report no. 5/09

Additional human exposure information for gasoline substance risk assessment (period 2002-2007)

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Prepared by the CONCAWE Health Management Group's Special Task Force on Gasoline Exposure Data (H/STF-31):

R. Bomer
M. Carter
B. Dmytrasz
M. Mulari
G. Pizzella
S. Roth
P. van de Sandt

J. Urbanus (Technical Coordinator)
G. Minsavage (Technical Coordinator)

Brussels
June 2009

ABSTRACT

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assessments had suggested that exposure was either elevated or highly variable or available data were considered out-of-date.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.

KEYWORDS

Gasoline, risk assessment, human exposure, occupational exposure

INTERNET

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CONTENTS

SUMMARY

CONCAWE previously published overviews containing human exposure data for gasoline vapour in European oil industry operations with the principal aim of informing substance risk assessments. In the context of an unpublished draft risk assessment of gasoline several data gaps were identified for particular activities where exposure data were either incomplete, out-of-date or had shown large variations suggesting that in certain locations, and/or on certain days, exposures were elevated. These activities included railcar loading without vapour recovery, test fuel blending, certain refinery maintenance activities, the use of gasoline-powered horticultural machinery, and general public indoor exposures.

In addition, exposure data were obtained for some operations for which data were previously lacking, in particular for gasoline pump repair and calibration. Also, more robust data have been obtained to characterise the impact of Stage II vapour recovery on occupational and ambient benzene levels.

This report provides details of monitored exposures to gasoline vapour in the priority activities, as well as an analysis of recent literature on ambient levels of the principal constituent of concern, benzene.

The following conclusions were drawn from the results obtained:

- Railcar loading without vapour recovery was phased out in the countries formerly constituting the EU-15, to be followed at various times by the new member states making up the EU-27;
- Among laboratory workers only those employed in research and development facilities and engaged in test fuel blending may have occasional elevated exposure to gasoline vapour;
- Exposure control during maintenance on refinery equipment dedicated to gasoline production is effective;
- Exposures during operation of gasoline-powered horticultural machinery are low;
- Exposures during gasoline pump repair and maintenance and during pump calibration are of a moderate level; proper use of risk management measures inside repair workshops is important to control exposures;
- Indoor exposures of the general public can be influenced by nearby service stations, but also by other factors such as traffic;
- Ambient levels of volatile organic compounds of concern, in particular benzene, have been falling over recent years.

1. INTRODUCTION

1.1. PURPOSE AND SCOPE

CONCAWE previously published reports containing exposure data for gasoline vapour in European oil industry operations [8,10] with the principal aim of informing substance risk assessments carried out according to the Technical Guidance Document [13] for the implementation of EU Existing Substances Regulation [14]. The data in these reports have been used for several EU risk assessment reports including those of toluene [17] and the draft report for benzene [19], as well as for an unpublished draft risk assessment of gasoline. In the context of the latter exercise several data gaps were identified for particular activities where exposure data were either incomplete, out-of-date or had shown large variations suggesting that in certain locations, and/or on certain days, exposures were elevated.

Further, information was recently acquired for some additional scenarios which had not been identified previously as priorities, but for which the publication of more complete and up-to-date exposure information is nevertheless warranted as part of product stewardship commitment. These scenarios included gasoline pump repair and calibration, aircraft refuelling (with aviation gasoline), service station attendants and general public exposures in the urban environment.

Finally, a number of publications have appeared since the publication of the previous reports which provided more recent information on exposure levels of gasoline and some of its constituents in countries of the EU, in particular benzene in ambient air, which can usefully be summarised and interpreted to inform the gasoline risk assessment.

1.2. RISK ASSESSMENT SCENARIOS PRIORITISED FOR FURTHER INVESTIGATION

For one scenario subjected to risk assessment, i.e. railcar loading without vapour recovery, the exposure data available at the time of the assessment formed the basis for a conclusion of potential concern about health risk, principally on the basis of the survey data from a single facility. It should be noted that the data reported previously [10] for this facility did not meet quality assurance criteria in full. For other facilities classified also as ‘railcar loading without vapour recovery’ lower exposures had been measured, possibly in part due to operational differences such as a greater distance of operators from loading hatches or a higher degree of process automation. Legal requirements for vapour recovery in gasoline distribution were introduced in a 1994 EU directive [15], with full implementation scheduled to be completed by 2003 and consequently railcar loading without vapour recovery was expected to be discontinued (at least in the countries of the former EU-15 and by later dates for countries that joined the EU subsequently).

For a second scenario identified previously [10], i.e. test fuel blending in research facilities, a potential concern was also based principally on data from a single facility. In addition to discrepancies in exposure data with other comparable facilities there was also a need to obtain further information regarding the frequency of the operation being conducted. As a substance risk assessment not only considers the level of exposure, but also frequency and duration, additional information on the latter two aspects was considered necessary.

When drafting the gasoline risk assessment, for a further set of scenarios, the available data were considered too limited to allow drawing conclusions about the level of health risk:

- refinery maintenance work;
- use of gasoline-powered equipment (e.g. for gardening and horticulture);
- indoor exposures due to gasoline-related emissions.

2. METHODS AND MATERIALS

2.1. TARGETED EXPOSURE MONITORING CAMPAIGNS BY MEMBER COMPANIES

Arrangements were made to generate new exposure data for the identified priority situations following the approach where on-site sampling was to be conducted by CONCAWE member company personnel, while sample analysis was centralised in a single high-quality contract laboratory in order to improve consistency of the results. The selected laboratory was in good standing regarding quality assurance of occupational hygiene sample analysis. The adopted sampling and analytical methodology was essentially identical to the CONCAWE recommended method [9].

This arrangement was followed for the studies of railcar loading, refinery maintenance and laboratory operations.

2.2. OTHER MONITORING STUDIES

Two institutions in Belgium and Finland dedicated to occupational hygiene research were commissioned by CONCAWE to study exposures during use of gardening equipment and in gasoline pump maintenance and calibration work respectively. Whereas the first scenario was already considered a data gap, the second opportunity arose as a result of a data gap identified in the European regulatory risk assessment of methyl-tertiary butyl ether (MTBE) [16]. Both studies used appropriate analytical methodologies although the methodology adopted in the Finnish study focussed on a limited set of gasoline constituents and oxygenate additives. This approach did not allow direct reporting of total gasoline vapour but rather required an extrapolation from constituent data. The second study used a method very similar to the CONCAWE recommended methodology [9].

