EXPOSURES IN THE TEXTILE MANUFACTURING INDUSTRY[1]

1. Historical Perspectives and Description of the Industry

1.1 Historical perspectives

Cloth and carpets have been made for thousands of years, and relics of ancient fabrics have been found throughout the world. Yarn was made as long ago as 8000 BC, and it is believed that grass and tree materials were the first substances used to make yarn-like strands of cloth (Marvin, 1973).

Mechanized production of textiles began in England at the end of the eighteenth century, as part of the industrial revolution. Since that time, the industrial production of textiles has spread rapidly to all parts of the world. During the last 20 years, much of the basic textile industry has shifted to developing countries.

Textile manufacture includes spinning, weaving, knitting, dyeing and finishing of all types of natural and synthetic fibres. Machines vary from primitive looms used in cottage industries to sophisticated machines in modern factories (Quinn, 1983). A glossary of some terms used commonly in the industry is given at the end of this volume (p. 279).

Textile workers are exposed to textile dusts (both natural and synthetic) throughout the textile manufacturing process. During spinning, weaving and knitting operations, the use of chemicals is limited. The most important chemicals used in these processes are sizing agents (e.g., starch) and yarn lubricants (spinning oil and polymers).

Workers in the cotton industry have been exposed to mineral lubricants used in the spindles during the operation called 'mule spinning' (twisting of yarn). This exposure has been evaluated previously (IARC, 1984). Mule spinning was discontinued in Italy in 1965 but may still be done elsewhere. Some countries have legislation prohibiting the use of oils for mule spinning other than those of animal or vegetable origin (Quinn, 1983).

The term 'dyestuff' refers to products used to impart colour to other materials and pertains to both dyes and pigments. Currently, the vast majority of textile dyes are synthetic

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[1]Excluding the manufacture of asbestos textiles (IARC, 1977) and mule spinning with exposure to mineral oils (IARC, 1984)

products. The synthetic dyestuff industry has developed from the discovery of the first synthetic dye, mauve, in 1856 by Perkin (Travis, 1988). Soon after, in 1859, another important dye, magenta (see IARC, 1974), was prepared by Verguin. One of the most remarkable landmarks in the development of synthetic dyes was Griess' discovery of the diazo reaction in 1858 (Peters, 1975), which led to the development of the azo dyes. The most important dye structures (chromophores) include triphenylmethane compounds, indigoid and azo structures, azines, thiazines, anthraquinone derivatives and phthalocyanines (Munn & Smagghe, 1983). A profound technological advance was achieved in the 1950s when reactive dyes were discovered. These compounds react chemically with the fibre and provide properties of fastness not achieved with the earlier water-soluble dyes.

Dyestuff manufacturing has become one of the major sectors of the chemical industry. The Colour Index lists approximately 38 000 different commercial colourants involving 7000-8000 different chemical structures. World production of dyestuffs was estimated to be 600 000-700 000 tonnes (active substance) in 1978, of which 50-60% were used for textiles (Clarke & Anliker, 1980). In 1986, 107 000 tonnes of textile dyes were produced in the USA (Reisch, 1988).

Benzidine-based dyes (see IARC, 1987a) are an important group of synthetic colourants. In 1948, about 14 million kg were produced, representing about 21% of world dye production, by about 50 companies in 19 countries. The production of benzidine-based dyes decreased drastically in the USA during the 1970s and in 1980 (National Institute for Occupational Safety and Health, 1980), but they may still be used elsewhere.

Development in the field of textile finishing has also been rapid. Through the use of different finishing treatments, the properties of textiles can be enhanced in many respects. The most important chemical finishing processes for cotton fabrics include crease-resistant, flame-retardant, water-repellent, antisoiling and antimicrobial treatments.

Treatment for crease resistance is the most widely used process for cellulosic textiles (e.g., cotton, viscose) because all cellulose fibres are susceptible to wrinkling. For this purpose, formaldehyde (see IARC, 1987b)-based resins have been in common use since the 1950s, when 'permanent press' fabrics and garments became available on the market. The first type of resin used was urea-formaldehyde resin (see IARC, 1982). The first commercial product of this type was placed on the market in 1933. Melamine-formaldehyde resins (see IARC, 1982) have also been and still are used for crease resistance (Hurwitz, 1987).

A new class of crease-resistant finishing agent for textiles was introduced in the USA about 1949. The most important group of these chemicals was cyclic ethylene ureas, such as dimethylol ethylene urea (Hurwitz, 1987), which react with the cellulose fibre (Marsh, 1962). Application of the new finishing agents increased gradually as the popularity of so-called 'permanent press' garments increased in the 1950s. In 1959, dimethylol dihydroxy ethylene urea was described, and it has become the most commonly used crease-resistant finishing agent (Hurwitz, 1987). It is made from urea, formaldehyde and glyoxal and releases much less formaldehyde than the earlier urea and melamine resins. In the 1980s, the release of formaldehyde from dimethylol dihydroxy ethylene urea was further reduced by alkylation. Other low-formaldehyde processes have been developed (Vail, 1983).

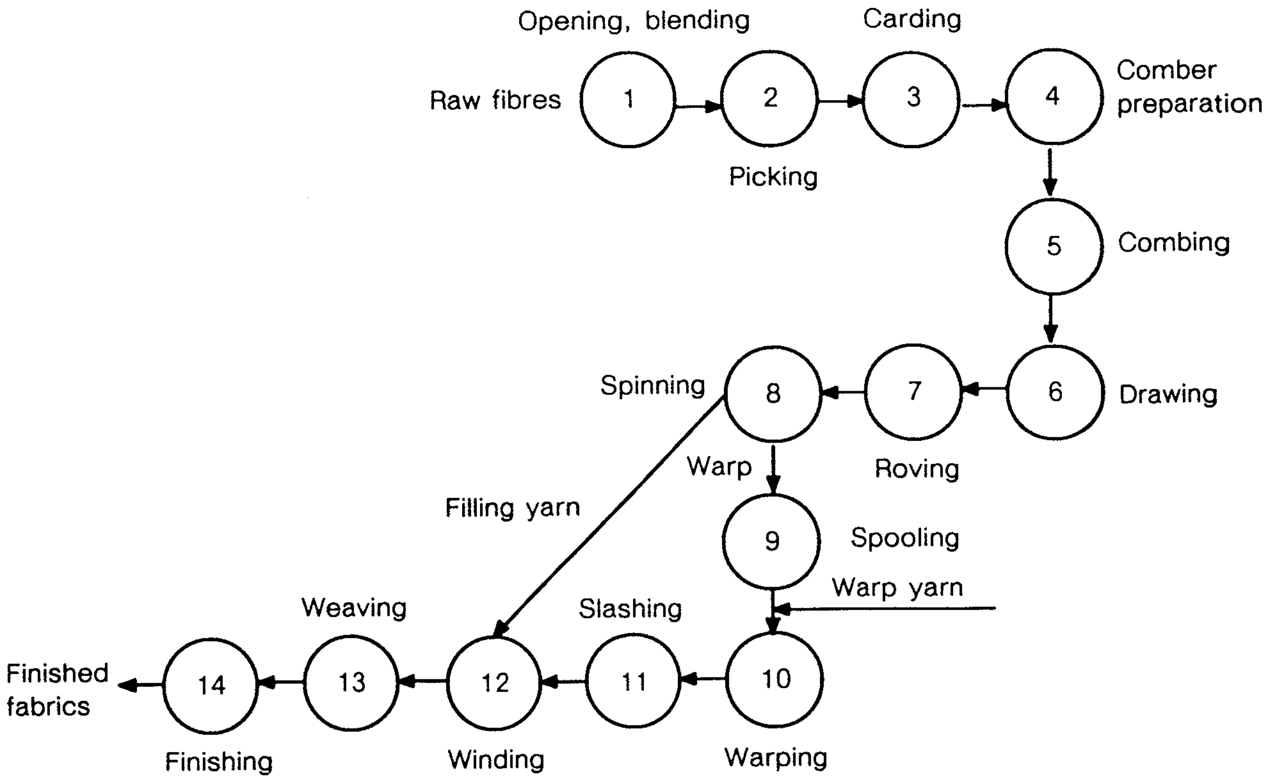
The use of flame retardants in textiles has a long history. Sea water, clay and vinegar are examples of ancient flame retardants. Over the last three decades, much research has been conducted into the development of fire-retardant textiles for such uses as work clothes, upholstery, space research and military purposes (Nousiainen, 1988). The flame retardants that are currently used are either inorganic salts or reactive phosphorus and nitrogen compounds.

Inorganic salts are easier to apply and often less toxic than organic reactive flame retardants, but they dissolve during normal laundering processes. Organic flame retardants, such as tetrakis(hydroxymethyl)phosphonium chloride (THPC; see monograph, p. 95) and *N*-methylol dimethylphosphonyl propionamide (Pyrovatex CP), react with cellulosic fibres to form chemical bonds that are stable for 50 or more launderings. The first compound of this type (THPC) was introduced in 1953 by Reeves and Guthrie (Nousiainen, 1988) and has given rise to a number of variants involving phosphonium structures (Bogle, 1977). One of the most widely used, durable flame retardants, Pyrovatex CP, was patented in 1965 (Nousiainen, 1988). In the 1970s, tris(2,3-dibromopropyl)phosphate (see IARC, 1979a) was commonly used for textiles and plastics and in particular for children's sleepwear in the USA; however, the compound was found to have carcinogenic and mutagenic properties, and its production ceased by the end of the 1970s. Corresponding chemical structures, such as tris(2-chloroethyl)phosphate (see monograph, p. 195) and tris(dichloropropyl)phosphate, are still used. Decabromodiphenyl oxide (see monograph, p. 73), introduced in 1976, has been used as a flame retardant in textiles.

1.2 Description of the industry

A typical flow diagram for the transformation of raw cotton into finished fabric is presented in Figure 1. Raw cotton bales are opened, and the cotton may be blended with synthetic or other natural fibres at the opening line. The cotton is then delivered to the picking machines, which transfer the fibres to the cards. During these first stages, fibres may be transported by air currents (blowing). Cotton fibres are then processed at the card. From the card, the fibre strands are run on the drawing frame. The best quality cotton and cotton blend yarn undergoes combing before drawing. From the drawing frame, strands of parallel fibres are moved to the roving frame. The product, called 'roving', goes to the spinning frame, and part is spun into warp yarn and part into filling yarn. The remaining processes before weaving are to prepare the yarn for weaving. Spinning-frame warp yarn is transferred from a bobbin to a large spool. A large number of these packages are placed on a warping machine to make a beam of yarn (beaming). The two machines, called a spooler and a warper, are actually types of winding machines. Several beams are run together on the last machine before weaving, which is called a 'slasher'. In this process, a hot solution of starch is applied to the warp yarn to reduce breakage and damage in the weaving. Yarn may be dyed before it is woven; this is particularly true for wool. Weaving is accomplished on a machine called a loom. 'Finishing' in Figure 1 comprises preparation, dyeing, finishing and inspecting the fabric.

Figure 1. Typical flow diagram for the transformation of fibre into fabric[a]



[a]From Marvin (1973)

Selected world production figures for woven cotton fabrics are given in Table 1, as an example of the recent production of basic textile products. In 1980, about 50% of world fibre production was accounted for by cotton, compared with about 70% in 1960 (Krol, 1985). Table 2 shows production figures for 1983 from the European Communities for some types of fabrics.

(*a*) *Fibre production*

Fabrics can be produced in two ways—by weaving and by knitting. Of these two processes, weaving is the older, being thousands of years old. The first knitting machine appeared in 1589 (Marvin, 1973).

The process of weaving involves the interlacing of two or more sets of yarn at right angles, the warp yarn running the length of the fabric and the filling yarn being inserted across the fabric. Each cross-wise insertion is called a pick. Knitting is the process of making a usable fabric from threads or yarns by arranging them into interlocking loops. The basic knit structure is called jersey fabric. In general, these same processes are followed for other fibres, both synthetic and natural.

Table 1. Selected production figures for woven cotton fabrics (in millions of square metres)[a]

Area	1976	1985
Africa	1 938	1 904
America, North	5 651	4 022
America, South	1 722	2 207
Asia	16 290	33 123
Australia	47	35
Europe	9 937	9 540
Eastern Europe	3 103	3 159
European Communities	4 726	4 714
European Free Trade Association	775	891
China	NA	15 202
Egypt	673	740
France	1 127	861
Germany, Federal Republic of	906	990
India	9 495	11 152
Japan	2 237	2 061
Mexico	523	510
Nigeria	367	285
Poland	979	887
Portugal	373	542
Romania	677	700
South Africa	126	139
USA	4 942	3 278
USSR	7 408	8 580

[a]From United Nations (1987)
NA, not available

Table 2. Production of fabrics in the European Communities, 1983[a]

Type of fabric	Production (tonnes)
Cotton	536 289
Wool or animal hair	162 803
Synthetic	436 081
Total	1 215 565

[a]From Commission of the European Communities (1988)

The yarn manufacturing process for synthetic fibres differs from that for cotton. The raw material is polymeric (plastic) material manufactured by the chemical industry. Synthetic fibre production involves melting of the polymer raw material and extrusion of the polymer melt through spinning heads or spinnerets. The production of the raw materials used to make yarn for synthetic textiles was not considered in this monograph. The description is included only for completeness.

(*b*) *Dyeing and finishing of fabrics*

The wet processing of textile fabrics is a combination of three separate operations: (i) preparing, (ii) dyeing and (iii) finishing. The combination is also sometimes referred to as finishing. A typical flow diagram for the dyeing and finishing of cotton fabric is presented in Figure 2. Most fabrics, except those prepared from wool, are dyed and finished after weaving. The end use of the textile determines whether it is dyed and/or finished.

Figure 2. A typical flow diagram of the dyeing and finishing of cotton[a]

Singeing
|
Desizing
|
Scouring
|
Mercerizing
|
Bleaching
|
Drying
|
Dyeing or printing
|
Drying
|
Impregnating finishing agent
|
Drying
|
Curing
|
Inspecting
|
Packing

[a]From Marvin (1973)

(i) *Preparing*

Preparation involves the removal of undesirable materials from fabrics so that they can be dyed or finished in later processes. Different fabric materials are processed in different ways.

In *singeing*, unwanted surface hairs or filaments are removed with a flame. The aim of *desizing* is the elimination of sizing agents applied earlier to warp yarns. Sizing agents are normally starch or polyacrylates. In *scouring*, the fabric is boiled to remove the remaining sizing agents and impurities accompanying cellulose and other fibres. *Mercerization* is the short-term treatment of cotton fabrics with a sodium hydroxide solution, which changes the physical and chemical properties of fibres and increases their strength and capacity to absorb dye. Fabric *bleaching* is intended to eliminate natural substances that impart a grey shade to the fabric. Chlorine-releasing compounds (such as hypochlorites) and hydrogen peroxide (see IARC, 1985) are the most commonly used bleaching agents (Bukayev, 1984).

(ii) *Dyeing*

Solid colours are produced by either continuous or noncontinuous methods. Continuous processes are used for large-yardage cotton materials and for carpets, as well as for fabrics that contain 100% man-made fibres.

The aim of the dyeing process is to impart a certain colour to the fabric through application and fixing of dyes. Table 3 lists the major classes of dyes now used. In dyeing, the dye molecules penetrate the pores of the swollen fibres and are retained there by chemical or physical forces. Cotton is generally dyed after the yarn has been woven or knitted into fabric, while wool yarn is usually dyed before.

Dyes developed for cotton can be divided into three main groups: (i) water-soluble dyes, (ii) dyes soluble by alkaline reduction and (iii) dyes formed on the fibre. Water-soluble textile dyes are direct dyes that have an affinity for cellulose fibres and reactive dyes that interact chemically with cellulose fibre. All water-soluble dyes used in the textile industry are electrolytes. Dyes soluble by alkaline reduction include vat and sulfur dyes. Dyes formed on the fibre comprise azo and oxidation dyes obtained from the oxidation of certain amines (Bukayev, 1984).

Polyester is normally dyed with disperse dyes, which can contain different chromophores. Carrier compounds are used to improve the capacity of polyester to accept dyes and include biphenyl, chlorinated benzene, naphthalene and naphthalene derivatives and phthalimides. The use of carrier compounds can be partially avoided if the dyeing temperature is increased to 130°C or if the Thermosol method is used, in which disperse dye is fixed to polyester fibre by hot air. Wool/polyester blends, however, cannot be dyed at high temperatures, and carriers have to be used.

Wool and polyamides are normally dyed with acid dyes, metal complex dyes or chromium dyes. The preparation of polyamide for dyeing involves scouring, some form of setting treatment and, in some cases, bleaching. Raw wool is first scoured by the emulsification process, then bleached with hydrogen peroxide or sulfur dioxide and finally neutralized in a sodium carbonate bath (Niyogi, 1983).

Table 3. Important classes of textile dyes and related compounds[a]

Class of compound	Major use	Major chemical structures
Acid dyes	Wool, polyamide	Azo (including premetallized dyes), anthraquinone, triphenylmethane, azine, xanthene, nitro and nitroso
Basic (cationic) dyes	Cotton	Triarylmethane, azo, azine, xanthene, thiazine, polymethine, oxazine and acridine
Direct dyes	Cotton, viscose	Diazo, triazo and polyazo, phthalocyanine, stilbene, oxazine and thiazole
Disperse dyes	Synthetic fibres (cellulose diacetate, cellulose triacetate, nylon, polyacrylic and polyester)	Simple azo, anthraquinone and nitroarylamine
Reactive dyes	Cotton, wool	Azo, anthraquinone, phthalocyanine and stilbene
Mordant dyes	Wool	Anthraquinone, azo, oxazine, triphenylmethane, nitroso and xanthene
Sulfur dyes	Cotton	Sulfur dyes
Vat dyes	Cotton, wool	Anthraquinone, polycyclic quinone and indigo
Optical brighteners	All fibres	Stilbene, dibenzothiophene, azole, coumarin and pyrazine
Dye carriers	Polyester, wool/polyester	Diphenyl, chlorinated aromatic hydrocarbon, benzoate and others

[a]From Bateman (1978) and Reisch (1988)

Basic (cationic) dyes are used for dyeing acrylic fibres.

