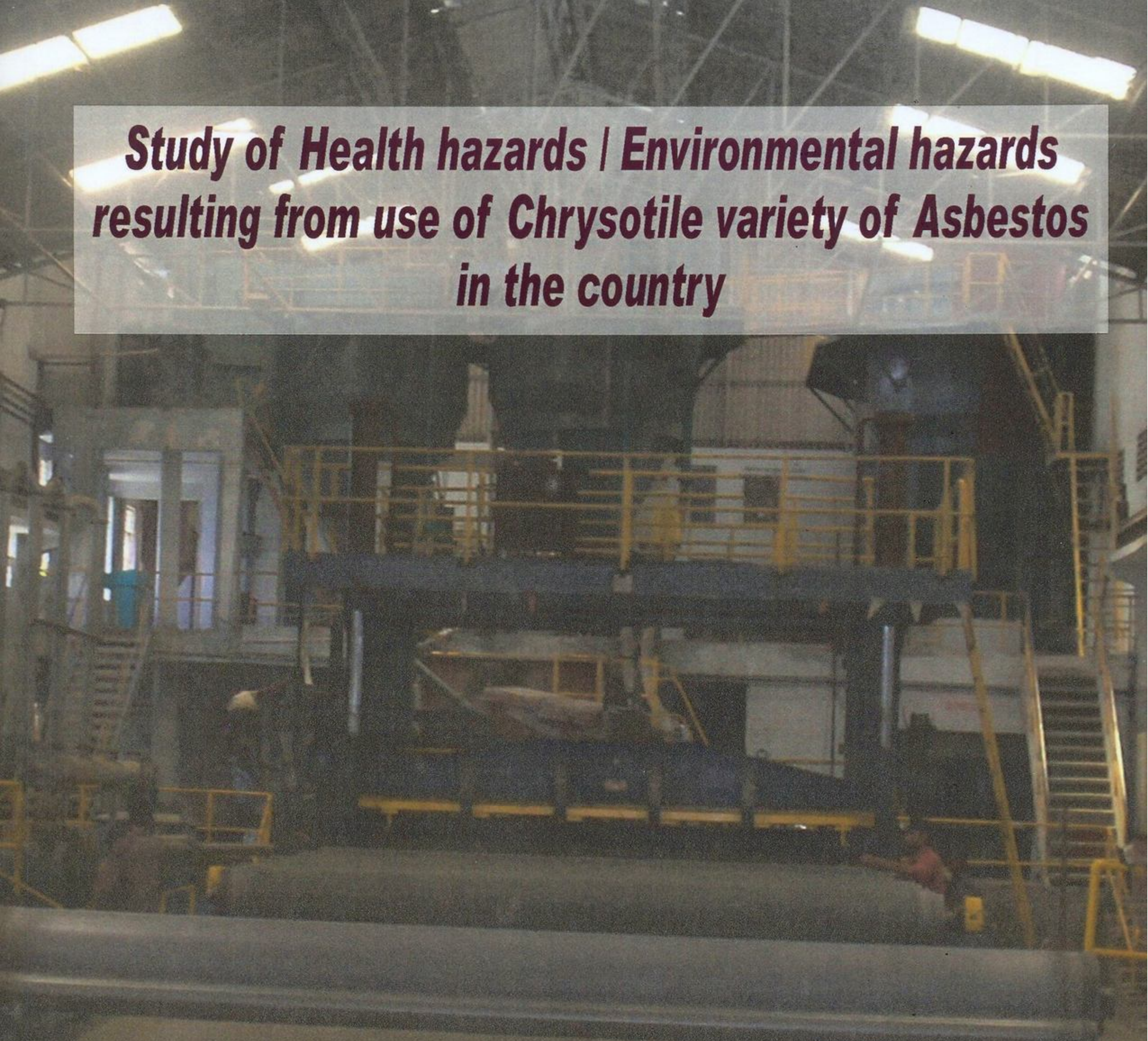
Study of Health hazards / Environmental hazards resulting from use of Chrysotile variety of Asbestos in the country



National Institute of Occupational Health

(Indian Council of Medical Research)

Meghaninagar, Ahmedabad - 380 016

MINISTRY OF CHEMICALS AND FERTILISERS, GOVT. OF INDIA

SPONSORED PROJECT

Study of Health hazards / Environmental hazards resulting from use of Chrysotile variety of Asbestos in the country

NATIONAL INSTITUTE OF OCCUPATIONAL HEALTH,

(INDIAN COUNCIL OF MEDICAL RESEARCH)

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FOREWORD

The name 'Asbestos' represents a group of minerals that have been used by human civilization for many purposes since long. Asbestos has frequently been a matter of concern for its adverse health impact and consequently its use has been questioned repeatedly. Burden of asbestos related diseases, pattern of use in different nations, possibility of safe controlled use of asbestos, safety of alternatives are being discussed in different spheres with great concern and scientific community is debating on the issue with the dual objective of protecting human health and meeting the needs of human civilization.

The National Institute of Occupational Health had conducted studies on workers engaged in different asbestos handling units. The health effects of asbestos exposure being well documented, this contribution includes work environmental exposure assessment and associating it to screening of health status of the workers in selected asbestos handling units from both organized and unorganized sectors.

PK Nag
Director

Background

A request from the Department of Chemicals and Petrochemicals, Ministry of Chemicals and Fertilizers, Govt. of India was received regarding carrying out a survey in relation to the hazards resulting from use of Chrysotile variety of asbestos in the country. The Ministry viewed that the study is required in the context of ongoing developments under the Rotterdam Convention to bring this chemical in the Prior Informed Consent (PIC) ambit. Further, it was stressed that a study may include all segments of the industry at workplace as also in the vicinity and the small scale sectors. Accordingly, the scientists of NIOH in consultation with the concerned officials of the Ministry of Chemicals and Fertilizers decided to carry out an environmental cum epidemiological study on selected settings.

Asbestos and its health hazards

Asbestos is a collective name given to a group of minerals that occur naturally as fiber bundles and posses high tensile strength, flexibility and chemical and physical durability. Asbestos is hydrated silicates with complex crystal structures and consists of two basic mineral groups, serpentine and amphibole.

Chrysotile (serpentine asbestos), the most abundant form of asbestos, is a sheet silicate composed of planar- linked silica tetrahedral with an overlying layer of brucite. It occurs naturally in fiber bundles of varying length (several mm to more than 10 cm)[1]. Chrysotiles [$Mg_3Si_2O_5(OH)_4$] may be white, gray, green, or yellowish, with a silky luster. Although chrysotile fibers are more flexible than the amphiboles, fibers from different geological locations may differ in flexibility. Chrysotile fibers have a net positive surface charge and form a stable suspension in water. These fibers degrade in dilute acids[2,3,4].

The amphibole group of asbestos includes crocidolite, amosite, anthophyllite, tremolite and actinolite varieties. Amosite is ash gray, greenish, or brown and is somewhat resistant to acids. It occurs as long, straight, coarse, and somewhat flexible fibers (less flexible than chrysotile or crocidolite) and may contain relatively more iron than magnesium. Anthophyllite is grayish white, brown-gray, or green and is very resistant to acids. It is relatively rare and occasionally occurs as a contaminant in talc deposits. These fibers are short and very brittle. Crocidolite is lavender or blue and has good resistance to acids, but less heat resistance than other asbestos fibers. Fibers typically are shorter and thinner than those of other amphiboles, but not as thin as chrysotile. Crocidolite usually contains organic impurities, including low levels of PAHs[2,3,4]. Tremolite is a calcium-magnesium amphibole and actinolite is an iron-substituted derivative of tremolite. Tremolite is white to gray, and actinolite is pale to dark green. Both are brittle; tremolite is resistant to acids, but actinolite is not[3, 4].

Chrysotile use today mainly involves products where it is incorporated into matrices. Chrysotile asbestos has been used in roofing, insulation, pipe and other moulded goods, gaskets, friction materials (brake linings, clutch facings) etc.[5,6]. Asbestos-cement industries manufacturing corrugated and flat sheets, moulded goods, pipes etc. are the major consumers of asbestos worldwide, accounting for about 85% of all use. These products contain 10-15% of asbestos[7].

Human exposure to asbestos may occur mainly during mining-milling of asbestos, manufacturing of asbestos products and cutting-fitting of end products. While manufacturing asbestos products chance of asbestos exposure may be relatively more during feeding of asbestos fibres to prepare mix and also during blending of the mix. The nature of the product, level of preventive measures and local work practices determine exposure. Non-friable products and appropriate technological controls may reduce fibre release. Manipulation of friable products without technological controls may release high levels of fiber.

Asbestos fibers when breathed in may get trapped in the lungs and may remain there for a long time. Over time, these fibers can accumulate and cause scarring and inflammation, which can affect breathing and lead to serious health problems[8]. Asbestos has been classified as a known human carcinogen (a substance that causes cancer) by the U.S. Department of Health and Human Services, the EPA, and the International Agency for Research on Cancer [9-12]. Studies have shown that exposure to asbestos may increase the risk of lung cancer and mesothelioma (a relatively rare cancer of the thin membranes that line the chest and abdomen). Although rare, mesothelioma is the most common form of cancer associated with asbestos exposure. In addition to lung cancer and mesothelioma, some studies have suggested (though inconclusively) an association between asbestos exposure and gastrointestinal and colorectal cancers, as well as an elevated risk for cancers of other organs like oesophagus, gallbladder etc.[12,13]. Asbestos exposure may also increase the risk of asbestosis (a chronic lung disease that can cause shortness of breath, coughing, and permanent lung damage) and other nonmalignant lung and pleural disorders, including pleural plaques (changes in the membrane surrounding the lung), pleural thickening, and pleural effusions (abnormal collections of fluid between the thin layers of tissue lining the lung and the wall of the chest cavity). Although pleural plaques are not precursors to lung cancer, evidence suggests that people with pleural disease caused by asbestos exposure may be at increased risk for lung cancer[14].

The occurrence of health effects of asbestos exposure also depends upon the type of asbestos used. While the occurrence of asbestosis, lung cancer and mesothelioma is widely reported with the use of amphibole variety there are inconclusive reports about the serpentine variety. The serpentine variety is a thin walled sheet silicate while the amphiboles are double chain silicates. These different chemistries result in chrysotile clearing very rapidly from lungs (11 days) while amphiboles are among the slowest clearing fibres (500 days)[15]. Due to these reasons some of the studies carried out among groups exposed to chrysotile asbestos concluded that it does not appear to contribute to the lung cancer burden[16] or excess mortality[17]. The dose and duration of exposure also plays an important role in the occurrence of clinical effects. A median exposure of 10-20 fibre years does not seem to cause an increased risk of lung cancer, particularly when chrysotile is used[18]. Moreover progressive improvement in occupational hygiene in a developing country is likely to reduce the risk of non-malignant consequences of dust inhalation in chrysotile miners and millers[19].

Asbestos exposure when combined with exposure to other toxicants may increase risk of carcinogenesis. Adsorption of components of cigarette smoke onto the surface of chrysotile fibres has been suggested to play a role in the etiology of lung cancer in fibre-exposed cigarette smokers. The binding of carcinogens such as benzo (a) pyrene, nitrosonornicotine and N-acetyl-2-aminofluorene to chrysotile has been studied[20]. The fibre may act as a vehicle, which transports polycyclic aromatic hydrocarbons across membranes of the target cells[21]. However, fiber length, surface chemistry, and other properties affect biological activity. Fibers longer than 8 µm with a diameter less than 1.5 µm have shown the greatest carcinogenic potency[4].

Literature Review

Over 95% of the total asbestos being used worldwide is chrysotile variety of asbestos. Though use of varieties like crocidiolite and tremolite are already restricted, due to its large applicability chrysotile is still being used in many countries. Discussion on the possibility of safe use of chrysotile asbestos is going on. Though studies have established that asbestos causes malignant mesothelioma of pleura and peritoneum, gastrointestinal cancer, oesophageal cancer, lung cancer, and asbestosis, there is contradiction regarding the extent of pathogenicity and biopersistence of different varieties after occupational and environmental exposure.

In a study indoor air asbestos fiber concentration was found to range between 0.009 to 0.28 f/ml (mean, 0.089 f/ml) in 11 villages around Eskisehir in central Anatolia, Italy. The asbestos in the air emerged from the asbestos contaminated white soil[22]. A study in an asbestos plant in Chongquin, China to assess the occupational exposure due to chrysotile asbestos reported that maximum fibre concentration was in the raw material handling section. Fiber concentrations near two main activities of this section were 6.5 (5.8-7.5) fibers/ml and 12.6 (5.2-58.4) fibers/ml respectively. High fiber concentration was also seen in textile section 4.5 (0.7-17.0) fibers/ml where carding, spinning and weaving were done[23].

A cohort study of 1176 Swedish asbestos cement workers did not indicate any asbestos related excess mortality. Possible explanations of the negative outcome are relatively low exposure levels and the predominant use of chrysotile in production. Such a tentative conclusion is supported by a review of five mortality studies of workers exposed to asbestos cement that report considerable differences in relative risks for lung cancer. These differences could be explained by various degrees of cumulative exposure, the amount of amphiboles in the production, and methodological shortcomings. A median exposure of 10-20 fibre-years does not seem to cause an increased risk of lung cancer, particularly when only chrysotile is used[18].

To estimate non-occupational exposure of chrysotile, a study was carried out in mining region of Quebec, Canada. The result indicated that estimated cumulative exposure was more in neighborhood area of mines (16 fiber-yr/ml) followed by household exposure (7.8 fiber-yr/ml) and occupational exposure (1.2 fiber-yr/ml) [24].

A study reported that there was fifty times more chrysotile fibres of length >5 μm present in Quebec mining region, Canada than in general urban environment of Montreal[25]. In another study, lung specimens from 97 autopsies were studied by electron microscopy and X-ray energy dispersive spectrometry for comparing chrysotile exposure in occupational, environmental and referent groups. The result indicated that total asbestos fiber concentration (>5 μm) was greater in occupational group than in environmental group but in case of tremolite, significantly higher amount of tremolite fiber (>5 μm) was found in environmental group ($p<0.05$) compared to referent group. Diagnoses from autopsy report from the same study indicated 23%, 39%, 12% and 4% of occupational group had lung cancer, asbestosis, gastrointestinal cancer and mesothelioma respectively, whereas only 3%, 0%, 7%, 0% and 5%, 0%, 7%, 0% of environmental and referent group members respectively had the same pathological condition. All the gastro intestinal cancer cases in occupational group were having malignancies in their colon[26].

In order to measure occupational exposure of workers to chrysotile asbestos, a study was carried out in a small factory manufacturing roofing materials. This study had a comparative evaluation of data collected in different points of time (1978, 1981, 1983). Samples of both 8 hr and 15 minute duration of exposure were collected and analyzed by PCM. In addition to PCM, analysis using TEM was also performed in the year 1981. TEM analysis of samples obtained by personal sampling observed 70 times more asbestos fibres (of all sizes and >5μm fibres) in at least half of the samples when compared to analysis by PCM technique. The air borne asbestos concentration measured was below the OSHA 8-hr time weighted average (2 fibres/cc by PCM). Chrysotile fibre was observed in the urine samples collected from both exposed and control group[27].

