Environmental Health Newsletter
Recognition, Evaluation & Control

Issue 7 3rd Quarter 2011

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Man-Made Mineral Fibers

Man-made mineral fibers, also known as man-made vitreous fibers, are a group of manufactured materials made from raw mineral products such as sand, rocks and clays. These materials are melted and spun or blown into continuous streams forming fibers that can be used in a wide range of products. Various health effects are attributed to these materials and toxicology depends on the type of fiber and the raw products used in their manufacture.

History
The Egyptians are reported to have used glass fibers in ancient times for decorative purposes. Patents for modern methods of production began in the late 1800's with the commercial use in the early 1900's. Widespread use of these materials began in World War I when German supplies of asbestos were cut off during the allied blockade. Production expanded dramatically by the 1950's and ceramic fibers were developed by the 1970's. Because of the adverse health effects from exposure to asbestos, which is a naturally occurring mineral fiber, man-made mineral fibers came into wide use by the late 1970's.

Use and Classification
The major uses of man-made mineral fibers are as thermal insulating materials. They are also used for acoustical insulation, ceiling tiles, fiber optics, industrial fabrics, filtration devises, electrical insulation, gaskets and seals and for reinforcement in rubber and plastics production as well as in roofing materials.

Man-made mineral fibers are divided into three classes depending on their composition and how they are manufactured. These are:

- Fibrous Glass
- Mineral Wool
- Refractory/Ceramic Fibers

Fibrous glass also known as fiberglass includes glass wool. These materials are composed of oxides of silicon, calcium, sodium, potassium, aluminum and boron. The raw ingredients used in making fibrous glass are silica sand, limestone, boron oxide and glass fragments.

Fibrous glass is made in a two part process. In the first process raw materials are melted and glass marbles are produced. In the second process these marbles are re-melted and are extruded or spun into fibers.

Mineral wool is derived from molten rock, or from molten slag produced in iron, steel or copper production. About 70% of the mineral wool in the U.S. is produced from blast furnace slag. Mineral wool is sometimes called rock wool or slag wool depending on which of these materials it is made from. The main components of mineral wool are oxides of silicon, calcium, magnesium, aluminum and iron.

Mineral wool is produced in a cupola furnace where raw materials are layered with coke. The combustion of the coke melts the raw ingredients which are then discharged in a stream and are fiberized by blowing and spinning in the same way that fibrous glass is made.

Refractory ceramic fibers encompass a wide variety of materials made from clay, oxides of aluminum, silicon or other metal oxides. Due to their ability to withstand high temperatures, they have been used as an asbestos replacement in many applications. Production of ceramic fibers includes blowing and spinning methods like those in the production of fibrous glass and mineral wool. Additional methods include colloidal evaporation where mixtures of ingredients in a colloidal suspension are evaporated or through vapor-phase deposition.

After these types of fibers are produced, there are a number of secondary processes that are linked to the final products. These include the addition of dust suppression agents such as oils or waxes. These are present in almost all insulation wools. Binders and resins may also be added depending on the final product.

Health Effects

We all have probably used fiberglass insulation at some time and have encountered the skin irritation caused by the glass fibers. Skin irritation is generally associated with fibers with diameters of 4.5 to 5 microns. These are the common size of fibers found is insulation wools and filamentous fibers. The irritation is mechanical in nature rather than chemical so irritant dermatitis is generally not severe and long lasting.

To understand respiratory hazards of exposure to man-made mineral fibers, a little background information is necessary. Many of the ingredients in man-made mineral fibers are a silicosis hazard is raw form. These include clays, silica sand and rocks and minerals. This is because they are in a crystalline form. Once these materials are melted, they become amorphous or glass like without any crystalline structure. This eliminates the silicosis hazard. Since loss control will be dealing with these products in final form, there is no need to worry about this hazard except for used refractory ceramic fibers which we will discuss in more detail later.

The human airway is composed of a series of branching tubes which decrease in size and diameter until the alveoli are reached deep within the lung. The alveoli are small thin walled sacs where gas exchange with the bloodstream takes place. Particles are deposited within this system according to size with the largest particles deposited in the upper airway while smaller particles go deeper into the lung with the smallest particles deposited in the alveoli. The body has a number of particle removal mechanisms which include mucous membranes in the upper airway and scavenger cells called macrophages deeper in the lung. These macrophages engulf and digest particles with powerful enzymes or move particles to the lymphatic system for clearance. Large particles deposited in the upper airways are more efficiently cleared than small particles deposited deep in the lungs.

