SPECIAL NIOSH HAZARD REVIEW

September 1993

DHHS (NIOSH) Publication Number 93-106

SPECIAL NIOSH HAZARD REVIEW

Preface

The Occupational Safety and Health Act of 1970 emphasizes the need for standards to protect the health and safety of American workers. To fulfill this need, the National Institute for Occupational Safety and Health (NIOSH) has developed a strategy for disseminating information that will help employers to protect their workers from workplace hazards. This strategy includes the development of Special NIOSH Hazard Reviews, which support and complement the major standards development and hazard documentation activities of the Institute. These documents deal with hazards that merit research and concern from the scientific community even though they are not currently suitable for comprehensive review in a criteria document or a Current Intelligence Bulletin. Special NIOSH Hazard Reviews are distributed to the occupational health community at large—industries, trade associations, unions, and members of the academic and scientific communities.

Abstract

Excess deaths from bladder, stomach, lung, hematopoietic, and other cancers have occurred among workers involved in the manufacture of rubber products. These workers may also risk adverse respiratory effects, dermatologic effects, reproductive effects, injuries, and repetitive trauma disorders. The adverse health effects cannot be attributed to a single chemical or group of chemicals because workplace exposures vary greatly and chemical formulations change frequently. Epidemiologic, toxicologic, and industrial hygiene studies are needed to assess the risk of cancer and other adverse health effects for rubber products workers.

Introduction

Many epidemiologic studies have reported excess deaths from bladder, stomach, lung, hematopoietic, and other cancers among tire and nontire rubber products workers. Most of these excess deaths cannot be attributed to a specific chemical because (1) workplace exposures involve many individual chemicals and combinations, and (2) changes occur in chemical formulations. Most of the chemicals found in these industries have not been tested for carcinogenicity or toxicity, nor do they have Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) or National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (RELs). This *Special NIOSH Hazard Review* summarizes the adverse health effects of worker exposures in the rubber products industry; it also examines research needed to assess and prevent these effects.

Background

Potential for Worker Exposure

Rubber products such as automobile tires, automotive and appliance moldings, rubber bands, rubber gloves, and prophylactics are an important part of modern life. However, production of these items involves subjecting heterogeneous mixtures of hundreds of chemicals to heat, pressure, and catalytic action during a variety of manufacturing processes. As a result, the work environment may be contaminated with dusts, gases, vapors, fumes, and chemical byproducts (e.g., Nnitrosamines). Workers may be exposed to these hazards through inhalation and skin absorption during rubber processing and product manufacturing. Physical hazards such as noise, repetitive motion, and lifting may also be present. Health scientists have been challenged to define these exposures and work conditions when investigating the health of rubber products workers.

The rubber products manufacturing industry employs a considerable number of workers. For example, in 1989, approximately 54,600 U.S. workers were employed in tire and inner tube production, and 132,500 workers were employed in the manufacture of nontire rubber products (Standard Industrial Classifications [SICs] 3021, 3052, 3053, 3061, and 3069; note that SICs 3021 and 3052 include plastic products and cannot be subdivided [see Table 1]) [U.S. Department of Commerce 1991].

Current Exposure Limits

Although the products and byproducts of tire and nontire rubber manufacturing contain hundreds of chemicals, only a small proportion of them are covered by applicable Federal occupational health standards [29 CFR* 1910].**Code of Federal Regulations*. See CFR in references.

Table 1.
Number of U.S. production workers in rubber products manufacturing: 1977, 1987, and 1989*(in thousands)

SIC Code	Number of production workers Industry segment	1977	1987	1989
3011	Tires and inner tubes	88.3	52.6	54.6
3021	Rubber and plastic footwear	16.4	9.1	9.2
3052	Rubber and plastic hoses and belting	23.4	16.6	18.5
3053	Gaskets, packing, and sealing devices	25.0	19.9	23.5
3061	Molded, extruded, and lathe-cut rubber mechanical goods	NA	37.9	37.3
3069	Fabricated rubber products not elsewhere classified	NA	40.4	44.0
	TOTAL	153.1	176.5	187.1

*Data from the U.S. Department of Commerce [1990, 1991].
SIC=Standard Industrial Classification.
NA=Not available (industry definition is new for the 1987 Census of Manufactures).

Summary of Health Effects

Historically, cancer has been the chronic disease most frequently reported in cohort studies of rubber products workers. In the late 1940s, British rubber workers were reported to be at increased risk of bladder cancer from exposure to an antioxidant that contained 1-naphthylamine(alpha-naphthylamine) and 2-naphthylamine (beta-naphthylamine) [Case and Hosker 1954]. In the United States, early investigations by Mancuso et al. [1968] revealed excess cancer deaths among a cohort of Ohio rubber products workers employed in 1938 and 1939; these investigators recommended additional studies of U.S. rubber workers. In 1970, the United Rubber, Cork, Linoleum, and Plastic Workers of America (URW) joined with six major American rubber companies to establish a joint occupational health program. A contract was negotiated with the Schools of Public Health at Harvard University and the University of North Carolina to conduct epidemiologic studies of rubber workers that emphasized cancer incidence and mortality [IARC 1982]. A large number of published and unpublished reports were produced as a result of these studies until the program was discontinued in 1980. The principal adverse health effects reported were cancer and respiratory effects (e.g., reductions in pulmonary function, chest tightness, shortness of breath, and other respiratory symptoms).