It has been documented that exposure to chrysotile asbestos poses risk for asbestosis, lung cancer and mesothelioma in a dose-dependent manner[28]. In a mortality study of 2242 women from 2 chrysotile asbestos mining area of Quebec (Canada), 7 cases of pleural mesothelioma were found. The study indicated a standardized mortality ratio (SMR) of 7.63 (95% confidence interval 3.06 to 15.73) for pleural mesothelioma. An SMR of 23.49 (95% CI 2.64-84.83) for asbestosis and 0.99 (95% CI 0.78-1.25) for lung cancer was also observed[24].

According to WHO Environmental Health Criteria[29] the overall relative risks for lung cancer are generally not elevated in the studies of workers in asbestos-cement production and in some of the cohorts of asbestos-cement production workers. The exposure-response relationship between chrysotile and lung cancer risk appears to be 10-30 times higher in studies of textile workers than in studies of workers in mining and milling industries. The reasons for this variation in risk are not clear, so several hypotheses, including variations in fibre size distribution, have been proposed.

In a survey of 181 workers of an asbestos industry of India 23% reported asbestosis. The mean age of the workers was 54 years and all had a minimum of 20 years of exposure to asbestos. Lung function test revealed that 62% of workers had FVC values less than 80% of predicted standard. Radiological findings revealed that 92% and 17% of the subjects were having parenchymal fibrosis and pleural abnormalities respectively[30].

Another study on chrysotile exposed employees reported an SMR of 3.73 with 95% confidence interval of 1.21 to 8.70 for pleural mesothelioma[31]. In a study 17 deaths (4.3% of all deaths) observed among 3276 male and female workers working in an asbestos plant (manufacturing textile products, friction materials and packing materials) were due to mesothelioma[32]. In a study of asbestos related mesothelioma, it was observed that out of 843 cases 67 were due to chrysotile asbestos exposure[33].

24 (12 men and 12 women) malignant pleural mesothelioma (MPM) cases were diagnosed between 1990 and 2000 out of the 377 deaths that occurred

while studying environmental exposure to asbestos in a total of 1886 villagers of Anatolia, Italy. Proportional mortality of MPM was 5.6%. The study reported average annual mesothelioma incidence rates of 114.8/100000 and 159.8/100000 for men and women respectively[22].

The lung tissue burden of asbestos fibres was studied in 151 human with malignant mesothelioma using electron microscopy. The majority of asbestos found in mesothelial tissue was chrysotile alone followed by chrysotile plus amphibole and amphibole alone. The average lung asbestos burden in mesothelial tissue was 49.84 x 106 fibers/dry gram (240.0 x 106 maximum, 0.03 x 106 minimum). The majority of asbestos fibres detected in both lungs and mesothelial tissue were shorter than 5 micron in length[34]. In another study it was observed that out of 268 cases of mesothelioma which had fiber burden analysis done, chrysotile was detected in 36 cases[35].

In a five-year follow up study of chrysotile asbestos textile workers in South Carolina, increased mortality due to lung cancer was observed among the white males SMR = 2.30 (95% CI = 1.88-2.79) and females SMR = 2.75 (95% CI = 2.06-3.61) [36].

A relative risk of 6.64 (95% CI 1.92 - 23.0) for death due to lung cancer (adjusted for age, smoking and employment) was observed in chrysotile asbestos exposed workers during a 25 year longitudinal study in Chongquin, China. Of the 132 deaths that occurred among asbestos workers during study period, 22 were due to lung cancer. Authors concluded that heavy exposure to pure chrysotile asbestos alone is sufficient to cause lung cancer and malignant mesothelioma in exposed workers[23].

In a recent study by Central Pollution Control Board, fiber counts in 4 grinding units at Deogarh, Rajasthan ranged from 4.07-15.6 f/cc, in 6 asbestos grinding units at Beawer, ranged from 2.0-5.09 f/cc, in organized sector unit of Nagpur ranged from 0.057-0.080 f/cc, in unorganised textile units of Mumbai ranged from 0.146-0.369 f/cc and in brake shoe factory, Ghaziabad ranged from 0.05-0.127 f/cc. In none of the workers interstitial lung fibrosis was observed on radiological investigation[37].

To see the changes induced in DNA synthesis in the gastrointestinal tract, a chrysotile ingestion dose-time related study was carried out in 61 young adult male Charles River CD strain rats[38]. The results indicated a significant increase in the DNA synthesis (by Thymidine-methyl-H^3 uptake) in the small intestine and colon and decrease in liver after 2 weeks with a dose of 5mg/kg. When DNA synthesis was examined in colonic tissue in a time dependant manner, marked increase in DNA synthesis was observed (compared to control) from 28 days onwards till 63 days after exposure to a single dose of 100 mg chrysotile A / kg[38].

To determine the role of long-term exposure of chrysotile in causing gastrointestinal cancer, a life time study was conducted in male Wistar rats. Rats were given 1% chrysotile asbestos and 5% corn oil in rat chow diet. In a group of 20 male Wistar rats, six malignant tumors were found in exposed group compared to one in control, but none being gastrointestinal cancer. In another group of 80 rats, eleven tumors each was found in both exposed and control groups, only two of which found in exposed rats were of gastrointestinal origin. Trace amount of asbestos was found in omentum, brain, lung, liver, blood and kidney when a group of 20 animals were treated with 1% asbestos for 6 weeks[39].

Many researchers have tried to assess the toxic effects of different asbestos fibres in terms of its genotoxicity and cytotoxicity. To assess ROS mediated genotoxicity generated after asbestos cement powder and chrysotile exposure, in an *in vitro* study in V79 cells (Chinese hamster lung cells), time and concentration dependent decreased viability was observed in both asbestos cement powder and chrysotile exposed cells. The result indicated that lower concentration ($1 \mu g/cm^2$) of chrysotile exposure induced almost equal number of micronulei formation as higher concentration ($3 \mu g/cm^2$) of asbestos cement powder. Both showed release of thiobarbituric acid-reactive substances (evidence for lipid peroxidation) but only after 24 hrs of exposure. The authors concluded that when compared to asbestos cement powder, chrysotile was more cytotoxic and genotoxic in V79 cells[40]. Weitzman and Weitberg also carried out an in vitro study to examine lipid peroxidation in phospholipid freshly prepared from asolectin. Asbestos mediated lipid peroxidation was determined by measuring thiobarbituric acid – reactive material formation. The authors observed that Canadian chrysotile ($1.00 \pm 0.06 \mu m$ TBA-RM, mean$\pm$ $SE_{M)}$) was most active followed by crocidolite ($0.690 \pm 0.03 \mu m$ TBA-RM, mean$\pm$ SE_M) and amosite ($0.535 \pm 0.04 \mu m$ TBA-RM, mean$\pm$ $SE_{M)}$) respectively[41]. Another study conducted in rat lung fibroblast did show significant increase in TBARS with chrysotile and crocidolite at concentration greater than 250μg/ml. Amosite showed similar significant increase in TBARS only at a concentration of greater than 500μg/ml[42]. Another study[43] showed increase in intracellular ROS and 8-oxoguanine in rat pleural mesothelial cells but not in lung fibroblast at chrysotile concentration in range of 5-10 μg/cm^2. Also an increase of 8-hydroxyguanine (oxidative DNA damage) in DNA and its repair activity in the lung of Syrian hamsters and wistar rats after intratracheal instillation of crocidolite asbestos is reported[44].

In a study to observe genotoxic effect of chrysotile, crocidolite and amosite by assessing micronuclei formation in Syrian hamster embryo fibroblast revealed that after 66 hrs of exposure, maximum number of micronuclei was found in both chrysotile (210.0 ± 56.5, mean ± SD) and crocidiolite (218.5 ± 80.3, mean ± SD) exposed fibroblast at a concentration of 5 μg/cm^2, whereas amosite showed maximum micronuclei (>250 MN/2000 cells) at a concentration of 0.25 μg/cm^2 [45]. Another *in vitro* study observed that cytotoxic doses of both chrysotile and crocidolite failed to induce any detectable gene mutation (i.e. frequency $<10^{-6}$) in Syrian hamster embryo cells, though chrysotile showed significant numerical chromosomal changes[46]. In another study an oral dose of 20mg/kg/day of chrysotile asbestos also failed to induce any chromosomal aberrations in the germ cells of Swiss albino male mice[47].

In vitro and *in vivo* studies have also been conducted involving human subjects to assess the genotoxicity of asbestos fibres. In a molecular epidemiological study of 82 human subjects (61 exposed and 21 factory control) with exposure duration between 5 to 40 years, DNA damage and repair, chromosomal aberration and micronuclei formation was evaluated. The result indicated higher level of strand breaks in case of exposed non-smokers than either control non-smokers or exposed smokers. Exposed workers had almost twice the chromosomal aberrations than non-exposed controls[48].

Apoptosis being an important mechanism by which injured cells are eliminated, it plays a significant role in prevention of tumor formation. An *in vitro* study examined apoptosis in human and rabbit pleural mesothelial cells following asbestos exposure. It was observed that apoptosis caused by crocidolite was more than chrysotile and amosite[49].

Only a few studies have been carried out to assess the effect of chrysotile asbestos on the reproductive system and development. No teratogenic effect in CD-1 mice was found, when exposed to chrysotile asbestos during 1-15 days of gestation period[50].

Neither type of chrysotile fiber (short-range fibers mostly <10 mm in length and intermediate-range fibers mostly >10 mm in length) adversely affected the fertility of the dams or the litter size of the F1 animals when they were administered to male and female F344/N rats at a concentration of 1% in the diet (500 mg/kg/day) for life, starting with the dams of the test animals[49].

Importance of this study

Certain varieties of asbestos are well known for their adverse effect on human health. These can cause a range of morbidities ranging from benign pleural effusion and hyaline pleural plaque to carcinoma of lungs and pleura. A typical diffuse interstitial fibrosis of lung known as asbestosis is also seen in the workers after asbestos exposure depending upon the dose and duration of exposure. There is a controversy all over the globe about the safe use of asbestos and about the safe limit of asbestos fibers in workplace as well as in general environment. In India also similar kind of a controversy is existent for last many years. The existing data in relation to environmental as well as human health status in India is insufficient. A comprehensive information of environmental / human health status in relation to asbestos handling is much needed in our country. So this study will form background national information in this area, which may be useful in future.

Manufacturing Processes

Asbestos cement sheet-manufacturing unit of Kolkata

Everest Industries Ltd. is India's one of the major fiber cement products' manufacturing company having largest network of manufacturing and sales. It is operating in India since 1934. Over 70 years of its presence, it has been offering a range of roofing products. It has got 4 manufacturing units at Kymore, Kolkata, Podanur and Lakhmapur. Kolkata unit was established in 1938 and is situated 9 km away from the center of the city. The factory has gone through different phases of modernization and now it produces 7300 tones of corrugated sheets and other moulded products.

Summary of the measures adopted by the industry to reduce workers' exposure (Information as collected from the factory):

- Entire manufacturing is wet process (even processing of asbestos fibre) since 1938
- 100% use of empty fibre bags in products since 1992
- Auto corrugation of AC Sheet in the year 1984
- Raw Material Feeding through PLC since 1992
- Sheeting Machine Automation in the year 2000
- Seasoning Cycle Automation since 1985
- Mechanized loading of finished products since 2002
- Complete Mechanical handling of Asbestos Fibre Bags in sealed condition since 2002
- Provision for Bag Opening Device in the year 2006

- Processing of fibre inside the chamber under negative pressure since 1992-93
- Cleaning of fibre processing floor/godown with vacuum cleaner
- Dust extractor unit at different point of operation since 1975
- Personal Protective Equipment to every individual workman

Manufacturing process:

The manufacturing process of fiber cement product is based on classical wet Hatschek process where in the asbestos fiber, Cellulose is mixed with Portland cement and Fly ash in aqueous condition. The raw materials that are used in the manufacture of asbestos cement products are asbestos fiber, Ordinary Portland Cement, Fly ash, Cellulose Pulp and AC waste. The entire asbestos fiber requirement is imported and received in ships at Kolkata Port. Fibers are available in impervious HDPE bags of 50\40 kgs each in palletized form. Pallets from the truck are unloaded, stored in the fiber storage godown, and subsequently transferred to raw material preparation section.

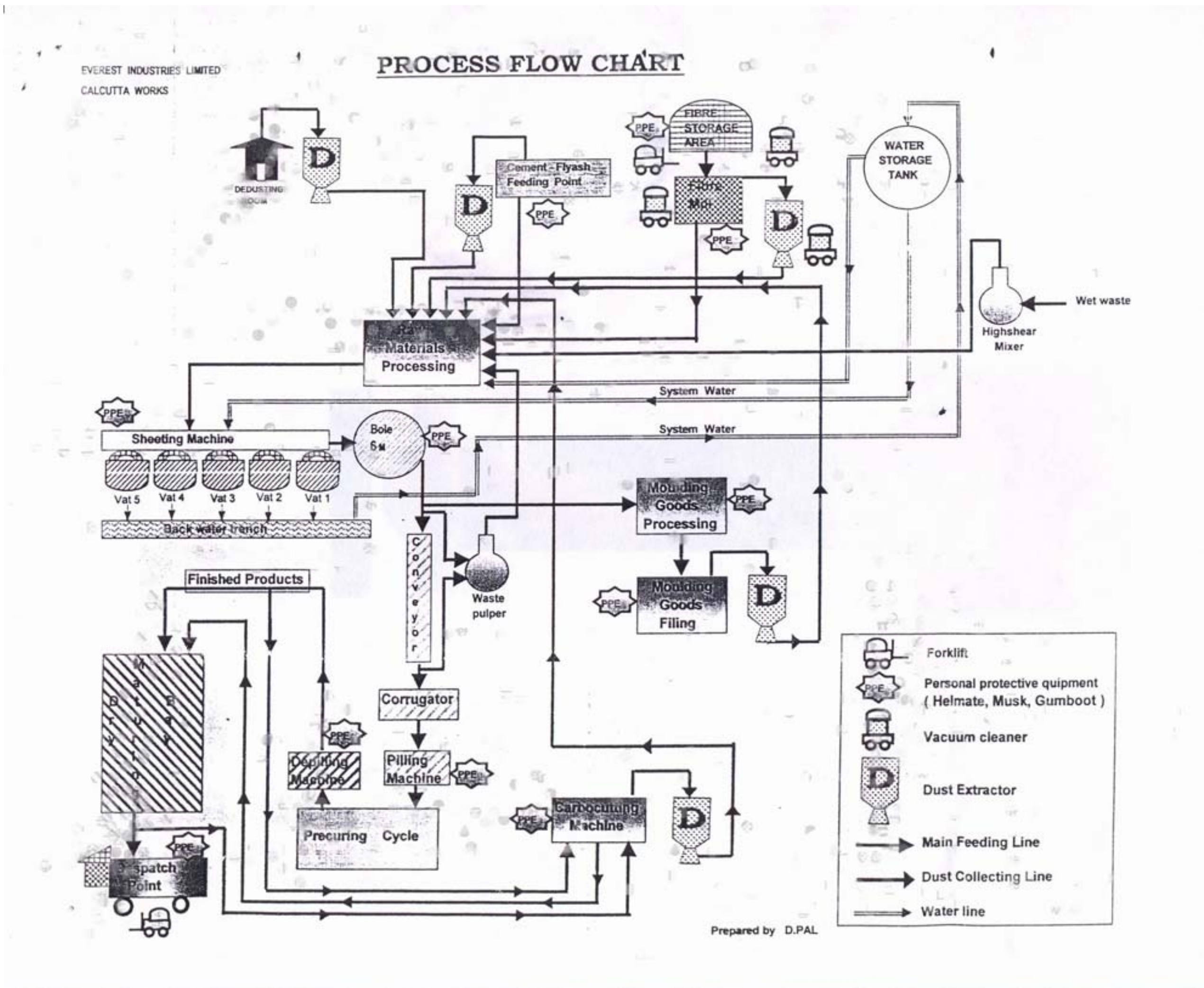
From agitator tank, the slurry is fed to the sheeting machine vat through pre-mixture (where the slurry is further diluted). In the vat there is sieve cylinder drum which pick-up the homogenous mixture and allow the water to go out. This homogenous mixture is transferred to the felt by coaching action, thus forming asbestos cement film. This film is again transferred to sheet forming bole. During transferring to sheet forming bole the films are made to pass through vacuum suction tray to extract water further from the film. Then this film is wrapped on the sheet-forming bole in order to make required thickness (generally 6 rotations).

