

**BEFORE THE NATIONAL GREEN TRIBUNAL,
PRINCIPAL BENCH, NEW DELHI**

Original Application No. 298 OF 2023

IN THE MATTER OF

DR. RAJA SINGH

...Applicant

VERSUS

UNION OF INDIA & ORS.

.... Respondents

INDEX

S.NO.	PARTICULAR	PAGES
1.	AFFIDAVIT IN COMPLIANCE OF THE ORDER DATED 18.07.2024 ON BEHALF OF MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE (RESPONDENT NO.1)	01-03
2.	Copy of the report titled "Study of Health Hazards/ Environmental Hazards resulting from use of variety of asbestos in the Country"	04-117

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Dated: 24/09/2024

BEFORE THE HON'BLE NATIONAL GREEN TRIBUNAL
PRINCIPAL BENCH AT NEW DELHI
ORIGINAL APPLICATION NO. 298 OF 2023

IN THE MATTER OF:

DR. RAJA SINGH

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VERSUS

UNION OF INDIA & ORS

...RESPONDENTS

**AFFIDAVIT IN COMPLIANCE OF THE ORDER DATED 18.07.2024 ON
BEHALF OF RESPONDENT - MINISTRY OF ENVIRONMENT,
FOREST AND CLIMATE CHANGE.**

I, Ved Prakash Mishra S/o Sh. R.S Mishra aged about 48 Years, presently working as Director with the Ministry of Environment, Forest and Climate Change (hereinafter referred to as MoEFCC) having office at Indira Paryavaran Bhawan, Jor Bagh, New Delhi -110003, do hereby solemnly affirm and state as hereunder:

1. That the present affidavit is filed in respectful compliance of the order of this Hon'ble Tribunal dated 18.07.2024, vide which this Hon'ble Tribunal was pleased to inter-alia direct as follows:

"6. We also require Ministry of Environment, Forest and Climate Change to find out whether in respect of user of asbestos sheets in



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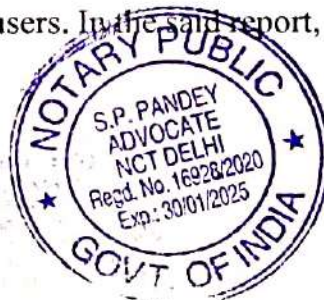
Educational Institutions, there are some different kinds of health hazards to students i.e. non-occupational health hazards, comparing to health hazards applicable to workers in Industrial Sector, and if there is a distinction, let the matter be given a scientific study and report of such scientific study be submitted along with reply."

2. That the Answering Respondent is engaged in, *inter alia*, policy formulation for abatement, control, and prevention of pollution and prescribing environmental standards to be implemented through the Central Pollution Control Board (CPCB) and State Pollution Control Boards (SPCBs)/ Pollution Control Committees (PCCs). Besides, the concerned State Pollution Control Boards/Pollution Control Committees are empowered to take all such measures as are deemed necessary or expedient for the purpose of protecting and improving the quality of the environment as well as prevention, control, and abatement of environmental pollution.

3. That, the Answering Respondent has received inputs from the Department of Chemicals and Petro-chemicals (DCPC) on this issue that a comprehensive study has already been made on the issue of health effects of chrysotile asbestos in 2006 by National Institute of Occupational Health (NIOH), sponsored by DCPC. NIOH submitted its final consolidated report titled "Study of Health Hazards/Environmental Hazards resulting from use of variety of asbestos in the country" in May 2012. The NIOH report did not indicate any significant health/environment hazards resulting from the use of Chrysotile asbestos under proper conditions at workplace, hence no significant occupational health hazard has been noticed.

4. With regard to the directions of Hon'ble Tribunal for a scientific study on non-occupational health hazards, the above referred study has also made findings on health hazards on end users. In the said report, in chapter 6 on results,

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health impact of chrysotile asbestos on end users as well as on community in the vicinity of the factory is discussed , which is regarding non-occupational health effects. It has also been observed in the report that fiber levels in all work places and in the vicinity of the factory were below national and international standards. It is also noted that no subject was found to have radiographic features suggestive of interstitial lung fibrosis.

5. Hence, it is kindly submitted that study has already been made on various health impacts of chrysotile asbestos both occupational & non-occupational. The above study report made by NIOH is submitted for kind perusal of the Hon'ble Tribunal.

