective of the Workshop was to address topics that have arisen following the publication of results demonstrating the presence of saturated and aromatic hydrocarbons in some foods. The Workshop was

attended by delegates from a range of industry sectors with an interest in the issue such as mineral oil producers, printing ink manufacturers, cardboard and paper packaging industries as well as regulators from the European Union (EU) and individual countries.

The topics of measurement and characterisation, exposure to and toxicity of hydrocarbons were discussed fully and openly and possible ways forward were identified. This report presents the proceedings of the MOCRINIS Workshop.

3/14 ASSESSMENT OF RECENT HEALTH STUDIES OF LONG-TERM EXPOSURE TO OZONE

This report summarises the assessment of the policy relevant long-term health studies published since the last update of the ozone Air Quality Limit Value (AQLV). This project was undertaken in preparation for the European Union 2013 Year of Air discussions on the Air Quality Directives, and the impact of new health science on the AQLV for key pollutants, including ozone. The types of studies reviewed in this assessment included chronic mortality and morbidity air pollution epidemiology studies and repeat-dose toxicology and mechanistic studies.

For each study, a summary of the findings as reported was prepared along with a critical review identifying the strengths and weaknesses of the study. In total thirteen chronic mortality studies, nine respiratory morbidity studies, nine epidemiology studies evaluating long-term exposure to zone and pulmonary function and nine repeat dose animal inhalation studies were reviewed. Reliability scores were provided for both the epidemiology and toxicology studies, and a weight-of evidence approach was implemented to determine causality.

In summary, for chronic mortality, the data were considered not sufficient to draw a causal conclusion between long-term exposure to zone and mortality. The available toxicology and mechanistic data did not support the mortality hypothesis at current ambient ozone levels since much higher levels (500 ppb) were required to produce serious effects. For chronic morbidity, the data were considered insufficient to establish a causal relationship between long-term exposure to ozone and new onset asthma. In addition, the data do not indicate that long-term exposure to ozone at current ambient levels causes reductions in lung function development. Short-term exposure to higher levels of ozone can cause transient change in lung function which, if accompanied with symptoms, could be considered as adverse. The serious effects in animals as a result of repeated high level (500 ppb) exposure are not expected to occur in humans exposed to ambient levels.

In summary, the quality of the evidence to evaluate the association between chronic exposure to ozone and mortality is highly unreliable, and information to support an objectively-based Air Quality Target Values (AQTV) is lacking.

4/14 USE OF MOTOR FUELS AND LUBRICANTS: HABITS AND PRACTICES OF CONSUMERS IN EUROPE

A structured survey of European consumers was carried out across 250 participants to better understand their habits and practices concerning their use of vehicle fuels and lubricants. This report contains the findings of the survey. The information obtained from this survey provides insight on the current nature of consumer exposures to fuels and lubricants, and will be used to support the REACH registrations of petroleum substances and the basis for the information included in the CONCAWE Specific Consumer Exposure Determinants (SCEDS).

5/14 METHODS FOR ESTIMATING VOC EMISSIONS FROM PRIMARY OIL-WATER SEPARATOR SYSTEMS IN REFINERIES

This report reviews the different methods available to estimate annual Volatile Organic Compound (VOC) emissions from primary oil-water separator systems in refineries and discusses the results obtained by applying some of these in two field trials carried out in European refineries in 2011. Average emission estimates over the trial periods were obtained using four published emission factors, three models and an empirical algorithm. DIAL (Differential Absorption LIDAR (Light Detection and Ranging)) was also used to derive estimates of short term emission fluxes from remote measurements of VOC concentration. Each method has been assessed for its adequacy in providing a reasonable estimation of emissions.

6/14 IMPACT OF FAME ON THE PERFORMANCE OF THREE EURO 4 LIGHT-DUTY DIESEL VEHICLES - PART 1: FUEL CONSUMPTION AND REGULATED EMISSIONS

By 2020, EU legislation will require that 10% of the total transport fuel energy demand is met by the use of renewable energy, primarily by blending bio-components. Although many types of blending components for diesel fuels are being considered to achieve this requirement, Fatty Acid Methyl Esters (FAME) are the most likely to be used in significant volumes over the coming decade. FAME products have been used in Europe for many years, both as blends and as neat fuels, in certain niche markets.

One unanswered question concerning FAME/diesel fuel blends is the effect of FAME on fuel consumption. Since FAME has a slightly lower energy content compared to hydrocarbon-only fuels, a higher volumetric fuel consumption is expected unless the vehicle is able to compensate in some way for the energy loss associated with the bio-component in diesel fuel.

To answer this question, Concawe completed a vehicle study in which four diesel fuel blends with FAME (as Rapeseed Methyl Ester (RME)) were tested in three Euro 4 light-duty passenger cars, each equipped with different after-treatment technologies. The FAME contents of these fuels varied from 0% to 50% v/v in order to accentuate the effect of FAME on the energy content of the blended diesel fuels. The programme was statistically designed to give a robust and repeatable testing schedule so that fuel consumption and tailpipe emissions data could be reliably collected over regulatory and transient driving cycles. The vehicle study was conducted for Concawe by the Laboratory for Applied Thermodynamics of the Aristotle University of Thessaloniki, Greece.

Fuel consumption data for all three vehicles over all driving cycles show that the volumetric fuel consumption increases in direct proportion with increasing FAME content and the decreasing volumetric lower heating value (energy content) of the FAME/diesel fuel blends. There was no detectable change in the energy efficiency of the vehicles on different fuel blends and they were not able to compensate for the lower energy content of the FAME/diesel blends through improved performance.

Increasing the FAME content also reduced the PM but increased the NO_x, HC, and CO emissions. The overall impact of FAME on tailpipe emissions was small when compared to the variations in emissions seen for different driving cycles and for different vehicles over the same driving cycle. No significant difference in emissions performance was observed for the two types of Diesel Particulate Filter (DPF) aftertreatment systems that were tested in these vehicles.

It is expected that these results will be of importance to those interested in the impact of FAME in diesel fuel on Well-to-Wheels fuel consumption and on tailpipe emissions from modern light-duty passenger cars.

7/14

IMPACT OF FAME ON THE PERFORMANCE OF THREE EURO 4 LIGHT-DUTY DIESEL VEHICLES - PART 2: UNREGULATED EMISSIONS

In 2009, EU legislation mandated that 10% renewable energy must be used in road transportation by 2020, primarily through the use of bio-blending components. For diesel fuel blending, Fatty Acid Methyl Esters (FAMES) manufactured from different natural oils are the most likely to be used in significant volumes over this time period. FAME products have been used in Europe for many years, both as blends and as neat fuels in some niche markets.

Concawe has completed a vehicle study in which one hydrocarbon-only diesel fuel and three blends of this fuel with FAME (from a single batch of Rapeseed Methyl Ester (RME)) were tested in three Euro 4 light-duty passenger cars. All vehicles used exhaust gas recirculation and were equipped with some type of diesel oxidation catalyst. One vehicle did not have a Diesel Particulate Filter (DPF) while the other two vehicles were equipped with DPFs that were regenerated using two different approaches. The FAME contents of the test fuels varied from 0% to 50% v/v in order to accentuate the effect of RME on the energy content of the blended fuels and on the emissions from the vehicles. The study was statistically designed and completed using a robust and repeatable testing schedule during which fuel consumption and emissions data were collected over different regulatory and transient driving cycles. These cycles included the New European Driving Cycle (NEDC), the ARTEMIS cycle, and two constant speed conditions. The effect of RME on fuel consumption was reviewed in Part 1 of this study.

In addition to the gaseous tailpipe emissions, particulate matter (PM) and particle number (PN) emissions were measured using the Particle Measurement Programme (PMP) regulatory procedure. Total PM, total PN, and solid PN emissions were measured as a function of RME content. In addition, the PM samples were chemically analysed for their soluble organic fraction, the fuel and lube contributions to this organic fraction, ionic species (nitrates and sulphates), and elemental carbon (by difference). Several carbonyl compounds were also collected from the tailpipe exhaust and characterized.

8/14

EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE. STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2013

In this twentieth annual report on European downstream oil industry safety performance, 2013 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Information was received from 39 Concawe Member Companies representing approximately 99% of the European refining capacity. Trends over the last twenty years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the fifth year of results for Process Safety Performance Indicators from Concawe members.

9/14

REVIEW OF RECENT HEALTH EFFECT STUDIES WITH NITROGEN DIOXIDE

This report focuses on published studies that have examined the epidemiologic associations of ambient air exposures to nitrogen dioxide and the occurrence of acute and chronic health effects in humans. All relevant studies published since the World Health Organization issued their Air Quality Review in 2005 were taken into consideration. Nearly a hundred of the 240 studies examined for preparation of this report dealt with the relationship between NO₂ exposures and acute respiratory disease

or asthma exacerbation. This continues to be the health outcome of greatest concern with NO₂ and will likely garner the most interest in future research programs.

Although a tremendous amount of new information has been gathered, there are still nagging issues that have not been sufficiently resolved to the extent needed to make definitive statements regarding causality and risk. Confounding and bias continue to plague many studies and the results from a limited number of new controlled human exposure studies suggest that NO₂ may not be responsible for the many of the reported associations that have been reported with asthmatics. Until improved statistical and monitoring methods are developed there will continue to be considerable doubt about the relevance of results from studies using single pollutant modelling and exposure estimates from fixed monitoring stations.

10/14 HAZARD CLASSIFICATION AND LABELLING OF PETROLEUM SUBSTANCES IN THE EUROPEAN ECONOMIC AREA – 2014

This report updates Concawe's classification and labelling recommendations Report No. 8/12 to reflect the publication of the 4th Adaptations to Technical Progress (ATP) of the EU Regulation on Classification, Labelling and Packaging (EC 1272/2008) that shall apply in respect of substances from 1 December 2014 and in respect of mixtures from 1 June 2015.

12/14 TOWARDS THE ESTABLISHMENT OF A PROTOCOL FOR THE QUANTIFICATION OF VOC DIFFUSE EMISSIONS USING OPEN-PATH REMOTE MONITORING TECHNIQUES: DIAL MONITORING OF A VOC SOURCE OF KNOWN EMISSION FLUX

This report provides the results of a programme of work undertaken to compare the controlled rate of release of propane from a simulated floating roof tank with the flux determined using information on wind data and DIAL measurements. The effects of sampling protocol, averaging time and location of the DIAL scan relative to the tank on the flux determinations were investigated.

The results have confirmed that the wind profile across the measurement plane is the main uncertainty in the determination of the emitted flux when relying on the use of wind-profile data from a meteorological mast in the unperturbed wind field. Adjusting the reference wind profiles to take account of local terrain and wake effect resulted in improved agreement between the DIAL flux calculations and the propane release rates.

The results of the campaign identified the following for inclusion in a draft protocol for the determination of tank emissions using DIAL: i) carry out concentration measurements between about 3H to 5H distance downwind of the tank shell (where H = tank shell height), ii) take into account the tank wake effect on the wind vertical profile of the horizontal wind speed, iii) take into account any difference in ground heights between the DIAL and where the scan intersects with the plume, iv) minimise uncertainty by making at least three DIAL scans and v) minimise the impact of any systematic effect by measuring along at least one other scan line.

Recommendations for further work have been made to minimize the uncertainties associated with DIAL measurements made very close to a tank shell.

13/14 EXPLORING A GASOLINE COMPRESSION IGNITION (GCI) ENGINE CONCEPT

This report describes initial engineering and experimental steps to assess the potential to improve efficiency and reduce both regulated and CO₂ emissions, and maintain acceptable noise performance by running gasoline in an advanced diesel engine. An

engineering paper study was carried out to analyse critical engine and fuel parameters and judge what speed/load range might be feasible for a Gasoline Compression Ignition engine concept.

Using an advanced diesel bench engine having a higher compression ratio, optimised valve timing, and flexible fuel injection, the engine could be operated on a European market gasoline over full to medium part loads. The combustion was found to be highly sensitive to exhaust gas recirculation (EGR) rates, however, and the simultaneous optimisation of all regulated emissions and combustion noise was a considerable challenge. An advanced glow plug was tested to improve low load performance but did not extend the engine operating range as much as expected. From a commercial perspective, it is well understood that there are significant challenges associated with bringing both a new engine concept and a dedicated fuel into the market at the same time. Although compression ignition (CI) using gasoline was not successful in this study, the potential benefits of fuelling advanced compression ignition engines with market gasoline merited further consideration for the following reasons:-

First, CI engines have a clear efficiency advantage over spark ignition (SI) engines and extending their capability to use a broader range of fuels could be advantageous. Second, the ability of CI engine concepts to use an already available market gasoline would allow these concepts to enter the fleet without fuel constraints. Third, more gasoline consumption in passenger cars would help to rebalance Europe's gasoline/diesel fuel demand on refineries and reduce GHG emissions from fuel supply. Fourth, a successful new CI vehicle of this type could potentially compete in predominantly gasoline markets in other parts of the world.

Computational fluid dynamics and KIVA simulations were completed on the same single cylinder bench engine configuration operating on market gasoline to identify ways of improving low load performance. This modelling has shown that variable valve timing offers considerable potential for increasing the temperature inside the combustion chamber and reducing the ignition delay. The simulations have also identified the preferred placement of combustion assistance, such as a glow plug or a spark plug, to extend the operating range and performance on gasoline, especially under the lowest load and cold engine starting conditions

14/14 DERMAL EXPOSURES ASSOCIATED WITH SERVICE STATION REFUELLING ACTIVITIES: PRELIMINARY EVALUATION

This study investigates dermal exposure to petrol and diesel fuel in service station attendants responsible for the refuelling of automobiles. In phase 1 of the study, six attendants from three service stations wore a carbon patch sample inside and outside their clothing to assess dermal exposure and to evaluate the potential clothing penetration. Hand washing samples were also obtained to assess fuel hydrocarbons on the skin as a result of routine contact with equipment surfaces such as the dispenser nozzle grip, button panel, and dispenser hoses. Dermal exposure to petrol and diesel fuel was also quantified as the amount of individual hydrocarbon congeners ranging from C₆-C₂₈. These determinations were supplemented with benzene, toluene, ethylbenzene, *m*+*p*-xylene, *o*-xylene, methyl *t*-butyl ether, *n*-hexane, and *n*-heptane measurements using gas chromatography with mass selective detection.

The hand wash measurements used to assess skin exposure to the hands from diesel fuel dispensing activities at service stations showed a considerable variability, the concentrations ranged 3,4 - 78 ng for hydrocarbons in the diesel fuel range. Hydrocarbon levels on the hands were compared against the corresponding levels on the dispensing equipment to identify components that could serve as tracers or markers

of exposure. The highest correlation coefficient ($r^2 = 0.958$) was observed for the C₂₁ hydrocarbon congener which was strongly related to the diesel fuel levels on the hands. Reduced variability was observed when the diesel fuel results were normalised for fuel volumes dispensed by operators during each work shift. Hydrocarbon concentration across the different equipment surfaces was not significantly correlated, except for the button panel and the nozzle grip of the diesel dispenser. The highest correlation coefficient found was for toluene associated with petrol fuel activities for patch samples placed inside or outside the clothing. Due to the small number of samples collected findings are limited and may represent under or over estimates.

Phase 2 of the study assessed the dermal transfer coefficient for C₁₄-C₂₈ hydrocarbons from equipment surfaces to the hands. For this study, hand wipe samples were taken at hourly intervals from attendants and separately from equipment surfaces for a period of 4 hours on each of three work days. The dermal transfer coefficient was calculated as the ratio of the hand wipes expressed as ng/hr to the levels on nozzle grips and button panels expressed ng/cm². The median value for the twelve measurements was 25 cm²/hr. This number provides a means of calculating the hydrocarbon load to the hands after measuring C₁₄-C₂₈ hydrocarbon levels on an equipment surface.

15/14 SPECIFIC CONSUMER EXPOSURE DETERMINANTS (SCEDS) FOR KEY USES OF FUELS AND LUBRICANTS

Under the REACH regulation, registrants are required to demonstrate the absence of significant risk when consumers are exposed to their registered substances. To do this, the European Chemicals Agency (ECHA) has identified preferred REACH consumer risk assessment tools, all of which are very conservative, and frequently lead to the (false) indication of a potential concern. Specific Consumer Exposure Determinants (SCEDs) were developed as a standardized way to transparently show when and how consumer exposures to substances occur and is now the preferred way forward to describe consumer exposures under REACH. As part of Concawe's contribution to the ECHA Network on Exposure Scenarios (ENES), Concawe worked with the Downstream Users of Chemicals Coordination Group (DUCC) to develop SCEDs for the two primary consumer uses of petroleum products, fuels and lubricants.

This report outlines the development and basis of the 9 Concawe's SCEDs that cover a range of common uses of petroleum products (fuels and lubricant uses).

1/15R RISK ASSESSMENT FOR EMISSIONS FROM HOT HEAVY FUEL OIL DURING BARGE LOADING

A series of emissions, occupational exposures, and mutagenic hazard studies were conducted to assess the risk associated with the loading of commercial Heavy Fuel Oils onto barges on the inland waterways. This report summarises the results from the laboratory investigations, exposure monitoring studies, and mathematical modelling exercise aimed at documenting the potential inhalation exposure, fractional release and intrinsic hazards of HFO vapours and aerosols under barge loading conditions. Analytical methodologies were developed to quantify HFO vapour and aerosol air concentrations, and an industrial hygiene assessment and worker exposure monitoring were conducted during the actual loading operations. The results indicated that during the loading of hot commercial HFO on inland waterway barges:

- The emissions resulted in low workplace exposures, well below limit values set by the American Conference of Governmental Industrial Hygienists
- There was no release of detectable amounts of benzo(a)pyrene

- There was no mutagenic risk of workers based on the mutagenic assays conducted on the fume condensates generated under similar operating conditions
- There was no substantial contribution to air emissions relative to other types of petroleum hydrocarbon cargos.

Therefore, based on these findings, the risk for workers handling commercial grade HFOs, as well as the environmental risks, during a barge loading operation on inland waterways do not pose a health concern. These studies did not indicate a need for additional control measures on the emissions of hot HFOs during barge loading beyond normal good operational industrial hygiene practices.

2/15

AIR EMISSIONS FROM THE REFINING SECTOR. ANALYSIS OF E-PRTR DATA 2007-2011

This report provides a review of the air pollutant emissions data submitted by national authorities for oil refineries in the E-PRTR from 2007 to 2011. Detailed analyses are given for five pollutants (SOx, NOx, NMVOCs, CO₂ and benzene).

Emissions of the five pollutants reviewed have decreased significantly between 2007 and 2011: SOx 37%, NOx 28%, NMVOCs 35%, benzene 44% and CO₂ 9% even after taking into consideration the mass of crude processed which has declined by almost 10% over the same five year period, the percentage reductions in kt of reported emissions per Gt of crude processed reduced for the five pollutants: SOx 30%, NOx 19%, NMVOCs 28%, benzene 38%, CO₂ -1.4%.

3/15

AIR POLLUTANT EMISSION ESTIMATION METHODS FOR E-PRTR REPORTING BY REFINERIES - 2015 EDITION

This report is an update of the Concawe publication "*Air Pollutant Emission Estimation Methods for EPER and PRTR Reporting by Refineries*". It provides algorithms to permit emission estimates to be made by refineries to meet the reporting requirements of the European Pollutant Release and Transfer Register (E-PRTR) regarding pollutant emissions to air. This version contains some additional algorithms and new and updated emission factors and supersedes previous versions of the report listed below:

Concawe Report 1/09
Concawe Report 3/07
Concawe Report 9/05R
Concawe Report 9/05

The control copy of this report is posted as an electronic document on the Concawe web-site (www.concawe.org).

There are 60 air pollutants which must be reported under the E-PRTR requirements if their respective annual emission threshold values are exceeded at a facility. All 60 pollutants are listed in Appendix 1 of this report. Emission estimation methods are provided for 24 of those pollutants. New and updated information is summarised in Appendix 2.

4/15

PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES. STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2013 AND SINCE 1971

Concawe has collected 43 years of spillage data on European cross-country oil pipelines. At over 36,000 km the inventory covered currently includes the vast majority

of such pipelines in Europe, transporting some 680 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2013 and a full historical perspective since 1971. The performance over the whole 43 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (inspection pigs) is also reported. The main feature of this 2013 survey is the dramatic rise of spillages related to product theft attempts, 18 of which were reported. Another 8 spillage incidents were reported in 2013, corresponding to 0.23 spillages per 1000 km of line, above the 5-year average of 0.18 but well below the long-term running average of 0.48, which has been steadily decreasing over the years from a value of 1.2 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. 3 incidents was due to mechanical failure, 1 to operational error, 1 to corrosion, and 3 were connected to third party activities (other than theft). Over the long term, third party activities remain the main cause of spillage incidents and the apparent rise of theft attempts will only increase this proportion.

**5/15 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE.
STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2014**

In this twenty-first annual report on European downstream oil industry safety performance, 2014 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Information was received from 38 Concawe Member Companies representing approximately 98% of the European refining capacity. Trends over the last twenty-one years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the sixth year of results for Process Safety Performance Indicators from Concawe members.

**6/15 TECHNIQUES FOR DETECTING AND QUANTIFYING FUGITIVE EMISSIONS –
RESULTS OF COMPARATIVE FIELD STUDIES**

Sniffing and Optical Gas Imaging (OGI) methods for the detection of refinery fugitive VOC emissions were compared under field conditions. Both of these methods are described as Best Available Techniques (BAT) in the EU BAT Reference (BREF) document for refining of mineral oil and gas. Sniffing is a traditional method defined by standards and OGI is a newer technique offering considerable advantages. The comparison of these methods was made quantitative by using a bagging technique to explicitly measure emission rates. It was found that Optical Gas Imaging was very successful in finding the majority of the mass emissions and therefore it can be considered as effective as Sniffing and as a standalone leak detection and repair method.

