review of european oil industry benzene exposure data

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ABSTRACT

Thia report aummarises data on exposure to benzene during the manufacture and distribution of gasoline in Europe. Exposures in various types of jobs are reviewed against the 8-hour time-weighted average 1 ppm "Action Level" and 5 ppm "Limit Value" of the EEC Proposal for a Directive on the Protection of Workers from the Risks Related to Exposure to Benzene at Work. The report concludes that with good work practices and control measures, most oil industry employee exposures are normally well below 5 ppm. Exposures of service station attendants are clearly normally below 1 ppm. 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.

Dit rapport geeft een samenvatting over expositiegegevens van benzene gedurende het verwerken en distributie van benzine in Europa. Blootstellingsniveaus van verschillende typen funkties worden bekeken in het licht van het EEG Voorstel om te komen tot een Richtlijn voor de bescherming van werknemers tegen de risico's verbonden aan benzene-blootstelling in de werksituatie; inhoudende een "Action Level" bij een gemiddelde van 1 ppm (8-uur TGG) en een Ceiling concentratie van 5 ppm. Het rapport concludeert dat met het in achtnemen van de normale hygiëne en goede controlemaatregelen het expositieniveau van het grootste deel van de werknemers in de olieindustrie ver beneden de 5 ppm ligt. Het blootstellingsniveau van personeel van tankstations ligt gewoonlijk beneden de 1 ppm evenals dat van chauffeurs van tankwagens en operators in de raffinaderijen. Het rapport geeft tevens aan voor welke beroepen onder bepaalde omstandigheden expositie boven de 1 ppm nivesu kunnen optreden.

In diesem Bericht werden Daten über Benzolbelastung von Arbeitnehmern in Herstellungs- und Verteilerbetrieb zusammengefasst. Belastungen an verschiedenen Arbeitsplätzen werden untersucht und mit dem 8-Stunden Zeit gemittelten 1 ppm "Aktions Grad" und dem 5 ppm "Grenzwert" in der von der EEC vorgeschlagenen Direktive über den Schutz von Arbeitnehmern vor dem Risiko der Benzolbelastungen am Arbeitsplatz verglichen. Der Bericht kommt zum Schluss, dass bei guten Arbeitspraktiken und Kontrollmassnahmen die Belastung fast aller aufgeführten Arbeitnehmer der Oelindustrie normalerweise weit unter 5 ppm liegen. Belastungen der Arbeitnehmer an Tankstellen liegen normalerweise klar unter 1 ppm. Ausserdem liegen Belastungen von Tankwagenfahrern und Raffineriarbeitern normalerweise unter 1 ppm. In diesem Bericht werden ausserdem solche Arbeitsplätze aufgeführt wo unter gewissen Voraussetzungen Belastungen von mehr als 1 ppm auftreten können.

Ce rapport résume des données d'exposition au benzène pendant la fabrication et distribution de l'essence en Europe. L'exposition au benzène en différents lieux de travail est analysée et comparée à la moyenne pondérée du "niveau d'action" de 1 ppm pendant un période de 8 heures et à "la valeur limite" de 5 ppm, comme indiqué dans la Proposition de Directive du Conseil concernant la protection des travailleurs contre les risques liés à une exposition au benzène pendant le travail. Ce rapport conclue que dans des bonnes conditions de travail et de mesures de contrôle, la plupart des employés de l'industrie pétrolière sont exposés à des valeurs largement inférieur à 5 ppm. L'exposition des employés dans des stations service est normalement en dessous de 1 ppm. En plus, l'exposition au benzène des chauffeurs de camions citerne et des opérateurs d'unités de raffinage est normalement en dessous de 1 ppm. Le rapport identifie aussi des types de travail pour lesquels l'exposition au benzène peut, dans certaines conditions, dépasser 1 ppm.

El presente informe es un resumen de datos sobre exposición al benceno durante la producción y distribución de la gasolina en Europa. Se analizan exposiciones que conciernen a varios tipos de empleos, en relación con "el nivel de acción a partir de la media ponderada de 1ppm en 1s jornada de 8 horas" y de 5ppm como "valor límite", que son sendos criterios del Ante Proyecto de Directiva de la CEE para la protección de los trabajadores contra los riesgos relacionados con la exposición del benceno en el puesto de trabajo. El informe llega a la conclusión de que con métodos de trabajo adecuados y con medidss de control, la exposición al benceno de la mayoría de los trabajadores de la industria petrolífera esta normalmente muy por debajo de las 5ppm. La exposición al benceno de los empleados de estaciones de servicio se encuentra normalmente y de una manera clara por debajo de 1ppm la exposición de conductorea de vehículos cisterna y la de los operadores de unidades en refinerías estan también normalmente por debajo de 1ppm. El informe identifica asimiamo determinados puestos de trabajo en los que en determinadas condiciones, la exposición puede exceder de 1ppm.

Questo studio riassume dati sull'esposizione al benzene durante la produzione e la distribuzione di benzina in Europa. L'esposizione per vari tipi di attività lavorativa sono esaminati riapetto al "livello d'intervento" di 1 ppm - media ponderale nel tempo per 8 ore - e al "livello limite" di 5 ppm della Proposta di Direttiva CEE sulla protezione dei lavoratori dai rischi relativi all'esposizione al benzene sul lavoro. Lo studio conclude che con buone pratiche di lavoro e misure di controllo, la maggior parte delle esposizioni dei lavoratori dell'industria petrolifera sono normalmente ben al di sotto dei 5 ppm - l'esposizione degli addettialle stazioni di servizio sono chiaramente al di sotto di 1 ppm, inoltre gli autisti di autocisterne e gli operatori di impianti petroliferi sono normalmente sotto 1 ppm. Lo studio individua anche attività nelle quali, in certe condizioni, l'esposizione puó eccedere 1 ppm.