2.3. LITERATURE REPORTS

A number of research groups in the EU actively study levels and trends of gasoline-related exposures of workers, customers and the general public. When published in the peer-reviewed scientific literature these studies may provide useful additional and up-to-date information on exposures for consideration in the gasoline substance risk assessment. Although no comprehensive and systematic literature survey was conducted several recently published papers were identified and are summarised in this report.

3. RESULTS

3.1. PRIORITY SCENARIOS

3.1.1. Railcar loading without vapour recovery

European Parliament and Council Directive 94/63/EC of 20 December 1994 [on the control of volatile organic compound (VOC) emissions resulting from the storage of petrol and its distribution from terminals to service stations] [15] required EU countries to introduce legislation which mandated installation of vapour recovery facilities in gasoline distribution operations, including railcar loading, at the latest by end of 2003. Information reported by CONCAWE member companies for the countries of the former EU-15 suggested that all railcar loading facilities have been equipped with vapour recovery facilities. Directive 94/63/EC also applies in the new member states of the EU-27, but with varying implementation deadlines.

Contextual information relevant to exposure estimation is presented in template format in **Appendix 1.1**.

Monitoring was conducted in two railcar loading facilities including the facility for which elevated exposures were reported previously [10] and where vapour recovery is now in place. Detailed results are provided in **Table A2.5** and summarised in **Table 1**. Due to the lack of a back-up sorbent for the very light gasoline constituents during air sampling for some of the samples no total gasoline vapour is reported. However, the overall picture emerging from the data indicates that exposures were low, consistent with efficient vapour recovery facilities.

3.1.2. Laboratory workers

Surveys were conducted in refinery laboratories in France and Norway and in Research & Development (R&D) facilities in Germany and the UK (**Tables A2.2** and **A2.3** plus summary data in **Table 1**). The results confirmed the earlier indication [10] that exposures in production labs are generally low, whereas in R&D facilities occasionally more elevated exposures occur during gasoline handling which may however be infrequent. It is therefore clearly necessary to distinguish the two categories of laboratory workers for risk assessment purposes.

Contextual information relevant to exposure estimation for production laboratory workers is presented in template format in **Appendices 1.2 & 1.3**.

3.1.3. Refinery maintenance workers

Worker exposures were monitored during maintenance activity on refinery equipment dedicated to gasoline (components) in Finland, Norway and the Netherlands (**Table A2.1** plus summary data in **Table 1**). The arrangements with the workers to conduct the monitoring confirmed that invasive maintenance on gasoline equipment is infrequent, typically one day per month. The activities included disconnection of pumps and opening these in workshops. Standard risk management measures included remotely controlled drainage of pumps and connecting piping prior to disconnection and opening. Contextual information relevant to exposure estimation is presented in template format in **Appendix 1.4**.

3.1.4. Use of gasoline-powered equipment (professional gardening)

The study conducted by VITO (Flemish technology institute) concerned garden and lawn maintenance workers on four locations in three Belgian municipalities [21]. The operated equipment included bush and hedge cutters, line trimmers and two- and four-stroke lawn mowers. Due to the nature of the equipment operation these workers were exposed to both gasoline vapour and engine combustion products. A total of fifteen operations were monitored (including five with duplicate samples for quality assurance purposes) with durations between 0.5 and 5 hours. Some of the operations were conducted using an aliphatic gasoline grade fuel marketed specifically for use in gardening equipment. All reported exposures were very low (gasoline vapour between 0.1 and 5.5 mg/m^3) (**Table A2.8** plus summary data in **Table 1**).

3.1.5. Indoor exposures to gasoline-related emissions

3.1.5.1. Residential exposures resulting from nearby service station operations

The exposure of the general population to gasoline vapour emissions from nearby service station operations has evolved in recent years as a result of a number of developments. These include a significant reduction in number of operating service stations (e.g. in France from approximately 28,000 in 1990 to about 14,000 in 2004), resulting in fewer people exposed in adjacent residences, an increase in throughput per service station, introduction of vapour recovery on all bulk gasoline deliveries to the stations and vapour recovery on gasoline dispensers in some countries. The qualitative nature of exposure has also changed as a result of fuel compositional changes imposed under EU directives. The most widely studied aspect of service station emissions concerns benzene levels in air at the station boundary. The largest study [32] in recent years, commissioned by a group of service station operators, was conducted in France following the publication in 2004 of a study linking childhood leukaemia to living in a home adjacent to a service station during the period of 1990-1998 [31]. The study protocol was based on earlier studies by CONCAWE and others [2,6] in which levels are measured directly at the perimeter of the station where they are considered as representative of the reasonable worst case exposure of nearby residents. Measurements were also taken at a nearby point assumed not to be influenced by the station (e.g. ‘upwind’) to represent the local background and starting point for the estimation of the station’s contribution. The measurement period was two weeks to allow for meteorological variation. Sampling was done in spring and autumn 2005, a time assumed to be indicative of annual average levels. Comprehensive additional data was recorded for each station, for example, including nearby traffic flow data, to help interpret the results. As the principal focus in this and most other studies was on benzene and not on the complete set of components in gasoline vapour, the gasoline vapour levels have to be estimated on the basis of the detected level of benzene. Previous studies [8,10] have indicated that a generic content of benzene in gasoline of 1% corresponds to a vapour content of typically 0.5%. For the purposes of this report the gasoline level is thus estimated as two hundred times the detected benzene level.

