



WORLD HEALTH ORGANIZATION
INTERNATIONAL AGENCY FOR RESEARCH ON CANCER

IARC Monographs on the Evaluation of Carcinogenic Risks to Humans

Volume 45

Occupational Exposures in Petroleum Refining; Crude Oil and Major Petroleum Fuels

Summary of Data Reported and Evaluation

[Occupational exposures in petroleum refining](#)

[Crude oil](#)

[Gasoline](#)

[Jet fuel](#)

[Diesel fuels](#)

[Fuel oils \(heating oils\)](#)

Last updated 01/21/98

OCCUPATIONAL EXPOSURES IN PETROLEUM REFINING (Group 2A)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 39)

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Approximately 3000 million tonnes of petroleum fuels, solvents, lubricants, bitumens and other products are produced annually from crude oil. World-wide, the petroleum refining industry employs about 500 000 persons in more than 700 plants. Process operators and maintenance workers may be exposed to a large number of substances which occur in crude oil, process streams, intermediates, catalysts, additives and final products. Aliphatic and aromatic hydrocarbons and hydrogen sulfide have commonly been measured in the air of working environments. Less commonly, polycyclic aromatic compounds have been detected at specific process units. In general, the concentrations of benzene in modern refineries have been reported to be less than 3 mg/m³, with higher levels in some operations. Exposure *via* the skin to high-boiling materials may also occur.

The major process streams are listed in Table 2 (see p. 44 of the monographs volume); the numbers given in square brackets below are those assigned to the streams.

5.2 Experimental data

Several refinery streams used in the manufacture of (or sold directly as) mineral lubricating oils and processing oils were evaluated in Volume 33 of the *IARC Monographs*. The Working Group that prepared that monograph concluded that there was *sufficient evidence* for the carcinogenicity in experimental animals of untreated vacuum distillates [19, 20], of hydrotreated vacuum distillates [based on 19 and 20] and of the high-boiling fraction of catalytically cracked oils [26, 27]. A more recent working group which met to re-evaluate all agents considered in volumes 1-42 of the *IARC Monographs*, resulting in Supplement 7, concluded that there was *sufficient evidence* for the carcinogenicity of untreated and mildly treated mineral oils in experimental animals. The following summary covers experiments on refinery streams that were not considered previously or which have been published since Supplement 7 was prepared. In most of these experiments, no distinction was made in the published reports between benign and malignant skin tumours.

Uncracked distillates and residues

(N.B.: Subsequent to the meeting, the Secretariat became aware of a study in which skin tumours were reported in mice after application to the skin of petroleum naphtha (boiling range, 53-213 °C) [near 4] (Clark *et al.*, 1988) and of another study in which it was reported that skin tumours developed in mice after skin application of a virgin heating oil blending base (boiling range, 142-307 °C) [probably 5] (Biles *et al.*, 1988).)

In a series of experiments of similar design, several atmospheric and vacuum distillates were tested by repeated skin application to mice. One sample of a light straight-run naphtha [3], one sample of light paraffinic vacuum distillate [19A], one sample of heavy paraffinic vacuum distillate [20A] and four samples of heavy naphthenic vacuum distillates [20B] produced a marked increase in the incidence of skin tumours. Two samples of straight-run kerosene [5] and one sample of hydrotreated kerosene [5A] also produced skin tumours.

Two samples of hydrotreated heavy naphthenic distillate [20D] and one sample of a chemically neutralized/hydrotreated heavy naphthenic distillate [20C/20D] tested in mice by skin application produced a

marked increase in the incidence of skin tumours.

One sample of vacuum residue [21] was tested by skin application in mice; no significant skin tumour response was observed.

Cracked distillates and residues

One sample of light catalytically cracked naphtha [22], three light catalytically cracked distillates [24] and one intermediate catalytically cracked distillate [25] were tested in mice by skin application and induced skin tumours.

Several high-boiling distillates [26] and residues [27] of catalytically cracked oils and several thermally cracked residues [31] were tested in experiments in mice by skin application, producing high incidences of benign and malignant skin tumours.

Thermally-cracked residues [31] originating from two different sources were tested by skin application in rabbits, producing some skin tumours, but the study was considered inadequate for evaluation. In one study in mice, skin application of water-quench pyrolysis fuel oil or oil-quench pyrolysis fuel oil (steam-cracked residues [34]) produced carcinomas and papillomas of the skin.

Effluents

Two studies on petroleum refinery effluents were inadequate for evaluation.

5.3 Human data

Taking into consideration the overlap in cohort studies conducted in the USA, ten separate, company-specific cohorts were studied. Two industry-wide study cohorts from the USA comprised various combinations of these cohorts. The cohorts mentioned hereafter refer to the ten separate US cohorts, two from Canada and one from the UK.

