exposure profile: kerosines/jet fuels

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ABSTRACT

This report details the available exposure data for kerosines and jet fuels. It provides information on estimated release rates; measured human exposure data for occupationally exposed groups; and environmental exposure data for air, water and soil. The potential for indirect exposure via the food chain is also addressed.

The report also summarises the compositions, hazards and occupational exposure limits for kerosines and jet fuels, and gives supply and consumption figures for the European Union over the years 1992 to 1996.

KEYWORDS

kerosines, jet fuels, composition, occupational exposure limits, human exposure, environmental exposure.

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PREFACE

The risk assessment of chemical substances is based on a comparison of the potential adverse effects of a substance with the known or foreseeable exposure for man and the environment. Identification of the intrinsic hazards of a substance together with data on the extent to which man and the environment are exposed are therefore two key sets of information in the risk assessment process.

Hazard assessment procedures are well developed and are based on the principles laid down in the Dangerous Substances Directive. For petroleum substances, comprehensive information on the human and environmental toxicological characteristics has been extensively reviewed and is published in CONCAWE Report 98/54 and the CONCAWE Product Dossiers.

However, the collection of the corresponding exposure data for petroleum substances is less well advanced and, in consequence, a CONCAWE Task Force has been established to collate and review the available information. The objective of the work has been to identify exposed populations for each of the main petroleum substance groups and to quantify the level of exposure to which they are subjected. This has been done by assessing available data from member companies and from the published literature, and documenting it in the form of Exposure Profiles for the main petroleum substance groups. These Profiles will eventually form companion documents to the Product Dossiers and will be available for use by member companies and by the risk assessors.

Generally, there are three groups of persons that potentially may be exposed to petroleum substances, namely, workers through exposure in the work place (occupational exposure), consumers during the normal use of the substance, and the general population through exposure to contaminated air, soil, water and via the food chain. For environmental risk assessment, the potential exposure of aquatic systems, sediments, soil and air are considered.

Exposure data can be obtained by field measurements and may include sampling of air concentrations in the breathing zone for workers and consumers, biological monitoring where such techniques are available, and the measuring of concentrations in soil, air and water. However, for complex hydrocarbon mixtures such as petroleum substances, difficulties arise because on release into the environment, the individual components of the mixture have different fate and distribution patterns. Although monitoring techniques can measure total hydrocarbons and specific individual hydrocarbons, attributing measured concentrations to a particular petroleum substance is rarely possible.

To overcome some of these monitoring difficulties and to compensate for the lack of measured data generally, the Risk Assessment Regulation (1488/94) allows the use of computer modelling techniques for the estimation of exposure. Such models have been referenced in the text as appropriate. Nevertheless, some measured values are needed to validate the model predictions and to assess the relevance of the predicted output to actual situations. The collection of meaningful exposure data is therefore an essential prerequisite for the risk assessment of petroleum substances.

Each Exposure Profile report is being structured along the following lines:

- Substance description: use, production and consumption figures, composition, summary of hazard characteristics, applicable occupational exposure limits.

- Human exposure
    - Exposure routes
    - Occupational exposure
    - Consumer exposure
    - Indirect exposure of the general public via the environment.

- Environmental exposure
    - Exposure routes
    - Atmospheric exposure
    - Aquatic exposure, including sediments
    - Soil and ground water exposure
    - Major spillages.

1. INTRODUCTION

This Exposure Profile is a review of the available published data on exposure to kerosines and jet fuels. It considers human exposure data for workers in the petroleum industry and kerosine fuel distribution, consumers, and indirect exposure to the general public via the food chain and through inhalation of air. Environmental exposure covers releases to air, water, soil and groundwater, where such information is available.

In addition, the report gives a summary of the uses, compositions, hazards, occupational exposure limits, and supply and consumption figures for kerosines and jet fuels.

1.1. DESCRIPTION

Kerosine is the generic name for the lighter end of a group of petroleum substances known as middle distillates, the heavier end being gas oils. It consists predominantly of hydrocarbons in the C_9 to C_{16} carbon number range.

There are various EINECS numbers for kerosines, depending on whether they are based on straight-run or cracked components, or components derived from other refinery processes. A complete list of the EINECS numbers in each of these three groups is given in the Product Dossier for kerosines/jet fuels.[1]

1.2. USE

The main uses of kerosines are as follows:

- a jet fuel,
- a fuel for industrial and domestic heating appliances,
- an industrial solvent in the formulation of products such as cleaning agents, pesticides and printing inks,
- a diluent for certain lubricants such as two-stroke engine oils.

In addition, kerosines are used for domestic cooking and as a lamp oil. A known misuse of kerosine is as a fire-eater’s fluid.

1.2.1. Jet fuels

Aviation turbine or jet fuels fall broadly into three main types:

- kerosine type, usually blends of different kerosine components,
- “wide cut” type, in which kerosine components are blended with low flash point naphthas, for example, heavy straight-run naphtha, to give more volatile fuels covering the C_4 to C_{16} carbon number range,
- high flash point kerosine type, blends of kerosine components having a minimum closed cup flash point of 60°C.

The main grades of jet fuel are as follows.

Jet A-1	kerosine type fuel used in civil aircraft. Maximum freezing point of -47°C.
Jet A	as Jet A-1, but with a freezing point of - 40°C maximum. This grade is only available in the USA and Canada.
Jet B	wide cut type used in civil aircraft.
JP-4 (AVTAG)	wide cut type used in military aircraft.
JP-5 (AVCAT)	high flash point kerosine type used in naval aircraft.
JP-8 (AVTUR)	kerosine type used in military aircraft.

Wide cut fuels are limited in availability and are mainly used in military aircraft. They constitute only about 0.3% of the total consumption of kerosines in the EU and are of decreasing importance.

Fuel specifications for aviation purposes are issued by government authorities, engine manufacturers and airlines. They detail the properties and performance factors required for given applications. Typical specification limits for jet fuels are given in **Table 1.1.a** and typical physical properties and compositions in **Table 1.1.b.**

1.2.2. Domestic and industrial heating fuels

In Europe, domestic and industrial fuels based on kerosines are similar in composition to Jet A1. Domestic fuels can be used for firing hot water boilers for central heating systems and for cooking appliances fitted with a flue.

1.2.3. Illuminating kerosines

A small quantity of kerosine is manufactured for use in flueless applications such as small space heaters, open cooking stoves and for lamps. Such premium grade kerosines are more severely refined than standard grade kerosines and have extremely low sulphur contents to ensure that sulphur compounds in the flue gas do not reach hazardous levels. Also, to reduce the smoke generated during combustion, the aromatic hydrocarbon content of illuminating kerosine is lower than that for standard grade kerosine. Some commercial grades of illuminating kerosine may contain a dye.

1.2.4. Solvents

Solvents extracted from the kerosine range of hydrocarbons are widely used in the preparation of formulated products. Typically, these solvents boil over the range from 160 to 300°C, although some are of a narrow cut boiling between, for example, 180 to 205°C. Such solvents are used in special applications such as printing inks. Another example is odourless kerosine which is essentially free of aromatics.

Kerosine solvents are not primary products of the petroleum industry and are not considered in detail in this exposure profile.

1.3. PRODUCTION AND CONSUMPTION

Figures for the production and consumption of kerosines and jet fuels in the Member States of the European Union for the years 1992 to 1996 are given in **Table 1.2**. [2] The figures reveal a steady increase in the consumption over this period, particularly for jet fuels. The use of jet fuel is so significant that pipeline transfer of the product from refineries to airports is practised in many countries.

In these tables, refinery output excludes refinery losses; imports and exports relate to the quantities of the product crossing the European Union boundaries; and total consumption is the net observed inland consumption. Stock levels refer to the quantity of the product held in storage at the end of the relevant year. (Due to statistical differences in reporting and internal transfers between countries, the theoretical and reported total consumption figures are not identical).

1.4. COMPOSITION

Kerosines consist predominantly of a complex mixture of hydrocarbons in the C_9 to C_{16} carbon number range, with a typical distillation range of approximately 145 to 300°C. The predominant types of hydrocarbons found in kerosines are normal and branched chain alkanes, cycloalkanes, alkylbenzenes and alkylnaphthalenes.

1.4.1. Blending components

Marketed kerosines are normally preparations consisting of a blend of individual refinery kerosine type streams. These components contain a number of undesirable contaminants such as mercaptans and naphthenic acids that must be removed by a sweetening process before the product can be put on the market. Processes currently used include hydrotreatment which converts sulphur compounds to hydrogen sulphide; Merox treatment which extracts mercaptans; and sulfolane extraction.

A list of the components available for kerosine blending is given in the Product Dossier on kerosines/jet fuels. [1] Physical and elemental analyses for three such components are given in **Table 1.3.**

A marketed fuel may contain additives and those that are commonly used are anti-oxidants, anti-static additives, corrosion inhibitors, fuel system icing inhibitors, metal de-activators and biocides. The total concentration of these additives is generally less than 0.1% (m/m).

1.5. HAZARD IDENTIFICATION

1.5.1. Physico-chemical hazards

Jet A-1 and most kerosines for industrial and heating applications have flash points in the range 35 to 55°C. Under the EC Dangerous Substances Directive, [3] these products are classified as Flammable. Wide cut fuel types will normally have a flash point below 21°C resulting in a classification as Highly Flammable. High flash point kerosines have a flash point above 60°C and are not classified for flammability.

1.5.2. Health hazards

The main health hazard associated with kerosines is aspiration. [1] If kerosines are accidentally swallowed, small quantities can be aspirated into the lungs, either directly or indirectly through vomiting. This can induce intense irritation of lung tissues and can give rise to pneumonitis that can be fatal.