In printing, colour is applied to the fabric surface and is bound there by physical and chemical forces. The process is similar to that of dyeing. Sometimes, organic solvents (alcohols, ketones, esters, aliphatic and aromatic hydrocarbons) are used in printing dyes and for the cleaning of printing frames. Several printing techniques, i.e., direct, discharge and resist printing, are used. Printing is done by roller, flat and rotary machines.

(iii) *Finishing*

Finishing agents (Table 4) are used to make fabrics crease-resistant, shape-retaining, nonshrinking, flame-retardant, water-repellent, antisoiling and antistatic. Antimicrobial agents, such as antimildew agents, can also be added to fabrics. For cotton fabrics, crease-resistant treatment is the most important. This process involves impregnating the fabric with cyclic reactants such as dimethylol dihydroxy ethylene urea, and improves the crease resistance and dimensional stability of the fabric. Several agents can be applied simultaneously. Finishing involves steps of impregnation, drying and curing. Following the curing step, the textile may also be washed (Priha *et al.*, 1988).

Table 4. Typical finishing agents used in the textile industry[a]

Type of agent	Typical chemicals	Use
Crease-resistant (durable press)	Urea-formaldehyde resin, melamine-formaldehyde resin, dimethylol ethylene urea, dimethylol dihydroxyethylene urea, carbamates, salt catalysts (e.g., magnesium chloride)	Cotton, viscose
Flame retardant	Tetrakis(hydroxymethyl)phosphonium salts, tris(2,3-dibromopropyl)phosphate, vinylphosphonate, decabromodiphenyl oxide, *N*-methyloldimethylphosphonyl propionamide (Pyrovatex CP)	Cotton, polyesters, polyamides, acrylics
Water repellent	Fluorocarbon compounds, silicones, zirconium-paraffin emulsions	Cotton
Antistatic	Tensides, polyethylene glycols, inorganic and organic salts, epoxy resins	Synthetic fibres
Antisoiling and soil-release	Aluminium, silicon and titanium oxides, starch, fluorocarbons, carboxymethyl cellulose, polymers (acrylates, epoxides)	Light-coloured textiles
Antimicrobial and related		
Antimildew	Pentachlorophenyl laurate, copper and zirconium compounds	Cotton (tent fabrics)
Bactericide	Quaternary ammonium compounds, tributyltin oxide	Socks, foot-wear lining fabric
Mothproofing	Dieldrin, pyrethroids, chlorinated aromatic sulfonamides, chlorinated urea derivatives	Wool, wool carpets
Softening agents	Tensides, polyethylene glycol, polysiloxanes	Synthetic fibres

[a]From Priha *et al.* (1988)

2. Exposures in the Workplace

2.1 Introduction

The textile industry is one of the largest employers worldwide. Table 5 gives recent figures for the numbers of workers in textile manufacturing in many countries. Figure 3 illustrates some trends for the European Communities, Japan and the USA.

Table 5. Numbers of workers (thousands) in the textile manufacturing industry (ILO code 321)[a]

Country or region	Workers (thousands)	Year
AFRICA		
Botswana	1	86
Burundi	< 1	82
Egypt	291	79
Ethiopia	36	84
Ghana	16	79
Kenya	26	87
Malawi	7	85
Mauritius	4	87
Nigeria	66	80
Sierra Leone[b]	< 1	81
South Africa	110	83
Tanzania, United Republic of[c]	38	80
Zimbabwe	21	85
AMERICA		
Argentina	1	85
Barbados[b]	2	86
Bolivia	5	84
Canada	84	87
Colombia	51	86
Cuba	33	86
Dominican Republic	4	84
Equador	15	86
ElSalvador	18	83
Guatemala	7	86
Haiti	2	83
Mexico	48	87
Antilles	< 1	82
Nicaragua	3	80
Panama	< 1	85
Puerto Rico	3	87
Uruguay	18	86
USA	725	87
Venezuela	30	84
Virgin Islands	0	87

Table 5 (contd)

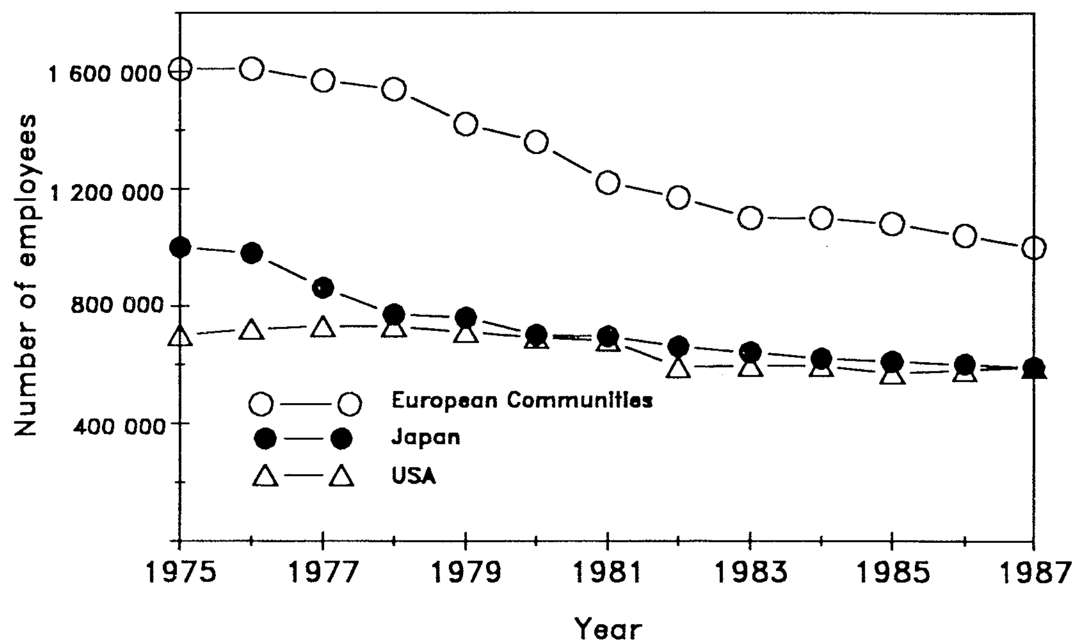
Country or region	Workers (thousands)	Year
ASIA		
Bangladesh	280	84
Brunei	< 1	86
China	4745	87
Hong Kong	119	87
India	1708	85
Israel	88	84
Japan	673	84
Jordan	1	84
Korea, Republic of	402	86
Malaysia	39	81
Philippines	91	86
Singapore	3	86
Sri Lanka	41	86
EUROPE		
Austria	42	87
Belgium	59	86
Bulgaria	121	86
Cyprus	2	87
Czechoslovakia	167	87
Denmark	15	86
Finland	15	87
France[b]	491	87
Germany, Federal Republic of[b]	582	86
Greece	61	83
Hungary	98	87
Ireland	10	87
Luxembourg	< 1	87
Malta	1	85
Netherlands	25	86
Norway	17	79
Poland	342	87
Portugal	134	85
Romania	412	85
Spain	170	87
Sweden	9	85
Switzerland	31	86
Turkey	180	84
UK[b]	559	87
Yugoslavia	281	87

Table 5 (contd)

Country or region	Workers (thousands)	Year
AUSTRALASIA		
Australia	47	85
New Zealand[b]	38	87

[a]From International Labour Office (1988)
[b]ILO Category 32, which includes leather industry

Figure 3. Employment trends in the textile industry[a]



[a]From Commission of the European Communities (1988)

A wide variety of occupational health hazards are present in the textile manufacturing industry. The most ubiquitous exposure in textile mills is to organic dust, in particular to cotton dust. Chemical exposure in spinning and weaving is limited mainly to sizing agents and spinning oils. Raw cotton may be contaminated with bacteria, desiccants and defoliants; raw wool may be contaminated by pesticides from sheep dips. There are no data, however, to indicate the levels of desiccants, defoliants or pesticides in textile mills. During fabric preparation, workers can be exposed to a variety of bleaching, scouring, singeing and mercerizing agents. In dyeing, printing and finishing, chemicals are widely used and exposures may be highly complex.

In 1970, it was estimated that 60 000-75 000 persons in the USA were involved in dyeing and finishing processes (National Institute for Occupational Safety and Health, 1981). In dyeing and printing, workers are frequently exposed to dyes, a variety of acids such as formic, sulfuric and acetic acids, fluorescent brighteners, organic solvents and fixatives. Workers in the finishing operations are frequently exposed to crease-resistant agents, many of which release formaldehyde, and to flame retardants, such as organic phosphorus compounds, chlorinated hydrocarbons and carbamates. These exposures may occur simultaneously with physical hazards, including noise, vibration and heat.

The wide range of substances to which workers in textile manufacturing may be exposed is indicated in Table 6.

Table 6. Substances and classes of substances found in the textile manufacturing industry[a]

Material	Principal use or source of emission
Acetic acid	Control of dye pH
Acid dyes	Dyeing
Ammonium sulfate	Control of dye pH
Basic dyes	Dyeing
Biphenyl	Dye carrier
Chlorendic acid	Flame retardant
Cotton dust	Opening, blending, carding, spinning, weaving, knitting
Cyclic ethylene ureas	Crease resistance
Decabromodiphenyl oxide	Flame retardant
Diammonium phosphate	Control of pH in wool dyeing
Dichloromethane	Fabric scouring
Dimethylformamide	Fabric finishing
1,3-Diphenyl-2-pyrazoline	Fluorescent brightener
Direct dyes	Dyeing
Disperse dyes	Dyeing
Endotoxins	Organic fibre contaminant
Ethylene glycol monomethyl ether	Fabric printing
Formaldehyde resins	Crease resistance
Formic acid	Control of dye pH
Hydrogen peroxide	Fabric bleaching
Hypochlorites	Fabric bleaching, preparation, singeing
Inorganic salts (e.g., bromides, phosphates, chlorides)	Flame retardants and other uses
Monochlorobenzene	Fabric printing
Monosodium phosphate	Control of pH in jet-dye machines
Mordant dyes	Dyeing
Phenol	Printing
Pigment dyes	Dyeing and printing
Polyvinyl alcohol	Fabric preparation, mercerizing cotton
Reactive dyes	Cloth dyeing

Table 6 (contd)

Material	Principal use or source of emission
Sodium acetate	Dyeing of 100% polyester
Sodium bichromate	Chrome-dyeing process
Sodium carbonate	Fabric bleaching
Sodium hydroxide	Fabric bleaching, mercerizing, scouring
Sodium perborate	Antisoiling agent for polyester
Spinning oils	Lubricants
Starch	Sizing agent
Sulfur dyes	Dyeing
Sulfuric acid	Carbonizing process of wool dyeing, desizing
Tetrachloroethylene	Fabric scouring, dye carrier
Tetrakis(hydroxymethyl)phosphonium salts	Flame retardants
Tetrasodium pyrophosphate	Control of dye pH
Trichloroethylene	Dye carrier ingredient, scouring
Tris(2,3-dibromopropyl)phosphate	Flame retardant
Vat dyes	Dyeing

[a]Adapted from Marvin (1973)

Very few data were available on the chemicals used, exposure levels and the numbers of workers involved in specific processes in developing countries. The exposure levels and chemicals used, in particular, dyes, could be quite different from those used elsewhere.

2.2 Organic dusts

(*a*) *Cotton*

The largest single exposure in the textile manufacturing industry is to cotton dust. Airborne dust levels associated with various operations are presented in Table 7.

Methods for sampling cotton dust differ from country to country, and, therefore, different results may be obtained (De Rosa *et al.*, 1984). The best established apparatus for sampling cotton dust is the vertical elutriator (cut-off point, 15 μm respirable dust; Neefus *et al.*, 1977). This method is commonly used in the USA and was also recommended by a study group of the World Health Organization (1983). Occupational limits for exposure to cotton dust in various countries or regions are presented in Table 8.

Table 7. Concentrations of cotton dust in the work environment[a]

Operation	No. of samples	Concentration (mg/m³)		Sample type	Method[b]	Country	Reference
		Mean	Range				
Opening, blending cleaning	NA	1.42	0.59–2.35	R, area	VE	Egypt	Noweir (1975)
Spinning	NA	0.2	0.14–0.26	R, area	VE	Egypt	Noweir (1975)
Willowing	NA	8.3	max, 8.6	T, NA	Filter[c]	India	Gupta (1969)
Winding room	NA	0.9	0.9–1.0	T, NA	Filter[c]	India	Gupta (1969)
Opening, blending	9	1.8	0.28–6.36	R, area	VE	USA	Jones *et al.* (1979)
Spooling, warping	9	0.2	0.10–0.38	R, area	VE	USA	Jones *et al.* (1979)
Opening	9	0.89	0.28–2.43	R, area	VE	USA	Hammad *et al.* (1981)
Cleaning	7	15.8	9.98–19.4	T, P	Filter[c]	USA	Hammad *et al.* (1981)
Blending	6	6.4	1.6–11.1	R, area	VE	USA	Hammad *et al.* (1981)
Blending	6	8.8	3.2–14.5	T, area	Filter[c]	USA	Hammad *et al.* (1981)
Twisting	3	0.28	0.14–0.42	R, area	VE	USA	Hammad *et al.* (1981)
Roving	6	0.5	0.36–0.52	R, area	VE	USA	Hammad *et al.* (1981)
Spinning	112	1.5	max, 30.0	T, P	Filter[d]	UK	Hobson (1974)
Spinning	84	1.1	0.59–1.59	R, P	Filter[d]	UK	Cinkotai *et al.* (1984)
Carding	24	4.63	1.45–7.81	R, P	Filter[d]	UK	Cinkotai *et al.* (1984)
Opening	26	1.6	0.42–2.90	R, area	VE	China	Christiani *et al.* (1986)
Winding	15	0.5	0.15–0.61	R, area	VE	China	Christiani *et al.* (1986)
Carding, blowing	NA	NA	0.06–5.28	NA	NA	Hong Kong	Ong *et al.* (1985)
Other	NA	NA	0.06–2.10	NA	NA	Hong Kong	Ong *et al.* (1985)
Winding & twisting	20	4.7	1.1–8.2	T, area	Filter[c]	Cameroon	Takam & Nemery (1988)
Weaving	20	6.0	5.1–6.8	T, area	Filter[c]	Cameroon	Takam & Nemery (1988)
Winding & twisting	6	2.0	NA	T, P	Filter[c]	Cameroon	Takam & Nemery (1988)
Spinning	6	8.9	NA	T, P	Filter[c]	Cameroon	Takam & Nemery (1988)
Weaving	6	4.5	NA	T, P	Filter[c]	Cameroon	Takam & Nemery (1988)

[a]R, respirable dust; VE, vertical elutriator (cut-off point, 15 µm); T, total dust; NA, not available; P, personal
[b]Filters analysed gravimetrically
[c]Open-faced cassette alone
[d]Open-faced cassette preceded by 12-in (30-cm) cube of 2-mm-mesh wire gauge to remove lint

Table 8. Occupational limits for exposure to cotton dust[a]

Country or region	Year	Concentration (mg/m³)	Interpretation[b]
Czechoslovakia	1987	2	TWA
Denmark	1987	0.5	TWA
Finland	1987	1	TWA
German Democratic Republic	1987	5	TWA (8.75 h)
Germany, Federal Republic of	1988	1.5	TWA
India	1987	0.2	TWA
		0.6	STL
Indonesia	1987	1	TWA
Mexico	1987	0.2	TWA
Netherlands	1987	0.2	TWA
Norway	1987	0.5	TWA
Sweden	1987	0.5	TWA (VE)
Switzerland	1987	1.5	MAC
Taiwan	1987	1	TWA
UK	1987	0.5	TWA (spinning to winding and weaving)
		5	TWA (all other processes)
USA[c]			
OSHA	1988	0.2	TWA (yarn industry, VE)
		0.75	TWA (slashing and weaving, lint-free VE)
		0.5	TWA (all other textile operations, lint-free VE)
ACGIH	1988	0.2	TWA (VE)
NIOSH	1983	0.2	TWA (lint-free, VE)
USSR	1987	2	MAC
Yugoslavia	1987	5	TWA

[a]From Cook (1987); Deutsche Forschungsgemeinschaft (1988); National Institute for Occupational Safety and Health (1988); American Conference of Governmental Industrial Hygienists (1989)

[b]TWA, time-weighted average (8-h); STL, short-term level (30 min); VE, occupational level as determined by vertical elutriation (cut-off point, 15 μm respirable dust); MAC, maximum allowable concentration (8-h). All occupational exposure limits are for total dust unless noted; the values are not comparable, as different sampling methods were used.

[c]OSHA, Occupational Safety and Health Administration; ACGIH, American Conference of Governmental Industrial Hygienist; NIOSH, National Institute of Occupational Safety and Health.

(*b*) *Wool*

Wool dust concentrations were quantified in a wool carpet weaving facility in Turkey using a filter method [not further specified]; levels varied within the plant, the highest being found in the opening area (3.4 mg/m³) and the lowest in the spinning area (1.7 mg/m³; Özesmi *et al.*, 1987).

(*c*) *Flax*

Respirable airborne flax dust was collected with a vertical elutriator in a flax mill in Alexandria, Egypt. The mean levels in mechanical textile operations ranged from 0.60 mg/m^3 in winding to 4.03 mg/m^3 in carding; those in the manual processing area varied from 1.54 mg/m^3 in spinning to 9.8 mg/m^3 in hackling (Noweir, 1975). [The Working Group noted that the number of samples collected was not reported.]