Currently, the risks for cancer and other chronic diseases in rubber products workers are unknown because of the lack of substantial epidemiologic and industrial hygiene research in the past decade. Toxicity data are also lacking for many chemical formulations found in tire and nontire manufacturing. Categories of rubber compounding additives may include the following [IARC 1982]:

- Accelerators
- Oils (process and extender)
- Antioxidants
- Organic vulcanizers
- Antiozonants
- Pigment blends
- Antitack agents
- Plasticizers
- Chemical byproducts
- Reinforcing agents
- Curing fumes
- Resins
- Extenders
- Solvents
- Fillers

Most studies of cancer among rubber products workers have been conducted as retrospective cohort or casecontrol mortality studies of workers employed in the tire and nontire industries between 1940 and 1975. Many of these studies have reported statistically significant numbers of excess deaths from bladder cancer ($P<0.05$) [Checkoway et al. 1981; Bovet and Lob 1980; Monson and Nakano 1976; Negri et al. 1989; Fox and Collier 1976], lymphatic and hematopoietic cancers [Checkoway et al. 1984; Arp et al. 1983; Wilcosky et al. 1984; McMichael et al. 1975; Wolf et al. 1981; McGlothlin and Wilcox 1984], lung cancer [Fox et al. 1974; Zhang et al. 1989; Andjelkovich et al. 1988; Delzell et al. 1982; Delzell and Monson 1985; Monson and Fine 1978; Parkes et al. 1982], and stomach cancer [Blum et al. 1979; McMichael et al. 1974; Parkes et al. 1982; Andjelkovich et al. 1977; Sorahan et al. 1989; Sorahan et al. 1986]. Excess deaths from colon cancer [Delzell and Monson 1982], prostate cancer [Goldsmith et al. 1980], liver and biliary cancer [Delzell and Monson 1982], and esophageal cancer [Parkes et al. 1982] have been noted in individual studies. Occupational exposure data do not exist for most of these studies and have been estimated historically. The uncertainty of these exposure estimates is exacerbated by chemical formulations that differ with each plant or process.

In 1980, OSHA [1980] published a report informing tire and nontire workers of their risk for cancer as reported in several studies by Harvard University and the University of North Carolina [Monson and Fine 1978; Monson and Nakano 1976; McMichael et al. 1974, 1975, 1976a,b,c; Andjelkovic et al. 1976; Tyroler et al. 1976; Andjelkovich et al. 1977; Blum et al. 1979].

In 1982, the International Agency for Research on Cancer (IARC) published a rubber industry monograph that evaluated the available epidemiologic, toxicologic, and industrial hygiene data [IARC 1982]. In that monograph, IARC concluded that sufficient evidence existed to associate leukemia with occupational solvent exposure in the rubber industry; however, no clear evidence existed to indicate an excess of bladder cancer in British rubber workers first employed after 1950 or in U.S. rubber workers. IARC also concluded in the monograph that evidence was limited for associating stomach, lung, and skin cancer with occupational exposures in the rubber industry, and inadequate for associating lymphoma and colon, prostate, brain, thyroid, pancreatic, and esophageal cancer with these exposures.

NIOSH recently recommended measures to reduce worker exposures to otoluidine and aniline (chemicals used as intermediates in the manufacture of rubber antioxidants and accelerators) to the lowest feasible concentrations [NIOSH 1990; Ward et al. 1991]. The epidemiologic evidence reported by NIOSH [1989] associated occupational exposure to otoluidine and aniline with an increased risk of bladder cancer among workers at a plant that manufactured rubber antioxidants and accelerators. However, it is unknown whether a similar risk exists for workers involved in the manufacture of rubber products.

Respiratory Effects

The studies conducted by Harvard University and the University of North Carolina report an increase in adverse respiratory effects (i.e., chest tightness, shortness of breath, reductions in pulmonary functions, and other respiratory symptoms) among rubber products workers [Fine et al. 1976; Fine and Peters 1976; Weeks et al. 1981a,b; McMichael et al. 1976b]. The University of North Carolina researchers also investigated chronic disabling pulmonary disease among rubber products workers [Lednar et al. 1977]. Emphysema was the primary condition responsible for early retirement that was due to pulmonary disease among rubber products workers who retired from a large Ohio company during the period 196473. Respiratory effects and chronic disabling pulmonary diseases were reported to be more prevalent among rubber workers in the curing, processing (premixing, weighing, mixing, and heating of raw ingredients), and finishing and inspection areas of tire and nontire plants [Fine et al. 1976; Fine and Peters 1976; Weeks et al. 1981a,b; McMichael et al. 1976b; Lednar et al. 1977]. The prevalence is unknown for respiratory effects and diseases resulting from current occupational exposures in the rubber products manufacturing industry.

The results from one study identified naphthalene diisocyanate (NDI) as the cause of respiratory irritation among workers in a Swedish tire plant [Alexandersson et al. 1986]. In another study, however, no agent could be identified as the cause of acute respiratory illnesses, recurrent bronchitis with loss of lung function, or peripheral eosinophilia among 30 workers involved in a synthetic chloroprene rubber thermoinjection process [Bascom et al. 1988, 1990]. A 1987 study by

NIOSH at nine U.S. tire plants found no significant increase in pneumoconiosis when investigators examined 987 chest Xrays of workers who were at least 40 years old [Jankovic and Reger 1989].

Dermatologic Effects

Contact dermatitis has been reported frequently among rubber workers and even more frequently among users of rubber products [Taylor 1986]. A crosssectional survey of 999 workers in an Australian tire plant reported a prevalence rate of 37 cases of occupational contact dermatitis per 1,000 workers [Varigos and Dunt 1981]. Table 2 lists chemicals identified in the rubber products industry as sensitizing agents for contact dermatitis.

Since 1972, several NIOSH health hazard evaluations (HHEs) have reported contact dermatitis in tire and nontire plants, but most of the evaluations (Table 3) could not identify a specific chemical as the causative agent [Gunter and Flesch 1977; Hollett and Klemme 1982; Williams et al. 1984; Ruhe et al. 1975].

