Ceramic Fibers (Respirable Size)

CAS No.: none assigned

Reasonably anticipated to be human carcinogens

First listed in the *Seventh Annual Report on Carcinogens* (1994)

Also known as refractory ceramic fibers

Carcinogenicity

Ceramic fibers of respirable size are *reasonably anticipated to be human carcinogens* based on sufficient evidence of carcinogenicity from studies in experimental animals.

Cancer Studies in Experimental Animals

Exposure of rats to ceramic fibers by inhalation caused benign or malignant lung tumors in rats of unspecified sex (IARC 1988). Since ceramic fibers (respirable size) were listed in the *Seventh Annual Report on Carcinogens,* additional studies in rodents have been identified. The induction of benign and malignant lung tumors following inhalation of ceramic fibers was confirmed in rats (adenoma, carcinoma, and histiocytoma) and also observed in hamsters (adenoma and carcinoma). In addition, mesothelioma of the pleural membrane was observed following exposure by inhalation in rats and male hamsters (Hesterberg *et al.* 1993, Rossiter and Chase 1995, McConnell *et al.* 1996, IARC 2002) and intrapleural injection in rats, and fibrosarcoma or mesothelioma of the peritoneum was observed following exposure by inhalation in rats and intraperitoneal injection in female hamsters and rats of both sexes (IARC 2002).

Cancer Studies in Humans

The data available from epidemiological studies are inadequate to evaluate the relationship between human cancer and exposure specifically to respirable ceramic fibers. Since ceramic fibers (respirable size) were listed in the *Seventh Annual Report on Carcinogens,* additional epidemiological studies have been identified. The International Agency for Research on Cancer (IARC 2002) concluded that the data available did not permit evaluation of the carcinogenicity of refractory ceramic fibers in humans, because the studies (Chiazze *et al.* 1997, Walker *et al.* 2002) were either preliminary or limited by small numbers. Since the IARC evaluation, a study of two refractory ceramic fiber manufacturing plants reported a significant threefold excess of urinary cancer (mainly urinary-bladder cancer) based on five deaths, but no excesses of lung cancer or mesothelioma (LeMasters *et al.* 2003).

Properties

Ceramic fibers comprise a wide range of amorphous or crystalline synthetic mineral fibers characterized by their refractory properties (i.e., stability at high temperatures) (IARC 1988). They typically are made of alumina, silica, and other metal oxides or, less commonly, of nonoxide materials such as silicon carbide. Most ceramic fibers are composed of alumina and silica in an approximate 50/50 mixture. By definition, monoxide ceramics, such as alumina and zirconia, are composed of at least 80% of one oxide; they generally contain 90% or more of the base oxide, and specialty products may contain virtually 100%. Nonoxide specialty ceramic fibers, such as silicon carbide, silicon nitride, and boron nitride, also have been produced. Because there are several types of ceramic fibers, such fibers exhibit a range of chemical and physical properties. Most ceramic fibers are white to cream in color and tend to be polycrystallines or polycrystalline metal oxides.

Use

Ceramic fibers are used as insulation materials, because of their ability to withstand high temperatures, and are used primarily for lining furnaces and kilns (IARC 1988, 2002). The products are in the form of blankets, boards, felts, bulk fibers, vacuum-formed or cast shapes, paper, and textiles. Their light weight, thermal-shock resistance, and strength make them useful in a number of industries. High-temperature resistant ceramic blankets and boards are used in shipbuilding as insulation to prevent the spread of fires and for general heat containment. Blankets, rigid boards, and semirigid boards can be applied to the compartment walls and ceilings of ships for this purpose. Ceramic blankets are used as insulation for catalytic converters in the automobile industry and in aircraft and space-vehicle engines. In the metal industry, ceramic blankets are used as insulation on the interior of furnaces. Boards are used in combination with blankets for insulation of furnaces designed to produce temperatures up to about 1,400°C. Ceramic boards are also used as furnace and kiln backup insulation, thermal covering for stationary steam generators, linings for ladles designed to carry molten metal, and cover insulation for magnesium cells and high-temperature reactors in the chemical-process industry. Ceramic textile products, such as yarns and fabrics, are used extensively in such end products as heat-resistant clothing, flame curtains for furnace openings, thermocoupling and electrical insulation, gasket and wrapping insulation, coverings for induction-heating furnace coils, cable and wire insulation for braided sleeving, infrared radiation diffusers, insulation for fuel lines, and high-pressure portable flange covers. Ceramic fibers coated with Teflon are used as sewing threads for manufacturing high-temperature insulation shapes for aircraft and space vehicles. The spaces between the rigid tiles on space shuttles are packed with this fiber in tape form. Ceramic fibers are also used for space-shuttle tiles and other heat shields in the aerospace industry (NIOSH 2006).