Forty-three stations were included in this study, with operators invited to nominate stations in three categories: along motorways (15); in towns and suburban areas (19); under apartment blocks (9). This sampling was constructed to be indicative of typical potential population exposure, but cannot strictly be seen as a random sample out of the entire 14,000 stations. Therefore, care should be taken when applying the results on an individual level in environmental health studies. At the time of this study, regulatory requirements in France for Stage II vapour recovery were linked to petrol throughput (> 3000 m^3/y). Both Stage I and Stage II stations were included in the study.[1]

Results of perimeter measurements were compared with data compiled by CONCAWE [7] for the previous decade. Furthermore, data were compared with the French air quality standard, which was set at 10 µg/m^3 (annual average) in 2005 and which is reduced by 1 µg/m^3 each year to reach 5 µg/m^3 in 2010. This is identical to the EU guidelines. In addition, France adopted a long-term policy objective of 2 µg/m^3.

The overall contribution of service stations to local ambient benzene levels was considerably lower in 2005 than in the 1990's. The average perimeter levels were 1.2 µg/m^3 for motorway sites, 2.8 µg/m^3 for urban sites and 8.2 µg/m^3 for stations under apartment blocks. The increases over the local background were on average 0.3, 0.5 and 2.1 µg/m^3, respectively. The station contributions were found to be comparable to the exit of a road tunnel or a traffic light at a busy junction.

The study also examined the difference in perimeter concentrations between Stage I and Stage II equipped stations, and in fact found none: the additional vapour recovery through Stage II appeared to be offset by the higher sales volume.

The authors concluded that for service stations on motorways and in suburban and urban areas, the increase of the benzene level in air at the boundary of the station compared to the background is less than 1 µg/m^3, considerably lower than a decade ago. Slightly higher numbers were found for stations at the foot of residential buildings, but these were nevertheless lower by a factor of 3 than in the mid-1990's.

Studies in Germany reported limited data which suggested that benzene (and gasoline vapour) levels are higher in homes above stations than in homes adjacent to stations (increase over benzene background of 1.0 vs. 0.5 µg/m^3) [24]. In another study in Paris, reported in 2006 by a consumers' organisation, benzene levels were measured simultaneously outside and inside seven homes nearby service stations; in all cases the outside levels (between 1.9 and 7.1 µg/m^3) were higher than the corresponding indoor levels (between 1.1 and 3.6 µg/m^3), although outside and inside levels were correlated [33].

Karakitsios and co-workers studied the contribution of five petrol stations to ambient benzene levels in their vicinity in a mountainous region characterised by low wind speeds and stable atmospheric conditions in Greece in 2005 [25]. The stations were characterised as urban (one), suburban (three) and rural (one). The contribution of the urban petrol station to the benzene level in ambient air over background was estimated at 6-9 µg/m^3.

Alexopoulos et al. [1] studied personal exposures to toluene and xylene in residents of Athens, Greece. Although their study was published in 2006, the field work had been conducted in 1997-1998. It was observed that residences within 50 metres of

[1] **Stage I Vapour Recovery**: system used to reduce hydrocarbon emissions during the refuelling of gasoline storage tanks. Vapours in the tank, which are displaced by the incoming gasoline, are routed through a hose back into the cargo tanker, instead of being vented to the atmosphere.
Stage II Vapour Recovery: system used to reduce hydrocarbon emissions during the refuelling of vehicles at service stations. Special nozzles and hoses at the pump capture the displaced gasoline vapours from the vehicle's fuel tank and route them back to the service station's storage tank.

a gasoline station had exposure levels about 1.5 times higher compared with residences over 50 metres away.

Finally, it is worth noting that average wind speed in an area plays an important role, with higher wind speeds resulting in more dilution and therefore a lower increase over background benzene levels downwind of service stations as demonstrated in a French study [22]. This same effect should also be assumed for gasoline vapour.

It is therefore concluded that, on the basis of the available data for benzene covering the time period up until 2007, it appears plausible that average gasoline vapour concentration in air inside residences near service stations was generally less than 1 mg/m^3 (two hundred times 5 μg/m^3). In areas of particularly unfavourable topographic and/or atmospheric conditions (temperature inversions and very low wind speeds) this may be increased, again using available measurements of benzene in air, up to 2 mg/m^3 of gasoline vapour [25].

3.1.5.2. Other exposure reports for the general public

At the time of the literature search, there appeared to be no easily retrievable studies of general public exposure to gasoline as a substance per se, but there were many studies that addressed gasoline-related exposures, in particular of benzene. Several of these studies are discussed below. Some of these studies were initiated as a consequence of the adoption of the European air quality limit value for benzene. Benzene is however not unique to gasoline as it may also originate from sources such as wood burning and cigarette smoking. Benzene is also formed in motor vehicle exhaust and as such considered outside of the scope of the gasoline substance risk assessment. Other studies have used MTBE as a marker for gasoline vapour. Although MTBE is nearly exclusively used as a gasoline additive it is not added to all marketed gasolines and therefore also not a perfect marker.

The PEOPLE project coordinated by the European Commission's Joint Research Centre can be considered as a follow-up of the MACBETH project conducted in the late 1990's, focussing on urban population exposures to benzene in six cities [20]. In addition to traffic, cigarette smoking was identified as an important source [27]. Commuting was identified as a scenario with relatively elevated exposure; some 1.5 times the median spatial urban background level. Indoor levels in homes without smokers were considered broadly equal to outside levels.

Chatzis et al. [5] recently studied indoor and outdoor personal exposure to benzene for city inhabitants of Athens, Greece, and found that indoor levels were generally lower than corresponding outdoor levels. These results are contrary to earlier findings in the MACBETH project for Western Europe where the opposite was observed.

Dollard et al. [12] reported trends in ambient concentrations of C_2-C_8 hydrocarbons at several measurement sites in the United Kingdom over the period from 1993 to 2004. Average annual means of benzene and 1,3-butadiene decreased by 20% per year as a result of a series of emission controls on gasoline-related operations and engine emission controls.

Hellén et al. [23] reported air concentrations, source profiles and source apportionment for a range of volatile organic compounds in southern Finland in 2004-2005. Their approach aimed at distinguishing, amongst others, traffic exhaust, liquid gasoline and gasoline vapour for the following classes of compounds: alkanes, alkenes, alkynes, halogenated hydrocarbons, aromatics, biogenic hydrocarbons, carbonyls, and gasoline additives. Gasoline liquid and vapour made quantifiable though minor contributions to alkanes, alkenes and aromatics, as well as the main contribution to gasoline additive compounds in air. Regarding the latter class, it should be noted that compounds such as MTBE are outside the scope of the gasoline risk assessment, as these are regulated substances by themselves. The average total concentration of volatile organic compounds at an urban site in Helsinki in winter was 50 μg/m^3.