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SUMMARY

In order to ensure that oil industry employees are protected against the potential adverse effects arising from excessive exposure to benzene vapour, exposures during the manufacture and distribution of gasoline have been measured over the last few years in several studies by European Petroleum Industry Associations and individual companies. This CONCAWE report summarises available exposure data for various types of jobs and reviews these against the 8-hour time-weighted-average (TWA) 1 part per million (ppm) "Action Level" and 5 ppm "Limit Value" of the EEC Proposal for a Directive on the Protection of Workers from the Risks Related to Exposure to Benzene at Work.

The review shows that:

- with good work practices and use of appropriate control measures, 8-hour TWA exposures of most oil industry employees are normally well below the proposed EEC Directive "Limit Value" of 5 ppm. Further attention needs to be given to marine loading and drum-filling operations;

- 8-hour TWA exposures of service station attendants are clearly normally below the proposed EEC Directive "Action Level" of 1 ppm;

- 8-hour TWA exposures of road tanker drivers and refinery unit operators are normally below 1 ppm;

- under some conditions, 8-hour TWA exposures may exceed 1 ppm for rack operators and supervisors in road tanker filling, in rail car and marine loading, and in drum filling;

- further local plant assessment is required against the proposed EEC "Action Level" for workers who are irregularly exposed to benzene vapour, such as refinery maintenance workers and laboratory technicians;

- additional data may be needed for bottom loading of rail cars, and drum filling with local exhaust ventilation.

The report also summarises available data on levels and durations of exposures for the component parts of some jobs, for example, the exposures of road tanker drivers during the loading of vehicles with gasoline and during delivery at service stations.

1. INTRODUCTION

Following the publication of the EEC Proposal for a Directive on the Protection of Workers from Risks Related to Exposure to Benzene at Work, CONCAWE has reviewed available benzene exposure data for various oil industry job types against the critical requirements of a 1 ppm 8-hour time-weighted-average (TWA) Action Level and a 5 ppm 8-hour TWA Exposure Limit. The objective of this report is to present typical pictures of the personal benzene exposures in various types of jobs to assist CONCAWE participants and national associations in assessing the need and priorities for further measurements. The review will also assist in assessment of the implications for the oil industry of the implementation of the EEC Directive proposals. Particular attention is given in this respect to the proposed 8-hour TWA Action Level in view of the additional requirements for monitoring, medical surveillance, record keeping, etc. if exposures are not assessed as below 1 ppm.

In order to ensure that employees were protected against the potential adverse health effects from excessive exposure to benzene, several studies of exposure levels have been carried out in the last eight years. Those reviewed in this report include industry association studies in France (UCSIP), Germany (DGMK Project 250, Measurement of Benzene Exposure during Handling and Production of Motor Gasolines, Hamburg, October 1983), Norway (Report No. HD 872/82, Occupational Exposure to Gasoline Vapours in the Norwegian Petroleum Industry, 1980-81, prepared by Institute of Occupational Health, Oslo and Norwegian Petroleum Institute) and the UK (IP/CIA) plus individual company studies in various countries. Two CONCAWE studies have also been used, one published and one not yet published. The former is that described in CONCAWE Report No. 2/81, "Exposure to Atmospheric Benzene Vapour Associated with Motor Gasoline". The latter is a gasoline vapour exposure study for which CONCAWE participants collected data during 1984 and 1985. In this study, analyses for up to 150 components of about 600 personal exposure samples have been stored in a computer data base. For use in this review, benzene exposures have been extracted from this database.

In all the studies reviewed similar sampling and analytical methods have been used. These are basically as described in the Appendix to CONCAWE Report No. 2/81. In the recent CONCAWE gasoline vapour exposure study some sampling modifications have been introduced to ensure that "light ends" are captured and a more complete analysis is carried out to identify and quantify more individual components. All benzene results obtained in the different studies reviewed should be essentially comparable.

Aspects covered in the report are:

- a summary of the proposed EEC Directive requirements;
- an overview of potential for benzene exposure during the manufacture and distribution of motor gasoline;
- 8-hour TWA exposures, including job outlines and exposure potentials;
- important components of total exposures;
- conclusions.

2. PROPOSED EEC DIRECTIVE REQUIREMENTS

The most important features of the proposed EEC Directive are Article 8, covering the proposed 8-hour TWA Exposure Limit of 5 ppm and Article 3.3, covering the proposed 8-hour TWA Action Level of 1 ppm. The latter is probably of greater importance for the oil industry. Assessment (which is not clearly defined in the Proposed Directive) is required to establish whether 8-hour TWA exposures are below 1 ppm. If not, the additional requirements of Articles 4, 7, 11, 13, 14 and 15 come into effect. These involve obligations to:

- undertake representative monitoring of exposures, generally every three months, or once a year if results of the two preceding measurements are below half the Exposure Limit;
- report quantities of benzene used, activities, processes, products manufactured, the number of workers exposed, the preventive measures taken and the type of protective equipment used;
- ensure that access is limited to essential personnel, protective clothing/equipment is provided (with separate storage from street clothing) and properly maintained, and separate eating/drinking areas are set aside for workers;
- provide employees with sampling results and explanation of their significance;
- assess the health state of each worker (clinical and biological) before start of exposure. Repeat assessments must be made at least once a year during exposure or if the worker shows any benzene-related clinical or biological abnormalities;
- maintain records of each worker's exposure and health assessment and keep these records for at least 30 years after the end of exposure.

3. OVERVIEW OF POTENTIAL BENZENE EXPOSURE IN OIL INDUSTRY OPERATIONS

European gasolines typically contain up to 5% of benzene. To minimise product losses by evaporation, gasoline is manufactured and distributed, as far as is practicable, in enclosed systems. Nevertheless, potential for exposure to benzene in European oil industry operations exists from:

- filling customers' vehicles and incidental tasks at service stations;
- loading of gasoline into road tankers, rail cars, ships and barges;
- delivery of gasoline into service station tanks;
- plant operations involving opening/closing of valves, collection of process samples, etc.;
- plant maintenance when enclosed equipment must be drained, opened up, cleaned, etc.;
- laboratory testing;
- tank dipping and sampling;
- treatment of contaminated water effluent;
- filling drums.

