Report to Congress on Workers' Home Contamination Study Conducted Under The Workers' Family Protection Act (29 U.S.C. 671a)

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FOREWORD

In 1992, the U.S. Congress passed the Workers' Family Protection Act (Public Law 102-522, 29 U.S.C. 671), which requested that the CDC's National Institute for Occupational Safety and Health (NIOSH) conduct a study to "evaluate the potential for, prevalence of, and issues related to the contamination of workers' homes with hazardous chemicals and substances...transported from the workplaces of such workers." With this request, Congress identified a compelling public health issue, bridging health concerns in the workplace and the home. NIOSH found that contamination of workers' homes is a worldwide problem, with incidents reported from 28 countries and from 36 States in the United States. Such incidents have resulted in a wide range of diseases and, in some cases, death among workers' families.

This report represents an important step in addressing the concerns outlined in the Act. It puts us on the road to preventing the exposure of families to potentially harmful substances unknowingly brought home from the job. It also serves as a reminder of the importance of occupational safety and health research to CDC's overall mission of promoting health and quality of life by preventing and controlling disease, injury, and disability.

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PREFACE

The legislative directive (Public Law 102-522, Section 209, the Workers' Family Protection Act, [29 U.S.C. § 671a]) to conduct this study of contamination of workers' homes by substances carried home on workers' clothing or bodies was enacted on October 26, 1992. However, this is not a new problem. Holt [1923] cited two early studies of lead-workers' families that were published in 1860 and 1896. Oliver [1914] reported on lead poisoning in wives of house painters who washed their husbands' overalls, observations that resulted in a series of laws in Great Britain to protect the workers' families from lead poisoning. Lead poisoning continues to be a problem; this report cites about 65 incidents of lead poisoning among workers' families. Of these, 35 are from the United States, 24 of which were reported in the last 10 years.

Lehmann [1905] reported that the mother and child of a worker exposed to chlorinated hydrocarbons developed chloracne (a condition similar to acne caused by certain chlorinated chemicals) ascribed to the worker's contaminated clothing. Lehmann also wrote of a laundress who developed chloracne as a result of washing the contaminated clothing of workers. Thirty years after Lehmann's report was published in Germany, a similar case was reported by Fulton and Matthews [1936] from the Pennsylvania Department of Labor and Industry. In this case a child's father who was exposed to hexachloronaphthalene and chlorodiphenyl wore his soiled clothing home from work. Additional cases of workers' homes being contaminated with chlorinated hydrocarbons have been reported in the last 10 years.

Prior to 1960, beryllium, toxaphene, mercury vapors, and diethylstilbestrol were also identified as hazards to the families of workers. In the last 10 years, 10 additional chemical substances have been identified in incidents of workers' home contamination, as well as allergens, radioactive materials, and infectious agents.

This report to Congress and the Workers' Family Protection Task Force summarizes the incidents of home contamination this study has discovered, including the health consequences, the sources, and the levels of contamination. The report contains information on the effectiveness of preventive measures and of decontamination procedures that have been used or studied. The report summarizes the relevant laws and regulations and responses of Federal and State agencies and industry to incidents of workers' home contamination.

The report should be useful not only to Congress and the Workers' Family Protection Task Force in deciding future actions, but also to all who have responsibilities and concern for protecting workers and their families from preventable illnesses.

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EXECUTIVE SUMMARY

The Workers' Family Protection Act of 1992 (Public Law 102-522, 29 U.S.C. § 671a) directed the National Institute for Occupational Safety and Health (NIOSH) to conduct a study of contamination of workers' homes with hazardous chemicals and substances (including infectious agents) transported from the workplace. NIOSH found that contamination of workers' homes is a worldwide problem; incidents have been reported from 28 countries and from 36 States in the United States. Such incidents have resulted in a wide range of health effects and death among workers' families exposed to toxic substances and infectious agents. About half of the reports of health effects have appeared in the last 10 years, revealing new sources of contamination.

In completing the study, NIOSH solicited information from Federal and State health, labor, and environmental agencies, groups with special circumstances such as firefighters, and the public. NIOSH then reviewed and compiled the information received along with information in published reports on contamination of workers' homes by substances brought home from the workplace. The report includes a survey of reported health effects, information on sources and levels of contamination, preventive measures, decontamination procedures, a review of Federal and State laws, and responses of agencies and industry to incidents involving contamination of workers' homes. This report is being considered by the Workers' Family Protection Task Force, which is charged under the Workers' Family Protection Act with evaluating the need for additional research.

Health Effects of Workers' Home Contamination

Workers can inadvertently carry hazardous materials home from work on their clothes, skin, hair, tools, and in their vehicles. As a result, families of these workers have been exposed to hazardous substances and have developed various health effects. Health effects have also occurred when the home and the workplace are not distinct--such as on farms or in homes that involve cottage industries. For some contaminants, there are other potential sources of home contamination such as air and water pollution and deteriorating lead paint in the home. Only a few of the studies found in the literature used epidemiologic methods to estimate the relative risks of health effects from the contaminant transported home by the worker independent of health risks due to other sources of the contaminant in the home.

Little is known of the full range of health effects or the extent to which they occur as a result of workers' home contamination. There are no information systems to enable tracking of illnesses and health conditions resulting from these circumstances. Many of the health effects among workers' family members described below were recognized because of their uniqueness their clear relationship to workplace contaminants, or their serious nature.

- **Chronic beryllium disease**
  This potentially fatal lung disease has occurred in families of workers exposed to beryllium in the nuclear and aviation industries and workplaces involved in the production of beryllium and fluorescent lights and gyroscopes.

- **Asbestosis and mesothelioma**
  Fatal lung diseases have occurred among family members of workers engaged in the manufacture of many products containing asbestos, including thermal insulation materials, asbestos cement, automobile mufflers, shingles, textiles, gas masks, floor tiles, boilers, ovens, and brakeshoes and other friction products for automobiles. Families have also been exposed to asbestos when workers were engaged in mining, shipbuilding, insulating (e.g., pipe laggers and railway workers), maintenance and repair of boilers and vehicles, and asbestos removal operations.

- **Lead poisoning, neurological effects, and mental retardation**
  These health effects have occurred in children of workers engaged in mining, smelting, construction, manufacturing (pottery, ceramics, stained glass, ceramic tiles, electrical components, bullets, and lead batteries), repair and reclamation of lead batteries, repair of radiators, recovery of gold and silver, work on firing ranges, and welding, painting, and splicing of cables.

- **Deaths and neurological effects from pesticides**
  Farm families and families of other workers exposed to pesticides have suffered these serious effects.

- **Chemical burns from caustic substances**
  Chemical burns of the mouth and esophagus and fatalities from ingesting caustic substances have occurred in farm families when hazardous substances were improperly used and stored on farms.

- **Chloracne and other effects from chlorinated hydrocarbons**
  Family members have been exposed when these substances were transported home on clothing of workers manufacturing or using these compounds in the production of insulated wire, plastic products, ion exchange resins, and textiles. Family members have been similarly exposed when workers' clothes became contaminated during marine electrical work, transformer maintenance, municipal sewage treatment, rail transportation, wood treatment, and application of herbicides.

- **Neurological effects from mercury**
  Family members have developed various neurological effects as a result of being exposed to mercury carried home on clothing of workers engaged in mining, thermometer manufacture, and cottage-industry gold extraction.

- **Abnormal development from estrogenic substances**
  Enlarged breasts have occurred in boys and girls and premature menstruation has occurred in girls from estrogenic substances brought home on contaminated clothing of pharmaceutical and farm workers.

- **Asthmatic and allergic reactions from dusts**
  Farm families and others have suffered asthmatic and other allergic effects from animal allergens, mushrooms, grain dust, and platinum salts.

- **Liver angiosarcoma from arsenic**
  Families of workers engaged in mining, smelting, and wood treatment have been exposed to arsenic from contaminated skin and clothing; one child developed liver angiosarcoma.

- **Dermatitis from fibrous glass**
  Family members have developed dermatitis when their clothing was contaminated with fibrous glass during laundering of insulation workers' clothing.

- **Status epilepticus from chemical exposure**
  A child experienced epileptic seizures following ingestion of an explosive compound brought home on the clothing of a worker engaged in the manufacture of explosives.

- **Diseases from infectious agents**
  Family members have contracted infectious diseases such as scabies and Q fever from agents brought home on contaminated clothing and skin of workers engaged in agriculture, hospital, and laboratory work. As intended by Congress, infectious agents are included as hazardous substances to the extent that pathogens can be transported on a worker's person or clothing.

Measures for Preventing Home Contamination

Preventive measures that were found to be effective when used in the workplace include:

- Reducing exposures in the workplace;
- Changing clothes before going home and leaving the soiled clothing at work to be laundered by the employer;
- Storing street clothes in separate areas of the workplace to prevent their contamination;
- Showering before leaving work; and
- Prohibiting removal of toxic substances or contaminated items from the workplace.

Preventive measures that have been used successfully at home include:

- Separating work areas of cottage industries from living areas;
- Properly storing and disposing of toxic substances on farms and in cottage industries;

- Preventing family members from visiting the workplace;
- Laundering contaminated clothing separately from family laundry when it is necessary to launder contaminated clothing at home; and
- Informing workers of the risk to family members and of preventive measures.

Other preventive measures that need to be used include:

- Educating physicians and other health professionals to inquire about potential work-related causes of disease;
- Developing surveillance programs to track health effects that could be related to home contamination; and
- Educating children, parents, and teachers about the effects of toxic substances.

Procedures for Decontaminating Homes and Clothing

Decontamination procedures include air showers, laundering, airing, vacuuming and other methods of surface cleaning, and destruction and disposal of contaminated items. These procedures appear to have widely varying effectiveness, depending on the specific methods employed, the contaminants, and the surfaces. In general, hard surfaces can be far more easily decontaminated than clothes, carpets, and soft furniture. In most cases effective decontamination requires relatively intensive methods. Normal house cleaning and laundry practices appear to be inadequate for decontaminating workers' clothes and homes. Lead, asbestos, pesticides, and beryllium contamination can be especially persistent. In some instances even intensive decontamination procedures may be ineffective.

Another serious concern is that decontamination methods can increase the hazard to the person performing the operation and to others in the household. Home laundering of contaminated clothing exposes the launderer. Vacuuming of floors contaminated with mercury can substantially increase air concentrations, and vacuuming of carpets contaminated with lead can increase lead concentrations on the carpet surface.

The difficulty of decontaminating work clothing, the prominence of clothing as a source of home contamination, and the potential exposure of the launderer are problems that can be avoided through the use of disposable work clothing. The use, availability, and cost of this alternative need to be assessed.

Federal and State Laws

Seven statutes provide Federal agencies with some mechanisms for responding to or preventing workers' home contamination. Twenty rules or standards in the Code of Federal Regulations (CFR) address workers' home contamination or have elements that serve to protect workers' families.

Under the Occupational Safety and Health Act of 1970 (Public Law 91-596), NIOSH research assessing the health of workers has also addressed the exposure of their families to workplace contaminants, resulting in recommendations to prevent home contamination. The Occupational Safety and Health Administration (OSHA) regulations and actions intended to protect workers also help assure that families are protected. In addition, OSHA can promulgate standards to protect workers' family members when workers are required to live in housing provided by the employer as a condition of employment. Under the Federal Mine Safety and Health Act of 1977 (Public Law 95-164), the Mine Safety and Health Administration (MSHA) has limited regulatory authority to address issues of workers' home contamination.

The U.S. Environmental Protection Agency (EPA) has broad authority under the Toxic Substances Control Act (Public Law 94-469) to regulate chemicals and to obtain information about the adverse effects of chemicals. In addition, EPA has specific authority and responsibility regarding the use of asbestos and lead. Under the Federal Insecticide, Fungicide, and Rodenticide Act (Public Law 92-516), EPA also regulates the use and disposal of pesticides (which also helps to protect workers' families). EPA and the Agency for Toxic Substances and Disease Registry (ATSDR) are authorized under the Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499) to address hazardous waste and releases of hazardous substances that may relate to identifying contamination of workers' homes and assuring decontamination.