6. That, the Answering Respondent reserves its right to file additional information before the Hon'ble Tribunal, if required, till *Pendente-Lite*.

7. That, in view of the foregoing submissions, this Hon'ble Tribunal may be pleased to pass such or further orders as it may deem fit in the given circumstances of the case.

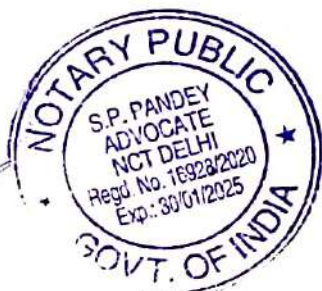
Identify the deponent who has Signed that T.I. in my presence


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VERIFICATION:

24 SEP 2024


Verified at New Delhi on the 24th of September, 2024 that the contents of the above affidavit are true and correct to the best of my knowledge and belief and nothing material has been suppressed or concealed therein.



ATTESTED


 NOTARY PUBLIC
 GOVT. OF INDIA

24 SEP 2024


DEPONENT
 (VED PRAKASH MISHRA)
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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)
MEGHANI NAGAR, AHMEDABAD

CONTENTS

S.No.	DESCRIPTION	Page No.
1.	BACKGROUND	4
2.	ASBESTOS AND ITS HEALTH HAZARDS	6
3.	LITERATURE REVIEW	12
4.	MANUFACTURING PROCESS	
	Asbestos sheet manufacturing unit, Kolkata	24
	Asbestos sheet manufacturing unit, Silvassa	32
	Asbestos Jointing material manufacturing unit, Vapi	39
	Asbestos sheet manufacturing unit, Hyderabad	43
	Asbestos brake-linings manufacturing unit, Hyderabad	50
	Asbestos pipes manufacturing unit, Hyderabad	58
5.	OBJECTIVES	64
6.	METHODOLOGY	66
6.	RESULTS	
	Asbestos sheet manufacturing unit, Kolkata	71
	Asbestos sheet manufacturing unit, Silvassa	77
	Asbestos Jointing material manufacturing unit, Vapi	82
	Asbestos workers, end-users and community in the vicinity of asbestos factory, Hyderabad	87
	Asbestos brake-linings manufacturing unit, Hyderabad	94
	Asbestos pipes manufacturing unit, Hyderabad	98
7.	CONCLUSIONS	103
8.	RECOMMENDATIONS	106
9.	REFERENCES	108

Background

A request from Department of Chemicals and Petrochemicals, Ministry of Chemicals and Fertilizers, Govt. of India was received regarding a survey in relation to the hazards resulting from use of Chrysotile variety of asbestos in the country. This study is required in view of the ongoing developments under the Rotterdam Convention to bring this chemical in the PIC ambit, which could impact this segment of Indian Chemical Industry engaged in this activity. It was stressed that a study including all the segments of the industry at workplace as also in the vicinity and the small scale sectors was required so that India could take a stand on scientific basis in the meeting of the conference of state parties under the Rotterdam Convention. Consequently in consultation of the scientists of National Institute of occupational Health and the concerned officers of the Govt. of India, Ministry of Chemicals and Fertilizers it was decided that an environmental cum epidemiological study would be carried out.

Asbestos and its health hazards

Asbestos is a collective name given to a group of minerals that occur naturally as fiber bundles and possess 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 asbestos⁷.

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

problems⁹. 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 Cancer⁹⁻¹². 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 esophagus, 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 cancer¹⁴.

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 burden¹⁶ or excess mortality¹⁷. 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 used¹⁸. 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 millers¹⁹.

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 studied²⁰. The fibre may act as a vehicle, which transports polycyclic aromatic hydrocarbons across membranes of the target cells²¹. 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 potency⁴.

While the fibre size and geometry appear to be the main issues for human health, the bulk and trace metal chemistry have been identified as

adverse factors and agents to plant growth. Plants on chrysotile-enriched soils showed stress symptoms, such as reduced growth, low diversity and slight discoloration. Apart from asbestos exposure magnesium exposure, low calcium: magnesium ratios, excessive nickel and cobalt, and deficiencies in molybdenum, calcium, phosphorus and nitrogen have all been cited as factors responsible for poor plant growth. Since many of these factors interact, it is impossible to single out any one of them as the responsible factor in limiting vegetation growth^{22,23}.