Actual TWA exposures will depend on a number of factors such as the nature of the job and exposure period(s) involved, ambient wind and temperature conditions, design of plant and facilities, installation and use of exhaust ventilation or vapour recovery, the use of respiratory protection in special situations and the extent to which employees follow the advice and instructions provided on the correct work practices for minimising exposures. In some activities, such as plant maintenance, exposures can also be irregular and often infrequent.

4. JOB OUTLINES, EXPOSURE POTENTIALS AND EXPOSURE DATA

4.1 SERVICE STATIONS

4.1.1 Job outline and exposure potential

Benzene exposures of service station attendants filling customers' vehicles with gasoline and conducting incidental duties on or around the forecourt can be expected to vary depending on the throughput of vehicles, ambient temperatures, wind conditions, the extent to which a station may be enclosed, the benzene content of the gasoline and the extent of any spillages which occur. The situation may vary to some extent between different types of service station which might be classified into the following groups:

- motorway (Autobahn, autoroute) stations with a fairly constant and high throughput but often situated in relatively open locations where vapours will be rapidly dispersed by wind;
- urban stations with a fairly constant and high throughput;
- suburban stations which may have variable throughput with peak periods;
- rural stations with lower throughputs;
- enclosed stations (open on only one side or underground) from which vapour may not be dispersed as quickly as in other locations.

Where vehicle servicing and engine maintenance are carried out, service station mechanics may be exposed to gasoline vapour for short periods, for example whilst making adjustments to engine timing or carburation.

Customers filling their own vehicles at self-service stations are exposed infrequently for short periods, typically lasting up to about 3 minutes. However, this is not a work activity and it is therefore not covered by the proposed EEC Directive.

4.1.2 Service station attendants' exposures

Various benzene exposure studies of service station attendants have been conducted in different European countries over the last few years. Available data covering a total of 546 personal breathing zone samples are summarised in Table 1 below.

Table 1: 8-Hour TWA exposures of service station attendants

Study	Type of station	Number of samples	Benzene exposure range, ppm	% of exposure below 1 ppm
Germany (DGMK)	Urban	256	<0.01 - 1.10	99.6
Germany (DMGK)	Autobahn	95	<0.01 - 1.23	99
Norway (NPI)	Not specified	39	0 - 5.7	77
France (UCSIP)	Autoroute	5	0.13 - 0.6	100
France (UCSIP)	Underground	4	0.1 - 0.2	100
France (UCSIP)	Urban	1	0.8	100
UK (IP/CIA)	All types	55	0.03 - 1.6	98
Italy * (1985)	Highway	29*	0.06 - 0.84	100
CONCAWE (1981)	Rural	21	0.27 - 0.53	100
CONCAWE (1981)	Urban	10	0.34 - 113.7**	?
CONCAWE (1981)	Suburban	6	0.07 - 1.8	?
CONCAWE (1981)	Motorway	15	0.03 - 0.7	100
CONCAWE (1984)	Not specified	10	0.1 - 0.7	100

* Ambient temperature during these tests were 30-33°C with wind speeds of 1.5 to 4.5 m/sec. (about 3 to 10 miles per hour or 5 to 16 kilometres per hour)

** Gasoline being misused to clean dispensing pumps, plus considerable spillage.

These data show that, except for the Norwegian study, at least 98 per cent of samples gave exposures below 1 ppm. In the Norwegian study, 9 out of 39 samples (23%) were greater than 1 ppm. Of the total of 507 samples apart from the 39 from the Norwegian study 499 or 98.4 per cent were below 1 ppm. These data indicate that, unless gasoline is being misused or mishandled, there is no significant probability that service station attendants' exposures to benzene will exceed the proposed EEC 8-hour TWA exposure limit of 5 ppm. These data are considered sufficient to support the "assessment" that service station attendants' exposures are below the proposed Action Level of 1 ppm and therefore the general exclusion of these workers from the additional requirements of the proposed EEC Directive.

It has been noted previously, for example in CONCAWE Report No. 2/81, that very little sample data was available from Southern Europe where higher ambient temperatures might be expected to lead to higher exposures. Table 1 includes 29 samples taken in the summer of 1985 at Italian service stations, when ambient temperatures were in the range of 30 to 33°C. None of the attendants' exposures exceeded 1 ppm, 0.84 ppm being the maximum.

In their service station attendant study, DGMK examined the data for the influence of throughput, ambient temperature and benzene content of the gasoline on exposures. No significant correlations were found between exposures and throughput or benzene content of gasoline; at one Autobahn station correlation existed with ambient temperature. The Norwegian Petroleum Institute commented in their report that it was difficult to see any statistical correlation between exposures and factors such as temperatures, wind and amount of gasoline handled. It appears likely that other factors such as work practices and individual features of each location outweigh, to a large extent, the influences of temperature, throughput and benzene content of the gasoline within the normal limits by which these vary.

4.1.3 Customer exposures in self-service stations

Limited data are also available on exposures of customers filling their own vehicles at self-service stations. In the CONCAWE 1984 gasoline vapour exposure study, 21 samples showed benzene exposures over 1 to 3 minute periods of 0.1 to 4.4 ppm. In view of the infrequent nature of customer exposures, these data are considered sufficient to show that such exposures do not present any problem. As already noted, this is not a work activity and self-service is therefore not covered by the proposed Directive.

4.1.4 Service station mechanics

Mechanics may be exposed to gasoline vapour for short periods whilst making adjustments to engine timing or carburation. The only recorded data available is that noted in CONCAWE Report No. 2/81 where 15-minute exposures were in the range 0.01 to 0.46 ppm with an arithmetic mean of 0.16 ppm. These limited data indicate that 8-hour TWA exposures in this activity will be below the proposed EEC Directive Action Level of 1 ppm.