**7/15 EVALUATION OF WHOLE EFFLUENT BIOASSAYS FOR ASSESSMENT OF
HYDROCARBON ECOTOXICITY – PHASE III STREAM STUDY REPORT**

The report describes collaborative research undertaken by Concawe and Total to benchmark the performance of laboratory- based whole effluent toxicity (WET) tests, which are increasingly used for environmental impact assessment, against effects observed in more realistic stream mesocosms. It is shown that for unmodified and hydrocarbon- fortified refinery effluents, 3 commonly used WET tests (*Vibrio fischeri* for bacteria, *Pseudokirchneriella subcapitata* for micro-algae and *Daphnia magna* for invertebrates) predict ecological effects similar to those observed in the streams, or over-predict the effects. These results suggest that environmental impact assessment based solely on data obtained from laboratory WET assays is likely to be conservative. i.e. the biological impact would be less in a more realistic exposure system.

8/15 MONITORING METHOD FOR INHALATION EXPOSURE TO GAS OIL VAPOUR AND AEROSOL

A study was conducted to characterize sampling and analysis methods for the measurement of the personal workplace exposure concentration of gas oil vapours and aerosols and, in particular, to describe their ability to quantify the aerosol-vapour partitioning. This project aims to address a deficiency identified in current monitoring methods where the principle focus has been on aerosol phase of exposure to mists.

Two sampling methods for the total concentration of gas oil atmospheres and aerosol-vapour partitioning were investigated in a laboratory set-up:

- a filter and XAD-adsorbent cartridge operated in series (BIA method)
- a virtual-impactor combined with filter-XAD cartridges (VI-method)

In conclusion, the BIA method allows for sampling and measuring the total concentration of the gas oil atmospheres for concentrations larger than 0.5mg/m³ for 8-hour sampling. In the BIA sampling system, evaporation effects can cause a shift of the aerosol-vapour partitioning towards the vapour phase. The magnitude of these effects depends on the material being sampled, thermodynamic conditions during sampling and sampling duration. In contrast, in the VI-method, the aerosol-vapour fraction is nearly independent of the thermodynamic conditions and the sampling time. However, the partitioning coefficient can be influenced by smaller aerosols with diameters less than the critical cut-off diameter; this aerosol fraction is falsely recorded as vapour phase. The VI methods has some other limitations (e.g., wall losses of up to 15-30% total concentration), however, it bears potential for further improvement.

9/15 HAZARD CLASSIFICATION AND LABELLING OF PETROLEUM SUBSTANCES IN THE EUROPEAN ECONOMIC AREA – 2015

The updated report contains an assessment of the hazardous properties of petroleum substances against the criteria of the CLP Regulation up to and including the 6th ATP and Corrigendum to Annex VI. C&L Permutations have been added in Appendix 6.

10/15R FIRST AID REFERENCE GUIDE – 2015

This reference guide is designed to provide additional information on the first aid measures in the event of significant on-site exposures to petroleum substances.

This document is intended for trained first aiders and site medical professionals and is not intended to replace the Safety Data Sheets, or other company specific procedures. This reference guide only address exposure from acute occupational exposure. First aid treatment should be carried out by appropriately qualified persons.

1/16 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES IN EUROPE (2010)

This report describes the results of the 2010 year survey into the sulphur pathways in European refining. This includes the distribution of sulphur in products, the capture and recovery of sulphur in refineries and the emission of sulphur oxides as part of the refining process. The archived results of surveys carried out for the years 1998, 2002 and 2006 are also included.

2/16 ANALYSIS OF N-, O-, AND S- HETEROCYCLICS IN PETROLEUM PRODUCTS USING GCXGC WITH SPECIFIC DETECTION

REACH dossiers on all petroleum product categories were compiled and submitted by Concawe in 2010. ECHA subsequently raised concerns regarding the technical justification of the assumptions and tools used to generate the current PNECs for petroleum substance components. One of these issues regarded the lack of 'oxygen and nitrogen containing petroleum substances' from the Concawe library of structures in the PETROTOX/PETRORISK IT tool. The uncertainty linked to this omission had not been addressed by the Registrant in the registration dossier in the context of assessment factor selection.

To address this specific issue, Concawe subsequently agreed to

- Perform a literature review of the presence on nitrogen, oxygen and sulphur heterocyclics (NOSHs) and their structures in petroleum products
- Carry out analysis of NOSHs in petroleum products using GCxGC with specific N- and S- detectors and GC-AED with O-detection

Literature review confirmed the relative abundance of C, H, N, O and S in petroleum was 83-87%, 10-14%, 0.1-2%, 0.05-1.5% and 0.05-6%, respectively with a relatively large number of (>150) of NOSH structures identified from previous analysis of petroleum products. Petroleum products ($n = 44$) ranging from low boiling naphthas to asphalts were analysed using GCxGC with selective N- and S-chemo-luminescence Detectors (NCD and SCD, respectively) and GC-AED (Gas Chromatography Atomic Emission Detector, used for O-containing components, since there is currently no existing O-specific detector for GCxGC analysis). Eleven different compound classes, each of varying carbon number, could be differentiated based on polarity for N- and S-heterocyclics. Total S-heterocyclics ranged from <0.01-3.24% (mean = 0.58%), whereas total N-heterocyclics, ranging from <0.01-0.08% (mean = 0.02%), were less abundant. No O-containing components could be detected (i.e. <0.1%).

Based on the analytical data generated, it is concluded that NOSH compounds only occur in low concentrations within petroleum products.

3/16

ASSESSING THE AQUATIC TOXICITY OF PETROLEUM PRODUCTS: COMPARISON OF PETROTOX CALCULATIONS AND SPME-GC SCREENING

Using detailed two-dimensional chromatography (GCxGC) analysis of a set of petroleum product samples of Gas Oils, Residual Aromatic Extracts (RAE) and Bitumen categories, PETROTOX predictions have provided information to support revised category justification documents and enable the selection of "worst case" products in each category for ecotoxicity testing.

In addition, analysis of Water Accommodated Fractions (WAFs) of these product samples using Biomimetic Extraction (BE) with solid phase microextraction (SPME) fibres was used to confirm that SPME data correlates to Toxic Units predicted by the PETROTOX model using GCxGC compositional data, thereby strengthening the linkage between composition, SPME data and aquatic toxicity. This provides a technical basis for further use of SPME as a more practical characterization tool for addressing the influence of variation in substance composition on aquatic toxicity within petroleum product categories as SPME correlates well with PETROTOX calculations and consistent TU-dose response relationships between algae and *daphnia* are observed.

BE-SPME is shown to be a cost-effective approach to toxicity screening for petroleum substances, and thus an alternative method to enhance currently available ecotoxicity data sets, as well as complement predicted ecotoxicity using PETROTOX.

4/16

REVIEW OF RECENT health EFFECT STUDIES WITH SULPHUR DIOXIDE

This report focuses on published toxicology and epidemiology studies that have examined the relationship between sulphur dioxide exposures and the occurrence of acute and chronic health effects in laboratory animals and humans. All relevant studies published since the World Health Organization issued their Air Quality Review in 2005 were taken into consideration. A total of 225 environmental epidemiology and toxicology studies were individually examined and summarized in the course of preparing this report. Whereas an appreciable number of new morbidity and mortality investigations have been conducted on both acute and chronic health outcomes, the focus of most studies continues to be on the relationship between SO₂ exposures and respiratory disease and asthma exacerbation. In addition, there has been a large increase in the number observational focusing on associations between SO₂ exposure and variety of birth outcomes such low body weight, malformations, and infant mortality.

Although a tremendous amount of new information has been published there are many problems with a majority of the observational studies including a heavy overreliance on concentration measurements from central monitoring sites as a surrogate for personal exposures. Despite the existence of studies showing that there is no relationship between these measures and personal SO₂ exposures, central monitoring site measurements continue to be used unabated. In addition, most of the studies have been performed used a single pollutant modelling approach that did not take into consideration the correlations between ambient SO₂ levels and the concentrations of other pollutants such as PM₁₀ and PM_{2.5}. Those studies that have incorporated a multi-pollutant design have generally shown that and observed health associations emerging from a single pollutant model are not robust to the inclusion of a correlated co-pollutant. As a result, a majority of the epidemiological studies conducted with SO₂ suffer from a very high degree of exposure misclassification that renders them unusable for a hazard or risk determination. Given these circumstances, there is no good justification for making any adjustment to current limit values.

5/16 THE NATURAL ATTENUATION OF FATTY ACID METHYL ESTERS (FAME) IN SOIL AND GROUNDWATER

With the increasing use of fatty acid methyl esters (FAME) in automotive fuels there is growing interest in the fate and effects of biodiesel, and biodiesel/ petroleum distillate blends in the environment. While biodegradation of FAME has been documented, uncertainty remains regarding how FAME partitions and degrades in the subsurface either alone, or in conjunction with other fuel components (e.g. hydrocarbons). A review of technical literature has therefore been completed to bring together the available data in this area.

The low solubility of FAME in groundwater means it is likely to behave as a light non-aqueous phase liquid (LNAPL) source with a relatively small region of influence. In this context, B5 or B20 biodiesel/petroleum blends may be expected to behave similarly to petroleum diesel in the subsurface. FAME does not appear to enhance the solubility of hydrocarbons as a whole, or individual components such as poly or mono-aromatic hydrocarbons. Individual FAME compounds have low aqueous solubility, low volatility and low mobility but the mechanisms of autoxidation and hydrolysis may result in the generation of more mobile but equally biodegradable components.

FAME is widely reported to be readily biodegradable under both aerobic and anaerobic conditions, although rates may vary from site to site as a function of ground conditions, electron acceptor concentrations and biodiesel composition. FAME appears to enhance the biodegradability of petroleum diesel at concentrations of B20 and higher, but this effect has not been demonstrated at field scale in the context of a subsurface release. At sites with limited electron acceptors and macronutrients (nitrogen and phosphate), microorganisms that degrade FAME have the potential to deplete available

electron acceptors and nutrients resulting in an extended time for diesel biodegradation. As with other labile biofuels such as ethanol, anaerobic biodegradation of FAME has the potential to produce significant quantities of methane, which should be taken into account during the risk assessment of biodiesel and biodiesel/ petroleum diesel blend release sites

Overall, natural attenuation would appear to be significant in controlling the fate, behaviour and potential risks posed by biodiesel and biodiesel/ petroleum diesel blends. Significant attenuation mechanisms include sorption, auto-oxidation and biodegradation via a variety of redox processes: the exact role and contribution of each will depend on the nature of the release, the characteristics of the biodiesel and the environmental setting.

6/16 CRITICAL REVIEW OF THE RELATIONSHIP BETWEEN IP346 AND DERMAL CARCINOGENIC ACTIVITY

The IP 346 method was adopted as a screening assay to predict the carcinogenicity of specific petroleum streams. Its application is based on a strong correlation with results from over 100 mouse dermal carcinogenicity studies, which were reported in a series of publications and formally documented in Concawe Report 94/51[1]. This correlation was used to establish the basis for defining a cancer hazard classification threshold for specific petroleum categories. It has been adopted in EU legislation through the use of note L as per the former Dangerous Substance Directive No 67/548 EC and continued in the Classification, Labelling and Packaging (CLP) Regulation (EC) No 1272/2008.

The purpose of this report is to review the current state of the science to determine if the IP 346 method continues to be fit for purpose to predict the carcinogenic potential of certain categories of petroleum streams. A systematic literature search was conducted to identify any new petroleum stream carcinogenicity studies published since 1994 that were correlated with IP 346 data.

Thirty-five new carcinogenicity study results were identified, with 28 of these on substances within the scope of the IP 346 method. With the addition of these new sample results and their complementary IP 346 test results, specificity and accuracy were not significantly changed, and most importantly, sensitivity was unchanged at 93% for all petroleum streams, and increased to 88% for lubricant base oils.

Therefore, based on an analysis of the results of additional studies identified since publication of Concawe report 94/51, the IP 346 method and the original criteria developed in 1994 continue to be fit for purpose for the prediction of carcinogenic potential for lubricant base oils, treated distillate aromatic extracts and foots oils.

7/16 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2014 AND SINCE 1971

Concawe has collected 44 years of spillage data on European cross-country oil pipelines. At nearly 38,000 km the current inventory includes the majority of such pipelines in Europe, transporting some 680 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2014 and a full historical perspective since 1971. The performance over the whole 44 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped

into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (inspection pigs) is also reported. The main feature of this 2014 survey is the continued dramatic rise of spillages related to product theft attempts, 54 of which were reported, confirming the trend already observed in 2013. Excluding theft-related events, 4 spillages were reported in 2014 corresponding to 0.12 spillages per 1000 km of line, less than the 5-year average of 0.18 and well below the long-term running average of 0.47, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. 1 incident was due to mechanical failure and 3 were connected to third party activities (other than theft). Over the long term, third party activities remain the main cause of spillage incidents and the rise of theft attempts will greatly increase this proportion.

8/16

ENVIRONMENTAL FATE AND EFFECTS OF POLY AND PERFLUOROALKYL SUBSTANCES (PFAS)

Aqueous Film Forming Foam (AFFF) and Fluoroprotein (FP)/ Film Forming Fluoroprotein Foam (FFFP) foam have been used since the 1960s and 1970s, respectively, for the suppression of class B (flammable liquid) fires at airports, refineries and other major petroleum facilities. In recent years, however, the use of these has been challenged due to concern that certain poly and perfluoroalkyl substances (PFAS) used in their formulation exhibit PBT characteristics (Persistent, Bioaccumulative and Toxic). While alternative PFAS-free foams are now commercially available, concerns have been raised that these may be less effective for fighting large-scale flammable liquid fires and that other issues such as shelf life, compatibility with conventional application equipment and suitability of different materials for storage have not been fully evaluated.

It is important that users of class B fire- fighting foams understand and manage both environmental and fire safety aspects of foam use. An assessment of site foam stocks is recommended to ensure that any legacy stocks containing >0.001wt% PFOS (banned for use in the EU since June 2011) are set aside for safe disposal by high temperature incineration. A similar assessment should be completed for foam stocks that may be brought to site from third parties in the event of an emergency. At locations where fluorochemical- based foams have been used for fire- fighting or fire- fighting training, users should consider how to manage the potential issues.

Fire- fighting foams designated "C6" by manufacturers are formulated using PFAS that cannot degrade to form PFOS or PFOA and so these seem of less concern from an environmental standpoint. It should be noted, however, that given the range of compounds present there is still uncertainty about their properties. In addition, low environmental concentration limits have been set for short chain PFAS (i.e. <C6 PFSA; <C7 PFCA) in many EU countries due to their persistence. Where possible, therefore, water containing PFAS- based fire- fighting foam residues should be captured for treatment and not discharged to the environment.

This report, which is a review of published literature on the environmental fate and effects of PFAS, has been produced to help Concawe members understand and manage environmental and human health risks associated with current and legacy formulations of PFAS- based class B fire- fighting foams. It describes the main types of PFAS, their use, fate and transport properties, toxicity data, regulation, and gives an overview of chemical analysis and remedial techniques.

The report has been reviewed by members of the Concawe Special Taskforce on Soil and Groundwater, and the Emerging Contaminant Working Group of the Network for Industrially Contaminated Land in Europe (NICOLE).

9/16 EMISSION FACTORS FOR METALS FROM COMBUSTION OF REFINERY FUEL GAS AND RESIDUAL FUEL OIL

This report provides emission factors for nine metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium and zinc) emitted to atmosphere during the combustion of refinery fuel gas in boilers and furnaces. It also provides a factor for nickel emissions from the combustion of refinery residual fuel oil. These factors are considered to provide more representative average emission estimates than those provided in the reference commonly used for these factors (API Publication 348) as substantially more data have been used in their derivation.

10/16 GASOLINE DIRECT INJECTION PARTICULATE STUDY

Two modern Gasoline Direct Injection (GDI) light duty vehicles have been tested to investigate the effect of oxygenates (mainly ethanol) on particulates - both mass and number, fuel economy and regulated emissions.

The GDI vehicles used in this study met Euro 4 and Euro 5 emissions limits and were tested over the New European Driving Cycle (NEDC) using ethanol containing gasolines at different oxygen levels and RON values. An ether-containing blend was also tested for comparison. Both matched RON and oxygen content ethanol and ether blends were specially prepared and tested as well as splash blended ethanol containing fuels. Fuels were tested in duplicate using a randomized test order in order to improve statistical certainty. A rigorous test protocol was used to allow the vehicle to adapt to each fuel and reduce carryover effects.

This report gives the results of this testing and makes some conclusions on the effect of matched and splash-blended oxygenates on particulates - both particulate matter (PM) and particulate number (PN). In general fuel effects were small compared to vehicle to vehicle effects and did not affect the vehicles ability to meet the legislated specifications. Some individual observations were made in one vehicle where PN reduced with ethanol levels at >3.7 mass% oxygen compared to lower levels and fuel consumption debits were observed in both vehicles although the low levels of PM produced by these modern vehicles made it difficult to come to any conclusions on fuel effects on this parameter.

11/16 URBAN AIR QUALITY STUDY

An exploration into the effect of emission reduction scenarios on compliance with the ambient air quality limit values for the EU27 countries in urban environments.

12/16 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE – STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2015

In this twenty-second annual report on European downstream oil industry safety performance, 2015 statistics are presented on work-related personal injuries for the industry's own employees and contractors. Information was received from 38 Concawe Member Companies representing 97.1% of the European refining capacity. Trends over the last twenty-two years are also highlighted and the data are compared to similar statistics from related industries. This report also presents the seventh year of results for Process Safety Performance Indicators from Concawe members.

13/16 PHASE 1: EFFECT OF FUEL OCTANE ON THE PERFORMANCE OF TWO EURO 4 GASOLINE PASSENGER CARS

This report details work that was carried out to study the response of modern gasoline passenger cars on octane. The objective of this phase 1 of the study was to investigate the effect of RON and MON on the power and acceleration performance of two Euro 4 gasoline vehicles under full throttle acceleration conditions. Fifteen fuels covering RON levels 95 to 103 and sensitivities (RON minus MON) up to 15 were blended and tested. Both pure hydrocarbon and blends containing ethanol or ETBE were included so that any specific effects of oxygenates could be identified. Three additional fuels, covering RON as low as 86, were blended using primary reference fuels. The results confirm the findings of previous studies on older vehicles by other workers that MON is not a good predictor of vehicle acceleration performance in more modern vehicles and in fact high MON levels increase acceleration time under full throttle conditions. In addition, it was found that during wide open throttle conditions efficiency deteriorated on the lowest octane (RON) fuels tested as expected as the engine adapts to knock. It was also observed that efficiency increased up to higher octane levels than would be expected for both vehicles.

14/16 IMPACT OF FAME CONTENT ON THE REGENERATION FREQUENCY OF DIESEL PARTICULATE FILTERS (DPFS)

Modern diesel passenger cars utilize Diesel Particulate Filters (DPFs) to reduce particulate matter exhaust emissions. In addition oxygenated fuels and fuel blending components such as Fatty Acid Methyl Esters (FAMES) are known to reduce PM formation in the combustion chamber and reduce the amount of soot that must be filtered from the engine exhaust by the DPF. This effect is also expected to lengthen the time between DPF regenerations and reduce the fuel consumption penalty that is associated with DPF loading and regeneration.

This study investigated the effect of FAME content, up to 50% v/v (B50), in diesel fuel on the DPF regeneration frequency by repeatedly running a Euro 5 multi-cylinder bench engine over the European regulatory cycle (NEDC) until a specified soot loading limit had been reached. The results verified the expected reduction of engine-out particulate mass (PM) emissions with increasing FAME content and the reduction in fuel economy penalty associated with reducing the frequency of DPF regenerations. Fuel dilution measurements on lubricant samples taken from the engine sump showed that the FAME content in the engine lubricant increased with higher FAME contents in the fuel blends.

1/17 ESTIMATING THE MARGINAL CO₂ INTENSITIES OF EU REFINERY PRODUCTS

Estimating the CO₂ emissions associated with production of individual oil products is challenging inasmuch as they are produced simultaneously through a combination of interrelated processes. This report proposes a new methodology that utilises the specific features of the Linear Programming (LP) technique used to model refineries to produce a consistent set of CO₂ intensities for all refinery products. The methodology is described in detail and applied to a study case reflecting EU refining in 2010. Results are compared to figures obtained in previous Concawe work.

2/17 AN EVALUATION OF AN OPTICAL GAS IMAGING SYSTEM FOR THE QUANTIFICATION OF FUGITIVE HYDROCARBON EMISSIONS

This report provides the results of a preliminary study undertaken to test the performance of a quantitative optical gas imaging (QOGI) system. This has been developed to measure the mass emission rate of hydrocarbon leaks from industrial process equipment. Testing was performed using controlled releases in the range 1.7 g/h to 1000 g/h. For comparison purposes a conventional sniffing technique was also used for leak detection with emission estimates determined using the correlation equations from US EPA Method 21. Sixty one leak tests were performed. The QOGI system detected all of these leaks but it was found that quantification required a differential temperature of > 5°C between the released gas and the background. Where leak rate quantification was achieved with the QOGI system the differences between the values determined and the known release rates were within a range of -23% to 69%, with an average difference of 6%. By comparison, where the US EPA Method 21 correlations were used to estimate leak rates these differed from the known release rates within a range of -92% to 667%, with an average difference of 31%.

3/17 EXPERIMENTAL EVALUATION OF THE FLUX CHAMBER TECHNIQUE TO DETERMINE VOC EMISSIONS FROM A WATER SURFACE

Tests have been undertaken under controlled conditions in a wind tunnel to compare the emission fluxes from an open tank containing an aqueous toluene solution with those determined using a flux chamber mounted on the water surface. The tests showed that the flux chamber under-estimated the toluene emission fluxes by approximately a factor of two. This result was the same for two concentrations of toluene in the aqueous solution and for the range of flux chamber sweep air flows tested.