Spruyt et al. [30] reported indoor environment air concentrations of contaminants that can be found in indoor and outdoor. Data covered the period of the first quarter of 2006 in Flanders, Belgium. The project included MTBE as a tracer for gasoline-related emissions. Although the full data analysis was not reported at the time of writing this report, initial findings indicated that home indoor levels of most measured pollutants were higher than outdoor levels measured at the front and back doors.

3.2. OTHER SCENARIOS WITH NEW EXPOSURE DATA

For a number of scenarios new information became available through projects and through literature reports which can be usefully included in the gasoline risk assessment.

3.2.1. Gasoline pump maintenance

Very limited exposure data were available previously for gasoline pump maintenance [8]. The opportunity arose for CONCAWE to participate in a study programme for this activity (as well as for pump calibration, see 3.2.2) conducted by the Finnish Institute of Occupational Hygiene (FIOH). The focus of the FIOH investigation was on oxygenates (MTBE and TAME) blended into gasoline, whereas the focus for CONCAWE was put on n-hexane and mono-aromatic constituents of gasoline. Two scenarios were distinguished, i.e. outdoor repairs at the service station and indoor repairs in a workshop. Full details are contained in the FIOH report [26]. It is noteworthy that testing of repaired pumps in the workshops was done with an aliphatic hydrocarbon mixture, thus avoiding benzene exposure. Although photographic evidence was provided for the presence of local exhaust ventilation (LEV) in the workshop it is not clear whether this provided effective exposure control. Detailed results are provided in **Table A2.6** plus summary data in **Table 1**.

No direct results for total gasoline vapour exposures were reported. On the basis of estimated content of 0.5% benzene and 2% toluene in gasoline vapour, the average gasoline vapour exposure during outdoor repair work is estimated at 50-120 mg/m^3 and for work inside a workshop at 360-900 mg/m^3. These results were reported for measurements with durations between 1.5 and 4 hours and were converted on a time-weighted basis to derive full shift estimates in **Table 1**.

3.2.2. Gasoline pump calibration

The activity of gasoline pump calibration (e.g. for fiscal purposes) is separate from pump repair and maintenance and had not previously been included in the inventory of job activities with potential exposure. Five measurements were obtained in the FIOH investigation, each covering two grades of commercial gasoline as well as diesel fuel. Full details are contained in the survey report [26]. On the same basis as for pump repair work (see 3.2.1) the average task-related exposure for gasoline vapour was estimated to be between 80 and 120 mg/m^3. Detailed results are provided in **Table A2.7**. The equivalent full-shift exposure estimates are included in **Table 1**.

3.2.3. Service station attendants

Occupational exposure of service station attendants dispensing gasoline into customer cars has been studied extensively in recent years, in particular, in Southern Europe where customer car refuelling services are still widely provided. Periago and Prado [28] reported exposure data for benzene, toluene and xylene for the hot summer month of July 2003 in Spain which were very similar to the data presented in CONCAWE report 9/02 (job group 3.1.1).

The principal technological development impacting on attendants' exposure in some countries is the introduction of vapour recovery facilities on the pump nozzle (Stage II). In the previous report [10] an initial estimate suggested a halving of attendant exposure to gasoline vapour was due to Stage II vapour recovery. Further data have been obtained to estimate this effect: Bono et al. [3] reported a four-fold reduction in benzene exposure in a study on Italian pump attendants, the same reduction as reported by Saarinen [29] for customer self-service refuelling in Finland. A French study [22] found that on the basis of static measurements near the pump that the efficiency of Stage II equipment is affected by ambient wind speed, with better reductions, up to 56%, at low wind speed (2 m/s).

3.2.4. Aircraft refuelling with aviation gasoline

During field surveys of exposure to jet fuel on airports for CONCAWE's risk assessment of kerosines, on a number of occasions mixed exposure to aviation gasoline and to jet fuel was encountered for aircraft refuelling workers. In view of the much higher volatility of gasoline it was assumed that these exposure data were not representative for jet fuel operations and hence excluded from the kerosine exposure data report [11]. The data are presented in **Table A2.9** plus summary data in **Table 1**. Because the monitoring had been intended to quantify kerosine vapour, the analytical system was calibrated to produce a measure of total hydrocarbons expressed as milligram n-nonane per cubic metre, as n-nonane is one of the principal components of kerosine vapour. Gasoline vapour composition is dominated by lighter components, typically C_5, which respond more weakly in the detection system. Consequently, the total hydrocarbon concentrations in air in **Table A2.9** might be slight underestimates of exposures (but in any case by no more than a factor two).

The data presented from the UK were obtained from refuelling operations with a tanker. This information was not available for the data obtained from French operations.

Table 1 Summary descriptive statistics of occupational exposures to gasoline vapour; measurements commissioned by CONCAWE in 2004-2007 (mg/m^3)

Job group	**Number of samples**	**Median**	**10-percentile**	**90-percentile**
Refinery maintenance (JG 1.3) – full shift	5	1.9	0.3	7.6
Refinery maintenance (JG 1.3) – short-term	8	12.2	2.3	29.4
Refinery laboratory technician (JG 1.4a) – full shift	5	3.2	1.4	20.6
R&D laboratory technician (JG 1.4b) – full shift	9	5.9	3.1	90.8
R&D laboratory technician (JG 1.4b) – short-term	5	35.1	9.3	191
Railcar loading operators	5	4.3	3.4	4.8
Aircraft refuelling (avgas)	8	21	4	62
Gasoline pump repair (JG 3.4) – outdoors	3	12-30	--	--
Gasoline pump repair (JG 3.4) – indoors	2	90-240	--	--
Gasoline pump calibration	5	50-75	--	--
Use of gasoline-powered equipment (JG 5.1)	15	3	0.2	5.5

Note: For full shift samples, exposures measured for periods well below 8 hours were recalculated to the 8-h equivalent value on the basis that no exposure occurred during the part of the work shift which was not monitored

4. DISCUSSION

4.1. DATA AVAILABILITY

The exposure monitoring surveys and literature analysis presented in this report have provided additional and recent data for the risk assessment of the substance gasoline which now enables previously identified data gaps and exposures of potential concern to be adequately addressed. Although the data sets commissioned by CONCAWE are generally small compared, for example, with those summarised in Report 2/00 [8], the extent of available contextual information for the samples, and the logical differences across exposure situations provides the ability to judge both typical and worst-case (i.e. 90^{th} percentile) situations. In addition, certain common features of different exposure situations may allow some broad groupings across industry segments in exposure ranges which can then form the basis of exposure estimation for further identified unquantified situations.