(*d*) *Hemp*

In an evaluation of mean respirable airborne levels of hemp dust collected with a horizontal laminar elutriator/filter in a Yugoslav textile mill, spinners had the highest levels of exposure (2.7 mg/m^3) and carders the lowest (0.9 mg/m^3; Valic & Žuškin, 1971).

2.3 Dyes and their components

(*a*) *Textile dyes*

Over 5000 workers were estimated to be potentially exposed to benzidine-derived dyes (see IARC, 1987a) in the USA textile dyeing and finishing industry in 1972-74 (National Institute for Occupational Safety and Health, 1977). In a study in a textile dyeing plant in the USA, four of ten dyers potentially exposed to benzidine-derived dyes had benzidine (see IARC, 1987c) or monoacetylbenzidine, a metabolite of benzidine, in their urine (National Institute for Occupational Safety and Health, 1978). Five of 20 workers involved in weighing benzidine-derived dyes in three UK textile mills had benzidine in their urine; all five worked in the same factory (Meal *et al.*, 1981).

About 16 000 workers are potentially exposed to textile dyes in the Finnish textile industries. Dyers' mean exposure to total dust in three dyehouses varied from 0.4 to 4.1 mg/m^3, depending on the dye type and other parameters; the corresponding mean dye concentrations were 0.02-0.12 mg/m^3. The proportion of dyes (mainly indigo) in this dust varied from 1.6 to 12% (Schimberg & Vuorinen, 1986).

(*b*) *Trichloroethylene* (see IARC, 1979b, 1987d)

About 22 000 workers were estimated to be potentially exposed to trichloroethylene in the US textile manufacturing industry in 1972-74 (National Institute for Occupational Safety and Health, 1977). Samples collected in the breathing zone of workers at two US textile mills during the weighing of dyes indicated a mean exposure to trichloroethylene of 0.38 ppm (2.04 mg/m^3), with a range of 0.11-0.56 ppm (0.59-3.01 mg/m^3; Bateman, 1978).

(*c*) *Acetic acid*

Samples collected in the breathing zone of workers at two US textile mills during the weighing of dyes indicated a mean exposure to acetic acid of 13 ppm (32 mg/m^3), with a range of 1-40 ppm (2.45-98 mg/m^3; Bateman, 1978).

(*d*) *Biphenyl*

Potential exposure to biphenyl in the USA is considerable because of its high production volume and widespread use as a dye carrier (National Cancer Institute, 1985a). High airborne concentrations were measured in a dyehouse in a Finnish textile factory in the early 1970s, due to the use of open-type dyeing machines. In this workplace survey, short-term (15-30 min) biphenyl concentrations were 7.5-44 mg/m³. In two later surveys in Finnish textile factories when closed-pressure dyeing machines were used, biphenyl concentrations were under 0.05 mg/m³ (Priha *et al.*, 1988).

2.4 Finishing agents and their components

Exposure to formaldehyde (see IARC, 1982, 1987b) is common in the finishing process. About 20 000 employees were estimated to be exposed to formaldehyde in US textile finishing plants in 1979 (Goodson, 1984). As indicated in Table 5, large numbers of workers are employed in the textile manufacturing industry in developing countries; however, no data were available on the numbers employed in the finishing process or on levels of exposure to formaldehyde. Measurements in a US textile printing and finishing plant indicated that during treatment of printed fabrics before finishing, operators had an 8-h time-weighted average (TWA) exposure to formaldehyde of 1.2 ppm (1.5 mg/m³), while chemical finishers had an 8-h TWA of 0.7 ppm (0.85 mg/m³; Keenlyside & Elliott, 1981). Levels of formaldehyde in US textile mills treating nylon fabric were reported to have ranged from 1 ppm to 11 ppm (1.2-13.4 mg/m³) in 1955; by 1979, however, these levels had fallen to 0.1-1.4 ppm (0.12-1.7 mg/m³; Ward, 1984). [The Working Group noted that duration of sampling was not reported.]

Formaldehyde levels in Finnish textile factories in 1975-78 and in the Swedish textile industry are given in Table 9.

Table 9. Airborne formaldehyde concentrations in Finnish and Swedish textile factories during selected finishing processes

Process/work	No. of samples	Formaldehyde concentration (mg/m³)[a]	
		Mean	Median
Finland[b]			
Crease-resistance treatment	52	0.5	0.4
Flame-retardant treatment	67	2.5	1.2
Other treatments	17	0.4	0.4
Mixing of finishing resin	8	1.1	0.3
Fabric warehouse	6	1.1	1.1
Sweden[c]			
Crease-resistance treatment	29	0.2	0.2
Flame-retardant treatment	2	1.5	NA

[a]Area sampling time ranged from 30-60 min
[b]From Nousiainen & Sundquist (1979)
[c]From Rosén *et al.* (1984)
NA, not available

Formaldehyde is also present in textile dust derived from finished cellulosic fibres for crease-resistant and flame-resistant textiles (Rosén *et al.*, 1984). Unstable *N*-methylol and other unstable bonds are easily hydrolysed and metabolized to formaldehyde (Vail, 1983; Priha *et al.*, 1988), and exposure *via* the skin may take place during contact with finished textiles. Formaldehyde is a common skin sensitizer in textile and clothing industries (Hatch & Maibach, 1986). Due to such problems, regulations limiting formaldehyde levels in fabric have been drawn up in some countries, including Japan and Finland. Formaldehyde concentrations ranging from 32 to 855 mg/kg were measured in textiles marketed in Finland (Priha *et al.*, 1988).

Exposure to other chemicals occurs in the textile manufacturing industry (see Table 6), but quantitative data were not available to the Working Group.

2.5 Other agents

(a) Bacteria and endotoxins

Endotoxin levels of 0.02-2.5 μg/m³ have been observed in cardrooms of the US cotton, flax and jute industries, on filters containing dust collected on vertical elutriators (Rylander & Morey, 1982). The mean endotoxin content in airborne, unwashed cotton dust in a model US cardroom was found to range from 40.3 ± 4.1 to 390.2 ± 22.6 ng/mg. Washing the cotton reduced the endotoxin concentrations to a range of 7.4 ± 1.0 to 21.6 ± 4.0 ng/mg. These samples were collected with a cascade impactor preceded by a vertical elutriator (Olenchock *et al.*, 1983).

Evaluation of area airborne levels of endotoxins in two cotton mills in Shanghai, China, collected with a vertical elutriator, revealed mean (range) levels of 0.002 (0.001-0.02)-0.53 (0.32-0.71) μg/m³ (Kennedy *et al.*, 1987). Evaluation of the levels of airborne endotoxins present in the work environment of a wool carpet-weaving plant in Turkey showed that the weaving process was the dustiest and contained the highest levels (maximal level, 31.2 μg/g wool dust) compared to the washing process (mean level, 0.7 μg/g wool dust). The range of endotoxin levels at the various processes was 0.1-31.2 μg/g wool dust (Özesmi *et al.*, 1987).

Samples of airborne bacteria were collected with an Anderson viable sampler in 21 English cotton spinning mills. The mean concentrations of endo agar bacteria were 270 ± 140—6150 ± 3380 organisms/m³, and those of the nutrient agar bacteria between 1200 ± 540 and 89 300 ± 21 300 organisms/m³ (Cinkotai & Whitaker, 1978).

(b) Ethylene glycol monomethyl ether

During use of a printing press in a textile printing plant in Massachusetts, USA, the average level of ethylene glycol monomethyl ether originating from cleaning agents was 8.0 ppm (30 mg/m³; Ohi & Wegman, 1978). [The Working Group noted that the range of levels and the number of samples collected were not reported.]

(c) Tetrachloroethylene (perchloroethylene) (see IARC, 1979c; 1987e)

About 6600 employees were estimated to be potentially exposed to tetrachloroethylene in the US textile manufacturing industry in 1972-74 (National Institute for Occupational Safety and Health, 1977). Tetrachloroethylene is used for scouring (mainly of double knits), sizing, desizing and as a dye carrier (National Cancer Institute, 1985b).

(*d*) *Monochlorobenzene*

During use of a printing press in a textile printing plant in Massachusetts, USA, the average airborne level of monochlorobenzene originating from cleaning agents was 15.0 ppm (69 mg/m^3; Ohi & Wegman, 1978). [The Working Group noted that the range of levels and the number of samples collected were not reported.]

(*e*) *Other solvents*

Results of a survey conducted in several Finnish textile manufacturing facilities in 1975-78 are given in Table 10.

Table 10. Exposure to common solvents used in the Finnish textile printing industry, 1975-78[a]

Solvent	No. of samples	Concentration (ppm) [mg/m^3]	
		Mean	Median
Acetone	57	40 [95]	1.0 [2.4]
n-Butanol	28	7.7 [23]	3.8 [11]
n-Butyl acetate	60	3.8 [16]	<0.1 [<0.4]
Dichloromethane	18	66 [230]	30 [104]
Ethyl acetate	35	31 [96]	4.8 [15]
Hydrocarbon solvent (white spirit)	52	[230]	[167]
1-Propanol	15	16 [39]	<0.1 [2.5]

[a]From Nousiainen & Sundquist (1979); study covered preparation of printing plates and rolls and cleaning of presses

(*f*) *Oil mist*

In Finland, workers have been exposed to average levels of 1.4 mg/m^3 (51 samples) oil mist, which results from the use of yarn lubricants in the weaving, knitting and fixing of cotton-polyamide yarn (Nousiainen & Sundquist, 1979).

(*g*) *Sodium hydroxide*

In a survey conducted in Finnish textile factories in 1975-78, mean airborne concentrations of sodium hydroxide were 1.7-6.8 mg/m^3 during mercerizing, bleaching, scouring and mixing operations (Nousiainen & Sundquist, 1979).

3. Biological Data Relevant to the Evaluation of Carcinogenic Risk to Humans

3.1 Carcinogenicity studies in animals

No data were available on the carcinogenicity of textile dusts to experimental animals.

3.2 Other relevant data

(*a*) *Experimental systems*

(i) *Absorption, distribution, excretion and metabolism*

No data were available to the Working Group.

(ii) *Toxic effects*

Studies on the toxic effects of exposures to dusts in the textile industry in experimental animals and in in-vitro systems have concentrated on three main areas: (i) identification of animal models that imitate human responses to inhaled dusts and that develop airway diseases similar to those of humans (Walker *et al.*, 1975; Kutz *et al.*, 1980; Ellakkani *et al.*, 1984, 1985, 1987; Witek *et al.*, 1988); (ii) identification of active components of dusts responsible for immediate and delayed airway responses, such as bronchoconstriction and recruitment of cells involved in the release of leukotrienes, histamine and other mediators of airway tone (Antweiler, 1960; Rylander & Snella, 1976; Buck *et al.*, 1986); and (iii) use of in-vitro cell systems or organ explants to evaluate the cytotoxicity and other effects of dusts and dust extracts (Johnson *et al.*, 1986; Thomson *et al.*, 1986). The findings from these lines of research do not appear to have immediate relevance to an evaluation of the potential carcinogenicity of exposures in the textile industry.

(iii) *Effects on reproduction and prenatal toxicity*

No data were available to the Working Group.

(iv) *Genetic and related effects*

No data were available to the Working Group.

(*b*) *Humans*

(i) *Absorption, distribution, excretion and metabolism*

No data were available to the Working Group.

(ii) *Toxic effects*

Effects on human health in the textile industry, apart from those arising from exposures to chemicals associated with textile manufacturing, are limited almost entirely to respiratory disease arising from inhalation of organic dust and to microbial contamination arising from vegetable and animal fibres. Other health effects reported include some dermatitis and possible increases in mortality rates from cardiovascular disease.

Respiratory disease, including byssinosis, bronchitis, acute and chronic changes in lung function and heightened airway reactivity, have been the subject of intensive study in the primary textile industries utilizing cotton, soft hemp, flax, wool and some other vegetable textile fibres (sisal, jute, manila, St Helena hemp). The worldwide prevalence of byssinosis, clinical manifestations, epidemiological studies, environmental and health assessments, and the relationship between exposure to cotton, flax and soft hemp dust and byssinosis, together with recommended permissible exposure limits, have been reviewed (World Health Organization, 1983).

There is further epidemiological evidence of the importance of endotoxins arising from gram-negative organisms as etiological agents in provoking acute airway constriction and symptoms of byssinosis among cotton textile workers (Castellan *et al.*, 1984; Malmberg, 1985; Rylander *et al.*, 1985; Castellan *et al.*, 1987; Rylander, 1987). Textile workers exposed to unscoured wool also develop lung function abnormalities consistent with byssinosis (Zuskin *et al.*, 1976). Respiratory symptoms consisting of bronchitic wheeze, breathlessness and persistent rhinitis, conjunctivitis and chills, which are related to concentrations of dust (contaminated with endotoxin), have been reported in Yorkshire wool textile workers (Love *et al.*, 1988) and as byssinosis among carpet weavers exposed to wool contaminated with endotoxins (Özesmi *et al.*, 1987).

Health effects following acute and chronic exposure to cotton dust, including mill fever, pulmonary function, chest tightness (byssinosis), hyperreactive airways and chronic bronchitis, have been summarized as the 'Manchester criteria' (Rylander *et al.*, 1987).

Case reports of both primary irritant and contact dermatitis, often occurring together, have been published. Nearly all of these reports refer not to occupational dermatitis related to exposure to textile dyes and other chemical irritants and sensitizers found in the textile industry, but rather to dermatological reactions to wearing garments made of irritating fibres and/or containing chemical residues (Hatch & Maibach, 1985, 1986). Occupational dermatoses, including contact and irritant dermatitis, have been attributed to mechanical irritation, dyes, synthetic detergents, oil products and microbes (Reinhard & Tronnier, 1970; Sokolova, 1972; Kieć-Świerczyńska, 1982; Makushkina, 1983; Mathur *et al.*, 1985).

Reviews of UK Registrar General death rates from 1891 to 1932 revealed high rates of respiratory and cardiovascular disease among cotton textile workers (Registrar General, 1897, 1908, 1923, 1927, 1938). These data were reanalysed in the light of subsequent studies of respiratory disease among Lancashire cotton textile operatives: after correcting for respiratory causes of death, excesses in cardiovascular morality were still noted, particularly among carding machine stripper and grinders, who traditionally have the dustiest jobs in textile mills (Schilling & Goodman, 1951). A subsequent mortality study of cotton textile workers revealed low rates for all causes of death, including respiratory disease, heart disease and cancer (Henderson & Enterline, 1973). A cohort employed in two North Carolina cotton mills also had no overall increase in mortality from nonmalignant respiratory disease; however, the rate doubled between persons with low duration of exposure and those with high duration. Significantly increased mortality from cardiovascular disease was also observed among men and women in yarn processing areas (Merchant & Ortmeyer, 1981).

(iii) *Effects on reproduction and prenatal toxicity*

Data from the Finnish National Board of Health hospital discharge register and the national census were used to analyse spontaneous abortions by occupational exposure of mothers and husbands for 1973-76. Using logistic regression models in which adjustment was made for several potential risk factors (age, place of residence, parity), relative risks (RRs) for spontaneous abortion were found to be increased among women employed as spinners (odds ratio, 1.3; 95% confidence interval (CI), 0.96-1.9), fabric inspectors (1.5; 0.96-2.4) and weavers (1.4; 1.1-1.9) over those in women employed in manufacturing (Lindbohm *et al.*, 1984).

In a study of prematurity and low birth weight in the region of Montréal, Canada, no increased risk was observed among women employed in the textile industry: 16 pre-term and 18 low birthweight babies were observed among 186 pregnancies (McDonald *et al.*, 1988).

An analysis of birth records in the state of Washington, USA (1980-81) revealed an increased risk for fetal death among offspring of women employed in the textile industry (RR, 1.5; 95% CI, 1.2-1.9; 71 cases) (Vaughan *et al.*, 1984).

(iv) *Genetic and related effects*

No data were available to the Working Group.

3.3 Epidemiological studies of carcinogenicity to humans[1]

A lack of data on occupational exposure was a major obstacle to an evaluation of specific risks in the textile manufacturing industry. 'Textile industry' and 'textile work' were frequently used as general terms, with no further specification, to include a wide range of exposures and occupations. In the text below, the terminology of the authors was used, and only the distinctions that appeared in the papers are made. Textile workers were also sometimes grouped jointly with garment workers and those in other occupations, so that estimates of the risks for workers in textile manufacturing may be biased.

Studies of occupational groups in which the Working Group considered there was probably a high proportion of garment workers or which included workers who manufactured dyes were not considered; however, in a number of studies, particularly those based on mortality statistics, the proportion of nontextile workers in joint occupational groups was unknown. In those cases, the study was included but it was considered to be of only limited importance for an evaluation of carcinogenic risk in the textile manufacturing industry.

Considerable differences may have existed in levels or patterns of exposure or in the presence of modifying or confounding factors in the occupational groups that have been studied, which may have produced apparently contradictory findings. A further difficulty in

[1]Calculations of statistical significance that were done by the Working Group are given in square brackets in the text.

evaluating carcinogenic risk in the textile industry is that many of the major studies—of different types—addressed risks for cancers at many sites. Some studies reported only statistically significant results, while others also reported negative findings. In order to make an unbiased evaluation, all the reported data, irrespective of statistical significance, were taken into account.

In the following, the design of studies that addressed cancer at several sites is summarized first. Then, the results of these and other studies are presented, by site, in the order given in the International Classification of Diseases. In general, duration of exposure appeared to have no effect on risk for workers in the textile industry; this aspect is therefore mentioned only when an effect was seen. Few of the studies were specifically designed to study the risk for cancer associated with working in the textile industry. The reported associations are therefore often incidental findings in studies in which many risk factors were considered.