4/17 AIR POLLUTANT EMISSION ESTIMATION METHODS FOR E-PRTR REPORTING BY REFINERIES - 2017 EDITION

This report is an update of the Concawe publication *"Air Pollutant Emission Estimation Methods for EPER and PRTR Reporting by Refineries"*. It provides algorithms to permit emission estimates to be made by refineries to meet the reporting requirements of the European Pollutant Release and Transfer Register (E-PRTR) regarding pollutant emissions to air.

5/17 COMPILATION OF CONCAWE MARKET FUEL SURVEYS: 2008-2012

Concawe conducted a number of market fuel surveys on petrol and diesel qualities in eighteen European countries. In total 547 samples (151 petrol and 396 diesel) were sampled from 18 EU countries in the years 2008, 2010 and 2012. This report summarises the data by country and illustrates the data in charts for comparison purposes.

**6/17 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE –
STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2016**

The twenty-third annual report on European downstream oil industry safety performance presents work-related personal injuries for the industry's own employees and contractors and process safety performance indicators. Information was received from 38 Concawe Member Companies representing approximately 99% of the European refining capacity. In 2016, there were two fatalities in the industry. While this is the lowest number of annual fatalities since Concawe began compiling industry records in 1993, we must consider this two too many. Lost Workday Injuries fell from 546 to 501, a drop of approximately 8%. The number of Tier 1 and 2 process safety releases continues to decline but the rate of decline per annum appears to be slowing (total count of 287 in 2015 down to 282 in 2016).

**7/17 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES
STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2015 AND SINCE
1971**

Concawe has collected 45 years of spillage data on European cross-country oil pipelines. At nearly 37,500 km the current inventory includes the majority of such pipelines in Europe, transporting some 751 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2015 and a full historical perspective since 1971. The performance over the whole 45 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (inspection pigs) is also reported. The main feature of this 2015 survey is the continued rise of spillages related to product theft attempts, 87 of which were reported, confirming the trend already observed in 2014. Another 6 spillage incidents were reported in 2015, corresponding to 0.17 spillages per 1000 km of line, similar to the 5-year average and well below the long-term running average of 0.47, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. 3 incidents were due to mechanical failure and 3 to corrosion. Over the long term, third party activities remain the main cause of spillage incidents and the rise of theft attempts will greatly increase this proportion.

**8/17 CONCAWE WORKSHOP REPORT “PAH INTEGRATED EXPOSURE
MODELLING”**

This report summarizes the discussions held during the “Polycyclic Aromatic Hydrocarbons (PAHs) integrated exposure modelling” 2-day workshop organized by the Flemish Institute for technological research (VITO) together with Concawe on 8 - 9th October 2015 at Concawe in Brussels.

Currently, Concawe aims to address the challenge of assessing the contribution of Petroleum Substances (PS) to aggregate PAH exposure. In this context, there

is an opportunity to identify integrated multi-source, multi-route (MSMR) exposure model(s) suitable for characterising exposure to PAHs including those that may derive from PS. The ultimate goal is to have a reliable, validated, integrated source-to-receptor PAH exposure modelling tool capable of generating realistic predictions of PAH exposure, which enables the determination of the relative proportion of PAHs exposures over different routes and sources (and which also extends beyond petroleum sources).

The overall aim of the workshop was to explore whether (and which of the) existing MSMR models meet the goal outlined above, and to identify databases (such as PAH monitoring in air, food and biomonitoring) that could be used to support and verify model predictions. The focus of the workshop was general population exposure modelling tools (including consumer exposure and indirect exposure via the environment).

This workshop report aims to reflect 1) the interaction and discussion between model developers and other workshop participants from a model user perspective, 2) the discussion on the potential bottlenecks and gaps when applying the models for PS scenarios, and 3) the way forward when using MSMR modelling in addressing Concawe's challenge to assess the contribution of PS to aggregated PAH exposure.

9/17 USING FOREST CARBON CREDITS TO OFFSET EMISSIONS IN THE DOWNSTREAM BUSINESS

This report examines if and how forest carbon credits can potentially be used to offset emissions from the EU refining and road transport sectors. Forest carbon projects involve either forestation (capturing CO₂ from the atmosphere during the growth of the forest) and/or protection of forests that would otherwise be cut. In both cases, the projects reduce the overall level of CO₂ in the atmosphere. Forest carbon projects can generate credits that, once certified by an independent agency, can be sold on the carbon market.

10/17 CONCAWE MARKET FUEL SURVEY 2015-2016

Concawe conducted a market fuel survey on petrol and diesel qualities, taking samples from seventeen European countries during mid-2015 – early 2016. A total of 244 samples (100 petrol and 144 diesel) were sampled - petrol samples were collected in the summer of 2015 and the diesels were sampled in the winter of 2016. This report summarises the data by country and illustrates the data in charts for comparison purposes.

11/17 TRANSCRIPTION OF CONCAWE CHEMICAL SAFETY ASSESSMENTS INTO CHESAR: SUMMARY OF A PILOT PROJECT & CURRENT STATUS

Registration dossiers for petroleum substances (PS) under the European chemicals control legislation REACH require Chemical Safety Assessments (CSAs) as the basis for the identification of operational conditions and risk management measures that ensure safe use.

A pilot study was conducted to assess the suitability of transcribing the Concawe CSAs into Chesar version 2.2. The aim was to identify areas that could affect the effective use of the Chesar tool as a vehicle for developing CSAs for PS with respect to human exposure and, where required, to describe possible methods for handling limitations resulting from the use of the Chesar tool.

In total, 10 significant limitations in the transcription of the petroleum substance CSA into Chesar were identified in this pilot project. For almost all limitations, an acceptable workaround has been identified in the Chesar v2.2 tool. One exception, where no workaround could be found, was a limitation related to the semi-volatile nature of the substance that would allow the use of different Derived No Effect Levels (DNELs) and different exposure assessments for different forms of the substance in one Chesar file. However, since the conclusion of this pilot, most limitations have been addressed in Chesar 3.2 and new functionalities have been added so that workarounds are no longer needed. A functionality to handle semi-volatile substances has also been built in Chesar 3.2.

An important benefit is the efficiency of the Chesar tool functionalities of copying assessments and assessment elements and the Concawe grouping approach. The initial workload of introducing a PS into Chesar is extensive.

In summary, the Chesar tool is suitable to conduct human health CSAs for petroleum substances. The initial workload of introducing such substances can be extensive but once key assessment elements are formed, beneficial functions in Chesar enable useful efficiencies be obtained in updating and managing Concawe dossiers.

12/17 2013 SURVEY OF WASTE PRODUCTION AND MANAGEMENT AT EUROPEAN REFINERIES

This report provides a statistical analysis of waste production by Concawe member company refineries in 2013, based on survey data returned from 74 member company refineries (71% response rate) situated in the EU-28 countries + Norway and Switzerland. It includes a breakdown of waste tonnage according to the origin of the waste, how it was managed and how it was classified under the 2008 Waste Framework Directive (2008/98/EC). This findings from the survey, together with those of previous Concawe waste surveys for 1993 (Concawe; 1-95) and 1986 (Concawe; 5-89), show how the sector has responded to developments in EU waste legislation over the past 30 years. In addition, the data constitute a modern baseline for the future assessment of performance.

Total waste production reported by the refining sector in 2013 was 1.2 million tonnes, of which 43% was classified as hazardous. The top 3 reported hazardous wastes types by tonnage are sludges (comprising tank bottoms, physical/chemical treatment, biological treatment and other), followed by spent chemicals/acids/bases and then contaminated soil/stones/aggregate/concrete (with approximately one third of these arising from remediation activities). The top 3 non-hazardous wastes comprise soils/stones/aggregate/concrete, followed by metal and biological wastewater treatment sludges.

Soils/stones/aggregate/concrete constitute 65% of the total non-hazardous waste reported, while metal and biological wastewater treatment sludges constitute 9% and 4%, respectively.

The vast majority (94%) of refinery wastes were disposed within the country of origin, with only spent catalyst exported outside the EU (to specialist recovery facilities). Recycling accounted for the largest waste tonnage (34%), followed by waste going to landfill (20%). This is in contrast to the 1993 survey, which found that landfill accounted for 40% and recycling 21%. In parallel, the percentage of waste used for energy recovery reduced from 15% in 1993 to 7% in 2013, while the percentage of waste disposed of by incineration reduced slightly from 8% to 6%. These findings demonstrate that the sector has been successful in moving

waste streams up the EU waste hierarchy, with an increasing proportion of waste going to recovery, recycling and re-use.

Legislative changes and associated changes in waste reporting practices mean that the 1993 and 2013 data on refinery waste tonnage and handling costs are not directly comparable. For example, the apparent increase in total waste tonnage from 1993 to 2013 may well reflect more systematic waste classification and reporting under the 2008 Waste Framework Directive. The total cost of refinery waste management appears to have significantly increased, from an inflation-adjusted figure of approximately 80 M\$ in 1986 (for 89 refineries), to 137.2 M\$ in 2013 (for 74 refineries).

13/17 HAZARD CLASSIFICATION AND LABELLING OF PETROLEUM SUBSTANCES IN THE EUROPEAN ECONOMIC AREA – 2017

This report updates Concawe's classification and labelling recommendations Report No. 9/15 to address changes to CLP regulation and include classification and labelling recommendations for Petroleum Gases and Other Petroleum gases.

1/18 ENVIRONMENTAL IMPACTS OF MARINE SO₂ EMISSIONS

This report details work that was carried out to study the impact of emissions from international shipping on air quality, with a focus on sulphur dioxide (SO₂) emissions. Emission inventories are discussed and put into perspective versus emissions from natural sources. Air quality modelling tools have been used to assess impacts on air quality in EU countries as a function of distance from shore of shipping emissions. This work demonstrates that, compared to further land based emission reductions, it is generally not cost-effective to reduce emissions from shipping outside of coastal zones. Options to reduce fuel sulphur levels as a route to mitigate SO₂ emissions from international shipping are compared with the use of on board techniques to remove SO₂ from the exhaust gas stream. Finally the likely climate impact of such mitigation actions are assessed.

2/18 A REVIEW OF TOXICITY TESTING CONDUCTED ON EUROPEAN REFINERY EFFLUENTS IN 2010 AND 2013

This report provides an initial assessment of the extent to which toxicity testing is carried on European refinery effluents, and the types of test being used. The analysis is based on responses given to Concawe water use and effluent quality surveys completed for the 2010 and 2013 reporting years.

Toxicity testing was predominantly carried out to fulfil permit requirements, or at the request of regulators. However, the part of effluent streams being voluntarily monitored with toxicity testing increased from 6% in 2010 to 27% in 2013 (from 10% to 27% for refineries reporting in both years). Voluntary toxicity testing was usually performed on an annual basis. The most frequently reported toxicity test in both the 2010 and 2013 surveys was *Daphnia magna*, with toxicity to fish eggs also commonly used in 2013. Both of these tests were usually performed on a quarterly basis. In both years most of the testing was carried out on treated process waters (52% of effluent streams in 2010 and 46% in 2013).

3/18 ADDENDUM TO “GASOLINE ETHER OXYGENATE OCCURRENCE IN EUROPE, AND A REVIEW OF THEIR FATE AND TRANSPORT CHARACTERISTICS IN THE ENVIRONMENT” (CONCAWE REPORT 4/12); ADDITION OF MORE RECENT DATASETS

Ether oxygenates are added to certain gasoline (petrol) formulations to improve combustion efficiency and to increase the octane rating. In 2012 Concawe published the findings of research to support effective environmental management practices for gasoline ether oxygenates (GEO) in Concawe Report 4/12 “Gasoline ether oxygenate occurrence in Europe, and a review of their fate and transport characteristics in the environment” (Concawe, 2012). This addendum report provides an updated appraisal of trends in 1999-2015 fuel GEO content as well as trends in the ethanol (EtOH) content of gasoline from 2010-2015.

4/18 AIR EMISSIONS FROM THE REFINING SECTOR. ANALYSIS OF E-PRTR DATA 2007-2014

This report is an updated version of the Concawe Report No 2/15 providing a review of the air pollutant emissions data submitted by national authorities for oil refineries in the European Pollutant Release and Transfer Register (E-PRTR) from 2007 to 2014. Detailed analyses are given for five pollutants of interest (SO_x, NO_x, NMVOCs, benzene, and CO₂). Emissions of the five pollutants reviewed have decreased significantly between 2007 and 2014: SO_x by 63%, NO_x by 44%, NMVOCs by 40%, benzene by 51% and CO₂ by 21%. The mass of crude processed over the same eight-year period reduced by 15%. When emissions are expressed as t per Mt of crude processed the reduction between 2007 and 2014 is: 57% for SO_x, 34% for NO_x, 30% for NMVOCs, 42% for benzene and 6.5% for CO₂.

5/18 SULPHUR DIOXIDE EMISSIONS FROM OIL REFINERIES IN EUROPE (2015)

This report describes the results of the 2015 survey into the sulphur pathways in European refineries. This includes the distribution of sulphur in products, the capture and recovery of sulphur in refineries and the emission of sulphur oxides as part of the refining process. The results of surveys carried out for the years 2002, 2006 and 2010 are also included.

In 2015 the 44 refineries considered in this report processed crude and feedstock amounting to 52% of the European refining throughput. The results confirm a downward trend in the sulphur content of major product streams, associated with a strong increase in sulphur recovered in the refinery process and a reduction of sulphur emitted from refinery operations.

6/18 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2016 AND SINCE 1971

Concawe has collected 46 years of spillage data on European cross-country oil pipelines. At nearly 37,500 km the current inventory includes the majority of such pipelines in Europe. This report provides an analysis of spillage incident data collected by Concawe from European petroleum pipeline operators for the 2016 reporting year, and a full historical perspective since 1971. 66 pipeline operators provided information for over 140 pipeline systems, with a total reported throughput of 755 Mm³ of crude oil and refined products, and a combined length

of 35,414 km. The analysis includes an appraisal of short and longer- term trends in spill volume, the main causes of spillage, and the use of in-line inspection tools (pigs). Product theft attempts continued to be the major cause of spills in 2016 although the total number (60) was lower than in 2015 (87). 6 non-theft related spillage incidents were reported in 2016, corresponding to 0.18 spillages per 1000 km of line. This is similar to the 5-year average and well below the long-term running average of 0.46, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these 6 spills. 1 incident was due to mechanical failure, 3 to corrosion and 2 to third party accidental interference. Overall, based on the Concawe 1971-2016 incident database and reports, there is no evidence that the ageing of the pipeline system implies a greater risk of spillage.

7/18 LOW CARBON PATHWAYS- CO2 EFFICIENCY IN THE EU REFINING SYSTEM. 2030 / 2050

8/18 A COMPARISON OF REAL DRIVING EMISSIONS FROM EURO 6 DIESEL PASSENGER CARS WITH ZERO EMISSION VEHICLES AND THEIR IMPACT ON URBAN AIR QUALITY COMPLIANCE

This report describes an extension to the Urban Air Quality Study commissioned by Concawe that explored how urban air quality is affected by emissions from road transport and domestic combustion. In the first report a particular focus was placed on the impact of real driving emissions (RDE) on urban concentrations of nitrogen dioxide (NO₂) and particulate matter (PM₁₀ and PM_{2.5}) and the effect this may have on compliance with ambient air quality limit values at European, national and regional level. The aim of this extension study is to determine how measured emissions from newer RDE compliant Euro 6 diesel passenger cars would affect the concentration of NO₂ in European urban environments. A comparison has also been made where the substitution of Euro 6d diesel passenger cars with zero exhaust emission equivalents is explored.

In 2017, Concawe commissioned Ricardo to collect data from literature sources and test a range of Euro 6 diesel passenger cars using the new on-road real driving emission test cycle to measure actual on-road emissions of NO_x for each of the Euro 6 categories; Euro 6b (pre and post 2015), Euro 6c and Euro 6d (Temp). The study showed that real world NO_x emissions from diesel passenger cars are significantly reduced by successive Euro 6 standards and suggests that the technical solutions available to Euro 6d cars will comply with the 80 mg/km EU NO_x emission standard for Euro 6 passenger cars under RDE test conditions.

Aeris Europe's AQUReS+ model has been populated with the emissions data collected by Ricardo and used to model population exposure to concentrations of NO₂, PM_{2.5} and PM₁₀ across the 28 EU member states and 10 European cities: Antwerp, Berlin, Bratislava, Brussels, London, Madrid, Munich, Paris, Vienna and Warsaw.

The principal findings of the study are:

- In the natural turnover of the vehicle fleet, the significantly reduced NO_x emissions from Euro 6d diesel passenger cars will be as effective as zero emission vehicles in helping cities become compliant with air quality standards.

- For NO₂, PM_{2.5} and PM₁₀, no appreciable effect on air quality compliance or population exposure is observed between any of the modelled diesel passenger car scenarios or their replacement with equivalent zero emission vehicles.
- NO₂ compliance issues in traffic “hot-spots” persist until 2030 in a number of European cities under all modelled scenarios. It is unlikely that measures targeting new diesel cars will address this issue.
- In the case of particulates, modern passenger car emissions are largely independent of the drive-train given that mechanical abrasion (brake, road and tyre wear) is the most significant source.
- It is important to identify the actual emission sources contributing to each unique area of non-compliance to effectively address outstanding issues, for example, domestic heating or urban power generation in addition to road transport and other sources.

9/18

REGULAR SHORT-TERM PEAK EXPOSURE TO BENZENE IN THE SUPPLY CHAIN OF PETROLEUM PRODUCTS - REVIEW OF EXPOSURE AND EXISTING INDUSTRY PRACTICES FOR TARGETED RISK MANAGEMENT

Exposures to benzene and benzene-containing products are generally well controlled within industry. However, given the recent findings of a possible association of myelodysplastic syndrome with exposure levels that approach some Short Term Exposure Limits, an evaluation of jobs/tasks across the supply chain for petroleum products, which may be associated with similar exposure levels, was undertaken. Review and summarisation of existing industry practices and control strategies in place for regular short-term peak exposures to benzene may support the formulation of best practices in these areas.

In this context, benzene exposure data, from the year 2000 onwards, were collected from Concawe member companies and sector reports, representing primarily the following work areas: refining, road tanker terminals, rail car terminals, and ship terminals. The exposure data were used to characterize tasks with potential short-term, regular, exposure to benzene vapor across the supply chain for petroleum products.

For the majority of tasks the 95th percentile of the benzene exposure levels was found to be generally low compared to existing reference values (for example TLV ACGIH, UE L.V or from literature). Only for a limited number of tasks and conditions, i.e. sample collection at road terminals (open system), tank dipping, and handling of hoses at ship terminals (products with high benzene content; >20%) measured exposures may occasionally peak. However, the use of proper respiratory protective equipment, as incorporated in benzene control programs in many member companies and also reflected in the contextual data as provided, will protect these workers against adverse health effects.

The collected data was additionally utilized to assess the indicative effect of risk management measures and their effect on the short-term benzene exposure levels. Closed system sampling (refining, products with low benzene content) may reduce the benzene concentration in air by 50-70% in comparison with open sampling. However, data availability is limited and for both conditions, measurements were found below the level of detection. Vapor recovery during top loading may reduce the benzene concentration by 30-70% in comparison with top loading without vapor recovery.

For majority of the analysed tasks, air concentrations were below the applied reference values for benzene. Limitations of this study include the limited coverage of identified tasks in the defined work areas, and the lack of contextual data from the collected measurements.

10/18 SURVEY OF NATURAL ATTENUATION OF PETROLEUM HYDROCARBON PLUMES IN GROUNDWATER IN EUROPE

This report presents a study conducted in Europe to characterize the typical size and plume stability condition for groundwater sites impacted by the petroleum hydrocarbons benzene, toluene, ethyl benzene, xylenes (BTEX), and the fuel oxygenates methyl tert-butyl ether MTBE and ethyl tert-butyl ether (ETBE). This “plumeathon” approach have previously been used in the United States (US) in the 1990s (Newell and Connor, 1998; Kamath et al., 2012; Connor et al., 2014).

The study of impacted sites across Europe consisted of an evaluation of 50 sites. Plume length analysis was conducted for a total of 171 plumes using a primary threshold (10 µg/L for all constituents) and 138 plumes using a secondary threshold (constituent-specific drinking water guideline value). Additionally, plume stability analysis was conducted for benzene and MTBE at 29 sites. Key site characteristics and an evaluation of biodegradation were also tabulated for each site.

This study expands the understanding of petroleum plume behaviour to European sites and evaluates site-specific factors that influence this behaviour.

11/18 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2017

The twenty-fourth annual report on European downstream oil industry safety performance presents work-related personal injuries for the industry's own employees and contractors and process safety performance indicators. Information was received from 40 Concawe Member Companies representing more than 96% of the European refining capacity. In 2017, there were two fatalities in the industry. While this equals the lowest number of annual fatalities recorded in 2016, we continue to consider this too many and work to reduce this number to zero. Lost Workday Injuries rose from 501 to 577, an increase of approximately 15%. Total work hours reported increased by 7%. The number of Tier 1 and 2 process safety releases continued to decline in 2017 (total count for Manufacturing and Marketing of 287 in 2017 down from 349 in 2016).

12/18 2013 SURVEY OF EFFLUENT QUALITY AND WATER USE AT EUROPEAN REFINERIES

Since 1969, Concawe has been gathering and compiling data on aqueous effluents from European oil refinery installations. Surveys have been completed at 3-5 yearly intervals and the survey design has been updated over time to address various scientific and legislative developments. Since 2010, for example, the data collection also focused on water uses within the installations. This report presents the findings of the survey completed in 2014 for the 2013 reporting year of European refinery effluent quality and water use.

