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Chrysotile asbestos exposure in the manufacturing of thermal insulating boards

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Abstract Exposure to asbestos fibers has been extensively studied in milling, mining of asbestos fibers, and in industries manufacturing asbestos—cement sheets, pipes, etc. However, very few studies have been reported in asbestos textiles, brake lining workers, and insulation products. In the present investigation, chrysotile exposure monitoring was carried out in a small thermal insulating boards manufacturing facility. Twenty-eight samples were analyzed from various locations like feeding of raw materials, weighing, pressing, machine grinding, and hand finishing of final products. Twenty-five percent of the samples were found to be above ACGIH TLV of 0.1 fibers per milliliter. However, mean fiber concentrations were found to be lower than 0.1 fibers per milliliter, except for the process of feeding of raw materials where the mean fiber concentration was 0.1087 ± 0.0631 fibers per milliliter.

Keywords Chrysotile asbestos · Thermal insulating board · Membrane filter method · Phase contrast microscope

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Introduction

It is well known that asbestos fibers, when inhaled, cause a lung disease called asbestosis (WHO 1986; Walton 1982; Dave et al. 1996; Dave and Beckett 2005; Algranti et al. 2001; Churg and Vedal 1994; Churg et al. 1993; Kilburn and Warshaw 1994), mesothelioma and lung cancer (Saitoh et al. 1993; Berry 1991; Churg 1985; DeKlerk et al. 1991; Lippman 1988). Asbestos is a fibrous mineral occurring in natural deposits. Asbestos fibers are divided into two classes, serpentine and amphibole, on the basis of their crystal structure (WHO 1986; Walton 1982). Chrysotile is a fibrous hydrated magnesium silicate mineral [$Mg_3Si_2(OH)_4$] belonging to the serpentine group, which is used in about 3,000 commercial products. Presently, the exposure to asbestos fibers is controlled in developed countries and pressure has started mounting in the developing countries to control exposure to asbestos (Ramanathan and Subramanian 2001; Rotterdam Convention 2004). Chrysotile, the commercial variety of asbestos, is known to cause mesothelioma (Lemen 2004; Nicholson 2001). Chrysotile accounts for over 95% of the world production and is exploited in more than 40 countries. The most important products based on chrysotile fibers are asbestos cement (AC) sheets, AC pipes, vinyl asbestos floor tiles, brake linings and clutch facings, thermal and electrical insulation boards, asbestos textiles, asbestos ropes, asbestos paper and felt, etc. The products classified as asbestos paper and felt range from thin paper to 1-cm-thick board, which may contain up to 97% asbestos (WHO 1986). Manufacturing of chrysotile products is undertaken in more than 100 countries and production is about 27 to 30 million tons annually. India consumes about 0.1 million tons of chrysotile every year, mostly imported from Canada, Brazil, Kazakhstan, Russia, and South Africa (Allen 2005; Ansari et al. 2007). Mostly wet processes are used in manufacturing all the products except textile products. Dave and Beckett (2005) reported that in India, there are nearly 673 small-scale asbestos mining and milling facilities and 33 large-scale asbestos manufacturing plants, of which 17 are manufacturing AC products and 16 are manufacturing non-AC products.

A lot of work has been reported in asbestos cement sheets, pipe manufacturing, milling, and mining of asbestos fibers (Mukherjee et al. 1992; Dave et al. 1996; Rees et al. 2001; Ramanathan and Subramanian 2001; Ansari et al. 2007; Bhagia et al. 1994), but very few studies have been reported in asbestos textiles, brake lining workers (Erdinc et al. 2003; Rohl et al. 1976), and insulation products. In the present investigation, chrysotile exposure monitoring was carried out in a small thermal insulating boards manufacturing facility. Thermal insulating boards have various applications in industries like top plates and support blocks on high-frequency induction furnaces, barriers, oven, furnace linings, laboratory tabletops, as a core plate in foundries, etc.