4.2 ROAD TANKER DRIVERS

4.2.1 Job outline and exposure potential

In European operations involving distribution of gasoline to service stations by road tankers, the most common practice is for the road tanker drivers to load their own vehicles at fuel terminals or refinery loading bays. The most usual current method is top loading, whereby the tanker compartments are filled through open hatches on top of the vehicle by the driver introducing the fill pipe and lowering it to the bottom of the compartment. This

technique of submerged filling, in which gasoline enters the compartment under liquid fuel already present, has generally replaced the earlier technique of "splash loading" in which only a short fill pipe was used and liquid gasoline entered the vapour space of the compartment. The submerged filling technique results in less vaporisation of the liquid gasoline. As each compartment is filled, the driver must remove the fill pipe, drain it and insert it into the next compartment.

During these operations, the driver has a potential for exposure to vapours which are displaced through the open hatch as liquid fills the compartment, from spillage, and from evaporation of liquid from the surface of the fill pipe as it is removed from one compartment and inserted in the next. There is a further potential for exposure during the closing of hatch covers and during tank dipping. Actual exposures may vary considerably depending on the type of equipment installed, the work practices of the driver, the benzene content of the gasoline and ambient weather conditions. In some installations the location of a "dead-man's handle" (which must be depressed during filling) may require the driver to stand close to the open hatch. In other cases he may be able to stand well away from the hatch opening where metered filling or a remote "dead-man's handle" are installed. High ambient temperatures and absence of wind can be expected to lead to higher vapour concentrations. If the driver can stand "up-wind" of the open hatch his exposure will clearly be lower. Exposures may also be affected by the vapour content of the empty compartments and by simultaneous filling of other tankers in adjacent loading bays. In some facilities, vapour control or recovery systems may have been installed; reduced exposures would be expected in such cases. Spillages of gasoline may occur occasionally and lead to higher exposures. Filling rates may also vary, as can tanker and compartment sizes.

In bottom loading of road tankers, compartments are filled through hose connections which are made by the driver to the vehicle near ground level. This method of loading has been less common in Europe than top loading but is becoming more favoured for new installations. The main sources of exposure potential are during the hose coupling and uncoupling procedures, and from vapour which may drift towards ground level from high-level vents. As with top loading, actual exposures will be subject to a number of variables such as weather conditions, simultaneous loading of other tankers in adjacent bays, occasional spillages, etc.

Actual exposure periods and levels can be expected to reflect the influence of these variables. In most cases, loading is completed within 30 minutes, although delays through technical, operating or other problems will inevitably occur occasionally. Installation of improved facilities, such as the use of more bottom loading and faster filling rates, would be expected to lead to future reductions in both levels and periods of exposures.

Delivery of gasoline at service stations from road tankers involves connection and disconnection of hoses by the driver between the vehicle and storage tanks, interspersed with waiting periods during the transfer of product. Some exposure may occur whilst making connections and disconnections. Small spillages may also occur occasionally. Depending on the relative location of storage tank vents, there may be a potential for exposure to displaced vapours. Low levels of gasoline vapour may also be present from the normal throughput of customer vehicles at the service station whilst the delivery is being made. The time required to make deliveries at service stations is typically about 45 minutes.

In addition to the tasks of loading the vehicle and delivery of product at service stations the vehicle is driven between the loading location and the service station(s). During driving, there should normally be little or no exposure to benzene beyond typical background levels. However, exposures may sometimes be higher as a result of contamination of overalls, shoes or gloves from spillages.

Typically, a driver will complete 2 to 3 loadings and deliveries each day with occasionally more where short delivery distances are involved.

4.2.2 8-Hour TWA exposures of road tanker drivers

Long-term personal sampling of road tanker drivers covering loading, driving and discharge has been carried out in the UK IP/CIA, UCSIP and CONCAWE (1981 and 1984) studies. Results are summarised in Table 2 below.

Table 2: 8-Hour TWA exposures of road tanker drivers

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of exposures below 1 ppm
UK (IP/CIA) (a)	28	0.1 - 2.1	0.4	96
UK (IP/CIA) (b)	21	0.1 - 0.4	0.14	100
France (UCSIP)	18	0.06 - 2.34	0.4	89
CONCAWE (1981)	22	0.07 - 0.36	0.16	100
CONCAWE (1984) (a)	62	0.1 - 10.2	0.52	82
CONCAWE (1984) (b)	33	0.1 - 4.0	0.38	91
Germany (DGMK)	54	<0.1 - 1.90	0.58	89

(a) Top loading
(b) Bottom loading

Of the total 238 samples, 215 (90.3%) were below 1 ppm. It is noted that only 82% of the CONCAWE (1984) top-loading samples were below 1 ppm. However, most of these samples were taken in typical "worst case" situations at higher-than-average summer temperatures and with high throughputs.

The data summarised in Table 2 indicate that 8-hour TWA exposures of road tanker drivers should not normally exceed 1 ppm. Exclusion from Action Level requirements of the proposed Directive therefore seems reasonable.

In addition to the long-term sampling of road tanker drivers summarised above, several studies have determined exposures during the component parts of the job of loading road tankers and delivery into service station tanks. These data are summarised in the following two sections.

4.2.3 Driver exposures during top loading of road tankers

Data on exposures during top loading of road tankers have been obtained in several studies. These are summarised in Table 3 below.

Table 3: Exposures during top loading of road tankers

Study	Number of samples	Benzene exposures, ppm		% of Exposures below		
		Range	Arithmetic mean	1 ppm	5 ppm	10 ppm
France (UCSIP)	116	0 - 16.5	1.85	51.7	90.5	95.7
Norway (NPI)	479	0.1 - 21	3.8	24	74	94.5
Finland (Neste)	84	0.1 - 4.4	0.75	82	100	100
CONCAWE (1984)	149	0.1 - 57.4	2.38	37	92	98.6
UK (IP/CIA)	142	0.1 - 34	2.35	32	84	95
CONCAWE (1981)	73	0.02 - 34	2.8	40	72	85

Note: Sampling times ranged from 4 to 60 minutes.

These data show that time-weighted average exposures over the loading period can often exceed 5 ppm but only occasionally exceed 10 ppm. Out of the total of 1043 samples only 52 (5.0%) exceeded 10 ppm.