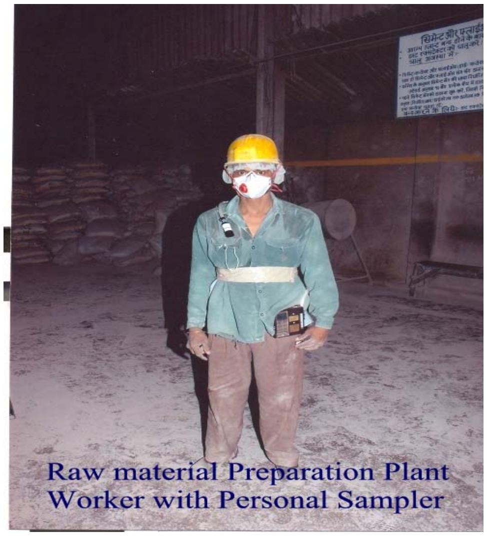
During rapping the films are compressed by pneumatic pressure. After getting the required thickness the compressed film are cut manually and transferred to take off conveyer, thus resulting a flat sheet. Then this flat sheets are sized by end trimming and will be sent to corrugator along with steel mould (known as templates) where the sheet were profiled as per steel mould by pneumatic pressure, thus resulting the corrugated sheets.

The corrugated sheets along with templates are piled on a bogie and made into 60 packs. These will be sent to procuring tunnel for hardening. After, pre-curing mix packs will be sent to depiling units for segregating the hard sheet and template. From this point the templates are sent back for reuse and the sheets were sent to the curing bay for curing for 21 days. Curing is done by covering the sheets with High Density Polyethylene (HDPE) covers. The sample sheets are taken out from each batch and the passed material is sent for dispatch.

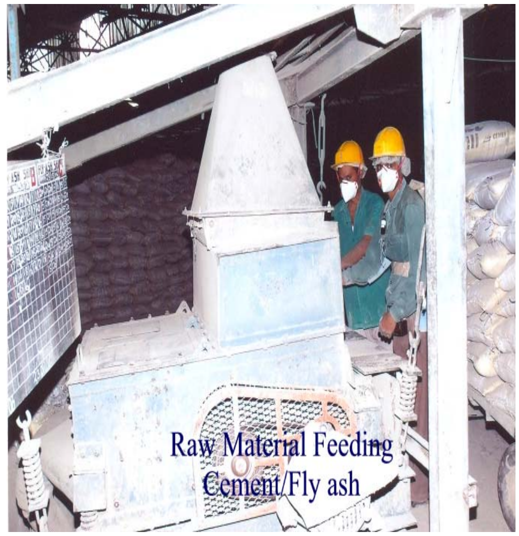
Manufacturing of moulded goods and accessories are carried out in MG department. All these are made out of wet sheets produced by the sheeting machine. The wet sheet is cut into sizes and then it is placed on the mould for making required articles. The article is allowed to remain in the mould for a period of 16 hours. After 16 hours the articles are stripped from the moulds and shaped by filing. The file articles are sent to maturing bay for natural air curing.

The curing is done for 21 days. After 21 days articles are made ready for dispatch.



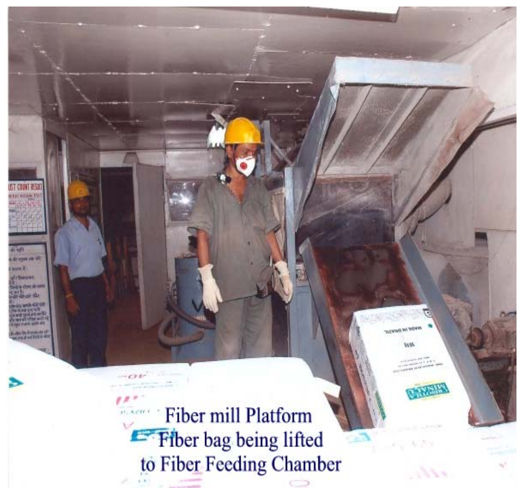


Raw material Preparation Plant
Worker with Personal Sampler



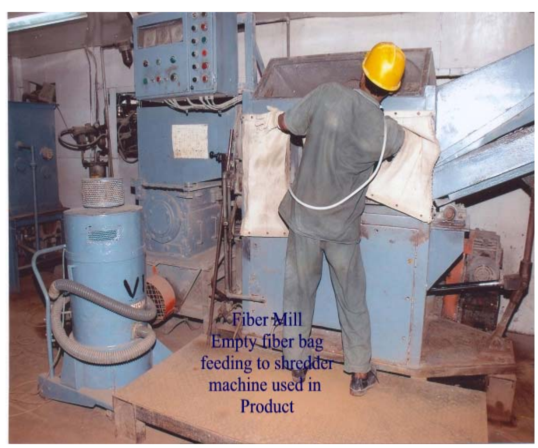
Raw Material Feeding
Cement/Fly ash

Fiber Mill Platform -
Hydrolic Pallet Used for
Handling Fiber Bags



Fiber mill Platform
Fiber bag being lifted
to Fiber Feeding Chamber

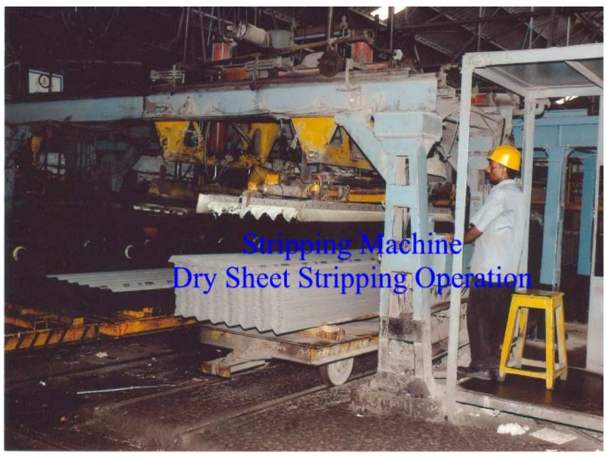
Fiber Mill Platform
Fiber bag cutting in
Closed Chamber under
Negative Pressure



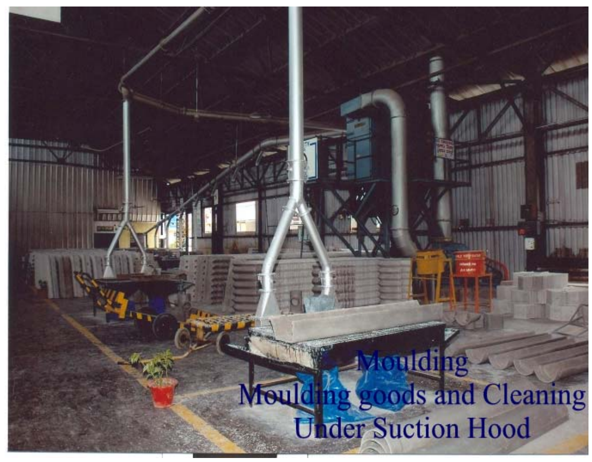
Fiber Mill
Empty fiber bag
feeding to shredder
machine used in
Product

Dust Exractor Unit
Connected to
Fiber Processing Device

Sheet Forming Machine 1



Stripping Machine
Dry Sheet Stripping Operation



Moulding
Moulding goods and Cleaning
Under Suction Hood

Moulding Dust Extractor Unit
Conncted with
Moulding Cleaning Machine

Sheet Cutting Machine
Connected with Dust Extractor

Asbestos cement sheet-manufacturing unit of Silvassa

Ramco Industries Limited (RIL) is one of the major manufacturers of asbestos cement sheets. The industry where this study was conducted is one of the major AC sheet-manufacturing units of Ramco Industries Limited (RIL). Ramco Industries Limited (RIL) belongs to the Rs.2000 crore Ramco Group of Companies, one of the well-known and leading Industrial Houses in South India. Apart from a range of other products, Ramco group produces cement and fibre Cement Products also.

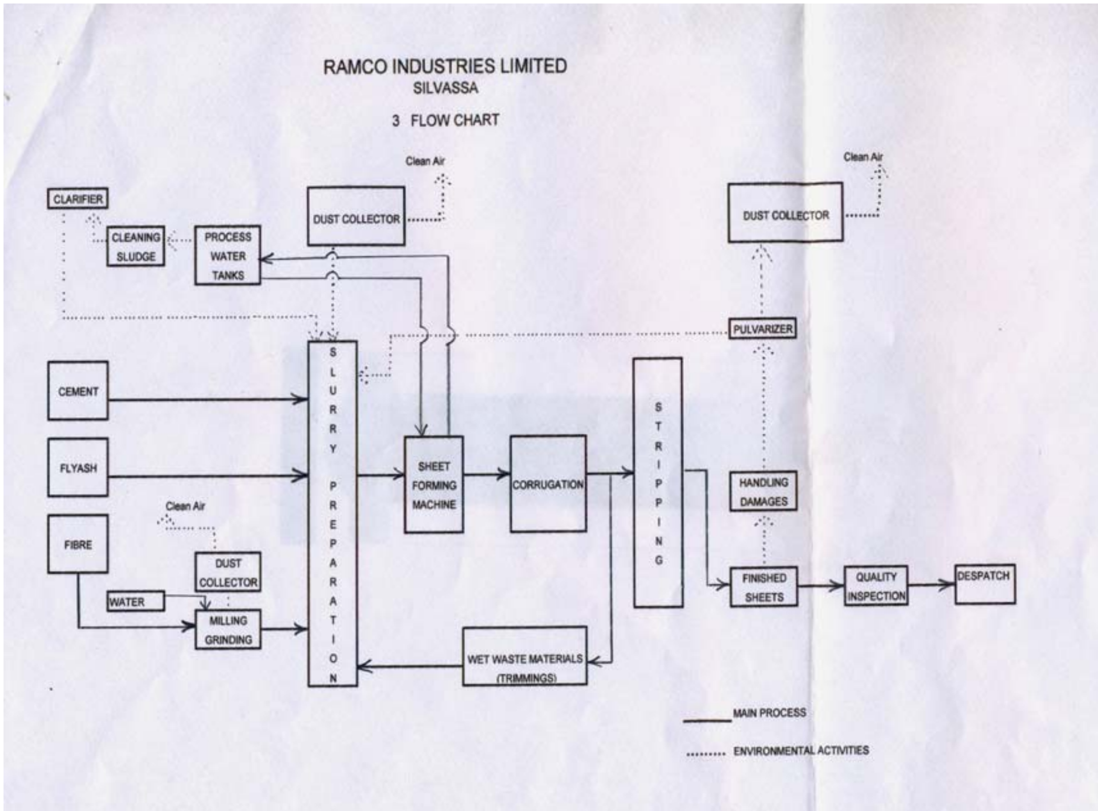
Manufacturing process:

The basic raw materials used by this industry are cement, raw asbestos fibre, dry fly ash and water. The fibre is fed to Fibre mill in an integrated fashion through an automatic bag-opening device and milled in the edge runner mill with pre-determined quantity of water. The fibre after milling passes through an elevator and stored in the fibre silo. A pre-determined quantity of fibre is taken to slurry mixer to maximize the area of reinforcement with water. Simultaneously cement, fly ash and additives are added to fibre in slurry mixer to form slurry. The slurry is pumped to storage mixer from where it is fed to the sheeting plant.

The sheeting plant consists of vats with rotating sieve cylinders inside covered with fine sieve meshes. As the slurry is admitted in to the vats, water gets filtered through the sieve covers leaving a fine film of asbestos cement coating on the sieves. The coating is then transferred on to an endless felt, which is moving in contact with sieve cylinders. As the felt moves forward the layer is dried by a system of Suction Trays. The multiple layers so formed on the felt are then transferred on to an accumulator drum, which rotates in contact with felt. As the thickness on the accumulator drum reaches the desired level, it is cut off from the drum. The wet sheets get trimmed to the desired width and then corrugated by an Atmospheric Corrugating Machine. The trimming waste is processed and mixed with raw materials and used in the process. The sheets are piled in trolleys with steel templates in between. The sheets are then dried and sheets and templates are separated with a stripping machine. The templates go back to the process. The sheets are then kept in separate area to attain maximum strength. Then they are tested to check conformity with the standards laid down by Bureau of Indian Standards and stacked in stacking yard for dispatch.

For making asbestos cement roofing accessories, the wet sheet coming from the sheeting machine are cut in to the required size and spread on the moulds manually. The articles are removed after 24 hours.

In a nutshell, the entire process is wet process and totally enclosed, moreover, fibre bags are fed in an integrated fashion with bag opening device, which is a closed chamber connected to dust collector. Bags are also shredded in to minute particles and added to the process. Total water is recycled and some quantity of make up water is consumed. Hence effluent is totally eliminated. Sludge from process water tanks during interruptions is collected in a clarifier for reuse. Wet solid waste, if any, is processed in ball mill and used in the process. Broken pieces of sheets, if any are pulverized in a pulveriser and consumed in the process.