Information on specific jobs or exposures was available in only a few of the epidemiological studies of petroleum refinery workers. Some caution should be applied in interpreting the relative risks for cancer in cohort studies of petroleum refinery workers. As for most cohorts of actively employed persons, the overall risk for cancer in all of the cohort studies reviewed here was lower than that in the general population. Yet, it is the cancer experience of the general population that has been conventionally used, in published papers, in evaluating the rates of specific cancers in refinery workers. Significant deficits were reported for cancers at some sites in certain studies; such findings are mentioned in this summary only when a consistent pattern emerged. Caution should also be applied in interpreting the findings from those case-control studies conducted within the general population setting. Most of the studies reported had positive findings, and are likely to be an incomplete selection of case-control studies in which occupational exposures have been investigated.

One case report and one case series describe clusters of skin cancer cases (squamous-cell carcinoma) among wax pressmen who had been exposed to crude paraffin wax saturated with aromatic oils. Significant excess mortality from skin cancer was reported among three refinery cohorts, one of which included the wax pressmen from the case series. In a second cohort, the overall excess was due to an elevated risk for malignant melanoma. In the third, excess skin cancer risk was experienced primarily by maintenance workers. Skin cancer mortality was elevated in three additional cohorts, but the increase was not significant. A case-control study showed a significantly elevated risk for malignant melanoma among men employed in the coal and petroleum products industry, with a cluster of cases employed in petroleum refineries.

Mortality from leukaemia was significantly elevated in two refinery cohorts; in one of these, mortality increased with duration employed and also with time since first employment. Nonsignificant excess mortality from leukaemia was reported among two additional cohorts; in one of these, the excess was significant for boiler

makers and pipe fitters. Elevated mortality from unspecified lymphatic leukaemia, unspecified myeloid leukaemia and acute monocytic leukaemia, but not other cell types, was reported in a subset of workers in the British cohort whose exposures included benzene. A significantly elevated incidence of lymphocytic leukaemia was reported in a large cohort study which included many of the refineries in the USA. Excess mortality from 'cancer of other lymphatic tissues' (multiple myeloma, polycythaemia vera and non-Hodgkin's lymphoma, excluding lymphosarcoma and reticulum-cell sarcoma), which was not significant, was reported in five refinery cohorts. One report indicated significant excess mortality from leukaemia and 'cancer of other lymphatic tissues' combined.

Mortality from malignant neoplasms of the brain was elevated in six of the refinery cohorts, but this was significant in only one of the studies and only for workers with short duration of employment. The elevated mortality was seen in operators and in maintenance and laboratory workers. A case-control study of astrocytic brain tumours showed a decreasing trend in risk with duration employed among men who had ever worked in petroleum refining during their lifetime. Another case-control study showed a significantly elevated risk for malignant neoplasms of the brain among men employed in petroleum refining.

Stomach cancer mortality was elevated among six refinery cohorts, significantly so in only one, among labourers, riggers and fire and safety workers; it was associated with lubricating oil production in one refinery and with solvent dewaxing in another. Mortality increased with increasing duration of employment in one of the studies.

Kidney cancer mortality was elevated, but not significantly so, among three petroleum refinery cohorts, particularly among operators, labourers and maintenance workers. Kidney and bladder cancer mortality combined was elevated in one refinery cohort. Five case-control studies of bladder cancer showed excess risk associated with employment in petroleum refining; the results were significant in two of these.

Pancreatic cancer mortality was reported to be elevated in four petroleum refining cohorts, and was associated with employment in the petroleum refining industry in one case-control study; however, none of these results was significant.

Excess mortality from cancer of the prostate, which increased with duration of employment, was reported in two refinery cohorts, and an overall excess was reported in two others. The only result that attained significance was found for men employed for 20 years or more in one of the refineries.

Lung cancer mortality was elevated in two refinery cohorts but not significantly so. There was a significant excess of lung cancer among workers with daily exposure to petroleum and its products in one of these cohorts. In five cohort studies, significant deficits in mortality from lung cancer were seen. In a case-control study, refinery maintenance workers and operators had a significantly elevated risk for lung cancer.

Mortality from malignant neoplasms of bone was elevated in two cohorts; the excess was significant in one of them, and specifically in association with employment in lubricating oil manufacture.

5.4 Other relevant data

It was reported in one study that wives of maintenance (crafts) workers employed in the waste-water treatment area of a petroleum refinery experienced an excess risk of fetal loss. In one study, an increased prevalence of chromosomal aberrations and of sister chromatid exchange was found in a group of workers in the sewage-treatment unit of a petroleum refinery, but no such effect was observed among a group of workers in a catalytic cracking unit.

Light straight-run [3], full-range alkylate [13] and thermally cracked naphtha [28, 29] produced severe renal toxicity in male but not in female rats.

Previous working groups have reported that vacuum distillates from petroleum refining [19, 20] and

hydrotreated oils induced mutation in bacteria (IARC, 1984, 1987).

