GENERAL REMARKS

This forty-fifth volume of the *IARC Monographs* comprises six monographs: one on occupational exposures in petroleum refining, one on crude oil, and four monographs on the main saleable fuel products of petroleum refining. Some other products of petroleum refining — mineral oils and bitumens — were evaluated previously (IARC, 1984, 1985a, 1987a,b). Petroleum solvents and engine exhausts will be considered by future working groups.

The selection of petroleum fuels for evaluation was based on four main criteria: their origin, use, chemical composition and physical properties. Only fuels that are produced from crude petroleum oil are considered. Some products based on shale-oil and coal were evaluated previously (IARC, 1985b,c, 1987c,d). Fuels produced from natural gas, biomaterials and synthetic chemicals were excluded.

Among saleable petroleum refinery products, only those used as engine or burner fuels for power or heat production or for illumination are included. All intermediate products used in the petrochemical industry to produce plastics, monomers and other products were considered to be outside the scope of the present volume. Similarly, nonfuel products, such as lubricant oils, bitumens and petroleum solvents, which have already been or will shortly be evaluated in the *IARC Monographs* programme, were considered only as process streams to which employees carrying out certain jobs in petroleum refineries may be exposed.

All the fuels considered are complex mixtures mainly of aliphatic, alicyclic and aromatic hydrocarbons. In addition, they may contain substances that have nitrogen, sulfur or some other element, but only (except for residual fuel oils) as a minor component or as an additive in blending of the final product. Table 1 lists agents previously evaluated in the *IARC Monographs* that may occur in petroleum refining, crude oil and in some of the fuel products considered in this volume. The fuels covered were further restricted to liquids or semisolids, thus excluding liquefied petroleum gas and petroleum coke, which are fuels of minor importance compared with those considered.

On the basis of these criteria, the monograph on petroleum refining covers occupational exposures to raw materials (different crude oils), intermediate process streams, petroleum products and a variety of process chemicals, fuel additives and other substances that occur in petroleum refineries. Experimental data on the carcinogenicity or other related effects of the main process streams are reviewed and summarized because they are relevant to making an overall evaluation of carcinogenicity of occupational exposures in petroleum refineries, and in evaluating the carcinogenicity of products that contain these streams as major

Table 1. Agents previously evaluated in the *IARC Monographs* that may occur in petroleum refining, crude oil or major petroleum fuels

Monograph	Agent	Evidence of carcinogenicity[a]		
		Human	Animal	Group
Petroleum refining	*ortho*-Anisidine	ND	S	2B
	para-Anisidine	ND	I	3
	Arsenic compounds	S	L	1*
	Asbestos	S	S	1
	Benzene	S	S	1
	Bitumens	I		3
	Steam-refined and cracking residue bitumens		L	
	Air-refined bitumens		I	
	Extracts of steam-refined and air-refined bitumens		S	2B
	1,3-Butadiene	I	S	2B
	Carbazole	ND	L	3
	Chlorinated hydrocarbons	varies	varies	2B–3
	Chromium and chromium compounds			
	Chromium metal	I	I	3
	Trivalent chromium compounds	I	I	3
	Hexavalent chromium compounds	S	S	1*
	1,2-Dibromoethane (ethylene dibromide)	I	S	2A
	1,2-Dichloroethane (ethylene dichloride)	ND	S	2B
	Hydrazine	I	S	2B
	Lead and lead compounds			
	Inorganic	I	S	2B
	Organolead	I	I	3
	Mineral oils			
	Untreated and mildly treated oils	S	S	1
	Highly-refined oils	I	I	3
	Nickel and nickel compounds	S	S	1*
	para-Phenylenediamine	ND	I	3
	Polycyclic aromatic compounds	ND	varies	2A–3
	Silica			
	Crystalline silica	L	S	2A
	Amorphous silica	I	I	3
Crude oil	Arsenic compounds	S	L	1*
	Benzene	S	S	1
	Carbazole	ND	L	3
	Nickel and nickel compounds	S	S	1*
	Polycyclic aromatic compounds	ND	varies	2A–3
Gasoline	Benzene	S	S	1
	1,3-Butadiene	I	S	2B
	1,2-Dibromoethane (ethylene dibromide)	I	S	2A
	1,2-Dichloroethane (ethylene dichloride)	ND	S	2B