In contact with the skin, kerosines cause irritation and repeated and/or long long-term exposure can give rise to defatting of the skin and dermatitis. CONCAWE recommends that, unless evidence is available to the contrary, kerosines should be classified according to EC criteria as skin irritants. [4]

Generally, kerosines are not considered to be carcinogenic. In a two-year dermal study in rats, CONCAWE demonstrated that a typical kerosine was not a skin carcinogen. [5] Wide-cut kerosines containing more than 0.1% (m/m) benzene must be regarded as potentially carcinogenic under the EU Dangerous Preparations Directive.

Depression of the central nervous system and respiratory irritation may be experienced if, for any reason, high concentrations of vapours are inhaled. The use of personal protective equipment (PPE) is essential when using kerosine in confined spaces. Saturated vapour concentrations of 5.28 mg/L and 5.20 mg/L at 21 to 24°C have been observed in inhalation studies with straight-run kerosine (CAS No 8008-20-6) [6] and hydrodesulphurised kerosine (CAS No 64742-81-0)[7] respectively. These are extreme concentrations and in the normal storage and handling of kerosines, it is considered that there is no significant health risk from exposure to vapours.

Wide cut kerosines are more volatile than the standard grades of kerosine and may present an inhalation hazard in transfers, during distribution and in aircraft refuelling.

1.5.3. Environmental hazards

Acute aquatic toxicities for kerosines to fish, Daphnia and algae are in the range 1-100 mg/l. [8] Furthermore, kerosines are regarded as being not readily biodegradable in standard tests and are potentially bioaccumulative, having components that have log K_{ow} values of greater than 3. However, metabolic processes may preclude the realisation of significant bioconcentration by kerosine components. CONCAWE recommends that kerosine substances should be classified as Dangerous for the Environment. [4]

When kerosines escape into the environment, most of the constituent hydrocarbons will evaporate, but the less volatile components may persist for longer periods. Generally, kerosine hydrocarbons have low water solubilities, although aromatic hydrocarbons are more soluble than aliphatic components.

1.6. OCCUPATIONAL EXPOSURE LIMITS

There are no accepted occupational exposure standards for kerosines, although ACGIH is currently considering the introduction of an 8-hour time weighted average threshold limit value of 100 mg/m^3 (ACGIH 1998). However, **Table 1.4** lists some standards that have been set for kerosine components by the ACGIH and certain European authorities. For mixtures of hydrocarbon solvents, the relevant OELs can be calculated by the Reciprocal Calculational Procedure. [9]

2. HUMAN EXPOSURE

The characterisation of exposure to kerosines indicates that all exposure routes (inhalation, skin contact and ingestion) are relevant and various exposure groups are involved, in particular, workers, consumers and children. An overview of human exposure is presented in **Section 2.1**, followed by a more detailed survey and references to occupational exposure data in **Section 2.2** and consumer exposure in **Section 2.3.** Indirect exposure of the general public via the food chain and through inhalation of air is discussed in **Section 2.4.**

2.1. EXPOSURE ROUTES

2.1.1. Inhalation

Over the normal range of ambient temperature, the vapour pressure of the main grades of kerosine is too low for hazardous concentrations of vapour to accumulate in unconfined spaces. However, use in confined spaces or at elevated temperatures may result in the build-up of high concentrations of vapour.

The sprayed application of products containing kerosine will generate a mixture of vapour and aerosol providing increased opportunity for exposure via inhalation, together with skin contact and ingestion.

Although military grades of kerosine are not addressed in detail in this report (see **Section 1.2.1.**), it is noted that wide cut fuels are generally more volatile than commercial kerosine grades. In view of this, handling of wide cut fuels may result in the presence of high concentrations of vapour under normal operating conditions and may include exposure to benzene, toluene and xylenes. Exposure effects from the use of JP5, a high flash point kerosine, have also been noted in the literature. Details of the references and available exposure data for these grades are summarised in **Appendix I.**

2.1.2. Skin contact

The widespread use of kerosines, particularly in solvent applications, provides the potential for skin contact to be a significant route of exposure. This is particularly the case where immersion of hands is involved, e.g. during cleaning of components, or during sprayed applications. In such conditions, it is recommended that gloves are worn to minimise skin contact.

There are no data indicating that systemic effects result from dermal exposure to kerosine. However, it is known that kerosines will cause local effects by defatting the skin, leading to dermatitis after repeated or prolonged exposure. These effects can be minimised by the use of appropriate skin protection and good hygiene practices.

2.1.3. Ingestion

There are many recorded cases of the accidental ingestion of kerosines by children in domestic situations. [10] In addition, it is known that fire-eaters use kerosines (this use is not condoned). Both can lead to accidental ingestion and aspiration into the lungs with fatal consequences (see Section 1.5.2.).

The ingestion of kerosines and jet fuels is very rarely encountered in the industrial use of these products, although accidental ingestion may occur as a result of misuse, e.g. storage in inappropriate containers or siphoning by mouth. A small amount may be ingested following inhalation as a mist.

2.2. OCCUPATIONAL EXPOSURE

2.2.1. Job categories

Occupational exposure to kerosines and jet fuels occurs in the following work situations:

- **Manufacture and distribution of kerosine fuels**

This involves a variety of work activities ranging from production and ancillary operations within the refinery and distribution depots, e.g. tank dipping, pump repairs and filter cleaning, to loading of road tankers, drum filling, aircraft refuelling and delivery to retail outlets, industrial customers and domestic residences.

Table 2.1.a. provides a broad description of job groups and associated tasks involving potential exposure during these activities. Information is also given on the type of exposure control measures usually used.

- **Manufacture of formulated products**

Kerosine type solvents are widely used in the preparation of formulated products, for example: cleaning, degreasing and mould release agents, enamels, paints, polishes, thinners and varnishes, herbicides, insecticides and pesticides. The manufacture of these products is not carried out by the oil industry and, in consequence, a review of potential exposures is beyond the scope of this document.

- **Industrial use of formulated products**

Formulated products containing kerosine may be used in an industrial environment. Often these products require sprayed application, for example, paints, road laying of cut-back bitumen, insecticides and pesticides, which increase the opportunity for exposure by all routes. As with the manufacture of these products, a detailed review of the potential exposures during their subsequent use is beyond the scope of this document. However, some exposure to kerosine during the road laying of cut-back bitumen has been identified and included in the profile.

2.2.2. Exposure data - inhalation

Available measured exposure data have been reviewed for the job groups identified in **Table 2.1.a**. and are presented as follows:

- **Table 2.1.b:** Summary of personal arithmetic mean, 8-hour time-weighted average exposure.
- **Table 2.1.c:** Summary of personal arithmetic mean short-term exposures.
- **Table 2.1.d:** Exposure to kerosine vapour during road laying of cut-back bitumen.

In all cases, exposure data refers to total hydrocarbons only. As there are no individual hydrocarbons contained in kerosines considered to be particularly hazardous to health, speciation of hydrocarbons during analysis is rarely observed. Additionally, the number of hydrocarbon isomers for each carbon number is such that analytical resolution is often not practical, e.g. there are 35 isomers for nonane C_9H_{20} and 75 isomers for decane $C_{10}H_{22}$.

2.2.3. Exposure data - skin contact

There are many reports in the open literature that provide evidence of effects from dermal exposure to kerosine. They include the following:

- A study by Jee et al (1985) [11] investigated the prevalence rate of dermatoses (erythema, scaling and eczema) among workers in a ball-bearing factory and its possible association with exposure to kerosine.
- Observations made by Upreti et al (1989) [12] on 24 human subjects chronically exposed to kerosine in an automobile workshop.
- A report by Tagami and Ogino (1973) [13] about four children that developed dermatitis following contact with kerosine-soaked clothing.
- The case reported by Patterson (1993) [14] of a 40 year old sales representative who developed hand dermatitis which he attributed to his work. This involved demonstrating the effectiveness of cleaning products, including thickened hand cleaners containing kerosine.

2.2.4. Exposure data - ingestion

No published reports of occupational exposure via ingestion have been identified.

2.2.5. Exposure data - biological monitoring

No published reports have been identified in which biological monitoring has been used to establish total absorbed dose following exposure to kerosine. However, an analytical technique for the determination of kerosine type hydrocarbons in the blood has been established by K. Kimura et al (1991) [15] using a capillary GC/MS analysis combined with the headspace method and salting-out technique.

2.2.6. Exposure data - modelling

No data derived by modelling have been included in this review.

2.3. CONSUMER EXPOSURE

2.3.1. General

Kerosine fuels are used widely for illumination, heating and cooking. **Table 2.2.** summarises the tasks involving potential consumer exposure.

Kerosines are also used in formulated products such as two-stroke engine oils, penetrating fluids, cleaning/degreasing fluids, mould release agents, and as solvents in enamels, paints, polishes, thinners and varnishes. The deodorised product is utilised mainly for household sprays, herbicides, insecticides and pesticides. A medicinal use is in veterinary decontamination.

Although a detailed review of consumer exposure to formulated products containing kerosines is beyond the scope of this document, it is important to note that other components of such preparations may be significantly more hazardous than kerosines, e.g. the active components for herbicides, insecticides and pesticides. For these products, any hazard from kerosines is secondary to the more toxicologically significant components.

No exposure data in terms of inhalation of kerosine have been identified for consumers. However, reports indicating incidents of ingestion by children, kerosine abuse and its use by fire-eaters have been identified and are referenced below.

2.3.2. Ingestion by children

Identified references indicating the occurrence of accidental ingestion of kerosine by children are summarised below:

- An article prepared jointly by CONCAWE and the European Commission (1997) on the ingestion of lamp oils [16] reports that most of the incidents are associated with young children drinking the liquids directly from lamps or from sucking the wicks, rather than swallowing directly from the containers in which the lamp oils are supplied.