Extracts of light paraffinic distillate [19A], heavy paraffinic distillate [20A], heavy naphthenic distillate [20B], straight-run kerosene [5], hydrotreated heavy naphthenic distillate [20D] and chemically neutralized/hydrotreated heavy naphthenic distillate [20C/20D] induced mutation in bacteria. Extracts of hydrotreated kerosene [5A], light straight-run naphtha [3] and vacuum residue [21] did not induce mutation in bacteria.

Extracts of an intermediate catalytically cracked distillate [25] and of a mixture of a heavy catalytically cracked distillate [26] and a catalytically cracked clarified oil [27] induced mutation in bacteria.

5.5 Evaluation

There is *limited evidence* that working in petroleum refineries entails a carcinogenic risk. This limited evidence applies to skin cancer and leukaemia; for all other cancer sites on which information was available, the evidence is inadequate.

There is *sufficient evidence* for the carcinogenicity in experimental animals of light and heavy vacuum distillates, of light and heavy catalytically cracked distillates and of cracked residues derived from the refining of crude oil.

There is *limited evidence* for the carcinogenicity in experimental animals of light straight-run naphtha, of straight-run kerosene, of hydrotreated kerosene and of light catalytically cracked naphtha.

In formulating the overall evaluation, the Working Group also took note of the following supporting evidence reported in Supplement 7: benzene and untreated and mildly treated mineral oils are *carcinogenic to humans (Group 1)*. There is *sufficient evidence* for the carcinogenicity in experimental animals of several polycyclic aromatic hydrocarbons.

(N.B.: Other agents previously evaluated in the IARC Monographs that may occur in petroleum refining are listed in Table 1 of the 'General Remarks' of the monographs volume).

Overall Evaluation

Occupational exposures in petroleum refining are *probably carcinogenic to humans (Group 2A)*.

For definition of the italicized terms, see [Preamble Evaluation](#).

Refinery streams

- Alkylation feed
- Atmospheric tower residue [reduced crude oil]
- *n*-Butane
- Catalytically cracked clarified oil
- Chemically neutralized kerosene
- Crude oil
- Full-range alkylate naphtha
- Full-range reformed naphtha
- Heavy catalytically cracked distillate
- Heavy catalytically cracked naphtha
- Heavy naphthenic distillate
- Heavy paraffinic distillate
- Heavy reformed naphtha

- Heavy straight-run naphtha
- Heavy thermally cracked naphtha
- Heavy vacuum distillate [heavy vacuum gas oil]
- Hydrodesulfurized heavy naphtha
- Hydrosulfurized kerosene
- Hydrosulfurized middle distillate
- Hydrotreated kerosene
- Intermediate catalytically cracked distillate
- Isomerization naphtha
- Kerosene
- Light catalytically cracked distillate
- Light catalytically cracked naphtha
- Light crude oil distillate
- Light hydrocracked naphtha
- Light naphthenic distillate
- Light paraffinic distillate
- Light reformed naphtha
- Light steam-cracked naphtha
- Light straight-run naphtha
- Light thermally cracked distillate
- Light thermally cracked naphtha
- Light vacuum distillate [light vacuum gas oil]
- Polymerization feed
- Polymerization naphtha
- Steam-cracked residue
- Straight-run kerosene
- Straight-run middle distillate
- Straight-run gas oil
- Thermally cracked residue
- Vacuum residue

CRUDE OIL (Group 3)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 119)

CAS No.: 8002-05-9

Chem. Abstr. Name: Petroleum

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Crude oil, which may be broadly characterized as paraffinic or naphthenic, is a complex mixture of alkanes, cycloalkanes and aromatic hydrocarbons containing low percentages of sulfur, nitrogen and oxygen compounds and trace quantities of many other elements. Worldwide, about 500 000 workers are employed in crude oil exploration and production. Occupational exposures during drilling, pumping and transportation of crude oil, including maintenance of equipment used for these processes, may involve inhalation of volatile compounds, including hydrocarbons and hydrogen sulfide. Skin contact with crude oils, which contain polycyclic aromatic compounds, may also occur during these operations. Accidental releases of crude oil into the aquatic environment are also potential sources of human exposure.

5.2 Experimental data

N.B. - Subsequent to the meeting, the Secretariat became aware of a study in which skin tumours were reported in mice after application to the skin of East Wilmington crude oil (Clark *et al.*, 1988).

Samples of crude oil from single sources and composite blends were tested for carcinogenicity by skin application in ten experiments in mice. Four samples of crude oil from single sources produced benign and malignant or unspecified skin tumours in two experiments. In one experiment, a composite sample produced a low incidence of skin carcinomas; in a similar experiment using the same treatment regimen but a blend of slightly different composition, no skin tumour was observed. The conduct and/or reporting of the results of six other experiments in mice were inadequate for evaluation.

Skin application to mice of fractions of two crude oil samples distilled under laboratory conditions and corresponding to various refinery streams produced skin tumours.

One sample of crude oil produced skin papillomas in rabbits in one experiment. Two other experiments were inadequate for evaluation.