Exposure periods in these studies varied from as short as 4 minutes up to 60 minutes. An indication of the distribution of exposure periods is provided by analyses of the 116 samples collected in the French (UCSIP) study and the 149 samples in the CONCAWE 1984 study in Table 4. These data assume that recorded sampling time is equal to exposure (loading) time.

Table 4: Exposure periods during top loading of road tankers

	UCSIP	CONCAWE
Percent up to 20 minutes	30.4	38.3
Percent up to 30 minutes	68.7	82.2
Percent up to 40 minutes	91.3	93.5
Arithmetic mean exposure period, minutes	28	24

CONCAWE data (with about 18 per cent of exposure periods exceeding 30 minutes) suggest slightly shorter exposure periods than the UCSIP study. It is believed that this may be due to some UCSIP sampling periods being from the arrival of a driver at the terminal to his departure rather than only during the loading operation. Other data also suggest that loading times are generally shorter than those reported in the French study. For example, periods for the 84 Finnish samples ranged from 6 minutes to a maximum of 30 minutes. In the 1981 CONCAWE study the range was from 6 to 47 minutes with a mean of 19 minutes. The German (DGMK) study reported typical loading times of 10 to 15 minutes, whilst the Norwegian (NPI) report states that loading "usually lasts about 10 to 30 minutes".

The majority of the exposure data summarised in Table 3 were collected in Northern Europe. It is reasonable to question therefore whether higher exposures may occur under the generally higher ambient temperature conditions in Southern Europe. Additional data from one CONCAWE participant (Table 5) provide a comparison between exposures at a terminal in a temperate climate (UK, London) and a warm climate (Southern Italy). Samples were collected periodically over a twelve month period.

Table 5: Exposures during top loading of road tankers in UK and Southern Italy

Conditions		UK (London)	Southern Italy
Number of tests		144	157
% Benzene in fuel	average range	2.5 1.8 to 3.1	1.2 0.9 to 1.6
Product temperature °C	average range	11.1 5 to 17	21.5 13 to 31.5
Air temperature °C	average range	8.2 -1 to 17.5	17.7 6 to 30
Loading Rate l/min	average range	1805 660 to 2790	1262 130 to 2900
Cargo volume (per load) l	mean range	22,020 6,100 to 27,500	21,710 2,000 to 40,000
Loading time min	average range	12.2 5 to 22	17.2 7 to 43
Number of tanks loaded per load	mean range	6.5 2 - 8	7.9 1 - 22
Windspeed m/sec	average range	1.9 0.2 to 4.2	2.9 0 to 15
Tank hatch diameter cm		25	18 to 50
Exposures			
Arithmetic mean (ppm Bz)		2.01	1.61
Geometric mean (ppm Bz)		1.39	0.95
95% of tests less than (ppm Bz)		5.6	4.9
No./% of test above 1 ppm Bz		95/66	80/51
No/% of tests above 5 ppm Bz		10/6.9	7/4.5
No./% of tests above 10 ppm Bz		0/0	2/1.3
Statistical predictions of exposures above or below specific levels			
Geometric standard deviation		2.5	2.9
95% less than (ppm Bz)		6.2	5.5
% above 1 ppm Bz		63	48
% above 5 ppm Bz		8	6
% above 10 ppm Bz		1.5	1.4

Data from another CONCAWE participant (Table 6) compare exposures during top loading of road tankers in Scotland and in Greece.

Table 6: Exposures during top loading of road tankers in Scotland and Greece

	Scotland	Greece
Per cent benzene in gasoline	2.2	3.8
Number of exposure measurements	19	26
Range of exposures, ppm	<0.1-2.7	<0.1-4.0
Arithmetic mean exposure, ppm	1.0	1.1
Mean loading time, mins	23	34
Arithmetic mean exposures in ppm - mins	23	37
Range of air temperatures, °C	8-15	25-33

The data from these two studies suggest that ambient and product temperature variations between Northern and Southern Europe do not necessarily result in major differences in exposures. The complex effects of other variables such as benzene content of the gasoline, loading rates, wind speeds, equipment design and work practices are probably greater than the influence of temperature alone. Although it might be expected in theory that higher ambient and product temperatures would lead to higher exposures, available data indicate that no generally applicable predictions can be made.

4.2.4 Driver exposures during bottom loading of road tankers

Data on exposures during bottom loading of road tankers are limited and are only available from the French (UCSIP) 1983 study and the CONCAWE 1984 study. These are summarised in Table 7 below.

Table 7: Short-term exposures during bottom loading of road tankers

Study	Number of samples	Benzene exposures, ppm		% of Exposures below		
		Range	Arithmetic mean	1 ppm	5 ppm	10 ppm
France (UCSIP)	20	0 - 8.9	1.19	85	90	100
CONCAWE (1984)	59	0.1 - 1.6	0.48	88	99	100

Of the small total number of samples (79), only 3 (3.8%) exceeded 5 ppm. Additional samples are probably required to confirm whether these data represent a valid assessment of actual exposures during the bottom-loading operations.

Exposure periods in these studies varied from 8 minutes up to 75 minutes. An indication of the distribution of exposure periods is provided from analyses of the 20 samples collected in the French (UCSIP) study and the 59 samples in the CONCAWE (1984) study (Table 8). These data again assume that recorded sampling time is equivalent to exposure (loading) time.

Table 8: Exposure periods during bottom loading of road tankers

	UCSIP	CONCAWE
Per cent up to 20 minutes	10	33.9
Per cent up to 30 minutes	80	61
Per cent up to 40 minutes	95	91.2
Arithmetic mean exposure period, minutes	30	27

These data indicate that up to about 40 per cent of exposure periods can exceed 30 minutes and that up to about 10 per cent (1 sample at 75 minutes) may be for longer than 40 minutes. The arithmetic mean of the 20 UCSIP exposure times was 30 minutes. In the CONCAWE studies, exposure times ranged from 8 to 60 minutes with an arithmetic mean of 27 minutes.

4.2.5 Driver exposures during delivery at service stations

Because of the anticipated lower potential for exposure, only limited exposure data during unloading of road tankers at service stations (Table 9) have been reported in the reviewed studies.