Flow chart showing the manufacturing process

Bag opening device

Bag cut Inside

Empty bag hooking

Empty bag removed

Empty Bags are powdered for Mixing with Fibre

Sheeting Machine

Corrugating Machine

Ball Mill for Recycling

Clarifier for Sludge Recycle

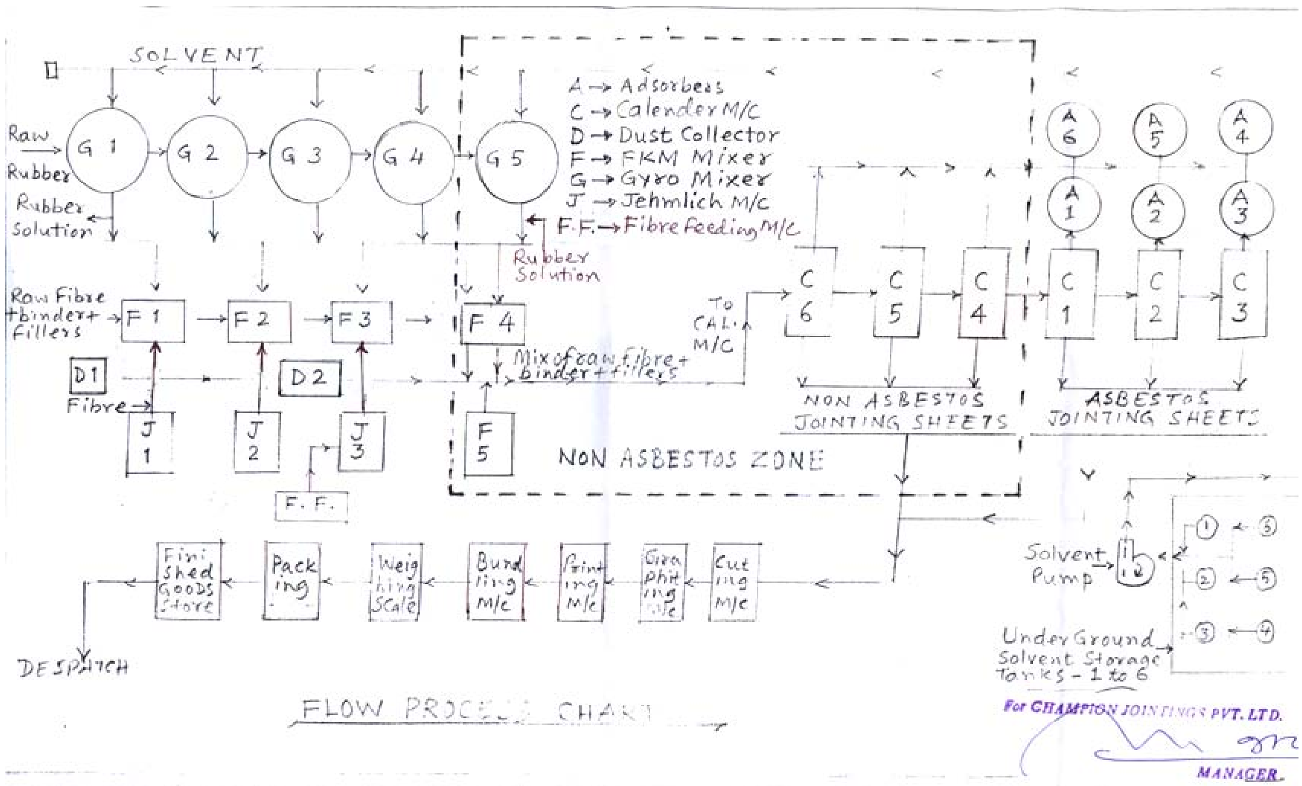
Handling of Sheets

Asbestos jointing material-manufacturing unit, Vapi

M/S Champion Jointings Pvt. Ltd. is a professionally managed company established in early 70's at Mumbai. Initially it had units at Vapi and Mumbai. Afterwards Mumbai unit was shifted to Pune. The Vapi unit, where this present study has been undertaken was established in the year 1982. The organization is having the head office at Mumbai. The Company manufactures Compressed Asbestos Fibre Jointing Sheets, Non Asbestos Fibre Jointing Sheets and Metallic Spiral Wound Gaskets. Besides supplying the above materials to the domestic market (Government, Non Government and Defense etc.), the company also exports the same.

Manufacturing process:

The Company manufactures Compressed Asbestos Fibre Jointing Sheets as one of its major products. Asbestos fibre is mixed with binders solution and fillers and then passed through the Calendar Machine to form Compressed Asbestos Fibre Jointing Sheets. These sheets are cut, as par required size, graphited, if required printed, bundled and packed.



Flow process chart

Feeding machine connecting to dust collector

Feeding Machine Connecting To Mixer

Mixing With Gyro Mixer

Calendar Machine

Asbestos sheet manufacturing unit, Hyderabad

Visaka Industries started manufacture in 1985 with the commissioning of its Fibre Cement division in Hyderabad, Andhra Pradesh, India. This joint sector company was promoted by a public private partnership to manufacture Fibre Cement Sheets with a capacity of 36,000 tonnes per annum. Currently Visaka produces 600,000 tonnes of fibre cement sheets per year.

Manufacturing process

Raw Material Composition

The product comprises an inert aggregate consisting of asbestos fibre, cemented together by 43 Gr./53 Gr. ordinary Portland cement (OPC) in combination with pozzolantic material, namely - Fly Ash that is around 32-35% of total raw material. Wood/cotton/paper pulp is added to increase the process efficiency and is limited to less than 1 % of total Raw Material.

1. ***Asbestos Fibre Milling***

   Various grades of asbestos fibre is blended together and milled in an Edge Runner Mill wherein around 32-38% water by weight of fibre is added to prevent the fibre length from breaking and to minimize the exposure to fibre dust in the ambient air.

   Fibre feeding into the Mill is done through the Automatic Bag Opener where the fibre bags are split open mechanically and under closed condition, with the empty fibre bags being separated and sent to the Bag Shredder to be shredded and sent to the E R Mill along with the fibre. Total operation is under closed door with E R Mill and Bag Opener, both, connected to Filter Bag Type Dust Collector. The clean air from the Dust Collector is let out via Wet Washer.

After milling the fibre is stored in the fibre silo.

2. ***Raw Material Slurry Preparation***

The milled fibre is converted into slurry in the wet opener, by adding water from recuperator tank (cone tank) and pulp slurry. After 3-4 minutes of circulation in the wet opener, the fibre slurry is pumped into the mixer tank. Fly ash in slurry form is also added in the mixer tank through the wet opener with the cement being added in the mixer tank separately and mixed for 3-4 minutes before. The raw materials slurry, thus prepared, is transferred to storage-agitator tank. From the storage agitator tank, the slurry is sent to the Dilution tank (Pre mixer tank) where it is further diluted and fed into the sheeting machine. Prior to the slurry preparation each raw material is batched and proportioned.

3. ***A C Layer Formation***

Raw material slurry in the Dilution tank is further diluted by adding the recycled water and then fed to the sheet-making machine consisting of 5 vats, placed in series. In each vat is placed a rotating hollow cylinder of an enmeshed peripheral surface (covered with a fine wire cloth of a definite mesh size). An endless felt continuously moves over the sieve cylinders tangentially. At the sheet-forming machine, from the time the raw material slurry is fed into the machine and till the sheet is formed, most of the water quantity added to form the slurry is freed from it and recycled for next batches. Dewatering is carried out through the following process applications.

I. Filtration through sieve cylinder:

The water of the slurry filters through the sieve cylinders allowing the asbestos cement film to deposit over the sieves. These picked-up deposits on the sieve cylinders get transferred to the moving endless felt in the form of fine asbestos cement layer by means of couch roller, which keeps the moving, endless felt tight pressed against the sieve cylinders. The water squeezed out during filtration and couching operation is pumped to the recuperator tank for recycling.

II. Vacuum Application:

The endless felt carrying the elementary layer of asbestos cement passes over the suction trays which are connected to the vacuum pumps, water thus separated from the water separator connected to vacuum pump is also taken to the recuperator tank for recycling.

III. Layer Compaction:

Asbestos cement layers from the endless felt is, then, transferred to and wrapped around a sheet-forming drum. The layer is allowed to get squeezed in through the drum and a rubberized roller and get wrapped around the drum while continuously being compacted under the pneumatic loading of the drum till the desired thickness is achieved. The water squeezed out during this compaction process is also sent to the recuperation tank for recycling.

4. ***Sheet Formation***

   The sheet is automatically cut off from the drum to fall into a moving conveyor (Take - off conveyor) and get carried to the side-trimming bench. Here each sheet is stamped using a roller stamping arrangement.

5. ***Corrugation***

   After being cut into the required size sheet is corrugated into the standard profile in the Atmospheric Corrugation BOX (ACB). The ACB has a sheet sucker hood, which sucks the sheet off the conveyor, corrugates it and places it over template placed over a mobile trolley. The Template Sucker Hood attached to the ACB, which lifts an empty template from the accumulated empty templates, placed over another mobile trolley places it over the corrugated sheet.

6. ***Initial Curing***

   When one trolley is full (around 30 X 2 sheets) it is taken to the initial curing chamber where it is kept for 10 to 16 hrs for initial curing. Heat evolved due to the exothermic reaction of cement with water in the A C sheet envelops the chamber making the sheet hard enough to be handled after 10 - 16 hrs.

7. ***Stripping Operation***

   After initial curing sheet trolley is taken to the Destacker where sheets are separated and stacked over an MS pallet with templates removed and accumulated over a trolley for recycling after oiling.

8. ***Final Curing***

The MS pallet with around 50 sheets is taken to the maturing bay and kept under showering water for 18 to 22 days for final maturing. Sheets after final maturing get fully hardened after cement hydration process is over.

Sheets after maturing are shifted out to the stock yard (after 18 to 24 days) and dispatched after final inspection and test.

9. ***Inspection***

Final inspection stage is as follows

- Dimensional and visual inspection - at stripping stage (dimensional inspection - 1% visual inspection - 100%).
- Load bearing capacity test - after final maturing (3 sheets per lot)

  (for details please refer quality plan)

Fiber bag being lifted to fiber feeding chamber

Sheet forming machine

Dry sheet stripping operation

Sheet cutting machine

Asbestos brake-lining manufacturing unit, Hyderabad

Rane brake linings limited was established in 1964 in technical and financial collaboration with Nisshinbo Industries, Japan for manufacturing Asbestos Free Brake Linings, Disc Pads and Clutch Facings. These products are in Application in every segment of the automobile industry. Thus Rane brake Linings Limited is a market leader in India with exports to more than 15 countries

Manufacturing process:

Mixing:

Various ingredients are mixed in definite proportion by weight in a mixer with particular time.

Pre-forming:

The pre-forms are pressed by hydraulic presses to get required shape and size

Curing:

It is a process where definite weight of the mix is cured under temperature and pressure for a fixed time in the relevant moulds to get the required size and shape of the product. Here the physical and chemical properties are built in to the product.

Baking:

Here the product is baked under specified temperature and time to further consolidate the physical and chemical characteristics

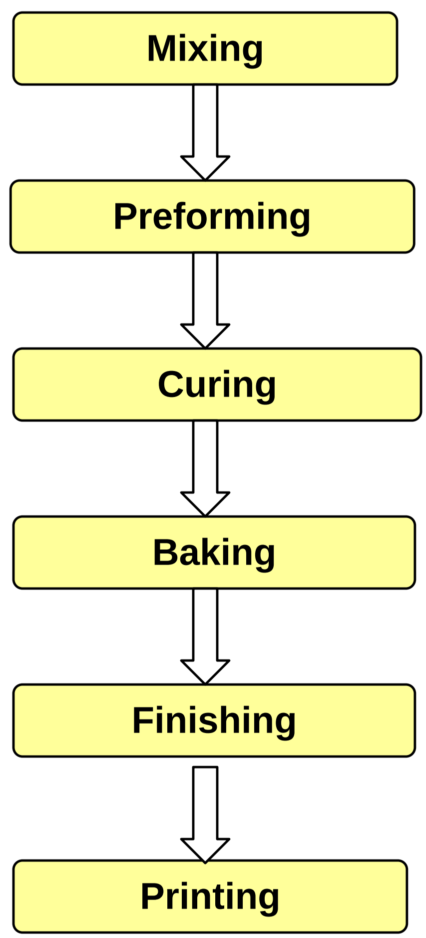
Finishing:

The baked blocks are moved to finishing area in the same trolleys. The blocks are cut to pieces as per the requirement. Each piece is ground, chamfered, drilled as per customer needs

Inspection & Packing:

The finished products are subjected to visual inspection. After inspection the materials are printed and packed in the cartons and sent to Finished Goods Stores.

MANUFACTURING PROCESS FLOW CHART IN BRAKE LINING




Pre-blending


Loading


Pre-forming


Curing


Baking


Cutting

OD grinding

Chamfering

Drilling

Wear marking

Inspection

Printing

Asbestos pipe manufacturing unit, Hyderabad

Manufacturing process:

The pipes are manufactured through a lamination process involving formation and consolidation of layers under hydraulic pressure, which is called MAZZA process. The process involves mainly three stages namely raw material preparation, pipe formation and finishing stage.

1. **Raw material preparation**

The primary raw materials for the manufacture are chrysotile asbestos fibres, fly ash and Portland cement. Different grades of fibres in required proportions are fed into the hopper from where it is conveyed to kollar gang (grinding machine) through spoke rollers. In kollar gang the fibres gets opened up and is conveyed to the mixture after getting weighed on the mechanical scale. In the mixture the required quantity of cement and fly ash is added after appropriate weighment. To this mixture of cement and fibres, water is added through water tank. The fibres and cement mixture is rotated through circulation pump to form a slurry. The slurry is then taken to pipe formation machine through a bucket elevator.

2. **Pipe formation:**

After the slurry i.e. formed in stage 1 is taken to the pipe formation machine, it is transferred to mandrels, which are placed under the rubber roller and over the formation roller, where the layers are formed continuously to the required wall thickness. The pipes of different diameters are made through steel mandrels or required diameter. The hydraulic consolidated pressure is used to generate dense and strong pipe. After forming the pipe on steel mandrels, the mandrels are removed and pipes sent to curing tanks.

3. Finishing stage

After curing the pipes in the curing tank they are removed for finishing where edges are cut and trimmed to required length and diameter to suit the jointing material.

Testing

After finishing the pipe as stated above the pipes are tested hydraulically and stacked in yard for dispatch, which will be taken into RG 1.

Figure 1:Asbestos fibres bags transported through conveyor belts

Figure 2:Mixing of asbestos fibres

Figure 3:Slurry taken to steel mandrels

Figure 4:Pipes are being manufactured through continuously laid layers of slurry

Figure 5:Water curing of manufactured pipes

Figure 6:Finishing work on manufactured pipes

Small-scale units at Panoli, NOIDA, Thane and Hyderabad

This includes textile making units at Panoli, Bharuch, Gujarat; Ambernath and Dahisar (East) of Thane, Maharashtra; brake shoe making units of NOIDA, Uttar Pradesh, and insulation board making unit at Hyderabad, Andhra Pradesh.

Textile and Rope making units

This type of industry manufactures asbestos woven products like yarn, rope, cloth and tape. Raw material used in this industry is chrysotile asbestos purchased from China and polyester waste/cotton. Asbestos fibers are opened and mixed with polyester waste in varying proportions depending upon the need. In mixing machines fibers and polyester are blended thoroughly.

Subsequent to blending, the asbestos-containing mix moves to what is known as a carding machine, which utilizes a series of rollers and blades to further separate asbestos fibers while aligning them in parallel rows. The carding process includes the three basic functions known as: working, stripping, and brushing, all of which involves a complex series of actions that bring the raw material one step closer to becoming a usable fiber.

During carding, fiber blend is continuously refined through the removal of impurities such as rock fragments, soil, dust, etc., and the material comes out in the form of sliver. From this sliver yarn is manufactured by a process called twisting/brading. Two or more slivers are twisted together to produce yarn. After this process there is a winding process. After winding, tape and cloth are manufactured by a process called weaving. In some units, a process called spinning manufactures the yarn. The spinning process is designed to add an increased twist to the rovings /slivers. The spinning process is typically facilitated by ring frame spinning machine, which provides the rovings/slivers with a specified diameter and tensile strength in a finished yarn suitable for weaving into cloth.