5.3 Human data

In a retrospective cohort mortality study of a large group of male employees in petroleum producing and pipeline operations, mortality from all types of cancer was low, except from thyroid cancer. There was a significant deficit of lung cancer and no death from testicular cancer.

In a population-based case-control study, an elevated risk for lung cancer was observed among older men who had been employed in petroleum exploration and production. Reanalysis of the risk for lung cancer among men who had worked in the petroleum mining and refining industry showed an elevated risk for lung cancer among welders, operators, boiler makers, painters and oil-field workers taken as a group; no data were available on smoking habits.

In one of two case-control studies, an excess risk for testicular cancer was observed among petroleum and natural gas extraction workers. No such excess was found in the other study.

In a case-control study of cancer at many sites, an association was observed between exposure to crude oil and rectal and squamous-cell lung cancer. However, the association was based on small numbers and may have been confounded by life style factors.

5.4 Other relevant data

Crude oil induces dermal xenobiotic metabolizing enzymes and ornithine decarboxylase after skin application in mice.

In single studies of mice treated *in vivo*, crude oil induced an increase in the number of sister chromatid exchanges at the highest dose tested but did not induce micronuclei in bone-marrow cells or sperm abnormalities. Crude oil did not increase the number of sister chromatid exchanges in cultured human lymphocytes. The aromatic fractions of crude oil induced sister chromatid exchange, but not chromosomal aberrations, in cultured mammalian cells. Crude oil extracts did not induce mutation in bacteria; when fractionated, the neutral fractions of crude oil, which contain aromatic or polycyclic aromatic compounds generally had mutagenic activity in bacteria.

5.5 Evaluation

There is *inadequate evidence* for the carcinogenicity in humans of crude oil.

There is *limited evidence* for the carcinogenicity in experimental animals of crude oil.

Overall Evaluation

Crude oil is *not classifiable as to its carcinogenicity to humans (Group 3)*.

For definition of the italicized terms, see [Preamble Evaluation](#).

Synonyms

- Naphtha
- Petrol
- Rock oil
- Seneca oil

GASOLINE

(Group 2B)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 159)

CAS No.: 8006-61-9 (for natural gasoline)

Chem. Abstr. Name: not assigned

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Gasoline is a complex mixture of volatile hydrocarbons, predominantly in the C₄-C₁₂ range, with a boiling range of 50-200 °C. Most automotive gasoline is produced by blending naphtha process streams, such as light straight-run [3], reformed [15], alkylate [13], isomerization [14] and thermally [28, 29] and catalytically cracked [22, 23] naphthas. Alkylate naphtha [13] is typically the main component used in the production of aviation gasoline. Saleable gasolines may contain numerous additives, such as alkyllead compounds, 1,2-dibromoethane (ethylene dibromide), 1,2-dichloroethane (ethylene dichloride), alkyl phosphates, phenols, alcohols and methyl-*tert*-butyl ether, in order to meet product specifications. Automotive gasoline may contain 0-7%, and typically contains 2-3%, benzene. Occupational exposure to gasoline vapours occurs during production in petroleum refineries and during transport and distribution to retailers. Exposures to vapours are in most cases principally to lighter hydrocarbons, C₆ or lower. Personal 8-h time-weighted average exposures of bulk and drum gasoline loaders and tank cleaners have been reported as 40-850 mg/m³ total hydrocarbons and 1-27 mg/m³ benzene, and for bulk loaders up to 6 mg/m³ 1,3-butadiene. Higher levels of exposure to benzene have been reported for gasoline rail-loading and for some gasoline storage tank cleaning operations. Service station attendants and customers are exposed to lower levels of gasoline vapours.

5.2 Experimental data

A sample of totally volatilized unleaded gasoline was tested for carcinogenicity in one strain of mice and in one strain of rats by inhalation, producing an increase in the incidence of hepatocellular adenomas and carcinomas in female mice; no such increase was observed in males. Exposure of male rats resulted in an increased incidence of adenomas and carcinomas of the kidney; no such tumour was found in females. One sample of light straight-run naphtha [3] and one sample of light catalytically cracked naphtha [22] produced skin tumours in mice. (See the monograph on occupational exposures in petroleum refining.)

5.3 Human data

This section describes studies of occupations in which exposure to gasoline may occur, including service station attendants and motor vehicle mechanics. None of the studies provided detailed data concerning exposure to gasoline. Furthermore, it was not possible to distinguish the effects of the combustion products from those of gasoline itself.

In a large UK cohort study on oil distribution workers, some of whom had presumably had occupational exposure to gasoline, a lower total cancer mortality was found than expected on the basis of national rates, but there was a slightly elevated number of deaths from neoplasms of the lymphatic and haematopoietic tissues. A Swedish register-based cohort study on pancreatic cancer showed moderately increased incidence among service station workers.

Two US proportionate mortality studies showed some consistency regarding elevated risks for some types of lymphopoietic cancers in motor vehicle mechanics, although not all findings were significant. For service station

workers, the proportionate mortality ratio for leukaemia and aleukaemia was increased in one study but not in another.