Table 9: Driver exposures during delivery at service stations

Study	Number of samples	Sampling duration (min)	Benzene exposure (ppm)
UK(IP/CIA)	10	30 - 50	0.1 - 1.6
CONCAWE (1981)	4	45 average	0.1 - 0.6
Italy	2	33 - 36	0.05 - 0.89
CONCAWE (1984)	6	23 - 77	0.1 - 1.9

These data confirm that, as expected from the nature of the task, exposures are normally very low during delivery of gasoline at service stations.

4.3 ROAD TANKER LOADING RACK OPERATORS AND SUPERVISORS

4.3.1 Job outline and exposure potential

Whilst it is normal practice for drivers to load their own vehicles, road tankers are loaded in a few locations by "rack operators". Their 8-hour TWA exposures will vary with the design of the loading equipment, throughput of vehicles, ambient temperature and wind conditions, work practices and the occurrence of any spillages.

Supervisors and management at loading terminals are also likely to be exposed intermittently whilst dealing with any problems or providing assistance to drivers or rack operators.

4.3.2 8-Hour TWA exposure of rack operators and supervisors

Available studies on terminal staff are summarised in Table 10 below.

Table 10: 8-Hour TWA exposures of rack operators and supervisors.

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below	
				1 ppm	5 ppm
UK (IP/CIA)	15	0.1 - 9.3	1.8	27	93
Germany (DGMK) (a)	50	0.01 - 2.19	0.35	94	100
CONCAWE (1981) (b)	8	0.03 - 9.3	2.0	-	87.5
CONCAWE (1981) (c)	16	0.17 - 0.33	0.25	100	100

(a) Supervisors
(b) Top loading, rack operators
(c) Bottom loading, rack operators

These data suggest that rack operators may sometimes be exposed to 8-hour TWAs of greater than 1 ppm. This is to be expected from the nature of their job and the exposure data in Sections 4.1.3 and 4.2.4 for drivers loading road tankers.

4.4 RAIL CAR LOADING

4.4.1 Job outline and exposure potential

During top and bottom loading of rail cars operators may be exposed to gasoline vapour at the gantry level during operations such as opening/closing of hatches and checking fill levels and at the track level while involved in the movement of cars and the connection/disconnection of hoses. Exposures will vary depending on the nature of the installation, for example, the degree of enclosure and automation, the throughput of rail cars, the ambient weather conditions, the location of any other vapour sources in the vicinity and possibly by occasional spillages. Although daily schedules for rail car loading are likely to vary considerably, operators generally carry out this task for several hours per day.

There is a tendency to move to bottom loading (with vapour recovery) in place of top loading of rail cars.

4.4.2 8-Hour TWA exposures of rail car loaders

Available 8-hour TWA exposure data on top loading of rail cars are summarised in Table 11 below.

Table 11: 8-Hour TWA exposures during top loading of rail cars

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below	
				1 ppm	5 ppm
UK (IP/CIA)	22	0.3 - 6.5	1.4	45	95
Germany (DGMK)	102	0.01 - 12.44	0.9	81	98
CONCAWE (1981)	2	0.62 - 0.75	0.7	100	100
Finland (Neste)	27	0.1 - 5.0	1.0	59	96
CONCAWE (1984)	33	0.1 - 3.2	0.5	87	100

These data indicate that 8-hour TWA exposures during rail car loading may exceed 1 ppm. Action Level requirements are therefore likely to apply. However, additional 8-hour TWA data on bottom loading of rail cars are desirable.

4.4.3 Other exposure data for rail car loading

In the Norwegian Petroleum Institute study 13 samples were collected over an average period of 24 minutes during bottom loading of rail cars. Exposures ranged from 0.1 to 6.4 ppm. It was noted that some spillage was associated with the connection and disconnection of hoses.

In the UK IP/CIA study 57 samples over 15-69 minute periods on gantry/general operators showed exposures in the range of less than 0.3 ppm to 12.2 ppm (46% less than 1 ppm, 95% less than 5 ppm, and 97% less than 10 ppm). 37 samples from track level operators over 14 to 75 minute periods showed exposures in the range 0.2 to 48 ppm (32% less than 1 ppm, 54% less than 5 ppm and 68% less than 10 ppm). These data suggest that operators at track level may receive high exposures from vapour drifting downwards from the top of the rail car.

In the CONCAWE (1984) study 5 samples taken over periods ranging from 15 to 95 minutes showed exposures in the range less than 0.1 to 0.37 ppm.

4.5 MARINE LOADING

4.5.1 Job outline and exposure potential

Loading of ships and barges can be "open" or "closed". In open loading, tank tops, ullage ports or dip hatches are left open and displaced hydrocarbon vapours are vented close to deck level. Crew can be exposed during connection and disconnection of cargo lines, whilst leaning over open hatches to check fill levels, and during tank dipping. In closed loading, automatic ullage measurement is installed, ullage ports and hatches are kept closed, and displaced vapours are vented at a remote point. Whilst exposures would be expected to be lower with closed loading, variations can be expected depending on wind conditions and vent locations in relation to personnel, ambient temperatures and the reliability of automatic ullage measurements. In many cases, open loading has been replaced by closed systems but it still appears to be common practice to take manual ullage measurements.

Jetty staff involved in supervision of loading operations also have a potential for exposure from displaced hydrocarbon vapours and whilst carrying out operations such as sampling and dipping. The position of vents and wind direction are likely to be important variables affecting the level of jetty staff exposures. It is noted that the proposed EEC Directive excludes sea transportation. However, it is probable that operations carried out alongside jetties will be covered.

4.5.2 8-Hour TWA exposures during marine loading

Available studies on 8-hour TWA exposures of deck crews during open and closed loading are summarised in Tables 12 and 13 and jetty staff data in Table 14 below.