Thirty States and Puerto Rico responded to the requests from NIOSH for information about State laws. Most indicated that there were no laws specific to workers' home contamination or protection of workers' family members. Some States identified laws requiring the reporting of cases of elevated blood lead levels and pesticide poisonings to a State agency; other States identified laws related to work at hazardous waste sites and emergency responses to releases of hazardous substances. An examination of occupational safety and health regulations of States with OSHA-approved occupational safety and health programs revealed none more stringent than Federal OSHA regulations - with respect to the protection of workers' families. However, extension of occupational safety and health regulations to State and local government employees in these States also helps protect the families of public employees' in these States.

Responses to Incidents of Workers' Home Contamination

Several Federal agencies have responded to incidents of workers' home contamination, often working together with State or local government agencies. These responses have resulted in identification of workers' home contamination, decontamination of workers' homes, and recommendations for instituting workplace changes that would prevent further contamination. NIOSH has conducted approximately 40 health hazard evaluations that address potential home contamination. In several cases, Federal agencies have referred incidents to State or local health departments for follow-up actions.

State agencies have investigated incidents of workers' home contamination, made referrals to Federal agencies for follow-up actions, and recommended workplace improvements to prevent further contamination of workers' homes.

Responses to incidents of workers' home contamination include educational materials such as those of the Lead Industries Association, Inc. on preventing workers' home contamination as well as responses of various employers to specific incidents of home contamination.

Limitations of the Report

The health information available for the report, which includes incidents of illness and home contamination obtained from public agencies and published literature, does not provide a basis for estimating the prevalence of this public health problem.

The Workers' Family Protection Act requires NIOSH to evaluate relevant information about indoor air quality as it relates to workers' home contamination and to study the special circumstances of firefighters as they relate to contamination of their homes.

- The only report found on indoor air quality applicable to workers' family protection involved tetrachloroethylene exposures in living quarters located in the same building as dry-cleaning establishments. Indoor air quality studies would be useful to protect family members in cottage industries.

- Incidents of contamination of firefighters' homes were not identified. However, NIOSH has conducted several studies of contamination and decontamination of protective clothing used by firefighters. These studies are reviewed in this report and NIOSH will continue to pursue the issues related to potential contamination of firefighters' homes.

Other limitations of the report include:

- Little research has documented the frequency and distribution of health effects among the families of workers in various industries and occupations. NIOSH is undertaking one study addressing lead exposure among families of bridge repair workers.

- Lead and pesticides are the only contaminants for which monitoring or reporting programs help to identify and prevent cases of poisoning from workers' home contamination.

- Despite various case reports, the prevalence of health effects from workers' home contamination is not known because there are no surveillance systems in place for tracking or monitoring such health conditions.

- Many diseases have long latency periods between exposure and manifestation of the disease, making identification and intervention difficult.

- The workplace origin of many common diseases that occur in workers' families (such as asthma, dermatitis, and infectious diseases) is probably unrecognized because physicians and other health professionals fail to inquire about the occupation of family members and to consider whether these diseases are work-related.

- The literature reviewed in this report contained only nominal information about contamination levels in workers' homes. Most measurements were of surface dust, for which there are no guidelines for acceptable levels of contamination.

Recommendations for Research and Education

- The prevalence of health effects of contaminants transported from the workplace should be determined. One possible approach would be to conduct surveys among occupational and environmental medicine health care providers and clinics.

- The employment practices and controls that work best in preventing the transport of contaminants from the workplace to the home should be identified.

- Educational programs to prevent home contamination should be developed for employers, workers, children, teachers, and parents, physicians, and other health professionals.

- The special needs and problems of individuals who work in home or cottage industries need to be identified.

Conclusions

- Workers' home contamination may pose a serious public health problem. Health effects and deaths from contaminants brought home from the workplace have been reported in 28 countries and 36 States.

- The extent to which these health effects occur is not known because there are no information systems to track them, and physicians do not always recognize the occupational contribution to various common diseases.

- About half of the reports of health effects from home contamination are less than 10 years old. The literature on the health effects involved approximately 30 different substances or agents. The potential exists for many of the thousands of other chemicals used in commerce to be transported to workers' homes or to be used in home-centered businesses.

- Health effects and deaths from contaminants brought home from the workplace are preventable using known effective measures. Educational programs are needed to promote their use.

- Normal house cleaning and laundry practices are often inadequate for decontaminating workers' homes and clothing and can increase the hazard to the person performing the tasks and others in the household.

- Only two Federal laws have elements that directly address workers' home contamination. However, other laws provide agencies with certain mechanisms for responding to, or preventing workers' home contamination. Operating under existing laws OSHA, MSHA, DOE, ATSDR, EPA, and CDC, including NIOSH and the National Center for Environmental Health have responded to incidents of workers' home contamination, made recommendations to prevent such incidents, and conducted relevant research.

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[1957] reported on five persons with beryllium disease who had exposure to clothing of beryllium extraction workers.

Other authors [DeNardi et al. 1949; Sussman et al. 1959; Eisenbud and Lisson 1983] discuss varying numbers of contact (household) cases. The cases discussed by these authors are likely included in the Beryllium Case Registry, but it is difficult to be certain of this because detailed descriptions are not always given.

According to the literature review, there were no more contact (household) cases added to the registry after Hardy et al. [1967] until the article by Newman and Kreiss [1992] who reported on a 56-year-old woman with chronic beryllium disease who had first been diagnosed with sarcoidosis. When it was determined that her husband was a beryllium worker, she was evaluated for beryllium disease. The clinical picture was compatible with beryllium disease and her blood test showed beryllium sensitization.

Because of the long period of time between the prior contact cases and this case, a review of her exposures to beryllium is useful. She was a non-smoker who had always lived in Ohio. She was self-employed and had sold cosmetics, done babysitting, brought up her children, and from 1973 until the time of the article, had done stockroom work for a retailer. Her husband had worked from 1959 to the current time at a beryllium production plant, with daily exposure to beryllium. When working directly with beryllium, he always changed clothing after work, showered before leaving for home, and did not bring his work clothing home. The family had always lived at least 28 miles from his work. She sought medical attention for this illness in November 1988. Her exposures consisted of the following:

- She took a tour of the plant in the 1960's;
- She took another tour in the 1970's at a time when it was not operating;
- During some months in 1976, her husband was an advisor to a new ceramics plant, where he did not do hands-on work and wore street clothes, which his wife cleaned on several occasions. Thus although beryllium was used at the plant, clothes worn to work were not left at work;
- A hydrogen furnace containing beryllium oxide exploded in her husband's face in February 1979. He was sent to the emergency room in his contaminated work clothes. When he was discharged from the emergency room, she was given the contaminated clothes which she put in a plastic bag at home before returning them to the plant guardhouse. Over the next several months, she scrubbed her husband's face several times daily with a motorized rotating brush to remove embedded metallic debris; and
- The husband injured his ankle while at work in September 1987. When she picked him up at the hospital, he was still wearing work clothes. He rode home in her car and she placed the dusty clothes in a plastic bag.

This case illustrates the need for vigilant application of industrial hygiene controls for beryllium even when exposures do not seem high or consistent. Moreover, it is possible that household and community cases of beryllium disease may still be occurring but are unrecognized or misdiagnosed as in this case.

ASBESTOS

Overview

Based on the studies reviewed in this section, families of asbestos-exposed workers have been at increased risk of pleural, pericardial, or peritoneal mesothelioma, lung cancer, cancer of the gastrointestinal tract, and non-malignant pleural and parenchymal abnormalities as well as asbestosis. Four cohort studies (Table 2), one community study (Table 3), seven case-control studies (Table 4), numerous case reports (Table 5) and case series (Table 6) provide evidence of these adverse effects in family members of asbestos workers.

The occupations associated with asbestos-related disease in family members are those where workers were exposed to asbestos dust during: construction and renovation; prospecting and mining; manufacturing textiles, tiles, boilers, and ovens; shipbuilding and associated trades; certain railroad shop trades; welding; insulation; use and manufacture of asbestos products such as cords, seals, and plates; and renovation and demolition projects within the construction industry.

Although many past uses of asbestos have been abandoned, and asbestos uses and occupational exposures are now subjected to regulation, potential exposures of family members in the United States may still exist, especially in the construction industry [Sullivan et al. 1995].

Background

Asbestos is a generic term for a number of silicate minerals with a fibrous crystalline structure. The asbestiform varieties of silicate minerals can be found in both the amphibole and serpentine mineral groups, in veins or small veinlets within rock containing or composed of the common (non-asbestiform) variety of the same mineral. The major asbestiform varieties of minerals used commercially are chrysotile, tremolite-actinolite asbestos, cummingtonite-grunerite asbestos, anthophyllite asbestos, and crocidolite. Asbestos is marketed by its mineral name (e.g., anthophyllite asbestos), its variety name (e.g., chrysotile, crocidolite), or its trade name (e.g., Amosite).

Mesothelioma is a tumor arising from the pleural, pericardial, and peritoneal membranes. When it occurs in asbestos workers' household contacts, it is a sentinel event for exposure to asbestos from home contamination [Gardner and Saracci 1989]. Lung cancer is a malignant tumor of the lung. Cancer of the gastrointestinal tract is a malignant tumor of any part of the gastrointestinal tract including the mouth, pharynx, esophagus, stomach, small intestine, pancreas, colon, rectum, and anus. Asbestosis is a fibrotic disease of the lungs caused by asbestos fibers which results in reduced lung volumes and difficulty in breathing. Pleural and hyaline plaques are localized thickenings which may be evident on radiographs 20 or more years after exposure. Pleural and hyaline plaques generally occur without symptoms but do provide a clinical marker of asbestos exposure.

Mesothelioma has occurred following short term asbestos exposures of only a few weeks, and can result from very low levels of exposure. There may be a latency period of 40 years or longer between exposure and clinical disease. Symptoms include chest pain, shortness of breath, and weight loss. Analysis of tissue obtained by biopsy (or at autopsy) is required for a definitive diagnosis [Dement et al. 1986]. Treatment is ineffective, with rapid disease progression and death [Lilis 1986].

Lung cancer may be associated with a range of symptoms including cough, shortness of breath, bloody sputum, and weight loss. Definitive diagnosis is made by tissue biopsy. Metastasis is common, and may present as bone pain or fracture, seizure, or various other syndromes. Progression of lung cancer is generally rapid, and treatments (including surgery, chemotherapy, and radiation) are unlikely to result in long term survival [Hodous and Melius 1986]. Although increased risk of lung cancer among household contacts of asbestos workers has been observed, the high prevalence of cigarette smoking among lung cancer cases frequently makes it difficult to detect cases which may be caused by exposure to asbestos resulting from workers' inadvertent contamination of the home.

Review of Studies

Information on exposure of family members has been elicited by questioning patients or relatives about the practice of bringing work clothes home and laundering the asbestos contaminated clothing at home. Other identified sources of exposure of workers' family members to asbestos include taking contaminate items home from work and using asbestos in cottage industries [Magee et al. 1986; Bittersohl and Ose 1971]. Additional evidence that exposures occurred in the homes of asbestos workers is the finding of asbestos in lungs of asbestos workers' family members who had no known exposures, other than contact with an exposed worker [Whitwell et al. 1977; Ashcroft and Heppleston 1970; Huncharek et al. 1989; Gibbs et al. 1989, 1990; Giarelli et al. 1992].