The Bureau of Labor Statistics (BLS) reported that in the rubber and miscellaneous plastics industry (SIC 30), the 1991 incidence rate for skin diseases or disorders (contact dermatitis, eczema, or rash caused by primary irritants and sensitizers) was 19.0 cases per 10,000 fulltime workers [DOL 1993]. This incidence rate was the ninth highest among the 32 major 2digit SIC industries. The relationship between dermatitis and the chemicals used in this industry has not been well defined [Williams et al. 1984], but some chemicals documented to cause dermatitis are no longer used. Many other chemicals used in the industry today have not been evaluated and are not regulated [Williams et al. 1984]. Lack of information about sources of worker exposure (including direct contact with bulk chemicals, processed stocks, and machinery contaminated with chemicals) has contributed to the difficulty in determining the association between contact dermatitis and specific chemicals [Williams et al. 1984].

A cluster of five vitiligo cases (cutaneous depigmentation) has also been reported [O'Malley et al. 1988; O'Malley and Mathias 1986]. The five cases were diagnosed among 199 workers at a company that manufactured hydraulic pumps with rubber injectionmolded interiors. Paratertiary butylphenol (PTBP) and 2,4ditertiary butylphenol (DTBP) were identified as probable causes for four of the five cases. Both compounds were present in rubber stock that was handled by the workers.

Reproductive Effects

Although pregnancy outcomes have been studied among Swedish and Finnish rubber workers [Holmberg and Nurminen 1980; Lindbohm et al. 1983; Hemminki et al. 1983; Axelson et al. 1983; Lindbohm et al. 1991], no conclusions can be drawn because of equivocal results and lack of occupational exposure data. NIOSH has investigated reports of spontaneous abortions among American rubber workers, but none of these could be attributed to exposures in the work environment [Boiano and Klemme 1984; Belanger 1981]. Investigators of reproductive impairment and occupation have rarely studied the possibility of synergistic effects occurring in industries where workers encounter a multitude of exposures [Rosenberg et al. 1987].

Table 2.
Agents reported to cause contact dermatitis in rubber products workers

	Number

Chemical	of cases	Process	Product	Country	Reference
2(2'-4'Dinitrophenylthio) benzothiazole (Pisa), which was contaminated with dinitrochlorbenzene (DNCB)	16	All areas	Tires	Italy	Zina et al. [1987]
4,4'-Dithiodimorpholine, 1%	45	Not specified	Tires	United States	Taylor [1986]
n-Isopropyl-n-phenylparaphenylenediamine (IPPD)	15	Assembly, maintenance, compounding	Tires	France	Herve-Bazin et al. [1977]
n-Dimethyl-1,3 butyl-n-phenylparaphenylenediamine (DMPPD)	15	Assembly, maintenance compounding (tested only on those who had reacted to IPPD)	Tires	France	Herve-Bazin et al. [1977]
para-Phenylenediamine compounds	48	Not specified (handling of uncured rubber)	Tires, footwear	Finland	Kilpikari [1982]
Ethylene thiourea (ETU)	1	Sewing	Nontire products	Sweden	Bruze and Fregert [1983]
Resorcinal (sic)	8	Not specified	Tires	Italy	Abbate et al. [1989]

Table 3.
NIOSH surveys for contact dermatitis in tire and nontire plants

Chemical	Number of cases	Product	Recommendations	Reference
Solution containing zinc oxide, resorcinol, formaldehyde, sodium hydroxide, ammonia; rayon fibers in cord	5	Reinforced rubber hose	Use ventilation and barrier cream.	Gunter and Flesch [1977], HHE 77-37-413
Various, not specified	60	Bladders for aircraft fuel cells	Use gloves and wash hands after contact.	Hollett and Klemme [1982], HETA 81-045C-1217
Various, not specified (present in dust in banbury, milling, and pigment blending areas)	NS*	Tires, tubes, flaps,	Use clean rubber stock liners; train workers in personal hygiene; relocate sensitized workers; maintain surveillance; implement a dust control	Williams et al. [1984], HETA 83-

		bladders	program.	196-1492
2,2'Dithioaniline (bis-2)	10	Urethane rubber bumper pads	Use disposable gloves and disposable smock; shower before leaving the worksite.	Ruhe et al. [1975], HHE 73-156-205

*NS=Not specified.
See also Ellish et al. [1977] and Suskind [1982] for other dermatitis investigations conducted in this plant.

Injuries

The BLS annual survey reports injury incidence rates for industries by total cases, lost workday cases, nonfatal cases without lost workdays, and lost workdays. The annual survey is based on a stratified random sample of employers and does not include selfemployed individuals, farms with fewer than 11 workers, employers regulated by Federal safety and health laws other than the Occupational Safety and Health Act, or Federal, State, or local government agencies. A review of the data indicates that the injury incidence rate for the rubber and miscellaneous plastics industry (SIC 30) was about 15.0 injuries per 100 fulltime workers in 1988, 1989, and 1990 [DOL 1990, 1991, 1992]. Although this rate had dropped to 13.9 injuries per 100 fulltime workers in 1991, it was still the eighth highest among the 70 major 2digit SIC industries [DOL 1993]. Other incidence rates for rubber products SIC codes (e.g., incidence rates for lost workdays) are comparable with those reported for other industries. However, the significance of these comparisons cannot be determined without more specific analyses of the type, frequency, and distribution of the injuries.