Table 12: 8-Hour TWA exposure of deck crew during open marine loading

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below		
				1 ppm	5 ppm	10 ppm
UK (IP/CIA)	65	0.1 - 61.3	2.2	35	66	74
CONCAWE (1981) (a)	10	0.7 - 21.0	7.7	-	-	-
CONCAWE (1981) (b)	19	0.6 - 61.0	8.8	-	-	-
Norway (NPI)	51	0 - 62	9.8	47	65	80
Germany (DGMK)	22	0.15 - 19.6	4.6	64	77	86
CONCAWE (1984) (a)	8	0.1 - 1.5	0.5	80	100	100

(a) ships
(b) barges

Table 13: 8-Hour TWA exposures of deck crew during closed marine loading

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below		
				1 ppm	5 ppm	10 ppm
CONCAWE (1981)	6	0.2 - 1.0	0.5	100	100	100
Germany (DGMK)	8	0.08 - 0.9	0.5	100	100	100
Finland (Neste)	11	0.1 - 0.7	0.2	100	100	100
CONCAWE (1984) (a)	9	0.1 - 7.3	1.5	67	90	100
CONCAWE (1984) (b)	12	0.1 - 11.7	2.4	68	87	95
UK Refy. (1983)	17	0.04 - 6.5	1.8	-	-	100

(a) ships
(b) barges

Table 14: 8-Hour TWA exposures of jetty staff during marine loading

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below		
				1	5	10
UK (IP/CIA) (a)	12	0.2 - 2.5	-	-	100	100
CONCAWE (1981) (a)	4	0.4 - 1.6	0.8	50	100	100
CONCAWE (1981) (b)	2	0.2 - 0.4	0.3	100	100	100
Germany (DGMK) (b)	51	0.02 - 3.10	0.45	92	100	100
Finland (Neste) (b)	18	0.1 - 9.5	0.8	89	94	100
UK Refy. (1983) (b)	11	0.06 - 0.58	0.15	100	100	100

(a) open loading
(b) closed loading

These data (apart from an anomaly in the CONCAWE 1984 data) confirm the reduced exposures in closed loading operations. Further confirmation is provided in data supplied by a CONCAWE contributing company and summarised in Table 15.

Table 15: 8-Hour TWA exposures of deck crew in open and closed marine loading

Type of vessel	Range of benzene exposures, ppm	
	Open loading	Closed loading
Estuarial	3 - 54	0.2 - 2.3
Coastal	0.2 - 14	0.1 - 0.2

Although exposures are reduced in closed loading, the available data indicate that 8-hour TWA-exposures may still exceed 1 ppm. These activities can therefore be expected to be subject to the requirements from exceeding the proposed EEC Action Level.

For closed loading operations it appears that 5 ppm is likely to be exceeded only occasionally, whereas in open loading it may often be exceeded.

4.6 REFINERY MAINTENANCE WORKERS

4.6.1 Job outline and exposure potential

Refinery maintenance workers carry out a variety of tasks, some of which may involve exposure to vapours when draining, cleaning, opening up and working on enclosed equipment. Exposures are likely to be intermittent and unpredictable.

4.6.2 8-Hour TWA exposures of refinery maintenance workers

Limited data available from studies where maintenance workers have been specifically identified separately from general refinery employees are summarised in Table 16.

Table 16: 8-Hour TWA exposures of refinery maintenance workers

Study	Number of samples	Benzene exposure range, ppm	Estimated TWA exposure, ppm	% of measurements below	
				1 ppm	5 ppm
Germany (DGMK) (a)	43	0.01 - 7.9	0.3	98	98
Finland (Neste) (b)	7	0.1 - 2.0	0.4	86	100
Finland (Neste) (c)	10	0.1 - 4.5	0.4	90	100
Finland (Neste) (d)	44	0.1 - 1.8	0.1	98	100
UK (IP/CIA)	30	-	-	80	97

(a) pump maintenance
(b) instrument maintenance
(c) maintenance in product storage areas
(d) maintenance on steam cracker units

These data indicate that exposures can occasionally exceed 1 ppm but there is a low probability of exceeding 5 ppm. It may be necessary to consider maintenance workers as possibly exceeding the proposed EEC Action Limit. Additional exposure data may be needed to define maintenance worker exposures more clearly. It may also be necessary to evaluate exposures for specific maintenance activities. However, because exposures of maintenance workers tend to be irregular and possibly infrequent, special consideration of their exposure situations may be justified. Cumulative daily average exposures are likely to be below 1 ppm because of the irregular exposures.

4.7 REFINERY OPERATORS

4.7.1 Job outline and exposure potential

Refinery operators carry out various tasks involved in controlling the processing of hydrocarbon streams containing benzene in plants such as crude distillation units, crackers, reformers, etc. Part of their time is spent inside the control room where no significant exposure to benzene will occur. In other tasks on the units themselves, such as opening and closing valves, collecting of samples, blowing down gauges, etc. there may be a potential for exposure, particularly if there are any leaks of liquid or vapour.

4.7.2 8-Hour TWA exposures of refinery operators

Extensive data collected in various studies are summarised in Table 17. In some studies, operators on specific units have been identified whereas for others this information is not available.

Table 17: 8-Hour TWA exposures of refinery operators

Study	Process	Number of samples	Benzene exposure range, ppm	Estimated TWA, ppm	% of exposure below	
					1 ppm	5 ppm
UK (IP/CIA)	Unspecified	270	-	-	94	98
Germany (DGMK)	Reformer	183	0.01 - 12.2	0.2	97	99
"	Cat. Cracker	46	0.01 - 4.4	0.3	91	100
"	Ethylene	51	0.01 - 2.6	0.3	92	100
Finland (Neste)	Unspecified	53	0.1 - 0.8	0.1	100	100
"	Reformer	6	0.1	0.1	100	100
"	Ref. Splitter	2	0.1	0.1	100	100
UK Refinery	Unspecified	27	0.02 - 0.75	0.5	100	100
CONCAWE (1984)	Unspecified	54	0.1 - 7.9	0.3	95	97

661 of the 692 samples (95.5%) were below 1 ppm. These data indicate that it is unusual for refinery operators to be exposed to an 8-hour TWA of more than 1 ppm. There may be a higher risk of exceeding 1 ppm on those units processing streams with a higher than usual benzene content, for example, reformer or cracker streams with 7% or more benzene content. Operators on such units may require further assessment to decide whether the requirements of the proposed EEC Action Level apply. In general it appears that refinery operators will not be subject to Action Level requirements.