Most cases of asbestos disease among workers' family members occurred in households where information indicated that asbestos-contaminated work clothing was brought into the home and women were exposed during home laundering of the contaminated work clothing [Ashcroft and Heppleston 1970; Dalquen et al. 1970; Edge and Choudhury 1978; Lander and Viskum 1985; Konetzke et al. 1990]. Children were exposed by playing in areas where asbestos-contaminated shoes and work clothes were located, or where products containing asbestos were used or stored. It is of interest to note that male children of asbestos workers appear to

CHAPTER 2. SOURCES OF WORKERS' HOME CONTAMINATION

CHAPTER SUMMARY

Sources of contamination of workers homes and poisonings of workers' family members reviewed in this chapter include: work clothing; the worker's body; tools and equipment; taking items home from work (such as scrap material); cottage industries (where work is done in or adjacent to the home); farms; and visiting a family member's workplace.

Clothing contamination was documented in 18 reports: 1 on beryllium; 7 on lead; 7 on pesticides; and 1 each on PCB's, an estrogenic substance (zeranol), and 3,4-benzo(a)pyrene. For lead, measurements of both clothing and home contamination were included in some studies. However, these were inadequate for establishing a quantitative relationship between the two. Other evidence of clothing as a source of home contamination includes: high levels of contamination in areas of homes where soiled clothing is stored and laundered (lead, mercury); contamination of washing machines (mercury) or dryers (3,3'-dichlorbenzidine, MOCA); and poisoning of launderers (beryllium, asbestos, lead, kepone).

The workers' body has been considered as a source of home contamination, and showering before leaving work has often been recommended as a preventive measure. However, reports have only documented contamination of workers' hands.

Hand tools and other equipment have been found to contribute to home and vehicle contamination by mercury and pesticides. The potential for contamination of homes by tools was also demonstrated for PCB's and radioactive substances.

Items taken home from work (beryllium-ore bags, cotton shipping-bags for asbestos, cloths from discarded filters, metal drums, contaminated milk, and radioactive scrap lumber) have resulted in serious, and sometimes fatal, poisonings of workers' family members.

Cottage industries, where work is undertaken in the same building or on the property where the family resides have been recognized as a hazard to family members since at least 1914. Cottage industries are the subject of 22 reports of home contamination or family poisonings from asbestos, lead, parathion, and mercury which are reviewed in this chapter. The levels of contamination were often extremely high and the poisonings were severe.

Farms are similar to cottage industries in that families live on the property where work is performed. Three types of products used on farms: pesticides; caustic substances; and estrogenic substances have resulted in several cases of poisoning of family members.

Visiting the workplace of a family member has been shown to be a hazard for families of dry cleaners and veterinarians.

CONTAMINATED CLOTHING

Overview

This section reviews reports that provide evidence for clothing worn, or otherwise taken home from work, as a source of home contamination. The reports are summarized in Table 15. In the health effects studies reviewed in Chapter 1, home contamination and family exposures were often attributed to contaminated clothing brought home from the workplace. This attribution was based on: information elicited by questioning household members; descriptions of workplaces and work practices; and the practice of wearing and laundering work clothes at home. Clothing contamination was documented in 18 reports reviewed below: 1 on beryllium; 7 on lead; 7 on pesticides; 1 on chlorinated hydrocarbons (PCBs); 1 on an estrogenic substance (zeranol); and 1 on 3,4-benzo(a)pyrene. Only for lead were measurements of both clothing contamination and home contamination included in the same studies; these few studies are inadequate for establishing any quantitative relationship between clothing contamination and home contamination.

Other evidence of clothing as a source of home contamination includes: the findings discussed below of high levels of contamination in laundry areas of workers' homes and in areas where contaminated clothing is stored (lead, mercury); contamination of washing machines (mercury) or dryers (3, 3'-dichlorbenzidine, MOCA); and poisoning of home launderers (beryllium, asbestos, lead, kepone). Estimates of exposure levels that could have occurred during home laundering of beryllium and asbestos suggest that such exposures could have exceeded OSHA occupational exposure limits for these substances.

Beryllium

There were no reports of measurements of home contamination by beryllium, although the case histories and epidemiology studies generally assumed that cases of berylliosis in workers' family members were due to laundering contaminated clothing. In support of this assumption, the following studies on clothing contamination indicate that substantial amounts of beryllium dust could have been brought into the workers' homes by contaminated clothing.

Fabrics experimentally exposed at a beryllium production worksite contained beryllium up to 2.8 mg/m^2 [Bohne and Cohen 1985]. In a subsequent study Cohen and Positano [1986], found that work shirts contained from 12 to 37 mg/m^2 of beryllium. It is likely that inhalation exposures of workers' family members occurred during laundering of the contaminated clothing, since resuspended beryllium dust concentrations in air from unwashed shirts at up to 0.64 $\mu g/m^3$ were found. In an earlier laboratory study, Eisenbud et al. [1949] found beryllium concentrations in air at 125-1,200 $\mu g/m^3$ when soiled clothes were shaken and estimated an inhalation dose of 17 μg during a single home laundry. The OSHA permissible exposure limit (PEL) for beryllium is 2 $\mu g/m^3$ as an 8-hr. time-weighted average (TWA) with permissible excursions up to 25 $\mu g/m^3$ for up to 30 minutes (29 CFR[2] 1910.1000).

Asbestos

Several studies of asbestos workers' families inferred that asbestos-related diseases were due to home contamination emanating from clothes contaminated at work, especially due to laundering the clothes [Anderson et al. 1979a,b; Bianchi et al. 1987; Giarelli et al. 1992; Gibbs et al. 1990; Huncharek et al. 1989]. However, no studies evaluated the relationships between home contamination by asbestos, contamination of clothing brought home from work, and exposures during home laundering. The few studies reported and reviewed in this section indicate that clothing probably was a source of home contamination by asbestos and support the hypothesis that home laundering of asbestos contaminated clothing could be especially hazardous.

One study reported measurements of asbestos contamination in workers' homes; however no measurements of clothing as a source of the contamination were made [Nicholson et al. 1980].

Two studies of workplace clothing contamination by asbestos have been reported [Seixas and Ordin 1986; Driscoll and Elliott 1990]. Chrysotile asbestos was found in all clothing vacuumed as employees left work at a brake shoe manufacturing facility, but neither report provided quantitative data on asbestos recovered from the workers' clothing.

No studies of exposure during home laundering were found. However, a study on laundering clothing contaminated by an asbestos removal operation produced an average of 0.4 fibers/cm^3 while picking up clothing and loading the washer. A maximum of 1.2 fibers/cm^3 was found during the total laundry operation [Sawyer 1977]. Although the study was not conducted in a home laundry and measurements of the level of clothing contamination that generated these concentrations were not made, the study is consistent with the hypothesis that home laundering of asbestos-contaminated clothing is hazardous. Another important aspect of laundering asbestos contaminated clothing is that the fibers can transfer to uncontaminated clothing washed with the contaminated clothing, as was found by NIOSH [1971] in a study of dry cleaning a coat made with 8% asbestos fiber.

[2]Code of Federal Regulations. See CFR in references.

Asbestos

Asbestos-contaminated cotton cloth bags that had been used to transport molded asbestos insulation were taken home by a worker and used as diapers [Li et al. 1989]; three family members died of mesothelioma at an early age. It should be noted that dirty clothes were also brought home.

Lead

Lead-contaminated cloths from discarded pollution control filters at a lead smelter were taken home by workers for use at home [Carvalho et al. 1984]. The children of these lead workers had a mean BLL of 67.5 μg/dL. In another case, discarded lead battery casings were taken home for fuel by a worker engaged in recovering lead from used batteries [Dolcourt et al. 1981]. The battery casings were burned in the family's wood-burning stove. House dust contained up to 43,281 ppm of lead; one child had a BLL of 220 μg/100 mL and developed encephalopathy with seizures. Osorio [1994] reported that when lead contaminated telephone poles were taken home for fire wood by a worker, the soil in the yard of the worker's home where the poles were located contained lead at 1,500-1,600 μg/dL.

Pesticides

Toxaphene-contaminated metal brought home from a processing plant resulted in the death of 2-year-old boy [McGee et al. 1952]. The metal, which consisted of flattened strips made from drums that had contained toxaphene, was used to cover the walls of a tool shed on the day the child, who played in the area, was poisoned. In another case, a loaded company truck was parked in an employees driveway overnight [Barnett 1994]. Part of the load was chloropicrin which leaked from the vehicle, poisoning the next-door neighbors.

Estrogens

Diethylstilbestrol poisoning of family members was considered by Pacynski et al. [1971] to be due in part to women bringing home contaminated factory-supplied milk which was consumed by the children.

Radioactive Substances

Radioactive waste lumber was used to construct a garage at home by a worker engaged in the manufacture of catalysts containing depleted uranium. About 20 years later the garage was found to be contaminated in excess of NRC release criteria [Brockman 1993].

COTTAGE INDUSTRIES

Cottage industries, those where work is undertaken in the same building or on the property where the family resides have been recognized as a hazard since at least 1914 [Oliver 1914]. Poisonings by asbestos, lead, parathion, and mercury have occurred in cottage industries.

Asbestos

Asbestos sheets brought home from work were used in a cottage industry to repair burned out mufflers [Epler et al. 1980]. The asbestos sheets were stored in the basement where the children played and were also used to construct a tree house in which the children played. Both children developed asbestos related lung disease at about age 30. Asbestos cement was produced in the basement of another home for about 20 years [Otte et al. 1990]. The mother, father and one son died of mesothelioma some 40 years after the beginning of the exposures to asbestos.

Lead

In addition to the early report by Oliver [1914] of lead poisoning in family members of home pottery manufacture, 14 recent reports on cottage-industry home contamination and poisoning of family members by lead were found, 6 of them involved pottery.

In the report by Oliver [1914], lead at up to 10,000 ppm was found in dust of potters' homes where the pottery was dipped in lead glaze in the same room in which the family lived and slept; lead was also found in the clothes of a young boy and a baby. Koplan et al. [1977] reported on six home potters and their families in Barbados and found BLLs up to 71 $\mu g/mL$, and average concentrations of lead in dust for the six households of 2,333-88,159 ppm with a maximum value of 325,892 ppm. The State of Alabama [1992] reported finding lead at up to 177,000 $\mu g/ft^2$ in a home pottery workshop where children with elevated BLLs spent some time; elevated lead levels were also found on the kitchen floor of the family's dwelling.

Other studies of home pottery manufacture did not report levels of contamination, but did report elevated BLLs. BLLs up to 74 $\mu g/100$ mL were found for children of workers engaged in ceramics (plates, cups, vases, etc.) production at home in Italy [Abbritti et al. 1979]. Molina-Ballesteros et al. [1983] found BLLs up to 98 $\mu g/dL$ in children of potters working in their homes in Mexico; and in Japan, Katagiri et al. [1983] reported lead in urine of children of home pottery workers up to 79.3 $\mu g/L$ compared to 59.9 $\mu g/L$ in control children; 11.2% of children of home potters had lead in urine greater than 30 $\mu g/L$ vs. 2.7% of control children. More recently in the United States, Fischbein et al. [1992] reported finding a BLL of 48 $\mu g/dL$ in a child of a home potter in New York.

Manufacture, repair and recycling of lead batteries by cottage industries have also resulted in contamination of living areas and exposure of family members. Lead loadings up to 53,140 $\mu g/m^2$ were found in households of cottage industry battery repair shops in Jamaica [Matte and Burr 1989; Matte et al 1989]. Matte and Burr [1989] also found that playing in the area of the battery repair shops was an independent predictor of elevated BLLs in children. Other reports did not measure home contamination but reported lead poisoning or elevated BLLs.

CHAPTER 3. LEVELS OF CONTAMINATION IN HOMES AND CARS

CHAPTER SUMMARY

Measurements of contamination in workers' homes and cars were reported for asbestos, lead, pesticides, mercury, a few chlorinated hydrocarbons, arsenic, and fungi (Table 15). However, for the other substances reviewed as contaminants of workers' homes, data on levels of contamination have not been reported; this is true for beryllium, estrogenic substances, asthmatogens, cadmium, fibrous glass, and radioactive substances.