(*a*) *Descriptions of studies of cancers at multiple sites*

(i) *Mortality/morbidity statistics*

Versluys (1949) analysed the registrations of 49 245 (23 318 men and 25 927 women) deaths from carcinoma in the Netherlands in the period 1931-35. For men in certain occupations, the distribution of deaths by site was compared to the distribution in all men.

Occupational mortality in England and Wales has been examined in a series of studies for the periods 1949-53 (Office of Population Censuses and Surveys, 1958), 1959-63 (Office of Population Censuses and Surveys, 1971; Logan, 1982) and 1970-72 (Office of Population Censuses and Surveys, 1978; Logan, 1982), and for Great Britain in 1979-80 and 1982-83 (Office of Population Censuses and Surveys, 1986). These compilations are referred to as the 1951, 1961, 1971 and 1981 decennial supplements, respectively. All analyses involved the calculation of age-adjusted standardized mortality ratios (SMRs), based on national mortality rates. For the 1951 supplement, only statistically significant results are given, and the study did not report overall cancer mortality in male textile workers. Before the 1981 supplement, married women were classified according to the occupation of their husband, whereas single women were classified according to their own occupation; this yielded overall cancer SMRs among textile workers of 106 in 1961 and 105 in 1971 for married women and 115 in 1961 and 148 in 1971 for single women (Logan, 1982). In 1981, the proportionate mortality ratio (PMR) for cancers at all sites in female textile workers aged 20-59 years was 91.

Guralnick (1963) published a report on mortality and occupation based on the entries of occupation and industry on the death certificates of men between the ages of 20-64 years who had died in the USA in 1950. The population at risk in each occupation and age class was estimated from the 1950 census figures. Expected deaths were calculated from the cause-, age- and ethnic-specific mortality rates for the entire US population. SMRs were reported only for sites for which >20 cases were observed.

Delzell and Grufferman (1983) investigated the distribution of causes of death among white female textile workers who had died in North Carolina (USA) during 1976-78. A total of 4462 deaths had occurred among women whose usual occupation, as recorded on the death certificate, had been in the textile industry and who were at least 15 years of age at death. It was estimated that 86% of the classifiable industries manufactured textile mill products and 14% manufactured clothing and other fabricated textile products. Expected deaths were calculated from the distribution of causes of death among other white female residents of North Carolina. Results were presented for selected cancer sites only.

In several studies, the Swedish Cancer Environment Register was used to study cancer incidence in 1961-79. Occupation was classified according to 1960 census records, and all analyses were standardized for sex, birth cohort and geographical region (Malker *et al.*, 1986a,b, 1987; McLaughlin *et al.*, 1987).

Olsen and Jensen (1987) analysed 93 810 cases of cancer registered in Denmark in 1970-79. These were linked to the Supplementary Pension Fund employment records, and age-standardized proportional incidence ratios (SPIRs) were estimated for various branches of industry. The observed number of cancer cases was allocated to the industry in which the cancer patient had been employed for the longest time.

A proportionate mortality study of 6113 male textile workers 16 years of age or more who had resided and had died in the State of Rhode Island (USA) during the period 1968-78 was carried out by Dubrow and Gute (1988). Information on occupation was retrieved from death certificate files, and all those coded as textile industry were double-checked against the original statements on the death certificates. The cause-specific mortality pattern of textile workers was compared with that of other Rhode Island decedents.

Another proportionate mortality study was conducted among carpet and textile workers in five counties in north-west Georgia, USA, a region with a very high percentage of textile industry employment (O'Brien & Decouflé, 1988). The study was based on mortality records, 1970-84, of white men aged 20-74 years at death. Statements about occupation and industry were abstracted from 1356 retrievable death certificates. For 28.5% of the decedents, the usual industry had been textile or carpet/textile. The final study group comprised 240 decedents who were classified as likely or possibly to have been production workers; for 91, no specific occupation in the textile industry was given. The number of expected deaths was calculated on the basis of the cancer mortality of other residents in the study area and that of all Georgia residents.

(ii) *Cohort studies*

Henderson and Enterline (1973) examined the mortality at ages 15-64 years of two cohorts of white male cotton textile workers at three mills in Georgia, USA, engaged in the processing of raw cotton into woven fabric. The first cohort consisted of 5822 men who had worked at some time in the mills between 1938 and 1941, and the second of 6316 men who were working in the same mills during 1948-51. A total of 1772 men were members of both cohorts and had probably worked at least eight to ten years in the cotton textile mills. The mortality experience of these textile workers was examined through 30 June 1963. The number of expected deaths was calculated from the age-specific death rates for white males in Georgia for 1940, 1950 and 1960; rates for 1945 and 1955 were obtained by interpolation. A total of 1134 deaths (SMR, 81) were reported during the study period; death certificates were available for 87% of these. The observed:expected ratio was consistently lower than 1.00 for deaths from cancers at all sites and for those from digestive, respiratory and urinary cancers. Exposure was specified only as 'work in cotton textile mills'; however, the authors stated that 'some' of the workers had been engaged in dyeing cotton yarn. Smoking was excluded as a possible explanation of the findings on the basis of previous investigations which had shown similar smoking habits in cotton industry workers and the rest of the population. [The Working Group noted that no data were provided on the completeness of follow up.]

A proportionate mortality study was based on 1429 death certificates preserved by a section of the National Union of Dyers, Bleachers and Textile Workers in Bradford (UK) for persons exposed before 1936 and followed for 1957-68 (Newhouse, 1978). Only data on cancers of the digestive system, lung and bladder were given. The authors noted that with this study design they would not have detected cancer cases with a latency shorter than 20 years.

A cohort of 2844 persons (2119 men, 725 women) employed for 'some time' at two cotton mills in North Carolina (USA) during 1937-40 was studied by Merchant and Ortmeyer (1981). Complete job history and vital status were available for 1444 persons (1062 men, 382 women), and mortality over 1940-75 was analysed. The number of expected deaths was calculated on the basis of race-, sex- and age-specific death rates for the US population in the same calendar period. Exposure to cotton dust was classified into four categories: 1, high exposure, including 'preparation activities' such as opening, blending, carding and work in the waste house; 2, moderate exposure corresponding to 'yarn processing', including spinning, warping, winding, spooling and beaming; 3, moderate to low exposure, including slashing, weaving and cloth handling; and 4, variable but generally low exposure, comprising 'other' jobs, such as finishing, packing, maintenance and administrative-clerical. A total of 513 deaths (SMR, 98) was seen. Overall SMRs for all malignant neoplasms tended to decrease with increased presumed exposure to cotton dust. Site-specific data were given only for cancer of the trachea, bronchus and lung; risks at other sites were reported not to be elevated.

(iii) *Case-control studies*

Detailed personal interviews were sought with a random 10% sample of all persons with invasive tumours newly diagnosed during a three-year period in eight areas of the USA surveyed in the Third National Cancer Surveys (Williams *et al.*, 1977). Interviews were obtained with 3539 men and 3937 women (57% of the original sample). The proportions of specific, main lifetime industries and occupations among patients with cancer at one site were compared with those of patients with cancers at other sites combined as a control group, while controlling for other variables such as age, sex, smoking and drinking habits, and educational level. 'Textile mill products' was classified as main lifetime industry for 11 male (0.3%) and 24 female (0.6%) patients. As a second analytical approach, the recent industries of patients who were interviewed were compared to those of people in industries at the same locations as those of the patients in the Third National Cancer Surveys, using the US 1970 census tabulations. Only sites and work categories 'showing an association' were reported. No association of any type of cancer with working in the textile industry was found.

During 1956-65, all persons referred to the Roswell Park Memorial Institute, Buffalo, NY, USA, were asked prior to diagnosis of disease to report their lifetime occupational history (Decouflé *et al.*, 1978). In total, 6434 white males and 7515 white females were selected for the study. The ratio of persons in a given occupation to those whose lifetime employment had consisted almost entirely of clerical jobs among cases of cancer at specific sites was compared with the ratio in controls without neoplastic disease, taking age into account. The categories considered included 'operatives in textile mills', 'spinners' and 'weavers'; only statistically significant findings were generally reported.

A subset of the data presented by Decouflé *et al.* (1978) was analysed in order to examine the possible cancer risk pertaining to occupations in which exposure to dust was suspected (Bross *et al.*, 1978). The study was limited to men. RRs adjusted for age, smoking and ethnicity were calculated as in the previous study. Only sites for which the RR was >2 were reported.

In a case-control study of cancer registrations in men aged 18-54 in three English counties during the period 1975-80, occupational histories were obtained by postal questionnaire from 1533 patients (52.1% of the 2942 cases identified) or next-of-kin (Coggon *et al.*, 1986a,b). Eighteen cancer sites were examined, and each was compared with all other cancers combined. All analyses were adjusted for age, county of residence, source of the history (patient or relative) and smoking history.

A case-control study of cases of cancer at different sites and occupational exposure to nine organic dusts was conducted in the area of Montréal, Canada (Siemiatycki *et al.*, 1986). Histologically confirmed cases of cancer at 19 sites newly diagnosed between September 1979 and June 1983 among male residents aged 37-70 were ascertained in 19 major hospitals. The number of eligible subjects was 2610, but completed interviews were obtained for only 2180 (83.5%); 19% of these were obtained from next-of-kin. The questionnaire was designed to obtain a detailed description of each job the subject had had in his working lifetime, as well as information on important potential confounders. A team of chemists and hygienists translated each job reported in the questionnaires into a list of potential exposures in accordance with all available information about each situation. This analysis covered nine cancer sites for which at least 100 subjects had been interviewed. Each series of subjects with a common tumour was compared with one or more controls drawn from among cases of cancer at the other sites included in the study. Exposure information was used to set up three exposure levels for each organic dust: 'unexposed', 'doubtful' and 'substantial'. The types of dust relevant to textile manufacturing were cotton, wool and synthetic fibres.

The case-control approach was used to examine mortality from five cancers—oesophagus, pancreas, cutaneous melanoma, kidney and brain—among men aged 18-54 in three English counties during the periods 1959-63 and 1965-79 (Magnani *et al.*, 1987). For each case, four controls were selected from deaths from other causes during the same year, matched for age, sex and residence. Occupations of cases and controls were identified from death certificates, and a matched analysis was performed.

(*b*) *Oral and pharyngeal cancer*

In his study of death registrations in the Netherlands, Versluys (1949; see p. 238) observed four deaths from these cancers among male weavers and workers in woollens, whereas 7.1 were expected.

A study of death registrations for oral and pharyngeal cancers in men aged 15-64 in England and Wales in 1959-63 (Moss & Lee, 1974) showed 31 deaths among male textile workers as compared with 17.5 expected on the basis of national age-specific rates (RR, 1.8; $p = 0.001$). The site-specific RRs were 2.0 for cancer of the tongue (nine deaths; $p < 0.05$), 2.3 for cancer of the mouth (eight deaths; $p < 0.05$) and 1.5 for pharyngeal cancer (14 deaths; not significant). The overall RRs for oral and pharyngeal cancer were 4.3 in fibre preparers (11 deaths; $p < 0.0001$), 1.3 in spinners, winders and warpers (five deaths), 0.68 in weavers and knitters (three deaths), 1.9 in bleachers, dyers and finishers (six deaths) and 1.7 in miscellaneous textile workers (six deaths). Data on the type of fibre worked with were not directly available; however, in an expanded series of 19 deaths in fibre preparers, 18 were in wool workers and only one in a cotton worker, whereas a ratio of less than 2:1 would have been expected on the basis of census data. [The Working Group noted that this study was a further analysis of a previously reported incidental finding and that information on tobacco and alcohol consumption was not available.]

Delzell and Grufferman (1983; see p. 238) found a PMR of 100 (95% CI, 60-150; 18 deaths) among white female textile workers in North Carolina (USA) for cancers of the oral cavity and pharynx; Dubrow and Gute (1988; see p. 239) reported a PMR of 86 (95% CI, 65-115; 39 deaths) for men in the textile industry in Rhode Island (USA), and O'Brien and Decouflé (1988; see p. 239) gave a PMR of 80 (95% CI, 40-150; eight deaths) for male carpet and textile workers in Georgia (USA).

Olsen and Jensen (1987; see p. 239) found four cases of cancer of the buccal cavity and pharynx (SPIR, 35; 95% CI, 13-93) among Danish men manufacturing textiles, and two (36; 9-144) among those in spinning, weaving and finishing. The data for women were seven cases (122; 58-255) and two cases (93; 23-371), respectively.

In the case-control study of Decouflé *et al.* (1978; see p. 240) at the Roswell Park Memorial Institute in upstate New York, men and women employed as operatives in textile mills had elevated risks for cancer of the buccal cavity and pharynx after controlling for smoking. Eleven deaths were observed among both men (RR, 2.2; not significant) and women (RR, 1.9; $p = 0.04$). The findings for other male textile workers were not reported. No case was found in female spinners or weavers, but the findings for other female textile workers were not reported.

In a case-control study in the north-west region of England (Moss, 1976), 32 of 57 women with squamous-cell carcinomas at oral and pharyngeal sites reported having worked with textiles for at least two years at some time in their lives, as compared with 19 of 57 age-matched female breast cancer controls from the same hospital [crude odds ratio [OR], 2.6; $p = 0.02$]. The ORs were highest for women who had worked in spinning and related jobs ([crude OR, 3.7] seven cases) for at least ten years.

A case-control study of oral and pharyngeal squamous-cell cancer in the two main textile regions of England involved interviews with 280 cases and 280 age- and sex-matched controls with cancers other than those of the bladder, skin, nasal cavity and sinuses, and larynx (Whitaker *et al.*, 1979). Overall, 86 cases and 77 controls had had at least two years' experience in textile work. [The matched OR was 1.2 (95% CI, 0.8-1.9).]

Coggon *et al.* (1986b, see p. 241) found no case of oral cancer among male textile workers in three English counties.

In a case-control study of oral and pharyngeal cancer among women in the southern USA, subsequent to a correlation study (Blot & Fraumeni, 1977), occupational histories were taken into consideration (Winn *et al.*, 1981). Cases and controls were identified from hospitals and from death certificate diagnoses in North Carolina. A total of 255 cases were identified (156 from hospital records and 99 from death certificates), and two female controls were sought for each case, matched for age, race, source of ascertainment and county of residence. Completed interviews were obtained for 232 cases (91%) and 410 controls (82%); next-of-kin were interviewed for 51% of the cases and for 21% of the controls. After controlling for oral use of snuff, no increased risk (RR, 1.0) was found to be associated with employment in the textile industry—a major employer of women in North Carolina.

A further analysis (Winn *et al.*, 1982) allowed categorization of each job a study subject had held in the textile, hosiery and apparel industries according to probable exposure to each of four agents: dusts, dyes, finishing chemicals and oil mists. Overall, neither the crude nor the tobacco-adjusted RR for oral cancer in relation to employment in the production of textiles was significantly raised. Too few women had worked in job titles involving exposure to dyes, finishing chemicals or oil mists to permit meaningful analyses, but 65 female textile workers had held potentially dusty jobs; spinners and spoolers predominated in this category. [The crude overall OR for workers in presumably dusty jobs was 1.4 (0.83-2.4). Adjustment for tobacco use was not reported for workers in this category, but made little change in different subcategories.] Risk did not increase with duration of exposure.

(*c*) *Cancers of the oesophagus and stomach*

In the death registration study of Verluys (1949; see p. 238) in the Netherlands, 116 deaths from stomach cancer (PMR, 121) and nine deaths from oesophageal cancer (PMR, 64) occurred in men in weaving and working in woollens.

In the decennial supplements of the UK Registrar General (see p. 238), one of the most consistent findings for male textile workers was an elevated risk for stomach cancer. In the 1951 supplement, an excess of stomach cancer was noted in bleaching, dyeing and finishing workers (SMR, 127; 65 deaths) and in dyehouse workers (SMR, 144; 36 deaths) in the textile industry; the SMRs were 139 in 1961, 149 in 1971 and 111 in 1981. Increased mortality from cancer of the oesophagus was noted in none of the supplements. For women, the most consistent site-specific finding was also an excess of stomach cancer: SMR, 147 in 1961 and 107 in 1971 in married women, and 164 and 157, respectively, in single women (Logan, 1982). In the 1981 supplement, there was little evidence of an increased risk for cancer of the stomach among female textile workers, but there was a suggestive increase in rates for oesophageal cancer (PMR, 191; not significant). [The Working Group noted that socioeconomic status was not taken into consideration in these studies.]

In the occupational mortality study of Guralnick (1963; see p. 238) of US men, a slight increase in the number of deaths from stomach cancer was seen (42 observed; SMR, 156) among operatives and allied workers in yarn, thread and fabric mills. [The Working Group assumed that, since cancer of the oesophagus was not mentioned, fewer than 20 cases were seen.]

Delzell and Grufferman (1983; see p. 238) found PMRs of 80 (95% CI; 40-170; eight deaths) for oesophageal cancer and 100 (95% CI, 90-120; 28 deaths) for stomach cancer from the death certificates of female textile workers in North Carolina, USA.

Olsen and Jensen (1987; see p. 239) found no case of oesophageal cancer; but for stomach cancer, 16 cases (87; 95% CI, 53-142) were seen in men in the manufacture of textiles, and eight cases (SPIR, 83; 41-166) in those in spinning, weaving and finishing. Among women in textile manufacture, the SPIRs were 56 (8-400; one case) for oesophageal cancer and 131 (80-214; 16 cases) for stomach cancer; among women in spinning, weaving and finishing, seven cases of stomach cancer (142; 68-297) were observed.

In the proportionate mortality study of Dubrow and Gute (1988; see p. 239) in Rhode Island (USA), textile workers classified as 'operatives' engaged in dyeing and finishing showed significantly increased mortality from cancer of the oesophagus (12 observed; PMR, 215; 95% CI, 125-371). The PMR for stomach cancer for all male textile workers was 98 (80-120; 78 deaths).