4.2. NEW INFORMATION FOR PRIORITISED EXPOSURE SITUATIONS

4.2.1. Railcar loading

Within the former EU-15 oil industry operations the principal scenario of concern identified in previous studies [10], i.e. railcar loading without vapour recovery, now appears to only be of historic interest due to full implementation of mandatory vapour recovery in bulk gasoline distribution operations. This will at various points in time also apply in the new member states of the EU-27.

4.2.2. Laboratory workers

The newly generated exposure data essentially confirmed the indications of the previous reports [8,10], that exposure levels are generally low in refinery laboratories dedicated to production quality control, whereas in Research and Development facilities more elevated exposures occasionally occur during blending of test fuels.

4.2.3. Refinery maintenance workers

Data summarised previously ([8], Job Group 1.3) suggested a large spread of exposures. The monitoring data generated in this study provided two important indications. First, current exposures during invasive maintenance on equipment dedicated to gasoline and its blending components are well controlled due to remotely controlled draining and flushing procedures prior to equipment opening. Second, these tasks are not frequent, i.e. not more than one work shift per week.

4.2.4. Operation of gasoline-powered gardening equipment

Data generated during this study showed lower exposure levels than the very limited data sets previously summarised for Job Group 5.1 [8].

4.2.5. Indoor exposure to gasoline-related emissions

Adequate data are available from recently published literature to estimate indoor exposures of the general public to gasoline-related emissions. The reasonable worst case appears to be represented by residency near a service station in a particularly unfavourable topographic mountainous region characterised by low wind speeds and stable atmospheric conditions where the estimated exposure level of gasoline vapour can be up to 2 mg/m^3.

Stage II vapour recovery equipment on gasoline pumps may not completely eliminate emissions. In addition there is a general trend towards larger (and fewer) service stations with increased sales volumes and associated emissions per station.

4.3. EXPOSURE INFORMATION FOR SITUATIONS PREVIOUSLY WITHOUT ADEQUATE DATA

Of the additional information obtained on gasoline exposure levels, the most elevated levels appeared to be associated with service station pump repairs inside a workshop. Due to the required interventions on the equipment it is also possible that a certain level of potential dermal exposure occurs in this situation. In the monitored operation two types of collective risk management measures were available, i.e. provision of flexible local exhaust ventilation equipment and the use of a non-aromatic gasoline or naphtha to test repaired pumps.

4.4. COMPARISON WITH LIMIT VALUES

Occupational exposure limits in the range of 200-240 mg/m^3 existed at the time of monitoring, as 8-hour time-weighted average, for gasoline vapour in some EU countries namely Germany, Sweden and The Netherlands. Other countries, such as Italy, Portugal and Spain, used the ACGIH TLV of 890 mg/m^3. In this study no exceedences of either of the OELs were encountered.

At the time of monitoring, of the gasoline constituents, benzene had the lowest OEL: 3.25 mg/m^3. No exposure above the benzene OEL was detected in this study. In addition, according to the provisions of the Carcinogens Directive [18], exposures should be minimised where possible.

There is no limit value for gasoline vapour in ambient air. However the European air quality limit value for benzene (AQLV, 5 µg/m^3 annual average) can be used as an useful benchmark for general population exposures. Indications from the service station studies described in this report suggested that in the vast majority of cases the contribution of the service station emissions over the background was lower than the AQLV and did not give rise to resultant populations exposures (when combined with other background benzene exposures) above the AQLV. In certain well-defined circumstances however the contribution can be higher such that they are likely to result in general population exposures (during certain periods) above the AQLV; this includes some stations below residential buildings and stations in mountainous areas with low wind speeds and stable atmospheric conditions.

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APPENDIX 1: CONTEXTUAL INFORMATION RELEVANT TO GASOLINE EXPOSURE ESTIMATION FOR PRIORITY GASOLINE-RELATED ACTIVITIES

Appendix 1.1 Railcar Operators

Job Type:	Railcar Operator	Railcar Operator - not carried out at all refineries, but also carried out at some terminals in Germany for one company
Operational area:	Railcar loading	
Overview of tasks:	Loading of railcars, including handling of loading arms or hoses and sample collection	

Typical number of staff per shift per site?	1 - 2		
Usual shift hours?	8 - 12 hours		
Maximum number of shifts worked per year per operator	225 (8 hour shift) - 144 (12 hour shift)	Is job rotation operated?	Not normally (yes in one case)

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
1. Top loading railcars. Fill railcars via top submerged loading, including opening and closing of hatches	Maximum 2 trains per shift (20 -24 railcars) Typically less	8 - 12 hours	Automated - in some cases automatic connection/disconn	X	Stand up wind	X	Gauntlets/ gloves	nitrile, PVC
			Vapour recovery system	X	Other - specify		Other - specify	Vapour filter mask - German legal requirement
			General ventilation	X				
			Other - specify					

Potential for skin contact : Potential for skin contact during contact with contaminated lance.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental			
Intermittent	X		
Extensive			

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
2. Bottom loading railcars. Fill railcars via bottom loading. Handling of loading hoses. NO RAILCAR BOTTOM LOADING CARRIED OUT	No railcar bottom loading carried out		Closed system - breakaway couplings		Stand up wind		Gauntlets/ gloves	
			Vapour recovery system		Other - specify		Other - specify	
			General ventilation					
			Other - specify					