For asbestos, there are no studies of contaminated surfaces, but in one study of the air of workers' homes asbestos concentrations up to one-half of the current 8-hr. time-weighted average OSHA exposure limit for workers were found.

There are many studies of workers' home contamination by lead that document the substantial contamination that has occurred. Lead contamination of surfaces is measured either as concentration of lead in dust, expressed as ppm or as the amount of lead covering an area of surface, expressed as weight of lead per unit of area, and referred to as lead loading.

- When the concentration of lead in household dust was measured, average concentrations in workers' homes ranged from 1,600 ppm to 5,000 ppm with maximum values up to 84,000 ppm. In control homes, concentrations were usually less than 1,000 ppm.

- When lead contamination was measured as weight/unit area, workers' homes had lead loadings that were greater than 2,500 $\mu g/m^2$, ranging up to 109,000 $\mu g/m^2$. Control houses had lead loadings that were less than 1,000 $\mu g/m^2$.

- Lead loadings in workers' cars ranged from 1,000 to 300,000 $\mu g/m^2$. Control cars had lead loadings that were less than 1,000 $\mu g/m^2$.

While measurements of lead in control homes provide some basis for evaluating contamination of workers' homes, guidelines for critical levels of contamination are needed. A value of 500 ppm for the concentrations of lead in dust was used in one study as a threshold for cleaning homes. For lead loading after lead-based paint removal, 2,152 $\mu g/m^2$ has been used for floors as a practical, not health-based level. A level of 1,500 $\mu g/m^2$ has been stated as a level of concern for children's health.

In three studies of workers' homes contaminated with mercury, concentrations of mercury in air ranging from 0.02 $\mu g/m^3$ to 50 $\mu g/m^3$ were found. In one study of control homes, concentrations in air ranged from 0.01-1 $\mu g/m^3$. Mercury concentrations in contaminated automobiles were 8-60 $\mu g/m^3$. The MSHA

permissible occupational exposure limit for inorganic mercury vapor is 50 $\mu g/m^3$ as an 8-hr. time-weighted average (30 CFR 57.5001).

The few reported measurements of workers' home contamination by pesticides, chlorinated hydrocarbons, arsenic, and fungi also demonstrated high levels of contamination.

ASBESTOS

Only one report on measurements of asbestos contamination in workers' homes was found. Nicholson et al. [1980] reported that chrysotile asbestos in 13 air samples from homes of miners and millers in California and Newfoundland ranged from less than 50 to somewhere in the range of 2,000ng/m^3 to 5,000 ng/m^3 (1,000 ng/m^3 equates to about 0.01 fiber/cm^3 [Cossette 1984]). The OSHA maximum permissible concentrations for workplace exposures are 0.1 fiber/cm^3 as an 8-hr. average and 1.0 fiber/cm^3 as a 30-minute average (29 CFR 1910.1001; 1915.1001; 1926.1101).

LEAD

Most of the measurements of lead contamination in workers' homes and cars are of lead concentration in dust expressed as ppm (or the equivalent $\mu g/g$) or of lead loading on surfaces expressed as $\mu g/m^2$ or $\mu g/ft^2$ ($1\ \mu g/ft^2 = 10.76\ \mu g/m^2$). Similar units are used for expressing measurements of contamination of carpets, furniture, and cars.

Concentrations of Lead in Dust. Concentrations of lead in house dust of control homes were reported in several studies. Baker et al. [1977] found lead at an average of 404 ppm in control homes for a study of smelter workers in Tennessee, and Rice et al. [1978] found 1,240 ppm in control homes of secondary smelter workers. In control homes for a study of ceramic workers in Colorado, Kaye et al. [1987] found lead concentrations from non-detectable levels up to 320 ppm. For a study of electric cable splicers, Rinehart and Yanagiswa [1993] found 121-879 ppm, in control homes. Watson et al. [1978] found lead at an average of 718 ppm in housedust of control homes used for a study of battery manufacturing workers in Vermont. As a guideline for cleaning lead contaminated homes in Idaho, an action level of 500 ppm was used [CH,M Hill 1991].

By contrast to these control measurements, Baker et al. [1977] found an average concentration of lead in house dust of smelter workers of 2,687 ppm, Rice et al. [1978] found 3,310 ppm in homes of secondary lead smelter workers, Kaye et al. [1987] found lead up to 3,400 ppm in homes of the ceramics workers, Rinehart and Yanagiswa [1993] found lead up to 1,600 ppm in homes of electric cable splicers, and Watson et al. [1978] found an average of 2,239 ppm in homes of battery manufacturing workers.

High concentrations of lead in house dust were also found in other studies of smelter workers, cable workers, and battery manufacturing workers. Smelter workers'

CHAPTER 4. PREVENTIVE MEASURES

CHAPTER SUMMARY

Several measures that have been taken to prevent contamination of workers' homes and to protect workers' families are identified in the reports reviewed in this Chapter. The measures include:

- reducing exposures in the workplace;
- changing clothes before going home and leaving the soiled clothing at work to be laundered by the employer;
- storing street clothes in separate areas of the workplace to prevent their contamination;
- showering before leaving work;
- prohibiting taking toxic substances or contaminated items home;
- separating work areas from living areas of cottage industries;
- storing and disposing of toxic substances on farms and in cottage industries properly;
- preventing family members from visiting the workplace;
- laundering separately from family laundry when it is necessary to launder contaminated clothing at home; and
- informing workers of the risk to family members from home contamination and ways to prevent it.

The few studies evaluating these measures indicate that they can be effective in reducing or eliminating home contamination. There have also been instances in which home contamination has occurred when one or more of these measures has been omitted.

BERYLLIUM

Following reports of occupational and non-occupational (community and workers' families) cases of berylliosis, the beryllium industry instituted a number of preventive measures, including: engineering controls to reduce air-borne exposures of workers'; community air pollution controls; and measures to prevent exposure of family members to contaminated clothing [Eisenbud et al. 1949; Metzner and Lieben 1961]. In one plant, a double locker system was installed in 1955 which prevented removal of work clothes, underwear, socks and shoes from the facility [Lieben and Metzner

1959]. Until Newman and Kreiss [1992] reported on a case, there were no new cases of berylliosis in beryllium workers' families reported for more than 30 years. This recent case report demonstrates the dangers of any relaxation of preventive measures as the uses of beryllium, the number of workplaces where it exists, and the number of workers exposed expand.

ASBESTOS

Although poisoning of asbestos workers' families has been known since the report by Newhouse and Thompson [1965], and has been repeatedly associated with laundering contaminated clothing, no information exists on effectiveness of preventive measures. Belanger et al. [1979] recognized the hazard in evaluation of a factory where asbestos was used in the manufacture of floor coverings. They specifically recommended that work clothes not be taken home because this could expose others at home.

Seixas and Ordin [1986] and Driscoll and Elliott [1990] investigated plants manufacturing brake linings and made recommendations for providing protective clothing, keeping street clothes separate from work clothes, company laundering and showering before leaving work. The OSHA asbestos standards [29 CFR 1910.1001, 29 CFR 1915.1001, and 29 CFR 1926.1101] require these actions when employee exposures exceed 0.1 fiber/cm^3 averaged over 8 hrs. or 1.0 fiber/cm^3 averaged over 30 minutes. In the absence of information on clothing and personal contamination levels when workers are exposed to asbestos at concentrations below these limits, the adequacy of the OSHA standards for protecting workers' families cannot be judged.

LEAD

The report of an investigation of a stained glass window-making studio [Donovan 1994a,b], documented that the use of controls by the studio effectively prevented lead contamination of the worker's home that was adjacent to the studio. Preventive measures used at the studio included local exhaust ventilation during soldering, general dilution ventilation equipped with an electrostatic filter, adhesive mats at doorways to decrease the migration of lead dust on shoes, a laundry room located between the studio and the house that was also used as a changing room, designated work clothing that was only worn in the studio, washing work clothes separately from other clothes, prohibiting work shoes from leaving the studio, and prohibiting the child from entering the studio. Based on the results of surface-wipe sampling, which demonstrated elevated lead levels in the studio (1.2 mg/m^3 to 1,600 mg/m^2) but not in the home (non-detected or trace), the author concluded that the measures used prevented contamination of the home. The Lead Industries Association, Inc. has produced a video tape entitled "Controlling Lead Exposure for Stained Glass Professionals and Hobbyists" [LIA 1994a].

In another cottage industry, a home-pottery operation, the concerned potter and her family were asked to discontinue being exposed in the facility because of their elevated BLLs [Fischbein et al. 1992]. Two years later, the BLLs were normal, indicating that corrective measures, though not described, were effective. The Lead

For lead loading, the Department of Housing and Urban Development (HUD) has guidelines for floors of 200 $\mu g/ft^2$ (2,152 $\mu g/m^2$) and for window sills of 500 $\mu g/ft_2$ (5,380 $\mu g/m^2$) [Jacobs 1994]. The HUD guidelines are not based on health considerations, they are based on levels that can be practically achieved following lead-paint abatement. These values were used by the State of Alabama [1992] and Pollock [1994]. Matte and Burr [1989] cited 1,500 $\mu g/m^2$ as a level of concern for children's health. CH,M Hill [1991] used a concentration of lead in dust of 500 ppm as an action level for cleaning residences.

Mercury concentrations in air of workers' homes of 0.5 $\mu g/m^3$ and 1.0 $\mu g/m^3$ were used as decontamination goals in the reports by ATSDR [1990a] and Zirschky and Witherell [1987] respectively. In a recent report on decontamination of homes in Florida, 0.3 $\mu g/m^3$ was the level at which families were allowed to return to their homes following decontamination [CDC 1995].

For PCBs, EPA guidelines for indoor solid surfaces and high contact outdoor solid surfaces state that post clean-up levels should not exceed 10 $\mu g/100\ cm^2$ (40 CFR 761.125). Based on PCB levels found in non-manufacturing buildings, 0.11 $\mu g/100\ cm^2$ was used as a guideline for decontaminating a school building [Orris and Kominsky 1984]. Other guidelines cited by Hartle et al. [1987] were 0.5 $\mu g/100\ cm^2$ for office buildings; for an aircraft plant, 2.50 $\mu g/100\ cm^2$ was cited for low contact surfaces, and 1 $\mu g/100\ cm^2$ for high contact surfaces.

REVIEW OF DECONTAMINATION PROCEDURES

BERYLLIUM

Shirts worn for one day in a beryllium plant were studied by Cohen and Positano [1986]. Three shirts were classified as "nearly new" and three were classified as "old." One "nearly new" and one "old" shirt was laundered at the workplace. Beryllium was present at 22 mg/m^3 and 30 mg/m^2 in the "old" washed shirt. Beryllium was present at 12 mg/m^3 and 20 mg/m^2 in the "nearly new" unwashed shirts and at 0.2 mg/m^2 in the "nearly new" washed shirt. Although this was a pilot study, it is the only study found that provides information on laundering clothing contaminated with beryllium or similar particulate material. The study indicates that the beryllium was laundered from the "nearly new" shirts, but that beryllium had accumulated and was well entrenched in the "old" shirts. Substantial levels of beryllium dust in air were generated during laundry procedures. The concentrations were up to 1.2 mg/m^3 [Eisenbud et al. 1949] compared to the occupational exposure limit of 2 $\mu g/m^3$ as an 8-hr. time-weighted average [29 CFR 1910.1000].