Methods and materials

Manufacturing process

High-temperature thermal insulating boards (sometimes called, syndania sheets) are manufactured by mixing chrysotile fibers (22%) and cement (78%). A mixture is weighed and water is added to the mixture for making slurry. Slurry is transported manually in buckets to the machine where it is pressed with the weight of 175 kg for half an hour. After removing the sheet, surface grinding is done by the machine. Final finishing is done manually by hand grinding. All the processes are shown in Fig. 1. The curing of boards is done for 24 h. The size of the boards is usually 100 × 120 cm and 4 × 3 ft, and thickness varies from 0.3 to 5 cm. As per the product catalogue of the manufacturer, the weight per sheet of 100 × 120 cm varies from 7.8 kg for 3-mm thickness to 122 kg for 50-mm thickness. These boards are designed to withstand the temperatures up to 350°C. Density of the boards is 1.90 gm/cc. The cross-breaking, shear, and crushing strengths are 4.90, 3.5, and 14.50 kg/mm^2, respectively.

Exposure

During a preliminary visit of the facility, manufacturing process was studied in detail to select sampling locations where an exposure to asbestos can occur. It was decided to carry out sampling at feeding of raw materials, weighing and slurry making, pressing, machine grinding of surface of the board, and hand finishing of final products.

Sample size

Sample size is vital because it relates directly to the confidence that can be placed in the resulting estimate of airborne concentration of the contaminant. The effects of sample size on requirements for demonstrating noncompliance have been illustrated by plotting approximate mean to standard ratio versus number of samples (Soule 1978). It has been reported that the curves for geometric standard deviations of 1.5 to 2.5 change slowly after the sample size of seven. These curves also show that mean exposure concentration must exceed the standard by unreasonably large amounts to demonstrate noncompliance when less than four samples are obtained. Therefore, it can be concluded that optimum sample size should be between 4 and 7. Further, it has been reported that for measurement of asbestos fibers, at least five random samples of 1-h duration should be taken (BIS 1986). Considering all these facts, it was decided to obtain six 1-h consecutive samples spread throughout the shift from all locations. Since the samples were consecutive and spread throughout the shift, it is unlikely that peak exposures will be missed.

Fig. 1 Manufacturing process for thermal insulating boards. **a** Feeding of raw materials, **b** Weighing and slurry making, **c** Pressing, **d** Machine grinding, **e** Hand finishing

Sampling and analysis

As suggested by NIOSH (1994) and BIS (1986), membrane filter method was used. In this method, a known volume of air is drawn from work environment with a constant flow rate of 1 l per minute. The duration of sampling for each sample was 1 h. Fibers are collected on cellulose ester membrane filters (Millipore) having diameter 25 mm and a pore size of 0.8 μm. For calculation purpose, an effective diameter of the filter (23 mm) was considered. Battery-operated personal samplers supplied by SKC were used (model PCXR4). Personal samplers were calibrated for flow rates before sampling by gas flow calibrator (UltraFlow, SKC). One filter blank was selected from the batch and was subjected to the same treatment as other filters, but without having air drawn from it. Filter holders with cowl (SKC preloaded cassette 225-321 A) were kept in downward position during sampling to avoid the contamination of heavy particles on filters. Samples were collected from breathing zone of workers by attaching filter holder with personal sampler to them. The collected samples along with sample holders were stored in upward position in sealed boxes and transferred to the laboratory for further analysis. Transparent slides were prepared by acetone–triacetin method (NIOSH 1994). Phase contrast microscope (Olympus, CX 41-TR) at a magnification of ×400 with Walton-Becket graticule (G 22) was used to count fibers having length >5 μm, width <3 μm, and having an aspect ratio of greater than 3:1. NIOSH method 7400 with A fiber counting rules was used. One hundred graticule areas were counted which were spread throughout the filter by zigzag method. Walton–Becket graticule was calibrated with stage micrometer slide.

Calculations

The fiber concentration, C, in fibers per milliliter for each single sample, is determined by the following formula:

$$C = (A/a) \times (N/n) \times (1/rt)$$

where C is the fiber concentration (fibers per milliliter), A the effective filter area (in square millimeters), a the graticule area (in square millimeters), N the total number of fibers counted, n the number of graticule areas counted ($n = 100$), r the flow rate (in milliliters/minute), and t the single sample duration (minutes).