Repeated Trauma Disorders

Disorders associated with repeated trauma is a broad BLS category that includes noiseinduced hearing loss, synovitis, tenosynovitis, carpal tunnel syndrome, and other conditions resulting from repeated motion, vibration, or pressure. No data show the number of rubber and plastics workers affected by each of these disorders, but the overall incidence in 1991 was 80.5 cases per 10,000 fulltime workers [DOL 1993]. Data also indicate that this incidence rate has increased yearly since 1988, when the incidence rate was 56.5 per 10,000 [DOL 1990, 1991, 1992, 1993]. Only 9 of 31 additional 2digit SIC industries have higher incidence rates, and rubber and plastics footwear manufacturing has the 18th highest rate (160.3 cases per 10,000) among 138 3digit SIC industries [DOL 1993].

Efforts To Characterize Exposures

Industrial Hygiene Studies

In the early 1980s, NIOSH conducted industrial hygiene surveys of the tire and rubber industry and recommended that engineering controls be implemented and that substitute chemical formulations be introduced to reduce worker exposure to toxic agents [NIOSH 1983a, 1984]. However, few studies have been conducted since then to determine whether these recommendations have been instituted.

Researchers in Italy sampled volatile emissions in three locations: the vulcanization area of a shoesole factory, the vulcanization and extrusion areas of a tire retreading factory, and the extrusion area of an electrical cable insulation plant [Cocheo et al. 1983]. Approximately 100 different chemicals were identified, but the health effects associated with exposure to these chemicals have not been studied. In addition, it is notknown whether the chemicals identified are representative of the emissions in other plants.

Laboratory Study

In 1976, a laboratory study was conducted in the United States to simulate the volatile emissions released during vulcanization of one rubber formulation [Fraser and Rappaport 1976]. Although various compounds were identified as contaminants in the raw materials or as reaction products, all rubber formulations contain different ingredients.

National Occupational Exposure Survey

The National Occupational Exposure Survey (NOES) lists many chemical and other possible hazards (e.g., elevated temperature, whole body vibration, infrared and microwave radiation, impact noise, handwrist manipulations, etc.) found in 37 tire and nontire plants surveyed from 1981 to 1983 [NIOSH 1983b]. The survey involved approximately 19,500 workers. Most of the NOES surveys were conducted in the work areas of fabricated rubber products plants (SIC 3069), where more than 1,000 potential chemical hazards were identified. Although the NOES results estimate the number and distribution of workers potentially exposed to these hazards, they provide no quantitative exposure data.

OSHA Reports

OSHA inspection reports were reviewed to identify occupational exposures that were most frequently found in the tire and nontire plants and to determine whether any of these exposures exceeded OSHA standards. Data were reviewed from OSHA inspections conducted during the period 198290 in tire and inner tube facilities (SIC 3011), rubber and plastics footwear facilities (SIC 3021), rubber and plastics hose facilities (SIC 3052), and fabricated rubber products facilities (SIC 3069) [OSHA 1990]. Citations can be issued by OSHA for chemical exposures that exceed the PEL, failure to abate a hazard, lack of adequate engineering controls and personal protective equipment, lack of adequate training, lack of medical surveillance, or failure to meet other occupational safety and health standards. Of the hazards cited, only continuous or intermittent noise was noted in all four of these SIC codes. However, because not all facilities were inspected and only a small proportion of the workers were observed, these data do not provide adequate information about the health and safety risks for this industry. For example, although most inspections were conducted in the fabricated rubber products industry (SIC 3069), only about onethird of the total plants in this industry were inspected. In addition, the substances monitored during these OSHA inspections were usually those that had OSHA PELs and sampling methods [29 CFR 1910]. Thus, the substances monitored may not have been the substances that represented the greatest hazards. Stewart and Rice [1990] have suggested that research be conducted to determine whether the OSHA database of monitoring results is representative of national exposure situations.

Research Needs

In the absence of current epidemiologic and occupational exposure data, information about chemical formulations, and specific injury analyses, it is impossible to assess the risk posed to rubber products workers by cancer, other occupational diseases, and certain injuries. The hazards that exist today may be different from those in the past because of changes in chemical formulations and the introduction of automated processes. To quantify the health risks for rubber products workers, the following types of research are needed:

- Evaluation of hazardous exposures
- Assessment of control measures
- Epidemiologic research
- Collection of injury data
- Evaluation of health and safety programs
- Identification of compounds or groups of substances

Evaluation of Hazardous Exposures

Industrial hygiene characterization studies should be conducted in tire and nontire plants to further evaluate hazardous agents. These data should be used to reconstruct historical exposures (e.g., airborne and dermal).

Assessment of Control Measures

The effectiveness of control measures (e.g., engineering controls and personal protective equipment and clothing) should be assessed in tire and nontire plants. Such an assessment should include the transfer of new and innovative technologies across industries. For example, control measures for bag dumping and powder weighout operations have been studied by NIOSH in other industries where powdered materials are handled [Gressel and Fischbach 1989; Gressel et al. 1987; Heitbrink and McKinnery 1986; Cooper et al. 1989].

Investigations are needed to determine the type and amount of personal hygiene information being communicated to rubber products workers (e.g., the information described by OSHA [1980]). Practices recommended by OSHA include (1) removal of chemical contaminants before eating, drinking, smoking, or using cosmetics, (2) refraining from eating, drinking, or smoking in work areas, (3) showering before going home, and (4) leaving protective clothing at work. The application of these practices by rubber products workers should also be surveyed.

Epidemiologic Research

From 1980 to the present, a gap exists in the epidemiologic research among rubber products workers. Only three retrospective cohort mortality studies were published after those done by Harvard University and the University of North Carolina [Carlo et al.1993; Negri et al. 1989; Zhang et al. 1989]. Updated retrospective cohort analyses and other epidemiologic designs are needed to determine whether current workers in this industry risk cancer and other adverse health effects such as respiratory effects, skin disorders, and reproductive impairments. Crosssectional surveys should be performed throughout the rubber products industry to determine the prevalence of skin diseases and repetitive trauma disorders.