In a US case-control study on kidney cancer, there was some evidence of a positive trend in risk with duration of employment as a service station attendant. Another US study showed a nonsignificant deficit in risk for renal-cell carcinoma among people classified as exposed to gasoline, but an increase in risk was suggested among heavy smokers with employment in service stations. A case-control study of cancer at many sites in Canada revealed an elevated risk for kidney cancer in men exposed to aviation gasoline; there were indications of a dose-response relationship.

Several case-control studies have investigated risks for cancer of the lower urinary tract in different occupations with possible exposure to gasoline. An early study from the USA revealed no excess risk among workers in occupations involving exposure to petroleum products. In a Danish study on bladder cancer, an elevated risk was associated with 'oil or gasoline work'. Nonsignificantly increased risks were found in two US studies on bladder cancer among motor vehicle mechanics, while no increase was seen in a third study. There was a significantly elevated risk for bladder cancer among garage workers and service station attendants in one of these studies, and another showed a nonsignificant elevation in risk for workers in the gasoline service industry. A US study on cancer of the renal pelvis suggested an elevated risk for workers exposed to unspecified petroleum, tar or pitch products.

A Swedish study, similar in design to a case-control study, indicated an increased risk for acute nonlymphocytic leukaemia in men with occupational exposure to petroleum products. One hospital-based case-control study in the USA revealed an increased risk for testicular cancer in service station attendants and garage workers; another showed an increased risk for pancreatic cancer in men with occupational exposure to dry cleaning agents or gasoline. Another US case-control study demonstrated an increased risk for liver cancer in service station attendants, particularly for hepatocellular carcinoma. A case-control study of cancer at many sites in Canada revealed an elevated risk only for stomach cancer among men exposed to automotive gasoline.

Nine case-control studies from four countries provide data on paternal occupations involving exposure to hydrocarbons and the risk for cancer in children. There was no consistent association between father's occupation and risk for childhood cancer, although significant results appeared in a few of the studies. Only one study gave detailed data on maternal occupations involving exposure to hydrocarbons during pregnancy; this suggested an increased risk for leukaemia in their children. No study specifically assessed exposure to gasoline, but paternal occupations such as motor vehicle mechanic and service station attendant were not consistently associated with an increase in risk.

5.4 Other relevant data

Urinary thioether excretion was increased in samples taken from service station attendants after work. The half-life of antipyrine was reduced in such workers.

No report specifically designed to study genetic and related effects in humans following exposures to gasoline was available to the Working Group.

Male, but not female, rats developed nephropathy after exposure to unleaded gasoline, with hyaline droplet accumulation, necrosis and degeneration of proximal convoluted tubules. The extent and severity of hyaline droplet accumulation paralleled the extent and localization of renal tubular cell proliferation.

Two samples of unleaded gasoline (one described as PS-6, the other as having a boiling range of 31-192 °C) were tested in a series of assays for genetic and related effects. Neither sample induced chromosomal aberration in the bone marrow of rats treated *in vivo*. The PS-6 sample induced unscheduled DNA synthesis *in vivo* in male and female mouse hepatocytes, but not in male rat hepatocytes or in male or female rat kidney cells, nor did it induce sister chromatid exchange or mutation in cultured human lymphocytes. Neither sample induced mutation in cultured mammalian cells; however, an extract of and the residue from the evaporation of the PS-6 sample did induce mutation in cultured mammalian cells. The PS-6 sample induced unscheduled

DNA synthesis *in vitro* in mouse, rat and human hepatocytes but not in rat kidney cells. A leaded gasoline induced somatic mutation in insects. The other sample of unleaded gasoline, an extract of the PS-6 sample and the residue from the evaporation of the PS-6 sample did not induce mutation in bacteria.

5.5 Evaluation

There is *inadequate evidence* for the carcinogenicity in humans of gasoline.

There is *limited evidence* for the carcinogenicity in experimental animals of unleaded automotive gasoline.

In making the overall evaluation, the Working Group also took note of the following supporting evidence. Unleaded gasoline induces unscheduled DNA synthesis in hepatocytes from male and female mice treated *in vivo* and in cultured mouse, rat and human hepatocytes. There is *limited evidence* for the carcinogenicity in experimental animals of light straight-run naphtha and of light catalytically-cracked naphtha (see the monograph on occupational exposures in petroleum refining). Benzene is *carcinogenic to humans* (Group 1); for 1,3-butadiene, there is *inadequate evidence* for carcinogenicity in humans and *sufficient evidence* for carcinogenicity in experimental animals (Group 2B) (IARC, 1987).

Overall evaluation

Gasoline is *possibly carcinogenic to humans* (Group 2B).

For definition of the italicized terms, see [Preamble Evaluation](#).