Table 1 (contd)

Monograph	Agent	Evidence of carcinogenicity[a]		
		Human	Animal	Group
Gasoline (contd)	Lead and lead compounds			
	Inorganic	I	S	2B
	Organolead	I	I	3
	para-Phenylenediamine	ND	I	3
Jet fuel	Benzene	S	S	1
Diesel fuels	Benzene	S	S	1
	Polycyclic aromatic compounds	ND	varies	2A–3
Fuel oils (Heating oils)	Benzene	S	S	1
	Carbazole	ND	L	3
	Nickel and nickel compounds	S	S	1*
	Polycyclic aromatic compounds	ND	varies	2A–3

[a]From Supplement 7 (IARC, 1987e); I, inadequate evidence; L, limited evidence; ND, no adequate data; S, sufficient evidence; 1, Group 1 – the agent is carcinogenic to humans; 2A, Group 2A – the agent is probably carcinogenic to humans; 2B, Group 2B – the agent is possibly carcinogenic to humans; 3, Group 3 – the agent is not classifiable as to its carcinogenicity to humans

*This evaluation applies to the group of chemicals as a whole and not necessarily to all individual chemicals within the group

components. The experimental studies summarized in the monograph on occupational exposures in petroleum refining are those in which any sample from petroleum refining processes or effluents was tested; laboratory fractions of process streams (e.g., distillates, extracts) are included but not evaluated.

The monograph on crude oil includes experimental studies in which undiluted or diluted crude petroleum oils or their composite mixtures were tested for carcinogenicity, and hygiene and epidemiological studies on persons potentially exposed to crude oil or its volatile components. Analogously to the treatment of process streams in the monograph on occupational exposures in petroleum refining, tests of laboratory-derived fractions of crude oil were included in the monograph.

The monograph on gasoline includes automotive gasoline (leaded and unleaded) used in automotive vehicles, and aviation gasoline used in aeroplanes with reciprocating engines. Aviation gasoline (boiling range, 25–170°C) differs from jet fuels (boiling range, usually 150–300°C), which are used in aeroplanes equipped with turbine engines. Automotive gasoline is manufactured by blending several process streams and additives. The principal streams used are full-range reformed naphtha, catalytically cracked and light steam-cracked naphtha, light straight-run naphtha and *n*-butane. One or more additional components may be used. Aviation gasoline usually contains 50–70% alkylated naphtha, as compared to 0–5% in automotive gasoline.

The fourth monograph in the present volume covers jet fuels. The basic component of most commercial and military jet fuels is the straight-run kerosene fraction produced by the

atmospheric distillation of crude oil. However, wide-cut jet fuels also include lower-boiling fractions, e.g., heavy straight-run naphtha. Straight-run kerosene is a versatile process stream used, for the most part, in the production of jet fuels, but which may also be used as diesel fuel (diesel fuel No. 1), as heating oil (fuel oil No. 1), as lamp oil, as a solvent and for other purposes. Studies concerning aviation kerosene are described in the monograph on jet fuels, whereas kerosene as a refinery stream or as diesel fuel or fuel oil is considered in the corresponding monographs.

The monograph on diesel fuels considers three grades of diesel fuel. Diesel fuel No. 1 is essentially similar to kerosene except for its additives, and it is used mainly in city buses. Diesel fuel No. 2 has a similar processing history and chemical composition, with the exception of the additives, to fuel oil No. 2; it is the most widely used diesel fuel and is employed in cars, lorries, locomotives and small boats. Diesel fuel No. 4 (marine diesel fuel), used mainly in ships, is slightly less volatile than diesel fuel No. 2 and may contain up to 15% residual process streams.