Literature Review

Over 95% of the total asbestos being used worldwide is chrysotile variety of asbestos. Though use of varieties like crocidolite 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 and happens to be an unresolved issue. 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 by Metintas S et. al. (2002), 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 soil²⁴. To assess the occupational exposure due to chrysotile asbestos Yano et. al. (2001), carried a study in an asbestos plant in Chongquin, china. Maximum fibre concentration was found 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 done²⁵.

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 used¹⁸.

To estimate non-occupational exposure of chrysotile, Camus *et. al.* (1998), carried out a study 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)²⁶.

A study by Sebastian P *et. al.* reported that there was fifty times more chrysotile fibres of length $>5 \mu\text{m}$ present in Quebec mining region, Canada than in general urban environment of Montreal²⁷. In a separate study by Case and Sebastian, 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 conc. ($>5 \mu\text{m}$) was greater in occupational group than in environmental group but in case of tremolite. Significantly higher amount of chrysotile fiber ($>5 \mu\text{m}$) 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 gastrointestinal cancer cases in occupational group were having malignancies in their colon²⁸.

In order to measure occupational exposure of workers to chrysotile asbestos, a study was carried out by Finn and Hallenbeck 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 $>5\mu\text{m}$ 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 group²⁹.

It has been documented that exposure to chrysotile asbestos poses risk for asbestosis, lung cancer and mesothelioma in a dose-dependent manner³⁰. 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 observed²⁶.

According to Environmental Health Criteria³¹ 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 relative risks of lung cancer in the textile manufacturing sector in relation to estimated cumulative exposure are, therefore, some 10-30 times greater than those observed in chrysotile mining. The reasons for this variation in risk are not clear, so several hypotheses, including variations in fibre size distribution, have been proposed.

Muridhar and Kanhere reported 23% asbestosis in a survey of 181 workers of an asbestos industry of India. 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 respectively³².

Another study by Dell and Teta on chrysotile exposed employees reported an SMR of 3.73 with 95% confidence interval of 1.21 to 8.70 for pleural mesothelioma³³. Robinson *et. al.* found that 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 mesothelioma³⁴. In a study of asbestos related mesothelioma, it was observed that out of 843 cases 67 were due to chrysotile asbestos exposure³⁵.

Metintas et. al. diagnosed 24 (12 men and 12 women) malignant pleural mesothelioma (MPM) cases 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 respectively²⁴.

Suzuki and Yuen studied the lung tissue burden of asbestos fibres 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 49.84×10^6 fibers/dry gram (240.0×10^6 maximum, 0.03×10^6 minimum). The majority of asbestos fibres detected in both lungs and mesothelial tissue were shorter than 5 micron in length³⁶. In another study Roggli VL et. al. observed that out of 268 cases of mesothelioma which had fiber burden analysis done, chrysotile was detected in 36 cases³⁷.

Dement JM and colleagues carried out 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)³⁸.

Yano E et. al. observed a relative risk of 6.64 (95% CI 1.92 - 23.0) for death due to lung cancer (adjusted for age, smoking and employment) 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 workers²⁵.

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 by Amacher D E *et. al.* 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 / kg³⁹.

To determine the role of long-term exposure of chrysotile in causing gastrointestinal cancer, Cunningham *et. al.*, carried life time study 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 weeks⁴⁰.

Many researchers have tried to assess the toxic effects of different asbestos fibres in terms of its genotoxicity and cytotoxicity. Genotoxicity refers to the ability of any substance / agent to cause alterations or damage to chromosome either directly or indirectly (via activation of any metabolic products). Chromosomal alterations play an important role in tumor or cancerous development and hence it is necessary to study this mechanism behind pathological development. Many studies have been carried out to study the mechanism of genotoxicity and its effects due to different types of asbestos (chrysotile, crocidolite, amosite, tremolite etc.) both *in vitro* and *in vivo*. Genotoxic effects have been measured in terms of DNA damage (DNA strand breaks, DNA oxidation and alkylation, micronuclei analysis etc.), chromosomal aberrations, sister chromatic exchange etc. Reactive oxygen species (ROS) induced lipid peroxidation being a prominent cause of structural alteration in DNA in both plants and animals, researchers have also tried to establish its role (after exposure to asbestos fibres) as a potential step in tumor development.