Collection of Injury Data

Detailed injury data (e.g., data on the types and severity of injuries within a particular job process) should be collected to identify areas where preventive measures such as worker education and training could be implemented. The BLS Annual Survey reports injury incidence rates but not types of injuries. Conversely, injury rates could be calculated from data in the BLS Supplementary Data System [DOL 1987], but the suppression of employment figures prevents the calculation of valid rates [U.S. Department of Commerce 1987].

Data are suppressed by the U.S. Bureau of the Census in many States to prevent disclosure of employment data that might identify the operations of specific plants. This practice is in accordance with a Federal regulation that prohibits publication of data that might disclose the operations of an individual employer [U.S. Department of Commerce 1987].

Evaluation of Health and Safety Programs

The injury incidence rate for 1991 in the rubber and miscellaneous plastics industry (SIC 30) was the eighth highest among the 70 major 2digit SIC industries [DOL 1993]. Current health and safety programs in the rubber products manufacturing industry should be evaluated to determine whether they are adequately addressing the need for injury reduction.

Identification of Compounds or Groups of Substances

Although toxicologic studies have been conducted on chemicals used or formed during rubber products manufacturing [Cox 1989; Susten et al. 1985; Hedenstedt et al. 1979, 1981; Hedenstedt 1982; Donner et al. 1983; IARC 1982; NTP 1992], this research has included only a small fraction of all chemicals used. Investigators have suggested that instead of focusing on individual chemicals, research in the rubber industry should address compounds or groups of substances such as accelerators or curing fumes [Holmberg and Sjstrm 1980; IARC 1982]. This research should include systematic identification and quantitation of the organic vapors and gases produced from the heating and curing of rubber compounds.

Conclusions

Epidemiologic, toxicologic, and industrial hygiene studies are needed to assess the risk of cancer and other diseases from current occupational exposures. Detailed analyses of worker injuries are also needed to identify areas for worker training and other preventive measures. The results of future studies should be closely monitored to determine whether recommendations to Federal regulatory agencies should be developed for the rubber products manufacturing industry.

References

Abbate C, Polito I, Puglisi A, Brecciaroli R, Tanzariello A, German¢ D [1989]. Dermatosis from resorcinal in tyre makers. Br J Ind Med *46*:212214.

Alexandersson R, Gustafsson P, Hedenstierna G, Rosen G [1986]. Exposure to naphthalenediisocyanate in a rubber plant: symptoms and lung function. Arch Environ Health *41*(2):8589.

Andjelkovich DA, Abdelghany N, Mathew RM, Blum S [1988]. Lung cancer casecontrol study in a rubber manufacturing plant. Am J Ind Med *14*:559574.

Andjelkovic D, Taulbee J, Symons M [1976]. Mortality experience of a cohort of rubber workers, 19641973. J Occup Med *18*(6):387394.

Andjelkovich D, Taulbee J, Symons M, Williams T [1977]. Mortality of rubber workers with reference to work experience. J Occup Med *19*(6):397405.

Arp EW Jr., Wolf PH, Checkoway H [1983]. Lymphocytic leukemia and exposures to benzene and other solvents in the rubber industry. J Occup Med *25*(8):598602.

Axelson O, Edling C, Andersson L [1983]. Pregnancy outcome among women in a Swedish rubber plant. Scand J Work Environ Health *9* (Suppl 2): 7983.

Bascom R, Baser ME, Thomas RJ, Fisher JF, Yang WN, Baker JH [1990]. Elevated serum IgE, eosinophilia, and lung function in rubber workers. Arch Environ Health *45*(1):1519.

Bascom R, Fisher JF, Thomas RJ, Yang WN, Baser ME, Baker JH [1988]. Eosinophilia, respiratory symptoms and pulmonary infiltrates in rubber workers. Chest *93*(1):154158.

Belanger PL [1981]. Health hazard evaluation report: Lear Siegler, Inc., San Diego, CA. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 812701012.

Blum S, Arp EW Jr., Smith AH, Tyroler HA [1979]. Stomach cancer among rubber workers: an epidemiologic investigation. In: Lemen R, Dement JM, eds. Dusts and Disease, Proceedings of the Conference on Occupational Exposures to Fibrous and Particulate Dust and Their Extension into the Environment. Park Forest South, IL: Pathotox Publisher, Inc., pp. 325334.

Boiano JM, Klemme JC [1984]. Health hazard evaluation report: Geauga Company, Middlefield, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 811071331.

Bovet P, Lob M [1980]. Death from malignant tumor of workers in a Swiss rubber factory. Epidemiological study, 19551975. Schweiz Med Wochenschr *110*(35):12771287.

Bruze M, Fregert S [1983]. Allergic contact dermatitis from ethylene thiourea. Contact Dermatitis *9*:208212.

Carlo GL, Jablinske MR, Lee NL, Sund KG, Corn M [1993]. Reduced mortality among workers at a rubber plant. J Occup Med *35*(6):611616.

Case RAM, Hosker ME [1954]. Tumour of the urinary bladder as an occupational disease in the rubber industry in England and Wales. Br J Prev Soc Med *8*:3950.

CFR. Code of Federal regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Checkoway H, Smith AH, McMichael AJ, Jones FS, Monson RR, Tyroler HA [1981]. A casecontrol study of bladder cancer in the United States rubber and tyre industry. Br J Ind Med *38*:240246.