Ceramic fibers have consumer applications in the automotive industry, commercial and domestic appliances, commercial fire protection, and hobby furnaces. In the automotive industry, papers and felts containing ceramic fibers are used in catalytic converters, heat shields, air bags, brake pads, clutch facings, and shoulder-belt controls. Commercial and domestic appliances using ceramic-fiber insulation include pizza-oven and deep-fryer heat shields, toasters, self-cleaning ovens, wood stoves, home-heating furnaces, gas hot-water heaters, and simulated fireplace logs. In commercial fire protection, ceramic fibers are used in grease-duct insulation and penetration and expansion-joint seals. They are also used in hobby furnaces, such as ceramic pottery and glass-enameling kilns and blacksmith forges (Venturin *et al.* 1997, NIOSH 2006).

Production

Ceramic fibers are produced by blowing and spinning, colloidal evaporation, continuous filamentation, and, to a lesser extent, whisker-making technologies (vapor-phase deposition used mainly for special applications). Although production of ceramic fibers began in the 1940s, they were not used commercially until the early 1970s (IARC 1988). Worldwide production of ceramic fibers in the early to mid 1980s was estimated at 154 million to 176 million pounds, with U.S. production accounting for about half. U.S. production was estimated at 85.7 million pounds in 1990 and 107.7 million pounds in 1997 (NIOSH 2006). In 2004, U.S. production by four major producers had fallen to 80 million pounds, accounting for 1% to 2% of worldwide production. No data specific to U.S. imports and exports of ceramic fibers were found.

Exposure

The routes of potential human exposure to ceramic fibers include ingestion and dermal contact; however, the primary route of exposure is inhalation during their manufacture, processing, and end use. Manufactured mineral-fiber products release airborne respirable fibers during their production and use. The upper-diameter limit for respirable fibers is considered to be 3 or 3.5 μm. In three refractory ceramic fiber manufacturing facilities, about 90% of airborne fibers were determined to be respirable (< 3 μm in diameter), and about 95% were less than 50 μm long (NIOSH 2006). It was estimated that 31,500 workers potentially were exposed to refractory ceramic fibers during their manufacture, processing, and end use, of whom only about 800 were involved in the manufacturing process (Rice *et al.* 2005).

In the U.S. manufacturing sector, the workplace time-weighted average (TWA) air concentration of refractory ceramic fibers was 10 fibers/cm^3 in the 1950s, decreasing to 0.05 to 2.6 fibers/cm^3 by the 1970s. Concentrations in the 1980s ranged from the level of detection to 0.66 fibers/cm^3. Average TWA exposures were 0.31 fibers/cm^3 between 1993 and 1998 and 0.2 fibers/cm^3 between 2002 and 2006. End users were exposed to refractory ceramic fibers at higher concentrations than were manufacturing workers; average air concentrations for end users were 0.56 fibers/cm^3 between 1993 and 1998 and 0.1 fibers/cm^3 between 2001 and 2005. TWA air concentrations were highest for workers engaged in removal of refractory ceramic fibers, averaging 1.92 fibers/cm^3 between 1993 and 1998, but decreasing to 1.27 fibers/cm^3 between 2001 and 2005. Starting in 2002, respirator use was required during the removal process; between 2002 and 2006, the average TWA concentration adjusted for respirator protection was 0.28 fibers/cm^3, much lower than the measured ambient concentration. The respirator-use rate was low for job categories with lower measured ambient concentrations of refractory ceramic fibers and higher in workplaces with high ambient concentrations (NIOSH 2006, Maxim *et al.* 2008). A study conducted among Ontario construction workers found that 40% of the measured ambient exposure concentrations exceeded the American Conference of Governmental Industrial Hygienists threshold limit value–TWA recommended concentration of 0.2 fibers/cm^3, indicating the need for additional controls, such as adequate ventilation and the use of respirators (Verma *et al.* 2004).

Regulations

Environmental Protection Agency (EPA)

Clean Air Act

National Emission Standards for Hazardous Air Pollutants: Fine mineral fibers are listed as a hazardous air pollutant.

Occupational Safety and Health Administration (OSHA, Dept. of Labor)

This legally enforceable PEL was adopted from the 1969 United States Department of Labor regulation *Safety and Health Standards for Federal Supply Contracts* shortly after OSHA was established. The PEL may not reflect the most recent scientific evidence and may not adequately protect worker health.

Permissible exposure limit (PEL) = 15 mg/m^3 total fibers; = 5 mg/m^3 respirable fibers (based on the standard for "particles not otherwise regulated").

Guidelines

American Conference of Governmental Industrial Hygienists (ACGIH)

Threshold limit value – time-weighted average (TLV-TWA) = 0.2 respirable fibers/cm^3 for refractory ceramic fibers.

National Institute for Occupational Safety and Health (NIOSH, CDC, HHS)

Recommended exposure limit (REL) = 0.5 fiber/cm^3) (10-h TWA).

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