In the proportionate mortality study of O'Brien and Decouflé (1988; see p. 239) in Georgia (USA) among carpet and textile workers, a suggestive increase was noted for cancer of the oesophagus (PMR, 150; 70-270; ten deaths). The PMR for stomach cancer was 110 (50-210; nine deaths).

In the study of Henderson and Enterline (1973; see p. 239) among men in Georgia (USA), a nonsignificant increase in mortality from cancer of the digestive system was noted, only among cotton textile workers in the second of the two cohorts studied (20 observed; SMR, 151.5 [95% CI, 92.5-234]).

Newhouse (1978; see p. 240) observed an age- and period-adjusted PMR of 115 for cancer of the digestive system (122 deaths) among members of the National Union of Male Dyers, Bleachers and Textile Workers in Bradford (UK).

In the case-control study of Bross *et al.* (1978; see p. 241), a statistically significant elevated risk, larger than 2.0, was seen for cancer of the stomach and a nonsignificant elevated risk of the same magnitude for cancer of the oesophagus among men with occupational exposures to dust admitted to the Roswell Park Memorial Institute in New York State (USA).

In the case-control study of Siematycki *et al.* (1986; see p. 241) among men in Montréal, Québec (Canada), the OR for stomach cancer was 0.4 (95% CI, 0.2-1.0; five cases) for working with cotton, 0.9 (0.4-1.9; seven cases) for working with wool and 0.8 (0.3-2.0; six cases) for working with synthetic fibres.

Coggon *et al.* (1986b, see p. 241) found RRs of 1.0 (one case) for oesophageal cancer and 1.4 (six cases) for stomach cancer among men in the UK textile industry; and Magnani *et al.* (1987; see p. 241) found an OR of 2.7 (0.4-16.0) for oesophageal cancer for men working in the textile industry in three English counties.

(*d*) *Colorectal cancer*

In the death registration study of Versluys (1949; see p. 238) in the Netherlands, there were 11 deaths from cancer of the small intestine (PMR, 69) and 12 from rectal cancer (PMR, 86).

In the study of Guralnik (1963; see p. 238) of occupational mortality among US men, increased numbers of deaths from cancer of the intestine and rectum (ICD 152-154) were seen among spinners and weavers in the textile industry (SMR, 162; 21 deaths) and among operatives and allied workers in yarn, thread and fabric mills (SMR, 130; 39 deaths).

In the study of Delzell and Grufferman (1983; see p. 238) of white female textile workers in North Carolina (USA), the PMR was 100 for cancers of both the colon (95% CI, 80-120; 115 deaths) and rectum (90-120; 21 deaths).

Olsen and Jensen (1987; see p. 239) found that 48 cases of cancer of the small intestine, colon and rectum (SPIR, 107; 95% CI, 81-142) had been registered among Danish men in the manufacture of textiles and 25 (SPIR, 107; 72-158) in those employed in spinning, weaving and finishing. For women, the SPIRs were 120 (94-153; 64 cases) and 153 (23-371; 32 cases), respectively.

Dubrow and Gute (1988; see p. 239) noted a statistically significant increase in mortality from cancer of the rectum (72 observed; PMR, 128; 95% CI, 104-158) among male textile workers in Rhode Island (USA). The elevated mortality from rectal cancer turned out to be statistically significant in the occupational category 'operatives, except transport', which included 63.2% of the decedents; 47 deaths were observed, yielding a PMR of 134 (95% CI, 102-175). Within the textile manufacturing categories, decedents engaged in 'dyeing and finishing' showed a significantly increased PMR for rectal cancer (174; 115-264; 21 observed). The PMR for cancer of the colon for all male textile workers was 90 (140 deaths).

In the proportionate mortality study of O'Brien and Decouflé (1988; see p. 239) among male textile workers in Georgia (USA), the PMRs were 80 (50-130; 16 deaths) for cancer of the colon and 48 (two deaths) for rectal cancer.

In the case-control study of Williams *et al.* (1977; see p. 240), the RR for rectal cancer for working in textile mills was 6.8 (three cases) among men and 3.2 (two cases) among women in the Third National Cancer Surveys in the USA.

In the case-control study of Decouflé *et al.* (1978; see p. 240) on admissions to the Roswell Park Memorial Institute in New York State (USA), the RR for colorectal cancer in male operatives in textile mills was 1.7 (eight cases); that for women was 0.6 (11 cases).

Vobecky *et al.* (1983) designed a case-control study to investigate further a previously suggested association between large-bowel cancer and working in a carpet factory also manufacturing synthetic fibres (from acetate and polypropylene (Vobecky *et al.*, 1984)) in Québec (Canada) on the basis of five cases observed in young men (Vobecky *et al.*, 1978). Cases occurring between 1 January 1965 and 31 December 1976 in 24 communities from which the carpet factory was likely to draw its manpower were identified, using medical records from local hospitals. Controls were chosen at random from all people living in the same communities and matched for sex, age and residence. There were 224 cases of large-bowel cancer and 224 controls available for study. Telephone interviews were attempted for all subjects or their next-of-kin, resulting in 207 pairs of cancer patients and matched controls (103 male and 104 female pairs). Thirty-five cancer patients had a history of employment [length unspecified] in a carpet factory *versus* 28 controls—a statistically nonsignificant difference. Among males, the number of patients who had worked in the factory was 29 *versus* 17 controls ($p < 0.05$). No association was found among women.

Vobecky *et al.* (1984) tried to address the question of whether the increased risk noted in the previous study was confined to any particular section of the plant. Analysis was limited to 34 male cases and 101 controls for whom an employment history was available. A significantly elevated risk was found for working in 'textile' (RR, 3.0; $p < 0.03$). An elevated risk (RR, 2.1; $p < 0.025$) was also observed for working in two extrusion departments of the plant; the risk was higher among those who had worked in these departments after 1974 (RR, 6.3; $p < 0.002$) and for longer than ten years ([RR, 4.7]; $p < 0.002$).

In order to investigate possible relationships between employment in the textile industry and cancers of the colon and prostate, suggested by a correlation study (Blair & Fraumeni, 1978), a case-control study was conducted using death certificates (Hoar & Blair, 1984). South Carolina (USA) was selected because a large proportion of the state's population is employed in the textile industry. Cases were residents of selected counties who had died during 1970-78. One control for each cancer death was selected from state mortality data, matched for year of death, race, sex, county and age at death. The 1975 and 1976 Industrial Directories were used to identify the manufacturing activity in all companies named on death certificates. For the study of colon cancer, 820 pairs of cases and controls were available; no significant result was obtained in relation to textile work.

Coggon *et al.* (1986b, see p. 241) reported RRs of 5.9 (three cases) for colon cancer and 0.8 (one case) for cancer of the rectum among male textile workers in three English counties.

In the case-control study of Siemiatycki *et al.* (1986, see p. 241) in Montréal, Québec (Canada), when the risk of 'substantial' exposure to synthetic fibres was compared with 'unexposed', the risk for colorectal cancer was elevated (22 exposed cases; OR, 1.5; 95% CI, 0.8-2.9). Also of borderline significance was the increased risk for rectal cancer from exposure to wool dust [number not reported]. When data were further analysed by logistic regression techniques to take into account all potential confounders, both occupational and nonoccupational, the association of exposure to wool dust with rectal cancer fell towards the null value. Results for the association between exposure to synthetic fibres and colorectal cancer were: 'doubtful exposure', 12 exposed cases (OR, 3.3; 95% CI, 1.3-8.2); 'substantial exposure', 22 cases (OR, 1.5; 0.9-2.7); 'substantial exposure' >15 years, 16 exposed cases (OR, 3.0; 1.4-6.6).

(*e*) *Nasal cavity cancer* (see Table 11)

In a study in England and Wales (excluding the Oxford region), Acheson *et al.* (1972) compared the occupations of 80 male cases of adenocarcinoma of the nasal cavity with those of 85 male cases of other nasal cancers matched for age, region and year of registration. The occupations of cases were also compared with the occupational distribution of working and retired men in the 1961 census. Two cases of adenocarcinoma occurred in male textile workers compared with 0.8 expected on the basis of the census data [SMR, 250; 95% CI, 30-903].

Two controls with other nasal cancers were also textile workers. Seven cases of adenocarcinoma or other nasal cancers occurred in female textile workers. No exposure to wood dust was reported. [The Working Group noted that expected numbers could not be calculated for women.]

Table 11. Studies of nasal cavity cancer among workers in the textile industry

Type of study and reference (country)	Sex	No. of cases in textile workers	Relative risk[a]	95% confidence interval	Comments
Mortality and morbidity statistics					
Acheson *et al.* (1972) (England and Wales)	M	2	2.5	0.30-9.0	
Acheson *et al.* (1981) (England and Wales)	M F	10 5	0.95 2.2	0.46-1.8 0.70-5.1	
Malker *et al.* (1986a) (Sweden)	M F	8 3	2.4* 3.0	NA NA	
Dubrow & Gute (1988) (USA)	M	4	1.4	NA	
Olsen (1988) (Denmark)	M F	1 2	1.6 5.6	NA NA	Spinners and weavers
Case-control studies					
Bross *et al.* (1978) (USA)	M	NA	>2.0*	NA	No numbers given
Brinton *et al.* (1985) (USA)	M F	12 22	0.8 2.1	0.4-1.7 1.1-4.3	Textile and clothing industry
Ng (1986) (Hong Kong)	M,F	14	2.9	1.1-7.9	Nasal cavity and sinus; mainly weavers
Roush *et al.* (1987) (USA)	M	17	0.7	0.4-1.3	Sinonasal and nasopharyngeal; formaldehyde-associated textile work

[a]Standardardized mortality ratios were converted to relative risks for comparison
*$p < 0.05$
NA, not available

In a survey of nasal cancer in England and Wales in 1963-67, information on occupation at the time of diagnosis was obtained from interviews, hospital notes and death certificates (Acheson *et al.*, 1981). Of the 925 male cases, ten were in textile workers, as compared with 10.5 expected on the basis of age-specific national census data (SMR, 95; [95% CI, 46-175]). In women, five of 677 nasal cancers were in textile workers, as compared to 2.3 expected [SMR, 217; 70-507].

The Swedish Cancer-Environment Register (see p. 239) was used to study nasal cancer incidence (Malker *et al.*, 1986a). Elevated risks for work in the textile industry were observed for both men (SIR, 180; 12 cases) and women (SIR, 260; four cases). The occupational category of textile worker was also associated with elevated risks for both men (SIR, 240; eight cases; $p < 0.05$) and women (SIR, 300; three cases). Only one of the eight cases among men was an adenocarcinoma; two were squamous-cell carcinomas and the others of other histological types. The authors noted that the smoking habits of this cohort were comparable to those of the general Swedish population.

Dubrow and Gute (1988; see p. 239) found a PMR of 141 (four deaths) for nasal cancer among male textile workers in Rhode Island (USA).

Olsen (1988) analysed all 382 cases of cancers of the sinonasal cavities diagnosed in 1970-84 in Denmark, many of which were the same as those described by Olsen and Jensen (1987). One male case (SPIR, 158) and two female cases (SPIR, 559) were recorded for the occupational category of spinning and weaving of textiles.

In the case-control study of Bross *et al.* (1978; see p. 241), male operatives in US textile mills had a statistically significant elevated risk, larger than 2.0, for cancer of the 'nose'.

Brinton *et al.* (1985) explored in detail the association they had noted previously between the occurrence of nasal cancer and working in the textile and clothing industry (Brinton *et al.*, 1977, 1984). The case series included patients 18 years or older diagnosed with primary malignancies of the nasal cavities and sinuses at four hospitals in North Carolina and Virginia (USA) between 1 January 1970 and 31 December 1980. For cases alive at the time the study was conducted, two hospital controls were selected, matched for hospital, year of admission, age, sex, race and residence. Patients with diagnoses of neoplasms of the buccal cavity and pharynx, oesophagus, nasal cavity and sinuses, larynx, benign tumours of the respiratory system, other diseases of the upper respiratory tract and mental disorders were excluded from the control group. For deceased cases, two matched control series were selected—one from hospitals and one from among deceased individuals identified through state vital statistics offices. Telephone interviews with study subjects or with their next-of-kin were completed for 160 of 193 cases and 290 controls (178 of 232 hospital controls and 112 of 140 death certificate controls). Twelve male cases and 28 male controls reported employment in the textile or clothing industry (RR, 0.82; 95% CI, 0.4-1.7), whereas 22 female cases and 20 female controls reported such employment (RR, 2.1; 95% CI, 1.1-4.3). Women who had worked for fewer than ten years were at higher risk (12 exposed cases; RR, 3.9; 95% CI, 1.4-11.0) than those who had worked for ten years or more (seven exposed cases; RR, 1.4; 95% CI, 0.5-3.8). Women first employed fewer than 20 years before diagnosis had a much higher risk (nine exposed cases; RR, 5.8; $p < 0.05$) than those first employed earlier (12 exposed cases [RR, 1.4]). Among women, an increased risk of borderline significance was found to be associated with exposure to dust (RR, 2.3; 95% CI, 0.9-5.5). The textile industries listed in the employment histories included primarily textile and cotton mills, clothing manufacture and hosiery; no occupation predominated. The primary origin of dust was cotton. The association of work in the textile industry with specific histological types of tumour was also investigated. An increased risk for adenocarcinoma was found in both women (RR, 2.5; 95% CI, 0.7-9.0) and men (RR, 2.5; 95% CI, 0.7-8.3), and the risk for adenocarcinomas associated with working in dusty conditions was elevated among both men (RR, 4.7; 95% CI, 1.2-17.8) and women (RR, 3.4; 95% CI, 0.8-14.1). The increases in risk were not affected by tobacco use or by employment in other high-risk industries.

A case-control study in Hong Kong (Ng, 1986) of 225 cases of nasal cavity and sinus cancer in persons 18 years old or more diagnosed in 1974-81, and of 226 controls with other cancers matched for treatment centre, year, age, sex, race and resident status gave an OR for textile work of 2.9 (95% CI, 1.1-7.9; 14 cases). The OR was 7.4 (1.2-45.1; seven cases) for persons who had been employed for at least 15 years in textile work. The ORs for weavers and other textile workers, adjusted for employment years, were 4.7 (1.2-19.2; nine cases) and 1.8 (0.4-7.3; five cases), respectively. The study included an additional control group of 224 persons with nasopharyngeal cancer, among whom there was a similar proportion of textile workers as in the case group, suggesting that textile workers also have elevated risks for this cancer type. Only two of the 225 cases in the study had worked with furniture or wood dust; it was not known whether they had worked with textiles.

A case-control study designed to examine potential associations between nasopharyngeal and sinonasal cancer and formaldehyde-related occupations failed to reveal any increased risk for persons in the textile industry (Roush *et al.*, 1987). Newly diagnosed cases were identified through the Connecticut Tumor Registry from among males who had died of any cause between 1935 and 1975, and controls were drawn randomly from men who had died in Connecticut in the same period. Information on occupation was obtained from death certificates and city directories. Among the 198 sinonasal and 173 nasopharyngeal cancer cases, there were, respectively, ten and seven cases whose formaldehyde-related occupation had been in 'textiles' *versus* 43 controls with such occupations out of a total of 605. The resulting OR was 0.7 (95% CI, 0.4-1.3).

(*f*) *Laryngeal cancer*

Kennaway and Kennaway (1936) examined death certificates for cases of cancer of the lung and larynx in men from England and Wales in 1921-32, and calculated age-adjusted mortality ratios based on the 1921 and 1931 censuses. For the occupational category 'cotton spinners and piecers (mule, ring, cap or flyer)', the RR was 1.5 (31 deaths) for laryngeal cancer. For the category of 'cotton strippers and grinders and card-room jobbers', the RR was 0.6 (two deaths), and, for the category of cotton weavers, the RR was 0.8 (22 deaths).

Versluys (1949; see p. 238) observed four deaths from cancer of the larynx (PMR, 103) among death registrations for male weavers and workers in woollens in the Netherlands.

In the 1981 decennial supplement of the UK Registrar General (see p. 238), there was little evidence of an increased risk for cancer of the larynx among female textile workers.

In their study of death certificates, Delzell and Grufferman (1983; see p. 238) found a PMR for laryngeal cancer of 280 (95% CI, 100-730; five deaths) among white female textile workers in North Carolina (USA); Dubrow and Gute (1988; see p. 239) reported a PMR of 108 (24 deaths) among male textile workers in Rhode Island, and O'Brien and Decouflé

(1988; see p. 239) found five deaths (PMR, 110) among male carpet and textile workers in Georgia.

Olsen and Jensen (1987; see p. 239) found three cases (41; 95% CI, 13-127) among male workers manufacturing textiles and one case (28; 4-199) among male spinners, weavers and finishers. Among women, there were five cases (SPIR, 235; 98-566) and one case (117; 16-831) in the two categories, respectively.

Decouflé *et al.* (1978; see p. 240) in their case-control study at the Roswell Park Memorial Institute, New York (USA), reported an increased, statistically nonsignificant RR of 2.0 for cancer of the larynx (five cases; adjusted for smoking) among male operatives in the textile industry, while in a subset of the same cohort, Bross *et al.* (1978; see p. 241) found increases of the same magnitude among male operatives in textile mills.

A case-control study was conducted in southern Ontario (Canada) between 1977 and 1979 on the role of tobacco, alcohol, asbestos and nickel in the etiology of cancer of the larynx (Burch *et al.*, 1981). Cases were ascertained through hospitals which served the study area for radiotherapy, and for each case an individually matched neighbourhood control was selected, matched on age and sex. Of 258 cases ascertained, 204 (79%) were interviewed; the same number of controls were interviewed out of a total of 315 eligible controls. Questions were asked on demographic data, smoking, alcohol use and detailed occupational history, including information on exposures, which allowed the investigation of occupational exposures other than asbestos and nickel. Estimates of RR were obtained by an individually matched case-control analysis; only numbers for discordant pairs were presented. Elevated risk was observed for individuals who reported exposure to textile dusts; in five of the pairs, the case had been exposed and the control not, but in none of the pairs had the control been exposed and the case not.