To assess ROS mediated genotoxicity generated after asbestos cement powder and chrysotile exposure, Dopp E *et. al.* carried out 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 ($1\mu\text{g}/\text{cm}^2$) of chrysotile exposure induced almost equal number of micronulei formation as

higher concentration ($3 \mu\text{g}/\text{cm}^2$) 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 cells⁴¹. 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 ($1.00 \pm 0.06 \mu\text{m TBA-RM}$, mean \pm SE_M) was most active followed by crocidolite ($0.690 \pm 0.03 \mu\text{m TBA-RM}$, mean \pm SE_M) and amosite ($0.535 \pm 0.04 \mu\text{m TBA-RM}$, mean \pm SE_M) respectively⁴². Another study conducted in rat lung fibroblast did show significant increase in TBARS with chrysotile and Crocidolite at concentration greater than $250 \mu\text{g}/\text{ml}$. Amosite showed similar significant increase in TBARS only at a concentration of greater than $500 \mu\text{g}/\text{ml}$ ⁴³. Kopnin P B *et. al.* in their study showed increase in intracellular ROS and 8-oxoguanine in rat pleural mesothelial cells but not in lung fibroblast at chrysotile concentration in range of $5\text{-}10 \mu\text{g}/\text{cm}^2$ ⁴⁴. Yamaguchi *et. al.* also reported 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 asbestos⁴⁵.

Dopp E *et. al.* (1994) tried to observe genotoxic effect of chrysotile, crocidolite and amosite by assessing micronuclei formation in Syrian hamster embryo fibroblast. After 66 hrs of exposure, maximum number of micronuclei was found in both chrysotile (210.0 ± 56.5 , mean \pm SD) and crocidolite (218.5 ± 80.3 ,

mean \pm SD) exposed fibroblast at a concentration of $5 \mu\text{g}/\text{cm}^2$, whereas amosite showed maximum micronuclei ($>250 \text{ MN}/2000 \text{ cells}$) at a concentration of $0.25 \mu\text{g}/\text{cm}^2$ ⁴⁶. Another *in vitro* study by Oshimura M *et. al.* 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 changes⁴⁷. In another study an oral dose of $20\text{mg}/\text{kg}/\text{day}$ of chrysotile asbestos also failed to induce any chromosomal aberrations in the germ cells of Swiss albino male mice⁴⁸.

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 controls⁴⁹.

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 amosite⁵⁰.

Only a few studies have been carried out to assess the effect of chrysotile asbestos on the reproductive system and development. In a study by Rita and

Reddy abnormal sperm frequency in Swiss male albino rats (6-8 weeks) fed on a diet of 20 mg/kg/day for 60 days were examined. The result indicated no statistically significant increase in the abnormal sperms in case of chrysotile (3.01%) exposed group when compared to control (2.90%)⁵¹. No change either in histopathology of reproductive organs or in fertility was observed in Syrian hamster when given diet of 500 and 830 mg/kg-day of chrysotile or amosite, during breeding, gestation and lactation period. Also no teratogenic effects were seen in offspring of either rats or hamsters⁵¹⁻⁵³. Schneider and Maurer also found no teratogenic effect in CD-1 mice, when exposed to chrysotile asbestos during 1-15 days of gestation period⁵⁴.

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 animals⁵¹. In a similar study, 1% concentration of crocidolite asbestos was administered in feed to male and female F344/N rats, beginning with exposure of the dams before and during gestation⁵⁵. Ingestion of crocidolite did not adversely affect the fertility of the dams or the litter size of the F1 animals, but the average weight gain of the offspring at weaning from exposed mothers was 19% lower than the offspring of nonexposed mothers. Slightly lower body weight was found in the offspring of asbestos-exposed mothers with similar exposure protocols with amosite asbestos⁵⁶.

Expected outcome of the study / 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 and it is preventable. 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 and very old. A comprehensive information of environmental / human health status in relation to asbestos handling is much needed in our country. So this study will form a set of comprehensive background national information in this area, which will be useful for many purposes 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:

- 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).

