GENERAL REMARKS

This forty-eighth volume of *IARC Monographs* covers some flame retardants, textile dyes, another textile chemical, as well as occupational exposures in the textile manufacturing industry. It is not the purpose of this volume to consider all of the chemical agents used in textile manufacture. Numerous textile dyes and other agents used in textile processing were evaluated previously by IARC working groups, and these are listed, with the evaluations, in Table 1.

Table 1. Agents used currently and in the past in the textile manufacturing industry that have been evaluated for carcinogenicity in *IARC Monographs*

Agent	Evidence for carcinogenicity[a]			Use in the textile manufacturing industry[b]
	Human	Animal	Group	
Acetamide	ND	S	2B	Cloth plasticizer
Acrylic fibres	ND	ND	3	Raw material
Amaranth	ND	I	3	Textile dye
Antimony trioxide	I	S	2B	Flame retardant
Auramine (technical grade)	I	S	2B	Textile dye
Asbestos[c]	S	S	1	Asbestos textiles
Benzidine-based dyes	I		2A	Silk dyes
Direct Black 38 (technical grade)		S		
Direct Blue 6 (technical grade)		S		
Direct Brown 95 (technical grade)		S		
Benzyl acetate	ND	L	3	Solvent
Benzyl violet 4B	ND	S	2B	Textile dye
Bis(2-chloroethyl)ether	ND	L	3	Scouring agent
Blue VRS	ND	L	3	Textile dye
Brilliant Blue FCF	ND	L	3	Textile dye
γ-Butyrolactone	ND	I	3	Solvent
Carmoisine	ND	I	3	Wool dye
Chlorendic acid[d]	ND	S	2B	Flame retardant
Chlorophenols	L		2B	
2,4,6-Trichlorophenol		S		Antimildew agent

Table 1 (contd)

Agent	Evidence for carcinogenicity[a]			Use in the textile manufacturing industry[b]
	Human	Animal	Group	
para-Chloro-*ortho*-toluidine and its strong acid salts[d]			2A	Dye intermediate
para-Chloro-*ortho*-toluidine	L			
para-Chloro-*ortho*-toluidine hydrochloride		S		
Chromium acetate (Cr^{+3})	I	I	3	Textile dye
Chromium compounds, hexavalent[c]	S	S	1	Textile printing
Chromium potassium sulfate (Cr^{+3})	I	I	3	Mordant for wool
Chromium sulfate (Cr^{+3})	I	I	3	Mordant
Chrysoidine	I	L	3	Textile dye
Copper 8-hydroxyquinoline	ND	I	3	Textile fungicide
Decabromodiphenyl oxide[d]	ND	L	3	Flame retardant
ortho-Dichlorobenzene	I	I	3	Carrier agent
para-Dichlorobenzene	I	S	2B	Carrier agent
Dichloromethane	I	S	2B	Solvent
Dieldrin	I	L	3	Moth-proofing agent
Diepoxybutane	ND	S	2B	Cross-linking agent
Di(2-ethylhexyl)adipate	ND	L	3	Cellulose-nylon plasticizer
Di(2-ethylhexyl)phthalate	ND	S	2B	Plastizicer in PVC-coated fabrics
3,3′-Dimethoxybenzidine (*ortho*-Dianisidine)	I	S	2B	Acetate rayon dye
Dimethyl hydrogen phosphite[d]	ND	L	3	Flame retardant
Dimethyl formamide	L	I	2B	Solvent
1,4-Dioxane	I	S	2B	Solvent
Disperse Blue 1[d]	ND	S	2B	Textile dye
Disperse Yellow 3[d]	ND	L	3	Textile dye
Ethyl acrylate	ND	S	2B	Back coating agent
Evans blue	ND	S	3	Textile dye
Formaldehyde	L	S	2A	Finishing agent
Glycidaldehyde	ND	S,	2B	Cross-linking agent (wool)
Guinea green B	ND	L	3	Textile dye
Hexachloroethane	ND	L	3	Moth repellent
Hexamethylphosphoramide	ND	S	2B	Solvent
Hydrogen peroxide	ND	L	3	Bleaching agent
Isopropyl alcohol	I	I	3	Solvent
Light green SF	ND	L	3	Textile dye

Table 1 (contd)