- The Official Journal of the European Communities [10] has reported in an answer to a written question that poisoning of small children following the ingestion of lamp oils has been documented in many Member States by the national poison centres. The incidence of poisoning is in the region of ten cases per year per million inhabitants. Some deaths have also been reported in Germany.

- The City of New York Department of Health (1963) [17] reported that a two-year-old male child ingested approximately 60g of furniture polish. The child vomited spontaneously soon after ingestion and was taken to hospital where the stomach was lavaged within thirty minutes following ingestion. During the stay in the hospital, the patient developed pneumonia that was diagnosed as hydrocarbon pneumonitis. After thirty-five days of hospitalisation the child recovered.

- In an editorial comment in the Journal of the American Medical Association (1955), [18] it was noted that in rural communities where kerosine is widely used for heating and cooking purposes and as a solvent for insecticides, physicians are frequently confronted with kerosene poisoning, particularly in young children. A review of 101 cases of kerosine poisoning in the previous nine years observed two fatalities in five hospitals in north-western Vermont. All the victims were children between eight months and two years of age, and inquiry among physicians in the area indicated that 30 to 40 other patients were treated at home. In most cases, the amount of kerosine ingested was not known, but it was considered unlikely that more than 90 ml were taken by any patient.

2.3.3. Kerosine abuse

Brander et al (1992) [19] reports two cases of hydrocarbon pneumonitis caused by the accidental aspiration of petroleum substances while performing fire-eating. Typically, fire-eaters use kerosine or kerosine type solvents.

In addition, one reference has been identified implicating kerosine in solvent abuse. This report by Partha (1992) [20] described an unusual case in New Delhi involving a 17 year old student with an 8-month history of kerosene use [abuse]. Swallowing half a teaspoonful the first time, she enjoyed the tingling sensation in the mouth and the heady feeling. Subsequently she started inhaling it also. Inhalation from a large container would occur almost daily for up to 60 minutes, and ingestion alone would occur once in about 15 days.

2.4. INDIRECT EXPOSURE OF THE GENERAL PUBLIC VIA THE ENVIRONMENT

As discussed in Section 3, the major environmental fate of kerosine components is volatilisation and therefore, many of these components are commonly found in urban air. However, their water solubility is low and therefore exposure via drinking water is expected to be negligible. Other potential environmental sources of human exposure are from contact with kerosine contaminated soil.

Most components of kerosine have log K_{ow} values such that they may be expected to bioaccumulate. Consequently, it is possible that some kerosine hydrocarbon components may be found in foods, for example, from plants grown on kerosine contaminated soil. There are numerous findings of the presence of aromatic components such as naphthalene [21] and methylnaphthalenes [22] in fish and shellfish, despite the ease of metabolism of these hydrocarbons. [23] These aromatic compounds are extensively metabolised in fish, so that biomagnification of these kerosine components is not encountered. [24]

Since hydrocarbons are naturally occurring in plants, it is likely that some of the heavier kerosine range paraffins would be present in foodstuffs arising from natural sources. However, n-paraffins are readily metabolised, but little is known of the disposition of branched alkanes in higher organisms. No data have been found on the occurrence of kerosine range paraffins in foodstuffs.

Thus, exposure to kerosine components via the food supply may be a remote possibility, but if found to be present in food, there may be a number of different sources of these components other than kerosine fuels (see **Section 3.1**).

Table 2.3 provides an overview of indirect exposure routes and likelihood of exposure.

3. ENVIRONMENTAL EXPOSURE

When a complex substance such as kerosine is released into the environment, the hydrocarbon constituents separate and distribute, in varying amounts, to the different environmental compartments according to their individual physico-chemical properties. Thus, the measurement of individual hydrocarbon components in the environment cannot be used directly to predict the environmental concentration of kerosine itself. Nor can this be predicted from the measurement of total hydrocarbons, since there may be multiple sources of hydrocarbons, both man-made and natural, in each environmental compartment.

Kerosine contains primarily aliphatic hydrocarbons with a carbon number range of C_9 to C_{16}. There is overlap in boiling range, and hence composition, between kerosine and gasoline at the lighter end of the range, and between kerosine and diesel fuel at the heavier end. The kerosine aliphatics range in log K_{ow} values from about 5 to 8. Aromatic hydrocarbons constitute about 25% of typical kerosines. These are mainly single ring compounds such as alkylbenzenes, but kerosine also may contain some 2-ring aromatics, mainly naphthalene and methylnaphthalenes. The aromatic components range in log K_{ow} from 3.3 to about 6.

The physical properties of log K_{ow}, vapour pressure and water solubility determine the equilibrium distribution of chemicals in the environment. [25] The level 1 (equilibrium) modelling approach of Mackay was used to calculate the environmental distributions of hydrocarbons spanning the range found in kerosine. The results of these calculations are shown in **Table 3.1.** In general, the lighter kerosine components are expected to distribute primarily to air, while the heavier components tend to distribute to soil. The aliphatic hydrocarbons, the main hydrocarbon type in kerosine, partition to water to a much smaller extent than similar carbon number aromatic hydrocarbons.

An estimate of the equilibrium concentrations of kerosine components in the environment can be made by the use of computer models that take into account the rates of input and degradation in the various environmental compartments. The European Commission model for risk assessment, EUSES, [26] contains the necessary algorithms for the prediction of environmental concentrations (PEC) of individual hydrocarbons. Furthermore, it provides for the estimation of environmental concentrations of “blocks” of similar hydrocarbons, the so called “hydrocarbon block method” developed by CONCAWE. [27] The detailed application of this model to estimate environmental concentrations of hydrocarbons from kerosine is not covered in this report.

Calculation of the environmental concentrations of kerosines requires data on the release rate of these substances to the environment. An approach to obtaining this data is to take the worst-case assumption that all C_9 through C_{16} hydrocarbons in refinery effluents are derived from kerosines. Such available data on refinery emissions, and monitoring data for C_9 to C_{16} hydrocarbons in air, water and soil generally are presented in the following Sections.

3.1. EXPOSURE ROUTES

Kerosines used as a fuel are mostly consumed during combustion. However, emission of kerosine components can take place during production in the refinery and subsequently during transport and use. Refineries and storage facilities are the only likely point source for such emissions, while the use of kerosine fuels is more likely to result in diffuse releases, primarily due to vapour emissions and incomplete combustion from the refuelling and operation of aircraft respectively. These diffuse releases may constitute the major portion of total kerosine emissions to the environment. Other sources of emissions are pipeline leakages, accidental spillages during transfer and transport, and deliberate discharges of fuel from aircraft for safety reasons.

It is not usually possible to identify kerosine as a single entity in the environment since its component hydrocarbons have different environmental fates. Moreover, these same hydrocarbons can come from other sources, both petrogenic and non-petrogenic, many of which are diffuse emission sources. For example, a US EPA study found that in four major US cities, of the hydrocarbons entering wastewater treatment plants (WWTP), 53% came from residential sources and 28% came from industry. [28] The hydrocarbons were measured as total oil and grease. On the other hand, naphthalene, a component of kerosine and analysed in the same study, came almost entirely (97%) from industrial sources. A subsequent EPA document identified naphthalene in the wastewater from 23 different industrial sources, of which petroleum refining was only one. [29]

Naphthalene is a component that is easily analysed and, in the US, is considered a “priority pollutant”. Thus, there is a considerable body of analytical data available on naphthalene in the environment, although the concentration of naphthalene in kerosine is small, generally less than 1%. Also, there are considerable environmental monitoring data on other aromatics found in kerosine, such as methylnaphthalenes and C_3-alkylbenzenes (propyl-, trimethyl- and, methylethyl-isomers).

However, it has been shown that other industries produce higher emissions of these aromatic compounds than petroleum refining and distribution activities. For example, BUA concluded that major sources of naphthalene in the environment are solvents and chemicals used for wood impregnation, chemical synthesis, mothballs, etc. [21] Much of this naphthalene comes from the coal tar industry, with only about 5% arising from petroleum. [21] Other major sources of naphthalene are combustion sources, including vehicle exhausts, heating, power generation, and cigarette smoke. Similar patterns are seen from other aromatic constituents such as 1,3,5-trimethylbenzene [30] and methylnaphthalenes. [22] These other aromatics are minor components of kerosine.

Saturated hydrocarbons occur in higher concentrations in kerosine than the aforementioned aromatics. The C_9 to C_{16} range of aliphatic hydrocarbons found in kerosine are present as an extremely large number of isomers. However, with the exception of the lower linear alkanes such as n-decane, it is generally not possible to analytically separate and identify all of these components and, as a consequence, few data on environmental occurrence exist. In addition, numerous products used in the building industry, as well as solvents, contain a similar range of aliphatic hydrocarbons.

Because there are a very large number of components in kerosine, presenting environmental exposure data on all of them is not practical. In consequence, a few typical components have been selected for the purpose of this profile; other components would be expected to behave in a similar fashion. The components that have been selected are n-decane, trimethylbenzene, naphthalene and methylnaphthalenes. Thus, in the following sections, environmental exposure data are presented primarily on these components.

3.2. ATMOSPHERIC EXPOSURE

Hydrocarbons emitted to air from refineries arise from the processing of crude oil and from finished products. Kerosine overlaps in boiling range and composition with several other refinery products, notably gasoline, gas oil/diesel fuels and several major solvent streams. Thus, the values shown in **Table 3.2** for airborne concentrations of selected hydrocarbons measured near refineries must be considered as worst case emission data for kerosine. [31] It is noted that near refineries, air concentrations of the heavier hydrocarbons are generally lower than the more volatile components such as C_8 hydrocarbons and below.