A further case-control study was conducted in the Greater Augusta area, Georgia, USA (Flanders *et al.*, 1984) involving all persons with newly diagnosed, histologically confirmed squamous-cell laryngeal cancer, who were resident in one of seven counties of Georgia and who were treated at one of the ten hospitals in the area between 1 September 1974 and 30 September 1979. By reviewing hospital medical records, potential controls matched by age, area of residence, history of tobacco smoking and alcohol drinking were identified for each case. Final matching was carried out for age, sex, alcohol and tobacco history, area of residence and source of medical care, and was successful for 85 of 353 potential controls and for 42 of 64 potential cases. For each occupational category in which at least 15 subjects had worked, laryngeal cancer rate ratios were estimated by comparing the incidence rate among those who had worked at least six months in that occupational category with the rate among those who had not. Only numbers for discordant pairs were presented. The rate ratio for all textile processors was 1.5 (at least seven cases; 90% CI, 0.6-3.9). For workers who separated, filtered or dried textile fibres, a statistically significantly increased risk for laryngeal cancer was found (at least nine cases; RR, 3.2; 90% CI, 1.3-8.0). In a further analysis, subjects were categorized as exposed only if they had worked for at least five years in a given occupation; in addition, only work experience during the time frame from the age of 14 until five years before diagnosis was considered to be relevant exposure. In this subset, the estimated rate ratio for the occupation 'all textile processors' was 4.2 (at least four cases; 90% CI, 1.0-22.4) and that for separating, filtering and drying was 5.6 (at least five cases; 90% CI, 1.4-29.1) in comparison with those who had never worked in the trade.

A case-control study in Denmark in the period 1980-82 involved interviews with all 326 incident cases of laryngeal cancer under 75 years of age and 1134 community controls matched for age and sex (Olsen & Sabroe, 1984). Cases and controls were asked about their present, latest and longest-held occupation and to describe their work place and type of work. The RRs, adjusted for age, sex, tobacco and alcohol consumption, were 1.0 (95% CI, 0.4-2.9; six cases) for any exposure to textile dyes, 1.4 (0.8-2.7; 16 cases) for exposure to wool dust and 1.5 (0.8-2.6; 20 cases) for exposure to cotton dust.

Coggon *et al.* (1986a; see p. 241) found a RR of 2.4 (one case) for laryngeal cancer among male textile workers in three English counties.

(g) *Lung cancer*

Kennaway and Kennaway (1936) examined death certificates of cases of cancer of the lung and larynx in men in England and Wales in 1921-32 and calculated age-adjusted mortality ratios based on the 1921 and 1932 censuses. For the occupational category 'cotton spinners and piecers (mule, ring, cap or flyer)', the RR was 0.3 (seven deaths) for lung cancer. For the category of 'cotton strippers and grinders and card-room jobbers', the RR was 0.3 (one death); and for the category of cotton weavers, the RR was 0.5 (13 deaths).

Versluys (1949; see p. 238) observed five deaths from lung cancer (PMR, 43) among death registrations of men in the Netherlands working as weavers and workers in woollens.

In the 1951 decennial supplement of the UK Registrar General (see p. 238), a decreased risk for lung cancer was noted among male bleaching, dyeing and finishing workers (SMR, 73; 77 deaths), and one of the most consistent findings in male textile workers in 1961, 1971 and 1981 was a decreased risk for this cancer (SMR, 85 (Logan, 1982), 88 and 94, respectively). Roman *et al.* (1985) analysed the 1971 data according to married women's own occupation and noted a decreased risk for lung cancer in textile workers, particularly in weavers (SMR, 71; 34 deaths). In the 1981 supplement, the PMR for lung cancer in female textile workers was 141 (39 deaths).

Guralnik (1963; see p. 238) reported that US male labourers in textile mill products had elevated mortality due to cancer of the lung (23 observed; SMR, 192).

In Los Angeles County, USA, all death certificates mentioning lung cancer for the period 1968-70 and all newly diagnosed cases of lung cancer reported in 1972-73 were examined in relation to statements on occupation and industry abstracted from death certificates and hospital admission sheets, respectively (Menck & Henderson, 1976). The study was limited to white males in the age group 20-64 years, and the total number of white males at risk for each occupation/industry was estimated from census figures. Expected deaths/incident cases were calculated for each specific occupation/industry from the age-specific rates of cancer for all occupations/industries. The ratios of observed deaths plus incident cases to expected deaths plus incident cases were then calculated. There were 27 deaths and 20 incident cases of lung cancer in the industry category 'textile, apparel', yielding a SMR of 119, which was statistically nonsignificant. Smoking was not controlled for.

In their death certificate analysis, Delzell and Grufferman (1983; see p. 238) reported a PMR of 90 (106 deaths) for white female textile workers in North Carolina (USA).

In the cancer registry study of Olsen and Jensen (1987; see p. 239) in Denmark, there was a moderately decreased risk for cancer of the lung and trachea in men (SPIR, 88; 95% CI, 70-111; 73 cases) and women (82; 56-120; 26 cases) employed in textile manufacture and in men (91; 66-125; 39 cases) and women (75; 39-143; nine cases) employed in spinning, weaving and finishing.

In the proportionate mortality study of Dubrow and Gute (1988; see p. 239) in male textile workers in Rhode Island (USA), lung cancer mortality was lower than expected, except among 'service workers' (24 cases) and workers manufacturing 'synthetic and silk only' (eight cases) for each of whom a 30% statistically nonsignificant elevation was noted. O'Brien and Decouflé (1988; see p. 239) found a PMR of 100 (90-110; 138 deaths) in male carpet and textile workers in Georgia (USA).

Henderson and Enterline (1973; see p. 239) reported a low observed:expected ratio for respiratory cancer (0.55) in their cohort study of mortality among male textile workers in Georgia. Newhouse (1978; see p. 240) observed 103 cases of lung cancer with 109.3 expected among male dyers, bleachers and textile workers in Bradford (UK).

Merchant and Ortmeyer (1981; see p. 241) found that overall SMRs for lung cancer tended to decrease with increased presumed exposure to cotton dust. Only in the 'other' job category was a small increase in SMR observed; workers in this category also had potential exposure to asbestos, cutting oils, solvents and dyes. The principal dye used was indigo. On the basis of cross-sectional data on North Carolina textile workers, the smoking habits of cotton textile workers were considered to be similar to those of other workers and the rest of the population. [The Working Group noted the small proportion of the cohort included in the analysis.]

In the case-control study of Williams *et al.* (1977; see p. 240), as part of the US Third National Cancer Survey, a suggestive increase in cancer of the lung was noted among male patients who had worked with textile mill products (RR, 2.6; three cases).

Decouflé *et al.* (1978; see p. 240) found that men admitted to the Roswell Park Memorial Institute (New York, USA) who had been employed as operatives in the textile mill industry had an elevated but statistically nonsignificant risk for lung cancer (RR, 1.5; nine cases; adjusted for smoking).

A comparison was made of death certificate statements on usual occupation and kind of industry for 858 white males who had lived in coastal counties of Georgia (USA) and who had died of primary lung cancer during 1961-74 with those for 858 controls (Harrington *et al.*, 1978). Each death certificate of a case was matched by age at death within one year, year of death within six years, sex, race and county of usual residence to a death certificate of a person who had succumbed to conditions other than lung cancer, chronic respiratory disease or bladder cancer. There were seven cases and eight controls in the industrial category 'textiles'; the matched pair analysis yielded an estimated RR of 0.88.

Milne *et al.* (1983) conducted a case-control study comparing lung cancer deaths *versus* deaths from all other cancers occurring in a county of California (USA) between 1958 and 1962. Usual occupation and industry of employment were extracted from death certificates. The 925 deaths from lung cancer were compared with 6420 deaths from all other cancers. The age-adjusted RR associated with textile manufacturing among males was 1.9, based on five exposed cases and 13 exposed controls; the result was statistically nonsignificant. [The crude RR was 2.7 (98% CI, 1.0-7.1)]. No data regarding textile industry were reported for female workers, and information on tobacco use was not available.

Coggon *et al.* (1986a, see p. 241) found a RR of 0.3 (one case) for cancer of the bronchus in their case-control study of male textile workers in three English counties.

In the case-control study of Siemiatycki *et al.* (1986; see p. 241), in Canada, the ORs for lung cancer were 0.8 (95% CI, 0.4-1.3; 25 cases) for people working with cotton, 0.5 (0.3-1.0; 15 cases) for those working with wool and 0.5 (0.2-1.1; 11 cases) for those working with synthetic fibres.

A case-control study of lung cancer mortality in persons aged 14-60 was conducted in Prato, Italy (Buiatti *et al.*, 1979). Information on occupation from death certificates was verified by interviews with next-of-kin. The RR for lung cancer mortality in textile workers compared with that of other residents was 2.0 in men ([95% CI, 1.4-2.7]; 42 deaths) and 4.8 in women ([95% CI, 0.9-14.0]; three deaths). Workers who had been employed only in the reprocessing of textiles to serve as raw material (nine deaths) or in dyeing (six deaths) had lung cancer mortality rates six to nine times higher than expected, whereas mortality was not markedly elevated in persons who had been involved only in spinning or weaving. [The Working Group noted that no adjustment was made for age or smoking habits.]

In a case-control study in Florence and Prato, Italy (Paci *et al.*, 1987), 65 of 441 cases of male lung cancer admitted during 1980-83 had been nonasbestos textile workers, as compared with 127 of 1075 hospital controls matched for age, sex and smoking habits (OR, 1.5; 95% CI, 0.98-2.3). The analysis was adjusted for area of residence, age and smoking habits. The elevated risk was greatest (OR, 2.4; 95% CI, 1.2-4.8; 16 cases) for the period 15-24 years from first employment in the industry. The authors concluded, however, that the elevated lung cancer risk may have been due to asbestos exposure in rag-sorting, weaving and refining.

A population-based case-control study in urban Shanghai (China) involved interviews with 1405 newly diagnosed lung cancer patients and 1495 general population controls (Levin *et al.*, 1987). Women were interviewed in 1984-86 and men in 1984-85. The analysis included adjustment for smoking and 'if necessary' for age, sex, education, place of birth, dietary vitamin A and previous history of chest diseases. The RR for cotton textile employment was 0.7 (95% CI, 0.6-0.9; 169 cases). This decrease in risk was observed for both men and women and for smokers and nonsmokers. The reductions in risk tended to be greater for lung cancer cell types other than adenocarcinoma. Low risks were observed in virtually all occupations in the cotton textile industry, and there was little difference in risk according to self-reported exposure to textile dust. In a subset of 733 newly diagnosed male lung cancer cases and 760 controls, the OR for employment in the textile industry was 0.7 (0.5-1.0; Levin *et al.*, 1988).

Possible explanations have been sought for the low rates of lung cancer observed in most studies. Ashley (1967) calculated SMRs for lung cancer in each of the county boroughs of England and Wales for the years 1958-63. The overall lung cancer SMR was 89 in the eight towns in which cotton textiles were an important industry, and 87 in the four county boroughs in which the wool industry assumed major importance. He found that the lung cancer deficit was associated with an excess of chronic bronchitis, and the findings were not related to the degree of air pollution or population density. He suggested that chronic lung disease associated with textile work may confer protection against carcinogenic substances. In a further analysis using multiple regression, Ashley (1969) found lower SMRs for lung cancer in both men and women in coal and textile towns, controlling for population density, social class, smoke pollution and sulfur dioxide pollution.

Enterline *et al.* (1985) proposed several possible explanations for the lower than expected mortality from respiratory cancer found among cotton textile workers. The first was based on the hypothesis that cotton textile workers in dusty operations smoke, on average, less than other workers and the rest of the population. The second possible explanation was that exposure to cotton dust may stimulate mucus production, which might protect against carcinogens such as cigarette smoke. The third explanation, which the authors considered most likely, was based on the evidence that endotoxins, which are found in airborne cotton dust, are potent anticancer agents.

[The Working Group noted that data on smoking habits were not available in most of the studies of lung cancer in textile workers, but, when data were available, adjustment for cigarette smoking made little difference to the findings.]

(*h*) *Bladder cancer* (see Table 12)

Versluys (1949; see p. 238) reported five deaths from bladder cancer (PMR, 93) among death registrations of male weavers and workers in woollens in the Netherlands.

Table 12. Studies of bladder cancer among workers in the textile industry

Type of study and reference (country)	Sex	No. of cases in textile workers	Relative risk[a]	95% confidence interval	Comments
Mortality and morbidity statistics					
Versluys (1949) (Netherlands)	M	5	0.93	NA	
Office of Population Censuses and Surveys (1961-1981); Logan (1982) (UK)	M	1	1.1	NA	1961
			1.2	NA	1971
			0.73	NA	1981
Delzell & Grufferman (1983) (USA)	F	13	1.00	0.7-1.5	Textile workers

Table 12 (contd)

Type of study and reference (country)	Sex	No. of cases in textile workers	Relative risk[a]	95% confidence interval	Comments
Olsen & Jensen (1987) (Denmark)	M	28	0.86	0.59-1.3	Textile manufacture
	F	13	1.1	0.62-1.8	
	M	13	0.77	0.45-1.3	Spinning, weaving, finishing
	F	6	1.3	0.57-2.8	
Malker *et al.* (1987) (Sweden)	M	147	1.1	NA	Textile industry
	M	49	1.1	NA	Cotton industry
Dubrow & Gute (1988) (USA)	M	58	0.85	0.68-1.07	Textile workers
O'Brien & Decouflé (1988) (USA)	M	8	1.2	0.6-2.5	Carpet and textile workers
Cohort studies					
Henderson & Enterline (1973) (USA)	M	9	1.6	0.75-3.1 (cohort 1)	Urinary system including bladder
	M	5	1.4	0.44-3.2 (cohort 2)	
Newhouse (1978) (UK)	M	14	1.1	NA	Dyers, Bleachers and Textile Workers' Union members
Case-control studies					
Wynder *et al.* (1963) (USA)	M	8	2.7	0.75-9.8	Textile workers
	F	10	2.2	0.71-6.6	Garment workers
Anthony & Thomas (1970) (UK)	M	50	2.2	NA	Textile workers
	F	24	< 1	NA	
	M+F	9	7.7	NA	Weaver } Employment for ≥20 yrs
	M+F	11	2.9	NA	Finisher } Employment for ≥20 yrs
	M+F	8	3.4	NA	Dyer } Employment for ≥20 yrs
Decouflé *et al.* (1978) (USA)	F	6	2.6	NA	Operatives in textile mills; adjusted for smoking
Tola *et al.* (1980) (Finland)	M	1	0.50	0.05-5.3	Textile workers
	F	1	0.32	0.04-2.9	
Cartwright (1982) (UK)	M+F	24	1.3	0.8-2.4	Dye users
Najem *et al.* (1982) (USA)	M+F	5	0.9	0.3-2.7	Textile industry
Silverman *et al.* (1983) (USA)	M	7	0.7	0.3-1.8	Textile industry
	M	2	0.5	0.1-2.7	Textile workers; lower urinary tract
Schoenberg *et al.* (1984) (USA)	M	12	0.61	0.30-1.2	Textile mill workers

Table 12 (contd)

Type of study and reference (country)	Sex	No. of cases in textile workers	Relative risk[a]	95% confidence interval	Comments
Morrison *et al.* (1985) (USA, UK, Japan)	M	30	0.9	0.6-1.4	Boston — Textile workers; lower urinary tract
	M	79	0.9	0.7-1.2	Manchester — Textile workers; lower urinary tract
	M	16	1.0	0.6-1.6	Nagoya — Textile workers; lower urinary tract
Vineis & Magnani (1985) (Italy)	M	21	1.8	0.9-3.6	Textile industry
Maffi & Vineis (1986) (Italy)	F	11	1.9	0.85-4.2	Textile industry
		2	∞		Carders
		2	4.0	0.6-26.9	Twisting machine operator
		3	2.6	0.4-15.5	Winding machine operator
		4	5.6	1.1-29.2	Other winders and twisters
		5	2.6	0.8-8.1	Weavers (power loom)
Coggon *et al.* (1986b) (UK)	M	5	1.3	NA	Textile workers; bladder and renal pelvis
Siemiatycki *et al.* (1986) (Canada)					'Substantial' exposure to:
	M	17	1.6	0.9-3.0	Synthetic fibres
		15	1.3	0.7-2.4	Wool fibres
		21	1.2	0.7-2.1	Cotton fibres
Corisco *et al.* (1987) (Spain)	M	5	4.9	0.7-34.9	Textile industry
Jensen *et al.* (1987) (Denmark)	M+F	56	1.7	1.1-2.4	Textile and leather industry
Claude *et al.* (1988) (FRG)	M	35	1.7	0.98-2.9	Textile industry
	M	8	0.73	0.29-1.8	Textile workers
Gonzáles *et al.* (1988) (Spain)	M+F	19	2.1	0.82-5.1	Textile industry
		8	4.4	1.2-16.8	Dyeing and printing
		10	1.9	0.71-5.0	Weaving
		2	0.33	0.06-1.9	Spinning
Gonzáles *et al.* (1989) (Spain)	M	41	1.9	1.1-3.1	Textile industry
	F	11	6.4	1.3-30.0	
	M	10	3.5[b]	1.3-9.3	Weavers
	F	9	21.2[b]	1.5-298	
	M	11	1.3[b]	0.5-3.1	Dyers
	F	1	0.34[b]	0.1-7.7	

Table 12 (contd)

Type of study and reference (country)	Sex	No. of case in textile workers	Relative risk[a]	95% confidence interval	Comments
Risch *et al.* (1988) (Canada)	M	21[c]	1.5	0.61-4.0	Dyeing
	M		4.6	1.1-31.6	Dyers employed 8-28 yrs before diagnosis
	M	61[c]	1.1	0.65-2.0	All fabric dust
	F	39[c]	1.1	0.50-2.2	
	M	18[c]	0.76	0.28-2.0	Cotton dust
	F	12[c]	1.4	0.44-4.9	
	M	10[c]	1.3	0.35-5.0	Synthetic fabrics dust
	M	13[c]	0.91	0.30-2.9	Wool dust
	F	12[c]	1.1	0.32-3.6	

[a]Standardized mortality ratios, standardized incidence ratios, standardized proportional incidence ratios and proportional mortality ratios were converted to relative risks for comparison
[b]Conditional logistic regression analysis
[c]Total number of subjects exposed (cases and controls)

In the UK Registrar General's decennial supplements for 1961, 1971 and 1981 (see p. 238), the SMRs for cancer of the bladder were 109, 123 (Logan, 1982) and 73, in men, respectively. In the 1981 supplement, there was little evidence of an increased risk for bladder cancer among female textile workers.