Agent	Evidence for carcinogenicity[a]			Use in the textile manufacturing industry[b]
	Human	Animal	Group	
Magenta	I	I	3	Textile dye
Methyl methacrylate	ND	I	3	Back coating agents
Mineral oils[c]				Yarn lubricants
Untreated and mildly-treated oils	S	S	1	
Highly-refined oils	I	I	3	
Mirex	ND	S	2B	Textile insecticide
Modacrylic fibres	ND	ND	3	Raw material
Nitrilotriacetic acid and its salts[d]	ND		2B	Chelating agents
Nitrilotriacetic acid and its sodium salts		S		
5-Nitro-*ortho*-toluidine[d]	ND	L	3	Textile dye
Nylon 6	ND	I	3	Raw material
Orange I	ND	I	3	Textile dye
Orange G	ND	I	3	Wool dye
Phenol	I	I	3	Textile printing agent
para-Phenylenediamine	ND	I	3	Textile dye developer
ortho-Phenylphenol	ND	I	3	Carrier agent
Polyacrylic acid	ND	ND	3	Textile warp sizing agent
Polybrominated biphenyls	I	S	2B	Flame retardants
Polyvinyl acetate	ND	I	3	Finishing agent
Polyvinyl alcohol	ND	I	3	Textile warp sizing agent
Polyvinyl pyrrolidone	ND	L	3	Stripping and colour lightening agent
Ponceaux MX	ND	S	2B	Textile dye
Ponceaux 3R	ND	S	2B	Wool dye
Potassium chromate (Cr^{+6})	S	S	1	Mordant, dye
Potassium dichromate (Cr^{+6})	S	S	1	Wool preservative
Rhodamine B	ND	L	3	Textile dye
Rhodamine 6G	ND	L	3	Textile dye
Styrene-butadiene copolymers	ND	ND	3	Carpet and upholstery backcoating agents
Tannic acid and tannins	ND	L	3	Nylon finishing agents
1,1,2,2-Tetrachloroethane	I	L	3	Moth repellent
Tetrachloroethylene	I	S	2B	Solvent
Tetrakis(hydroxymethyl) phosphonium salts[d]	ND	I	3	Flame retardant
Thioacetamide	ND	S	2B	Solvent
Thiourea	ND	S	2B	Flame retardant

Table 1 (contd)

Agent	Evidence for carcinogenicity[a]			Use in the textile manufacturing industry[b]
	Human	Animal	Group	
Toluene	I	I	3	Solvent
1,1,1-Trichloroethane	ND	I	3	Solvent
Trichloroethylene	I	L	3	Solvent
Tris(1-aziridinyl)phosphine oxide	ND	I	3	Flame retardant
2,4,6-Tris(1-aziridinyl)-*s*-triazine	ND	L	3	Finishing agent
Tris(2-chloroethyl) phosphate[d]	ND	I	3	Flame retardant
Tris(2,3-dibromopropyl)phosphate	I	S	2A	Flame retardant
Tris(2-methyl-1-aziridinyl)phosphine oxide	ND	I	3	Cross-linking agent
Trypan blue	ND	S	2B	Textile dye
Vat Yellow 4[d]	ND	L	3	Textile dye
Xylene	I	I	3	Solvent

[a]From Supplement 7 (IARC, 1987) or *IARC Monographs* volume 47 (IARC, 1990); 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

[b]From *IARC Monographs* volumes 1-47 and Priha *et al.* (1988)

[c]Excluded from consideration in this volume

[d]In this volume

The main criterion for selecting agents to be evaluated in this volume was the availability of data on carcinogenicity and on human exposure. Originally, data were also collected for three other agents: two groups of flame retardants, bis(2,3-dibromopropyl)phosphate and its salts and tris(dichloropropyl)phosphates, and sodium(2-ethylhexyl)sulfate. Some bis(2,3-dibromopropyl)phosphate salts have been reported to be nephrotoxic to rats and mutagenic to bacteria (Nakamura *et al.*, 1979; Elliott *et al.*, 1982; Lynn *et al.*, 1982; Søderlund *et al.*, 1982; Nakamura *et al.*, 1983). Tris(dichloropropyl)phosphates have induced chromosomal aberrations in animal cells and exerted mutagenic effects in bacteria (Gold *et al.*, 1978; Nakamura *et al.*, 1979; Brusick *et al.*, 1980; Kawachi *et al.*, 1980a,b; Ulsamer *et al.*, 1980; Ishidate *et al.*, 1981; Søderlund *et al.*, 1985; Mortelmans *et al.*, 1986). However, studies on the carcinogenicity of these chemicals had not been published in peer-reviewed journals by the time of the meeting and these compounds were therefore not considered by the Working Group. Sodium(2-ethylhexyl)sulfate is a surfactant used in bleaching and mercerizing textiles, in metal cleaning and in some other applications. This compound was reported to have nephrotoxic effects in mice and rats (Smyth *et al.*, 1941, 1970; National Toxicology Program, 1984; Kluwe *et al.*, 1985). It was not mutagenic to several strains of *Salmonella typhimurium* in the presence or absence of an exogenous metabolic system (National Toxicology Program, 1984; Zeiger *et al.*, 1985). The only carcinogenicity study available on this compound has been retracted (National Toxicology Program, 1984).