Asbestos containing yarn is eventually woven into a wide variety of textile products through the use of equipment that is much the same as the machineries used to weave cotton, wool or other organic fibers. Asbestos is woven into a broad spectrum of textile products that are created on looms that employ numerous weaving patterns and processes to produce high quality asbestos-containing cloth.

For rope manufacturing 2-12 threads are twisted together to achieve the desired thickness of the rope. Initially there is a process of winding yarn on bobbins. 2-12 bobbins are restored on brading machine, which twists them together. Thickness of the rope depends upon the number of yarns twisted together. In some units there is a process called calliperation, which is done on a machine called calendaring machine, ensures the uniform thickness of the rope. After calliperation the rope is cut into small pieces of desired length and weight as per the orders. The exposure of workers might occur at all these processes during a shift of eight hours.

Mixing

Spinning

Ring Frame

Weaving

Brading

Local Exhaust Ventilation at Winding section

PROCESSES IN ASBESTOS TEXTILE MAKING UNITS

Brake shoe manufacturing unit

This small-scale industry manufactures brake liners for two wheelers. The raw material used in this industry is re-cycled asbestos fiber waste of gaskets and jointing materials, synthetic rubber, resin and friction dust. The sheet of desired thickness is produced from this mixture on rubber mixing mill. The sheet is cut into big pieces of about 2 X 1 inches. However in the units manufacturing brake liners for four wheelers and disc pads, cold forming of the raw material is an initial process where raw material is pressed into biscuits. After this there is a process called moulding. Moulding makes the sheet/biscuits curvi-linear and wire mesh is fitted in the mould. After moulding the sheet /biscuit is again cut into small pieces of required measurement and holes are drilled into the brake liners. After drilling, grinding is done for finishing. The liner is then pasted on a metallic mould and brake liners are packed.

Some units manufacture industrial friction products like brake liner rollers, which are used in four wheelers, trains, locomotive lifts and cranes. The raw materials used in these units are asbestos fibers and cotton, which are used in varying proportions. The process of yarn making is same as in textile making units. However after weaving, the thick roll is made instead of thin cloth. Thickness of the roll varies from 6-250 mm whereas the width of the roll is normally 20 inches. Finally, roll is dipped into Cashew Nut Seed Liquid (CNSL) resin for making it hard.

Biscuit making

Moulding

Grinding

Drilling

Resin treated hard asbestos textile roll

Brushing or cleaning

PROCESSES IN BRAKE SHOE MAKING

Insulation board making unit

High temperature thermal insulating boards 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. The curing of boards is done for 24 hours. Size of the board is usually 100 x 120 cm and 4 x 3 feet and thickness varies from 0.3 to 5 cm. As per the product catalogue of the manufacturer, the weight per sheet of 100 x120 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.

Slurry making

Asbestos mixing

Machine grinding

Hand grinding and finishing

PROCESSES IN INSULATION BOARD MAKING

Objectives

1. To find out the concentrations of chrysotile asbestos fibers in the workplace environment, in the vicinity of the process area and also in the area where chrysotile asbestos products are in use.

2. To assess the health status of the workers engaged in organized and small-scale industries, the residents of the vicinity as well as the end users of chrysotile asbestos products.

Methodology

After getting approval from the high-powered institutional Ethical Committee and Scientific Advisory Committee the present study was undertaken. The present descriptive study was carried out including the asbestos workers, community residing in the vicinity of factories and end-users of chrysotile asbestos products. In this study across the country, the asbestos workers of following sectors using chrysotile asbestos were involved:

- Asbestos cement industry manufacturing asbestos cement sheets
- Asbestos industry manufacturing asbestos containing friction materials (brake linings)
- Asbestos industry manufacturing asbestos containing jointing materials
- Asbestos cement industry manufacturing asbestos cement pipes
- Small scale industries making textile, rope and brake linings

The sample size of the study was calculated by the software Epi5 (World Health Organization). For a total workforce of 4800 workers in the organized sectors of chrysotile asbestos product manufacturing industries and by assuming the prevalence of asbestosis as low as 1%, the samples size at 99% level of significance and 80% power was calculated to be 578. After adjusting for 10% non-response rate the final sample size for the asbestos workers was calculated to be 625. Therefore the study included a total of 1248 subjects, which comprise of 625 asbestos workers, 362 community subjects residing in the vicinity of asbestos sheet manufacturing factory at Hyderabad, 135 end-users of chrysotile asbestos product and 126 small scale unit workers. The universal sampling technique was used to include the study subjects in each group. However due to lack of consent in 12 workers of sheet manufacturing unit of Kolkata the sample covered was 188. Similarly, in the sheet-manufacturing unit of Hyderabad due to incomplete information of one subject, the final analysis included only 59 subjects. Table 1 shows the details of the study participants.

Table 1: The details of study participants

Group	Number of subjects	
Asbestos workers	**625**	
Sheet manufacturing unit, Kolkata		188
Sheet manufacturing unit, Silvassa		60
Sheet manufacturing unit, Hyderabad		59
AC Pipes manufacturing, Hyderabad		95
Friction material manufacturing unit, Hyderabad		153
Jointing material manufacturing unit, Vapi		70
Community residing in the vicinity of sheet manufacturing factory	**362**	
End-users of chrysotile asbestos products	**135**	
Small scale unit workers	**126**	
Total	**1248**	

The aim and purpose of the study was explained to the participants and consent was obtained accordingly.

Every individual subject was interviewed with a pre-designed questionnaire to collect information in relation to personal, occupational and morbidity details of the subjects.

Lung function test was carried out in all subjects. Vital Capacity (VC), Forced vital capacity (FVC), and Peak Expiratory Flow Rate (PEFR) were recorded by Spirovit-SP-10 (Schiller Health Care Ltd, Switzerland). Three successive recording of VC, FVC and PEFR were made in standing posture and the nose clip was used. The best of the three performances was considered for calculation purpose. The volumes like FEV_1 and ratio such as $FEV_{1\%}$ (FEV_1/FVC) were calculated from the same tracings. All volumes obtained were expressed in body temperature on atmospheric pressure of air saturated with water vapour (BTPS). Body height and body weight were measured in bare feet on a standard scale. Predicted Forced vital capacity for each individual is calculated using Chatterjee's equation[51] for Kolkata workers and Kamat's equation[52] for other workers. On the basis of the predicted values and the observed values the pulmonary function impairment were labeled as "***obstructive***" when the FEV_1/FVC ratio was <80% while observed FVC value was >80% of predicted FVC, "***restrictive***" when the FEV_1/FVC ratio was >80% while observed FVC value was <80% of predicted FVC, "***combined***" when the FEV_1/FVC ratio was <80% while observed FVC value was <80% of predicted FVC and "***normal***" when the FEV_1/FVC ratio was >80% while observed FVC value was >80% of predicted FVC. The FVC and FEV_1 were expressed in litres, PEFR in lit/min, Forced Expiratory Flow ($FEF_{25-75\%}$) in lit/sec and $FEV_{1\%}$ was expressed as ratio of FEV_1 and FVC expressed in %. The instrument was calibrated every day before starting the measurements.

All the study subjects were evaluated by radiological examination. Chest X- rays (PA view) were obtained with the subject in full inspiration. The X-rays were read by the radiologist working in the field for more than two decades. Collected data were analyzed by using Epi Info 5 and SPSS software.

Fiber concentrations in the workplaces were evaluated using SKC personal samplers with a flow rate of 1-2 litre/min. The membrane filter method using phase contrast microscopy was used. Samples were collected on cellulose acetate membrane filters (diameter –25 mm, pore size 0.8 μm) using personal samplers with flow rates of 1-2 LPM. Samples were shifted to the laboratory and slides were prepared using acetone-triacetin method. Fibres (length >5 μm, width <3 μm and aspect ratio ≥3:1) were counted using Walton-Becket gratitude at magnification of 400X. Fibre concentrations were computed using following formula:

$$C = \frac{A}{a} \times \frac{N}{n} \times \frac{1}{r} \times \frac{1}{t}$$

Where,

	C	=	Concentration (fibres/c.c).
	A	=	Effective filter area (mm^2)
	a	=	Graticule area (mm^2)
	N	=	Total number of fibres counted
	n	=	Number of graticule areas counted
	r	=	Flow rate (c.c./min)
	t	=	Sample duration (minutes)

Fibre levels were then compared with the permissible levels mentioned in the Indian Factories Act, 1948[57] (1 fibre/ml) and the recommended exposure levels of OSHA[58] (0.1 fibre/ml), NIOSH[59] (0.1 fibre/ml), and ACGIH[60] (0.1 fibre/ml).

Results

Asbestos cement sheet-manufacturing unit of Kolkata

Environmental monitoring was carried out at six sampling locations. Fiber concentrations are shown in Table 1. Permissible Exposure level (PEL) in India[53] is 1 fiber/ml where as other agencies like OSHA[54], NIOSH[55] and ACGIH[56] recommend 0.1 fiber/ml (Table 2). It can be seen from table-3 that fiber concentrations are much lower than the PELs.

Table 1: Mean Fiber Concentration (Fibers/ml) at different locations

Location	Fibre Concentration	No. of samples
Cement/Fly Ash Feeding	0.007 ± 0.0025	6
Fiber Mill	0.067 ± 0.0027	6
Sheeting	0.010 ± 0.0026	6
Stripping	0.007 ± 0.0017	6
Moulding/Filing	0.007 ± 0.0018	6
Carbo Cutting	0.009 ± 0.0029	6

Table 2: Permissible exposure limits

Limit prescribed by	**Limit**
OSHA	0.1 Fibres/ml
NIOSH	0.1 Fibres/ml
ACGIH	0.1 Fibres/ml
Factories Act	1 Fibre/ml

The health monitoring included 188 workers. The mean age of the study subjects was 40.5 ± 6.9 years (range 24-55 years). Only 7.4% of the workers were upto 30 years of age. 43.1% workers were in 31-40 years age group and 49.5% workers were in 41-60 years age group (Table 3). 97.3% workers were married and about 18% workers had primary level education only. 58% workers had secondary level education and about 23% workers pursued higher education. 82.4% workers were non-smokers, whereas 13.3% and 4.3% workers were smokers and past smokers respectively.

Table 3: Age wise Distribution of the workers

Age group (Yrs.)	**Number of workers (%) (N=188)**
Up to 30	14 (7.4)
31-40	81 (43.1)
41-60	93 (49.5)

Majority of the workers (54.8%) were from Process Division followed by Maintenance (12.2%), Loading (11.1%) and Moulding Division (8%). Other workers participated in the study were from Stores, Laboratory, General Pool and other departments (Table 4).

Table 4: Department wise Distribution of the Workers

Department	**Number (%) (N=188)**
Canteen	7 (3.7)
General	5 (2.7)
Laboratory	6 (3.2)
Loading	21 (11.1)
Maintenance	23 (12.2)
Moulding	15 (8)
Personal	1 (0.5)
Process	103 (54.8)
Production	1 (0.5)
Stock	1 (0.5)
Store	5 (2.7)

Mean job duration of the workers was 15.9 $\pm$ 6.8 years. Only 1.1% of the workers had duration of work less than 5 years, whereas 30.3% workers had 6-10 years duration of work. 68.6% of workers were having duration of work 11 years and above (Table 5).

Table 5: Distribution of the Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=188)
Up to 5	2 (1.1)
6-10	57(30.3)
11 and above	129(68.6)

The workers did not report any complaint of cough or dyspnoea. Some workers complained of occasional eye irritation during working hours. On clinical examination crepitations were found in two subjects only. So far as pulmonary function of the workers is concerned, almost 68% workers were normal whereas 19% showed restrictive abnormality. Combined and obstructive abnormality was found in 5.9% and 6.9% workers respectively (Table 6). The PFT impairment can be both occupational (e.g. exposure to dust or fibres) and non occupational (e.g. smoking, chronic lung infections, environmental exposure to dust and fumes).

Table 6: Distribution of PFT Abnormalities

PFT Status	Frequency	%
Normal	128	68.1
Mixed	11	5.9
Obstructive	13	6.9
Restrictive	36	19.1

While analyzing PFT status with duration of work it was observed that abnormal pulmonary function was more prevalent in the workers with higher duration of work (Table 7). The workers with exposure of 15 or more years were having higher abnormalities as compared to those with work exposure of less than 15 years and the difference was statistically significant ($\chi2=8.01;df=1,p<0.01$).

Table 7: PFT Status according to duration of work

PFT Status	Duration of Work (years)					
	< 5	**5 - 9**	**10 - 14**	**15 - 19**	**≥20**	**Total**
Normal	1(50.0)	25(78.1)	45(78.9)	18(56.3)	39(60.0)	128(68.1)
Abnormal	1 (50.0)	7 (21.9)	12 (21.1)	14 (43.7)	26 (40.0)	60 (31.9)
Mixed	0(0.0)	0(0.0)	2(3.5)	3(9.4)	6(9.2)	11(5.9)
Obstructive	0(0.0)	3(9.4)	3(5.3)	3(9.4)	4(6.2)	13(6.9)
Restrictive	1(50.0)	4(12.5)	7(12.3)	8(25.0)	16(24.6)	36(19.1)
All Cases	2(100)	32(100)	57(100)	32(100)	65(100)	188(100)

Figure in parantheses are percentages

During analysis of PFT status with smoking status it was observed that abnormal pulmonary function (restrictive and combined abnormalities) was more prevalent in the workers who are smokers or past smokers.

So far as radiological findings are concerned, 107 workers showed normal X-ray features, 77 workers had prominent broncho-vascular markings in their radiographs and four workers had interstitial fibrosis seen in all the lung fields. These four workers were then advised High Resolution Computed Tomography (HRCT) of thorax. The HRCT did not reveal any finding suggestive of interstitial lung fibrosis.

Highlights of the study results

- Fiber level in all the workplaces were below national and international standards
- There were no complaints of the workers related to respiratory system.
- About 32% of the workers showed impaired lung functions. The major abnormality was restrictive type.
- Prevalence of PFT restrictive type of impairment was more with employees of higher duration of work (experience) and in smokers.
- Some workers had prominent broncho vascular markings in their radiographs and four workers had radiographs suggestive of interstitial lung fibrosis. However HRCT did not reveal any finding suggestive of interstitial lung fibrosis.

Asbestos cement sheet-manufacturing unit of Silvassa

Environmental monitoring was carried out at six sampling locations. Fiber concentrations are shown in Table 8. When compared with the permissible exposure level (PEL) in India[53], which is 1 fiber/ml, and with recommended levels of other agencies like OSHA[54], NIOSH[55] and ACGIH[56] which is 0.1fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 8: Fibre concentration (fibres/ml) at different locations

Location	Fibre Concentration (fibres / ml) Mean ± SD	n
Cement/Fly ash feeding	0.015 ± 0.0036	6
Fibre mill	0.032 ± 0.0204	6
Sheeting	0.009 ± 0.0034	6
Stripping	0.008 ± 0.0026	6
Moulding	0.008 ± 0.0038	6
Carbo -cutting	0.011 ± 0.0054	6

The health monitoring included 60 workers. The mean age of the study subjects was 27.4 ± 6.5 years (range 18-45 years). Majority of the workers (71.7%) were up to 30 years of age. Three percent workers were of more than forty years age. Twenty five percent workers were in 31-40 years age group (Table 9). Among the total number of workers 29(49.2%) were married and the rest were unmarried. Only 16.7% workers had more than secondary level education and about 23% workers illiterate (Table 10).