Delzell and Grufferman (1983; see p. 238) reported a PMR of 100 (13 deaths) among white female textile workers in North Carolina (USA).

In the cancer registry study of Olsen and Jensen (1987; see p. 239), the SPIRs for bladder cancer were 86 for men in textile manufacturing (95% CI, 59-125; 28 cases) and 107 for women (62-184; 13 cases) and 77 for men in spinning, weaving and finishing (45-133; 13 cases) and 127 for women (57-283; six cases).

The Swedish Cancer-Environment Register (see p. 239) was used to study male bladder cancer incidence in 1961-79 (Malker *et al.*, 1987). Of the 11 702 cases of bladder cancer, 147 were in workers in the textile industry (SIR, 108), 49 of whom had worked in the cotton industry (SIR, 108). There were 62 cases in the occupational category of textile worker (SIR, 91) and 32 cases in carpet makers (SIR, 129).

Dubrow and Gute (1988; see p. 239) found a PMR of 85 (95% CI, 68-107; 58 deaths) for bladder cancer among male textile workers in Rhode Island (USA), and, in their proportionate mortality study, O'Brien and Decouflé (1988; see p. 239) noted a suggestive increase for cancer the bladder (PMR, 120; 60-250; eight cases) among male carpet and textile workers in Georgia (USA).

In the cohort study of Henderson and Enterline (1973; see p. 239) in the USA, an exception to the generally low observed:expected ratios for cancer deaths was cancer of the urinary system. In the first cohort, nine cases were observed between 1938 and 1963 *versus* 5.5 expected (SMR, 164 [95% CI, 74.8-310.6]); in the second cohort, five cases were observed between 1948 and 1963, whereas 3.7 were expected (SMR, 135 [43.9-315.4]). Among workers belonging to both cohorts, two cases were observed, while 1.6 were expected (SMR, 125). [The Working Group noted that the proportion of cases of cancer of the urinary system that were bladder cancer was not specified.]

Newhouse (1978; see p. 240) found 14 cases of bladder cancer with 13.1 expected (PMR, 110) among male bleachers, dyers and textile workers in Bradford (UK).

Histologically confirmed bladder cancer cases and controls were interviewed at seven main hospitals in the New York metropolitan area from January 1957 to December 1960 (Wynder *et al.*, 1963). In total, 300 male cases and 70 female cases were matched individually by age and sex to controls who were patients from the same hospitals, excluding those with cancer of the respiratory system or upper alimentary tract as well as those with myocardial infarction. The interview included data on occupation, age, race, smoking habits and residence. Eight male cases and three controls were classified as textile workers [crude RR, 2.7; 95% CI, 0.75-9.8]. Seven of the cases and one control had been employed in the textile industry for five or more years. Among female study subjects, ten cases and five controls had been engaged in the textile or garment industry [crude RR, 2.2; 0.71-6.6]. The possible role of exposure to dyes in certain textile operations was suggested. [The Working Group noted that exclusion from the control group of patients with tobacco-related diseases might introduce a bias with regard to bladder cancer.]

In a case-control study in Leeds, UK, 1422 bladder cancer cases were identified in 1959-67, and the occupational histories of 812 male cases and 218 female cases were compared with those of 390 surgical controls and 341 controls with other cancers (Anthony & Thomas, 1970). Controls were matched on age, sex and residence and (for 340 male and 50 female cases) for smoking history. Comparisons with the two control groups yielded similar findings. For textile workers, the crude OR for bladder cancer in men was 2.2 ($p < 0.01$), whereas the RR in women was less than 1.0. The RRs were particularly elevated in persons who had worked for 20 years or more as weavers (RR, 7.7; nine cases), finishers (RR, 2.9; 11 cases) and dyers (RR, 3.4; eight cases).

Decouflé *et al.* (1978; see p. 240), in their case-control study of admissions to a hospital in New York State (USA), found that female operatives in textile mills were at high, but statistically nonsignificant, risk for cancer of the bladder (RR, 2.6; six cases; adjusted for smoking).

The occupational histories of 180 of the 274 cases of bladder cancer that occurred in the industrial part of Finland in 1975-76 were compared with those of 180 hospital controls matched for age and sex (Tola *et al.*, 1980). Two cases and five controls gave textile worker as their predominant occupation [crude OR, 0.39; 95% CI, 0.1-1.9].

Cartwright (1982) conducted a case-control study of 991 cases of bladder cancer in West Yorkshire (UK) in the period 1978-80. All prevalent cases were matched with one hospital control and all newly diagnosed cases were matched with two, by health district, age and sex. Cases and controls were interviewed regarding their occupational history. The RR associated with the dyeing of woollens was 1.3 (95% CI, 0.8-2.4; 24 cases). [The Working Group noted that no data were given concerning other jobs in the textile industry.]

Najem *et al.* (1982) conducted a case-control study of bladder cancer in two northern counties of New Jersey (USA). The study was based on 75 prevalent cases admitted to four private clinics and two community hospitals in 1978. Two controls for each case were derived from the consecutive admission lists of the same clinic or hospital, matched on age, place of birth, sex, race and residence, excluding patients with a history of any neoplasm or with 'tobacco-related' heart disease. Interviewers were aware of the subjects' status as a case or control. Lifetime occupational history was determined beginning at age 16; study subjects were classified as having been employed in a particular industry if they had worked in that industry for at least one year. Five cases and ten controls had worked in the textile industry, yielding an estimated RR of 0.9 (95% CI, 0.3-2.7).

A population-based case-control study was conducted in Detroit, MI (USA) with the purpose of identifying industries and occupations in which workers might have an increased risk for cancer of the lower urinary tract (Silverman *et al.*, 1983). The case series consisted of all 420 histologically confirmed, newly diagnosed cases of carcinoma of the lower urinary tract (bladder (95%), renal pelvis, ureter and urethra) in 60/61 hospitals of the tricounty area, occurring between December 1977 and November 1978 among male residents between the ages of 21 and 84 years. The controls were selected from the general male population of the study area and matched to the cases for age. Analysis was restricted to white males. Interviews were completed for 303 cases and 296 controls. Seven cases and ten controls had ever been employed in the 'textiles' industry (RR, 0.7; 95% CI, 0.3-1.8). Analysis by occupational category revealed two cases and four controls who had ever been employed as a 'textile worker' (RR, 0.5; 95% CI, 0.1-2.7).

As part of the National Cancer Institute study of the geographic distribution of bladder cancer mortality in the USA, the association between occupational exposure and bladder cancer risk was examined in a case-control study in New Jersey (Schoenberg *et al.*, 1984), similar in design to the study described above. Analysis was restricted to 658 white male cases 21-84 years old, diagnosed during 1978-79, and 1258 white male controls. For working in a textile mill the OR was 0.61 (95% CI, 0.30-1.2; 12 cases).

A collaborative study of environmental risk factors for bladder cancer was carried out in Boston, USA (1976-77), Manchester, UK (1976-78), and Nagoya, Japan (1976-78; Morrison *et al.*, 1985). Cases were male patients 21-89 years old with an initial diagnosis of a primary neoplasm of the lower urinary tract (bladder, ureter, renal pelvis, urethra). A pathology review indicated that virtually every case had a transitional- or squamous-cell tumour; 95% of the tumours occurred in the bladder. Controls were selected from electoral registers in such a way as to ensure an age and sex distribution similar to that of the cases. Subjects or their proxies were interviewed according to a standardized schedule; employment histories were obtained by interview. The 'textiles' group included both the textile industry and manufacture of cloth and cloth garments. Analysis was restricted to persons for whom smoking history was known; there were 430 such cases and 397 such controls in Boston, 399 cases and 493 controls in Manchester, and 226 cases and 443 controls in Nagoya, which were about 60% of the original numbers. In none of the study areas was the RR for bladder cancer elevated among 'textile' workers. In Boston, the estimated RR was 0.9 (90% CI, 0.6-1.4); in Manchester, the RR was 0.9 (0.7-1.2), and that in Nagoya 1.0 (0.6-1.6).

A case-control study in the province of Turin, Italy, involving interviews with 512 male cases of bladder cancer between 1978-83 and 596 age-matched male hospital controls (Vineis & Magnani, 1985) gave an OR of 1.8 (95% CI, 0.9-3.6) for employment in the textile industry. Adjustment for smoking did not affect the OR, but it fell to 0.9 when only cases and controls living in the city of Turin were considered. The authors suggested that this indicated the possibility of a selection bias. [The Working Group considered that this may have been due to different referral patterns of cases and of controls.]

In a hospital-based case-control study among female residents of the province of Turin, Italy between 1981-83 (Maffi & Vineis, 1986), 11 of 55 patients with bladder cancer had been employed in the textile industry for at least six months, as compared with 17 of 202 general surgical controls (cardiac and thoracic surgery excluded). The age-adjusted OR was 1.9 (95% CI, 0.85-4.2). The following jobs in the textile industry showed elevated risks: carder (two cases, no control), twisting machine operator (OR, 4.0; 95% CI, 0.6-26.9; two cases), winding machine operator (2.6; 0.4-15.5; three cases), other winders and twisters (5.6; 1.1-29.2; four cases) and weavers (2.6; 0.8-8.1; five cases).

Coggon *et al.* (1986b; see p. 241) reported a RR of 1.3 (five cases) for cancer of the bladder and renal pelvis among male textile workers in three English counties.

In the case-control study of Siematycki *et al.* (1986; see p. 241) in Montréal (Québec, Canada), the association of 'substantial' exposure with synthetic fibres and bladder cancer was statistically significant (OR, 1.8; 95% CI, 1.0-3.2, on the basis of logistic regression analysis; 17 cases). For exposure to wool, the OR was 1.3 (0.7-2.4; 15 cases), and for exposure to cotton, the OR was 1.2 (0.7-2.1; 21 cases), on the basis of analogous analysis.

Corisco *et al.* (1987) studied 180 male patients 41-87-years old with histologically proven bladder urothelioma and 180 age-matched healthy volunteer controls in Madrid, Spain. Five cases and one control were textile workers (OR, 4.9; 95% CI, 0.7-34.9). [The Working Group noted the potential for bias from using volunteer controls.]

A case-control study in Copenhagen (Denmark) involved interviews with 371 patients with bladder cancer diagnosed in 1979-81 and 771 general population controls matched for age and sex (Jensen *et al.*, 1987). All analyses were adjusted for age and sex. A RR of 1.7 was observed for ever having worked in the textile and leather industry (95% CI, 1.1-2.4; 56 exposed cases); however, there was only a weak association with duration of employment.

Claude *et al.* (1988) conducted a case-control study in northern Federal Republic of Germany which involved interviews with 531 male cases of cancer of the lower urinary tract occurring during the period 1977-85 and 531 age-matched, male hospital controls chosen primarily from urological wards. The matched RR for textile workers was 0.73 (95% CI, 0.29-1.8; eight exposed cases) and that for the textile industry, 1.7 (95% CI, 0.98-2.9; 35 exposed cases).

In a case-control study of bladder cancer in the county of Mataro, Spain, in 1978-81 (Gonzáles *et al.*, 1988), 19/57 cases and 21/107 controls reported past employment in the textile industry (OR, 2.2; 95% CI, 1.0-4.7). The case group included newly diagnosed and prevalent cases identified through a hospital registry and deceased cases identified through a death registry. Controls were selected from the same registries as the cases, matched on sex, age, residence and date of hospitalization or death. For each case, one control was chosen with cancer other than of the bladder or lung, and one with a non-neoplastic disease. The OR decreased slightly to 2.1 (95% CI, 0.82-5.1) when the analysis was adjusted for tobacco smoking. The risk was particularly elevated for textile workers who worked in dyeing or printing (OR, 4.4; 95% CI, 1.2-16.8). The risk for weaving was 1.9 (0.71-5.0) and that for spinning, 0.33 (0.06-1.9).

Gonzáles *et al.* (1989) performed a further study involving interviews with 497 prevalent and newly diagnosed cases of bladder cancer in five provinces of Spain in 1985-86, 583 hospital controls and 530 population controls matched by age, sex and residence. A matched analysis adjusted for smoking and other high-risk occupations gave ORs for textile work of 1.9 in men (95% CI, 1.1-3.1; 41 cases) and 6.4 in women (1.3-30.0; 11 cases). The mean latent period since time of first employment to diagnosis of the cancer was 41 years. When analysed by conditional logistic regression, the highest risk was for the subgroup of weavers in both men (OR, 3.5; 1.3-9.3; ten cases) and women (OR, 21.2; 1.5-298; nine cases); the RR for textile dyers was 1.3 in men (0.5-3.1; 11 cases) and 0.34 in women (0.1-7.7; one case). [The Working Group noted that the numbers of cases on which the final analysis was based were not presented, and also noted the discrepancy between the crude (3.6, as computed by the Working Group) and logistic OR (21.2) for female weavers.]

The occupational factors possibly linked to the incidence of cancer of the bladder in the provinces of Alberta and southern Ontario (Canada) were investigated in a case-control study based on all urothelial and other primary malignant tumours of the bladder newly diagnosed in 1979-82 among male and female residents aged 35-79 years (Risch *et al.*, 1988). Controls were identified randomly from population listings and individually matched to cases by sex, age and residence; of the eligible cases and controls, 67% and 53% were interviewed, respectively, and, for the analysis, 781 matched case-control sets were available. For male cases who had been employed in 'dyeing of cloth' for at least six months eight to 28 years before diagnosis, a significant association was found (OR, 4.6; 95% CI, 1.1-31.6; adjusted for smoking). A significant trend with duration of employment was also noted. No increased risk was associated with exposure to cotton dust, wool dust or dye.

[The Working Group noted that data on smoking habits were not available in most of the studies of bladder cancer in textile workers, but, when data were available, adjustment for cigarette smoking made little difference to the findings.]

(*i*) *Haematopoietic malignancies*

In the study of death certificates of white women in the USA by Delzell and Grufferman (1983; see p. 238), the ratio of observed:expected deaths was significantly increased for non-Hodgkin's lymphoma (1.7; 95% CI, 1.2-2.3; 51 deaths). A suggestive increase (1.2; 0.8-1.6; 45 deaths) in the number of leukaemia deaths was also noted. Information on type of textile manufacturing or on specific jobs and duration of employment was not available.

Dubrow and Gute (1988; see p. 239) found PMRs of 104 (95% CI, 57-191; nine deaths) for Hodgkin's disease; 92 (65-129; 28 deaths) for non-Hodgkin's lymphoma; and 73 (53-100; 31 deaths) for leukaemia among male textile workers in Rhode Island (USA).

In the proportionate mortality study of O'Brien and Decouflé (1988; see p. 239) among male carpet and textile workers in Georgia (USA), ten deaths from lymphocytic leukaemia were observed, where 3.4 would have been expected (PMR, 290; 95% CI, 140-540). For non-Hodgkin's lymphoma, six deaths were seen (PMR, 70; 30-160); for Hodgkin's disease and multiple myeloma, three deaths each (expected, 2.9 and 4.1, respectively); and for all leukaemia, 19 deaths (PMR, 150; 90-240).

In the cancer registration study of Olsen and Jensen (1987; see p. 239) in Denmark, the risk for Hodgkin's disease was elevated in men in both textile manufacturing (214; 95% CI, 96-476; six cases) and spinning, weaving and finishing (312; 117-831; four cases); there were only two cases (39; 10-155) among women in textile manufacture and none among those in spinning, weaving and finishing. Other figures for men in the two occupational categories were: for non-Hodgkin's lymphoma, six cases (87; 40-198) and four cases (124; 47-330); for acute leukaemia, four cases (129; 48-344) and two cases (134; 34-536); for other leukaemia, three cases (51; 16-158) and three cases (99; 32-307); and for other haematopoietic cancers, 14 cases (126; 75-213) and four cases (72; 27-192).

Coggon *et al.* (1986b), in their case-control study of men in three English counties (see p. 241), found RRs of 0.8 (three cases) and 1.2 (one case) for Hodgkin's disease and 1.4 (five cases) and 3.0 (two cases) for non-Hodgkin's lymphoma for working in the textile industry and among textile workers, respectively.

Schumacher and Delzell (1988) performed a death certificate-based case-control study to investigate associations between occupation and non-Hodgkin's lymphoma in men aged 35-75 in North Carolina (USA), focusing mainly on farming and the textile manufacturing industry. The 501 cases were in men who had been residents of the state and whose death certificates mentioned non-Hodgkin's lymphoma. Controls were selected from all non-neoplastic deaths among male residents of North Carolina in the same periods, and were frequency matched to cases on year of death, age and race. A total of 569 controls were selected. The usual occupation and industry, as listed on the death certificate, was coded by a person who was unaware of the subjects' status as a case or a control. The RR for non-Hodgkin's lymphoma among white males employed in the textile industry (59 cases and 68 controls) was 0.81 (90% CI, 0.59-1.1) and that for black textile workers (six cases and five controls) was 2.4 (90% CI, 0.88-6.6). The specific occupation of 'dye workers' within the textile industry was listed for only one case and no control.