Potential for skin contact :

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low			
Incidental			
Intermittent			
Extensive			

Additional comments : No bottom loading of railcars takes place in Europe

Appendix 1.2 Laboratory Operators

Job Type:	Laboratory Technician		
Operational area:	Production laboratory		
Overview of tasks:	A variety of quality control tasks, e.g. density, flash point, sulphur, particulate, viscosity, distillation		
Typical number of staff per shift per site?	1 - 25, majority 4 - 8		
Usual shift hours?	8 (by 12 by exception)		
Maximum number of shifts worked per year per operator	188 / 225	Is job rotation operated?	Not normally

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
1. Laboratory tests. Carried out in dedicated laboratory area.	3 - 40 per shift	1 - 2 min. per sample	Automated (test conducted in closed system)	X	Standard laboratory practice	X	Gauntlets/ gloves	Disposable nitrile gloves
	Typical 3 - 6		Local exhaust ventilation - fume cupboard or LEV above lab equipment	X	Other - specify		Other - specify	
			General ventilation - on bench	X				
			Other - specify					

Potential for skin contact: Only small quantities of product handled. Minimal potential for skin contact.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low	X	One hand front	210
Incidental			
Intermittent			
Extensive			

Additional comments: Level of controls vary depending on the nature of the test.

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
2. Sample bottle washing. Emptying of product from sample bottles into waste collection system. Loading of drained bottles into washing machine.	1 - 40 per shift typical 6 per shift	5 - 20 min. (10 min)	Closed system, e.g. bottle washing machine	X	Standard laboratory practice	X	Gauntlets/ gloves	Disposable nitrile gloves
			General ventilation	X	Other - specify		Other - specify	
			Other - specify					

Potential for skin contact: Some potential for spashing during drainage of bottles, breakage and surface contamination depending on care in handling.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental	X		
Intermittent			
Extensive			

Additional comments: Normally carried out in dedicated work area. In some cases: single-use bottles are applied

Appendix 1.3 Laboratory Blending Operators

Job Type:	R&D Lab Blending Operator
Operational area:	Research & Development Laboratory
Overview of tasks:	Receipt of gasoline; Transfer, storage and blending of gasolines; A variety of quality control tasks; Drumming off with batch pump

Typical number of staff per shift per site?	4		
Usual shift hours?	8		
Maximum number of shifts worked per year per operator	225	Is job rotation operated?	Not normally

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	Additional PPE used?	Specify type
1. Bottom unloading of road tankers, with pump to storage tank: connection/ disconnection of hose, draining of residu in lines	2 per week (average)	up to 2 hours	Closed sytem - breakaway couplings	X	Stand up wind	X	Gauntlets/ gloves	PVC
			Vapour recovery system		Other - specify		Other - specify	
			General ventilation	X				
			Other - specify: Remote venting of storage tanks to atmosphere through PV valves on top of tanks	X				

Potential for skin contact: Minimal potential for spillage and contact with contaminated equipment during hose handling. Some potential for spillage during hose disconnection and draining of residu from lines in pail or bucket.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental	x		
Intermittent			
Extensive			

Additional comments: Activity carried out together with road tanker driver

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	Additional PPE used?	Specify type
2. Transfer from bulk storage vessels or drums into blending vessels. Use of batch pump rig with flexible hoses. Blended volume ranges from 50 to 30.000 litres	Daily	Variable: from 30 minutes to 8 hours	Closed system		Stand up wind		Gauntlets/ gloves	PVC
			General ventilation	X	Other - specify		Other - specify	
			Local Exhaust Ventilation	X				

Potential for skin contact: Minimal potential for spillage and contact with contaminated equipment during hose handling. Some potential for spillage during hose disconnection and draining of residu from lines in pail or bucket.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental	x		
Intermittent			
Extensive			

Additional comments: Activity carried out outside, under a roof.

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	Additional PPE used?	Specify type
3. Drumming off test fuels. Use of batch pump rig & hose with nozzle	Daily	10 minutes to 1 hour	Automated		PTW		RPE - specify type	
			Closed system		Stand up wind		Full face mask	
			Local exhaust ventilation	X	Drain and flush		Half mask	
			General ventilation	X	Purge		Filtering	
			Other - specify		Other - specify		Air supplied	
							Gauntlets - specify type	
							PVC	X
							Nitrile	
							Other	
							Face shield?	
							Impervious coverall?	

Potential for skin contact: Some potential for spillage during drum filling via nozzle.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		One hand front	210
Incidental	X		
Intermittent			
Extensive			

Additional comments: Activity carried out outside, under a roof.

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	Additional PPE used?	Specify type
4. Bottom loading of road tanker: connection/ disconnection of hose, draining of residu in lines	2 per week (average)	up to 2 hours	Automated		PTW		RPE - specify type	
			Closed system		Stand up wind	X	Full face mask	
			Local exhaust ventilation		Drain and flush		Half mask	
			General ventilation	X	Purge		Filtering	
			Other - specify: Remote venting from road tanker top	X	Other - specify		Air supplied	
							Gauntlets - specify type	
							PVC	X
							Nitrile	
							Other	
							Face shield?	
							Impervious coverall?	

Potential for skin contact: Minimal potential for spillage and contact with contaminated equipment during hose handling. Some potential for spillage during hose disconnection and draining of residu from lines in pail or bucket.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental	X		
Intermittent			
Extensive			

Additional comments: Activity carried out together with road tanker driver

Appendix 1.4 Maintenance Operators

Job Type:	Mechanical maintenance		
Operational area:	Production		
Overview of tasks:	Maintenance and cleaning activities on process equipment and vessels		
Typical number of staff per shift per site?	2 - 8 (one site max. 25)		
Usual shift hours?	8 hours		
Maximum number of shifts worked per year per operator	Approx. 225. Not known for specialist contractors	Is job rotation operated?	Not normally

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
1. Maintenance on pre-drained and flushed equipment.	3 - 12 per month	1 - 4 hours	Automated		Pre-drained and flushed equipment	X	Gauntlets/gloves	PVC
	Max 1 per shift		Closed system, e.g. Dopak type		Other - specify		Other - specify	
			Local exhaust ventilation					
			General ventilation	X				
			Other - specify					

Potential for skin contact: Although equipment has been pre-drained and flushed, there is still potential for residual product to be present and therefore there is some potential for skin contact with surface contamination.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front	420
Incidental	X		
Intermittent			
Extensive			

Additional comments: Includes emptying and steaming of lines.