A total of 79 refineries participated in the survey from the EU-28 countries, Norway and Switzerland. Of the 79 questionnaires returned, 79 yielded data on effluent quality and 70 provided data on site water use. A statistical assessment of site water use is presented, including aggregated data on intake and effluent

volumes, water treatment processes, and costs associated with water use. In addition, annual average concentration and discharge mass for a number of substances and parameters regulated at EU level are compared with survey data from previous years. The data returned from the surveys provides perspective on historic trends in refinery water use and effluent discharge and insight into the recent refinery sector performance. The data also allows Concawe to assess the potential impact of proposed changes to existing European legislation.

A total of 3.5 billion m³ of water was withdrawn in 2013 by the 70 refineries that returned data on site water use (vs 4.5 billion m³ in 2010 for 100 refineries). Approximately 3.0 billion m³ or 86 % of the total abstracted water was brackish or saline and used for once-through cooling. The total freshwater withdrawal was 493 million m³ (average 7.0 million m³ per refinery), with 371 million m³ (average 5.3 million m³ per refinery) used for purposes other than once-through cooling. By way of comparison, the 2010 survey of 100 refineries indicated a total freshwater withdrawal (for purposes other than once-through cooling) of 4.2 million m³ per refinery on average. Using the IPIECA definition for freshwater consumption (indicator E6; IPIECA, API and IOGP, 2015), refineries consumed a total of 271 million m³ of fresh water in 2013 vs 282 million m³ in 2010. The average relative freshwater consumption was apparently higher in 2013 at 621 m³/kilotonne throughput vs 467 m³/kilotonne throughput in 2010. All comparison with 2010 water use data could, however, reflect the different population of refineries reported under the 2010 and 2013 surveys, or differences in the way that the surveys were designed (the 2013 survey captured more detailed information on water uses).

An average of 0.48 m³ of process water was discharged from the reporting refineries per tonne of annual feedstock throughput, which was lower than reported in the previous two Concawe surveys (0.82 in 2008; 0.67 in 2010).

With regard to effluent quality, the results of the 2013 survey are consistent with the long-term trend towards reduced discharge of Total Petroleum Hydrocarbons (TPH), reported as Oil in Water (OiW) or TPH. While total and relative TPH discharge (i.e. normalised to throughput) are lower relative to the 2010 and 2008 survey years at 354 tonnes and 0.71 g/tonne throughput, respectively, fewer refineries participated in the 2013 survey and so the discharge data are not directly comparable. For the 59 refineries that reported under both the 2010 and 2013 survey average relative TPH discharge decreased by 28% from 2010 to 2013. From 1993 to 2013 the survey data indicate a large decrease in total and relative discharge of ammonia and phenols, and a smaller decrease in total nitrogen. For Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD) and Total Organic Carbon (TOC) survey data from 2000-2013 indicate an overall decrease in relative load.

13/18 REVIEW OF TIER 1 WORKPLACE EXPOSURE ESTIMATES FOR PETROLEUM SUBSTANCES IN REACH DOSSIERS

For the exposure assessment in the 2010 REACH dossiers of petroleum substances, Concawe has used the Tier 1 exposure model ECETOC TRA v.2. In order to account for the heavier, less volatile and more complex petroleum substances and the corresponding exposure situations, several modifications not originally within the scope of the ECETOC TRA were developed. These modifications include an approach to estimate liquid aerosol along with some risk management measures describing the use and handling of petroleum substances commonly in use in the European oil refining industry.

In this project, Chemical Safety Assessments (CSAs) on these petroleum substances were evaluated concerning relevant industry areas and included scenarios. Measured data were collated in order to evaluate the exposure estimates in general and the modifications made by Concawe.

Data were collected from the database built in the course of the Evaluation of Tier 1 Exposure Assessment Models (eteam) project (www.eteam-project.eu) undertaken by IOM and ITEM, from Concawe reports and via literature search. These include kerosines (mainly as jet fuel), heavy fuel oils (HFOs), two naphtha groups (0-1% and 1-5% benzene, essentially corresponding to gasoline after and before the year 2000), gas oils (vacuum, hydrocracked gas oils and distillate fuels; i.e. mainly diesel fuels) and other lubricant base oils (OLBOs). The quantity and quality of datasets, however, varies between the groups and there are still a number of substance groups and scenarios which could not be evaluated due to lack of suitable data (e.g. gas oils, foots oils, other naphthas). This was partly due to changes brought about by the REACH process in how exposures are assessed against a reference value. For instance, it was customary to assess inhalation exposure to diesel fuel as vapour, but the REACH process resulted in a Derived No Effect Level (DNEL) expressed as aerosol.

The comparison exercise showed some discrepancies depending on substance group and the specific scenarios. These discrepancies may be partly attributed to new modifiers or other changes of the ECETOC standard algorithm (e.g. concentration modifier in case of naphthas). In general, for most measures such as draining of equipment or training of operatives, both under- and overestimations can be found; therefore, it is difficult to reach a final conclusion concerning their applicability.. Other possible reasons for the observed underestimations were variations within an exposure scenario (e.g. Research and Development laboratory activity vs. production laboratory activity, bottom loading vs. top loading) or the age of datasets (e.g. in case of naphthas).

Concerning aerosol exposure, measured data for OLBOs and HFOs could be identified. No significant underestimations were found for the evaluated scenario in case of OLBOs while in the case of HFOs results were inconclusive (partly underestimations but only few data points). Overall it is recognised that available sampling methods for liquid aerosol often tend to give biased or at least variable exposure results and this has to be taken into account for future investigations concerning risk assessment of petroleum substances or validation of the existing CSAs. Measurements made for HFOs show higher overall and vapour concentrations compared to the aerosol values which may suggest that either vapour may be more relevant than previously assumed for high boiling petroleum substances or the corresponding aerosol measurements may not be suitable for a comparison with DNELs or model estimates. Comparable difficulties will probably exist for other semi- or low volatile substances which tend to form aerosols.

Although some underestimations have been observed, there are also cases where clear overestimations were observed and thus, a further refinement with higher Tier tools may be possible. Two possible tools, STOFFENMANAGER® and ART were discussed and illustrated with an example scenario. Petroleum substances and the resulting exposure types (vapour and aerosols) are within the scope of both models; however, the new modifiers introduced by Concawe are only implemented to a limited extent (vapour recovery in the case of ART).

A qualitative evaluation of the updates made when changing from ECETOC TRA v.2 to v.3 suggested that inhalation exposure estimates will probably be lower if

the more recent version is used. This is partly due to newly introduced or changed measures or operational conditions and partly due to modified initial exposure estimates.

Overall, there are a number of situations where the comparison of measurements and estimates suggests reasonable results and a controlled risk. There are other situations, however, where, due to different reasons, the contrary is observed. A particular problem seems to be the lack of high quality aerosol data.

14/18 REVIEW OF OPTIONS FOR REFINERY EFFLUENT ASSESSMENT USING EFFECT-BASED TOOLS IN COMBINATION WITH PASSIVE SAMPLERS

The European Commission (EC) is considering the use of “effect-based tools” (EBTs) for environmental monitoring as an alternative to, or in combination with, chemical analysis. In addition, there is interest in the use of passive sampler devices for the time- integrated monitoring of water quality.

In order to better understand the opportunity for using EBTs and passive samplers in combination, Concawe has completed a literature review of relevant EBTs that can be applied to extracts from passive samplers. The study builds on previous work by Concawe in this area, for example the 2012 review of effect-based assays relevant for use in the assessment of refinery effluents and receiving waters (Concawe 2012a). It also takes into account the findings from several literature reviews published over the last 3-4 years that address the potential application of EBTs for screening of effluents, surface waters, sediments and drinking waters (Hamers et al. 2016, CIS 2014, Brack et al. 2016, Di Paolo et al. 2016, Schriks et al. 2015).

Relevant EBTs were identified based on:

- Their commercial availability;
- Their general validation maturity;
- The extent to which they have tested on environmental samples,
- The extent to which they have been applied for screening of petroleum residues
- Their suitability for use with passive sampler extracts.

This initial screening generated a list of 22 assays. An in-depth literature review was then completed on these to obtain a more complete understanding of their performance, interpretation and application. The findings from the review are summarised in a series of fact sheets included in this report.

The short-listed assays were then compared using the information identified in the literature review to develop a suite of bioassays that can be used in combination with passive samplers for refinery effluent assessment. This suite of bioassays is summarised in this report, along with their assay-specific trigger values (identified in the literature review) that can be applied to denote an effect, according to the endpoint under investigation.

It should be noted that the bioassays assessed in the present study are by no means assessed in terms of availability with regard to being “available techniques” as defined by the Industrial Emissions Directive (IED; 2010/75/EU) article 3(10). Moreover, the suite of bioassays are restricted to those assessed in the present study, and are based on the information identified in this review, and the relative advantages and disadvantages of using each of the assays. In addition, it is recognised that new bioassays are continually being developed,

and those currently at a relatively early stage of validation are in the process of being standardised and demonstrated to be reproducible.

15/18 AIR POLLUTION AND LUNG CANCER: A REVIEW OF ISSUES AFFECTING THE INTERPRETATION OF THE EPIDEMIOLOGICAL LITERATURE

The following report examines key issues that need to be considered when evaluating the attributes and implications of studies examining the association between ambient air pollution and lung cancer. Following a brief general discussion of the types of epidemiology studies that can be used to investigate the association between an environmental or occupational exposure and a particular health outcome, the report goes on to examine specific topics that need to be considered when evaluating the strength and weakness of any relationships that are purported to exist. Areas of focus include exposure estimation, confounding, quantitative risk assessment, heterogeneity, and plausibility. Each of these topics is explored in detail and information is provided showing how reported relative risk estimates may have been impacted by the failure to fully evaluate or consider specific methodological, procedural, or interpretive characteristics of the study. As such, the aim of the report is to highlight some generally overlooked areas of inquiry that need to be addressed in order to frame and draw conclusions from the results of a chronic health effects investigation focusing on lung cancer and air pollutant exposures.

1/19 AN OVERVIEW OF HCN EMISSIONS FROM FCCU'S AND THEIR POTENTIAL IMPACTS ON HUMAN HEALTH

This report provides an overview of the monitoring methods and abatement techniques available for hydrogen cyanide (HCN) emissions in fluid catalytic cracking units (FCCU's). Recommendations are made for emission factors (EF's) that can be used to estimate HCN emissions from European FCCU's (for two different operating modes, namely full and partial coke burn) for E-PRTR reporting purposes. An overview of the potential health effects of HCN is given.

The EPA OTM-29 wet chemistry method and the instrumental FTIR technique are the two HCN monitoring techniques used in refineries. Currently applied abatement techniques for flue gas cleaning at FCCU's are not specifically designed for HCN emission control, but for particulate matter, NO_x, SO_x and CO reduction.

Emission factors for each mode of operation of an FCCU were developed using measurements undertaken on 10 FCCU's in European refineries together with data reported by the US EPA. The emission factors derived are: 0.58 kg HCN/t coke burn for full burn FCCU's, and 0.042 kg HCN/t coke burn for partial burn units. It is recommended that these be used for E-PRTR reporting purposes if measured values are not available.

A dispersion modelling assessment was conducted to establish the potential risk that HCN emissions from FCCU's could pose to human health. All runs showed that the predicted HCN ground-level concentrations were below the US EPA reference concentration (RfC) of 8×10^{-4} mg/m³ (0.8 µg/m³) for chronic inhalation exposure. This indicates that HCN emissions from the 10 European FCCU's tested are not considered a potential risk for human health.

2/19 EFFECT OF DIESEL FUEL PROPERTIES ON FUEL ECONOMY AND EMISSIONS OF THREE PASSENGER CARS

The objective of this project was to assess the effects of varying diesel fuel properties associated with increasing FAME content on pollutant emissions and fuel consumption of light-duty vehicles. To that aim three passenger cars were tested, each one of them equipped with a different exhaust after-treatment system and complying with different European emissions standards, - Euro 4, 5 and 6. Four diesel fuel properties were examined namely density, cetane number, biodiesel (FAME) content and Polycyclic Aromatic Hydrocarbon (PAH) content. The study focused on the effect of potentially increasing FAME content in the fuel above the current 7% limit to help meet the original renewable energy directive (RED) obligations. Tests included two driving cycles, the New European Driving Cycle (NEDC) and the Worldwide Harmonized Light Duty Test Cycle (WLTC), as well as a steady-state point for the characterization of particle emissions. Changes were then statistically modelled to look for trends in the data. Some established trends were confirmed but overall the effect of increasingly sophisticated after-treatment system, vehicle calibration and test cycle clearly dominated over fuel effects for emissions and efficiency in this study where changes in fuel properties were relatively small.

3/19 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES - STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2017 AND SINCE 1971

Concawe has collected 47 years of spillage data on European cross-country oil pipelines. At nearly 37,500 km the current inventory includes the majority of such pipelines in Europe, transporting some 720 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2017 and a full historical perspective since 1971. The performance over the whole 47 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party interference. The rate of inspections by in-line tools (inspection pigs) is also reported.

Product theft attempts continued to be the major cause of spills in 2017 although the total number (11) showed a sharp decline from previous years (60 in 2017, 87 in 2015).

Another 2 spillage incidents were reported in 2017, corresponding to 0.06 spillages per 1000 km of line, just over 1/3rd of the 5-year average and an order of magnitude below the long-term running average of 0.45, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. Both incidents were due to operational errors.

Although there have been relatively few incidents due to third party activities (excluding theft), in recent years this category remains the main source of spillage incidents.

4/19 AIR POLLUTANT EMISSION ESTIMATION METHODS FOR E-PRTR REPORTING BY REFINERIES - 2019 EDITION

5/19 CONCAWE SUBSTANCE IDENTIFICATION GROUP - ANALYTICAL PROGRAM REPORT (ABRIDGED VERSION)

This report describes the work undertaken and results obtained from the Concawe 2015 Analytical Program, which involved the chemical characterisation of 189 petroleum substances from 20 substance categories. As a limited number of samples were analysed per substance and in light of the Unknown or Variable Composition, Complex Reaction Products and Biological Materials (UVCB) nature of petroleum substances, the report provides supporting information only and should not be regarded as definitive for any substance.

To avoid the possibility that any analytical data presented can be attributed to a sample provided by a specific REACH registrant, the identities of 29 substances for which there are fewer than 3 active registrations have been “anonymised” by identifying only the category to which they belong. A further 6 petroleum substances for which there is only a single active registration within a category are omitted from this report. A full report on the 2015 Analytical Program includes data on all 189 substances and is available to Concawe secretariat only for reference purposes.

Given that, for most substances, this report relates to one sample per substance, Concawe is now combining these data with additional information to conduct a statistical analysis of the similarity between substances within a category. This information is relevant in the optimisation of human health and environmental hazard testing.

6/19 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2018

The 2018 annual report on European downstream oil industry safety performance presents work-related personal injuries for the industry's own employees and contractors and process safety performance indicators. Information was received from forty-two Concawe Member Companies and Joint Ventures comprised of member companies, together representing more than 98% of the European refining capacity. Total work hours reported (579 million) were around 3% lower in 2018 than in 2017. In 2018, there were ten fatalities reported by the industry, six of these as a result of a single incident. This is a significant increase since 2017 and 2016 when 2 fatalities were recorded each year. The number of Lost Workday Injuries recorded in 2018 (586) is slightly higher than those in 2017 (577). The combined number of Tier 1 and 2 process safety releases across Manufacturing and Marketing in 2018 declined 6% since 2017 (270 releases in 2018 and 287 in 2017). However, the number of Manufacturing Tier 1 events rose over 20% from 62 in 2017 to 75 in 2018.

Note that 2017 data in this report has been revised based on new member company information received in the 2018 data collection. This report therefore provides the most accurate and up to date details of both 2017 and 2018 data.

7/19 PHASE 2: EFFECT OF FUEL OCTANE ON THE PERFORMANCE OF FOUR EURO 5 AND EURO 6 GASOLINE PASSENGER CARS

Research Octane Number (RON) and Motor Octane Number (MON) are used to describe gasoline combustion antiknock performance under different conditions. Recent literature suggests that MON is less important than RON in modern cars due to a move towards negative k-values which are a factor in the relationship between RON and MON and that a relaxation in the MON specification could

improve vehicle performance, while also helping refiners in the production of gasoline. At the same time, for the same octane number change, increasing RON appears to provide more benefit to engine power and acceleration than reducing MON. Some workers have advocated the use of an octane index (OI) which incorporates both parameters instead of either RON or MON to give an indication of octane quality. Previous Concawe work investigated the effect of RON and MON on the power and acceleration performance of two Euro 4 gasoline passenger cars during an especially-designed acceleration test cycle. In phase 1 of this programme which has been previously reported, a large number of fuels blended with and without oxygenates and ranging from around 95 to 103 RON and sensitivities (RON minus MON) up to around 15 were tested. The results were vehicle dependent but in general, showed that sensitivity and octane index appear to be better predictors for improved acceleration times versus either RON or MON alone. In the current study a wider range of newer vehicles (Euro 5+) have been screened on a more limited fuel set and several chosen for further evaluation on the full fuel set. Improvements in fuel efficiency were observed during this testing and additional testing using standardized test cycles was carried out on one vehicle.

8/19 CO₂ REDUCTION TECHNOLOGIES. OPPORTUNITIES WITHIN THE EU REFINING SYSTEM (2030/2050). QUALITATIVE & QUANTITATIVE ASSESSMENT FOR THE PRODUCTION OF CONVENTIONAL FOSSIL FUELS (SCOPE 1 & 2)

This report describes the work being conducted by Concawe with the objective to explore a range of **Low Carbon Pathways** with the potential to reduce the CO₂ emissions associated with the production of refined oil products. This document demonstrates that the effective deployment of different technologies has the potential to achieve a significant reduction of the CO₂ emissions associated with oil refining by 2050. External factors such as future energy prices together with more effective R&D programs will play a role in boosting the deployment of the key technologies identified. It is important to note that this work is not intended to be a roadmap for the whole EU refining industry. Factors such as the CO₂ efficiency of existing facilities coupled with local and structural constraints will determine individual refineries' preferred route to contribute to mitigation of climate change.

Whilst this report details opportunities to improve the CO₂ efficiency of the EU Refining system, other studies are underway which examine the potential for integrating different, non-petroleum derived feedstocks and their implications in a future picture of the **Refinery 2050**.

9/19 REFINERY 2050: CONCEPTUAL ASSESSMENT. EXPLORING OPPORTUNITIES AND CHALLENGES FOR THE EU REFINING INDUSTRY TO TRANSITION TOWARDS A LOW-CO₂ INTENSIVE ECONOMY

This report is the second in a series of publications that explore opportunities and challenges for EU refineries to integrate technologies and feedstocks that would reduce the fossil carbon intensity of petroleum products.

The first Concawe report (*Low Carbon Pathways: CO₂ reduction technologies in the EU refining system. 2030/2050*) explored opportunities to invest in new technologies to reduce the CO₂ emissions from refineries in the short and then medium term. The current report goes beyond this approach by exploring the

potential to substitute crude oil with bio-feedstocks and the use of renewable electricity. Sustainable vegetable oils, lignocellulosic biomass and e-fuels have been selected as initial examples of key low carbon feedstocks in this conceptual assessment.

As the starting point, this reports defines two potential **2050 demand scenarios** followed by the description of the conversion pathways required for the integration of the selected low-carbon feedstocks within a notional mid-range European refinery.

Then, the results of the modelling exercise are presented, moving from mostly **oil based cases**, where the EU refineries meet the 2050 demand in the most plausible CO₂ efficient manner consistent with the first report mentioned above, to the progressive integration of low-carbon feedstocks illustrated by two series of cases:

- **Limited penetration cases** (individual pathways): where the implications of the production of 1 Mt/a liquid products from each of the selected low carbon feedstocks are described.
- **Maximum low carbon feedstock cases** (Combined pathways): Based on the different nature of the feeds explored, this report moves further in the analysis by looking at the combination of different low carbon feedstocks. This second series of cases illustrate a hypothetical situation where these alternative feedstock would provide the bulk of the total intake to the refineries. These cases highlight the need for multiple pathways in order to meet the demand effectively without impacting on the European import/export balance.

In all the cases modelled, the implications in terms of feedstock supply, key processing requirements such as hydrogen and electricity and the impact such changes have on the CO₂ emissions intensity both at refinery level and for the end products in Europe are initially assessed and quantified. Potential impacts and synergies with the existing assets, as crude oil is progressively replaced, are also investigated.

With this report, Concawe aim to provide a better understanding of the implications and framework conditions that would be required, showing how the challenges for such a transformation go beyond the battery limits of the refining system. A joint effort integrating multiple actors would be essential to achieve an effective and sustainable transition.

Finally, this conceptual assessment is not intended to be a roadmap for the whole refining industry. The low-carbon feedstocks explored are selected examples. Multiple additional pathways/feedstocks could be also integrated within the EU refining system subject to the location of the sites and individual company strategies.

10/19

INVESTIGATING THE HCBM – GCXGC RELATIONSHIP: AN ELUTION MODEL TO INTERPRET GCXGC RETENTION TIMES OF PETROLEUM SUBSTANCES

Risk assessments on petroleum substances (PS) are challenging due to the fact that these complex materials contain thousands of individual chemical components having widely differing physico-chemical characteristics, environmental degradation rates, and toxicities. However, comprehensive two-

dimensional gas chromatography (GCxGC) is well-suited to meet this challenge: can be used due to its unrivalled ability to separate hydrocarbon complex mixtures, thereby GCxGC can supporting studies of environmental risk associated with PS.

To facilitate the application of GCxGC to the assessment of PBT (persistence, bioaccumulation, toxicity) properties of PS, Concawe developed the hydrocarbon block method (HCBM). The HCBM delineates the GCxGC chromatogram into hydrocarbon blocks (HCBs) of closely related hydrocarbon compounds: a PS containing thousands of individual constituents can be described using about 200 HCBs. Nonetheless, the mass assignments attributed by the HCBM may contain uncertainties. The objective of the present study is to investigate the assumptions and approximations that underlie the application of the HCBM to GCxGC-FID data for the purposes of supporting PBT assessment.