Measured data on the airborne concentrations of kerosine components from locations other than refineries are shown in **Tables 3.3 and 3.4.** **Table 3.3** summarises data on kerosine components from the United Kingdom directory of air quality data, [32] while **Table 3.4** summarises other available data on the selected components n-decane, trimethylbenzenes, naphthalene, and methylnaphthalenes. In general, the data on the selected hydrocarbons in **Table 3.4** were associated primarily with urban areas and, moreover, with roadway traffic. [22] As regards industrial sources, trimethylbenzenes in air near refineries are of the same order of magnitude (about 1 $\mu g/m^3$) as for plastic film manufacturing sites, and much lower than at a metal foundry (1400 to 4900 $\mu g/m^3$). [33] The same observations are true for naphthalene, where concentrations are also associated with urban areas and roadway traffic. [21] High levels are also reported in the vicinity of aluminium reduction plants, metal rolling mills and coke plants. [21] n-Decane is found at higher levels in urban air than rural air. [34]

The air concentration of kerosine components near roadways and traffic is likely to be due to exhaust from gasoline and diesel fuelled vehicles, both as combustion products and as escaped vapours. These same sources, together with the combustion of oil and coal for heating and power generation, are likely to contribute most of the C_9 to C_{16} kerosine components in urban air. Jet fuel can contribute to these components in urban areas near airports both through refuelling operations and unburnt kerosine in aircraft exhaust emissions. [35] It is commonly found that indoor air concentrations of these selected hydrocarbons are higher than for outdoor air, for example n-decane. [34]

3.3. AQUATIC EXPOSURE

The concentrations of individual hydrocarbon species in refinery wastewater has been studied and reported by the petroleum industry in the US [36] and Canada. [37] Both of these studies were done in conjunction with the national authorities and a selection of the kerosine components analysed is presented in **Table 3.5**. These are aromatic components, which are more soluble in water than aliphatic components for the C_9 to C_{16} carbon number range. No data are available for aliphatic kerosine components in refinery wastewater. In general, the aromatic components are present in low concentrations in influents to the refinery wastewater treatment plant and are removed to below the limit of detection by biological wastewater treatment.

Although hydrocarbons are known to be inherently biodegradable and may be expected to biodegrade to some extent in biological wastewater treatment plants, the higher molecular weight hydrocarbons found in kerosines are expected to partition to sludge as well, due to their hydrophobic nature. The majority of European refineries have advanced biological wastewater treatment plants and the sludges from these plants are burned and landfilled; none are used for agricultural purposes.[38] A Danish study reported finding naphthalene, methyl naphthalenes and other kerosene range hydrocarbons in sludges from nineteen wastewater treatment plants, but the source of these substances was not known.[39] An earlier US study found naphthalene in the sludge at three out of seven publicly owned treatment plants, but these occurrences were not particularly associated with refining, petrochemical or fuel industries.[40]

Measured data for the selected components, n-decane, trimethylbenzenes, naphthalene, and methylnaphthalenes in the aquatic environment are available for a number of locations. These data are shown in **Table 3.6**. In general, waterways that have heavy industrial use have higher concentrations of these compounds. Some of the contamination of waterways with hydrocarbons is likely to be due to fuel spills, including kerosines. As noted in **Table 3.5**, refinery contributions to waterborne hydrocarbons are quite low.

3.4. SOIL EXPOSURE

No monitoring data were found on the occurrence of kerosine components in soil. There are a few data on the concentrations of kerosine hydrocarbons in sediments and some of these data are presented in **Table 3.7**.

If the sludges mentioned in the previous section are disposed of on land, it may be expected that kerosine range components present in the sludges will be found in the soil where this practice is carried out. Kerosine components can also be transported from the atmosphere to the ground through rain. Deposition measurements for kerosine components from the UK directory of air quality data[32] are listed in **Table 3.8**.

As previously discussed, the physical properties of kerosine components cause them to partition primarily to air. In a study of kerosine components in soil columns, it was found that volatilisation from soil was the major fate process. Once the liquid phase of a “synthetic kerosine” had gone, downward mobility of components into soil was limited.[41] The heavier components of kerosine components are less volatile and, due to their high log K_{ow}, are likely to adsorb strongly to soil and have low mobility.

The hydrocarbon components of kerosine are inherently biodegradable.[42] Illustrating this, agencies in the Netherlands have successfully used landfarming techniques to remediate kerosine-contaminated soil.[43] In the case of a pipeline leak of 1.9 million litres of kerosine into a New Jersey wheat field, a similar remediation technique was used. This consisted of application of lime and fertiliser and frequent tilling. Seed germination and crop yield showed that the field returned to a near normal productive state one year after the spill and hydrocarbon levels of the soil decreased to an insignificant level in two years.[44]

Although kerosine components are biodegradable, adsorption to sediment and soil can slow biodegradation.[45] As a result, large spills may affect the soil environment for a prolonged period. In a study of an acid sludge containing kerosine range hydrocarbons, heavier (280-350°C) non-paraffinic hydrocarbons, and sulphuric acid which was purposefully dumped in a moorland soil, effects on vegetation and microflora were still evident after seven years.[46] In the case of a spill on to very sandy soil, kerosine may not be adsorbed and hence may migrate downwards as a non-aqueous liquid. In the report of a storage tank leak of 315,000 litres of jet fuel, the liquid moved through porous sandy ground to the water table approximately 2 to 4m below the surface.[47]

3.5. MAJOR SPILLAGES

3.5.1. Pipeline spillages

CONCAWE maintains records of all petroleum pipeline spillages exceeding 1 m^3 and issues annual summary reports detailing these incidents. A number of these spillages have involved the release of jet fuels.

3.5.2. Fuel jettisoning

Sommerville (1997) [48] reports that jet fuel can be jettisoned from aircraft for safety reasons. Data on the quantities involved are not given. As far as possible, such discharges are made at a high altitude and away from areas of population. The vast majority of the fuel will be vaporised.

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Table 1.1 Specification limits and properties for typical jet fuels.

Table 1.1.a Specification limits.

Property	Unit	Method (ASTM)	Jet fuels A and A1	Jet fuel B	JP-4 Wide Cut (Avtag)	JP-5 High flash kerosine (Avcat)	JP-8 kerosine (Avtur)
Distillation range, 10% over	°C	D86	205	-	-	205	205
Distillation end point, max	°C	D86	300	-	270	300	300
Density at 15°C	kg/m^3	D4052	775-840	751-802	751-802	788-845	775-840
Reid vapour pressure at 37.8°C	hPa	D323	-	-	140-210	-	-
Closed cup flash point, min	°C	D3828	38	-	-	60	38
Kinematic viscosity at -20°C, max	mm^2/s	D445	8.0	-	-	8.5	8.0
Freezing point, max	°C	D2386	-40 (Jet A) -47 (Jet A1)	-50	-58	-46	-47
Aromatics, max	%v/v	D1319	25	25	25	25	25

Source: CONCAWE (1995) [1]

Table 1.1.b Physical properties and compositions.

	Commercial Jet A	Commercial Jet A1	Wide-cut JP-4	High flash JP-5
Sample origin	USA	Europe	USA	USA
Density at 15°C, kg/m^3	0.814	0.801	0.760	0.820
Distillation temperatures:				
10% evaporated, °C	188	169	92	198
50% evaporated, °C	213	194	138	215
90% evaporated, °C	246	236	198	242
Kinematic viscosity, mm^2/s at -20°C	5.48	3.85	-	-
Freezing point, °C	-45	-52	-61	-49
Sulphur, % m/m	0.035	0.054	0.018	0.020
Naphthalenes, % m/m	1.59	1.74	-	-
Aromatic content. % V/V	18.5	18.5	13.4	19.1
Olefin content, % V/V	1.0	0.5	0.7	0.8

Source: IARC (1989) [49]

Table 1.2 Kerosine production and supply figures for the European Union.

Table 1.2.a Jet fuels (aviation kerosine).

Units: 000 tonnes

	1992	1993	1994	1995	1996
Refinery output	30439	31446	33548	34972	37941
Imports	7886	7730	7790	7223	7194
Exports	8452	7927	9113	9553	10357
Total consumption	27901	29249	30599	32084	33685
Stock level at year end	3237	3359	3517	3368	3526

Source: IEA/OECD (1997) [2]
Note: Designated “kerosine type jet fuels” in OECD statistics

Table 1.2.b Kerosines used as heating fuels and for other applications.

Units: 000 tonnes

	1993	1994	1995	1996
Refinery output	5108	5488	5059	5619
Imports	2064	2272	1458	1306
Exports	1540	1357	698	764
Total consumption	4225	4563	4649	5292
Stock level at year end	977	927	916	1129

Source: IEA/OECD (1997) [2]
Note: Designated “other kerosine” in OECD statistics

Table 1.2.c Wide cut kerosines.

Units: 000 tonnes

	1992	1993	1994	1995	1996
Refinery output	598	418	435	697	357
Imports	68	86	2	0	1
Exports	382	331	402	425	47
Total consumption	344	185	93	80	102
Stock level at year end	44	40	26	10	12

Source: IEA/OECD (1997) [2]
Note: Designated “Gasoline type jet fuel” in OECD statistics.

Table 1.3 Physical and elemental analyses for three different kerosine types of European origin.