Synonyms for Automotive gasoline

- Benzin
- Benzine
- Casinghead
- Essence
- Ethyl
- Gasohol
- Mogas
- Motor gasoline
- Naphtha
- Petrol
- Premium leaded
- Premium low-lead
- Premium unleaded
- Regular leaded
- Regular unleaded
- Super premium leaded
- Super premium unleaded

Synonyms for Aviation gasoline

- Avgas
 - Avgas [grade] 80
 - Avgas [grade] 100
 - Avgas [grade] 115
 - Grade 100LL
-

Last updated 01/21/98

JET FUEL (Group 3)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 203)

CAS No.: not assigned (kerosene, 8008-20-6)

Chem. Abstr. Name: not assigned

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Jet fuels are produced mainly from straight-run [5] and hydrotreated kerosene [5A] or kerosene blended with heavy naphtha streams [4 and derived streams] from the atmospheric distillation of crude oil. Jet fuels are composed mainly of aliphatic and aromatic hydrocarbons with boiling ranges of 150-300 °C (kerosene type) and 45-280 °C (wide-cut type). The formulated products are used in turbine engines of civil and military aircraft. Exposures to jet fuel may occur during its production, transport and storage as well as during refuelling and maintenance of aircraft. Heavier exposures may occur during inspection and repair of aircraft wing tanks owing to the confined working space.

5.2 Experimental data

One sample of jet fuel was tested by skin application in one experiment in male and female mice. No skin tumour occurred at the application site.

Two samples of straight-run kerosene [5] and one sample of hydrotreated kerosene [5A] produced skin tumours in mice. (See the monograph on occupational exposures in petroleum refining).

N.B. - Subsequent to the meeting, the Secretariat became aware of a study in which skin tumours were reported in mice after application to the skin of jet fuel A [kerosene type] and JP-4 [wide-cut type] (Clark *et al.*, 1988).

5.3 Human data

A cohort of men exposed to jet fuel, aviation kerosene and other fuels in the Swedish Air Force had no increased cancer risk during ten years of follow-up. A case-control study of cancer at many sites in Canada revealed an elevated risk for kidney cancer, with some indication of a positive dose-response relationship, in men exposed to jet fuel.

5.4 Other relevant data

In single studies, one sample of jet fuel induced chromosomal aberrations in bone-marrow cells of rats and mutations in cultured mammalian cells in the presence of an exogenous metabolic system but did not induce mutation in bacteria. A further sample was also not mutagenic to bacteria.

5.5 Evaluation

There is *inadequate evidence* for the carcinogenicity in humans of jet fuel.

There is *inadequate evidence* for the carcinogenicity in experimental animals of jet fuel.

In formulating the overall evaluation, the Working Group also took note of the following supporting evidence from the monograph on occupational exposures in petroleum refining. There is *limited evidence* for the carcinogenicity in experimental animals of straight-run kerosene and of hydrotreated kerosene.

Overall evaluation

Jet fuel is *not classifiable as to its carcinogenicity to humans (Group 3)*.

For definition of the italicized terms, see [Preamble Evaluation](#).

Synonyms

- Aviation kerosene
- AVCAT [JP-5]
- AVTAG [JP-4]
- AVTUR [JP-8]
- Jet A
- Jet A-1
- Jet B
- Jet kerosine
- JP-7
- Kerosine
- Turbo fuel A
- Turbo fuel A-1
- Wide-cut jet fuel

DIESEL FUELS

Marine diesel fuel (Group 2B)

Distillate (light) diesel fuels (Group 3)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 219)

CAS No.: 68334-30-5

Chem. Abstr. Name: Diesel oil

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Diesel fuels are complex mixtures of alkanes, cycloalkanes and aromatic hydrocarbons with carbon numbers in the range of C₉-C₂₈ and with a boiling-range of 150-390 °C. Kerosene-type diesel fuel (diesel fuel No. 1) is manufactured from straight-run petroleum distillates [5]. Automotive and railroad diesel fuel (diesel fuel No. 2) contains straight-run middle distillate [6], often blended with straight-run kerosene [5], straight-run gas oil [7], light vacuum distillate [19] and light thermally cracked [30] or light catalytically cracked distillates [24]. Some blended marine diesel fuels also contain heavy residues from distillation [8, 21] and thermal cracking [31] operations. In diesel fuel consisting mainly of atmospheric distillates, the content of three- to seven-ring polycyclic aromatic hydrocarbons is generally less than 5%; in diesel fuel that contains high proportions of heavy atmospheric, vacuum and light cracked distillates, the content of such polycyclic aromatic hydrocarbons may be as high as 10%. Some marine diesel fuels may contain higher levels. Saleable diesel fuel may also contain a variety of additives, such as organic nitrates, amines, phenols and polymeric substances. Exposure to diesel fuel through the skin and by inhalation may occur during its production, storage, distribution and use as well as during maintenance of diesel engines.

5.2 Experimental data

One sample of marine diesel fuel was tested for carcinogenicity in one strain of mice by skin application, producing a few squamous-cell carcinomas and papillomas at the application site in animals of each sex and a few carcinomas at the adjacent inguinal region in males.