Table 9: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=60)
Upto 30	43 (71.7)
31-40	15 (25)
41-60	2 (3.3)

Table 10: Educational status of the workers

Educational Status	Number of workers (%) (N=60)
Illiterate	14 (23.3)
Primary	18 (30)
Secondary	18 (30)
Higher Secondary	7 (11.7)
College	3 (5)

Mean body mass index of the workers was 20.14 $\pm$ 2.5 kg/m^2. Majority (73.3%) had normal body mass index values (18.5 – 24.99) whereas 20% and 6.7% workers had values lower and higher than normal respectively.

Among the total number of workers, 16(27.1%) were smokers and 39(65%) workers were tobacco chewers.

Highest number of the workers (41.7%) was from Process Division followed by Packing/Loading (25%), Maintenance (18.3%), and Moulding Division (11.7%). Other workers participated in the study were from Stores and other departments (3.3%) (Table 11).

Table 11: Department wise distribution of the workers

Department	Frequency (%) (N=60)	Mean experience $\pm$ SD (years)
Maintenance	11(18.3)	4.7 $\pm$ 3.3
Process	25 (41.7)	4.2 $\pm$ 3.3
Packing / loading	15 (25)	3.27 $\pm$ 1.8
Molding	7 (11.7)	8.7 $\pm$ 2.1
Others	2 (3.3)	2 $\pm$ 1.4

Mean job duration of the workers was 4.5 $\pm$ 3.2 years. Minimum experience was 1 year and maximum experience was 13 years. Majority of workers (60%) had experience of work up to 5 years, whereas 36.7% workers had duration of work of 6-10 years. Almost three percent of workers were having experience of more than ten years (Table 12).

Table 12: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=60)
Up to 5	36 (60)
6-10	22(36.7)
11 and above	2(3.3)

So far as morbidity is concerned, 5% of the workers were suffering from cough, 6.7% from backache and 3.3% from joint pain. Eye irritation (8.3%) and nasal irritation (1.7%) during or immediately after work were the other complaints of the workers. On auscultation it was found that rhonchi and crepitations was present in 6.7% and 10% subjects respectively.

Table 13 shows the distribution of pulmonary function abnormalities as compared with predicted values. It can be observed that 4(6.8%) had obstructive impairment while remaining were having no pulmonary function impairment

Table 13: Distribution of PFT Abnormalities

PFT Status	Frequency [n=60]	%
Normal	56	93.2
Obstructive	4	6.8
Restrictive	-	-

Table 14 and 15 depicts the distribution of spirometric parameters according to age and duration of exposure respectively. No significant effect of age and work experience on pulmonary function test parameters' values was observed.

Table 14: Distribution of pulmonary function test parameters according to age

Age Group (Yrs.)	FVC (Litres)	FEV_1 (Litres)	$FEF_{25\%-75\%}$ (Litre/sec)
Up to 30*	4.10 ± 0.67	3.65 ± 0.62	4.51 ± 1.14
31-40	4.14 ± 0.58	3.59 ± 0.54	4.47 ± 1.22
41-60	3.49 ± 0.23	3.29 ± 0.49	4.78 ± 1.88
Single way ANOVA	F=0.92;df=2;p=0.4	F=0.41;df=2;p=0.7	F=0.06;df=2;p=0.9

*one person did not perform PFT

Table 15: Distribution of pulmonary function test parameters according to job duration

Experience Group (Yrs.)	FVC (Litres)	FEV_1 (Litres)	$FEF_{25\%-75\%}$ (Litre/sec)
Up to 5*	4.08±0.69	3.63 ± 0.65	4.53±1.32
6-10	4.10±0.55	3.61 ± 0.49	4.38±0.88
11 and above	4.22±1.12	3.83 ± 0.86	5.53±0.27
Single way ANOVA	F=0.05;df=2;p=0.9	F=0.12;df=2;p=0.9	F=0.92;df=2;p=0.4

*one person did not perform PFT

On radiological examination, findings suggestive of Koch's infection (Right Middle Zone) were observed in a single worker. No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Highlights

- Fiber level in all the workplaces were below national and international standards.
- On clinical examination of respiratory system, rhonchi and crepitations was present in 6.7% and 10% subjects respectively.
- No worker was found to have restrictive type of pulmonary function impairment.
- No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Asbestos jointing material-manufacturing unit, Vapi

Environmental monitoring was carried out at 12 sampling locations in fiber feeding and calendar machine section and at six sampling locations in Cutting/Finishing and near godown. Fiber concentrations are shown in Table 16. When compared with the permissible exposure level (PEL) in India[53], which is 1 fiber/ml, and with recommended levels of other agencies like OSHA[54], NIOSH[55] and ACGIH[56] which is 0.1 fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 16: Fibre concentration (fibres/ml) at different locations

Location	Fibre Concentration (fibres / ml) Mean ± SD	n
Fiber Feeding	0.038 ± 0.0224	12
Calendar machine	0.014 ± 0.0128	12
Cutting/finishing	0.011 ± 0.0071	6
Near Godown	0.022 ± 0.0114	6

The health monitoring included 70 workers. The mean age of the study subjects was 37.8 ± 9.02 years (range 22-60 years). Majority of the workers were more than 30 years of age. Twenty-four workers (34.2%) were of more than forty years age. Thirty workers (42.9%) were in 31-40 years age group. Sixteen workers (22.9%) were up to thirty years of age (Table 17). Among the total number of workers 63 (90%) were married and the rest were unmarried. Only 27.1% workers had more than secondary level education and about 14.3 % workers illiterate (Table 18).

Table 17: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=70)
Up to 30	16 (22.9)
31-40	30 (42.9)
41-60	24 (34.2)

Table 18: Educational status of the workers

Educational Status	Number of workers (%) (N=70)
Illiterate	10(14.3)
Primary	12(17.1)
Secondary	29(41.4)
Higher Secondary	7(10)
College	12(17.1)

Mean body mass index of the workers was 20.6 ± 4.4 kg/m^2. Majority (57.1%) had normal body mass index values (18.5 – 24.99) whereas 30% and 12.9% workers had values lower and higher than normal respectively.

Among the total number of workers, 10 (14.3%) were smokers and 28 (40%) workers were chewers.

Majority of the workers (51.4%) were from Process Division followed by Maintenance (24.3%) and Packing/Loading (8.6%). Other workers participated in the study were from Stores and other departments including persons employed for cleaning (15.7%) (Table 19).

Table 19: Department wise distribution of the workers

Department	Frequency (%) (N=70)	Mean experience ± SD (years)
Maintenance	17 (24.3)	11.76 ± 8.09
Process	36 (51.4)	11.50 ± 7.54
Packing / loading	6 (8.6)	8.33 ± 5.16
Others	11 (15.7)	14.54 ± 8.77

Mean job duration of the workers was 11.77 ± 7.71 years. Minimum experience was 1 year and maximum experience was 30 years. Highest number of workers (45.7%) had experience of more than 10 years, whereas 25.7% workers had duration of work of 6-10 years. Almost twenty nine percent of workers were having experience of up to 5 years of work (Table 20).

Table 20: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=70)
Up to 5	20 (28.6)
6-10	18 (25.7)
11 and above	32 (45.7)

So far as morbidity is concerned, 5.7 % of the workers were suffering from cough, 2.9% from backache and 2.9% from joint pain. Headache (5.7%), eye irritation (2.9%) and nasal irritation (2.9%) during or immediately after work were the other complaints of the workers.

Table 21 shows the distribution of pulmonary function abnormalities as compared with predicted values. It can be observed that 8(11.4%) had obstructive impairment and 2(2.9%) had restrictive impairment. Remaining were not having any pulmonary function impairment

Table 21: Distribution of PFT Abnormalities

PFT Status	Frequency [n=70]	%
Normal	60	85.7
Obstructive	8	11.4
Restrictive	2	2.9

Table 22 and 23 depicts the distribution of spirometric parameters according to age and duration of exposure respectively. Significant effect of age on pulmonary function test parameters' values was observed but no such significant effect was observed in relation to work experience.

Table 22: Distribution of pulmonary function test parameters according to age

Age Group (Yrs.)	FEV_1 (Litre)	FVC (Litre)	$FEF_{25\%-75\%}$ (Litre/sec)
Up to 30	3.57 ± 0.62	4.07 ± 0.75	4.22 ± 1.36
31-40	3.29 ± 0.55	3.76 ± 0.65	3.94 ± 1.18
41-60	2.87±0.75	3.43 ± 0.97	3.15 ± 1.23
Single way ANOVA	F=5.9;df=2;p=0.004*	F=3.2;df=2; p=0.04*	F=4.3;df=2;p=0.02*

*Significant

Table 23: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV_1 (Litre)	FVC (Litre)	$FEF_{25\%-75\%}$ (Litre/sec)
Up to 5	3.19 ± 0.61	3.65 ± 0.71	3.98 ± 1.17
6-10	3.33 ± 0.76	3.85 ± 0.84	3.67 ± 1.46
11 and above	3.16 ± 0.7	3.69 ± 0.89	3.61 ± 1.30
Single way ANOVA	F=0.3;df=2;p=0.7	F=0.3;df=2;p=0.7	F=0.5;df=2;p=0.6

On radiological examination, findings suggestive of Koch's infection (Right Upper Zone) were observed in two workers. One of them had right-sided pleural effusion also. No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Highlights

- Fiber level in all the workplaces were below national and international standards.
- Almost three percent (2.9%) workers were found to have restrictive type of pulmonary function impairment.
- No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Asbestos workers, end-users and community in the vicinity of asbestos sheet factory, Hyderabad

Environmental monitoring was carried out at six sampling locations in the factory and two locations each in Velmala and Sanduguda village. The indoor samples were taken under the asbestos sheet roof thereby suggesting levels of exposure to end-users while the outdoor samples were taken in the ambient air suggesting the exposure to community. Fiber concentrations in the factory are shown in Table 24 while the fibre levels in the village situated near the vicinity of the factory are shown in Table 25. Permissible Exposure level (PEL) in India[53] is 1 fiber/ml where as other agencies like OSHA[54], NIOSH[55] and ACGIH[56] recommend 0.1 fiber/ml. It can be seen from Table 24 and 25 that fiber concentrations are lower than the PELs.

Table 24: Mean Fiber Conc. (Fibers/ml) at different locations of the asbestos sheet-manufacturing factory

Location	Mean Fiber levels ± SD
Fiber Mill	0.008± 0.0042(6)
Sheeting	0.010 ± 0.0066 (6)
Carbo Cutting	0.033 ± 0.0282 (6)
Moulding	0.011 ± 0.0054 (6)
Stripping	0.013 ± 0.0140(6)
Outdoor	0.010 ± 0.0076 (7)

Figures in the Parenthesis indicate number of samples

Table 25: Mean Fiber Conc. (Fibers/ml) at different locations around the vicinity of factory

Village	Location	Mean Fiber levels ± SD
Velmala	Indoor	0.004 ± 0.0021 (12)
	Outdoor	0.003 ± 0.0013 (8)
Sanduguda	Indoor	0.004 ± 0.0019 (7)
	Outdoor	0.003 ± 0.0013(8)

Figures in the Parenthesis indicate number of samples

The health monitoring included 59 asbestos sheet workers, 362 subjects living in the vicinity of asbestos sheets manufacturing unit and 135 end-users of asbestos. The mean age of the asbestos sheet workers was 42.98 ± 3.5 years (range 35-53 years) while that for community and end users was 37.66 ± 9.5 years (range 18-80 years) and 36.96 ± 9.4 years (range 20-75 years) respectively. Among the asbestos workers majority of the workers were ≥40 years of age while majority of the community and end users were in the 21-40 years age group (Table 26). While only 23.7% of the asbestos workers were illiterate the proportion for community and end-users was 39.2% and 42.3% respectively. One asbestos worker and eleven community individuals were educated up to graduation level (Table 27).

Table 26: Age wise Distribution of the workers

Age group (Yrs.)	**Asbestos workers (N=59)**	**Community (N=362)**	**End Users (N=135)**
Up to 20	-	2 (0.6)	1 (0.7)
21-40	12 (20.3)	253 (69.9)	98 (72.6)
≥40	47 (79.7)	107 (29.6)	36 (26.7)
Mean Age(years)	42.98 ± 3.5	37.66 ± 9.5	36.96 ± 9.4

Figures in parenthesis indicate percentage

Table 27: Educational status of the workers

Educational Status	Asbestos workers	Community	End Users
Illiterate	14(23.7)	142 (39.2)	57 (42.3)
Primary	18 (30.5)	136 (37.6)	58 (43.0)
Secondary	18 (30.5)	63 (17.4)	20 (14.8)
Higher Secondary	8 (13.6)	10 (2.8)	-
College	1(1.7)	11 (3.0)	-

Figures in parenthesis indicate percentage

Mean body mass index of the workers was 25.42 ± 3.3 whereas the mean body mass index for community and end-users was 23.18 ± 4.8 and 22.34 ± 4.4 respectively. Among the workers only 49.2% had normal body mass index values (18.5 – 24.99 kg/m^2) whereas 1.7% and 49.2% workers had values lower and higher than normal respectively. Similarly among community individuals, majority (54.7%) had normal body mass index whereas 10.8% and 34.5% subjects had values lower and higher than normal respectively. In the end-users group 52.6% had normal body mass index values whereas 15.6% and 31.8% individuals had values lower and higher than normal respectively.

Among the asbestos workers, 20 (33.9%) were smokers and 3 (5.1%) were chewers. In the community the prevalence of tobacco use in smoking and chewing form was 31.2% and 5.6% while in the end-users the prevalence of smoking and tobacco chewing was 36.7% and 5.2% respectively.

Majority of the workers (62.7%) were from process division followed by maintenance (16.9%) and production (10.2%) (Table 28).

Table 3: Department wise distribution of the workers

Department	Frequency (%) (N=59)
Electrical	5 (8.5)
Maintenance	10 (16.9)
Mechanical	1 (1.7)
Process	37 (62.7)
Production	6 (10.2)

Mean job duration of the workers was 21.84 ± 2.43 years. Minimum experience was 15 years and maximum experience was 29 years. Majority of workers (76.3%) had experience of more than 20 years, whereas 23.7% workers had work experience between 11-20 years (Table 29).

Table 29: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=59)
< 10	-
11-20	14 (23.7)
≥20	45(76.3)

In the community 249 (68.8%) individuals were involved in the agriculture while in the end users 95 (70.4%) were farmers. Remaining individuals in both the group included miscellaneous occupations like driving, supervisor, washerman, etc.