To investigate the HCBM-GCxGC relationship, a theoretically-based elution model of GCxGC retention times was developed and tested. According to the elution model, the GCxGC retention times of known or hypothesized analytes can be predicted from their chemical structures, formatted as SMILES input. The retention time model was calibrated with a set of previously measured retention times for 56 hydrocarbon compounds having diverse chemical structures. The calibrated model was then applied to the entire Concawe GGraph library of 15397 individual hydrocarbon structures, providing an unprecedented theoretical prediction of the elution patterns of petroleum hydrocarbon compounds spanning the GCxGC chromatogram of diverse PS. We plotted the simulated GCxGC retention times for the 14190 chemical structures that were predicted to fall in the n-C₁₀–n-C₃₀ elution window. To visually differentiate the chromatographic region occupied by the structural members of each structural class and carbon number, a solid-line coloured polygon was overlaid onto the plots of modelled retention times. Each coloured polygon represents the convex hull that envelops the two-dimensional retention times of all members of a single class and carbon number.

By visualizing the location of each polygon for each class and carbon number in the n-C₁₀ to n-C₃₀ elution window, we conclude that the majority of modelled retention time polygons exhibit overlap with neighbouring groups of differing compound classes having the same carbon number. This approach made it possible to quantify the extent of overlap among the different chemical classes. As an example, we assumed a worst case of a PS that contains all 14190 library constituents in the n-C₁₀–n-C₃₀ elution window at relevant concentrations. Ignoring differences in carbon number within each class, we found that 79% of individual compound structures were enveloped by polygons representing two or more distinct classes, whereas 21% of individual compound structures fell into an area of the chromatogram occupied by only a single class. However, in practice, the majority of PS contain far fewer constituents in relevant concentrations, and many PS contain only a subset of the classes that are encompassed by the library.

In conclusion, the GCxGC retention time model enables an improved understanding of the elution patterns of diverse hydrocarbon compound structures on the GCxGC chromatogram. In particular, the retention time model reveals substantial overlap among the elution regions of most of the hydrocarbon classes that the HCBM was designed to quantify. This finding contrasts with current implementations of the HCBM, which assume that the designated hydrocarbon classes do not overlap in the GCxGC chromatogram. Further work

would be needed to elucidate the uncertainties of the HCBM that arise from overlapping elution patterns of compound classes.

11/19 STUDY TO EVALUATE TEST METHODS TO ASSESS THE STABILITY AND COMPATIBILITY OF MARINE FUELS IN VIEW OF THE IMO MARPOL - ANNEX VI REGULATION 14,1,3 FRO 2020 SULPHUR REQUIREMENTS

This report describes work sponsored and coordinated by Concawe and conducted by ISO/ TC28/ SC4/ WG6 in view of the variety of fuel blend formulations expected to enter into the market as a result of tightening sulphur limits for marine fuels as of 1 January 2020. The objective was to explore whether the test methodologies of ASTM D7157, D7112 and D7060 can be applied to residual marine fuels to obtain additional insight into their stability with respect to precipitation of asphaltenes and whether these methods can be used to predict the compatibility between fuels, without blending the fuels together. The study was conducted on a limited number of fuel samples as 0.50% max. sulphur fuels were not widely available at that time. The study shows that ASTM D7157, D7112 and D7060 can be used to obtain information on the degree of compatibility, though in some cases inconsistencies have been observed. Where possible, testing for compatibility of fuels to be comingled is recommended. Good practices to minimise the risk of incompatibility of fuels should be maintained and more data collected on commercially available samples.

12/19 A STUDY OF WIND FLOW AROUND A REFINERY

Assessment of diffuse emissions using remote sensing needs appropriate information on vertical profiles of wind speed and wind direction. This information has then to be combined with concentration, or path-integrated concentration, in order to estimate the mass flux of hydrocarbons through the measurement plane.

The presence of plant units, buildings, tanks, process areas, etc. modifies the wind as it passes across the refinery. It is not practical to make wind measurements at alongside concentration measurements in order to determine flux explicitly. Assumptions about the wind spatial and temporal resolution are therefore necessary and contribute to overall uncertainty in flux determinations.

To provide information on variability in wind parameters, Concawe carried out a programme of wind measurements on a refinery site using a combination of traditional meteorological instruments mounted on fixed masts and a wind LIDAR which was made mobile by mounting it on a pick-up truck. The study was carried out during a 9-day period. The purpose of the exercise is to investigate whether there are significant differences in wind data gathered at various locations.

This report is confined to an inter-comparison of the fixed mast data. Review of the LIDAR data revealed obvious errors in some of the LIDAR measurements (see Appendix B) and so these were not used in the analysis.

It was found that the wind vector (speed, direction) is modified as the wind interacts with the refinery. Measurements at one reference station are not always representative of measurements elsewhere. The difference in wind vector between stations varies with time denying the development of a correction factor. The difference is greater for measurements made at 3.7 m height compared to those made at 10 m height.

Recommendations have been made for the placement of wind masts to provide data to support remote sensing campaigns.

Recommendations are also made for both the evaluation of wind data and exclusion of time periods for meaningful interpretation of data. The need for sensitivity calculations to account for uncertainty in wind parameters in the derivation of emission flux is identified.

Although there were problems in this wind campaign with the use of a truck-mounted wind LIDAR, pre-campaign experience with a static mounted LIDAR was positive and the technique has advantages for measuring vertical profiles.

13/19 A COMPARISON EXERCISE BETWEEN A WIND LIDAR AND ANEMOMETERS MOUNTED ON A 30 M MAST

This report describes the results of a side-by-side comparison of a ZephIR wind LIDAR with anemometers mounted on a 30 m meteorological mast at an open-field site. The work was done as part of a refinery wind study and is novel in the use of wind LIDAR to obtain measurements of speed and direction at heights below 40 m. Good agreement was found for heights between 11 m and 30 m. This is important for dispersion of released gases on refineries and such data are difficult to obtain with traditional methods because of the need to anchor a tall mast. Profiles obtained from the LIDAR were consistent with stable atmospheric conditions.

14/19 ROLE OF E-FUELS IN THE EU TRANSPORT SYSTEM. LITERATURE REVIEW

In December 2015, COP21 in Paris made an important step to address the risks posed by climate change and to keep the global temperature increase to “well below 2°C” and drive efforts to limit it even further to 1.5 degrees. To achieve these goals, the European Union (EU) is exploring different mid-century scenarios leading to an EU low-carbon economy by 2050.

To support the EU low emissions strategy, Concawe is exploring a cross-sectorial Low Carbon Pathways (LPC) programme, identifying opportunities and challenges for different low carbon technologies to achieve a significant reduction of the CO₂ emissions associated with both the manufacturing and use of refined products in Europe in the medium (2030) and longer-term (2050).

As part of the LPC programme, this report is a literature review on e-fuels, which aims to build a better understanding of the e-fuel production technologies and implications in terms of efficiency, greenhouse gases (GHG) reduction, technology readiness level, environmental impact, investment, costs and potential demand.

The main recent state-of-the-art publications have been identified and compared in this literature review, covering detailed assessments, presentations, technology providers and position papers, helping to define a better picture of the potential role of these low-carbon fuels in Europe.

1/20 ODOUR MANAGEMENT GUIDANCE FOR REFINERIES

This document aims to help refineries, in conjunction with any existing national guidance, to develop methods to prevent odour nuisance and how to manage a complaint should an odour event arise on site.

It describes some of the main aspects relating to odour emissions at refineries that should be considered. These include methods of measuring and

investigating odour, the key regulatory instruments, odour management and control methods, contents of an odour management plan (OMP) and implementation of an odour complaint handling system.

2/20 ADDITIONAL WORKER INHALATION EXPOSURE MEASUREMENTS FOR HEAVY FUEL OIL EMISSIONS DURING BARGE/TRUCK LOADING

The report details the outcome of a follow-up project of a study initiated by Concawe in 2013, investigating the occupational exposure to emissions from hot Heavy Fuel Oil (HFO) (inhalation exposure to aerosols and vapours) during inland barge loading (Concawe rpt. 1/15R).

In the current follow-up project the objective was to increase the number of measurements for a better representativeness of the exposure assessment used in the Chemical Safety Assessment in the HFO REACH registration dossier. This issue was identified following a comparison of measured exposure data and modelled estimates, as documented in Concawe rpt 13/18.

Inhalation exposure samples (personal and stationary) were collected at four barge loading sites and one truck loading facility on three different occasions, respectively. Total organic matter (TOM) and indicator aromatic hydrocarbons (AH) such as naphthalene and the three polycyclic aromatic hydrocarbons (PAH) phenanthrene, pyrene and benzo[a]pyrene were chosen as parameters to assess the occupational inhalation exposure during inland HFO loading operations.

For the monitored barge loading events, the aerosol-related TOM exposure levels adjusted to 8 hour exposure to account for the variable duration of HFO barge loading and to align with the reference period of the DNEL. These ranged from < 2 to 40 µg/m³; whereas for the TOM content in the vapour phase, values between 78 and 7,600 µg/m³ were observed. For truck loading, the TOM in the aerosol phase was considerably lower than in the vapour phase (< 42 to 182 µg/m³ and 876 to 21100 µg/m³, respectively). Naphthalene concentrations varied between 0.2 and 140 µg/m³. Benzo[a]pyrene was in all personal samples below the limit of quantification and the sum of pyrene, phenanthrene and benzo[a]pyrene ranged between 69 to 678 ng/m³. A comparison of monitoring results for barge loading from personal samplers (TOM and naphthalene) for off-shore and on-shore workers reported in Concawe rpt. 1/15R and in the present study, evidenced similar exposure levels.

Measured data collected in the present study were used to refine the Concawe REACH Chemical Safety Assessment for substances in the HFO category.

3/20 AQUATIC TOXICITY OF PETROLEUM SUBSTANCES: EXTENDING THE VALIDATION OF THE BIOMIMETIC EXTRACTION (BE) METHOD FOR USE IN HAZARD ASSESSMENTS

Analysis of Water Accommodated Fractions (WAFs) of petroleum product samples using Biomimetic Extraction (BE) with solid phase microextraction (SPME) predicts accumulation and baseline toxicity of chemicals with a narcotic mode of action. Recent BE-SPME screening of WAFs of a large set of petroleum product samples (e.g. naphthas, kerosines, heavy fuel oils, cracked gas oils and other gas oils), supported by high quality compositional data, has been carried out. Compositional data have been used to predict toxicity values in toxic units (TU) and accumulation in target lipid (C_{TL}) from the TU data. These data confirm that BE-SPME data correlate to accumulation in target lipid (C_{TL}) and as such

provide additional support to the use of BE-SPME as a practical screening tool for assessing aquatic toxicity of petroleum substances and addressing the influence of variation in substance composition on aquatic toxicity within petroleum product categories.

4/20 AIR EMISSIONS FROM THE REFINING SECTOR. ANALYSIS OF E-PRTR DATA 2007-2017

This report is an updated version of the Concawe Report No 4/18 providing a review of the air pollutant emissions data submitted by national authorities for oil refineries in the European Pollutant Release and Transfer Register (E-PRTR) from 2007 to 2017. Detailed analyses are given for six pollutants of interest (SO_x, NO_x, NMVOCs, benzene, CO₂, and PM₁₀).

Emissions of all the six pollutants reviewed have decreased significantly between 2007 and 2017: SO_x by 65%, NO_x by 45%, NMVOCs by 38%, benzene by 50%, CO₂ by 20%, and PM₁₀ by 65%. The mass of crude processed over the same eleven-year period has reduced by 9% (based on assumptions taken to determine the transformation input for 2017). When emissions are expressed as t per Mt of crude processed the reduction between 2007 and 2017 is: 61% for SO_x, 40% for NO_x, 32% for NMVOCs, 45% for benzene, 12% for CO₂, and 61% for PM₁₀.

5/20 REAL DRIVING EMISSIONS FROM FOUR EURO 6 DIESEL PASSENGER CARS

In Europe, the development and implementation of new regulatory test procedures including the chassis dynamometer (CD) based World Harmonised Light Duty Test Procedure (WLTP) and the road-based Real Driving Emissions (RDE) procedure, has been driven by the close scrutiny that real driving emissions and fuel consumption from passenger cars have come under in recent times. This is due to a divergence between stated certification performance and measured on-road performance, and has been most pointed in the case of NO_x (oxides of nitrogen) emissions from diesel cars. The RDE test is more relevant than CD test cycles, but currently certification RDE cycles will not necessarily include the most extreme low speed congested, low temperature or high speed highway conditions which are likely to be more challenging for NO_x after-treatment systems. To build understanding of the emissions and fuel consumption performance of the latest available diesel passenger cars, Concawe has conducted a study of the performance of four vehicle types over a range of test cycles. The data generated provides insights into the emissions performance of Euro 6 diesel passenger cars, and their after-treatment systems, in extreme congested cold urban conditions including, and beyond, the most demanding likely to be encountered under regulatory RDE testing.

6/20 THREE-WAY CATALYST PERFORMANCE USING NATURAL GAS WITH TWO DIFFERENT SULPHUR LEVELS

Stoichiometric engines running on natural gas rely on three-way catalysts to meet limits e.g. Euro 6 regarding emissions of hydrocarbons (including methane), carbon monoxide and oxides of nitrogen. As is well known from decades of industry experience with three-way catalysts for petrol applications, sulphur naturally present in the fuel can, following combustion in the engine, cause poisoning of the aftertreatment system. Through complex mechanisms including steric effects, sulphur blocks active sites and prevents the metals in the washcoat from performing their task of facilitating the simultaneous oxidation and

reduction of harmful components in the exhaust gas. Through related mechanisms, the presence of sulphur reduces the washcoat's oxygen storage capacity, which severely limits the catalyst's ability to oxidise hydrocarbons and carbon monoxide under rich conditions. However, desulphation processes can occur during normal driving, which might lead to partial (or even full) recovery of the catalyst's performance. Little work has been done recently to understand the effect of sulphur and especially on the catalyst systems of modern natural gas vehicles.

7/20 PETROTOX VERSION 4.0 - USER MANUAL

PetroTox is a modelling tool implementing the Target Lipid Model (TLM) for the calculation of the aquatic toxicity of complex hydrocarbon mixtures. The model allows for the calculation of acute and chronic toxicity values for several trophic levels, as well as Predicted No-Effect Concentrations (PNEC). The previous implementation in an excel sheet has been migrated to the open source data mining platform KNIME, providing several advantages in terms of performance, transparency and potential for connecting to external tools, while offering the same options and results that the previous version. The herein text serves also as a manual for the use of the PetroTox too.

8/20 TESTING AND MODELLING THE EFFECT OF HIGHER OCTANE PETROLS ON AN ADAPTED VEHICLE

Gasoline combustion has traditionally been measured using Research Octane Number (RON) and Motor Octane Number (MON) which describe antiknock performance under different conditions. All European gasoline cars must be capable of running on the 95 RON petrol grade, however some vehicles are calibrated to be able to take advantage of higher octane fuels available in the market, typically by advancing spark timing or increasing boost pressure which allows more power and perhaps also better fuel consumption. In the future vehicles may be made available which have increased or variable compression ratio which can fully take advantage of higher octane but these are not commercially available at present. This engine modelling and vehicle testing study was carried out to understand the effect of high octane fuels on the efficiency of a downsized higher compression ratio engine.

9/20 CONCAWE - INVESTIGATION OF THE VALUE OF SPECTRAL DATA FOR THE IDENTIFICATION OF PETROLEUM UVCB SUBSTANCES

This report provides further information on the value of spectral data generated from the Concawe Analytical Program, and provides scientific justification that spectral data provides no additional composition information to that obtained by the other techniques recommended to registrants.

10/20 2016 SURVEY OF EFFLUENT QUALITY AND WATER USE AT EUROPEAN REFINERIES

Since 1969, Concawe has been gathering and compiling data on aqueous effluents from European oil refinery installations. Surveys have been completed at 3-5 yearly intervals and the survey design has been updated over time to address various scientific and legislative developments. Since 2010, for example, the data collection also focused on water uses within the installations. This report presents the findings of the survey completed for the 2016 reporting year of European refineries' effluent quality and water use. Compared to previous

surveys, the 2016 survey design had improved Quality Assurance and Quality Control (QA/QC) and data integrity.

A total of 72 refineries from the EU-28 countries, Norway and Switzerland participated in the survey from 98 potential respondents (73% response rate). A statistical assessment of site water use is presented, including aggregated data on intake and effluent volumes, water treatment processes, and costs associated with water use. In addition, annual average concentration and discharged mass for a number of chemical substances and parameters regulated at EU level are compared with survey data from previous years. The data returned from these surveys provides perspective on historic trends in refinery water use and effluent discharge and insight into the recent refinery sector performance. The data also allows Concawe to assess the potential impact of proposed changes to existing European legislation.

All 72 refineries were included in the 2016 record of water intake, showing a total of 2.9 billion m³ of water being withdrawn in 2016 (vs 3.5 billion m³ for 78 refineries included in the 2013 survey analysis). Out of the total water withdrawn, 80% represented by once-through cooling water, which was primarily salt/brackish surface water (97%). The water withdrawn excluding once-through cooling water and pass-through waters (non-harvested rainwater) was 475 million m³, out of which 352 million m³ was fresh water (average 4.8 million m³ fresh water withdrawn per refinery).

Of the total intake used for site purposes, most was used for recirculating cooling purpose (44%), followed by use in demineralised water production and/or steam/boiler (25%), and use in flue gas scrubbers (7 %). Water losses by use type was reported to be dominated by losses in recirculating cooling use (76 %), followed by steam/boiler use (10%) and demineralised water production (7%).

An average of 0.65 m³ of treated effluent water was discharged from the reporting refineries per tonne of annual feedstock throughput, which is lower than that reported in the previous two Concawe surveys (0.90 in 2013; 0.94 in 2010). With regard to process effluents, over 90% of the reporting refineries in 2016 applied three-stage biological waste water treatment, or transferred their process water effluent to an external facility applying three-stage biological waste water treatment. This clearly illustrates that the vast majority of the reporting refineries utilised the provisions of the Best Available Techniques (BAT) Reference document (BREF) for the Refining of Mineral Oil and Gas (REF BREF) and its BAT Conclusions (2014/738/EU) for treatment of effluents.

With regard to effluent quality, the results of the 2016 survey are consistent with the long-term trend towards reduced discharge loads of oil (reported as Oil in Water (OiW) or Total Petroleum Hydrocarbons (TPH)). Moreover, the total and relative load (i.e. normalised to throughput) are lower relative to the 2013 and 2010 survey years, being at 262 tonnes and 0.51 g/tonne throughput, respectively, for 2016. The decrease was confirmed by looking at the median relative TPH load for only the 46 refineries that reported under all surveys from 2010 to 2016.

For other effluent quality parameters, taking 2010-2016 data into account, reductions in relative load was observed for 12 of the analysed quality elements (various organics and heavy metals such as Chemical Oxygen Demand (COD), Total Suspended Solids (TSS) and cadmium) in 2016. Whereas three were kept at constant levels (total nitrogen, phenols and total phosphorus) and two increasing (mercury and vanadium) in 2016.

**11/20 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE
STATISTICAL SUMMARY OF REPORTED INCIDENTS – 2019**

The 2019 annual report on European downstream oil industry safety performance presents work-related personal injuries for the industry's own employees and contractors and process safety performance indicators. Information was received from forty-two Concawe Member Companies and Joint Ventures comprised of member companies, together representing more than 98% of the European refining capacity. Total work hours reported (613 million) were around 6% higher in 2019 than in 2018. In 2019, there were three fatalities reported by the industry, all were Manufacturing contractors. The number of Lost Workday Injuries recorded in 2019 (595) is 1.5% higher than those in 2018 (586). The combined number of Tier 1 and 2 process safety releases across Manufacturing and Marketing in 2019 declined 13% since 2018 (236 releases in 2019 and 270 in 2018). However, the number of Manufacturing Tier 1 events rose 12% from 75 in 2018 to 84 in 2019.

**12/20 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES -
STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2018 AND SINCE
1971**

Concawe has collected 48 years of spillage data on European cross-country oil pipelines. At nearly 36,000 km the current inventory includes the majority of such pipelines in Europe, transporting some 680 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2018 and a full historical perspective since 1971. The performance over the whole 48 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of inspections by in-line tools (inspection pigs) is also reported. **Product theft attempts continued to be the main cause of spills in 2018 although the total number (10) confirmed the sharp decline observed in 2017 (11) from previous years (87 in 2015).** Another 2 spillage incidents were reported in 2018, corresponding to 0.06 spillages per 1000 km of line, about 40% of the 5-year average and an order of magnitude below the long-term running average of 0.45, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. One incident was related to a construction defect and the other caused by accidental third-party interference. **Although in recent years there have been relatively few incidents due to third party activities (excluding theft), this category remains the main source of spillage incidents.**

**13/20 DETAILED EVALUATION OF NATURAL SOURCE ZONE DEPLETION AT A
PAVED FORMER PETROL STATION**

This report presents the results of an investigation that was carried out to demonstrate Natural Source Zone Depletion (NSZD) occurred under a paved site and compare various monitoring measurement methods in that context. The site is considered typical of many services stations in Europe, as a paved surface is present and extends beyond the boundaries of the site. Below the pavement and surface fill, native unconsolidated material comprising pebbles and gravels in a fine sand to clayey matrix extends down to a perched water table at 8 - 12 m depth. Two plumes exist at the site; a dissolved phase gasoline plume and a diesel light non-aqueous phase liquid (LNAPL) plume, both extending in a south-easterly direction.

Three well-documented monitoring methods were utilized to assess NSZD at the site:

- CO₂ Traps, which involve measurement of CO₂ efflux from the soil at ground surface;
- The soil gas concentration gradient method, based on measurement of subsurface O₂ and CO₂ concentration profiles; and
- The biogenic heat method based on subsurface temperature measurements.