Analysis	Unit	Sweetened kerosine CAS No 91770-15-9	Hydro-desulphurized kerosine CAS No 64742-81-0	Hydrocracked kerosine CAS No 101316-80-7
Boiling range °C	°C			
Initial		151	156	187
Final		257	255	288
Density at 16°C	kg/m^3	800	803	808
Sulphur	mg/kg	281	<20	<20
Nitrogen	mg/kg	1	1	1
Chloride	mg/kg	<5	<5	<5
Oxygen	mg/kg	290	290	290
Branched alkanes	%(m/m)	20.0	16.5	36.6
n-Alkanes	%(m/m)	22.2	19.4	5.8
n-Alkane range (>0.1%)	%(m/m)	C7-C17	C8-C15	C8-C18
Cycloalkanes	%(m/m)	33.5	35.9	30.9
Alkylbenzenes	%(m/m)	15.4	20.4	14.3
Indanes and tetralins	%(m/m)	3.1	3.8	8.2
Indenes	%(m/m)	0.1	not detected	0.2
2 ring aromatics	%(m/m)	5.5	3.8	3.5
3-ring aromatics	%(m/m)	0.2	0.2	0.3

Source: CONCAWE (1996) [8]

Note: Hydrocarbon distributions by gas chromatography/mass spectrometry.

Table 1.4 Occupational exposure limits for kerosine components.

Units: mg/m^3

	Limit	ACGIH	France	Germany	NL	Sweden	UK
Trimethylbenzene (isomers) CAS No 2551-13-7	TWA STEL	123 NA	125 NA	100 400	100 NA	120 170	125 NA
Naphthalene CAS No 91-20-3	TWA STEL	52 79	50 NA	50 NA	50 NA	NA NA	53 80
Nonane CAS No 111-84-2	TWA STEL	1050 NA	1050 NA	NA NA	1050 NA	800 (1) 1100 (1)	NA NA
Isopropylbenzene (cumene) CAS No 98-28-8	TWA STEL	246 Sk NA	245 Sk NA	250 Sk NA	100 Sk 250	120 Sk 170	125 Sk 375
Reference		ACGIH (1998) [50]	INRS (1993) [51]	DFG (1998) [52]	SZW (1998) [53]	AFS (1996) [54]	UK HSE (1998) [9]

Notes:

TWA:	Time Weighted Average for 8-hour day and 40 hour week
STEL:	Short Term Exposure Limit (measured over a 15 -min period, unless noted otherwise).
Sk:	Can be absorbed through the skin.
NA:	Not assigned. No figure quoted by the authority.

(1) Nonanes (all nonane isomers)

See original references for details of the individual exposure limits.

Table 2.1.a Tasks involving potential for exposure to kerosine and usual control measures for workers.

	Job Group	Description of tasks	Pattern of control
1.	REFINERY		
1.1.	On-site operator	Operators carry out tasks involved in controlling plants which process hydrocarbon streams to produce kerosine, e.g. valve operation, sample collection, blowing down gauges, draining down lines/vessels in preparation for maintenance.	Full containment, Natural ventilation; PPE(Note a) (skin)
1.2.	Off-site operator	Ancillary operations carried out by refinery workers, e.g. laboratory technicians (quality control/research tests), tank farm activities (dipping/sampling/discharge of tank water bottoms), sample bottle washing, interceptor cleaning.	Full containment; Local exhaust ventilation (laboratory); Natural ventilation; Safe operating procedure; PPE (skin)
1.3.	Maintenance worker	Carry out a variety of tasks some of which may involve exposure to kerosine liquid and vapour when draining, cleaning, opening up and working on normally enclosed equipment.	Natural ventilation; Safe operating procedure: PPE (skin)
1.4.	Tank cleaning	A specialist activity involving cleaning out sludge from bulk storage tanks, interceptor cleaning.	Dilution ventilation; Safe operating procedure (Permit to Work); PPE (skin and possibly breathing)
2.	DISTRIBUTION		
2.1.	Road Tanker Driver	Top and bottom loading of road tanker vehicles. Fuel testing for water. Road tank flushing to dump trolley following change of grade. Delivery to industrial and domestic customer storage. Some drivers may be involved in top loading heated cut back bitumen (potential exposure to kerosine vapour).	Natural ventilation; Safe operating procedure; PPE (skin) Local exhaust ventilation during loading of cut-back bitumen.
2.2.	Rail car operators (loading)	Operators involved in top loading of rail cars.	Full containment (bottom loading with vapour recovery). Dilution ventilation; Safe operating procedure; PPE (skin)
2.3.	Rail car operators (off-loading to storage)	Operators involved in hose connection/ disconnection and sampling. Note: this may form part of the Terminal Operator’s tasks.	Full containment; Dilution ventilation; Safe operating procedure; PPE (skin)
2.4.	Jetty staff	Supervision of ship/barge loading operations, sampling, tank dipping, handling of hoses.	Natural ventilation; Safe operating procedure; PPE (skin)
2.5.	Deck crew: ships/barges	Loading of ships/barges using flexible hoses and venting via cargo tank relief valves. Tasks include connection/disconnection of cargo lines, checking tank fill levels, tank dipping.	Closed filling connections; Natural ventilation; Safe operating procedure; PPE (skin)
2.6.	Terminal operators	Carry out tasks as per 1.2. 'off site operators' within the Distribution depot. In addition, return of tank flushings to storage.	Natural ventilation; Safe operating procedure; PPE (skin)
2.7.	Meter provers	Meter proving and minor repairs to metering equipment. Connection/disconnection of road vehicle hoses.	Natural ventilation; Safe operating procedure; PPE (skin)

Table 2.1.a Tasks involving potential for exposure and usual control measures for workers. *continued.*

	Job Group	Description of tasks	Pattern of control
2.8.	Vehicle Mechanic	Hose repair and pressure testing. Use of kerosine as a degreasant for washing vehicle components. Tank compartment inspection.	Dilution ventilation; Safe operating procedure (PPE (skin)
2.9.	Small pack filling	Filling e.g. 25 L containers, 200 L drums, intermediate bulk containers. This may be carried out at a retail outlet.	Dilution ventilation; PPE (skin)
3.	AIRPORTS (Jet A-1)		
3.1.	Operators (b)	Bottom loading of road tankers, aircraft refuelling by tanker, aircraft refuelling via hydrant, aircraft unloading by tanker, fuel testing for water and specific gravity.	Full containment (loading); Dilution ventilation; Safe operating procedure; PPE (skin).
3.2.	Yard staff (b)	Fuel testing for water and specific gravity, testing of cylindrical water filters for efficiency, filter changing, meter proving and meter servicing.	Natural ventilation; Safe operating procedure; PPE (skin)
3.3.	Vehicle (shop) mechanic	Hose repair and pressure testing. Use of kerosine as a degreasant for washing vehicle components. Tank compartment inspection.	Dilution ventilation; Safe operating procedure PPE (skin)
3.4.	Yard (ramp) mechanic	Carry out a variety of tasks some of which may involve exposure to kerosine liquid and vapour when draining, cleaning, opening up and working on normally enclosed equipment.	Natural ventilation; Safe operating procedure: PPE (skin)
3.5.	Tank cleaning	A specialist activity involving cleaning out sludge from bulk storage tanks.	Dilution ventilation; Safe operating procedure (Permit to Work); PPE (skin and breathing)
4.	DOMESTIC RESIDENCE		
4.1.	Domestic heating supplier	Replacement of domestic oil fired heating storage vessels that may involve draining fuel storage tank.	Full containment (except for draining of storage tank), Natural ventilation, Safe operating procedure; PPE (skin)
4.2.	Domestic heating engineer	Servicing of oil fire central heating system including visual and mechanical inspection of entire system including the storage vessel, boiler and radiators. Little or no contact occurs with kerosine.	Full containment; Natural ventilation; PPE (skin)

Notes:

(a) PPE: Personal protective equipment.
(b) These jobs may be combined at small airports.

Table 2.1.b Summary of personal arithmetic mean, 8-hour exposures.

Job Group/ Activity	**Region**	**Sample duration (min)**	**Units - mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)** **Total hydrocarbons**	**Reference (Date)**
1. REFINERY				
1.1. On-site operator	no data			
1.2. Off-site operator	no data			
1.3. Maintenance worker				
- Refinery shut down	Sweden	460 - 713	28.0 [11] (12.2 – 66.4)	In-house data [55] (1988-89)
1.4. Tank cleaner	no data			
2. DISTRIBUTION				
2.1. Road tanker driver				
- top loading	UK	323	4.4 [1]	In-house data [56] (1989)
2.2. Rail car operator - loading	no data			
2.3. Rail car operator - off loading	no data			
2.4. Jetty staff	no data			
2.5. Deck crew: ships/barges	no data			
2.6 Terminal operator	no data			
2.7. Meter prover	no data			
2.8. Vehicle mechanic	no data			
2.9. Small pack filling	no data			
3. AIRPORTS (Jet A-1)				
3.1. Operators	Norway	480 equivalent	8.0 [5] (0.17 - 38.0)	In-house data [58] (1995)
	France	480 equivalent	1.0 [16] (0.2 - 1.9)	In-house data [59] (1997a)
	Italy	480 equivalent	0.7 [8] (no data)	In-house data [60] (1996)
	Italy	480 equivalent	0.4 [4] (no data)	In-house data [60] (1997b)
	USA	330 - 519	2.25 [16] (0.4 - 7.6)	NIOSH [61] (1994)
3.2. Yard staff - tank sampling	UK	419	2 [1]	In-house data [55] (1988-89)
3.3. Vehicle (shop) mechanic	USA	451 - 493	5.8 [6] (3.0 - 7.8)	NIOSH [61] (1994)
3.4. Yard (ramp) mechanic	USA	529 - 538	1.4 [4] (0.8 - 2.3)	NIOSH [61] (1994)
3.5. Tank cleaning	no data			

Table 2.1.b Summary of personal arithmetic mean, 8-hour exposures…..*continued.*

Job Group/ Activity	**Region**	**Sample duration (min)**	**Units - mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)**	**Reference (Date)**
			Total hydrocarbons	
4. DOMESTIC RESIDENCE				
4.1. Domestic heating supplier	no data			
4.2. Domestic heating engineer	no data			

Table 2.1.c Summary of personal arithmetic mean short-term exposures.