ASBESTOS

There were no studies on the effectiveness of any methods for removal of asbestos from clothing contaminated in the workplace. One study conducted on dry cleaning a coat which contained 8% asbestos in its fabric, indicated that some of the loose fibers were removed [NIOSH 1971]. Concentrations in the air of asbestos fibers longer than 5 μ that were generated by wearing the coat before cleaning were around 2/cc whereas after cleaning the concentrations were about 0.5/cc. Since the fibers were part of the fabric, the study may underestimate the ability of laundry procedures to remove asbestos from contaminated clothing. Asbestos fibers were transferred to sport coats dry cleaned with the coat containing asbestos.

In a laboratory study, asbestos-contaminated carpets were cleaned for about 65 minutes by either dry vacuuming or hot water extraction, using vacuum cleaners equipped with high efficiency particulate air (HEPA) filters [Kominsky et al. 1990]. The carpets were artificially contaminated with 9.3×10^4 and 9.3×10^7 asbestos structures per meter squared (s/m^2), based on levels found in carpets from an asbestos-containing building. Dry vacuuming removed little or no asbestos from the carpets whereas hot water extraction removed about 70%. An important aspect of this study was the effect of the cleaning procedures on airborne asbestos concentrations. During carpet cleaning, by either method and at either level of carpet contamination, average asbestos concentrations in room air of 0.15-0.25 s/cm^3 were generated. The OSHA permissible exposure limit for asbestos is 0.1 fiber/cm^3 as an 8-hr. time-weighted average [29 CFR 1910.1001; 29 CFR 1915.1001; 29 CFR 1926.1101].

Resuspension of asbestos fibers was observed with a fiber aerosol monitor during a daily cleaning period of a classroom by Litzistorf et al. [1985]. Resuspension of dust by cleaning activities is an important consideration not only for the decontamination process, but also for persons living in the home and performing routine cleaning operations.

LEAD

No studies on laundering of clothes contaminated with lead were found. However, Simonson and Mecham [1983] showed that a workplace airshower removed from 5% to 72% of lead oxide dust from clothing samples contaminated with about 1 mg/cm^2, and from 23% to 69% from samples contaminated with about 0.6 - 2.5 mg/cm^2 in laboratory studies. A small amount of lead was blown through the clothing to the underclothing and body of the workers (up to 1% of the dust loading).

Ewers et al. [1994b] studied the effectiveness of dry vacuuming for removal of lead from carpets taken from homes of children who had high BLLs. These carpets were highly contaminated with surface lead loadings of 114,000 μg/m^2 to 5,650,000 μg/m^2. The carpets were vacuumed with commercially available vacuum cleaners intended for industrial use. The vacuum cleaners were equipped with HEPA filters and fitted with a commercial beater bar nozzle. The carpets were vacuumed 10 times for 1 min/m^2 each time. Surface loadings and amount of lead removed were measured after each vacuuming. After some of the earlier vacuumings, lead loading on the surface increased by up to four times, but by the tenth vacuuming the surface lead loading was reduced to 6%-61% (average 20%) of the initial loading. The

Table 2. Health Effects of Take-Home Asbestos Exposure (Cohort Studies)

Author (year)	Location Industry/ Population at Risk	Study Design	Results	Comments
Anderson [1983] Anderson et al. [1976, 1979a, 1979b]	Patterson, New Jersey Amosite workers employed 1941-1945 in thermal insulation materials factory	Cohort study. Morbidity and mortality among 2,218 household contacts of amosite workers identified. 679 of 1,545 alive through 1980 were examined. Occupational, residential, smoking, medical history questionnaire administered to the exposed cohort. Vital status follow-up is through 1980. Radiographs were taken 20+ years after first exposure. For radiographic analysis, a frequency matched (age, gender) control group was assembled of 326 unexposed people from the same urban New Jersey community who presented for chest radiograph 1975-1976.	3/663 observed deaths were due to mesothelioma. Lung cancer overall SMR=152 (25 observed/16.4 expected) after 20 years latency SMR=185. Among females, there were 8 respiratory cancers observed vs. 6.4 expected. Excess risk was confined to those with 20+ years latency (8 observed vs. 4.7 expected, SMR=170. Among males with 20+ years latency, there were 12 lung cancer deaths observed vs. 6.1 expected (SMR=197). Increased frequency of asbestos-associated radiographic abnormalities among household contacts. Prevalence of radiographic abnormality associated with secondary exposure was 35% vs. 5% expected based on the comparison population ($p<0.001$). Prevalence of abnormalities increased with duration since first exposure; 40% prevalence among those with longest latency ($p<0.01$). Those with 10+ years of household exposure had a prevalence of abnormal radiographs of 53%. For 1971 ILO classification 1/1 and greater, a prevalence of 10.3 observed vs. 0.6% in controls. Prevalence of parenchymal or pleural abnormality 20+ years after first household exposure (1979b): 48% among wives, 21% among daughters, 42% among sons, and 37% among siblings.	Mesothelioma deaths occurred 20+ years after childhood domestic exposure (2 female; 1 male). There were 2 additional mesotheliomas among children of workers that were excluded from analysis. Dust from work clothes, shoes, hair assumed causal. No changing facilities at factory.
Magnani et al. [1993]	Italy Asbestos cement workers	Retrospective cohort mortality study of 1,964 wives of asbestos cement workers; cohort had no history of occupational exposure. Husbands employed 1950-1985; deaths occurred 1965-1988.	Between 1965-1988, there were 4 pleural tumors (1 mesothelioma) observed vs. 0.5 expected; 6 lung cancer vs. 4.0 expected. Expected based on local rates. Among women with domestic exposure, cancer of the pleura was significantly elevated SMR=792.3 (95% CI 215.9 - 2,028.8).	This plant had no laundering facilities, and work clothes were laundered at home. All 6 cases reported more than 10 years of exposure. There were 2 additional mesotheliomas observed after 1988.

Table 2. (Continued) Health Effects of Take-Home Asbestos Exposure (Cohort Studies)

Author (year)	Location Industry/ Population at Risk	Study Design	Results	Comments
Joubert et al. [1991]	New Jersey Amosite asbestos workers	Cohort study. Followed household contacts of amosite asbestos workers employed at a single facility 1941-1954. Of 4,044 household contacts, 878 were examined 1973-1976.	Vital status follow-up through January 1990 indicates that 28% died of lung cancer, 23% died from cancer of the gastrointestinal tract, and 9% died of mesothelioma. The authors state that cancer deaths were 2 times expected based on national estimates.	Some figures reported in the paper seem contradictory. This appears to be additional follow up of the Anderson et al. studies.
Navratil and Trippe [1972]	Czechoslovakia Chrysotile asbestos product processing	Cohort study. Prevalence of pleural calcification in three asbestos exposed groups compared with prevalence in non-exposed residents of the same area (Group #4). <u>Group #1</u> 800 workmen employed for more than 10 years at a factory. <u>Group #2</u> 155 persons living in the neighborhood of the factory. <u>Group #3</u> 114 persons older than 20 years who were relatives of factory employees. <u>Group #4</u> 8,127 persons over the age of 40 who lived in the same district as the factory but not in the same neighborhood as the factory.	Each group was evaluated by X-ray for the prevalence of pleural calcification, with or without other signs of asbestosis. Observed statistically significant ($p<0.01$) increased risk of calcification among each asbestos exposed group compared with Group #4. <u>Group #1</u> 42/800 (5.3%) observed vs. 2.75 expected <u>Group #2</u> 9/155 (5.8%) observed vs. 0.53 expected <u>Group #3</u> 4/114 (3.5%) observed vs. 0.39 expected <u>Group #4</u> 28/8127 (0.34%)	In group #2, 5 were also relatives but were counted in group #2 rather than group #3. Blood relations were assumed to have increased exposure due to contact with workers wearing contaminated work clothes.

Table 3. Health Effects of Take-Home Asbestos Exposure (Community Studies)

Author (year)	Location/ Industry/ Population at Risk	Study Design	Results	Comments
Kilburn et al. [1985, 1986]	Los Angeles County Shipyard workers	Community-based cohort. Prevalence of radiographic evidence of asbestos among shipyard workers and their household contacts with at least 20 years latency (n=1017) was compared with that of 2 previously studied comparison groups (Long Beach census tract and Michigan adults). Medical and occupational history obtained by examination and interview.	Prevalence among household contacts without occupational exposure was reported. Among 274 wives of shipyard workers, 11.3% had radiographic evidence of asbestosis (profusion 1/0 or greater), compared with prevalence of 0.6% in the California and 0.0% in the Michigan comparison groups. Prevalence increased with time since first exposure; the prevalence rate among those with longest latency was 32%. Among 140 female children, the prevalence rate was 2.1%; a prevalence of 7.6% was observed among 79 sons of shipyard workers.	Possible selection bias resulting from volunteer study participants. No difference in prevalence observed by smoking status. Most shipyard workers had indirect (bystander) exposure. Families of insulators appear to be at increased risk of asbestosis compared with other shipyard workers. (1% of shipyard workers were insulators; about 25% of asbestosis in workers' families occurred in families of insulators.)

Table 4. Health Effects of Take-Home Asbestos Exposure (Case-Control Studies)

Author (year)	Location	Industry/ Population at Risk	Study Design	Results	Comments
Newhouse and Thompson [1965]	London, England	Hospital-based	Matched case-control. Cases (n=83) were autopsy series who died of mesothelioma (pleural and peritoneal) 1917-1964; matched on gender and birth date (+/- 5 years) to in-patient controls from same hospital who were hospitalized 1964. Two other comparison groups were used to verify results, but not reported in paper: 1. matched on gender, birth date, and date of admission, and 2. 17 patients from same hospital pathology series who were misdiagnosed as mesothelioma.	9/76 cases (7 female; 2 male) reported domestic exposure compared with 1/76 controls from the inpatient series.	Most female exposures from laundering work clothes; 2 males exposed in childhood to family members who worked in asbestos factory; latency ranged from 16-55 years.
Vianna and Polan [1978]	New York State	Population-based	Matched case-control. Cases were 52 (30 pleural/20 peritoneal) histologically confirmed female mesothelioma (pleural and peritoneal) deaths (1967-1977); one-to-one matching on gender, race, county of residence, marital status, age and year at death; controls died from causes other than cancer; occupational history by questionnaire, medical and industrial records.	Relative Risk from matched pairs analysis for domestic exposure (included 2 with occupational exposure) reported as 10 (95% CI=1.4-37.4). Analysis on subset of 46 non-occupationally exposed cases: 8/46 reported domestic exposure vs. 1/46 controls ($p=0.02$).	All 10 domestic cases exposed during hand-laundering of work clothes.

Table 4. (Continued) Health Effects of Take-Home Asbestos Exposure (Case-Control Studies)

Author (year)	Location	Industry/ Population at Risk	Study Design	Results	Comments
McDonald and McDonald [1980]	Canada and USA	Population-based autopsy series (Canada 1960-1972: USA 1972)	Matched case-control. 557 pleural and peritoneal mesotheliomas with autopsy; matched on hospital, gender, age, and year of death to controls with pulmonary metastases from non-pulmonary primary who were autopsied; occupational, residential, smoking, and non-occupational exposure histories from interview (blind) with relatives for 490 matched pairs. Occupational exposures coded blind and cumulated to 10 years before death of case.	8/557 cases vs. 2/557 controls reported domestic exposure to asbestos dust on work clothes of household contact (p=0.08 for matched pairs analysis).	5/8 non-occupational cases and 2 controls were exposed to contaminated clothing in childhood. 3/8 cases and 1 control were exposed to clothing of a chrysotile production worker; 5 cases and 1 control were exposed to contaminated clothing of insulation factory workers.
Whitwell et al. [1977]	England	Hospital-based	Case-control. Asbestos fiber content in lungs of 100 consecutive pleural mesothelioma autopsies compared with 100 lung cancer cases and 100 lungs of people who died from causes other than industrial lung disease or lung cancer for whom occupational histories were available. Occupational and residential history obtained from patients or relatives.	1 mesothelioma reported in asbestos worker's family. Although not explicitly stated in published report, apparently no cases were observed in either control series in asbestos workers' families.	Father worked in gas mask production and brought work home. Lungs of his son had 50,000-100,000 asbestos fibers/gram dried lung tissue.