The use of multiple monitoring measurement methods provided insights into the conceptual site model and allowed for identification of site-specific interferences between some of the measurements. Complex soil gas concentration profiles and near-surface CO₂ contributions in some areas of the site presented data interpretation challenges. However, all data indicate ongoing biodegradation near the interface of LNAPL and water table.

14/20**REVIEW OF WATER TREATMENT SYSTEMS FOR PFAS REMOVAL**

The group of perfluoroalkyl and polyfluoroalkyl substances (PFAS) is a large family of anthropogenic substances with a wide range of industrial applications. Due to their specific properties, PFAS are also used as ingredients in many formulations of Class B firefighting foams designed to fight flammable liquid fires. PFAS can and have been released into the environment during firefighting events, testing of firefighting equipment or firefighting training exercises. Due to the persistence, bioaccumulation potential and toxicity of several members of the PFAS family these substances are regarded as environmental contaminants of concern. Several regulations have been recently introduced, which restricts the manufacture and use of PFAS substances, particularly those containing more than six fully fluorinated carbon atoms.

Due to their numerous and widespread uses, mobility and persistence, PFAS are ubiquitous environmental contaminants. They have also been found at oil refinery sites in soils and groundwaters as a consequence of their historic use. As such there is an interest in removing PFAS from fire fighting (also referred to as fire-extinguishing) water run-off and groundwater in contaminated areas. This is the second of two Concawe reports on PFAS. The first report (Concawe report no. 8/16) provided an overview of the environmental fate and effects of poly- and perfluoroalkyl substances. This second report critically evaluates technologies and treatment systems for removing PFAS from both fire fighting water and groundwater. Firefighting water is likely to have PFAS concentrations which are two orders of magnitude higher than in groundwater, along with several co-contaminants. While groundwater may require pre-treatment, for example to remove ferrous iron which can cause clogging issues.

The technologies under consideration can be grouped in four main categories:

1. Adsorption technologies, including activated carbon, resins and novel PFAS-specific absorbents;
2. Flocculation technologies,;
3. Liquid-liquid separation technologies, including nanofiltration and reverse-osmosis, foam fractionation, and distillation; and,

4. Destructive technologies, including electrochemical degradation, sonochemistry, UV radiation, plasma destruction and water incineration.

A brief description of each technology is provided, followed by an evaluation of their suitability to remove different PFAS from either firefighting water or groundwater. The evaluation of both types of water was undertaken because some technologies may only be suitable for specific PFAS concentration ranges which may preclude their use depending on the type of water to be addressed. When available each evaluation is supported with technology case studies which are summarised in the Appendix to this report.

The results of the evaluation towards different criteria are summarized in lookup tables for groundwater treatment and fire-extinguishing water treatment, respectively, allowing an informed selection of the most suitable technology for a given scenario.

15/20 ASSESSMENT OF PHOTOCHEMICAL PROCESSES IN ENVIRONMENTAL RISK ASSESSMENT OF PAHS

Petroleum substances may contain polyaromatic hydrocarbons (PAHs) that can interact with sunlight. These interactions can increase hazard, via photo-enhanced toxicity, and reduce exposure, due to photodegradation. These processes are not considered in the PETRORISK model, developed and used by Concawe for risk assessments of petroleum substances under REACH. To assess the role of photochemical reactions on hazard and exposure and resulting risks to aquatic life, available photodegradation and phototoxicity data were used to calibrate hazard and multimedia exposure models for representative 3, 4, and 5-ring PAHs. These models were then used to calculate risks for a range of sunlight exposures in natural waters. Risks derived for these scenarios were then compared to the default case without light. Results showed risks with sunlight were similar to or lower than the no light scenario since the predicted enhancement in toxicity was mitigated by reduced exposure from photodegradation. Study findings indicate that neglecting light interactions in petroleum substance risk assessments do not preclude effective chemical management since risks are not increased.

16/20 LITERATURE REVIEW: EFFECTS-BASED ANALYSIS FOR SOILS, RISK MANAGEMENT, AND WASTE DISPOSAL

Classification of wastes is based on different pieces of legislation including the Waste Framework Directive (Directive 2008/98/EC) (WFD), as well as EU Member State guidance, that can vary between Member States. Waste is assessed for different hazard properties (HP) and ultimately classified as either hazardous or non-hazardous, resulting in different disposal considerations, and associated costs. The current calculation approach to waste classification is based on chemical characterisation, with the possibility of replacement by so-called effect-based tests being discussed here.

Based on an assessment of the currently available literature and the understanding of the base science, this study concludes that it is not appropriate to use effects-based testing as a substitute for the calculation approach. Effects-based tests could have value if used to assess particular site or waste-specific issues on a case by case basis, but cannot be used for some HPs where only animal tests (which are not permitted under the WFD) would be suitable.

17/20 HIGH OCTANE PETROL STUDY

The long-term goal of the EU is ambition of climate neutrality by 2050 (EU Energy Roadmap 2050). As introduction to reach this target, vehicle efficiency targets for passenger cars and light commercial vehicles have been defined in [Regulation \(EU\) 2019/631](#) in the EU up to 2030. The expected benefit, from the CO₂ emission performance standards for cars and vans, is a 23% reduction of greenhouse gas emissions from road transport (total fleet) in 2030 compared to 2005.

In the current Regulation, vehicle efficiency targets are formulated in a technology neutral manner, but from a Tank-To-Wheel (TTW) perspective only. Manufacturers have the possibility to use the CO₂ reduction potential of internal combustion engines and electrification to be compliant. In this perspective, Concawe investigated the CO₂ reduction potential of High Octane Petrol when used in an optimized engine with high compression ratio. This report investigates the feasibility of such High Octane Petrol production and its cost for EU refining.

This study was performed with the Linear Programming model developed by Concawe. It is used to simulate the performance, capabilities and behaviour of the European refineries. The model aggregates all the capacities from each individual refinery in European countries (EU27 + UK, Norway, Switzerland and Iceland).

As a first step, a series of cases have been developed with 10% of the demand switched to the High Octane Petrol grade. For the reference case of the HOP 102 RON, this evolution can easily be absorbed by the flexibility of refineries.

In a second step, a 2030 scenario is developed in which 50% of the gasoline demand switches to HOP 102 RON. A significant evolution is required in the refineries: the use of oxygenated components is increased significantly, which requires important imports of Oxygenates or investment in new Oxygenates plants, and the oxygen specification to be relaxed from 2.7 wt% to 3.7 wt% in most of the regions. Exchanges between regions are also needed.

No simulation with demand post 2030 or with HOP percentage higher than 50% have been performed. We consider these scenarios as this long term ones, which will be very dependent on the evolution on the powertrain, the Demand for gasoline and the consequent evolution of the refinery system. The analysis of constraints of the 50% case shows that the European refining system is not able to produce much more than 50% HOP 102 RON without significant investments.

In the central case, 50% demand of RON 102, the CO₂ savings is more than 4Mt/y (5% vehicle efficiency gain from R95 to R102) per year and the cost of additional octane is assessed at 4.7\$/t/point of RON. Even though it is significant, this octane value remains consistent with the market valorisation around 8.6 \$/t/pt. RON (US market, historical figure).

18/20 TECHNOLOGY SCOUTING – CARBON CAPTURE: FROM TODAY’S TO NOVEL TECHNOLOGIES

The EU Commission has recently published its long-term strategic vision exploring different scenarios leading to an EU low-carbon economy by 2050. In all these scenarios, the Carbon Capture and Storage (CCS) has been identified as a key technology to achieve this ambitious target, playing a crucial role to

reduce emission levels required to limit global warming to 2°C and pursuit efforts to limit the temperature increase even further to 1.5°C.

This study, conducted by Future Bridge at the request of Concawe, provides an overview of the carbon capture technologies state-of-art, with focus not only on the commercial but also on the near-term technologies, which are likely to be commercialized in the 2025-2030 timeframe, and on the several new emerging technologies.

For this mapping exercise, FutureBridge has considered various techno-economic factors such as carbon capture efficiency/rates, purity, cost of CO₂ capture per ton, levelised cost of electricity, risks and barriers to assess the near-term and emerging carbon capture technologies. It has collected information from patents, scientific literature, published techno-commercial reports, white papers, annual reports and sustainability reports to assess the overall available technologies around carbon capture. In addition to this, FutureBridge has also analyzed the published front-end engineering and design reports, integrated assessment models, and techno-economic analysis report for pilot and demonstration plants to gauge the near-term commercial carbon capture technologies.

19/20 EFFECT OF ENVIRONMENTAL CONDITIONS AND MICROBIAL COMMUNITIES ON ETBE BIODEGRADATION POTENTIAL IN GROUNDWATER

This report describes research carried out to determine: a) the environmental conditions which may support Ethyl *tert* butyl ether (ETBE) biodegradation in groundwater, b) the prevalence of ETBE biodegradation potential at ETBE-release sites (mainly) within Europe, and c) the organisms and mechanisms involved in aerobic ETBE biodegradation. The research included laboratory biodegradation (microcosm) studies, using samples from an ETBE-impacted site in France, and complementary microbiological studies of groundwater samples collected from several ETBE-impacted sites.

The results of this research suggest that biodegradation of ETBE is likely to occur in groundwater in the presence of dissolved oxygen and is not inhibited by the presence of other ether oxygenates, such as MTBE. Hydrochemical assessments, based on the analysis of dissolved ETBE, TBA and dissolved oxygen, can be used to demonstrate ETBE biodegradation in groundwater at an ETBE-release site. An additional line of evidence that may be relevant at some sites is microbiological assessment of ETBE biodegradation potential. This is site-specific and may be appropriate in cases where the hydrochemical assessment suggests that conditions are favourable for ETBE biodegradation but this is not observed. In this case, the presence of the *ethB* gene in the aquifer microbial community should be determined using aquifer material (e.g. core samples) or mixed groundwater-aquifer material (e.g. sampled from monitoring wells).

20/20 A CLEAN PLANET FOR ALL. IMPACT ASSESSMENT ON THE POTENTIAL IMPLICATIONS FOR OUR REFINING SYSTEM AND THE LINK WITH REFINERY 2050

The “A Clean Planet for All” [ACP4A 2018] long-term strategy published by the European Commission (DG CLIMA) in 2018 analyses different long-term scenarios that could lead to significant GHG emission reduction levels on the way towards a carbon-neutral and circular European economy by 2050.

Focussing on three of these scenarios as defined in the DG CLIMA publication (2050 baseline, Power-to-X and 1.5TECH), this report examines the implications for the EU refining sector, the CO₂ emissions reductions that could be achieved through the whole value chain and the key barriers and enablers.

With the appropriate combination of resources, including some crude oil (driven by the domestic jet fossil fuel component defined in *A Clean Planet for all*), bio-feeds and e-fuels (from captured CO₂ and electrolytic hydrogen), the European refining system, even adapted to suit the domestic demand as much as possible, is forced to export important surpluses of oil-base gasoline, gasoil and heavy fuel oil components, and even some bio-based ones, to match the domestic demand of Jet Fuel. The fossil fuels consumption mix foreseen by the European Commission's report is indeed so weighted towards Jet fuel that no refinery can come close to technically realising this yield on the crude barrel. One can question whether these levels of 'fossil' and 'bio' exports could be sustained in the low carbon world of 2050.

Overall, this Concawe study points out the risk of these scenarios, which will add significant burdens to the EU refining system in 2050. Based on the points described above, this could potentially reach a point where meeting the defined domestic demand (and fuel composition), as described in the European Commission's report, could not be economically feasible for the refining system in Europe with the consequent refinery closures, being replaced by fossil jet fuel imports from other regions of the world to Europe, with no benefit for climate change globally.

21/20 PRODUCING LOW SULPHUR MARINE FUELS IN EUROPE – 2020-2025 VISION

The global Sulphur cap entered into force from the 1st of January 2020, and it is seen by the refinery sector as an unprecedented step evolution for a key specification of one of their products. The sulphur going down from 3.50% max to 0.50wt%S is not just operating the refinery in a different way to remove the Sulphur from the current High Sulphur Bunker fuel. For the vast majority of refineries, it means producing the bunker using different internal streams, with new blending recipes, new constraints and resulting in a new optimum operation, which is affecting the refinery sector.

Being ready for the transition is a top priority for the refiners. They have done many simulations and lab testing to ensure their product will meet the required quality, and especially the stability. Internal procedure and blending rules will make sure that incompatibility of internal streams will be avoided.

This Concawe Supply study (Linear Programming modelling) is highlighting several constraints and potential difficulties. It appears feasible to supply the demand of Marine Fuel (MF) 0.50%S, but with a significant market incentive and debottlenecking when required for the Sulphur Recovery (SRU) and Hydrogen Production (HMU). The crude slate is not expected to evolve in a significant way, even though marginal, the current evolution (lower density, lower S content) goes in the right direction to ease the production of MF 0.50%S.

A key uncertainty remains on the export of High Sulphur (HS) fuel oil. Historically, European refiners have exported to Asia, with the current volume being around 10Mt per year. However demand for HS fuel oil in Asia is also declining, according to public sources, creating potential supply issue. The degree of installation of on-board installed scrubbers may also impact the situation.

For middle distillate, the issue is the opposite with a strong need for import in Europe (more than 30 Mt/year). With an expected evolution towards middle distillate for the marine fuels, the global demand will increase, creating tension in regions already seeing a deficit of middle distillate.

The typical current heavy fuel oil quality is widely available over the globe (high sulphur, high density, and high viscosity) and evolves towards a multiple range of different qualities just like hybrid fuels. The trend being a clear evolution towards middle distillate type of fuel (low density, low viscosity) for more than 50% of the market demand. Every new fuel will raise the concern of stability and compatibility; every stakeholder will have to consider it as a top priority and develop its own learning curve accordingly.

The data and vision have been updated in 2019. Therefore, the economic and Trade crisis, linked to the Covid-19 pandemic, have not been taken into account in this study. The impact on our sector being an unexpected and dramatic decrease in fuels Demand, the year “2020” is only relevant as representative of a year where the Demand goes back to 2019 level. The year “2025” as referred in this study remains, so far, fully relevant.

The data used in this study are historic and/or based on publicly available reports from independent consultancies. This study does not rely on data from Concawe members.

22/20 HAZARD CLASSIFICATION AND LABELLING OF PETROLEUM SUBSTANCES IN THE EUROPEAN ECONOMIC AREA – 2020

This report updates Concawe’s classification and labelling recommendations Report No. 13/17 to address changes to CLP regulation and include classification and labelling recommendations for Petroleum Gases and Other Petroleum gases.

23/20 RESULTS OF A COMPARATIVE PILOT FIELD TEST STUDY OF A FIRST GENERATION QUANTITATIVE OPTICAL GAS IMAGING (QOGI) SYSTEM

Quantitative optical gas imaging (QOGI) is a new system to detect fugitive emission sources and quantify their mass release rates. This report presents an evaluation of QOGI technology compared to other techniques (Sniffing/EPA Method 21 and high flow sampling (HFS)), during a field study in a European petro-chemical manufacturing site. A sample of 33 leaks from those detected during a Leak Detection and Repair (LDAR) campaign were surveyed during the field study. The QOGI system was able to quantify 18 in the field. A further 10 leaks were quantified following the field test after processing of the leak images by the system manufacturer. Unstable imaging of the background was the main reason for not being able to quantify emissions from the other 5 leaks.

For the portion of the leaks that could not be quantified, there is no procedure envisaged which can overcome this limitation with the generation of QOGI system tested at the time of this field study (2016). When comparing the quantification between HFS and QOGI, the most accurate QOGI results were obtained with leak rates > 60 g/h. QOGI was shown to be as accurate as using Sniffing/Method 21 to estimate total VOC fugitive emissions.

The results from the evaluation of the QOGI technology, showed that QOGI is a promising technology for detecting fugitive emission sources and quantifying the mass release rate for each individual leak. Sniffing/Method 21 also provide

emissions quantification but only at the level of the facility, using statistical-derived factors.

This field trial has identified issues with the use of the first generation of QOGI system in a refinery process plant environment which should be further assessed before any recommendation for using it in such an environment can be made. A second generation has been developed and the vendors state that some of the issues have been overcome. However, further field testing is required to evaluate these developments.

24/20 CAT-APP: NEW TECHNOLOGIES TO UNDERPIN CATEGORY APPROACHES AND READ-ACROSS IN REGULATORY PROGRAMMES

This report describes the main results of the multi-year Cat-App project by Concawe, which was initiated to address one of the most challenging practical issues under REACH, namely grouping and read across assessments for complex [UVCB] substances. These assessments are available as alternative approaches under the REACH regulation, in order to minimize animal testing of chemicals. They are based on the structural (i.e., molecular) composition of the chemicals in question. This makes these tools fit for purpose for simple, well-defined chemicals, but the challenge arises when a substance composition is complex. Such is the case for petroleum substances, which may contain thousands to millions of constituents, and which are partly unknown (UVCB) and variable in nature (UVCB).

For this reason, grouping substances and supporting read across of data between them cannot be justified by relying solely on structural data anymore for these complex UVCBs, and Cat-App aimed to address this challenge by adding a biological component to the assessment. The idea is that if a substance is similar in chemical composition, it will have a similar biological response in a test system. This principle may add further evidence to the grouping and eventually read across assessments for these complex substances, as these biological data can be relatively easily generated on all substances where the level of analytical data is not sufficient.

Biological response data (i.e., bioactivity) were generated by exposing extracts from petroleum substances to cell models, applying so called in vitro screening assays as alternatives to animal tests, also referred to as “New Approach Methods” (NAM). These NAM data generated in Cat-App showed that substances that are chemically similar also have similar bioactivity, further supporting the grouping of these substances. In addition, it was shown that trends can be observed across the chemical space in line with the hypothesized dose [of the specific chemical constituents]-response [in terms of bioactivity] relationship, which can be used in combination with other available data to build read across hypotheses and assessments. This is expected to help address practical challenges with the regulatory assessment of UVCB substances, which may help to avoid unnecessary animal testing on the short term, and if these data find regulatory acceptance for this purpose they can be further build on and ultimately help to develop alternatives to animal testing on the longer term.

1/21 LITERATURE REVIEW ON EMISSIONS OF SEMI- AND INTERMEDIATE VOLATILE ORGANIC COMPOUNDS AND FORMATION OF ORGANIC AEROSOLS WITH FOCUS ON THE REFINERY SECTOR

Organic aerosols (OA) are an important component of ambient particulate matter (PM) but their origin and formation is not well understood. Traditionally, OA have

been described by two classes: a) primary organic aerosol (POA) and b) secondary organic aerosol (SOA). POA refers to non-volatile organic compounds (VOC) that are emitted directly from the source in the particle phase and do not undergo any atmospheric process other than dilution and deposition, while SOA include all OA formed by oxidation and subsequent condensation of gaseous precursors. Recent studies have shown that this classification of OA is too simple because the semi-volatile nature of emitted POA is not taken into account and that other organic compounds such as condensable particulate matter (CPM) and semi- and intermediate-volatile organic compounds (S/IVOC) are also precursors of OA. The organic fraction of CPM contributes to POA (since it forms aerosol without any chemical reaction) but not to SOA. S/IVOC, on the other hand, can play a significant role in the formation of SOA in the atmosphere. The definitions of CPM and S/IVOC partly overlap, since both are defined by their volatility at a certain temperature.

This report reviews the main literature, and provides insights regarding the sources and emissions of S/IVOCs and CPM and the impact of the former on SOA concentrations. It also provides high-level estimations of S/IVOC emissions from the European refinery sector and reviews their importance in comparison to those from other sectors.

The literature review has shown that there are no published S/IVOC emissions measurements from refineries in Europe. However, S/IVOC emissions can be estimated using indicator substances, such as polycyclic aromatic hydrocarbons (PAHs). An indicative estimate of total S/IVOC emissions from all refineries in the EU27+ is 100 t S/IVOC per year, with a range of 10 to 1000 t/year. This is, by comparison, three orders of magnitude lower than the estimates for wood burning in Europe.

In addition, the results from modelling simulations using atmospheric chemical and transport models (CTMs) have shown that S/IVOC emissions from refineries contribute only a minor fraction to secondary OA concentrations over Europe. Any uncertainties of modelling OA concentrations could be reduced through undertaking refinery S/IVOC measurements that can help to develop representative sectoral emission inventories and determine the refining contribution to OA more accurately.

2/21 CONCAWE'S TRANSPORT AND FUEL OUTLOOK TOWARDS EU 2030 CLIMATE TARGETS

This Concawe report aims at providing an outlook on the European transport sector by modelling elements such as the evolution of the different powertrains and the availability of different alternative fuels over the period 2018-2030.

An analytical fleet-based model has been used, projecting the evolution of the fleet composition as well as the corresponding fuel demand towards 2030. The analytical tool is used to simulate different parameter combinations of vehicle and fuel (and thereof renewable fuel) technologies to assess fuel demand scenarios looking at vehicle fleet mix, fossil fuel demand, total renewable energy demand, and RED-II target. The composition of 2030 new vehicle sales has been defined based on market trends and experts' view, in compliance with the current 2030 CO₂ intensity targets for new sales in road transport. Besides this, a current and future estimate on both the total energy requirements and alternative fuel penetration have been included for other transport modes including aviation, rail and maritime sectors. The analytical tools evaluate fuel supply availability based

on an updated market-based outlook on production plants currently in operation as well as the planned capacities for biofuels.

This study finally explores the compliance with RED II regulation and 2030 targets in a baseline scenario considering the impact of two different interpretations of using renewable electricity in the transport sector. Complementing the baseline, additional sensitivities on key individual parameters have been explored, mainly around the uptake of electric vehicles, bio-kerosene, biomethane, liquid biofuels, and gasoline fuel grades. The sensitivity analysis was conducted to show their individual impact on reaching the RED II targets, to inform the currently on-going process on future RED II targets for road transport (to be agreed in 2021).