4.8 REFINERY "OFF-SITE" WORKERS

4.8.1 Job outline and exposure potential

Refinery "off-site" workers include laboratory technicians, employees involved in tank dipping and sampling and those involved in water effluent treatment such as skimming open oily water separators, e.g. API separators. Potential for exposure will vary with the type of job and the extent to which it involves handling of gasoline or light hydrocarbon refinery streams where they are not entirely contained within process units, pipework, or storage tanks.

4.8.2 8-Hour TWA exposures of refinery "off-site" workers

The available studies provide limited data on off-site activities with the specific jobs involved not identified in all cases. Data are summarised in Table 18.

Table 18: 8-Hour TWA exposure of refinery "off-sites" workers

Study	Activity	Number of samples	Benzene exposure range, ppm	Estimated TWA, ppm	% of Exposure below	
					1 ppm	5 ppm
Germany (DGMK)	Storage	54	0.01 - 6.5	0.7	80	98
Finland (1982/3)	API Sep.	7	0.1 - 13	0.5	86	86
Finland (1982/3)	Storage	33	0.1 - 5.1	0.3	91	97
CONCAWE (1984)	Various	25	0.1 - 4.7	0.4	92	100

These data indicate that there are possibilities for 8-hour TWA exposures greater than 1 ppm. 116 of the 119 samples (97.5%) were below 5 ppm. Additional data appear to be necessary for specific jobs within this general group in order to make an assessment against the EEC proposed Action Level and to evaluate the implications.

4.9 EXPOSURES IN MISCELLANEOUS ACTIVITIES

4.9.1 Drum filling

When filling of drums (about 200 litres) with gasoline is carried out without effective local exhaust ventilation, the operator is exposed to vapours displaced by the liquid. A limited amount of data on drum-filling without local exhaust ventilation confirms that quite high exposures to benzene can occur. For example, the range of benzene exposures for 9 samples in the CONCAWE 1984 gasoline vapour exposure study was 0.1 to 38.8 ppm with an arithmetic mean of 9.1 ppm. In the Norwegian Petroleum Institute study, 4 results ranging from 8.8 to 82 ppm were obtained over sampling periods of about 15 minutes. Two results provided by a CONCAWE participant for drum filling with good local exhaust ventilation show exposures of 1.7 and 3.2 ppm.

These data confirm that adequate local exhaust ventilation and/or respiratory protection will be essential in drum-filling operations to ensure compliance with proposed future 8-hour TWA exposure limits.

4.9.2 Octane rating laboratories

In quality control and research laboratories, the octane number of gasoline is measured in special (CFR) engines. The operator may be exposed to gasoline vapour for short periods during blending of standard samples and whilst setting up and running a test. Exposures can be expected to vary depending on the effectiveness of any local exhaust ventilation (such as a fume cupboard for blending and exhaust extraction on the fuel container and carburettor) and on the work practices of the operator.

In the Norwegian Petroleum Institute study, 12 samples taken over periods of 17 to 35 minutes showed exposures in the range 0.3 to 4.8 ppm. In the UK IP/CIA study it was noted that two 8 hour TWA exposures for octane test operators were in the 1 to 5 ppm range. Since testing may be intermittent and sometimes conducted for only part of the working day, these data suggest that exposures during octane testing need further consideration against exposure limit proposals.

4.9.3 Fuel testing laboratories

In laboratory testing of gasoline, such as vapour pressure, distillation range, specific gravity, etc., technicians may be exposed to vapour. In the studies reviewed by CONCAWE no specific data relating to such laboratory technicians have been identified. However, one CONCAWE participant has provided details of 18 personal samples for fuel laboratory technicians over sampling periods of 8 to 185 minutes; 9 exposures were less than 1 ppm, 8 in the range 1 to 5 ppm and one exceeded 10 ppm. These results suggest that exposures of laboratory technicians testing gasoline and ancillary workers such as bottle washers may need further evaluation.

5. CONCLUSIONS

From the review of available exposure data the following conclusions can be drawn.

(1) With good work practices and use of appropriate control measures 8-hour TWA exposures should not normally exceed the proposed EEC Directive "Limit Value" of 5 ppm. However, drum filling and marine loading may require further attention.

(2) 8-Hour TWA exposures of service station attendants are clearly normally below 1 ppm. Exclusion from additional requirements of the Directive appears justified.

(3) The proposed EEC "Action Level" of an 8-hour TWA of 1 ppm is unlikely to be exceeded by:

- road tanker drivers;
- refinery unit operators (but those working on units processing higher than normal benzene content streams, i.e. more than about 7%, may require further assessment).

The summarised data on road tanker drivers may be adequate to justify a general exclusion in the Directive from the additional requirements. Refinery operators may need to be considered on an individual plant basis.

(4) The "Action Level" of 1 ppm is likely to be exceeded under some conditions by:

- rack operators and supervisors in road tanker filling;
- rail car loading;
- marine Loading;
- drum filling without efficient local exhaust ventilation.

In "good installations", exposures may still be below the 1 ppm 8-hour TWA "Action Level". "Good installations" are likely to include those with vapour recovery or control systems.

(5) More data may be needed on a local plant basis to assess 8-hour TWA exposures against the "Action Level" for:

- refinery maintenance workers;
- specific "off-sites" activities such as API separator operators, fuel laboratory technicians (including CFR engine operators);
- refinery operators on units processing higher than normal benzene content streams;
- drum filling with local exhaust ventilation;
- bottom loading of rail cars.

In some of these activities, exposures are infrequent or irregular and cumulative daily average exposures may well be below 1 ppm.

(6) It is recommended that additional data are collected according to recommended protocols and added to the general CONCAWE data base for use in preparing future summaries of exposures.