Table 4. (Continued) Health Effects of Take-Home Asbestos Exposure (Case-Control Studies)

Author (year)	Location	Industry/ Population at Risk	Study Design	Results	Comments
McEwen et al. [1971]	Scotland	Population-based	Matched case-control. 83 mesothelioma cases who died 1950-1967 from all pathology departments in Scotland. Two control groups were matched on age and gender to the nearest chronologic pathology report from the same hospital: (1) coronary artery disease deaths, and (2) lung and gastric carcinoma cases were matched to pleural and peritoneal mesothelioma cases, respectively.	Only a few cases and controls had shared households with asbestos workers. No statistically significant differences between these two groups.	The number of non-occupational cases was not reported in the publication. The case of a woman who washed the clothes of her husband who was a dockworker is described.
Rubino et al. [1972]	Italy (Piedmont)	Various industries; Piedmont produces only chrysotile	Case-control study of 50 confirmed cases of pleural mesothelioma admitted to 2 Turin clinical settings 1960-1970. Controls were 50 patients from the same institution matched on gender and age.	12% of mesothelioma reported in the case series were in workers' family members; 3 cases (2 men and 1 woman) had lived with persons employed in the asbestos industry, compared with none in the control group.	The wife of a man worked in the asbestos industry, and 1 woman's brother worked in an asbestos cement factory. Occupational exposure was unequivocally demonstrated in 5 men. Asbestos bodies were found in only one case.
Ashcroft and Heppleston [1970]	Britain	Shipbuilding	Case-control study of 23 cases of mesothelioma (20 pleura, 3 peritoneum; 19 males, 4 females) that came to autopsy compared with 46 hospital controls matched on sex and age, free from malignant disease.	91% of the cases had a history of exposure to asbestos vs. 41% of 46 matched controls ($p<0.001$); 1 of the cases resulted from domestic exposure.	A widow of an asbestos worker was exposed for 3 years to asbestos dust brought home on her husband's clothes, hair and shoes. Paper includes table of fiber and asbestos body counts.

Table 5. Health Effects of Take-Home Asbestos Exposure (Case Reports)

AUTHOR(S) (YEAR) COUNTRY	INDUSTRY	HEALTH EFFECT	# CASES/RELATIONSHIP	AGE(S) AT DEATH OR DIAGNOSIS	COMMENTS
Rusby [1968] England	Asbestos	Mesothelioma	1 Female	71	Woman laundered clothing of 3 daughters who had worked in an asbestos factory for 1-2 years. 26 year latency.
Teyssier and Lesobre [1968]	Asbestos	Asbestosis Pleural plaques	Case report of asbestosis in a man exposed as a teen to his father's work clothes worn home from an asbestos plant.		May also have had environmental exposure since he lived near an asbestos plant for 2 years.
Champion [1971] Canada	Asbestos	Mesothelioma	1 Male	31	Father was a pipe lagger and had asbestosis. Son never had occupational exposure.
Knappmann [1972] West Germany	Asbestos	Mesothelioma	Man lived for several years with sister who was an asbestos worker who came home with dusty clothes and hair.	66	42 years from beginning of exposure to onset of tumor.
Lillington et al. [1974] USA	Asbestos	Familial mesothelioma	1 Wife	52	Domestic case resulting from residence in the same house as an asbestos worker who died of mesothelioma.
Li et al. [1978] USA	Asbestos	Familial mesothelioma	1 Mother, and 1 daughter	51,34	Father was shipyard insulation worker who had asbestosis and died of lung cancer. His wife and eldest daughter died of mesothelioma. Wife laundered dusty work clothes.
Epler et al. [1980] USA	Asbestos	Pleural changes Mesothelioma	2 Wives of asbestos workers 2 Brothers	60,56, 33 and 27	Wives were involved with cleaning husbands' clothes resulting in mesothelioma in one and pleural changes in the other. Brothers played as children in room used as muffler shop. Both developed pleural changes in young adulthood, although changes in one could have been related to subsequent occupational exposure.
Risberg et al. [1980] USA	Construction	Familial pleural and peritoneal mesothelioma	Father, 2 brothers and 1 sister	61,71, 60, and 52	All cases smoked. Father died of peritoneal mesothelioma. The 2 sons and their sister died of tubulo-papillary mesothelioma. No asbestos industry employment; father and sons worked in construction industry.
Jorgensen [1981] Denmark	Asbestos (insulation work)	Pleural plaques	3 Wives of insulation workers	71,54 and 58.	Exposure was limited to laundering of clothes, dusty shoes, etc. Of the 3 women, 2 smoked and 2 had other relatives who were insulation workers.

Table 5. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Reports)

AUTHOR(S) (YEAR) COUNTRY	INDUSTRY	HEALTH EFFECT	# CASES/RELATIONSHIP	AGE(S) AT DEATH OR DIAGNOSIS	COMMENTS
Martensson et al. [1984b] Sweden	Asbestos (foundry)	Familial pleural mesothelioma	Sister and brother	52,58	Brother dead, sister survived. Father's work clothes hung in kitchen when they were children.
Krousel et al. (1986) USA	Asbestos	Familial pleural mesothelioma	Mother, son and daughter of a lumber and shingle company worker.	74, 40, and 35.	Son was only one with possible occupational exposure, but diagnosis at age 35 suggests childhood exposure.
Magee et al. [1986] Italy	Chrysotile ore contaminated with tremolite and actinolite.	Mesothelioma	Single male case.	41	Indirect exposure to asbestos from Canari Mine in Corsica. Exposed as child in pub in house. Analysis of lung mineral content showed chrysotile at background and elevated levels of tremolite and actinolite asbestos. Fiber size and mesothelial carcinogenesis discussed. Paper contains data on lung fiber burden.
Huncharek et al. [1989] USA	Asbestos	Pleural mesothelioma	Single case (female)	76	Indirect exposure to husband, a shipyard machinist, who dismantled boilers and other related machinery for 34 years. She laundered his clothes. Paper contains data on lung fiber burden.
Li et al. [1989] USA	Asbestos	Familial mesothelioma	2 Female cases. Father worked in asbestos plant.	32, 49	Cotton cloth sacks in which molded asbestos insulation had been transported had been used to make diapers for children. Results were the deaths of the mother, a sister, and a young uncle who lived there and worked as insulator. In addition, the father died of asbestosis. Mother laundered asbestos-contaminated diapers and work clothes.
Otte et al. [1990] Denmark	Amosite asbestos cement	Familial mesothelioma	Family cluster of 3 deceased.	74, 79, 45.	Family produced asbestos cement in their home. Used dry hand mixing procedure. Mother, father and a son died of mesothelioma; 2 sons and a daughter survived. All decedents smoked.

Table 5. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Reports)

AUTHOR(S) (YEAR) COUNTRY	INDUSTRY	HEALTH EFFECT	# CASES/RELATIONSHIP	AGE(S) AT DEATH OR DIAGNOSIS	COMMENTS
Oern et al. [1991] Norway	Asbestos (various)	Pleural mesothelioma	1 Woman	79	Family made up of 2 brothers, a sister and her husband. All males were asbestosis insulators and 2 were smokers. Oldest brother (alive) has asbestosis. Other brother and sister died from mesothelioma. Brother-in-law died from cancer bronchiale. Woman cleaned asbestos-contaminated work clothes.
Anonymous [1993b] England	Asbestos	Pleural plaques	3 Daughters	63,62 60	Daughters of pipe lagger. Exposure was laundering of work clothes; 2 younger daughters were asymptomatic but all 3 had varying degrees of pleural plaques. Father died of peritoneal mesothelioma.

Table 6. Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Lieben and Pistawka [1967] USA	Asbestos (insulation, shipbuilding)	Mesothelioma: 1 pleural and 2 peritoneal.	3-year-old girl whose father worked with asbestos insulation. 40-year-old woman whose father and brother were asbestos insulation workers. 67-year-old woman whose two sons were shipyard asbestos insulation workers.	3, 40, 67. No numerical exposure data given.	Of 42 mesothelioma cases reported from 152 Pennsylvania hospitals 1958-1963, 3 were family members of asbestos workers.
Dalquen et al. [1970] Germany	Asbestos	Pleural plaques	22 cases among domestic contacts		133 cases of pleural plaques and 145 cases of asbestosis from the Hamburg area are reviewed. Of 92 cases of pleural plaques with a history of exposure to asbestos dust, 34 were occupationally exposed, 22 domestically, 21 by urban dwelling and 10 by multiple cause. 5 had no history of asbestos exposure. The latency period for plaques was 40.2 years.
Heller et al. [1970] USA	Asbestos	Pleural mesothelioma	1 woman. Washed pipefitter husband's asbestos-contaminated work clothes.		Radiological review of a series of 10 cases of pleural mesothelioma seen at Massachusetts General Hospital 1960-1967, 1 case was the wife of an asbestos worker.
Bittersohl and Ose [1971] Germany	Asbestos (insulation and products such as cords, seals, plates, etc.)	Pleural mesothelioma	1 woman whose husband was exposed to asbestos insulation at a chemical plant. She laundered his work clothes.	Exposure data given in terms of East German standard.	26 cases of pleural mesotheliomas from chemical plants in the district of Merseburg, East Germany. This group is made up of 22 patients from the Leuna Chemical combine, 2 patients from the Beuna Chemical Combine, 1 patient from a metal foundry, and 1 case in the wife of a chemical plant workers. Chemical plant workers were exposed to asbestos insulation. All occupational cases had been exposed to dust levels exceeding the East German standard. This group includes workers not directly working with asbestos, but working near-by. Of the cases, 46% occurred after retirement.

Table 6. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Vianna et al. [1981] USA	Six New York counties	Mesothelioma	Of 7 cases of indirect exposure, 6 were females.		Population-based incidence study (case series). Descriptive survey of 31 (22 male; 9 female) histologically confirmed mesothelioma cases diagnosed 1973-1978; occupational histories from cases or relative. No control group.
Grundy and Miller [1972] USA	U.S. population-based	Childhood mesothelioma	13 cases of childhood mesothelioma in US children.	Age range: 4 through 17.	U.S. population-based death certificate search. No exposure history, although occupational history of some fathers consistent with asbestos exposure. Apparent short latency in children compared to adults.
Greenberg and Davies [1974] England/Wales	Asbestos	Mesothelioma	2 women with mesotheliomas associated with household exposure of 2 and 3 years duration; 1 woman's husband worked in an asbestos factory, and 1 was exposed to her brother's work clothes.		1967-1968 mesothelioma case series (n=413: 365 pleural; 48 peritoneal) from population-based registry. Asbestos exposure history obtained by interview from cases, relatives, employers and workmates. For 246 of the 413 cases, the diagnosis was histologically confirmed.
Milne [1976] Australia	Asbestos (asbestos/cement)	Mesothelioma	1 case in a woman whose father worked in the asbestos cement industry.	No exposure in the series began after 1943; length of exposure ranged from 6 months to 30 years.	Retrospective survey of 32 cases of mesothelioma in Victoria, Australia. These authors found occupational history equally effective as an asbestos body count to indicate past exposure. In 16% of cases, there was no evidence of exposure to asbestos, and 2 cases of peritoneal cancer were in siblings without asbestos exposure.
Edge and Choudhury [1978] England	Asbestos (shipyard workers)	Pleural mesothelioma	1 woman married to shipyard plumber who may have brought dust home on clothes.		47 men and 3 women diagnosed with pleural mesothelioma 1966-1976 among 64,000 residents, 7,000 of whom worked in ship construction. All 50 cases of pleural mesothelioma histologically proven and accepted by Pneumoconiosis Panel. All men plus 1 woman occupationally exposed; 1 woman exposed at home, another had no known exposure. Asbestos content of last 20 cases was measured; 18 cases substantially exceeded that of the general population. Metastases, frequent at necropsy, occurred in 25 of 47 cases autopsied.