Fibers are classified as particles that have length to diameter (aspect ratio) greater than 3:1. The problem with fibers is because of their shape; they can align parallel with the airstream and pass deep into the lungs. As the ratio of fiber length to diameter increases, fiber length begins to affect the properties of fiber inhalation and deposition in the alveoli. Fibers longer than 200 to 250 microns are filtered out in the upper airways. Fibers longer than 60 microns are only very rarely found in the alveoli. Recent studies show that fibers with a length equal or greater than the diameter of a lung macrophage (15 microns) pose the highest risk.

Asbestos is a natural mineral fiber that has a long history as a respiratory hazard causing cancer and mesothelioma. Since made – man mineral fibers have similar aspect ratios as asbestos, numerous studies have been carried out to see if there are similar long term health effects with exposure to man-made mineral fibers.

Studies have shown that glass fibers have low toxicity in humans and in animals. Studies have shown that mineral wool can cause cancer in animals. These studies have been very controversial. Cancer was found in animal studies where the fibers were injected into the pleural cavity. Injection studies are commonly used to assess toxicological properties of chemicals but they bypass natural defense mechanisms in the lungs and do not correlate with actual routes of exposure. Results from these studies are questionable.

Inhalation studies have found that ceramic fibers cause fibrosis, lung cancer and mesothelioma in animals. One of the main reasons hypothesized why asbestos causes cancer and mesothelioma is due to the durability of the fibers once they are deposited in the lungs. Studies have shown that asbestos fibers are very stable while glass fibers are dissolved by physiologic solutions in the lung. These studies have shown that ceramic fibers are more durable than glass or mineral wool fibers and this may be the cause of their increased potential for causing mesothelioma.

Ceramic fibers are used for thermal insulation in furnaces, crucibles and other high temperature applications. Studies have shown that high temperatures over 1700°F convert the ceramic material from an amorphous to a crystalline structure, specifically cristobalite which is a form of crystalline silica. Although ceramic refractory materials don't contain silica and are not a silicosis hazard, this conversion poses a silicosis risk for employees replacing or repairing furnace and other high temperature linings made from ceramic fibers.

Exposure Limits

The exposure limits for man-made mineral fibers depend on the type of material. Based on their effects as irritants, the ACGIH (American Conference of Governmental Industrial Hygienists) TLV (Threshold Limit Value) for continuous glass filament fibers is 1 f/cc (fiber per cubic centimeter) as a time weighted average for respirable fiber. Respirable fibers are those with length over 5 microns and an aspect ratio greater than 3:1.

The ACGIH TLV for glass wool, rock wool, slag wool and special-purpose glass fibers is also 1 f/cc as a time weighted average as a respirable fiber. The ACGIH also classifies these materials as confirmed animal carcinogens.

Long term studies have shown that ceramic fibers cause lung cancer and mesothelioma in animals. The ACGIH TLV for ceramic fibers has been established at 0.2 f/cc as a time weighted average for respirable fiber as a consequence of this increased hazard. Study periods for exposed workers have been insufficient to confirm carcinogenic effects, so ceramic fibers are classified as a suspected human carcinogen by the ACGIH.

OSHA is way out of date with the latest studies on the health effects of man-made mineral fibers and they do not differentiate between the various forms of these materials. They are treated as nuisance dust with a PEL (Permissible Exposure Limit) of 5 mg/m^3 for the respirable fraction and 15 mg/m^3 as total dust. In light of the more recent information used for establishing the exposure limits used by the ACGIH, the TLVs should always be used as the basis for hazard evaluation and risk.

Control

Man-made mineral fibers are most likely to be encountered in construction where these materials are widely used as insulating material. Fiber glass is also used to make fiberglass bodies of cars and boats as well as other equipment where a lightweight durable material is required. Factors such as the presence of binders and resins will also have an impact on potential exposures. Employees should be provided with disposable particulate respirators (dust masks). Due to skin irritation, disposable clothing and gloves should also be worn. Exposure monitoring may be applicable if there are questions about actual exposure levels. Contractors who are involved with demolition may need to take extra precautions since other dusts may be present that contain lead, asbestos and silica. A good rule of thumb in construction is that if dust is being generated during a construction activity, respirators should be worn.