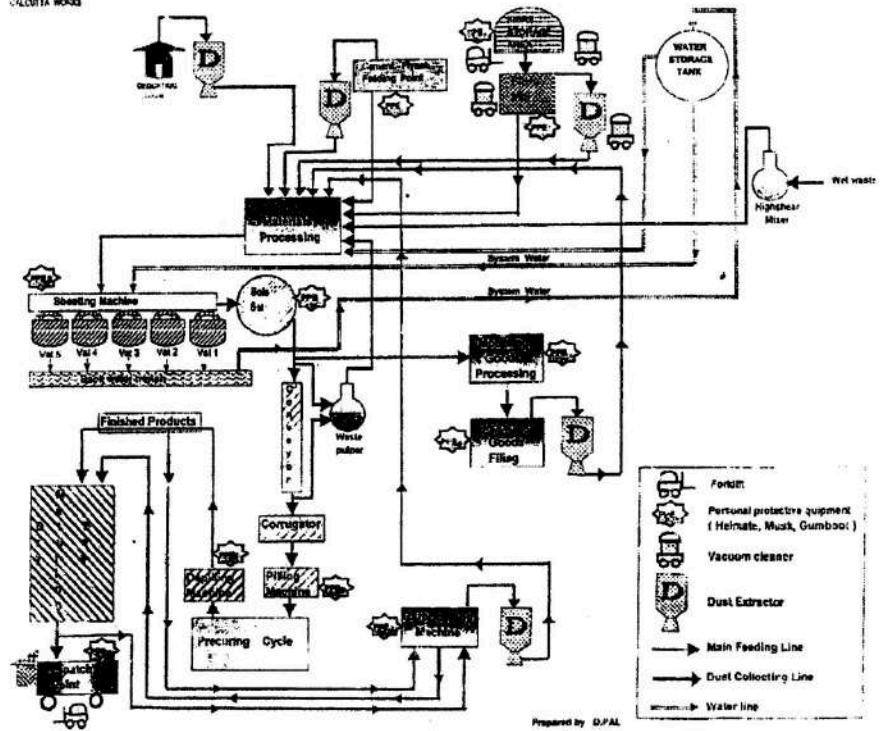
During rapping the films are compressed by pneumatic pressure. After getting the required thickness the compressed film are cut manually and transferred to take off conveyer, thus resulting a flat sheet. Then this flat sheets are sized by end trimming and will be sent to corrugator along with steel mould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

BY APST INDUSTRIES LIMITED
CALCUTTA WORKS

PROCESS FLOW CHART





Raw material Preparation Plant
Worker with Personal Sample



Raw Material Feeding
Cement/Fly ash



Fiber Mill Platform -
Hydraulic Pallet Used for
Handling Fiber Bags



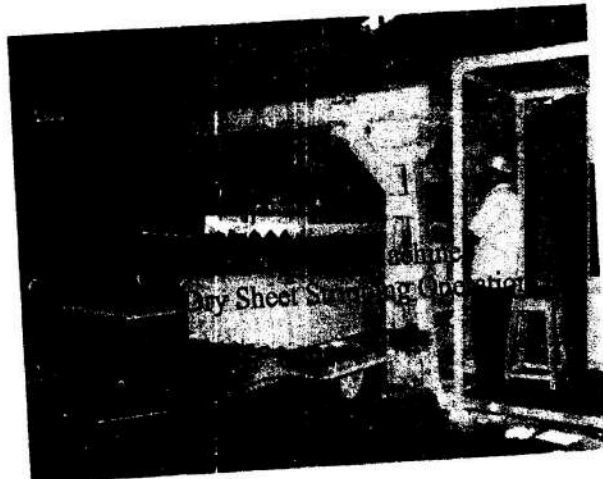
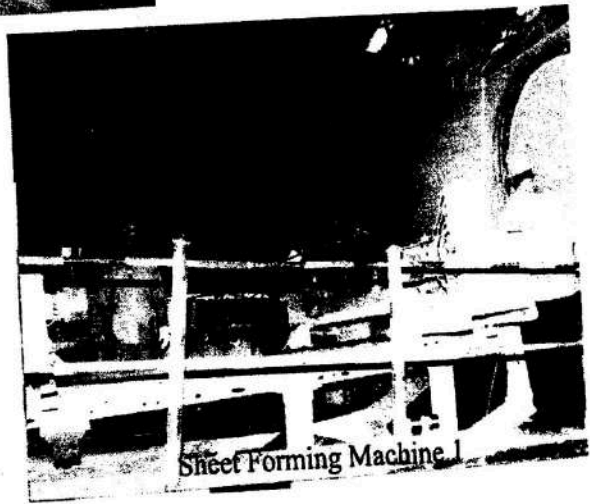
Fiber mill Platform
Fiber bag being lifted
to Fiber Fixing Chamber