Checkoway H, Wilcosky T, Wolf P, Tyroler H [1984]. An evaluation of the associations of leukemia and rubber industry solvent exposures. Am J Ind Med *5*:239249.

Cocheo V, Bellomo ML, Bombi GG [1983]. Rubber manufacture: sampling and identification of volatile pollutants. Am Ind Hyg Assoc J *44*(7):521527.

Cooper TC, Heitbrink WA, O'Brien DM [1989]. Study report: evaluation of dustiness test methods and recommendations for improved dust control at Heubach Inc., Newark, NJ. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, ECTB No. 15411a, NTIS No. PB 89187876.

Cox GV [1989]. Letter of August 11, 1989, from G.V. Cox, Chemical Manufacturers Association, Washington, D.C. to Document Control Officer, Chemical Information Division, Office of Toxic

Substances, U.S. Environmental Protection Agency,Washington, D.C.

Delzell E, Andjelkovich D, Tyroler HA [1982]. A casecontrol study of employment experience and lung cancer among rubber workers. Am J Ind Med *3*:393404.

Delzell E, Monson RR [1982]. Mortality among rubber workers: V. Processing workers. J Occup Med *24*(7):539545.

Delzell E, Monson RR [1985]. Mortality among rubber workers: IX. Curing workers. Am J Ind Med *8*(6):537544.

DOL [1987]. Supplementary data system (SDS): 19801987. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics. Unpublished data base.

DOL [1990]. Occupational injuries and illnesses in the United States by industry, 1988. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2366, August 1990, pp. 2337, 4146.

DOL [1991]. Occupational injuries and illnesses in the United States by industry, 1989. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2379, April 1991, pp. 2336, 4045.

DOL [1992]. Occupational injuries and illnesses in the United States by industry, 1990. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2399, April 1992, pp. 2336, 4045.

DOL [1993]. Occupational injuries and illnesses in the United States by industry, 1991. Washington, DC: U.S. Department of Labor, Bureau of Labor Statistics, Bulletin 2424, May 1993, pp. 2336, 4245, 5051, 7374.

Donner M, HusgafvelPursiainen K, Jenssen D, Rannug A [1983]. Mutagenicity of rubber additives and curing fumes. Scand J Work Environ Health *9* (Suppl 2):2737.

Ellish N, Symons M, Andjelkovich D, Williams T, Peterson T [1977]. Special study of dermatitis at the Goodyear Gadsden plant, 19711974. Report by the Occupational Health Studies Group, University of North Carolina to the Joint URW Goodyear Occupational Health Committee, No. GY18, April 1977.

Fine LJ, Peters JM [1976]. Respiratory morbidity in rubber workers. I. Prevalence of respiratory symptoms and disease in curing workers. Arch Environ Health *31*(1):59.

Fine LJ, Peters JM, Burgess WA, Di Berardinis LJ [1976]. Studies of respiratory morbidity in rubber workers. IV. Respiratory morbidity in talc workers. Arch Environ Health *31*(4):195200.

Fox AJ, Collier PF [1976]. A survey of occupational cancer in the rubber andcablemaking industries: analysis of deaths occurring in 197274. Br J Ind Med *33*:249264.

Fox AJ, Lindars DC, Owen R [1974]. A survey of occupational cancer in the rubber and cablemaking industries: results of fiveyear analysis, 196771. Br J Ind Med *31*:140151.

Fraser DA, Rappaport S [1976]. Health aspects of the curing of synthetic rubbers. Environ Health Perspect *17*:4553.

Goldsmith DF, Smith AH, McMichael AJ [1980]. A casecontrol study of prostate cancer within a cohort of rubber and tire workers. J Occup Med *22*(8):533541.

Gressel MG, Fischbach TJ [1989]. Workstation design improvements for the reduction of dust exposures during weighing of chemical powders. Appl Ind Hyg *4*(9):227233.

Gressel MG, Heitbrink WA, McGlothlin JD, Fischbach TJ [1987]. Realtime, integrated, and ergonomic analysis of dust exposure during manual materials handling. Appl Ind Hyg *2*(3):108113.

Gunter BJ, Flesch JP [1977]. Health hazard evaluation determination report: Gates Rubber Company, Denver, CO. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. 7737413.

Hedenstedt A [1982]. Genetic health risks in the rubber industry: mutagenicity studies on rubber chemicals and process vapours. Occupational health series #46: International Symposium on Prevention of Occupational Cancer. Helsinki, Finland: Finnish Institute of Occupational Health, pp. 476482.

Hedenstedt A, Ramel C, Wachtmeister CA [1981]. Mutagenicity of rubber vulcanization gases in Salmonella typhimurium. J Toxicol Environ Health *8*:805814.

Hedenstedt A, Rannug U, Ramel C, Wachtmeister CA [1979]. Mutagenicity and metabolism studies on 12 thiuram and dithiocarbamate compounds used as accelerators in the Swedish rubber industry. Mutat Res *68*:313325.

Heitbrink WA, McKinnery WN Jr. [1986]. Dust control during bag opening, emptying and disposal. Appl Ind Hyg *1*(2):101109.

Hemminki K, Niemi ML, Kyyrnen P, Kilpikari I, Vainio H [1983]. Spontaneous abortions and reproductive selection mechanisms in the rubber and leather industry in Finland. Br J Ind Med *40*(1):8186.

HerveBazin B, Gradiski D, Duprat P, Marignac B, Foussereau J, Cavelier C, et al. [1977]. Occupational eczema from NisopropylN-phenylparaphenylenediamine (IPPD)and Ndimethyl1,3 butylNphenylparaphenylenediamine (DMPPD) in tyres. Contact Dermatitis *3*:115.