Operation such as cutting, sanding and drilling of products containing man-made mineral fibers can also produce dust. Control through the use of tools with dust capture systems and hoods incorporated into the tools are often the best solution. Spraying surfaces with water reduces fiber generation. Housekeeping practices such as use of HEPA vacuums instead of dry sweeping can also reduce potential exposure.

As mentioned previously, ceramic fibers are converted to crystalline silica at high temperatures associated with furnaces, ovens, ladles and other applications. Maintenance staff may be involved with relining and repairs of this equipment land exposures can be extremely high. Respiratory protection should always be used in these situations and dust control methods such as wetting surfaces should also be implemented.

Bakers' Asthma

One doesn't normally think of environmental health hazards when looking at food industries but there are some significant exposures. One of the most common diseases in food industries is Baker's asthma. Respiratory disease associated with grain and flour dust exposure was reported as long ago as 1713 when Ramazzini wrote De Morbis Artificum (Diseases of Workers). Ramazzini noted that grain handlers almost all had shortness of breath and rarely reached old age. By the early 1900's the concept of Bakers' asthma and association with wheat and soybeans was clearly established.

Asthma is a disease characterized by airway hyperresponsiveness caused by the interaction of the body's immune system with a chemical or protein. Allergic sensitization develops over a 1-3 year latency period when the body develops antibodies to the specific chemical or protein agent (antigen). After sensitization occurs, exposure to the antigen elicits the release of histamines and other chemicals by the immune system that causes bronchial inflammation and constriction of air passages in the lungs.

In the food processing industries occupational asthma is caused by exposure to proteins. Employees who have existing allergies such as food allergies, dog or cat allergies, hay fever, etc, are most likely to develop occupational asthma.

There are many causes of asthma and in the past each was given a different name based on the exposure or occupation where the condition developed. In the case of asthma where flour is handled the asthma was called "Bakers' Asthma". If asthma developed in a grain mill it was called grain handlers disease, etc.

Bakers' Asthma is defined as allergic sensitivity to inhaled flour dust. Numerous allergens associated with grain and enzymes added as dough improvers are thought to be the cause. The allergens include gluten, grain storage mites, grain weevils, and molds. Wheat, soy, rye and barley flour can cause the disease. Studies have shown that 10-30% of bakers are sensitized to flour. In most cases the sensitivity is only identified through blood tests and is not manifested into full blown asthma.

Bakeries and other food processing operations where grain or flour are used or processed pose a risk for Baker's Asthma. Areas where dry flour is weighed and dumped from bags into mixers usually pose the highest risk for the disease.

Health Effects
Bakers' asthma is characterized by a latency period between exposure and development of symptoms. Latency can range from a few weeks to 35 years. Studies have found that the average latency period is 8 to 9 years of exposure and asthma within 13 to 16 years. Early symptoms include cough, shortness of breath, wheezing, eye irritation, rhinitis, and dermatitis. Symptoms are worse at work with improvement on weekends and over vacations. Once sensitized, only small amounts of flour dust can provoke an asthma attack.

Exposure Limits
The ACGIH TLV for flour dust is 0.5 mg/m^3 as inhalable dust. The ACGIH has also given flour the sensitizer designation. OSHA uses the grain dust PEL of 10 mg/m^3 for evaluation of flour exposures. It is recommended that the TLV be used as the control level for flour dust since the OSHA PEL is outdated.

Controls
Prevention of Bakers' Asthma involves control of dusts associated with grain and flour. Local exhaust ventilation hoods where flour is dumped into mixers and blenders is the usual control method. When dust cannot be controlled, respirators should be used. Disposable type N95 respirators (dust masks) provide adequate protection in most situations. Housekeeping is an important component to an effective control program. Dust on floors and equipment should be minimized by regular cleaning. Dry sweeping should be avoided and HEPA vacuums should be used instead. Often, one of the greatest exposures is from handling empty bags after dumping flour. Ideally, bags should be rolled up of folded in a hood so dusts emanating from the bags are collected.