Two samples of straight-run kerosene [5], one sample of light vacuum distillate [19] and three samples of light catalytically cracked distillate [24] produced skin tumours in mice. Some residues from thermal cracking [31] produced benign and malignant skin tumours in mice. (See the monograph on occupational exposures in petroleum refining.)

N.B. - Subsequent to the meeting, the secretariat became aware of a study in which skin tumours were reported in mice after application to the skin of petroleum diesel (boiling range, 198-343 °C) [corresponding to diesel fuel No. 2] (Clark et al., 1988).

5.3 Human data

In a case-control study of cancer at many sites, there was evidence of an increased risk for squamous-cell carcinoma of the lung in men estimated to have had substantial exposure to diesel fuel. There was also an indication of an increased risk for cancer of the prostate. No attempt was made to separate the effects of combustion products from those of exposure to diesel fuel itself.

5.4 Other relevant data

Inhalation or ingestion of diesel fuel resulted in acute and persistent lung damage in humans.

No report specifically designed to study genetic and related effects in humans following exposure to diesel fuel was available to the Working Group.

Application of marine diesel fuel to the skin of mice resulted in ulceration.

In a single study, diesel fuel induced chromosomal aberrations in bone-marrow cells of rats; it did not induce mutation in cultured mammalian cells but was weakly mutagenic to bacteria. Another sample did not induce mutation in bacteria or algae; a sample of marine diesel fuel and aliphatic and aromatic fractions of a further sample were also not mutagenic to bacteria.

5.5 Evaluation

There is *inadequate evidence* for the carcinogenicity in humans of diesel fuels.

There is *limited evidence* for the carcinogenicity in experimental animals of marine diesel fuel.

In formulating the overall evaluation, the Working Group also took note of the following supporting evidence reported in the monograph on occupational exposures in petroleum refining. There is *limited evidence* for the carcinogenicity in experimental animals of straight-run kerosene and *sufficient evidence* for the carcinogenicity in experimental animals of light vacuum distillates, of light catalytically cracked distillates and of cracked residues derived from the refining of crude oil.

Overall evaluation

Marine diesel fuel is *possibly carcinogenic to humans (Group 2B)*.

Distillate (light) diesel fuels are *not classifiable as to their carcinogenicity to humans (Group 3)*.

For definition of the italicized terms, see [Preamble Evaluation](#).

Synonyms for Diesel fuel (general)

- Auto diesel
- Automotive diesel oil (ADO)
- Derv
- Diesel
- Diesel fuel oil
- Gas oil

Synonyms for Diesel fuel No. 1

- No. 1 Diesel
- Kerosine
- Arctic diesel
- Diesel fuel oil No. 1
- Diesel oil No. 1
- Dipolar

Synonyms for Diesel fuel No. 2

- Diesel fuel
- Diesel fuel oil No. 2
- Diesel oil No. 2

Synonyms for Diesel fuel No. 4

- Marine diesel fuel
 - Distillate marine diesel fuel
-

Last updated 01/21/98

FUEL OILS (HEATING OILS)

Residual (heavy) fuel oils (Group 2B)

Distillate (light) fuel oils (Group 3)

For definition of Groups, see [Preamble Evaluation](#).

VOL.: 45 (1989) (p. 239)

5. Summary of Data Reported and Evaluation

5.1 Exposure data

Fuel oils are complex and variable mixtures of alkanes and alkenes, cycloalkanes and aromatic hydrocarbons, containing low percentages of sulfur, nitrogen and oxygen compounds. Kerosene fuel oils are manufactured from straight-run petroleum distillates from the boiling range of kerosene [5]. Other distillate fuel oils contain straight-run middle distillate [6], often blended with straight-run gas oil [7] and light vacuum distillates [19], and light cracked distillates [24, 30]. The main components of residual fuel oils are the heavy residues from distillation and cracking operations [8, 21, 31]; various refinery by-products and heavy distillates [20, 26, 27] may be added. In fuel oils consisting mainly of atmospheric distillates, the content of three- to seven-ring polycyclic aromatic hydrocarbons is generally less than 5%. In fuel oils that contain high proportions of heavy atmospheric, vacuum and cracked distillates or atmospheric and vacuum residues, the content of three- to seven-ring polycyclic aromatic hydrocarbons may be as high as 10%; if large quantities of cracked components are incorporated, levels may approach 20%. Fuel oils are used mainly in industrial and domestic heating, as well as in the production of steam and electricity in power plants. Skin and inhalation exposures to fuel oil may occur during its production, storage, distribution and use and during maintenance of heating equipment. During the cleaning of fuel oil tanks, high, short-term exposures to total hydrocarbon vapours have been measured at levels ranging from 100-1600 mg/m³.

5.2 Experimental data

A cracked bunker fuel was tested both alone and blended with the residue from the thermal cracking of catalytically cracked clarified oil [31] by skin application to mice. When applied alone, it induced benign and malignant skin tumours; a further increase was observed when cracked residue was added to the blend.