In the case-control study of Siemiatycki *et al.* (1986; see p. 241), the OR by logistic regression analysis for the association between 'substantial' exposure to cotton dust and non-Hodgkin's lymphoma was 1.9 (95% CI, 1.0-3.7; 11 cases) and that for 'substantial' exposure for more than years was 3.0 (1.3-7.2; seven exposed cases). When only textile processing workers with 'substantial' exposure to cotton dust were considered, the OR was 12.6 (4.7-33.3). Other workers exposed to cotton dust had no excess risk.

A case-control study in Yorkshire, UK, in 1979-84 involved interviews with 248 patients with Hodgkin's disease and 489 other hospital patients without current malignant disease, matched by health district, sex and age (Bernard *et al.*, 1987). Thirty cases and 51 controls were textile workers [crude OR, 1.2; 95% CI, 0.73-1.9].

(*j*) *Other cancers*

Delzell and Grufferman (1983, see p. 238) observed eight deaths (PMR, 220; 95% CI, 100-500) from cancer of the *thyroid* among white female textile workers in North Carolina (USA). In the proportionate mortality study of O'Brien and Decouflé (1988, see p. 239) among male carpet and textile workers in Georgia (USA), a suggestive increase for cancer of the thyroid (two observed, 0.5 expected) was seen.

Versluys (1949; see p. 238) reported a PMR of 184 (21 cases) for cancer of the *liver* among male weavers and workers in woollens in the Netherlands. In a study of *biliary tract* cancer in Sweden, using the Swedish Cancer-Environment Registry (see p. 239), 23 of 1304 male cases of *gall-bladder cancer* (SIR, 150) and seven of 764 other biliary tract cancers (SIR, 60) had worked in the textile industry in 1960 (Malker *et al.*, 1986b). There were 11 cases of gall-bladder cancer (SIR, 150) and four cases of other biliary tract cancers (SIR, 70) in spinners, weavers and knitters.

In the cancer registry study of Olsen and Jensen (1987; see p. 239), elevated risks were observed for cancer of the *pancreas* in men (SPIR, 168; 95% CI, 110-258; 21 cases) and women (123; 74-204; 15 cases) employed in textile manufacture and in men (170; 94–307; 11 cases) and women (145; 69-305; seven cases) in the industrial subcategory of spinning, weaving and finishing textiles. Bross *et al.* (1978; see p. 241), in their case-control study of admissions to the Roswell Park Memorial Institute (New York State, USA), reported a statistically significant elevated risk, larger than 2.0, for cancer of the pancreas among male operatives in textile mills; and, in the case-control study of Magnani *et al.* (1987; see p. 241) in three English counties, occupation in the textile industry resulted in an OR for men of 1.6 (95% CI, 0.3-8.2) for pancreatic cancer.

Delzell and Grufferman (1983; see p. 238) found significantly increased PMRs for cancer of the *cervix* (210; 95% CI, 160-280; 59 observed) and for unspecified genital cancer (270; 150-470; 16 observed) in white female textile workers in North Carolina (USA). In the cancer registry study of Olsen and Jensen (1987; see p. 239), the SPIRs for cancer of the cervix uteri were 132 (95% CI, 107-163; 86 cases) for textile manufacture and 136 (96-193; 31 cases) for spinning, weaving and finishing. However, in the UK Registrar General's 1981 decennial supplement (see p. 238), there was little evidence of an increased risk for cancer of the cervix.

O'Brien and Decouflé (1988; see p. 239) observed five deaths from *testicular* cancer among carpet and textile workers in Georgia (USA), whereas 1.8 were expected (PMR, 270; 95% CI, 90-630); all occurred in young men, who had probably spent relatively little time in the industry.

Bross *et al.* (1978; see p. 241) reported a nonsignificantly elevated risk (larger than 2.0) for cancer of the *prostate* among operatives in textile mills. In the study of Hoar and Blair (1984; see p. 246), 1037 pairs of cases and matched controls were available for the study on prostatic cancer. An increased risk for prostatic cancer of borderline statistical significance was found for black workers under 65 years of age at death (OR, 2.5; 95% CI, 1.0-6.4; 15 cases). Among white males, increased risks for prostatic cancer were found in two subcategories of the textile industry: broad-woven fabric mills (OR, 4.0; 0.5-35.8) and dyeing and finishing occupations (OR, 2.0; 0.5-8.0). Siemiatycki *et al.* (1986; see p. 241) reported ORs for prostatic cancer of 1.0 (95% CI, 0.6-1.8; 16 cases) for working with cotton, 0.9 (0.4-1.8; nine cases) for working with wool and 0.7 (0.3-1.7; seven cases) for working with synthetic fibres, among male textile workers in Montréal, Québec, Canada.

Olsen and Jensen (1987; see p. 239) observed an increased risk for *melanoma* of the skin among cases of cancer registered for men involved in textile manufacture (SPIR, 189; 95% CI, 107-333; 12 cases) and spinning, weaving and finishing (224; 101-499; six cases), but not in women (98; 62-156; 18 cases; and 101; 45-225; six cases, respectively). In the 1981 decennial supplement of the UK Registrar General (see p. 238), there was little evidence of an increased risk for either melanoma or cancer of the *connective tissue*. Delzell and Grufferman (1983, see p. 238) found a significantly increased PMR for cancer of connective tissue (260; 95% CI, 130-520; ten observed cases) among white female textile workers in North Carolina (USA).

A case-control study in Copenhagen and Sjaelland island (Denmark) involved interviews in 1979-82 with 96 male and female patients less than 80 years old with cancer of the *renal pelvis and ureter* and with 288 controls selected from admissions to the same hospital for diseases other than of the urinary tract or other smoking-related diseases (Jensen *et al.*, 1988). Controls were matched for age and sex, and analyses were adjusted for age, sex and lifetime tobacco consumption. The case group included eight textile workers (OR, 0.9; 95% CI, 0.4-2.4).

Siemiatycki *et al.* (1986; see p. 241) reported ORs for cancer of the *kidney* of 1.1 (95% CI, 0.5-2.7; seven cases) for working with cotton, 1.0 (0.3-3.0; five cases) for working with wool and 0.8 (0.2-2.8; four cases) for working with synthetic fibres among male textile workers in Montréal, PQ (Canada).

The Swedish Cancer-Environment Registry (see p. 239) was used to estimate age-standardized incidence ratios for *intracranial gliomas* (McLaughlin *et al.*, 1987). Of the 3394 intracranial gliomas in men, 35 were in textile workers (SIR, 90; adjusted for age and region). A total of 1035 intracranial gliomas were seen in women, but the findings for textile workers were not reported; a SIR of 230 (15 cases) was found for female wool workers.

Van Steensel-Moll *et al.* (1985) conducted a case-control study in the Netherlands of 519 *children* under the age of 15 years with acute lymphocytic leukaemia diagnosed in 1973-80 and 507 controls matched for age, sex and municipality. Questionnaires were mailed to the children's parents. All analyses were adjusted for age and sex. Birth order and social class were not found to be confounders. Eight case mothers and two control mothers had worked in the textile industry during pregnancy (OR, 4.2; 95% CI, 1.0-17.7).

4. Summary of Data Reported and Evaluation

4.1 Exposure data

The textile manufacturing industry employs over ten million workers throughout the world. The industry includes the spinning, weaving, knitting, dyeing and finishing of numerous types of natural and synthetic fibres. The products include fabrics, yarns and carpets.

Textile workers are exposed to textile-related dusts throughout the manufacturing process. During spinning, weaving and knitting operations, exposure to chemicals is generally limited.

In dyeing and printing operations, workers are frequently exposed to dyes (including those based on benzidine as well as a variety of acids and bases), optical brighteners, organic solvents and fixatives. Workers in finishing operations are frequently exposed to crease-resistance agents (many of which release formaldehyde), flame retardants (including organophosphorus and organobromine compounds) and antimicrobial agents. In the dyeing, printing and finishing processes, workers typically have multiple exposures, which can vary with time and process.

4.2 Experimental carcinogenicity data

No data were available to the Working Group.

4.3 Human carcinogenicity data

Oral and pharyngeal cancers

Five studies of mortality and morbidity statistics did not indicate an increased risk for cancers at these sites. In the USA, a hospital-based case-control study showed an association between cancer of the buccal cavity and pharynx and textile work for both men and women working in textile mills. Of four case-control studies conducted in the UK, one had no case of oral cancer in textile workers, another showed an elevated risk for oral and pharyngeal cancers particularly among male fibre preparers, the third demonstrated an increased risk among female textile workers employed in spinning and weaving, and the fourth showed a small increase in risk in textile workers. A case-control study in the USA showed no increase, but a further study suggested a slightly increased risk for women potentially exposed to dust in the textile industry.

Cancers of the oesophagus and stomach

Ten studies based on mortality or incidence statistics in four countries were available to the Working Group. Seven of them showed an increased risk for stomach cancer among textile workers, and another showed an increase only among women in textile manufacturing. Oesophageal cancer risk was found to be elevated in three of these studies, and, in one of these, the increase was significant among a group of workers engaged as operatives in dyeing and finishing. In none of these studies was socioeconomic status taken into consideration. Two cohort studies, one in the USA and one in the UK, found moderate increases in mortality from cancer of the 'digestive system', without further specification. A case–control study in the USA showed an increased risk for stomach and oesophageal cancer. A Canadian case–control study did not show an increased risk for stomach cancer associated with exposure to cotton, wool or synthetic fibre dusts. Two case–control studies were conducted in the UK; one showed an increased risk for cancer of the stomach but not of the oesophagus, and the other showed an increase for oesophageal cancer.

Colorectal cancer

Of six large studies based on routinely collected cancer incidence or mortality data, two showed an elevated risk for colorectal cancer among textile workers; one showed an elevated risk for rectal cancer and a decreased risk for cancer of the colon. The incidence of cancers of the large bowel was reported to be increased in sequential case–control studies on workers in the synthetic fibres unit of a carpet factory in Canada. In another case–control study in Canada, the incidence of colorectal cancer was found to be significantly associated with exposure to synthetic fibre dust; the study took possible confounders into consideration. In two case–control studies, one in the UK and one in the USA, increased risks for cancers of the colon and rectum were observed, respectively, but there were few cases. A further case–control study in the USA showed an increased risk for colorectal cancer in men and a decreased risk in women; however, a large case–control study in the USA showed no evidence of an association between cancer of the colon and work in the textile industry.

Nasal cancer

Five studies based on mortality and morbidity statistics consistently showed increased risks for nasal cancer in textile workers, one in women only. In the USA, a hospital-based case–control study showed a significantly elevated risk in men employed as operatives in textile mills. In another study in the USA, an increased risk was noted among female textile and garment workers, predominantly in those first employed fewer than 20 years before diagnosis; an elevated risk for adenocarcinoma of the nasal cavity was noted among men and women in dusty operations. A significantly elevated risk related to duration of employment was found for textile workers in Hong Kong, particularly among weavers. Another study in the USA did not show an increased risk among men employed in formaldehyde-associated textile work.

Laryngeal cancer

Three mortality studies and one study of national mortality statistics in the UK revealed no association between textile work and laryngeal cancer. One US and one UK mortality study suggested a borderline positive association between textile work and laryngeal cancer; one Danish record-linkage study suggested a positive association only for women. Four case–control studies reported positive associations; and two further case–control studies showed positive associations between textile processing and exposures to textile dust and laryngeal cancer when controlling for alcohol and tobacco use.

Lung cancer

Four studies based on national mortality statistics in the UK found decreased risks for lung cancer among male textile workers; one of the studies showed a decreased risk among women and one showed an increased risk. Of seven further studies based on routinely collected cancer mortality or incidence statistics, five showed a decreased risk for lung cancer in textile workers and one an increased risk. Two cohort studies in the USA revealed a decreased risk for lung cancer among textile workers; in one, the decreased risk was associated with increased presumed exposure to cotton dust. One cohort study in the UK showed no increased risk. Of four case–control studies in the USA, two showed relative risks greater than 2.0, one showed a smaller increase in risk and one showed a decreased risk for lung cancer in textile workers. A case–control study in Canada showed a moderately decreased risk for lung cancer in textile workers, particularly among those working with wool or synthetic fibres. Two case–control studies in Italy showed an elevated risk for lung cancer in textile workers. A case–control study in China also showed a decreased risk for lung cancer in cotton textile workers.

Bladder cancer

Of three studies based on national mortality statistics in the UK, two showed an increased risk for bladder cancer among textile workers. Of six other studies based on routinely collected mortality or incidence statistics, two reported increased risks among textile workers and one showed an increased risk only for women. Two cohort studies, one in the USA and one in the UK, showed moderately increased risks.

Of a total of 19 case–control studies in which bladder cancer in textile workers was investigated, 14 showed elevated risks. These include five studies in which the risk for dyers was examined (two in the UK, one in Canada and two in Spain), all of which reported elevated risks. In the Canadian study, there was a nearly five-fold increase in risk in workers who had been employed for at least six months during the period eight to 28 years before diagnosis, and there was a trend with duration of exposure.

Four studies also addressed risks in weavers (the two Spanish studies, a study in the UK and a study in Italy), and all reported an elevation of risk of approximately two fold or more.

The findings of the 13 case–control studies that did not specifically address risks in dyers or weavers (five in the USA, one each in the UK, Canada, Denmark, Finland, the Federal Republic of Germany, Italy and Spain, and a collaborative study in the USA, UK and Japan) are less consistent: eight reported elevated risks and five reported decreased risks among textile workers.

Data on smoking habits were not available in most of the studies on textile workers. When they were available, adjustment for cigarette smoking made little difference to the findings.

Haematopoietic malignancies

One mortality study of white female textile workers in the USA showed a positive association between work in manufacturing textile mill products and non-Hodgkin's lymphoma. Two further US mortality studies of textile and of textile and carpet manufacturers reported no increase in risk. A Danish record-linkage morbidity study gave no evidence of an increased risk for this cancer among men or women in textile manufacturing. A case-control study in the UK showed a moderately increased risk, on the basis of a few cases, and a case-control study in the USA showed no significant association between non-Hodgkin's lymphoma and employment in the textile industry. A Canadian case-control study showed a positive association between non-Hodgkin's lymphoma and 'substantial' exposure to cotton dust, which became stronger when analysis was limited to textile processing workers exposed to cotton dust.

A Danish record-linkage morbidity study based on a small number of cases reported a borderline positive association for Hodgkin's disease among men engaged in spinning, weaving and finishing. Two US mortality studies and two UK case-control studies found a nonsignificant association between textile work and Hodgkin's disease. One mortality study reported a significant positive association between leukaemia and textile work.

Other cancers

Two mortality studies reported a borderline positive association between *thyroid* cancer and work in the textile industry.

One mortality study reported an elevated but nonsignificant association between cancer of the *liver* and working with textiles. A similar association was reported for cancer of the *gall-bladder* in another mortality study.

In one record-linkage morbidity study and in one case-control study, the risk for cancer of the *pancreas* was elevated in men working in the textile industry; in a further case-control study, the risk was increased, but not significantly so.

A mortality study and a record-linkage morbidity study reported a significant association between *cervical cancer* and textile work, while examination of mortality statistics gave little evidence of such an association. These studies were not controlled for social class.

A single mortality study found an increase in the number of deaths from *testicular cancer* among carpet and textile workers.

One case-control study showed a borderline increase in risk for *prostatic cancer* among black but not white textile workers; for white workers, increased risk was seen in two subcategories of the industry. One further case-control study showed no significant association between prostatic cancer and work in the textile industry; another showed a nonsignificantly elevated risk.

A single record-linkage morbidity study reported an increased risk of borderline significance for *melanoma* among male, but not female, textile workers.

One mortality study in the USA showed a significantly increased risk for cancer of *connective tissue* among white female textile workers. A study based on national statistics in the UK showed no increase in risk for cancer at this site.

One case–control study showed no association between cancer of the *renal pelvis and ureter* and work in the textile industry; another case control study showed no association between cancer of the *kidney* and work in the textile industry.

A single cancer registry study showed a significant association between the incidence of *intracranial gliomas* in women and employment in the wool industry.

One Dutch case–control study of lymphocytic leukaemia showed a risk of borderline significance among *children* whose mothers had been employed in the textile industry during pregnancy.

4.4 Other relevant data

A study of spontaneous abortions in Finland showed a moderately increased risk among mothers employed as spinners, fabric inspectors and weavers. A study in Canada gave no evidence of an increased risk of prematurity or low birth weight in babies of women employed in the textile industry. An analysis of birth records in the USA found an increased risk for fetal death among offspring of women employed in the textile industry.

4.5 Evaluation[1]

There is *limited evidence* that working in the textile manufacturing industry entails a carcinogenic risk.

This evaluation is based mainly on findings of bladder cancer among dyers (possibly due to exposure to dyes) and among weavers (possibly due to exposure to dusts from fibres and yarns) and of cancer of the nasal cavity among weavers (possibly due to exposure to dusts from fibres and yarns) and among other textile workers.

Working in the textile manufacturing industry entails exposures that are *possibly carcinogenic to humans (Group 2B)*.

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[1]This evaluation applies to exposures in the textile manufacturing industry that exclude the manufacture of asbestos textiles (IARC, 1977, 1987) and mule spinning with exposure to mineral oils (IARC, 1984, 1987). For description of the italicized terms and criteria for making the evaluation, see Preamble, pp. 25–29.

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