LOD and LOQ

Limit of detection (LOD) for PCM analysis is 5.5 fibers/100 fields and limit of quantitation (LOQ) is 80 fibers/100 fields (NIOSH 1994). Effective filter area in our case is 379.94 mm^2, whereas field area is 0.0113 mm^2 with a graticule diameter of 120 μm. Sample volume is 60 l. LOD and QOD are calculated using the equation for fiber concentration and are found to be 0.03 and 0.45 fibers per milliliter, respectively.

Results and discussion

Table 1 shows fiber concentrations in different processes like feeding of raw materials (0.1087 ± 0.0631), weighing of raw materials and slurry making (0.0571 ± 0.0255 fibers per milliliter), pressing of the boards (0.0656 ± 0.0378 fibers per milliliter), machine grinding of the boards (0.0817 ± 0.0437 fibers per milliliter), and hand finishing (0.0451 ± 0.0257 fibers per milliliter). The highest concentration of 0.1681 fibers per milliliter was found in feeding of raw materials. Blank filter did not show any fibers in 100 graticule areas. Table 1 also shows the number of samples for all operations. As mentioned earlier, six samples were collected from all selected locations. However, two samples from feeding were spoiled by accident during slide making, leaving a total of 28 samples for counting of fibers. The threshold limit value (TLV) for exposure to chrysotile fibers is 0.1 fibers per milliliter (ACGIH 2008). Out of a total of 28 samples, 25% of the samples were found to be above ACGIH TLV of 0.1 fibers per milliliter. The average fiber concentrations are below the ACGIH standard except in the process of manual feeding of raw materials. However, out of 28 samples, seven samples (25%) were above 0.1 fibers per milliliter.

The highest (mean) fiber concentration was observed in manual feeding of raw materials. This may be due to the fact that feeding of raw materials is a dry process where dust/fiber becomes airborne easily. The lowest concentration of fibers was found in hand finishing of thermal boards. This process is also dry, but since fibers are fixed in thermal insulating boards (crushing strength

Table 1 Fiber concentrations (fibers per milliliter) for different processes in the manufacturing of thermal insulating boards

Process	Mean fiber conc. (mean ± SD)	Range
Feeding of materials	0.1087 ± 0.0631 (4)	0.0341–0.1681
Weighing/ Slurry making	0.0571 ± 0.0255 (6)	0.0571–0.0812
Pressing	0.0656 ± 0.0378 (6)	0.0383–0.1220
Machine grinding	0.0817 ± 0.0437 (6)	0.0289–0.1384
Hand finishing	0.0451 ± 0.0257 (6)	0.0189–0.0783

Figures in the parenthesis indicate number of samples

−14.50 kg/mm^2), chances of a fiber becoming airborne are minimized. Pressing is a wet process where slurry is pressed. Here, again, the chances of fibers becoming airborne are minimized as the process is wet. Machine grinding, where there is increased potential for exposure to chrysotile fibers, has a powerful local exhaust system with bag filters (Fig. 1d). The facility where this survey was carried out was very small, having only 11 workers. No case of asbestosis was reported as per factory medical records. All the workers were provided necessary masks, but the masks were not NIOSH-approved. Hence, management should ensure that all the workers wear NIOSH-approved respirators. Housekeeping was poor and needs improvement. Local exhaust system should be periodically checked for leaks in ducts and bag filters.

Conclusions and recommendations

The average fiber concentrations in all the processes were found to be below 0.1 fibers per milliliter except feeding where the mean fiber concentration was 0.1087 fibers per milliliter. But this does not mean that the disease will not occur in the future. Mesothelioma or lung cancer may occur years after a person has stopped working in a factory where there is asbestos exposure. In India, we do not have any infrastructure to track workers after their retirement. The management should ensure that all the workers wear NIOSH-approved respirators and should properly maintain dust control system. Housekeeping of the facility needs improvement. The management should train supervisors in safe methods of work. It is essential that people with supervisory responsibility ensure that proper, safe methods and systems of work are always in place and used.

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