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
2. Tank Cleaning. Removal of sludge from drained bulk storage tank.	1 - 5 per year Typical 2 per year	8-12 hours	Forced ventilation	X	PTW	X	Gauntlets/Gloves	PVC
			General ventilation	X	Specialist contractor	X	Other - specify	PVC coverall
			Other - specify		Drain and flush	X		Impervious knee length boots
					Other - specify			Breathing Apparatus as required - see comments
								Other

Potential for skin contact: High potential for skin contact if insufficient personal protection worn.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low			
Incidental			
Intermittent			
Extensive			
Not applicable - PTW	X		

Additional comments: Risk assessment carried out prior to tank entry to determine exact controls. Standard confined space entry requirements to check oxygen and vapour levels applied prior to entry. Clean the tank from the entrance, as far as possible, prior to entry. Enter tank to remove residue using air-supplied Breathing Apparatus until measurements indicate it is satisfactory to downgrade the respiratory protection requirement.

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
3. Interceptor cleaning Removal of sludge from drained interceptor	0 - 2 per year	8 - 12 hours	Forced ventilation	X	PTW	X	Gauntlets/Gloves	PVC
			General ventilation	X	Specialist contractor?	X	Other - specify	PVC coverall
			Other - specify					Impervious knee length boots

Potential for skin contact: High potential for skin contact if insufficient personal protection worn.

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low			
Incidental			
Intermittent			
Extensive			
Not applicable - PTW	X		

Additional comments: Interceptors not dedicated to gasoline. Standard confined space entry requirements to check oxygen and vapour levels applied. If necessary appropriate respiratory protection would be worn.

For any other standard tasks involving potential exposure to gasoline performed please list details below:

Task	Frequency	Duration	Engineering Controls?	Select as approp.	Procedural controls?	Select as approp.	PPE used?	Specify type
4. draining equipment (pumps and valves) Most sites carried out by production operator	2 per month	30 mins	Automated		PTW	X	**RPE - specify type**	
			Closed system		Stand up wind	X	Full face mask	
			Local exhaust ventilation		Drain and flush		Half mask	
			General ventilation	X	Purge		Filtering	
			Other - specify		Other - specify		Air supplied	
							Gauntlets - specify type	
							PVC	X
							Nitrile	
							Other	
							Face shield?	
							Impervious coverall?	

Potential for skin contact

Dermal contact level		Skin surface area	Total surface area (cm2)
Very low		Two hands front and back	840
Incidental	X		
Intermittent			
Extensive			

Additional comments: product residues are caught in bin and removed by vacuumtruck (up to 50 litres)

APPENDIX 2: EXPOSURE MEASUREMENTS FOR PRIORITY GASOLINE-RELATED ACTIVITIES

Table A2.1 Refinery maintenance on gasoline-related equipment

Date	**Country**	**Job/task**	**Peak/shift (duration)**	**Benzene mg/m^3**	**Toluene mg/m^3**	**Total gasoline volatiles mg/m^3**
May 2006	Finland	Pump disconnection	P	0.042	0.046	27.3
May 2006	Finland	Pump opening in workshop	P	0.006	0.042	8.2
May 2006	Finland	Pump opening in workshop	P	0.003	0.030	1.7
May 2006	Norway	Replacement benzene heartcut pump	S	0.032	0.004	0.3
May 2006	Norway	Replacement benzene heartcut pump	S	0.026	0.004	0.4
June 2006	Finland	Valve repair	S	0.099	0.243	8.7
June 2006	Finland	Pump disconnection and opening	P	0.061	0.874	23.6
June 2006	Finland	Pump disconnection and opening	P	0.122	1.55	34.2
August 2006	Finland	Pump disconnection	P	0.054	0.399	11.7
August 2006	Finland	Pump disconnection	P	0.115	0.239	14.4
August 2006	The Netherlands	Maintenance naphtha pump	S	0.006	0.004	1.9
August 2006	The Netherlands	Maintenance naphtha pump	S	0.006	0.004	6.0
September 2006	Finland	Pump disconnection	P	0.099	0.277	12.7
September 2006	Finland	Pump opening inside workshop	P	0.019	0.061	2.5

Table A2.2 Refinery production laboratory

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m^3	Toluene mg/m^3	Total gasoline volatiles mg/m^3
May 2006	Norway	Fuel testing	S	0.038	0.669	5.0
May 2006	Norway	Fuel testing and gas lab	S	0.006	0.057	3.2
May 2006	Norway	Fuel testing	S	0.010	0.258	1.6
May 2006	Norway	Fuel testing and gas lab	S	0.006	0.133	1.3
Jan 2007	France	No details available	S	0.052	2.28	-

Table A2.3 Research and Development laboratory: handling of test fuels (gasolines)

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m^3	Toluene mg/m^3	Total gasoline volatiles mg/m^3
Nov 2006	UK	Blending operator	S	0.054	0.209	133
Nov 2006	UK	Test fuel blending	P	0.560	6.620	260
Nov 2006	UK	Test fuel blending	P	0.346	1.273	88.4
Nov 2006	UK	Blending operator	S	0.170	0.380	5.9
Nov 2006	UK	Blending operator	S	0.038	0.122	2.7
Nov 2006	UK	Test fuel blending	P	0.106	0.752	7.7
Dec 2006	Germany	Blending operator	S	0.064	0.220	12.0
Dec 2006	Germany	Blending operator	S	0.074	0.760	7.3
Dec 2006	Germany	Fuel blending	P	0.237	0.627	35.1
Dec 2006	Germany	Fuel sample disposal	P	0.061	0.464	11.6
Dec 2006	Germany	Blending operator	S	0.029	0.167	5.6
Dec 2006	Germany	Blending operator	Half Shift	0.147	0.353	3.6
Dec 2006	Germany	Fuel dispensing	S	0.726	2.23	80.2
Dec 2006	Germany	Blending operator	S	0.090	0.148	3.2