The last monograph in this volume covers data on fuel oils (heating oils). Fuel oils are numbered from 1 to 6 according to the type of burner in which they may be used. The most volatile fuel oils (Nos 1 and 2) are manufactured from straight-run or processed distillates; their chemical composition is approximately the same as that of kerosene (equivalent to fuel oil No. 1) and diesel fuel No. 2 (equivalent to fuel oil No. 2). Fuel oils Nos 4–6 are also called residual fuel oils because they normally include residues from atmospheric distillation, vacuum distillation and cracking processes as major components. Also, other by-products from refinery processes, such as propane-precipitated bitumen and solvent extracts of lubricant oils may be added. Studies on bitumens and lubricant oils, which have been evaluated in previous volumes (IARC, 1984, 1985a, 1987a,b) and which are minor components of residual fuel oils, are not reported in this volume; the main results are summarized briefly when the data were considered useful for the evaluation of residual fuel oils.

It was noted that there is a paucity of data on occupational exposures to volatile hydrocarbons prior to the 1970s. Since that period, more data have been published, and it is assumed that considerably more data exist in unpublished company records. The Working Group suggests that scientists in the petroleum industry be encouraged to publish representative exposure data in the open literature, which would be useful in the design and interpretation of epidemiological studies. Such data should preferably cover the ranges encountered under both normal operating conditions and in non-routine situations such as major turn-rounds. Also noted is the fact that no standard methodology exists for the objective assessment of skin exposure to petroleum oils of biological concern. It is hoped that academic and industrial scientists can address this perceived need in order to attain objectivity in assessing skin exposures and to improve standards of surveillance.

The Working Group recognized that in many of the carcinogenicity bioassays reported there was no detailed characterization of the test materials, and the results could not necessarily be taken to be representative of all samples in a given category. In addition, most samples were tested in only one test system — mainly mouse skin painting assays.

The paucity of data on genetic and related effects in humans relevant to the evaluation of human exposures in the petroleum refining industry or to crude oil or any of the saleable fuel products was also noted.

In the few epidemiological studies available, there was little information on actual exposures to the final saleable products. In nearly all of the cohort studies reviewed in these monographs, the cancer experience of an entire occupational cohort was compared with that of the general (national) population. Because of the influence of the 'healthy worker effect', such comparisons tend to underestimate the true magnitude of any risk attributable to occupation; the extent of this underestimation, however, cannot be quantified. (This methodological consideration is discussed further on p. 81.)

In the many population- and hospital-based case-control studies reviewed in this volume, most of the positive associations with the exposures considered arose as a result of simultaneous exploration of a number of industries and occupations as risk factors for cancer. A 'positive reporting bias' may therefore have applied. (This methodological consideration is discussed further on p. 100.)

The main products of petroleum refining are evaluated in the last four monographs in this volume. The available data on the carcinogenicity in experimental animals of the component streams of these products are described and evaluated in the monograph on occupational exposures in petroleum refining. These evaluations were used in the overall evaluation of the carcinogenicity of the petroleum products in the relevant monograph, when deemed appropriate, i.e., when the refinery stream was considered to be a consistent and major component of the product. Some of the minor components of petroleum fuels were evaluated in previous monographs. These evaluations are also used as supporting evidence in some overall evaluations. When possible, process streams cited in each monograph are cross-referenced to Table 2 and Figure 1 of the monograph on occupational exposures in petroleum refining, by the use of the systematic names and the square-bracketed numbers assigned in the table and figure.

References

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IARC (1985a) *IARC Monographs on the Evaluation of the Carcinogenic Risk of Chemicals to Humans*, Vol. 35, *Polynuclear Aromatic Compounds, Part 4, Bitumens, Coal-tars and Derived Products, Shale-oils and Soots*, Lyon, pp. 39–181, 243–247

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