Hollett BA, Klemme JC [1982]. Health hazard evaluation report: Uniroyal, Incorporated, Mishawaka, IN. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 81045C1217.

Holmberg B, Sjstrm B [1980]. Toxicological aspects of chemical hazards in the rubber industry. J Toxicol Environ Health *6*(56):12011209.

Holmberg PC, Nurminen M [1980]. Congenital defects of the central nervous system and occupational factors during pregnancy: a casereferent study. Am J Ind Med *1*:167176.

IARC [1982]. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans: the rubber industry. Vol. 28. Lyon, France: World Health Organization, International Agency for Research on Cancer.

Jankovic J, Reger R [1989]. Health hazard evaluation report: United Rubber Workers'

International Union, Akron, OH. Morgantown, WV: Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 870171949.

Kilpikari I [1982]. Occupational contact dermatitis among rubber workers. Contact Dermatitis *8*:359362.

Lednar WM, Tyroler HA, McMichael AJ, Shy CM [1977]. The occupational determinants of chronic disabling pulmonary disease in rubber workers. J Occup Med *19*(4):263268.

Lindbohm ML, Hemminki K, Bonhomme MG, Anttila A, Rantala K, Heikkil P, et al. [1991]. Effects of paternal occupational exposure on spontaneous abortions. Am J Public Health *81*(8):10291033.

Lindbohm ML, Hemminki K, Kyyrnen P, Kilpikari I, Vainio H [1983]. Spontaneous abortions among rubber workers and congenital malformations in their offspring. Scand J Work Environ Health *9* (Suppl 2):8590.

Mancuso TF, Ciocco A, ElAttar AA [1968]. An epidemiological approach to the rubber industry. J Occup Med *10*(5):213232.

McGlothlin J and Wilcox T [1984]. Health hazard evaluation report: Kelly Springfield Tire Company, Cumberland, MD. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 791091538.

McMichael AJ, Spirtas R, Kupper LL [1974]. An epidemiologic study of mortality within a cohort of rubber workers, 196472. J Occup Med *16*(7):458464.

McMichael AJ, Spirtas R, Kupper LL, Gamble JF [1975]. Solvent exposure and leukemia among rubber workers: an epidemiologic study. J Occup Med *17*(4):234239.

McMichael AJ, Andjelkovic DA, Tyroler HA [1976a]. Cancer mortality among rubber workers: an epidemiologic study. Ann NY Acad Sci *271*:125137.

McMichael AJ, Gerber WS, Gamble JF, Lednar WM [1976b]. Chronic respiratory symptoms and job type within the rubber industry. J Occup Med *18*(9):611617.

McMichael AJ, Spirtas R, Gamble JF, Tousey PM [1976c]. Mortality among rubber workers: relationship to specific jobs. J Occup Med *18*(3):178185.

Monson RR, Fine LJ [1978]. Cancer mortality and morbidity among rubber workers. JNCI *61*(4):10471053.

Monson RR, Nakano KK [1976]. Mortality among rubber workers. I. White male union employees in Akron, Ohio. Am J Epidemiol *103*(3):284296.

Negri E, Piolatto G, Pira E, Decarli A, Kaldor J, La Vecchia C [1989]. Cancer mortality in a northern Italian cohort of rubber workers. Br J Ind Med *46*:624628.

NIOSH [1983a]. NIOSH technical report: Nnitroso compounds in the factory environment. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Contract No. 210770100, DHHS (NIOSH) Publication No. 83114.

NIOSH [1983b]. National occupational exposure survey (NOES), 198183: estimated total and female employees, actual observation and tradenamed exposure in rubber products SIC codes. Cincinnati OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Division of Surveillance, Hazard Evaluations, and Field Studies, Surveillance Branch, Hazard Section. Unpublished data base; provisional data as of 7/1/90.

NIOSH [1984]. Research report: Control of air contaminants in tire manufacturing. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 84111.

NIOSH [1989]. Hazard evaluation and technical assistance report: Goodyear Tire and Rubber Company, Niagara Falls, NY. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, Interim Report No. 1, NIOSH Report No. HETA88159.

NIOSH [1990]. NIOSH Alert: request for assistance in preventing bladder cancer from exposure to otoluidine and aniline. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 90116.

NTP [1992]. NTP results report, October 13, 1990. Results and status information on all NTP chemicals produced from NTP chemtrack system. Research Triangle Park, NC: National Toxicology Program, pp. 1188.

O'Malley MA, Mathias CGT [1986]. Health hazard evaluation report: Robbins & Myers, Inc., Moyno Products Division, Springfield, OH. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 860181758.

O'Malley MA, Mathias CGT, Priddy M, Molina D, Grote AA, Halperin WE [1988]. Occupational vitiligo due to unsuspected presence of phenolic antioxidant byproducts in commercial bulk rubber. J Occup Med *30*(6):512516.

OSHA [1980]. Cancer in the rubber industry: the risks and what you can do about them. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, Publication No. OSHA 3068.

OSHA [1990]. National sampling activity by SIC: OHR (OSHA health report) 1.2N for the period between 1/1/82 to 6/30/90 for rubber products SIC codes 3011, 3021, 3052, and 3069. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration. Unpublished data.

Parkes HG, Veys CA, Waterhouse JAH, Peters A [1982]. Cancer mortality in the British rubber industry. Br J Ind Med *39*:209220.

Rosenberg MJ, Feldblum PJ, Marshall EG [1987]. Occupational influences on reproduction: a review of recent literature. J Occup Med *29*(7):584591.