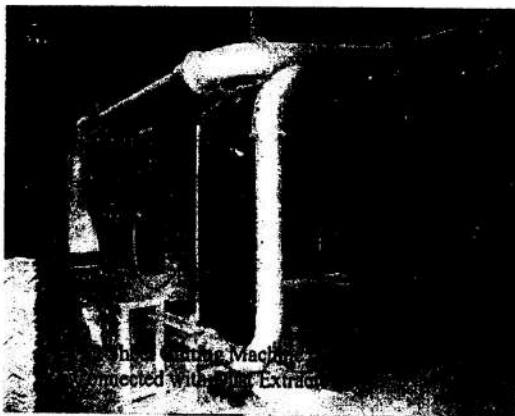
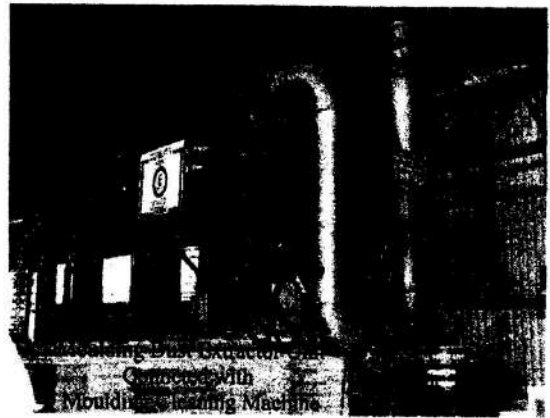
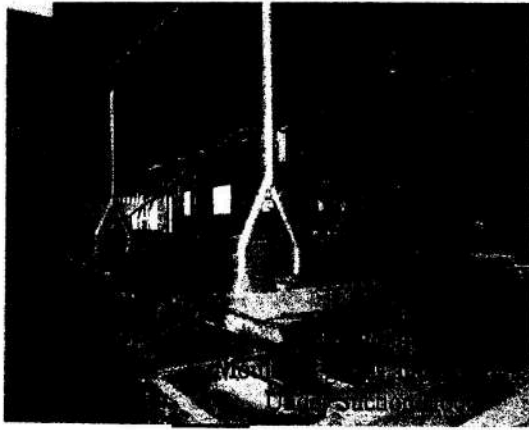


Fiber Mill Platform
Fiber bag curing in
closed Chamber under
Negative Pressure



Product





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.

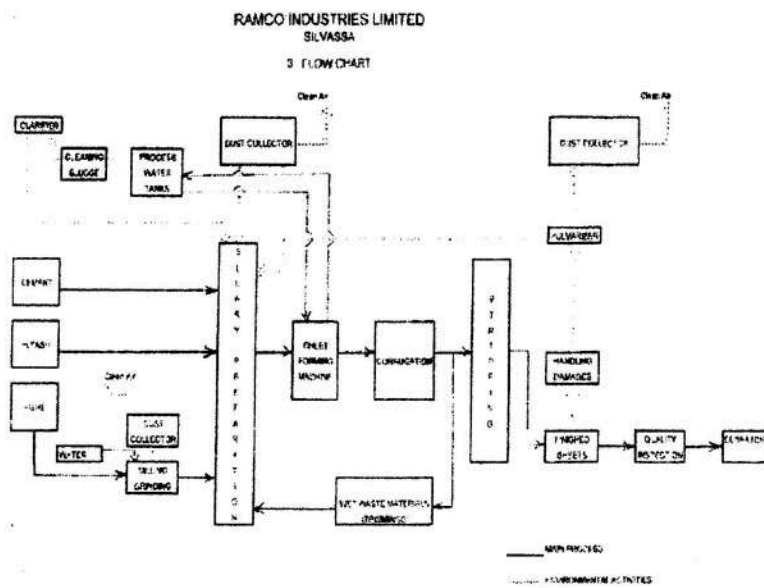
The sheeting plant consists of vats with rotating sieve cylinders inside covered with fine sieve meshes. As the slurry is admitted in to the vats, water gets filtered through the sieve covers leaving a fine film of asbestos cement