Table 30: Distribution of study subjects according to symptoms

Symptoms	Asbestos workers (N=59)	Community (N=362)	End Users (N=135)
Backache	7 (11.9)	106 (29.3)	37 (27.4)
Joint pains	9 (15.3)	96 (26.5)	31 (23.0)
Eye irritation	1(1.7)	2 (0.6)	1 (0.7)
Allergy	-	4 (1.1)	-
Recurrent acute episodes of respiratory distress	-	5 (1.4)	
Chest pain	3 (5.1)	38 (10.5)	10 (7.4)
Dyspnoea	-	14 (3.9)	4 (3.0)
Phlegm	-	4 (1.1)	2 (1.5)
Cough	-	8 (2.2)	4 (3.0)
Headache	2 (3.4)	-	-
Throat irritation	1 (1.7)	-	-

Figures in parenthesis indicate percentage

So far as morbidity is concerned, in the asbestos workers group backache and joint pain were the common symptoms being reported by 11.9% and 15.3% workers. In the community individuals the common symptoms included backache in 29.3%, joint pains in 26.5% and chest pain in 10.5%. Similarly in the end-users the common symptoms were backache in 27.4%, joint pains in 23% and chest pain in 7.4% (Table 30).

Table 31 shows the distribution of pulmonary function abnormalities as compared with predicted values. Pulmonary function test revealed that among asbestos sheet workers, 22.4% workers were having restrictive disorder, 10.3% were having obstructive abnormality, 3.4% were having combined type of abnormality and rest were normal. Similarly in the community individuals 10.8% were having restrictive disorder, 7.7% were having obstructive abnormality, 2.5% were having combined type of abnormality and rest were normal. In the end-users 11.9% were having restrictive disorder, 7.4% were having obstructive abnormality, 2.2% were having combined type of abnormality and rest were normal.

Table 31: Distribution of PFT Abnormalities

PFT Status	Asbestos sheet workers [n=58*]	Community [n=362]	End-users [n=135]
Normal	37 (63.8)	286(79.0)	106(78.5)
Obstructive	6 (10.3)	28(7.7)	10(7.4)
Restrictive	13 (22.4)	39(10.8)	16(11.9)
Mixed	2 (3.4)	9(2.5)	3(2.2)

*One worker did not performed PFT

Table 32 and 33 shows the distribution of FEV_1 and FVC according to age respectively. It can be observed that in the community and end-users both FEV_1 and FVC were significantly higher in those < 40 years of age as compared to those aged >40 years. However in the asbestos workers so such difference was observed. But in the workers the mean FVC values of those employed for >20 years were significantly lower than those employed for 11-20 years (Table 34).

Table 32: Distribution of FEV_1 according to age

Age Group (Yrs.)	Asbestos workers	Community	End-users
Up to 20	-	2.6 ± 0.0	2.2 ± 0.0
21-40	2.4 ± 0.45	2.9 ± 0.72	2.9 ± 0.68
≥40	2.6 ± 0.52	2.4 ± 0.72	2.3 ± 0.78
Single way ANOVA	F=0.69;df=2;p=0.4	F=11.13;df=2; p<0.01*	F=10.58;df=2; p<0.01*

*Significant

Table 33: Distribution of FVC according to age

Age Group (Yrs.)	Asbestos workers	Community	End-users
Up to 20	-	2.9 ± 0.0	2.9 ± 0.0
21-40	2.8 ± 0.56	3.4 ± 0.79	3.3 ± 0.76
≥40	2.9 ± 0.54	2.7 ± 0.79	2.7 ± 0.81
Single way ANOVA	F=0.91;df=2; p=0.34	F=11.13;df=2; p<0.01*	F=6.47;df=2; p<0.002*

*Significant

Table 34: Distribution of lung function parameters according to duration of exposure among asbestos workers

Experience Group (Yrs.)	FEV_1 (Litre)	FVC (Litre)	$FEF_{25\%-75\%}$ (Litre/sec)
11-20	2.7 ± 0.6	3.2 ± 0.64	3.4 ± 1.62
≥20	2.5 ± 0.45	2.9 ± 0.49	3.1 ± 0.96
t-test	t=3.07; df=1;p=0.08	t=4.37;df=1;p=0.04*	t=1.09;df=1; p=0.29

*Significant

On radiological examination, in asbestos sheet workers two subjects had findings suggestive of sternal sutures. In the community group, eight subjects had findings of Koch's infection, one had pleural effusion while one had pleural thickening of right chest wall. In the end-users group seven had findings suggestive of Koch's infection. No subject was found to have radiographic features suggestive of interstitial lung fibrosis.

Highlights

- Fiber level in all the workplaces and in the vicinity of the factory was below national and international standards.
- Pulmonary function test revealed that among asbestos sheet workers, 22.4% workers were having restrictive disorder and 3.4% were having

combined type of abnormality while in the community individuals 10.8% were having restrictive disorder and 2.5% were having combined type of abnormality. In the end-users 11.9% were having restrictive disorder, and 2.2% were having combined type of abnormality.

- No subject was found to have radiographic features suggestive of interstitial lung fibrosis.

Asbestos brake-lining manufacturing unit, Hyderabad

Environmental monitoring was carried out at different locations. Fiber concentrations are shown in Table 35. When compared with the permissible exposure level (PEL) in India[53], which is 1 fiber/ml, and with recommended levels of other agencies like OSHA[54], NIOSH[55] and ACGIH[56] which is 0.1 fiber/ml, it was found that except in the pre-forming section the fiber concentrations in all sections were lower than the PELs. In the pre-forming section the fibre levels were lower than the national PEL but more than the levels recommended by international agencies like OSHA[58], NIOSH[59], and ACGIH[60].

Table 35: Mean Fiber Conc. (Fibers/ml) at different locations

Location	Mean Fiber levels ±SD
Fiber Feeding	0.057 ± 0.0325 (6)
Curing	0.040 ± 0.0194 (6)
Pre-forming	0.106 ± 0.0415*(6)
Grinding	0.021 ± 0.0084 (6)
Drilling	0.019 ± 0.0054 (4)
Cutting	0.030 ± 0.0120 (4)
Inspection	0.051 ± 0.0435(3)
Bag filter	0.058 ± 0.0261(7)
Outdoor	0.009 ± 0.0111 (8)

Figures in the Parenthesis indicate number of samples

*Levels higher than international standards

The health monitoring included 153 brake lining workers. The mean age of the study subjects was 33.63 ± 4.3 years (range 26-51 years). Majority of the workers were more than 30 years of age. Eleven workers (7.2%) were of more than forty years of age. 109 (71.2%) workers were in 31-40 years age group. 33 (21.6%) workers were up to thirty years of age (Table 36). 62 (40.5%) workers had more than secondary level education and only 4 (2.6%) workers were having primary level of education (Table 37).

Table 36: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=153)
Up to 30	33 (21.6)
31-40	109 (71.2)
41-60	11 (7.2)

Table 37: Educational status of the workers

Educational Status	Number of workers (%) (N=153)
Primary	4(2.6)
Secondary	62(40.5)
Higher Secondary	31(20.3)
College	56(36.6)

Mean body mass index of the workers was 24.73 $\pm$ 3.4 kg/m^2. Majority (55.9%) had normal body mass index values (18.5 – 24.99 kg/m^2) whereas 7.9% and 36.1% workers had values lower and higher than normal respectively.

Among the total number of workers, 15 (9.8%) were smokers and none were chewers.

Majority of the workers (85.6%) were from production division followed by maintenance (18.5%) and other (5.9%) (Table 38).

Table 38: Department wise distribution of the workers

Department	Frequency (%) (N=153)
Production	131 (85.6)
Maintenance	13 (8.5)
Others	9 (5.9)

Mean job duration of the workers was 12.13 ± 2.77 years. Minimum experience was 6 years and maximum experience was 22 years. Majority of workers (65.4%) had experience of more than 10 years, whereas 32.7% workers had work experience of less than 10 years. Three workers had more than 20 years of experience (Table 39).

Table 39: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=153)
< 10	50 (32.7)
11-20	100 (65.4)
≥ 20	3 (2.0)

So far as morbidity is concerned, 2 % of the workers were suffering from cough, 15.7% from backache and 12.5% from joint pain. Dyspnoea, chest pain and throat irritation was reported by one worker each.

Table 40 shows the distribution of pulmonary function abnormalities as compared with predicted values. Pulmonary function test revealed that 6(3.9%) workers were having restrictive disorder, 20(13.1%) were having obstructive abnormality, 1(0.7%) worker was having combined type of abnormality and rest were normal.

Table 40: Distribution of PFT Abnormalities

PFT Status	Frequency [n=153]	%
Normal	126	82.3
Obstructive	20	13.1
Restrictive	6	3.9
Mixed	1	0.7

Table 41 and 42 depicts the distribution of spirometric parameters according to age and duration of exposure respectively. Significant effect of age and work experience on Forced Vital Capacity (FVC) and Forced Expiratory Volume in first second (FEV_1) was observed.

Table 41: Distribution of PFT parameters according to age

Age Group (Yrs.)	FEV_1 (Litres)	FVC (Litres)	$FEF_{25\%-75\%}$ (Litres/sec)
Up to 30	2.9 ± 0.42	3.3 ± 0.48	3.46 ± 0.8
31-40	2.8 ± 0.47	3.3 ± 0.48	3.55 ± 1.2
41-60	2.2 ± 0.61	2.56 ± 0.59	2.61 ± 1.45
Single way ANOVA	F=10.89;df=2; p=0.000*	F=11.13;df=2; p=0.000*	F=3.33;df=2; p=0.38

*Significant

Table 42: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV_1 (Litres)	FVC (Litres)	$FEF_{25\%-75\%}$ (Litres/sec)
Up to 10	2.9 ± 0.49	3.3 ± 0.49	3.7 ± 1.16
11-20	2.8 ± 0.48	3.2 ± 0.5	3.4 ± 1.17
21 and above	1.8 ± 0.49	2.0 ± 0.41	2.37 ± 1.21
Single way ANOVA	F=7.43;df=2; p=0.001*	F=9.59;df=2; p=0.001*	F=2.13;df=2; p=0.12

*Significant

On radiological examination, findings suggestive of Koch's fibrosis (both Upper Zone) were observed in one worker while one worker showed cardiac enlargement. No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Highlights

- Fiber level in all the workplaces were below national standards.
- 3.9% workers were found to have restrictive type and 0.7% had combined type of pulmonary function impairment.
- No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Asbestos pipe manufacturing unit, Hyderabad

Environmental monitoring was carried out at different locations. Fiber concentrations are shown in Table 43. When compared with the permissible exposure level (PEL) in India[53], which is 1 fiber/ml, and with recommended levels of other agencies like OSHA[54], NIOSH[55] and ACGIH[56] which is 0.1fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 43: Mean Fiber Conc. (Fibers/ml) at different locations

Location	Mean Fiber levels ± SD
Fiber Mill	0.049 ± 0.0629(6)
Cement Feeding	0.027 ± 0.0078(5)
Lamina Rolling	0.017 ± 0.0082 (6)
Finishing	0.027 ± 0.0139 (12)
Cutting	0.035 ± 0.0238 (4)
Outdoor	0.004 ± 0.0020 (6)

Figures in the Parenthesis indicate number of samples

The health monitoring included 95 workers of asbestos pipe making units. The mean age of the study subjects was 30.09 ± 8.7 years (range 18-62 years). Majority of the workers were more than 20 years of age. Eleven workers (11.6%) were of more than forty years age. 79 (83.2%) workers were in 21-40 years age group. 5 (5.3%) workers were up to twenty years of age (Table 44). 69 (72.6%) workers had more than primary level education and only 7 (7.4%) workers were illiterate (Table 45).

Table 44: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=95)
Up to 30	60 (63.2)
31-40	24 (25.3)
≥41	11 (11.5)

Table 45: Educational status of the workers

Educational Status	Number of workers (%) (N=95)
Illiterate	7 (7.4)
Primary	19 (20.0)
Secondary	26 (27.4)
Higher Secondary	27 (28.4)
College	16 (16.8)

Among the total number of workers, 4 (4.2%) were smokers and 12 (12.7%) workers were chewers.

Majority of the workers, 52 (54.8%) were from finishing division followed by 12 (12.7%) in production and 9 (9.5%) in maintenance. The other departments included crane operator, supervisor, storekeeper, computer operator and office staff (Table 46).

Table 46: Department wise distribution of the workers

Department	Frequency (%) (N=95)
Production	12 (12.7)
Finishing	52 (54.8)
Maintenance	9 (9.5)
Others	22 (23.0)

Mean job duration of the workers was 5.14 ± 3.13 years. Minimum experience was 1 year and maximum experience was 12 years. Majority of workers, 91 (95.8%) had experience of less than 10 years. Only 4 (4.2%) workers had more than 10 years of experience (Table 47).

Table 47: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=95)
< 5	52(54.7)
6-10	39(41.1)
11 and above	4 (4.2)

So far as morbidity is concerned, 2.1% of the workers were suffering from cough, 20% from backache and 7.4% from joint pain. Other complaints included dyspnoea in 4 (4.2%), headache in 6 (6.3%), chest pain in 4 (4.2%), Itching in skin in 3 (3.2%) and eye irritation in 3 (3.2%) workers.

Table 48 shows the distribution of pulmonary function abnormalities as compared with predicted values. Pulmonary function test revealed that 2.1% workers were having restrictive disorder, 7.4% were having obstructive abnormality, 1.1% were having combined type of abnormality and rest were normal.

Table 48: Distribution of PFT Abnormalities

PFT Status	Frequency [n=95]	%
Normal	85	89.5
Obstructive	7	7.4
Restrictive	2	2.1
Mixed	1	1.1

Table 49 and 50 depicts the distribution of spirometric parameters according to age and duration of exposure respectively. Significant effect of age was observed in all the pulmonary function parameters while the significant effect of work experience was not seen on Forced Vital Capacity.

Table 49: Distribution of PFT parameters according to age

Age Group (Yrs.)	FEV_1 (Litres)	FVC (Litres)	$FEF_{25\%-75\%}$ (Litres/sec)
Up to 30	3.4 ± 0.46	3.7 ± 0.45	4.4 ± 1.22
31-40	3.2 ± 0.58	3.6 ± 0.65	3.8 ± 0.92
≥41	2.5 ± 0.56	2.9 ± 0.57	3.1 ± 1.29
Single way ANOVA	F=15.76;df=2;p=0.000*	F=9.19;df=2;p=0.000*	F=7.44;df=2;p=0.001*

*Significant

Table 50: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV_1 (Litres)	FVC (Litres)	$FEF_{25\%-75\%}$ (Litres/sec)
Up to 5	3.4 ± 0.49	3.7 ± 0.53	4.5 ± 1.06
6-10	3.0 ± 0.63	3.5 ± 0.58	3.7 ± 1.39
11 and above	3.1 ± 0.57	3.4 ± 0.57	4.3 ± 0.37
Single way ANOVA	F=5.02;df=2;p=0.009*	F=2.53;df=2;p=0.08	F=4.75;df=2;p=0.011*

*Significant

On radiological examination, findings suggestive of Koch's infection (Upper Zone) were observed in three workers. One of them had fracture of right 8^{th} rib posteriorly. No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Highlights

- Fiber level in all the workplaces were below national and international standards.