Job Group/ Activity	**Region**	**Sample duration (min)**	**Units - mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)**	**Reference (Date)**
			Total hydrocarbons	
1. REFINERY				
1.1. On-site operator	no data			
1.2. Off-site operator	no data			
1.3. Maintenance operator	no data			
1.4. Tank cleaning	no data			
2. DISTRIBUTION				
2.1. Road tanker driver:				
- top loading	UK	43	27.2 [1]	In-house data[57] (1990)
- top loading	UK	30	4.5 [1]	In-house data[55] (1988-89)
- top loading cut back bitumen (a)	UK	25	19 [1]	In-house data[55] (1988-89)
- off loading cutback bitumen (a)	UK	29	24 [1]	In-house data[55] (1988-89)
2.2. Rail car operators (loading)	no data			
2.3. Rail car operators (unloading)	no data			
2.4. Jetty staff - barge loading (b)	Holland	no data	no data [5] (1.0 - 9.0)	In-house data[55] (1988-89)
2.5. Deck crew: ships/barges	no data			
2.6. Terminal operators				
- General duties, incl. Water testing	UK	38	16.1 [1]	In-house data[57] (1990)
- Laboratory testing	UK	51 (usually 25)	56.5 [1]	In-house data[57] (1990)
2.7. Meter prover	no data			
2.8. Vehicle mechanic	no data			
2.9. Small pack filling	no data			
3. AIRPORTS (JET A-1)				
3.1. Operators				
- refuelling aircraft	Norway	17 - 36	0.6 [5] (0.15 - 1.6)	In-house data[58] (1995)
- refuelling aircraft	Europe	150	57 [1]	In-house data[62] (1991)
- road tanker bottom loading	Norway	11 - 27	1.6 [3] (1.4 - 2.0)	In-house data[58] (1995)
- over-wing loading	UK	typically up to 45 min	18.4 [1]	In-house data[55] (1988-89)

Table 2.1.c Summary of personal arithmetic mean short-term exposures…..*continued.*

Job Group/ Activity	**Region**	**Sample duration (min)**	**Units - mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)**	**Reference (Date)**
			Total hydrocarbons	
3.2. Yard staff				
- filter inspection	Norway	13 and 30	45.0 [2] (34.0 - 56.0)	In-house data [58] (1995)
- filter testing	UK	86 and 93	77.0 [2] (68.3 - 85.7)	In-house data [55] (1988-89)
- fuel sampling and testing road tankers	Europe	25	8.9 [1]	In-house data [55] (1988-89)
- fuel sampling and testing bulk storage	Europe	49	28.4 [1]	In-house data [55] (1988-89)
3.3. Vehicle mechanic				
- hose repair and pressure test	Europe	130	6.4 [1]	In-house data [55] (1988-89)
3.4. Tank cleaning	no data			
4. DOMESTIC RESIDENCE				
4.1. Domestic heating supplier				
- replacement of storage vessel	Europe	116	15.5 [2] (8.0 - 23.0)	In-house data [55] (1988-89)
4.2. Domestic heating engineer	no data			

Notes:

(a) Exposure measurements refer to the kerosine component of the cutback bitumen only. Local exhaust ventilation used

(b) On scrutiny of chromatograms, it is possible that some exposure occurred to light hydrocarbons either from the previous load, or an adjacent barge loading gasoline.

Table 2.1.d Measured exposures to kerosine vapour during road laying of cut-back bitumen.

Job Group/ Activity	**Region**	**Sample duration (min)**	**Concentration in mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)**	**Reference (Date)**
			Total hydrocarbons	
ROAD LAYING CUT BACK BITUMEN				
1. Spray bar operator (a)	UK	362 - 478	216 [2] (145 - 287)	In-house data [63] (1987)
2. Spreader driver (a)	UK	362 - 478	27 [2] (23 - 31)	In-house data [63] (1987)

Notes:

(a) Exposure measurements refer to the kerosine component of the cutback bitumen only

Table 2.2 Typical tasks involving potential for exposure and usual control measures for consumers.

	Task	**Task description**	**Pattern of control**
1.	Use of lighter fuel	Small quantity poured from storage container on to e.g. barbecues, open fires and bonfires to assist ignition.	Natural ventilation; infrequent and short term exposures
2.	Refilling lamp oil appliances	Small quantity poured from storage container into appliance.	As above
3.	Refilling heating and cooking oil appliances	Small quantity poured from storage container into appliance.	As above
4.	Use as a degreasant or cleaner of mechanical components	Small quantity poured into a container into which components are placed and manually cleaned. Transfer of waste into container pending controlled disposal.	As above, impervious gloves recommended to prevent skin contact during contact with kerosine, e.g. during manual cleaning of components.

Note: This table does not include consumer exposure to formulated products containing kerosines.

Table 2.3 Overview of indirect exposure routes.

	Environmental compartment	**Source of emission**	**Exposure**
1.	Air (inhalation)	Ambient air concentrations dependent on location (rural, urban, close to airports):- - fugitive emissions from refineries, oil depots, airports; - evaporative losses from e.g. distribution of kerosine; storage tanks; spills; contaminated soil - fuel dumping by aircraft in emergency situations - emission of unburnt fuel during aircraft take off	May occur around emission sources
2.	Water (ingestion/skin contact)	Drinking water; rain fall	Negligible in drinking water
3.	Soil (ingestion/skin contact)	Contaminated soil	Negligible, except at contaminated sites
4.	Food (ingestion)	Contamination, indirect	Negligible

Table 3.1 Calculated environmental distribution for typical kerosine components.

Hydrocarbon	Air (%)	Water (%)	Soil (%)	Sediment (%)
n-Nonane	99.7	0	0.3	0
n-Hexadecane	5.4	0	92.4	2.1
Trimethylbenzene	95.4	0.6	3.9	0.1
n-Pentylbenzene	95.2	0.5	4.6	0.1
Naphthalene	76.3	8.2	15.2	0.3
Trimethylnaphthalene	10.0	0.4	87.6	1.9

Table 3.2 Measured concentrations of selected kerosine components in air near refineries.

Chemical	Refinery	Upwind		Downwind	
		Range ($\mu g/m^3$)	Detected N(a)	Range ($\mu g/m^3$)	Detected N(a)
1,2,4-trimethylbenzene	1	Not detected	0	Not detected	0
	2	-	-	<1-6.4	6/27
	3	<1-4	6/12	<1-3	8
Isopropylbenzene	1	Not detected	0/18	Not detected	0/9
	2	-	-	Not detected	0/27
	3	Not detected	0	Not detected	0/15
Naphthalene	1	Not detected	0	Not detected	0
	2	-	-	Not detected	0
	3	Not detected	0	Not detected	0

Source: API (1989) [31]

Notes
(a) N = number of samples with analyte detected / total number of samples analysed.

Table 3.3 Measured airborne concentrations of kerosine hydrocarbons at various UK sites from the UK directory of air quality data.

Component	21 day mean air concentrations measured at eight sites in Leeds, UK (1994)		Annual mean concentrations across six sites in the UK (1991-92)	
	Range, µg/m^3	Mean, µg/m^3	Range, µg/m^3	Mean, µg/m^3
n-Nonane	0.129 – 0.295	0.200	-	-
2-methyloctane and 4-methyloctane	0.071 – 0.351	0.149	-	-
3-methyloctane	0.044 – 0.148	0.069	-	-
Dimethylheptanes (two isomers)	0.025 – 0.111	0.044	-	-
n-Decane	0.260 – 0.730	0.474	-	-
Dimethyloctanes (mixed isomers)	0.039 – 0.110	0.070	-	-
2-methylnonane	0.068 – 0.294	0.149	-	-
4-methylnonane and 1,3,5-trimethylbenzene	0.161 – 0.950	0.399	-	-
n-Undecane	0.106 - 0.313	0.202	-	-
n-Dodecane	0.044 – 0.236	0.104	-	-
1,2,3-trimethylbenzene	0.081 – 0.522	0.216	-	-
1,2,4-trimethylbenzene	0.388 – 2.608	1.028	-	-
1,3,5-trimethylbenzene and 4-methylnonane	0.162 – 0.951	0.400	-	-
2,2,5-trimethylhexane	0.032 – 0.119	0.050	-	-
n-Propylbenzene	0.081 – 0.364	0.160	-	-
i-Propylbenzene	0.038 - 0.093	0.047	-	-
Propylcyclohexane	0.037 – 0.098	0.062	-	-
1,2-dimethyl-4-ethylbenzene	0.041 – 0.280	0.100	-	-
1,3-dimethyl-4-ethylbenzene	0.029 – 0.222	0.080	-	-
1,4-dimethyl-2-ethylbenzene	0.042 – 0.255	0.103	-	-
1,2,4,5-tetramethylbenzene	0.030 – 0.161	0.057	-	-
1-methyl-3-n-propylbenzene	0.033 – 0.224	0.088	-	
1.2.3.5-tetramethylbenzene	0.036 – 0.289	0.098	-	-
n-butylbenzene (plus two unidentified components)	0.055 – 0.568	0.228	-	-
Naphthalene	0.051 – 0.272	0.140	-	-
Acenaphthene	-	-	0.001 – 0.009	0.003
Acenaphthylene (three sites only)	-	-	0.002 – 0.011	0.005
Fluorene	-	-	0.007 – 0.048	0.021
Anthracene	-	-	0.002 – 0.010	0.005

Source: Bertorelli and Derwent (1995)[32]

Table 3.4 Measured concentrations of selected kerosine components in the atmospheric environment.