A West Texas uncracked residue [8 or 21] was tested alone or in combination with the residue described above [31]. When tested alone, it produced one skin papilloma, but a high incidence of skin papillomas and carcinomas was observed when cracked residue was added to the blend.

One sample of fuel oil No. 2 was tested by skin application to mice and produced skin carcinomas and papillomas.

Two samples of straight-run kerosene [5], one sample of light vacuum distillate [19], several samples of heavy vacuum distillates [20] and three samples of light catalytically cracked distillates [24] produced skin tumours in mice. Several heavy catalytically cracked distillates [26], residues of catalytically cracked clarified oils [27], thermally cracked residues [31] and steam-cracked residues [34] produced high incidences of benign and malignant skin tumours in mice. (See the monograph on occupational exposures in petroleum refining.)

N.B. - Subsequent to the meeting, the Secretariat became aware of one article accepted for publication which reported that skin tumours developed in mice after skin application of furnace oil [probably fuel oil No. 2] in initiating/promoting studies (Gerhart *et al.*, 1988), and another study which reported that skin tumours developed in mice after skin application of several samples of commercial No. 2 heating oil [fuel oil No. 2] (Biles *et al.*, 1988).

5.3 Human data

Two large historical cohort studies of workers were conducted in Japan. In the first, an excess of lung cancer was observed among men exposed to kerosene, diesel oil, crude petroleum and mineral oil considered as a group. In the second, an excess of stomach cancer was observed among workers possibly exposed to kerosene, machine oil or grease. Leukaemia was reported to have occurred in excess in industries where kerosene, paraffin oil or petroleum combustibles were said to have been used or produced. Since none of the exposures could be defined clearly, these results are difficult to interpret.

In a large case-control study, a significant excess of colorectal cancer was associated with estimated exposure to solvents and fuel oil. In a second, an excess of stomach cancer was associated with exposure to kerosene, and excesses of rectal cancer and oat-cell lung cancer with exposure to heating oil.

Three case-control studies found a relationship between lung cancer and use of kerosene stoves for cooking in women in Hong Kong. No distinction was made between exposure to kerosene and exposure to its combustion products.

5.4 Other relevant data

Kerosene ingestion is a common cause of childhood poisoning and may result in lung damage.

No report specifically designed to study genetic and related effects in humans following exposure to fuel oil was available to the Working Group.

In single studies, kerosene did not induce chromosomal aberrations in rat bone marrow, nor did it induce mutation in cultured mammalian cells or in bacteria.

In single studies, fuel oil No. 2 induced chromosomal aberrations in rat bone marrow and mutation in cultured mammalian cells and in bacteria. Aromatic fractions of fuel oil No. 2 induced sister chromatid exchange, but not chromosomal aberrations, in cultured mammalian cells. One four- to seven-ring polycyclic aromatic hydrocarbon fraction of fuel oil No. 2 induced mutation in bacteria.

In single studies, a heavy fuel oil [B-class] induced chromosomal aberrations in cultured mammalian cells; bunker fuel did not induce mutation in bacteria or algae.

5.5 Evaluation

There is *inadequate evidence* for the carcinogenicity in humans of fuel oils.

There is *sufficient evidence* for the carcinogenicity in experimental animals of residual (heavy) fuel oils.

There is *limited evidence* for the carcinogenicity in experimental animals of fuel oil No. 2.

In formulating the overall evaluation, the Working Group also took note of the following supporting evidence reported in the monograph on occupational exposures in petroleum refining. There is *sufficient evidence* for the carcinogenicity in experimental animals of light and heavy catalytically cracked distillates, of light and heavy vacuum distillates and of cracked residues derived from the refining of crude oil. There is *limited evidence* for the carcinogenicity in experimental animals of straight-run kerosene.

Overall evaluation

Residual (heavy) fuel oils are *possibly carcinogenic to humans (Group 2B)*.

Distillate (light) fuel oils are *not classifiable as to their carcinogenicity to humans (Group 3)*.

For definition of the italicized terms, see [Preamble Evaluation](#).

Synonyms for Distillate fuel oils

- Chemically neutralized light distillate
- Domestic fuel oil
- Domestic heating oil
- Fuel oil No. 1
- Fuel oil No. 2
- Furnace oil No. 1
- Furnace oil No. 2
- Heating oil
- Home heating oil
- Hydrotreated light distillate
- Kerosene
- Kerosene, straight run
- Kerosine
- Lamp oil
- Light heating oil
- Paraffin oil
- Petroleum distillate
- Rotary burner fuel
- Stove oil

Synonyms for Residual fuel oils

- Bunker C
- Bunker C fuel oil
- Bunker fuel oil
- Bunker oil
- Fuel oil lourd
- Fuel oil No. 4
- Fuel oil No. 5
- Fuel oil No. 6
- Fuel oil, residual
- Industrial fuel oil
- Marine boiler fuels
- Power station fuel oil
- Residual fuel oil grade 4
- Residual fuel oil grade 5
- Residual fuel oil grade 6