Table A2.4 Road tanker operations

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m^3	Toluene mg/m^3	Total gasoline volatiles mg/m^3
Jan 2007	France	Loading	P	0.066	0.606	-
Jan 2007	France	Loading	P	0.024	2.85	-

Table A2.5 Rail car operations

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m³	Toluene mg/m³	Total gasoline volatiles mg/m³
Jan 2007	France	Control room (stationary)	S	0.011	0.052	-
Jan 2007	France	Hatch closing	P	0.023	0.399	-
Jan 2007	France	Hatch opening, sampling	S	0.017	0.500	-
Jan 2007	France	Hatch closing, sampling	S	0.020	0.139	-
Jan 2007	France	Control room (stationary)	S	0.003	0.005	-
Jan 2007	France	Hatch closing, sampling	S	0.096	0.760	-
June 2007	France	Loading (personal)	S	0.030	0.271	4.67
June 2007	France	Loading (area)	S	0.152	0.504	19.51
June 2007	France	Loading (area)	S	0.029	0.116	2.51

Table A2.6 Gasoline pump repair and maintenance

Date	**Country**	**Job/task**	**Peak/shift (duration)**	**Benzene mg/m³**	**Toluene mg/m³**	**n-Hexane mg/m³**
April 2004	Finland	Outdoors gauge repair	Half shift	0.11	1.2	0.15
April 2004	Finland	Outdoors hose replacement	2 hours	0.24	2.2	0.35
April 2004	Finland	Outdoors hose replacement	2.5 hours	0.26	10.6	0.32
May 2004	Finland	Indoors gauge repair and test	Half shift	0.63	8.2	1.5
June 2004	Finland	Indoors gauge repair	1.5 hours	2.9	27.8	4.0

Table A2.7 Gasoline pump calibration

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m^3	Toluene mg/m^3	n-Hexane mg/m^3
June 2004	Finland	Calibration of fuel pumps outdoors	Half shift	0.92	6.7	2.6
June 2004	Finland	Calibration of fuel pumps outdoors	Full shift	0.06	0.28	0.12
June 2004	Finland	Calibration of fuel pumps outdoors	Full shift	0.40	2.3	1.3
June 2004	Finland	Calibration of fuel pumps outdoors	Full shift	0.42	2.3	1.3
June 2004	Finland	Calibration of fuel pumps outdoors	Full shift	0.25	1.4	0.73

Table A2.8 Operation of gasoline-powered garden maintenance equipment

Date	Country	Job/task	Peak/shift (duration)	Benzene mg/m^3	Toluene mg/m^3	Gasoline vapour mg/m^3
09/09/05	Belgium	Bush cutting	P	< 0.002	0.2	5.5
09/09/05	Belgium	Lawn mowing	Half shift	0.02	0.03	0.7
13/09/05	Belgium	Bush cutting	Half shift	0.02	0.4	3.5
13/09/05	Belgium	Bush cutting	Half shift	0.01	0.3	2.5
13/09/05	Belgium	Line trimming	Half shift	0.01	0.5	2.3
13/09/05	Belgium	Line trimming	Half shift	< 0.002	0.006	0.2
13/09/05	Belgium	Lawn mowing	Half shift	0.001	< 0.002	0.2
27/09/05	Belgium	Bush cutting	Half shift	0.02	0.1	1.6
27/09/05	Belgium	Bush cutting	Half shift	0.02	0.2	1.8
03/10/05	Belgium	Bush cutting	Half shift	< 0.002	0.001	1.5
03/10/05	Belgium	Hedge cutting	Half shift	< 0.002	< 0.002	2.6
03/10/05	Belgium	2-stroke lawn mower	1 hour	< 0.002	0.1	1.2
03/10/05	Belgium	4-stroke lawn mower	Half shift	0.005	0.004	0.3
04/10/05	Belgium	Bush cutting	Half shift	0.002	< 0.002	1.3
04/10/05	Belgium	Hedge cutting	0.5 hour	< 0.002	< 0.002	4.2

Table A2.9 ***Aviation gasoline operations***

Date	**Country**	**Job/task**	**Peak/shift (duration in minutes)**	**Benzene mg/m^3**	**Toluene mg/m^3**	**Total gasoline volatiles mg/m^3**
07/12/04	Two regional airports, UK	Refuelling 4 planes with Jet A1, 1 with aviation gasoline, by tanker	361	0.03	4.4	27.5
07/12/04	Two regional airports, UK	Refuelling 2 planes with Jet A1, 2 with aviation gasoline, by tanker	198	< 0.03	< 1.0	13.9
08/12/04	Two regional airports, UK	Refuelling 1 plane with Jet A1, 1 with aviation gasoline, by tanker	365	0.02	3.5	32.6
08/12/04	Two regional airports, UK	Refuelling 1 plane with Jet A1, 1 with aviation gasoline, by tanker	195	< 0.03	< 1.0	5.8
09/12/04	Two regional airports, UK	Refuelling 2 planes with Jet A1, 1 with aviation gasoline, by tanker	435	0.04	5.6	84.4
09/12/04	Two regional airports, UK	Refuelling 2 planes with Jet A1, 1 (or more) with aviation gasoline, by tanker	165	< 0.03	3.4	53.1
18/10/05	National and regional airports, France	VLE1 (aviation gasoline)	13	< 0.03	3.4	83.9
18/10/05	National and regional airports, France	VLE4 (aviation gasoline)	19	< 0.03	5.9	59.1
18/10/05	National and regional airports, France	VME1 (Jet and aviation gasoline)	326	< 0.03	< 1.0	3.33
18/10/05	National and regional airports, France	VME2 (Jet and aviation gasoline)	329	< 0.03	< 1.0	3.6

CONCAWE
Boulevard du Souverain 165
B-1160 Brussels
Belgium

Tel: +32-2-566 91 60
Fax: +32-2-566 91 81
e-mail: info@concawe.org
website: http://www.concawe.org