Table 6. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Bianchi et al. [1982] Italy	Asbestos (shipyard work)	Pleural mesothelioma	1 woman whose husband was a shipyard worker.		Of 70 cases (64 men; 6 women) seen at Institute of Pathological Anatomy of Trieste 1967-1980 1 was due to probable domestic exposure. Necropsy findings available in 63 cases. Remaining 7 cases were diagnosed at thoracotomy. Of the cases, 43 employed in shipyards, most prior to 1940. Intervals between first exposure and death ranged from 28 to 61 years. Asbestos bodies found in 48 of 61 cases.
Bianchi et al. [1987] Italy	Asbestos (shipyard, sodium carbonate factory)	Hyaline pleural plaques	59 cases were attributed to domestic exposure (laundering asbestos-contaminated work clothes of family members). 9 cases with occupational and domestic exposure.	Not stated	74 women with hyaline pleural plaques found at necropsy. 2 cases with occupational exposure. Sufficient exposure data could not be obtained on 4 cases. Pleural malignant mesothelioma was noted in 2 cases with a history of household exposure.
Bianchi et al. [1990] Italy	Shipyard, sodium carbonate factory, textile, artisans, domestic maids)	Hyaline pleural plaques	Pleural plaques at necropsy were found in 55% of 121 women with history of domestic exposure.		1,620 necropsies (1,040 men, 580 women) were performed from Oct 1979 to Dec. 1987 in Monfalcone, Italy. 121 women with history of domestic exposure were compared to 57 women with no history of domestic exposure. Pleural plaques were significantly more prevalent in those women with domestic exposure ($p<0.001$). The prevalence of hyaline plaques was higher in every occupational category for women with domestic exposure than for women without domestic exposure.
Bianchi et al. [1991] Italy	Shipbuilding, sodium carbonate factory	Asbestos bodies Hyaline pleural plaques	1,765 necropsies (1,127 men; 638 women). In women, cleaning of work clothes polluted with asbestos was the main source of exposure. Domestic exposure resulted in pleural plaques in about half the necropsies on female patients.		Prevalence of pleural plaques and asbestos bodies varied by occupation in men; the highest prevalence was in those who had worked in the sodium carbonate factory. Only 21 of the 638 necropsies on females had a history of occupational exposure.

Table 6. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Bianchi et al. [1993] Italy	Asbestos (shipyard, sodium carbonate factor)	Mesothelioma	6 women had history of domestic exposure (laundering asbestos-contaminated clothing of family members).		92 malignant mesotheliomas were diagnosed between Oct. 1979 and April 1992 at Monfalcone Hospital. 6.5% of these were associated with domestic exposure. 75 cases had occupational history of exposure to asbestos. One case had a history of probable environmental exposure.
Lander and Viskum [1985] Denmark	Asbestos work	Pleural plaques, Pleural calcification, Pulmonary fibrosis, Asbestosis	Of 63 women (spouses of workers exposed to asbestos) with indirect (non-occupational) exposure to asbestos, 9 (17%) had radiological changes characteristic of exposure to asbestos. Exposure consisted of laundering asbestos-contaminated work clothes.	Adult women	The researchers attempted to enroll 125 spouses of asbestos-exposed workers. 90 participated in the study. 20 were excluded due to lack of exposure (X-rays were normal). 5 were excluded due to occupational exposure (one had pleural plaques). 2 were excluded for other pulmonary diseases.
Gibbs et al. [1989] Wales	Asbestos	Pleural mesothelioma	1 male and 12 females with non-occupational exposure (Zielhuis group II, e.g., the wives of asbestos workers) included in the study.	47-72	84 cases diagnosed 1979-1986 chosen because the history of asbestos exposure was absent, indirect, or ill-defined. 3 purposes of study were: 1. correlate lung mineral count with Zielhuis (1977) occupational exposure groupings; 2. determine whether any mesotheliomas were unrelated to asbestos exposure; and 3. compare the role of amphiboles and chrysotile in causation. Conclude that: 1. Zielhius method too complex; 2. mesotheliomas may develop in absence of asbestos exposure; and 3. amphiboles are more important than chrysotile. Electron microscope mineral fiber analysis data provided by exposure group.

Table 6. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Gibbs et al. [1990] Wales	Asbestos (shipyard work, lagging, building, ordnance)	Malignant pleural mesothelioma	10 cases in family members, 9 of whom were spouses of asbestos workers and 1 was daughter of a man who died of asbestosis.	Age range: 47 to 72.	This was a comparison of types of lung fibers and size distribution in a series of non-occupational cases of mesothelioma with a series of known occupational exposure in female gas mask workers. The non-occupational group fiber exposure was variable; 6 showed high crocidolite; 7 showed high amosite; 1 high chrysotile; and 2 showed normal for all fiber (several showed more than 1 high fiber group).
Konetzke et al. [1990] Germany	Asbestos	Asbestosis Mesothelioma	48 non-occupational registry cases of mesothelioma and 19 cases of asbestosis (11 male; 56 female). 10 of these lived near an asbestos plant.		Confirmed reports that even in the non-occupational area, asbestos represents a non-negligible risk for diseases of the lung. Non-occupational risk factors identified in this study included: laundering (46%); use of asbestos containing materials in the house (21%); and leisure activities (15%).
Kiviluoto [1965] Finland	Asbestos	Pleural plaques, Pleural adhesions, Pulmonary fibrosis, Mesothelioma.	4 cases of asbestoses in 4 sisters whose father had been occupationally exposed to mixed dusts.		The father 50 years earlier had been occupationally exposed to mixed dusts and presumably brought them home on his clothes.
Martensson et al. [1984a]	Asbestos work	Mesothelioma	Woman who had been exposed to asbestos during childhood via her father's work clothes.		Analysis of 32 cases of malignant mesothelioma. All but one case was occupational.
Sider et al. [1987] U.S.A.	Insulation work	Radiographic pleural changes (plaques, calcification, thickening)	18 (19.4%) wives of asbestos-exposed insulation workers screened had radiographic abnormalities.		117 wives of asbestos-exposed insulation workers were screened with X-rays and pulmonary function tests. None of the 24 women under age 40 had any X-ray abnormalities. Exposure for all of them was less than 8 years. These 24 were excluded. 18 (19.4%) of the remaining 93 had radiographic abnormalities.

Table 6. (Continued) Health Effects of Take-Home Asbestos Exposure (Case Series)

AUTHOR(S) YEAR COUNTRY	INDUSTRY	HEALTH EFFECT	#/RELATIONSHIP	AGE AT DEATH EXPOSURE	COMMENTS/ ISSUES
Giarelli et al. [1992] Italy	Asbestos (shipyard)	Mesothelioma	5 women with a history of domestic exposure to asbestos (laundering the asbestos-contaminated clothing of family members).	Age at death of all cases 33 to 92 years (median 70 years).	170 pleural mesotheliomas examined at necropsy between 1968-1987 (Trieste University). Occupational histories consistent with asbestos exposure in 150 cases. 5 had no asbestos exposure history but lung sections showed asbestos bodies. 5 women had a history of domestic exposure to asbestos (laundering the asbestos-contaminated clothing of family members).

Table 15. Workers' Home Contamination–Industrial Hygiene Aspects

Author [year] Location	Contaminant Basis for Study	Process	Industrial Hygiene Methodology	Industrial Hygiene Observation	Comments or Recommendations
Bohne and Cohen [1985] Ohio	Beryllium	Beryllium production	Fabrics exposed at worksite.	Electrostatic charges increased fabric contamination of cotton, but not Nomex® fabric loading up to 2,800 $\mu g/m^2$.	
Chamberlin et al. [1957] Pennsylvania	Beryllium	Beryllium plant		5 patients were family members of beryllium workers and cleaned their dusty clothes.	The authors state: "The introduction of proper industrial hygiene measures has evidently reduced the number of new cases of chronic granulomatous pneumonitis due to secondary transfer, since none has been seen by us for the past three years."
Chesner [1950] Ohio	Beryllium	Beryllium plant	Case histories of chronic pulmonary granulomatosis	Woman used empty beryllium ore bags for dish clothes. She got the bags from a neighbor who worked at the plant.	
Cohen and Positano [1986] Ohio	Beryllium	Beryllium refinery	New and used shirts worn at work were analyzed for beryllium in the fabric. Fabrics were agitated in a glove box to measure re-suspended beryllium.	Beryllium concentrations ranged from 12 to 37 mg/m^2 in unwashed shirt fabric. Air concentration of beryllium measured in refinery was only a fraction of the PEL of 0.002 mg/m^3. The old shirts also showed significantly higher concentrations of beryllium and resuspended significantly higher quantities of beryllium to the air than newer shirts.	Concentrations of resuspended dust from old, unwashed shirts up to 0.64 $\mu g/m^3$ were found.
Eisenbud et al. [1949] Ohio	Beryllium	Beryllium production.	Study of dust generated by laundry procedures using 100 uniforms worn for one day by plant employees.	Air concentrations of beryllium: shaking soiled clothes 0.1-1.2 mg/m^3; scrubbing 3-7 $\mu g/m^3$; shaking and folding washed clothes 4-6 $\mu g/m^3$. Estimated inhalation dose during single home-cleaning of work clothes was 17 μg of beryllium.	
Anderson et al. [1979b] New Jersey	Asbestos	Amosite asbestos product manufacturing	Evaluate health status of 679 household contacts of asbestos workers. Interviews, X-rays, physical exams.	Family contacts had no other known asbestos exposure. 35% of household contacts had radiographic abnormalities vs. 5% of controls.	Plant did not have change rooms or change of clothing available; clothes were washed at home.

Table 15. (Continued) Workers' Home Contamination-Industrial Hygiene Aspects

Author [year] Location	Contaminant Basis for Study	Process	Industrial Hygiene Methodology	Industrial Hygiene Observation	Comments or Recommendations
Belanger et al. [1979] Illinois	Asbestos	Vinyl asbestos & asphalt asbestos floor covering manufacturing	Personal & area sampling	Separate lockers for clean and dirty clothes. Coveralls provided. Showers provided.	Recommendations were made to change clothes and leave all work clothes at work. Specifically, work clothes must not be taken home to be washed as this could expose others at home.
Bianchi et al. [1987] Italy	Asbestos	Asbestos related industries	Interviews to determine occupational histories and practices of washing clothes at home.	For women, cleaning work clothing was the main source of exposure. Many women were exposed in this way for more than 20 years.	
Driscoll and Elliott [1990] Michigan	Asbestos	Manufacturing of asbestos brake linings; production of adhesives, sealers and paints.	Vacuumed samples of work clothes and car seat via phase contrast microscopy (PCM) and transmission electron microscopy (TEM).	Vacuum Samples: all clothing (n=7) was contaminated with asbestos, 4 of 6 samples from workers car seats were contaminated with asbestos.	Recommendation included leaving contaminated clothing at work and showering before leaving.
Giarelli et al. [1992] Italy	Asbestos	A variety of work performed by shipyard workers, dock workers and sailors	Review of 170 clinical cases in which necropsies were performed.	5 cases had domestic exposures to asbestos in cleaning the work clothes of their husbands who were employed in shipyards.	
Gibbs et al. [1990] United Kingdom	Asbestos	Shipyard, lagging building and ordinance work	Study of 10 non-occupational cases of mesothelioma	9 cases were due to exposures to asbestos from washing husbands' work clothes.	
Huncharek et al. [1989] USA	Asbestos	Exposure of spouse to contaminated clothing for 34 years.	Post mortem fiber counts from removed lung	Fibers/g of wet lung tissue: Chrysotile 1.72×10^3 Amocite/crocidolite 59×10^3 Tremolite/actinolite/anthophyllite 221×10^3.	Husband was a shipyard machinist whose work clothes became covered with dust. His wife regularly laundered these clothes at home.