Flame retardants are used in a wide variety of products, including carpets, home furnishings, fabrics, plastics, paints, adhesives and construction materials. Tetrakis(hydroxymethyl) phosphonium salts, sulfate and chloride, are flame retardants used in cotton and rayon fabrics. Decabromodiphenyl oxide (used in polyester/cotton blends and nylon) and tris(2-chloroethyl)phosphate (used in carpet backings) are also widely used as flame retardants in the textile industry (Ulsamer *et al.*, 1980), but their main use is in plastics. Similarly, chlorendic acid and dimethyl hydrogen phosphite have some specific uses in textile manufacture, but their major applications are not related to textiles. Chlorinated paraffins are saturated hydrocarbons with usual chain lengths of 10-30 carbon atoms and chlorination grades of 40-70%. They are used mainly as high-pressure lubricant additives in the metal industry but may be added as plasticizers and flame retardants to a variety of products, including plastics, rubber and paints. Chlorinated paraffins are used with decabromodiphenyl oxide and antimony trioxide in polyester fabrics for tents (Priha *et al.*, 1988). Some other chemicals that are used as flame retardants were evaluated previously by IARC working groups. These include tris(2,3-dibromopropyl)phosphate (IARC, 1979, 1987), polybrominated biphenyls (IARC, 1986, 1987) and antimony trioxide (IARC, 1989).

Hundreds of dyes are used in the textile industry in large quantities. In the USA, more than two-thirds of the annual production of dyes is used in textiles (Anon., 1988). Several compounds considered in this volume are used as dyes, dye components or intermediates in the textile industry. The aromatic amines, 4-chloro-*ortho*-toluidine and 5-nitro-*ortho*-toluidine, have two major applications: as intermediates in the manufacture of dyes and some other chemicals and as components of naphthol dyes for fabrics and yarns. Dyeing with naphthol dyes takes places in two phases: the textile is first immersed in a solution of azoic coupling component (naphthol) and then allowed to react with an azoic diazonium component, which is an aromatic amine converted to an azo derivative. An anthraquinone compound, Disperse Blue 1, is a hair colourant which is also used to dye synthetic textiles. Disperse Yellow 3 is a monoazo pigment dye used mainly for synthetic materials. Vat Yellow 4 is a diketone derivative of dibenzo[*a*,*h*]pyrene which may be applied to a variety of natural and synthetic textile materials. A number of textile dyes were evaluated previously, mainly in *IARC Monographs* volumes 8 and 16 (IARC, 1975, 1978) and in Supplement 7 (IARC, 1987). The evaluations of two of the dyes included in this volume — 4-chloro-*ortho*-toluidine and Disperse Yellow 3 — have been brought up to date on the basis of new data on carcinogenicity that have become available. The previous evaluation of the carcinogenicity of Disperse Yellow 3 was based on a study in mice by Boyland *et al.* (1964). It has since been brought to the attention of the IARC that the compound tested in that study was in fact an isomer of Disperse Yellow 3.

Nitrilotriacetic acid and its sodium salts are chelating agents used, for example, to remove interfering metal ions from textile processing solutions. More than 50% of the 70 000 tonnes of this product that are made annually, however, is used as the basis for laundry detergents. Data on solutions of nitrilotriacetic acid and its sodium salts and metal salts were also included because metal complexes may be formed *in vivo* and because some solutions, e.g., of nitrilotriacetic acid disodium salt and iron nitrate, have been tested for carcinogenicity in animals. Several other solvents, carrier agents, plasticizers, sizing agents, fungicides and

other textile chemicals including, e.g., formaldehyde, were evaluated previously by IARC working groups (see Table 1).

The last monograph of this volume covers occupational exposures in the textile manufacturing industry. These exposures include the manufacture of fabrics, yarns, carpets, knitwear, linen, curtains and some other industrial and domestic textiles. The main raw material used in the textile industry is cotton. Other widely used materials include wool and synthetic materials, such as polyester, rayon, acrylic fibres and polyamide. Materials such as hemp, jute, silk, flax and rags may be important or even predominate in some areas. The Working Group was concerned that so little published information was available on exposures in the textile industry in areas other than Europe, Japan and the USA, especially in view of the fact that exposures may be higher in areas where old technologies are still used.

The term 'textile industry' as used in this volume was considered to exclude manufacture of garments and of synthetic fibres. In addition, two specific textile processes that had been evaluated previously — manufacture of asbestos textiles (IARC, 1977) and mule spinning with exposure to mineral oils (IARC, 1984) — were excluded.

The main criterion for including biological data in this monograph was that the individuals or populations studied be textile workers, with the exclusions mentioned above. Detailed descriptions of biological data on specific chemical agents used or present in textile mills were considered to be outside the scope of this monograph. Chemical agents used currently or in the past in the textile industry are listed in Table 1 to facilitate the interpretation of possible carcinogenic risks among textile workers.

Since 1975, benign nodular hepatoproliferative lesions in rats have been classified as 'neoplastic nodules' by the National Cancer Institute and subsequently by the National Toxicology Program of the USA. Recently, the term 'hepatocellular adenoma' has been reintroduced (Maronpot *et al.*, 1986). Therefore, in this volume 'adenoma' has been indicated in square brackets whenever 'neoplastic nodules' of the liver were reported.

In evaluating studies of carcinogenicity in experimental animals, the occurrence of dose-related increases in tumour incidence was considered to be more relevant than the finding only of differences between treated and control animals. Tests for trend were therefore presented whenever possible.

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