Chemical	Source	Place	N[a]	Range $\mu g/m^3$	Mean $\mu g/m^3$	Reference (Date)
n-Decane	urban	Tulsa OK, USA	?/8	3.5-40.8	16.0	Arnts (1981) [64]
	urban	Rio Blanco CO, USA	?/6	7.7-31.9	16.0	Arnts (1981) [64]
	urban	Neenah WI, USA	-	-	0.16	Shields (1987) [65]
	urban	Newark NJ, USA	-	-	2.23	Shields (1987) [65]
	urban	Cities, USA	?/790	-	0.36	Shaw (1988) [66]
	urban	Brunel Univ., UK	-	-	72.2	Colenutt (1980) [67]
	urban	Paris	-	4.3-11.2	-	Raymond (1974) [68]
	urban	Zurich	-	-	9.5	Grob (1971) [69]
	urban	Pretoria, SA	-	-	3.5	Louw (1977) [70]
	urban	Johannesburg, SA	-	-	4.1	Louw (1977) [70]
	urban	Durban, SA	-	-	3.0	Louw (1977) [70]
	urban	Sydney	-	0.6-19.5	4.1	Nelson (1982) [71]
	urban	Netherlands	?/20	-	45.0	Smyers-Verbeke (1984) [72]
	urban	Netherlands	?/24	-	45.0	Smyers-Verbeke (1984) [72]
	suburban	various, USA	?/336	-	1.2	Shaw (1988) [66]
	rural	Duren, Germany	-	-	<1.2	Rudolph (1985)[73]
	rural	Jones Forest TX, USA	?/10	2.4-163.8	33.1	Seila (1979) [74]
	remote	Smokey Mtn. NC, USA	?/9	2.4-5.3	3.5	Arnts (1981) [64]
	remote	various, USA	?/6	-	<1.2	Shaw (1988) [66]
Trimethylbenzene	urban	Germany	-	2.1-11.2	-	Schenck (1986a) [75]
1,3,5-trimethylbenzene	urban, heavy traffic	Frankfurt roadway	-	-	2.4	Battelle (1974) [76]
	urban, light traffic	Frankfurt roadway	-	-	0.7	Battelle (1974) [76]
	urban, heavy traffic	Frankfurt city centre	-	-	29	Battelle (1974) [76]
	urban, light traffic	Frankfurt residential	-	-	3.4	Battelle (1974) [76]
	underpass	Bavaria	-	-	55	Bavarian EPA (1989) [33]
	rural	Bavaria	-	0.4-1	-	Bavarian EPA (1989) [33]

Table 3.4 Measured concentrations of selected kerosine components in the atmospheric environment…..*continued.*

Chemical	Source	Place	N(a)	Range µg/m^3	Mean µg/m^3	Reference (Date)
1,3,5-trimethlbenzene	suburban	Munich	-	2-2.7	-	Bavarian EPA (1989) [33]
Continued	urban	Los Angeles	?/136	up to 54	15	Lonneman (1968) [77]
	tunnel	Rotterdam	?/12	up to 25	15	Jeltes (1977) [78]
	urban	The Hague	?/12	up to 20	10	Jeltes (1977) [78]
	suburban	Netherlands	?/12	up to 2.5	2.5	Jeltes (1977) [78]
	urban	European Community	-	<1 to 16	<5.3	Schenk (1986a) [75]
	remote	Black Forest	-	0.01-0.07	-	Juttner (1988a) [79]
	rural	Tubingen	-	0.07-0.29	-	Juttner (1988a) [79]
	various	Netherlands	-	0.4-1.2	-	Guicherit (1985) [80]
Naphthalene	urban	Germany	-	0.3-0.6	-	Schenck (1986b) [81]
	suburban	Kiel Bay, Germany	-	0.002-0.03	0.01	Bouchertall (1986) [82]
	industrial	Berlin	-	<0.01-1.0	0.3	Schenck (1986b) [81]
	traffic	Berlin	-	<0.01-2.9	0.6	Schenck (1986b) [81]
	residential	Berlin	-	<0.01-1.8	0.4	Schenck (1986b) [81]
	remote	Black Forest	-	0.02-0.22	-	Juttner (1988a) [79]
	rural	Tubingen	-	0.19-0.47	-	Juttner (1988a) [79]
1-methylnaphthalene	urban, heavy traffic	Oslo	-	0.04-0.24		Alfheim (1985) [83]
	urban, heavy traffic	Oslo	-	-	0.03	Larssen (1985) [84]
	urban, light traffic	Oslo	-	-	0.02	Larssen (1985) [84]
	urban + industrial	Sundsval, Sweden	-	0.02-0.12	-	Thrane (1984) [85]
	urban	Sundsval, Sweden	-	0.005-0.05	-	Thrane (1984) [85]
	urban	Pasadena CA, USA	-	0.01-0.17	-	Schuetzle (1975) [86]
2-methylnaphthalene	urban, heavy traffic	Oslo	-	0.07-0.40	-	Alfheim (1985) [83]
	urban, heavy traffic	Oslo	-	-	0.04	Larssen (1985) [84]
	urban, light traffic	Oslo	-	-	0.02	Larssen (1985) [84]
	urban + industrial	Sundsval, Sweden	-	0.04-0.24	-	Thrane (1984) [85]
	urban	Sundsval, Sweden	-	0.01-0.10	-	Thrane (1984) [85]
	urban	Portland OR, USA	-	0.05-0.21	0.10	Ligocki (1985) [87]
	urban	Portland OR, USA	-	0.11-0.46	0.02	Ligocki (1985) [87]
methylnaphthalenes	rural	Kieler Bucht, Germany	-	0.002-0.01	-	Bouchertall (1986) [82]

Notes
(a) N = number of samples with analyte detected / total number of samples analysed.

Table 3.5 Measured concentrations of selected kerosine components detected in refinery wastewater.

Chemicals	Refinery	Influent wastewater		Effluent wastewater		Reference (Date)
		Range (µg/L)	Detected N[(a)]	Range (µg/L)	Detected N[(a)]	
Naphthalene	A	190-1200	11/12	Not Detected - 11	1/12	API (1981) [36]
	B	Not detected - 830	10/12	Not Detected - 1	1/12	API (1981) [36]
	S	Not Detected	0/6	Not Detected	0/18	PACE (1987) [37]
	T	189-280	6/6	Not Detected	0/6	PACE (1987) [37]
Methylnaphthalenes	S	Not Detected - 15	1/6	Not Detected	0/18	PACE (1987) [37]
	T	2120-2710	6/6	Not Detected	0/0	PACE (1987) [37]
Dimethylnaphthalenes	S	Not Detected -282	5/6	Not Detected	0/18	PACE (1987) [37]
	T	2010-3680	6/6	Not Detected - 12.8	2/6	PACE (1987) [37]
Trimethylnaphthalenes	S	Not Detected - 390	5/6	Not Detected	0/18	PACE (1987) [37]
	T	1550-2600	6/6	Not Detected - 44	2/6	PACE (1987) [37]
Acenaphthene	S	Not Detected - 7.8	2/6	Not Detected	0/18	PACE (1987) [37]
	T	Not Detected	0/6	Not Detected	0/6	PACE (1987) [37]
	B	Not Detected - 31	1/12	Not Detected	0/12	API (1981) [36]

Notes:
(a) N = number of samples with analyte detected / total number of samples analysed.

Table 3.6 Measured concentrations of selected kerosine components in the aquatic environment.

Chemical	Source[a]	Place	N[b]	Range µg/L	Mean µg/L	Reference (Date)
n-Decane	urban	Little Britain Lake, UK	?/6	-	1.8	Colenutt (1980) [67]
	urban	Welsh Harp Lake, UK	?/6	-	12.2	Colenutt (1980) [67]
	urban	Luton Brook	?/52	-	7.9	Colenutt (1980) [67]
	urban	River Pinn	-	-	1.6	Colenutt (1980) [67]
	marine, urban coast	Gulf of Mexico	6/8	0.9-1.6	1.4	Sauer (1978) [88]
	marine, unpolluted	Gulf of Mexico	-	Up to 2.0	-	Sauer (1981) [89]
	polluted river	Besos, Spain	?/12	-	26	Gomez-Belinchon (1991) [90]
	polluted river	Llobregat, Spain	?/12	-	1.7	Gomez-Belinchon (1991) [90]
	marine, urban coast	Barcelona Spain	?/17	-	0.02	Gomez-Belinchon (1991) [90]
C_{10}-alkanes	polluted harbour	Pontchartrain LA, USA	2/3	0.1	-	McFall (1985) [91]
1,3,5-trimethylbenzene	canal, boat traffic	Lake Constance	-	7-267	-	Juttner (1988b) [92]
	polluted river	Rhine, Netherlands	-	0.01-10	-	EEC (1984) [93]
	polluted river	Rhine, Netherlands	-	-	0.01	Zoeteman (1980) [94]
Trimethylbenzenes	polluted river	Rhine, Maassluis, NL	1/6	Up to 1	0.17	Morra (1979) [95]
	polluted river	Delaware, USA	1/5	4	4	Sheldon (1978) [96]
1,2,3-trimethylbenzene	polluted river	Besos, Spain	?/12	-	5.5	Gomez-Belinchon (1991) [90]
	polluted river	Llobregat, Spain	?/12	-	0.75	Gomez-Belinchon (1991) [90]
	marine, urban coast	Barcelona Spain	?/17	-	0.004	Gomez-Belinchon (1991) [90]
Naphthalene	polluted harbour	Pontchartrain LA, USA	2/3	0.02-0.1	-	McFall (1985) [91]
	river, various loc.	Mississippi, USA	4/4	4-34	20	DeLeon (1986) [97]
	polluted river	Delaware, USA	16	6-10	-	Hites (1979) [98]
	polluted river	Delaware, USA	3/5	0.7-0.9	-	Sheldon (1978) [96]
	urban runoff	various, USA	3/86	0.8-2.3	-	Cole (1984) [99]
	polluted river	Besos, Spain	?/12	-	1.3	Gomez-Belinchon (1991) [90]
	polluted river	Llobregat, Spain	?/12	-	0.18	Gomez-Belinchon (1991) [90]
	marine, urban coast	Barcelona Spain	?/17	-	0.009	Gomez-Belinchon (1991) [90]