3/21 **OVERVIEW OF FIELD-BASED ANALYTICAL TECHNIQUES, DEVICES AND KITS TO DETERMINE PETROLEUM HYDROCARBONS IN SOIL**

Determination of petroleum hydrocarbons in soil has long been an area of active investigation and still attracting interest as there are important and complex environmental contaminants. Several standardised lab-based analytical techniques providing both accuracy and analytical precision are being used for their determination and quantification in soil. However, the procedures involved can be time-consuming and expensive, and therefore not always providing cost effective approaches to the assessment of sites contaminated with petroleum hydrocarbons.

Over the past decade, the emergence of various field analytical techniques has enabled real-time petroleum hydrocarbons detection and on-site measurement, which has the potential to drastically reduce cost and time of analysis, sampling design and site assessment compared with traditional technologies. In this review, we have designed and developed a practical guide on the use of field analytical technologies to rapidly assess petroleum hydrocarbons in soil. The basic principle along the advantages and limitations of each field analytical technique, and the recent developments over the past years, are highlighted.

The synthesis of information outlined in this review provides a firm foundation for an informed decision process in the selection of field analytical technologies for the detection and characterisation of petroleum hydrocarbons in soil.

4/21 **PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES - STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2019 AND SINCE 1971**

Concawe has collected 49 years of spillage data on European cross-country oil pipelines. At nearly 36,000 km the current inventory includes the majority of such pipelines in Europe, transporting some 620 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2019 and a full historical perspective since 1971. The performance over the whole 49 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of use of in-line inspection tools/pigs is also reported. **Significantly in 2019, there were no spillages associated with third party interference, either accidental or intentional (product theft attempts). This is the first time since records began in 1971 and the first year since 2010 for theft attempts.** A total of 6 spillage incidents were reported in 2019, corresponding to 0.18 spillages per 1000 km of line, somewhat above the 5-year average but still well below the long-

term running average of 0.44 spillages per 1000 km per year, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. There were no fires, fatalities or injuries connected with these spills. Two incidents were due to mechanical failures, 1 to an operational issue and 3 to corrosion. The historical data show a long-term downward trend in the frequency of corrosion-related spillages since the early 1980's, albeit with notable shorter-term peaks and troughs. Nine cases were reported in the last 4 years and it is not clear at this stage whether this is a warning of a wider issue.

5/21 PERFORMANCE OF WATER TREATMENT SYSTEMS FOR PFAS REMOVAL

Per- and polyfluoroalkyl substances (PFAS) are a group of widely used man-made organic chemical substances. They contain alkyl groups on which all or many of the hydrogen atoms have been replaced with fluorine. As such, they contain at least one perfluoroalkyl moiety, $-(CF_2)_n-$. PFAS have been used because of their particular physicochemical properties: most are stable at high temperatures, recalcitrant to chemical oxidation and biological degradation (i.e., persistent), and act as a surfactant. Although beyond the scope of this report, as reported by the Australian Ministry of Defense⁶, among others these properties mean there are a wide variety of PFAS-containing materials (e.g. stain-resistant fabrics, nonstick cookware, polishes, personal care products, and fire-fighting foams), or materials where PFAS is used in the process (e.g. Mist suppression in metal plating or photography). Many such substances may also be bio-accumulative and toxic.

In this study several treatment technologies for PFAS removal were tested in the laboratory on both groundwater containing PFAS, and firefighting wastewater obtained from a firefighting training site where firefighting foam was applied. The treatment technologies assessed were performance of sorbents, coagulation/flocculation, nanofiltration, foam- and ozo fractionation technologies. In all cases the PFAS removal effectiveness was evaluated.

This report provides:

- Criteria and background information to select potential treatment technologies.
- Results of these performance tests of water treatment technologies for PFAS removal.
- Practicalities such as availability of the technology and experimental feasibility which are included in the evaluation.
- Recommendations for selection of treatment technologies for PFAS removal in practice for impacted groundwater and firefighting wastewater.

Experiments showed that all tested sorbents were able to remove PFAS from firefighting wastewater but the required sorbent dosages were in the g/L range. It is therefore concluded that groundwater containing PFAS can be treated with one of the tested sorbents directly, while for firefighting wastewater, which typically has higher PFAS concentrations as well as other contaminants, a treatment train approach is likely to be more efficient. An initial treatment, such as flocculation, nanofiltration or foam- / ozo fractionation that removes bulk PFAS load including co-contaminants followed by a polishing treatment (e.g. sorbents) that further reduces PFAS concentrations to acceptable levels is advised, unless a relative small fixed volume of firefighting wastewater needs to be treated.

This study provides a basis for readers of this publication to select, study and apply the best available technologies to mitigate risks associated with PFAS contamination.

6/21 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE - STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2020

The 2020 annual report on European downstream oil industry safety performance presents work-related personal injuries for the industry's own employees and contractors and process safety performance indicators. Information was received from forty-two Concawe Member Companies and Joint Ventures comprised of member companies, together representing more than 97% of the European refining capacity. Total work hours reported (543 million) were around 12% lower in 2020 than in 2019, potentially associated with the reduction in staffing and fall in product demand due to the Covid-19 pandemic. In 2020, there were two fatalities reported by the industry, one Manufacturing staff and one Marketing contractor. The number of Lost Workday Injuries recorded in 2020 (476) is 20% lower than those in 2019 (595). The combined number of Tier 1 and 2 process safety events across Manufacturing and Marketing in 2020 declined by almost 17% since 2019 (197 releases in 2020 and 236 in 2019). The numbers of Tier 1 and Tier 2 events declined in both sectors, with the largest reduction in the number of Marketing Tier 1 events 50% from 8 in 2019 to 4 in 2020.

Note that 2019 data in this report has been revised based on new member company information received in the 2020 data collection. This report therefore provides the most accurate and up to date details of both 2019 and 2020 data.

7/21 TRANSITION TOWARDS LOW CARBON FUELS BY 2050: SCENARIO ANALYSIS FOR THE EUROPEAN REFINING SECTOR

This report is a theoretical assessment of different potential trajectories (*scenarios*)

for the EU refining industry to contribute to EU climate targets. With a wide focus on road, aviation and maritime sectors, three potential demand scenarios show the total volume of low carbon fuels that could be required to contribute to climate neutrality in EU transport by 2050 as well as the number of plants and level of investment required (Volumes ranging from ~70 up to ~160 Mtoe/y with a cumulative ~190-660 B€/y investment at the end of the period). For the purpose of simplification, it includes only a limited number of examples of low carbon feedstocks and technologies (food-crop based, hydrotreated vegetable oils (HVO), Biomass-to-Liquid (BTL), e-fuels, clean hydrogen and Carbon Capture and Storage). A look into sustainable biomass availability identifies no major constraints in the realisation of the scenarios according to a recent publication from Imperial College London Consultants [IC 2021]. This document is not intended to become a roadmap for the industry; other trajectories could be defined or appear depending on the framework conditions as well as the successful development and scale-up of the different technologies and their related value chains.

8/21 FIRST AID REFERENCE GUIDE - 2021 UPDATE

This reference guide is designed to provide additional information on the first aid measures in the event of significant on-site exposures to petroleum substances.

This document is intended for trained first aiders and site medical professionals and is not intended to replace the Safety Data Sheets, or other company specific procedures. This reference guide only addresses exposure from acute occupational exposure. First aid treatment should be carried out by appropriately qualified persons.

The 2021 update of the guide is based on an intensive evidence-based research on medical databases by the Centre for Evidence-Based Practice (CEBaP) of the Belgian Red Cross (www.cebap.org). Evidence summaries were based on a systematic literature review, collecting relevant studies to answer the specific research question of interest:

“For people exposed to one of the listed petroleum substance categories (Population) which first aid interventions (Intervention) are effective or helpful to improve health outcomes (Outcome)?”

9/21 DEVELOPING WORKER AND CONSUMER EXPOSURE SCENARIOS FOR IDENTIFIED USES OF PETROLEUM SUBSTANCES UNDER REACH - 2020 EDITION

Under REACH, Exposure Scenarios (ES) need to be developed for all identified uses of chemical substances that are manufactured or imported in quantities above 10 tonnes per year and classified as hazardous according to Regulation (EC) No 1272/2008 on the classification, labelling and packaging of substances and mixtures (CLP Regulation). ES constitute an essential part of the REACH Chemical Safety Assessment (CSA) and are included in the Chemical Safety Report of the registration dossier. These scenarios describe the Risk Management Measures and Operational Conditions to be followed by supply chain actors to ensure that the substance can be used safely, i.e. without harm to humans or the environment, and which are required to be communicated to downstream users as an Annex to the extended Safety Data Sheet.

This report sets out the approaches that Concawe has adopted in developing worker and consumer ES for identified uses of petroleum substances under REACH. Exposure Scenarios had been initially developed by Concawe in view of the REACH 2010 registrations (Concawe report 11/12), and have been updated in 2020, as documented in the present report. Using the Generic Exposure Scenarios of the European Solvents Industry Group (ESIG) as reference point for consistency across other supply chains of complex substances, the 2020 updates for the Human Health (HH) part have been based on the most recent ECHA guidance documents on exposure and risk assessment and have considered further refinements needed for the Concawe CSAs, given the complex nature of petroleum substances. Concawe HH CSAs have been transcribed using the CHEmical Safety Assessment and Reporting (CHESAR) tool v3.3 developed by ECHA.

10/21 LITERATURE REVIEW ON CNG/H₂ MIXTURES FOR HEAVEY-DUTY CNG VEHICLES

Sustainably produced hydrogen (H₂) is seen as a low carbon fuel for transportation. Likewise compressed natural gas (CNG) could reduce CO₂ emissions from vehicles, especially if it is produced from renewable sources such as biomethane. Being both gaseous, H₂ and CNG can easily form a mixture (H₂/CNG), and the existing gas network could potentially be used for a smooth transition from fossil natural gas to a mixture of renewable CH₄ and H₂, thereby achieving a low carbon energy supply for internal combustion engines (ICEs).

Concawe commissioned DNV a literature review to assess the benefits, drawbacks and barriers of using H₂/CNG mixtures in ICEs, with a focus on heavy duty vehicles.

The report reveals that the European heavy-duty CNG vehicle market is moving from lean burn (excess air, the technology that was most used in pre-Euro V vehicles) to stoichiometric engines (current technology of choice in Euro VI vehicles). In general, the literature primarily focusses on the effect of H₂ addition to CNG in lean-burn engines, limited information being available on stoichiometric heavy-duty engines.

When 20% vol. H₂ is mixed with CNG, the literature shows:

- Engine efficiency gains between 0% and 13% in a spark-ignited lean burn engine, strongly dependent on engine parameter settings; in a stoichiometric engine, the efficiency gain is unknown;
- Greenhouse gases emissions reductions between 8% (if no efficiency gain) and 20% (13% efficiency gain)
- Vehicle driving range reductions between 24% (if no efficiency gain) and 14% (13% efficiency gain), due to the unfavourable compressibility factor of H₂ compared to CH₄.

The tolerance to H₂ content in the natural gas grid is heterogeneous in Europe, ranging between 0.1% (Belgium, UK) to up to 10% (Germany, on a case-by-case basis, depending on the grid specificities). In the whole supply chain connected to the gas grid, CNG vehicles are among the end-use applications with the lowest tolerance to H₂ addition (2% vol. max) because the steel tanks (Type 1) used in the legacy fleet may suffer from H₂ embrittlement. For this reason, the H₂ limit of 2% vol. max is fixed in the European standard EN 16723-2 for CNG as automotive fuel. However, new vehicles are no longer concerned by this issue thanks to new tank types made of non-steel composite materials. The report identifies knowledge gaps and research needs regarding the compatibility of engines and retail stations with higher rates of H₂ in CNG which concern the aftertreatment system, the spark plugs, the lubricating oil, the CNG tank and fuel lines, the injectors, the knock management and rating, the engine calibration and the sensors; the effects on engine-out emissions and combustion stability are also listed.

Moreover, the report compares the merits of use of pure H₂ both in fuel cell electric vehicles (FCEVs) and in ICEs. On the one hand, FCEVs show better fuel economy and no pollutant emissions compared to ICEs. But on the other hand, they require a very high degree of purity of H₂ at the retail station and have a higher total cost of ownership (TCO).

1/22 HAZARD CLASSIFICATION AND LABELLING OF PETROLEUM SUBSTANCES IN THE EUROPEAN ECONOMIC AREA – 2021

This report updates Concawe's classification and labelling recommendations Report No. 22/20 to address changes to CLP regulation and include classification and labelling recommendations for Petroleum Gases and Other Petroleum gases.

2/22 LITERATURE REVIEW OF PARTICULATE MATTER (PM) FROM TRANSPORT WITH A SPECIAL FOCUS ON ORGANIC AEROSOLS

Several recent scientific studies on urban air quality have suggested that air quality modelling based on current emission inventories for mobile sources systematically underestimates the contribution of these sources to ambient particulate matter (PM) levels, and organic aerosol levels in particular.

This document discusses a number of factors that may explain the reasons for this apparent systematic underestimation. It reviews the main literature under this research area with the aim to put into perspective the importance of road transport emissions on PM concentrations and enhance Concawe's understanding on the role of the different components and in particular those of organic origin (e.g., intermediate/semi-volatile organic compounds (IVOC/SVOC), condensable particulate matter (CPM)).

3/22 IMPACTS OF LOW CARBON TECHNOLOGIES ON ENVIRONMENTAL PARAMETERS: AIR/WATER/WASTE

Concawe's Low Carbon Pathways (LCP) programme aims to identify opportunities and challenges for different low-carbon technologies and feedstocks to achieve a significant reduction of the carbon dioxide (CO₂) emissions associated with both the manufacturing and use of refined products in Europe in the medium (2030) and longer-term (2050). The low carbon technologies/feedstocks explored under the LCP work identified significant positive effects on reducing CO₂ emissions associated with the refining system by 2050. However, the associated effects on other environmental parameters, such as air quality, water quality, water usage and waste, are not yet well defined.

This report provides a summary of the findings of an industry consultation and literature review carried out on four LCPs explored previously by Concawe [Concawe 2019a, 2019b]. It presents information on the likely environmental emissions and demands relating to air, water, and waste (other than CO₂) associated with the four LCP, and identifies where gaps exist.

4/22 DEFINITION GUIDELINES OF WATER REUSE, RECYCLING AND RECLAMATION FOR EUROPEAN REFINERY SECTOR

The current Best Available Techniques (BAT) Reference document (BREF) for the mineral oil refining sector (REF BREF) contains requirements such as reducing water consumption by water recycling and internal water reuse. However, the terms water reuse, water recycle, and water reclamation are not defined in the Industrial Emissions Directive (IED) and associated reference documents.

This report reviews the main literature and provides an overview of current definitions of water reuse, recycle and reclamation used by industry, reporting organisations and international institutions. The literature review has shown that there are no consistent definitions of the terms.

The report provides recommended definitions of the terms water reuse, water recycle and water reclamation, based on technical evidenced encountered

during the literature review and industry sources. It also provides guidelines on which refinery processes can be considered water reused, recycled and reclaimed, to facilitate future technical discussions and to allow Concawe members, and others, to report water reused, water recycled, and water reclaimed in a more consistent way.

5/22 USER MANUAL FOR CONCAWE LNAPL TOOLBOX

LNAPL stands for “Light Non-Aqueous Phase Liquids” or hydrocarbons that exist as a separate undissolved phase in the subsurface at some sites with legacy releases of fuels. They are referred to as “Light” because most petroleum hydrocarbons are less dense than water. Because LNAPLs can sustain dissolved groundwater plumes for long time periods, it is important to understand how much LNAPL may be present at site, if the LNAPL can migrate, if it can be recovered, how the LNAPL composition changes over time, how long it may persist, and finally quickly the LNAPL body is attenuating.

Understanding LNAPL behavior is complex, and therefore Concawe envisioned compiling a unique collection of useful tools, calculators, data, and resources to help LNAPL scientists and engineers better understand how to manage LNAPL at their sites. Concawe commissioned the development of the Concawe LNAPL Toolbox, a wide-ranging but easy to use web-based toolbox to deliver key LNAPL knowledge to the LNAPL remediation community. The LNAPL Toolbox is intended to be a clear, transparent tool that regulators can use to validate site information that is given to them and to learn about LNAPL so that they are able to make informed decisions using sound science. The toolbox uses a three-tiered approach that provides access to over 20 different LNAPL tools (key infographics, nomographs, calculators, mobility models, videos, checklists, and other formats) with different levels of complexity, activation energy, and time requirements. The three tiers of complexity are:

- Tier 1: Simple, Quick Graphics, Tables, Background Information
- Tier 2: Middle Level Quantitative Methods, Tools
- Tier 3: Gateway to Complex Models

In terms of content, the Concawe LNAPL Toolbox is designed to address six questions via six different sections:

1. How much LNAPL is present?
2. How far will the LNAPL migrate?
3. How long will the LNAPL persist?
4. How will LNAPL risk change over time?
5. Will LNAPL recovery be effective?
6. How can one estimate Natural Source Zone Depletion (NSZD)?

The Concawe LNAPL Toolbox is designed to be accessed via a webpage on an internet browser (https://lnapltoolbox.concawe.eu/lnapl_toolbox), or by downloading the Toolbox for use on a personal computer (<https://github.com/concawe/LNAPL-Toolbox>). In this manual, there are stand-alone description of each component of the LNAPL Toolbox, such as the Overview and supporting information for each of the three Tiers in each of the 6 questions.

6/22 PERFORMANCE OF EUROPEAN CROSS-COUNTRY OIL PIPELINES - STATISTICAL SUMMARY OF REPORTED SPILLAGES IN 2020 AND SINCE 1971

Concawe has collected 50 years of spillage data on European cross-country oil pipelines. At nearly 36,000 km the current inventory includes the majority of such pipelines in Europe, transporting some 615 million m³ per year of crude oil and oil products. This report covers the performance of these pipelines in 2020 and a full historical perspective since 1971. The performance over the whole 50 years is analysed in various ways, including gross and net spillage volumes, and spillage causes grouped into five main categories: mechanical failure, operational, corrosion, natural hazard and third party. The rate of use of in-line inspection tools is also reported. A total of 8 spillages were reported for 2020, 4 of which were theft-related. The other 4 incidents correspond to 0.12 spillages per 1000 km of line, equal to the 5-year average and well below the long-term running average of 0.43 spillages per 1000 km per year, which has been steadily decreasing over the years from a value of 1.1 in the mid-70s. 2 incidents were due to mechanical failures, 1 to corrosion and 1 to (accidental) third party activity. There were no fires, fatalities or injuries connected with these spills.

7/22 PETROLEUM REFINERY EFFLUENT CONTRIBUTION TO CHEMICAL MIXTURE TOXIC PRESSURE IN THE ENVIRONMENT

Petroleum refinery effluents (PRE) are wastewaters from industries associated with oil refining. Within EU, PREs are regulated through local discharge permits and receive significant treatment before emission. After treatment, PREs can still contain various pollutants potentially toxic to organisms. Earlier work, including whole-effluent toxicity assessments, has shown that toxicity of PREs is often limited. However, the extent to which PREs contribute to mixture pressure in the receiving environment is unknown. Therefore, our study aimed to assess the contribution of PREs to mixture effects in the environment, using the multi-substance potentially affected fraction of species (msPAF) as an indicator.

Based on measured chemical concentrations, compiled species sensitivity distributions (SSD) and dilution factors, msPAF levels were computed for undiluted effluents at discharge points and diluted effluents downstream in receiving waters. Average msPAF-chronic and msPAF-acute levels of PREs at discharge points were 69% (P50) and 40% (P95), respectively. Levels were reduced substantially <5% downstream, indicating low to negligible toxicity of PREs in receiving environments. Regardless of differences in endpoints and locations, hydrocarbons (mainly total petroleum hydrocarbons) and inorganics (mainly ammonia) explained at least 85% of the mixture toxic pressure. The msPAF levels of PREs were on average 2.5-4.5 orders of magnitude lower than background levels, suggesting that PREs were minor contributors to the toxic pressure in the environment.

Our results provide effluent and substance rankings, helping identify hotspots and take effective targeted action to remediate potential risks. We explicitly discuss the uncertainties for further refinement and development of the method.

8/22 EUROPEAN DOWNSTREAM OIL INDUSTRY SAFETY PERFORMANCE - STATISTICAL SUMMARY OF REPORTED INCIDENTS - 2021

9/22 GUIDANCE ON THE COMPILATION OF SAFETY DATA SHEETS FOR PETROLEUM PRODUCTS

This Guidance addresses the specific Concawe recommendations for authoring of (extended) Safety Data Sheets for Unknown or Variable composition, Complex

reaction products or of Biological materials (UVCB) petroleum substances, and mixtures containing one or several of these substances, in the Member States of the European Union. The present document provides guidance for the application of Regulation (EU) 2020/878 amending the requirements for the Safety Data Sheets (SDS) in revised Annex II of the REACH Regulation (EC) No 1907/2006, enforced in January 2021 and transition ending in December 2022.

Since the previous legal changes of REACH Annex II in 2015, more stringent requirements are now introduced to several SDS sections (most notably to 1.1, 1.3, 2.3, 3.1/3.2, 9.1, 9.2, 11.1, 11.2, 12.6, 14.1 and 14.7). There are also new mandatory sub-headings potentially requiring changes in the template format of SDS authoring software in companies

10/22 EVALUATION OF PLUG-IN HYBRID VEHICLES IN REAL-WORLD CONDITIONS

Assessing the real-world energetic performance and emissions of Plug-in Hybrid Vehicles (PHEVs) is complex. First, because of the complexity of the powertrain itself, pairing thermal and electric propulsion. Second, because their evaluation results are extremely sensitive to their usage while driving (e.g. trip distance) and before driving (e.g. recharging behaviour). In this context, the present study aims at delivering energy consumptions and GHG emissions data of the PHEVs in real-world conditions and as a function of their use cases.