Table 15. (Continued) Workers' Home Contamination-Industrial Hygiene Aspects

Author [year] Location	Contaminant Basis for Study	Process	Industrial Hygiene Methodology	Industrial Hygiene Observation	Comments or Recommendations
Kominsky et al. [1990] Ohio	Asbestos	Wet & dry vacuuming to remove asbestos fibers from contaminated carpets and determination of airborne levels during vacuuming.	Transmission electron microscopy was used to analyze air samples collected during vacuuming. An EPA method was used for analysis of carpet samples. Carpets contaminated at 1 million and 1 billion asbestos structures/ft^2. Decontamination by HEPA filtered dry vacuum and hot-water extraction cleaners.	Wet vacuuming reduced carpet contamination by 70%. There was no significant evidence of change following dry vacuuming.	Air concentrations increased 2-4 times during vacuuming compared to prevacuuming levels.
Nicholson et al. [1980] California & Newfoundland	Asbestos	Workers' home contamination from mining and milling asbestos.	Air samples were collected in homes of asbestos workers.	13 Chrysotile asbestos samples ranged from > 50 to > 2,000 < 5,000 ng/m^3.	These are the only measurements of asbestos concentrations in workers' homes.
NIOSH [1971] Ohio	Asbestos	Laundering-transfer of fibers to other clothes and cleaning solution.	An asbestos-containing coat (8% asbestos) was dry cleaned with non-asbestos containing clothes.	Demonstrated substantial transfer of fibers to other clothes and to the dry cleaning fluid.	
Sawyer [1977] Connecticut	Asbestos	Laundry	Air samples collected on membrane filter analyzed by phase contrast microscopy. Samples collected in building laundry, not homes.	Asbestos fibers/cm^3: Picking up clothing 0.4 Loading washer 0.4 Loading dryer 0.0 Personal 0.4 (up to 1.2)	In this asbestos abatement project, controls were substantial so these are probably minimum estimates of many home laundry exposures in the past. Clothes only worn for 4 hours.
Selmas and Ordin [1986] New Jersey	Asbestos	Brake shoe manufacturing	Work clothing was vacuumed as employees left work and dust was analyzed using polarized light microscopy and X-ray diffraction.	Vacuum samples from all work clothes contained chrysotile asbestos fibers. Quantitative data not presented.	Potential for home contamination via clothes brought home by the workers. Provide clean uniform or disposable ones to all employees. Separate soiled work clothes from street clothes.
Abbritti et al. [1989] Italy	Lead	Ceramic factories & workshops at home	Sampling of house dust. Methodology not reported.	Mean lead concentrations in house dust were 2.7 and 4.7 mg/m^2 where workers were exposed in factories and where workshops were adjacent to houses, respectively (vs. 0.8 mg/m^2 in controls).	

Table 15. (Continued) Workers' Home Contamination-Industrial Hygiene Aspects

Author [year] Location	Contaminant Basis for Study	Process	Industrial Hygiene Methodology	Industrial Hygiene Observation	Comments or Recommendations
Apol and Singal [1980] Alaska	Lead	*Lead acid storage* battery manufacturing	*Air sampling in plant*	Personal breathing zone samples (5) ranged from 111 to 1,053 $\mu g/m^3$.	Owner & family lived above plant. Recommended: Installing change room, closing up hallway between plant and home, clean home, and *monitor family* for lead exposure.
Baker et al. [1977] Tennessee	Lead	Secondary lead smelter	Sampled homes for lead content in house dust. Analyzed wipe samples by anodic stripping voltametry.	Dust in workers' homes contained lead at 2,687 ppm (<1,000-80,000) vs. 404 ppm for controls.	As a result of study, workers homes were cleaned. Workers started showering and changing clothes before going home.
Barnett [1994] Oregon	Lead	Tile manufacturing	Not applicable	1 worker had a blood lead level of 73 $\mu g/dL$.	Investigators think at least one child (of a worker) has high blood lead.
Barnett [1994] Oregon	Lead	Bronze foundry	Not applicable.	2 children of foundry workers had high BBLs (14 & 23 $\mu g/dL$).	Oregon OSHA documented that employees were taking lead dust home on clothes.
Carvalho et al. [1984] Brazil	Lead	Lead smelter	Blood lead samples analyzed via atomic absorption spectrophotometry with heated graphite furnace atomizer.	Children of lead workers had higher blood lead values (67.5 $\mu g/dL$) than other children (56.6 $\mu g/dL$). Lead workers took used "filters" home from the plant, for re-use in their home.	
CH2M Hill [1991] Idaho	Lead	Lead smelter	Vacuuming and shampooing; analyses for lead and other metals.	Lead loading in carpets ranged from 12 to 283 mg/ft^2 and in furniture from 57 to 1,100 mg/ft^2, only 14-30% of lead was removed from carpets; 5-40% from furniture.	500 $\mu g/g$ (lead/total dust) action level for cleanup advisory.
Cook et al. [1993] Colorado (Leadville)	Lead	Lead mining and smelting	Work practices questionnaire. Samples of floor dust, window sill dust, paint and tap water were analyzed for lead.	Lead in window sill dust 30-27,900 ppm, floor dust 8-11,000 ppm.	Positive association between miner wearing work clothes home and BLLs in children.
Czachur et al. [1995] New Jersey	Lead	Various lead industries	Telephone interviewers asked about showering at work, washing clothes at home, etc.	The data indicate that elevated blood lead levels in children are associated with parents washing dirty work clothing at home.	Data collected after June 1992.

Table 17. (Continued) Federal Laws Relevant to Workers' Home Contamination

Popular Name	Public Law	U.S. Code	Sections Relevant to Workers' Family Protection
Asbestos Hazard Emergency Response Act of 1986	Public Law 99-519	[15 U.S.C. § 2642 & Seq.]	§ 2646 Contractor and laboratory accreditation (b) Accreditation by State (1) Model plan (B) Plan requirements (xi) Housekeeping and personal hygiene practices, including the necessity of showers, and procedures to prevent asbestos exposure to an employee's family.
Residential Lead-Based Paint Hazard Reduction Act of 1992	PL 102-550 Title X Subtitle B	[15 U.S.C. § 2681 & Seq.]	§ 2681 Definitions For the purposes of this subchapter: (1) Abatement The term "abatement" means any set of measures designed to permanently eliminate lead-based paint hazards in accordance with standards established by the Administrator under this subchapter. Such term includes- (A)the removal of lead-based paint and lead-contaminated dust, the permanent containment or encapsulation of lead-based paint, the replacement of lead-painted surfaces or fixtures, and the removal or covering of lead-contaminated soil; and (B) all preparation, cleanup, disposal, and postabatement clearance testing activities associated with such measures. (11) Lead-contaminated dust The term "lead-contaminated dust" means surface dust in residential dwellings that contains an area or mass concentration of lead in excess of levels determined by the Administrator under this subchapter to pose a threat of adverse health effects in pregnant women or young children. (12) Lead-contaminated soil The term "lead-contaminated soil" means bare soil on residential real property that contains lead at or in excess of the levels determined to be hazardous to human health by the Administrator under this subchapter. § 2683 Identification of dangerous levels of lead Within 18 months after October 28, 1992, the Administrator shall promulgate regulations which shall identify, for purposes of this subchapter, and the Residential Lead-Based Paint Hazard Reduction Act of 1992 [42 U.S.C.A. § 4851 et seq.], lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil.

Table 18. Regulations of Federal Agencies Relevant to Workers' Family Protection

RULE/CFR NO.	AGENCY	DESCRIPTION OF RELEVANT ELEMENTS
Inorganic arsenic [29 CFR 1910.1000] (general industry) [29 CFR 1915.1018] (shipyards) [29 CFR 1926.1118] (construction)	OSHA	The PEL is 10 $\mu g/m^3$ as an 8-hr. average. Where employees work in areas where exposure concentrations exceed 10 $\mu g/m^3$ or where the possibility of skin or eye irritation from inorganic arsenic exists, the employer must provide clean protective work clothing weekly (daily if exposure levels exceed 100 $\mu g/m^3$). Protective clothing must be removed in change rooms and placed in a closed container prior to removal for cleaning, laundering or disposal. The container must be labeled and the launderer informed of the hazards. When exposures exceed 10 $\mu g/m^3$, the employer must provide showers and separate storage facilities for street and work clothes.
Asbestos [29 CFR 1910.1001] (general industry)	OSHA	PEL is 0.1 fiber/cc as an 8-hr. average. Excursion Limit (EL) is 1 fiber/cc as a 30-min. average. Where employees are exposed above these limits, or where the possibility of eye irritation exists, the employer must provide, and ensure: that the employee wears appropriate protective work clothing; that contaminated clothing is removed only in change rooms; that no employee takes contaminated work clothing out of the change room (except those authorized to do so for purposes of laundry, maintenance and disposal); that containers for contaminated clothing are labeled; that laundering is done in a way that will minimize release of fibers to the air; that the launderer be informed of the hazards; and that contaminated clothing be transported in sealed containers. The employer must provide facilities to assure that street clothes do not become contaminated if the employees' exposures exceed the PEL, that such employees shower at the end of the work shift and that they do not leave the workplace with any clothing or equipment worn during the work shift.
[29 CFR 1915.1001] (shipyards) [29 CFR 1926.1101] (construction)		In addition to the requirements for general industry, clothes of workers who work in certain regulated areas where the decontamination area and the shower cannot be located next to the regulated area, must be vacuumed with a HEPA vacuum cleaner before proceeding to the shower, or the employee must remove contaminated clothing in the equipment room and don clean work suits before proceeding to the shower. For other regulated areas, work clothing must be vacuumed before it is removed, but showering is not required.
Cadmium [29 CFR 1910.1027] (general industry) [29 CFR 1915.1027] (shipyards) [29 CFR 1926.1127] (construction)	OSHA	The PEL is 5 $\mu g/m^3$ as an 8-hr. average. If an employee is exposed above the PEL or where skin or eye irritation is associated with cadmium at any level, the employer must provide clothing and equipment that prevents contamination of the employee and the employee's garments. Contaminated clothing must be removed at the end of the work shift in change rooms which have separate storage facilities for street clothes and work clothes. The facilities must be designed to prevent contamination of the street clothes. The employer must assure that employees exposed above the PEL shower during the end of the work shift. The employer must assure that no employee takes contaminated protective clothing from the workplace, except when authorized to do so for laundry, cleaning, maintenance or disposal at an appropriate location or facility. Contaminated clothing must be stored in a closed container, and labeled. Launderers and cleaners must be informed of hazards.
Hazard Communication [29 CFR 1910.1200] (general industry) [29 CFR 1915.1200] (shipyards) [29 CFR 1926.59] (construction)	OSHA	These standards have elements that could be used for preventing workers' home contamination. These elements include: the written hazard communication which employers must prepare; the requirements that all containers of hazardous chemicals be labeled; the requirement for preparation of material safety data sheets containing information on applicable precautions for safe handling and use, including appropriate hygiene practices, work practices, or personal protective equipment; the requirement for employee information and training.
Hazardous Waste Operations and Emergency Response [29 CFR 1910.120] (general industry) [29 CFR 1926.65] (construction)	OSHA	These standards require a written safety and health program for employees involved in hazardous waste operations. Among the requirements are: use of appropriate protective equipment for each hazardous waste site; appropriate decontamination of all employees and contaminated clothing and equipment before leaving the area; location of the decontamination procedures to minimize cross-contamination; removal of protective clothing or equipment from the site only by authorized employees; advising laundries and cleaning establishments of the hazards of contaminated clothing; and provision of showers and change rooms outside of the contaminated area, when the need is indicated.