Table 3.6 Measured concentrations of selected kerosine components in the aquatic environment…..*Continued.*

Chemical	Source(a)	Place	N(b)	Range µg/L	Mean µg/L	Reference (Date)
Naphthalene	river, various loc.	various, USA	44/630	-	<10*	Staples (1985) [100]
continued	polluted river	Rhine, Netherlands	-	up to 1.4	-	Schenck (1986b) [81]
	polluted river	Rhine, Lobith, D	-	-	0.03	Linders (1981) [101]
	polluted river	Rhine, Lobith, D	-	<0.1-0.1	-	IAWR (1982) [105]
	polluted river	Rhine, Maassluis, N	-	-	0.03	Linders (1981) [101]
	polluted river	Rhine, Maassluis, N	-	-	0.01	Linders (1981) [101]
	polluted river	Rhine, Gorinchem, N	-	-	0.03	Linders (1981) [101]
	polluted river	Rhine, Dusseldorf, D	-	-	0.08	Schenck (1986b) [81]
	polluted river	Rhine, Dusseldorf, D	-	up to 0.6	0.1	IAWR (1982) [102]
	polluted river	Rhine, Dusseldorf, D	-	up to 0.12	0.02	Schenck (1986b) [81]
	polluted river	Rhine, Dusseldorf, D	-	-	0.03	Schenck (1986b) [81]
	polluted river	Rhine, Dusseldorf, D		<0.01-0.05	-	ARW (1986) [103]
	polluted river	Rhine, Dusseldorf, D	-	<0.01-0.03	-	ARW (1987) [104]
	polluted river	Rhine, Cologne, D	-	up to 2.6	0.5	IAWR (1982) [102]
	polluted river	Rhine, Cologne, D	-	<0.01-0.09	-	ARW (1986) [103]
	polluted river	Rhine, Wessel, D	-	<0.01-0.05	-	ARW (1986) [103]
	polluted river	Rhine, Wessel, D	-	<0.01-0.02	-	ARW (1987) [104]
	polluted river	Rhine, Weisbaden, D	-	<0.01-0.03	-	ARW (1986) [103]
	polluted river	Rhine, Karlsruhe, D	-	up to 0.01	0.1	IAWR (1982) [102]
	polluted river	Rhine, Karlsruhe, D	-	<0.01	-	AWBR (1986) [105]
	polluted river	Rhine, Karlsruhe, D	-	up to 0.32	-	AWBR (1986) [105]
	polluted river	Rhine, Karlsruhe, D	-	<0.01-0.03	-	AWBR (1987) [106]
	polluted river	Rhine, Karlsruhe, D	-	<0.01-0.01	-	AWBR (1987)[106]
	river	Rhine, Basel	-	up to 0.9	0.1	IAWR (1982) [102]
	river	Danube, Leipheim, D	-	up to 0.1	<0.1	AWBR (1986) [105]
	river	Danube, Leipheim, D	-	<0.01-0.02	-	AWBR (1987) [106]
	river	Nexkar, Ludwigsburg, D	-	up to 0.03	<0.01	AWBR (1986) [105]

Table 3.6 Measured values of selected kerosine components in the aquatic environment.....*Continued.*

Chemical	Source[(a)]	Place	N[(b)]	Range µg/L	Mean µg/L	Reference (Date)
Naphthalene	river	Nexkar, Ludwigsburg, D	-	up to 0.03	<0.01	AWBR (1986) [105]
continued	river	Nexkar, Ludwigsburg, D	-	<0.01	-	AWBR (1987) [106]
	canal, boat traffic	Lake Constance	8/8	0.002-0.22	-	Juttner (1988b) [92]
	marine, polluted bay	New York	12/12	2.1-16	6.8	Boehm (1983) [107]
1-Methylnaphthalene	rivers	Germany	-	0.02-0.04	-	EEC (1984) [93]
2-Methylnaphthalene	rivers	Germany	-	0.02-0.03	-	EEC (1984) [93]
methylnaphthalenes	polluted river	Rhine, Netherlands	-	-	0.1	Linders (1981) [101]
	polluted river	Rhine, Netherlands	-	up to 1200	-	Schenck (1986b) [81]
	polluted river	Delaware, USA	3/5	0.7-0.9	-	Sheldon (1978) [96]
	polluted river	Besos, Spain	?/12	-	0.93	Gomez-Belinchon (1991) [90]
	polluted river	Llobregat, Spain	?/12	-	0.17	Gomez-Belinchon (1991) [90]
	marine, urban coast	Barcelona Spain	?/17	-	0.001	Gomez-Belinchon (1991) [90]

Notes:
(a) Description of source taken from primary literature
(b) N = number of samples with analyte detected / total number of samples analysed.

Table 3.7 Measured concentrations of selected kerosine components in sediments.

Chemical	Source(a)	Place	N(b)	Range mg/kg	Mean mg/kg	Reference (Date)
Trimethylbenzenes	polluted river	Delaware, USA	1/19	30	30	Hites (1979)[98]
Naphthalene	polluted river	Delaware, USA	1/19	1.5	1.5	Hites (1979)[98]
	polluted river	Detroit R., USA	15/31	0.13-1.8		Fallon (1985)[108]
	estuary, polluted	Tacoma WA, USA	18/20	0.04-0.59	0.19	Schultz (1987)[109]
	river, various loc.	various, USA	19/267	-	<0.5*	Staples (1985)[100]
1-methylnaphthalene	marine, urban coast	World-wide	-	up to 0.5		BUA (1990)[22]
2-methylnaphthalene	marine, urban coast	World-wide	-	up to 0.62	-	BUA (1990)[22]
Methylnaphthalenes	estuary, polluted	Puget Sound, USA	-	up to 1.7	-	Malins (1985)[110]
	estuary, unpolluted	Puget Sound, USA	-	<0.004	-	Malins (1985)[110]

Notes:
(a) Description of source taken from primary literature
(b) N = number of samples with analyte detected / total number of samples analysed.

Table 3.8 Measured concentrations of kerosine components deposited at various UK sites.

Component	No. of measurement Sites.	Annual mean measured at sites in the UK (1991-93)	
		Range, µg/m^2/day	Mean, µg/m^2/day
Acenaphthene	5	0.060 – 0.793	0.245
Acenaphthylene	3	0.027 – 0.035	0.030
Fluorene	5	0.095 – 0.237	0.243
Anthracene	5	0.002 – 2.045	-

Source: Bertorelli and Derwent (1995)[32]

APPENDIX 1 WIDE CUT AND HIGH FLASH POINT KEROSINES

Appendix 1a Measured occupational exposure data for wide cut fuels.

Job Group/ Activity	Region	Sample duration	Concentration in mg/m^3: Arithmetic Mean [no. of samples] (minimum and maximum levels)			Reference (Date).
			Total hydrocarbons	n-Hexane	Benzene	
AIRPORTS						
Operators: Jet fuel handling	Sweden (a) (b)	½ day	0.9 [12] (no data - 7)	0.2 [6] (no data - 0.1)	0.03 [5] (no data - 0.1)	Holm (1987) [111]
		15 min	6.0 [6] (no data - 48)	0.1 [6] (no data - 0.9)	0.06 [5] (no data - 0.2)	
Operators: Flight service	Sweden (a) (b)	½ day	3.3 [56] (no data - 135)	0.09 [28] (no data - 10.4)	0.08 [28] (no data - 1.2)	
		15 min	9.3 [28] (no data - 370)	0.17 [28] (no data - 40.8)	0.18 [28] (no data - 4.4)	
Aircraft maintenance: Workshop	Sweden (a) (b)	½ day	2.1 [24] (no data - 149)	0.05 [12] (no data - 16.1)	0.05 [12] (no data - 4.1)	
		15 min	5.8 [12] (no data - 649)	0.23 [12] (no data - 157.4)	0.1 [12] (no data - 39.4)	
Operators: Refuelling aircraft	Denmark (c) (d) (e)	30 - 480 min	31 [no data] (1.0 - 1,020.0)			Dossing, Loft, Schroeder (1985) [112]

Notes:

(a) No duration is given for the ½ day sampling
(b) Arithmetic Mean not available, Geometric Mean result reported
(c) Arithmetic Mean not available, Median result reported
(d) 94 staff participated in the study, but the number of samples collected have not been reported
(e) Sample duration has not been linked to results, however, it is reported that the 3 highest results >700 mg/m^3 were 3 hours duration and obtained in indoor locations

Appendix 1b Jet fuel Intoxication from exposure to wide cut and high flash point fuels.

The following references include reports of intoxication resulting from inhalation of wide cut jet fuel. However, no indication of exposure levels is given:
Davies (1964) [113] reported that a 32 year old male Air Force pilot became intoxicated due to JP-4 fuel fumes in high concentration in the cockpit of a new Air Force jet trainer.
Porter (1990) [114] reported aviators experiencing burning eyes, nausea, fatigue, impairment of eye-hand co-ordination, euphoria, and memory defects when their cockpit became overwhelmed with the odour of JP-5 fuel.