The study is based on an extensive experimental campaign. Two Euro 6d PHEVs were selected to allow a back-to-back comparison between petrol and diesel internal combustion engines. The first purpose of the test campaign is to evaluate and compare the energy consumptions (in terms of electricity and fuel), the CO₂ and pollutant emissions of different vehicle configurations: charged PHEVs vs non-charged PHEV; non-charged PHEV vs non-plug-in hybrid electric vehicles (HEV); Diesel vs gasoline; traditional fossil-based fuels vs renewable fuels, etc. These vehicles were tested in a first step on a chassis dynamometer to accurately control and reproduce experimental conditions allowing the different configurations to be compared and to allow the implementation of advanced measurement systems (engine-out and tailpipe emissions of both regulated and non-regulated pollutants, energy consumptions, AdBlue consumption). In a second step, the vehicles were tested on-road to allow a comparison of the measurements made in the laboratory and assess their representativeness. All the driving cycles performed, either in lab or on-road, were RDE-compliant. Both PHEVs tested show low regulated emissions (well below Euro 6d limits) and unregulated pollutant emissions in the range of Euro 7 proposals. Compared to the gasoline PHEV, in charge sustaining (CS) mode, the Diesel PHEV shows a 20.5% reduction in tank-to-wheels (TtW) greenhouse gases (GHG) emission, and a reduction of regulated pollutant emissions. On the gasoline PHEV under the operating conditions tested in this program, switching from a standard E10 fuel (mostly fossil-based) to a 100% renewable gasoline blended with 20% v/v of ethanol (E20) fuel has no significant impact on the pollutant tailpipe emissions, or on the TtW CO₂ emissions. However, it implies a higher volumetric fuel consumption (+4.5%), linked to the higher oxygen content in E20 (hence the lower energy density). For the Diesel PHEV under the operating conditions tested in this program, switching from a standard B7 fuel (mostly fossil-based) to a 100% renewable HVO fuel also has no significant impact on the pollutant tailpipe emissions. In charge sustaining mode, it decreases by 2% the TtW CO₂ emissions, and increases by +8,4% the volumetric fuel consumption, due to the fuels physico-chemical properties (resp. CO₂ emission factor and energy density).

These experimental measurements allowed the calibration of energy simulation models of both vehicles, using Simcenter Amesim™ software and its IFP-Drive library. The simulator was calibrated to fit roller test bench results, real road measurements, and climatic cell data. For the latter, elementary thermal models of Heating, Ventilation and Air Conditioning (HVAC) and battery conditioning were added to the vehicle simulator to fit with overconsumption and electrical range decrease due to cold or warm ambient conditions. Regarding the other powertrain components, their parametrization relied on a dedicated tool that generates efficiency maps based on engine/motor/battery general description. Special attention was paid to the on-line hybrid control strategy, so that the simulated vehicle behavior remains accurate for various types of driving, including the harshest ones, while still fitting with both electric and fuel consumptions. As this simulator modelled properly the available experimental data, a comprehensive range of real-world uses was forecasted over a wide Design of Experiments (DoE). This DoE spans vehicle configurations, battery capacity, outside temperature, and driving profiles extracted from IFPEN's clustered trips database. The huge amount of results was then synthesized through an analytical method, since it would be too heavy to re-simulate and generalize day to day patterns.

Finally, a mathematical method of weighting each of the simulated use-cases according to their representativeness of real use was proposed, based on usage statistics in terms of daily distance travelled and temperature. The study is carried out for a wide range of battery sizing and recharging frequency, thus making it possible to determine the weighted average energetic performance and emissions of PHEVs according to these two key parameters, determined respectively by the original equipment manufacturers (OEMs) and the end user. Considering the technology sensitivity to real use conditions and considering the statistical conditions of use in Europe (temperature and daily mileage), this approach allows to quantify the weighted average energetic performance (share of electric drive, fuel and electricity consumption) and TtW CO₂ emissions of PHEVs depending on their battery sizing and recharging frequency. It shows that frequent recharging of PHEVs is a necessary condition for a high electric drive rate: recharging every day a gasoline PHEV having a battery of 15 kWh leads to an average fuel consumption of 2.25 L/100km and a share of electric drive (utility factor, UF) of 77 %, whilst recharging it every 3 days leads to a fuel consumption of 4.85 L/100km (+116 %) and a UF of 48 % (-29 points). By comparison, the non-rechargeable gasoline HEV with a 2kWh battery evaluated under the same conditions shows an average fuel consumption of 7.3 L/100km and a UF of 24%. Compared to this reference HEV, the gasoline 15kWh PHEV vehicle allows a consumption reduction of 69% if it is recharged every day and a reduction of 34% if it is recharged every three days. Furthermore, it is observed that the first kilowatt-hours of battery capacity are the most effective in electrifying the PHEVs: for instance, adding another 15 kWh of battery capacity to the vehicle, leading to a 30 kWh PHEV, would increase by only 10 points the utility factor, from 77 % to 87 %, if recharged every day; instead, the same 15 kWh battery capacity could have electrified 77% of the mileage of another PHEV, which is more efficient if the total amount of available batteries is constrained .

The assessment of life cycle GHG emissions of PHEVs, adding the vehicle production emissions and the Well-To-Tank (WtT) emissions of energy carriers are not covered in this report, and will be addressed in a further study.

This report provides an overview of spot and passive sampling data of three refinery effluents after treatment that were collected for chemical and ecotoxicological effluent assessment. The report includes a discussion of the relationships between toxic units derived from spots samples and passive samplers. Further, it discusses if the observed toxicity from the passive sampler extracts can be explained by chemical analyses and makes an overall comparison between spot and passive sampling.

Return of experience on the application of passive samplers within refinery effluent assessments, including technical considerations on the use of passive vs. spot sampling are summarized. If and how passive sampling can help towards making better decisions and assessments of refinery waters is also discussed.

The report concludes that passive sampling provides information on the dissolved fraction as well as a time-weighted averaged sample over several weeks, which is not provided by spot sampling. However, there are a number of challenges when translating bioassay outcomes of the passive sampler extracts to the toxicity response of the original waters, and these challenges seem largely related to the use of partition based passive samplers. From the work conducted in this project it can be concluded that expert labs and detailed knowledge are needed to properly interpret the results from assessments that combine passive sampling studies with effect-based methods testing. Overall, this approach is not yet ready for routine monitoring but might be more suitable for targeted, location specific surveillance studies.

12/22 QUALITATIVE AND QUANTITATIVE COMPARISON OF FIELD-BASED ANALYTICAL TECHNOLOGIES FOR PETROLEUM HYDROCARBONS DETERMINATION IN SOILS

The performance of seven field-based technologies including 3 portable solvent-based technologies and 4 handheld solvent free technologies were evaluated for petroleum hydrocarbons determination in soil and soil-gas samples from a range of gasoline and diesel spiked soils as well as soils from field sites contaminated with hydrocarbons. Performance of the field technologies were compared to an established reference gas chromatography coupled to mass spectrometry (GC-MS) analytical method for petroleum hydrocarbons. Further to this, the recovery and performance of the solvent-based technologies were assessed using a certified soil reference material and benchmarked against commercial accredited laboratory analysis for the field contaminated samples.

13/22 A REVIEW OF TOXICITY TESTING CONDUCTED ON EUROPEAN REFINERY EFFLUENTS IN 2010, 2013, 2016, AND 2019

This report provides an assessment of the extent to which toxicity testing is carried on European refinery effluents, and the types of tests being used. The analysis is based on responses given to Concawe water use and effluent quality surveys completed for the 2010, 2013, 2016, and 2019 reporting years. The overall response rate of toxicity data has remained similar (~37%) over the period despite a general decrease in both the number of operational refineries and the number of responses to the surveys.

Toxicity testing was predominantly carried out to fulfil permit requirements, or due to regulatory demand. Voluntary monitoring continues to be performed on an annual basis across many country groups. The most frequently reported

toxicity tests across the four survey years were *Daphnia magna* and *vibrio fischeri*/Microtox.

14/22 PETRORISK VERSION 8.01 – USER MANUAL

This report provides a detailed description of version 8.01 of Concawe's PetroRisk model: (1) conceptual design, (2) main improvements compared to previous versions, (3) KNIME, the open-source software wherein PetroRisk is developed, (4) use instructions, and a (5) technical basis.

PetroRisk calculates the environmental exposures and risks resulting from the different lifecycle stages of multi-constituent hydrocarbon substances, using the principles provided by the European Chemical Agency (ECHA) under the EU REACH regulation. Environmental exposures and risks can be predicted at the manufacture/formulation/distribution stages and at industrial/professional/consumer use stages for multi-constituent hydrocarbon substances, such as naphthas (gasolines), kerosenes, gas oils, heavy fuel and lubricant oils, and solvents. PetroRisk version 8.01, including its Generic Exposure Scenario (GES) scaling tool, can be downloaded free-of-charge from Concawe website.

15/22 ESTIMATING THE CO₂ INTENSITIES OF EU REFINERY PRODUCTS: STATISTICAL REGRESSION METHODOLOGY

This study aims at estimating the CO₂ intensity of petroleum products, at the gate of an average EU refinery, using a novel approach, which reconciles economic relevance with accounting conventions in joint production industries. It revisits and finds a fair and logical way to distribute total CO₂ emissions from the EU refineries over the most significant finished products, selected from the refinery slate.

The refinery linear programming model of Concawe is used in combination with an innovative restricted regression methodology to determine the linear coefficients which are equal to the CO₂ intensities of the EU finished refined products.

To satisfy LCA standard methodology, this novel data-driven framework is combined with supervised machine learning technics to extend the scope of results, providing positive CO₂ intensities for all selected products.

The concept of average CO₂ footprint is controversial in a multiproduct industry, as the refining industry. In this report, we reconcile, the causal methodology relevance with the accounting conventions for additivity and non-negativity simultaneously. The computation principles are transparent and readily replicable by all stakeholders.

16/22 ASSESSMENT OF CHEMICAL OXYGEN DEMAND/TOTAL ORGANIC CARBON (COD/TOC) RATIOS IN REFINERY EFFLUENTS

Chemical Oxygen Demand (COD) analysis is one of the most commonly used analytical methods to indirectly measure organic pollutants in effluent waters. The standard COD methods use potassium dichromate which is restricted under the REACH regulation. The European Commission (EC) and EU member states are considering whether to replace COD analysis with Total Organic Carbon (TOC) analysis for effluent discharge monitoring. An empirical relationship has been applied between TOC and COD in regulatory contexts, where a global COD/TOC ratio of 3 is most commonly suggested. In the Commission

Implementing Decision establishing Best Available Techniques (BAT) conclusion for the refining of mineral oil and gas (REF BATc), it states that where on-site correlation is available, COD may be replaced by TOC and the correlation between COD and TOC should be elaborated on a case-by-case basis. Further, the REF BATc states that TOC monitoring would be the preferred option because it does not require the use of very toxic compounds, i.e., potassium dichromate, in laboratory testing.

In this report we assess if, and which, value of COD/TOC ratio would be applicable for treated wastewater effluents arising from oil refineries. To achieve this, we first performed a scientific literature study on reported COD/TOC ratios in effluents. As a second step, we investigated the COD/TOC ratio for eight refinery effluents.

In conclusion COD/TOC ratios varied, and a single global COD/TOC ratio could not be established for refinery effluents due to the specific conditions of each refinery. COD/TOC ratios specific to each site is challenging to establish. Nevertheless, a site-specific assessment allows for a more meaningful discussion on values that could be considered for discharge permits. In the case that it is not possible to establish a reliable COD/TOC ratio for a specific site, and thus the COD analysis cannot be omitted, we would recommend the use of the Sealed Tube (ST) COD method to achieve significant reduction in the laboratory use of hazardous chemicals compared to the traditional open reflux method.

3. PRODUCT DOSSIERS

<https://www.concawe.eu/publications/product-dossiers>

Concawe's Product Dossiers are currently unavailable pending update with the most recent information compiled for registration under REACH.

92/101	AROMATIC EXTRACTS
92/102	LIQUEFIED PETROLEUM GAS
92/103	GASOLINES
92/104	BITUMEN AND BITUMEN DERIVATIVES
93/105	PETROLEUM COKE
94/106	KEROSINES/JET FUELS
95/107	GAS OILS (DIESEL FUELS/HEATING OILS)
97/108	LUBRICATING OIL BASESTOCKS
98/109	HEAVY FUEL OILS
99/110	PETROLEUM WAXES AND RELATED PRODUCTS

4. MISCELLANEOUS

90/02 GASOLINE VAPOUR EMISSIONS - A EUROPEAN CONCERN

CONCAWE considered it helpful to prepare a brochure on gasoline vapour emissions for a non-technical audience. The objective is to promote the enlarged carbon canister in a more focused way, whilst providing briefing on the area of gasoline emission control.

5. JOINT PUBLICATIONS

<https://www.concawe.eu/publications/joint-publications>

92/02	PROCEEDINGS OF THE CONCAWE/DGMK SCIENTIFIC SEMINAR "REMEDIATION OF OIL SPILLS" ON MAY 18-21, 1992, IN HAMBURG/GERMANY. (IN TWO VOLUMES)
2006	JRC/EUCAR/CONCAWE (JEC) STUDY: EFFECTS OF GASOLINE VAPOUR PRESSURE AND ETHANOL CONTENT ON EVAPORATIVE EMISSIONS FROM MODERN CARS
2008	EURODELTA II: EVALUATION OF A SECTORAL APPROACH TO INTEGRATED ASSESSMENT MODELLING INCLUDING THE MEDITERRANEAN SEA
2010	BEP525 STUDY FINAL REPORT BY CONCAWE & SHELL RESEARCH: ETHANOL/PETROL BLENDS: VOLATILITY CHARACTERISATION IN THE RANGE 5-25 VOL% ETHANOL
2010	EURODELTA: EVALUATION OF A SECTORAL APPROACH TO INTEGRATED ASSESSMENT MODELLING - SECOND REPORT
2011	JRC/EUCAR/CONCAWE (JEC) BIOFUELS PROGRAMME: EU RENEWABLE ENERGY TARGETS IN 2020: ANALYSIS OF SCENARIOS FOR TRANSPORT
2012	A GLOBAL AND HISTORICAL PERSPECTIVE ON TRADITIONAL AND NEW TECHNOLOGY GASOLINE ENGINES AND AFTERTREATMENT SYSTEMS
2012	A GLOBAL AND HISTORICAL PERSPECTIVE ON THE EXPOSURE CHARACTERISTICS OF TRADITIONAL AND NEW TECHNOLOGY DIESEL EXHAUST
2012	A GLOBAL AND HISTORICAL PERSPECTIVE ON THE EXPOSURE CHARACTERISTICS OF TRADITIONAL AND NEW TECHNOLOGY DIESEL EXHAUST
2012	EFFECT OF IN VEHICLE STORAGE ON B10 DIESEL QUALITY
2013	INTRODUCTORY GUIDE TO CONTAMINATED SEDIMENTS
2013	GUIDANCE ON CHARACTERISING, ASSESSING AND MANAGING RISKS ASSOCIATED WITH POTENTIALLY CONTAMINATED SEDIMENTS
2013	EFFECT OF OXYGENATES IN GASOLINE ON FUEL CONSUMPTION AND EMISSIONS IN THREE EURO 4 PASSENGER CARS
2013	JRC/EUCAR/CONCAWE (JEC) WELL-TO-WHEELS STUDIES
2014	JEC BIOFUELS STUDY: 2014 UPDATE
2022	BIODIVERSITY IMPACT ASSESSMENT OF FUTURE BIOMASS PROVISION FOR BIOFUEL PRODUCTION - PHASE 1
2022	WASTE TO PRODUCTS – TECHNOLOGY AND ECONOMIC ASSESSMENT (PHASE 1)

6. CONCAWE REVIEW

<https://www.concawe.eu/publications/concawe-reviews/>

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- Fuel effects on modern diesel passenger car and commercial vehicle emissions

As both vehicle technology and emissions legislation continue to evolve, Concawe has conducted studies to examine the multidimensional effects that fuels can have on greenhouse gases (GHGs) and pollutant emissions from diesel passenger cars (PCs) and commercial vehicles (CVs). Three diesel passenger cars spanning Euro 5, 6b and 6d-TEMP were tested in the PC study over the Worldwide harmonized Light-duty Test Cycle (WLTC), and a Euro VI bus and Euro V delivery truck were tested in the CV study over the World Harmonized Vehicle Cycle (WHVC) and Transport for London Urban Inter-Peak (TfL UIP) cycle. Test fuels used in the studies were common to both the PC and CV work: an EN 590-compliant B5, hydrotreated vegetable oil (HVO) sustainable paraffinic fuel, a 50/50% v/v blend of the aforementioned fuels, a low density petroleum-derived B5, a B30 containing 30% v/v sustainable fatty acid methyl ester (FAME) and the same B30 additised with a high dose of cetane number improver (CNI).

The expected tank-to-wheels reductions in CO₂ were detected from low-density fuels versus EN 590 B5 due to their lower carbon intensity. Some benefits in pollutant emissions from low-density fuels were detected in older vehicle technologies but are reduced below any detection threshold in later technology vehicles due primarily to exhaust after-treatment (AT) effectiveness, and an engine-out benefit in NO_x in the Euro VI bus manifested as a reduction in consumption of SCR (selective catalytic reduction) reductant (AdBlue). The increased NO_x emissions from B30 reported in some previous studies were not evident in any vehicle except the Euro 5 PC with no NO_x AT. The addition of CNI to B30 did not counter the increase in NO_x observed in one vehicle, and it is postulated that this would be broadly the case in modern vehicles. N₂O emissions from the vehicles fitted with NO_x AT catalysts (lean NO_x traps and SCR) can contribute around 5–7% of the total GHGs emitted, whereas this is less than 0.5% in vehicles without NO_x AT, highlighting the challenges of optimising vehicle technology to minimise both GHG and pollutant emissions.

Overall, this work illustrates the complex and evolving interactions between fuels and vehicle technology affecting emissions.

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- Technological, operational and energy pathways for maritime transport to reduce emissions towards 2050

This article provides a summary of a 'deep dive' study into the future development of emissions from international maritime transport. The study is part of Concawe's Low Carbon Pathways project, and has been undertaken by Ricardo on behalf of the Oil and Gas Climate Initiative (OGCI) and Concawe.

The context for the study is the International Maritime Organization's level of ambition to reduce the total carbon emissions from international shipping by 50% in 2050 compared to 2008 levels, as well as reducing the carbon intensity of international shipping by at least 40% by 2030 and 70% by 2050 (again compared to a 2008 base year).

The study reviewed available literature, and interviewed multiple stakeholders, to identify the technologies and alternative fuels that are available to decarbonise international shipping.

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- How additional actions in the road transport sector could improve air quality in Europe — an extension of the Concawe urban air quality studies

This article presents results from a modelling study carried out to examine how concentrations of the major urban pollutants (i.e. nitrogen dioxide (NO₂), particulate matter (PM) and ozone (O₃))

would vary under different emission reduction scenarios, and to assess the practicability of achieving compliance with the current European Union (EU) air quality limit values (AQLVs), with road transport being the core focus of the research.

The study builds on the findings of the earlier Concawe urban air quality studies which are used here as base case. Through a scenario sensitivity analysis, the study aims to give insights into the question of what additional actions can be considered to improve compliance with AQLVs in the future — an important question from a policy point of view. A number of road transport scenarios were examined, assuming various rates (up to 100%) of substitution of diesel-powered road transport vehicles with electric-powered vehicles. Although road transport emissions were the primary focus of the study, additional scenarios were explored which examined emissions reductions from other sectors so that the contribution of road transport to improving compliance could be considered in context with other sources.

The major findings of the study indicate the following:

- All 'beyond the base case' road transport scenarios offer a further small and time-limited (between 2020–2025) improvement in NO₂ compliance. In the longer term (post 2025), the already-legislated measures as described in the base case result in almost full compliance of NO₂ with the current EU AQLVs across Europe. The impact of further NO_x measures, either on road transport or on other urban emissions sources (domestic sector) will be negligible.
- Any remaining exceedances of NO₂ would require targeted, city-specific measures based on a thorough source attribution analysis, and any EU-wide and/or national reductions measures will no longer be effective.
- Lowering the EU NO₂ AQLV to align closely with the revised World Health Organization (WHO) air quality guideline value will impose significant EU-wide non-compliance issues.
- Any additional measures to mitigate exhaust PM emissions from road transport will only offer a limited further improvement of PM_{2.5} compliance and only in the shorter term, while post 2025 the impact will be negligible.
- The most effective strategy for reducing PM_{2.5} concentrations is related to actions concerning further emission controls or fuel substitution for solid fuel burning in the domestic sector. This will be important in addressing the significant and widespread PM_{2.5} non-compliance issues that will likely occur in the EU with any future move to closely align the current EU AQLV with the WHO air quality guideline value.
- Ozone (O₃) compliance will not show any further improvement in any of the 'beyond the base case' road transport scenarios. Indeed, further reductions in NO_x emissions and the accompanying loss of NO titration could eventually lead to an increase in the number of O₃ exceedance days, making compliance even more challenging.

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- Fifty years of European oil pipeline safety and environmental performance statistics

At the beginning of the 1970s, Concawe, then a young organisation less than 10 years old, launched a new activity aimed at recording loss-of-containment incidents affecting European cross-country oil pipelines, including their consequences (environmental impact, fires, injuries and/or fatalities) and the underlying causes. This activity has now been sustained for the past 50 years with publication of the results in an annual report, from the first one published in 1972 and covering incidents recorded in 1971, to the latest edition covering incidents recorded up to 2020. Over the years, the *Performance of European cross-country oil pipelines* report has become one of the most noted Concawe publications, used by pipeline operators, pipeline designers, regulators and industry actors in general to shed light on the risks and potential consequences associated with oil pipeline operations, and to support the learning of lessons from past incidents.

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- Abbreviations and terms
- CONCAWE reports and other publications

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