- 2.1% workers were found to have restrictive type and 1.1% had combined type of pulmonary function impairment.
- No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Small-scale units at Panoli, NOIDA, Thane and Hyderabad

Environmental monitoring was carried out at different locations of all the six units. Fiber concentrations are shown in Tables 51-53. When compared with the permissible exposure level (PEL) in India[53], which is 1 fiber/ml, it was found that fiber concentrations were lower than the PELs. However when compared with recommended levels of other agencies like OSHA[54], NIOSH[55] and ACGIH[56] which is 0.1 fiber/ml, it was found that at some processes of brake lining making units (Table 51), asbestos textile making units (Table 52) and insulation board making units (Table 53) fiber concentrations were higher than the PELs.

Table-51: Fiber concentrations (fibers/ml) in different processes of brake shoe making units

Process	Fiber Concentration (fibers/ml) Mean ± SD (N)
Unit I	
Mixing	0.139 ± 0.0794* (6)
Moulding	0.126 ± 0.0357* (6)
cutting	0.072 ± 0.0328 (6)
Drilling	0.052 ± 0.0221 (7)
Grinding	0.066 ± 0.0289 (6)
Unit II	
Forming	0.175 ± 0.1621* (5)
Moulding	0.103 ± 0.0423* (6)
Drilling	0.112 ± 0.0496* (6)

Figures in the parenthesis indicate number of samples
*Levels higher than international standards

Table-52: Fiber concentrations (fibers/ml) in different processes of asbestos textile making units

Process	Fiber Concentration (fibers/ml) Mean ± SD (N)
Unit I	
Mixing	0.114 ± 0.0267* (6)
Carding	0.097 ± 0.0292 (6)
Twisting	0.093 ± 0.0449 (6)
Winding	0.193 ± 0.0496* (6)
Cloth weaving	0.153 ± 0.0928* (5)
Rope brading	0.213 ± 0.3245* (6)
Tape weaving	0.136 ± 0.0471* (6)
Unit II	
Mixing	0.150 ± 0.0489* (6)
Carding	0.056 ± 0.0297 (6)
Ring Frame	0.074 ± 0.0603 (6)
Twisting	0.111 ± 0.0629* (6)
Weaving	0.257 ± 0.1332* (8)
Unit III	
Mixing	0.059 ± 0.0268 (6)
Carding	0.121 ± 0.0585* (6)
Ring Frame	0.072 ± 0.0372 (6)
Twister/ Doubler	0.0.047 ± 0.0293(6)
weaving	0.076 ± 0.0468 (6)
Unit IV	
Winding	0.025 ± 0.0186 (6)
Brading	0.046 ± 0.0555 (6)
Calliperation & Cutting	0.016 ± 0.0087 (4)

Figures in the parenthesis indicate number of samples
*Levels higher than international standards

Table 53: Fiber concentrations (Fibers/ml) for different processes in of thermal insulating boards

Process	Fiber Concentration (Fibres/ml) Mean± SD (N)
Feeding of materials	0.109 ± 0.0631* (4)
Weighing/Slurry making	0.057 ± 0.0255 (6)
Pressing	0.066 ± 0.0378 (6)
Machine grinding	0.088 ± 0.0437 (6)
Hand finishing	0.045 ± 0.0257 (6)

Figures in the parenthesis indicate number of samples
*Levels higher than international standards

The health monitoring included 126 workers of small scale asbestos units. The mean age of the study subjects was 32.75 ± 10.64 years (range 18-58 years). Majority of the workers (52.4%) were up to 30 years of age. 23.8 percent workers were of more than forty years of age. 23.8 percent workers were in 31-40 years age group (Table 54). Among the total number of workers 36(28.6%) were single and the rest were married. Only 11.1% workers were illiterate while 70.6% had more than secondary level education (Table 55).

Table 54: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=126)
Up to 30	66 (52.4)
31-40	30 (23.8)
41-60	30 (23.8)

Table 55: Educational status of the workers

Educational Status	Number of workers (%) (N=126)
Illiterate	14 (11.1)
Primary	23 (18.3)
Secondary	56 (44.4)
Higher Secondary	30 (23.8)
College	3 (2.4)

Among the total number of workers, 19(15.1%) were smokers and 44(34.9%) workers were tobacco chewers.

Majority of the workers (61.1%) were from textile and rope making units followed by brake lining making units (22.2%), rope making (9.5%), and insulation board making units (7.1%) (Table 56).

Table 56: Industry wise distribution of the workers

Type of unit	Frequency (%) (N=126)
Brake lining	28(22.2)
Rope making	12 (9.5)
Textile and rope making	77 (61.1)
Insulation board	9 (7.1)

Mean job duration of the workers was 5.33 ± 6.68 years. Minimum experience was 1 month and maximum experience was 35 years. Majority of workers (73.8%) had experience of work up to 5 years, 11.1% workers had duration of work of 6-10 years and 15.1% workers were having experience of more than ten years (Table 57).

Table 57: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=126)
Up to 5	93 (73.8)
6-10	14(11.1)
11 and above	19(15.1)

So far as morbidity is concerned, 5.6% of the workers were suffering from cough, 3.2% had sputum production, 4.8% from backache and 4% from joint pain. Eye irritation (13.5%) and nasal irritation (4.8%) during or immediately after work were the other complaints of the workers. On auscultation it was found that two subjects had fine crepitations while one each had coarse crepitations and pleural rub.

Table 58 shows the distribution of pulmonary function abnormalities as compared with predicted values. Pulmonary function test revealed that 21(61.7%) workers had obstructive disorder, 22(17.5%) were having restrictive disorder, 7(5.6%) were having combined disorder and rest were normal.

Table 58: Distribution of PFT Abnormalities

PFT Status	Frequency [n=126]	%
Normal	76	60.3
Obstructive	21	16.7
Restrictive	22	17.5
Mixed	7	5.6

Table 59 and 60 depicts the distribution of spirometric parameters according to age and duration of exposure respectively. A significant decline in FVC and FEV_1 was observed with increasing age and duration of exposure.

Table 59: Distribution of pulmonary function test parameters according to age

Age Group (Yrs.)	**FEV_1 (Litres)**	**FVC (Litres)**	**$FEF_{25\%-75\%}$ (Litres/sec)**
Up to 30	2.9 ± 0.61	3.4 ± 0.64	3.6 ± 1.09
31-40	2.5 ± 0.57	2.9 ± 0.65	2.9 ± 1.06
41-60	2.3 ± 0.43	2.8 ± 0.46	2.4 ± 0.91
Single way ANOVA	F=18.7;df=2;p=0.000*	F=13.8;df=2;p=0.000*	F=14.4;df=2;p= 0.000*

*Significant

Table 60: Distribution of pulmonary function test parameters according to job duration

Experience Group (Yrs.)	**FEV_1 (Litres)**	**FVC (Litres)**	**$FEF_{25\%-75\%}$ (Litres/sec)**
Up to 5	2.8 ± 0.62	3.32 ± 0.64	3.37 ± 1.15
6-10	2.4 ± 0.43	2.94 ± 0.42	2.64 ± 0.97
11 and above	2.1 ± 0.39	2.53 ± 0.50	2.51 ± 0.91
Single way ANOVA	F=14.9;df=2;p=0.000*	F=14.9;df=2;p=0.000*	F=6.5;df=2;p= 0.002*

*Significant

On radiological examination, 14 (11.1%) showed prominent bronchovascular markings, 3(2.4%) showed interstitial lung fibrosis, 8(6.4%) showed findings suggestive of Koch's infection and 2(1.6%) showed cardiac enlargement.

When knowledge of these workers was assessed, only 50.4% of the subjects knew that the workplace in which they are working uses asbestos as one of the raw material. Further 75(64.1%) considered asbestos as harmful material for health. Only 10(8.5%) workers received formal training to safe handle the asbestos while only 3(2.6%) subjects knew that health hazards caused by asbestos are compensable. All the workers were using personal protective device such as a piece of cloth as mask to protect themselves against the dust. However, 29% of the workers did not know about the safe disposal of asbestos waste. About one-fourth underwent periodic medical examination and only 13.7% were ever radiographed after joining the job.

Highlights

- Fiber level in few work processes of asbestos textile making, brake shoe making and insulation board making units were above international PELs. The fibre levels at all workplaces were below national PELs.
- On clinical examination, it was found that two subjects had fine crepitations while one each had coarse crepitations and pleural rub.
- Pulmonary function test revealed that 21(61.7%) workers had obstructive disorder, 22(17.5%) were having restrictive disorder and 7(5.6%) were having combined disorder.
- On radiological examination, 14 (11.1%) showed prominent bronchovascular markings, 3(2.4%) showed interstitial lung fibrosis, 8(6.4%) showed findings suggestive of Koch's infection and 2(1.6%) showed cardiac enlargement.

Risk Analysis

A risk assessment/analysis usually means the understanding of probability of occurrence of adverse outcome given the scenario of present prevailing conditions.

This present study has been a cross sectional effort to understand the prevailing environmental condition in different work places handling chrysotile variety of asbestos, as well as to screen workers for asbestos related adverse health conditions.

Asbestos is the generic name for a group of minerals found in nature and frequently used for many purposes. Chrysotile asbestos or the white asbestos is the variety that is used more commonly. Asbestos has its adverse health effects on human being ranging from pleural plaque and benign pleural thickening to mesothelioma of pleura-peritoneum, lung cancer and a type of interstitial lung fibrosis known as asbestosis. Usually a relatively long latent period is required for the causation of such health abnormalities following exposure to asbestos.

Studies on asbestos exposure, carried out earlier than a decade or more, has shown high levels of asbestos fiber in working environment and also observed good percentage of health morbidities among the exposed workers.

This present study found the fiber levels in working atmosphere to be relatively much lower in comparison to the earlier studies mentioned. Most of the occasions these levels have remained considerably lower than the permissible exposure levels. So far as the adverse health effect is concerned three workers of small-scale sector had radiological findings suggestive of interstitial lung fibrosis. However, restrictive pulmonary function abnormality was observed in good number of subjects. Crepitations were also found on auscultative examination in some subjects. Though these findings in isolation are not pathognomonic of asbestos related health outcome, these observations may very well be associated with asbestos related health abnormalities.

When compared with the findings of earlier studies, the observations of this present study indicate that the risk of asbestos exposure and resulting adverse health outcome has lessened over a period of last 1-2 decade and present day work places are more worker friendly than the previous days workplaces. However, this presumption may be limited by the facts that even low exposure for considerable duration may cause diseases, latent period of disease occurrence may be long, and finding of a good number of restrictive health abnormality may indicate presence of sub-clinical disease entity.

Mathematical expression of risk

Possibility of finding the asbestos related health outcomes during a cross sectional study is many times limited by long latent period and resulting sub-clinical level existence of the disease entity. Hence it is difficult and may look a bit arbitrary to ascertain probability points for occurrence of established asbestos related adverse health outcome. However, an effort may be made putting an impact rating scale between 1 & 3 and probability point scale between 1 & 10 (low=1, medium=5, high=10) and expressing the risk mathematically as a product of the two values. As the occurrence of an established asbestos related health abnormality may produce grave outcome/consequence on the health of the concerned person, impact rating should be marked as 3 for such scenario. No established asbestos related health outcome is observed in this study but finding of respiratory impairment may suggest that some sub-clinical asbestos related disease entity might be there in a hidden state. Hence probability point allotted in this case should be within a range of 3 to 5. So, mathematical expression of risk in this case may be expressed as a numerical entity ranging from 9 to 15 (3x3 to 3x5) in a scale of one to thirty.

Conclusions

1. This study was carried out with the objectives of workplace monitoring and health status of the workers of chrysotile asbestos products manufacturing units including the small scale sectors.

2. The study included a total of 1248 subjects, which comprise of 625 asbestos workers, 362 community subjects residing in the vicinity of asbestos sheet manufacturing factory, 126 small-scale unit workers and 135 end-users of chrysotile asbestos product.

3. The mean age of the workers was found to be highest in the sheet workers of Hyderabad (42.9 $\pm$ 3.5 years) while in the sheet industry at Silvassa it was lowest (27.4 $\pm$ 6.5 years). The mean age of the community residing in the vicinity of sheet factory was 37.6 $\pm$ 9.5 years while that of end-users was 36.9 $\pm$ 9.4 years. The mean age of small-scale unit workers was 32.7 $\pm$ 10.6 years. Accordingly the mean duration of job was highest among sheet workers of Hyderabad (21.8 $\pm$ 2.4 years) while in the sheet industry at Silvassa it was lowest (4.5 $\pm$ 3.2 years).

4. The literacy levels of the workers in most of the industries was found to be good. This helps in motivating the workers to use personal protective devices (PPDs) and in implementing the control measures such as health education for the prevention of diseases related to asbestos exposure.

5. On medical examination majority of the workers were found to be in a good state of health.

6. The pulmonary function test reveal that out of total 1248 subjects, 136 (10.9%) had restrictive abnormality, 117 (9.4%) had obstructive abnormality and 34 (2.7%) had combined (restrictive + obstructive) type of pulmonary function abnormality. Rest of the subjects were normal. However on radiological examination, only three workers of small-scale units showed interstitial lung fibrosis. While this number is small, this needs proper monitoring in future. Also finding of respiratory impairment may suggest that some sub-clinical asbestos related disease entity might be there in a hidden state. Further analysis showed that 10.8% asbestos workers had restrictive abnormalities as comparison to 11.1% community subjects. The difference was statistically non-significant (χ^2= 0.03, df=1, p>0.05).

7. Common findings on radiological examination included suggested old pulmonary tuberculosis in 22(2.4%) subjects, prominent broncho-vascular markings in 14 (11.1%) subjects and pleural effusion and pleural thickening in few subjects.

8. The asbestos fibres monitoring in the workplace showed that the fibre levels in the workplace were well below the national standards of 1fibre/ml. When comparison was made with the recommended international standards (0.1fibre/ml) like OSHA, NIOSH or ACGIH, it was found that in 18.73% samples the fibre levels were above the recommended international levels. Also, the dust levels in the ambient air as well as under the asbestos sheet roof was also found to much lower that these standards. The low levels of fibres reflect enclosed manufacturing processes particularly in the large sector industries. Further

talking to the owners also revealed that the proportion of asbestos added to the cement is also reduced due to cost and availability factors. This could also be a reason of reduced liberation of dust in the working environment and thereby low fibre levels.

9. During the study it was found that all of the organized factories were using protective measures for the control of occupational and environmental health hazards. In small scale units it was found that workers were using a piece of cloth in place of standard mask.

Recommendations

1. In the present study the fibre levels were found to be lower than the national permissible levels. However 80(18.73%) out of 427 samples showed fibre levels above the international standards of 0.1fibre/ml. This suggests that periodic monitoring of the workplace fibre levels may be ensured to keep it below permissible levels.

2. At the present low fibre levels, no subject was found to have radiological finding suggestive of interstitial lung fibrosis except three workers (2.4%) of small-scale sector. While the situation is satisfactory, it is recommended that the workers particularly those having restrictive, obstructive and combined type of pulmonary function abnormalities should be periodically monitored medically so as to detect any adverse health effects at the earliest.

3. The industries were using protective measures like use of personal protective devices, pre-placement, periodic and post retirement medical examination, for the control and prevention of asbestos related health hazards. However there is a further scope of improvement of occupational health and safety conditions of small-scale units.

4. In general, education and training of the workers should be regularly conducted. These programmes should cover the health hazards associated with asbestos exposure, safe handling of asbestos and the preventive measures available so as to make the environment totally safe for the workers.

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