Ruhe RL, Lucas JB, Flesch JP [1975]. Health hazard evaluation determination report: Goodyear Tire & Rubber Company, St. Mary's, OH. Cincinnati, OH: U.S. Department of Health, Education, and Welfare, Public Health Service, Center for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. 73156205.

Sorahan T, Parkes HG, Veys CA, Waterhouse JAH [1986]. Cancer mortality in the British rubber industry: 194680. Br J Ind Med *43*:363373.

Sorahan T, Parkes HG, Veys CA, Waterhouse JAH, Straughan JK, Nutt A [1989]. Mortality in the British rubber industry 194685. Br J Ind Med *46*:111.

Stewart PA, Rice C [1990]. A source of exposure data for occupational epidemiology studies. Appl Occup Environ Hyg *5*(6):359363.

Suskind RR [1982]. Report: Dermatitis Research Program, Goodyear Tire and Rubber Company Plant, Gadsden, AL. Cincinnati, OH: University of Cincinnati, Department of Environmental Health, College of Medicine.

Susten AS, Dames BL, Burg JR, Niemeier RW [1985]. Percutaneous penetration of benzene in hairless mice: an estimate of dermal absorption during tirebuilding operations. Am J Ind Med *7*(4):323335.

Taylor JS [1986]. Rubber. In: Fisher AA, ed. Contact dermatitis. 3rd ed. Philadelphia, PA: Lea & Febiger, pp. 603643.

Tyroler HA, Andjelkovic D, Harris R, Lednar W, McMichael A, Symons M [1976]. Chronic diseases in the rubber industry. Environ Health Perspect *17*:1320.

U.S. Department of Commerce [1987]. County business patterns 1985United States, CBP851. Washington, DC: U.S. Department of Commerce, Bureau of the Census, p. vii.

U.S. Department of Commerce [1990]. 1987 Census of manufactures: industry series; rubber products, MC87I30A. Washington, DC: U.S. Department of Commerce, Bureau of the Census, p. 30A6.

U.S. Department of Commerce [1991]. 1989 Annual survey of manufactures: statistics for industry groups and industries, M89(AS1). Washington, DC: U.S. Department of Commerce, Bureau of the Census, pp. 118, 119.

Varigos GA, Dunt DR [1981]. Occupational dermatitis. An epidemiological study in the rubber and cement industries. Contact Dermatitis *7*:105110.

Ward E, Carpenter A, Markowitz S, Roberts D, Halperin W [1991]. Excess number of bladder cancers in workers exposed to orthotoluidine and aniline. J Natl Cancer Inst *83*(7):501506.

Weeks JL, Peters JM, Monson RR [1981a]. Screening for occupational health hazards in the rubber industry. Part I. Am J Ind Med *2*:125141.

Weeks JL, Peters JM, Monson RR [1981b]. Screening for occupational health hazards in the rubber industry. Part II: health hazards in the curing department. Am J Ind Med *2*:143151.

Wilcosky TC, Checkoway H, Marshall EG, Tyroler HA [1984]. Cancer mortality and solvent exposures in the rubber industry. Am Ind Hyg Assoc J *45*(12):809811.

Williams TM, Hickey JLS, Bishop CC [1984]. Health hazard evaluation report:Goodyear Tire and Rubber Company, Gadsden, AL. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control, National Institute for Occupational Safety and Health, NIOSH Report No. HETA 831961492.

Wolf PH, Andjelkovich D, Smith A, Tyroler H [1981]. A casecontrol study of leukemia in the U.S. rubber industry. J Occup Med *23*(2):103108.

Zhang ZF, Yu SZ, Li WX, Choi BCK [1989]. Smoking, occupational exposure to rubber, and lung cancer. Br J Ind Med *46*:1215.

Zina AM, Bedello PG, Cane D, Bundino S, Benedetto A [1987]. Dermatitis in a rubber tyre factory. Contact Dermatitis *17*(1):1720.

Acknowledgements

This document was prepared by the staff of the Division of Standards Development and Technology Transfer (DSDTT), Richard W. Niemeier, Ph.D., Director. Faye L. Rice developed the document. The contributions of other National Institute for Occupational Safety and Health (NIOSH) personnel are gratefully acknowledged: Vernon Anderson, Ph.D.; Philip Bierbaum; Nancy Bollinger; Carol Burnett; Gangadhar Choudhary, Ph.D.; Joseph Cocalis; Gayle DeBord, Ph.D.; Derek Dunn, Ph.D.; John Fajen; Jerome Flesch; Kent Hatfield, Ph.D.; David Hard, Ph.D.; Bryan Hardin, Ph.D.; William Heitbrink, Ph.D.; Suzanne Kisner; Lynn Jenkins; Robert Larkin; Deanna Letts; Howard Ludwig; Robert Mason, Ph.D.; Lawrence Mazzuckelli; William Perry; Robert Roscoe; Steve Schrader, Ph.D.; Teresa Seitz; Joseph Seta; Martha Seymour; Leslie Stayner, Ph.D.; David Votaw; Joann Wess; John Whalen; Ralph Zumwalde.

Ruth Grubbs and Anne C. Hamilton performed editorial review and coordinated production; Vanessa Becks and Susan Kaelin provided editorial assistance and produced cameraready copy; and Pamela S. Graydon formatted and typed the draft.

The author would also like to thank Margo Nelson of the Occupational Safety and Health Administration (OSHA) for providing data for this review.

Disclaimer

Page last reviewed: June 6, 2014
Page last updated: June 6, 2014
Content source: National Institute for Occupational Safety and Health Education and Information Division

Centers for Disease Control and Prevention 1600 Clifton Rd. Atlanta, GA 30329-4027, USA
800-CDC-INFO (800-232-4636) TTY: (888) 232-6348 - Contact CDC-INFO