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 mix 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



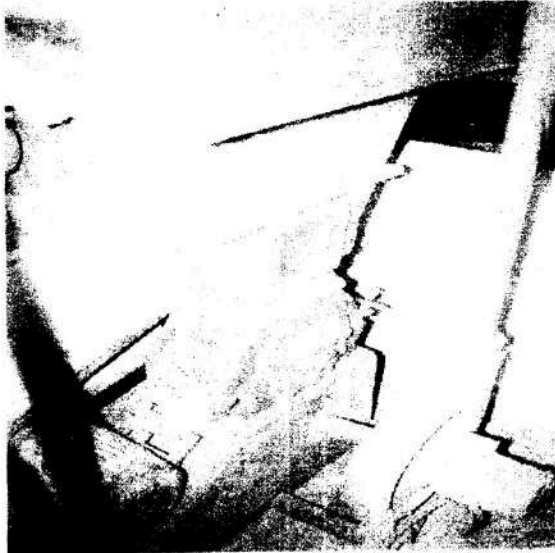
Bag Cut Inside



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

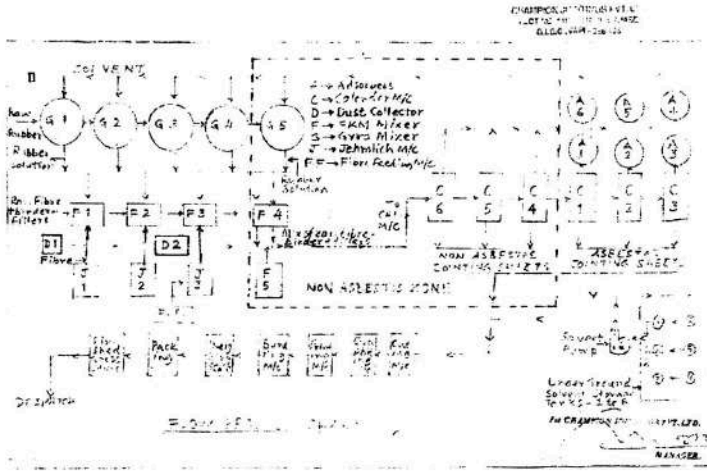
Asbestos jointing material-manufacturing unit, Vapi

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 per required size, graphited, if required printed, bundled and packed.

40

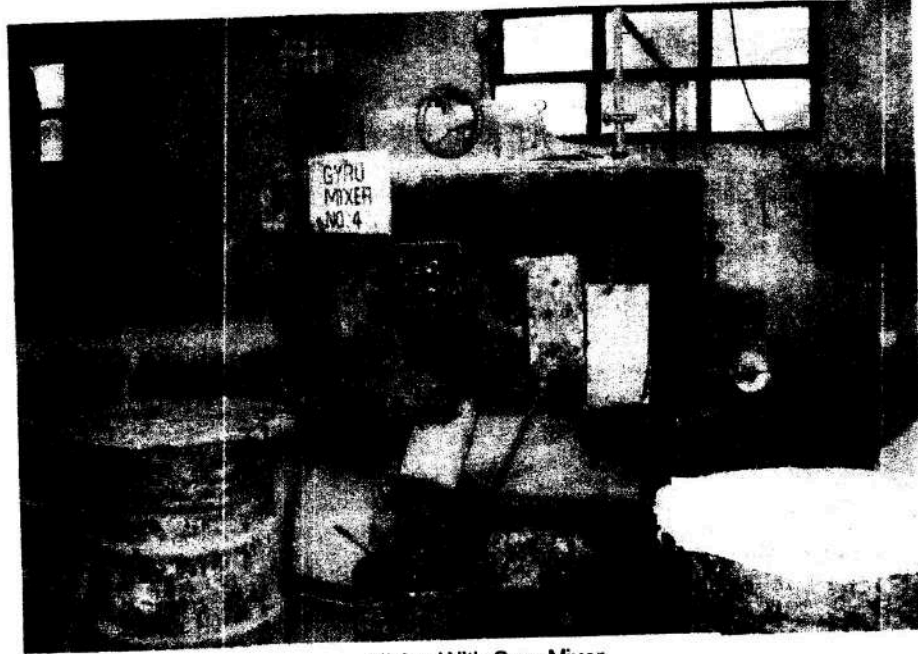




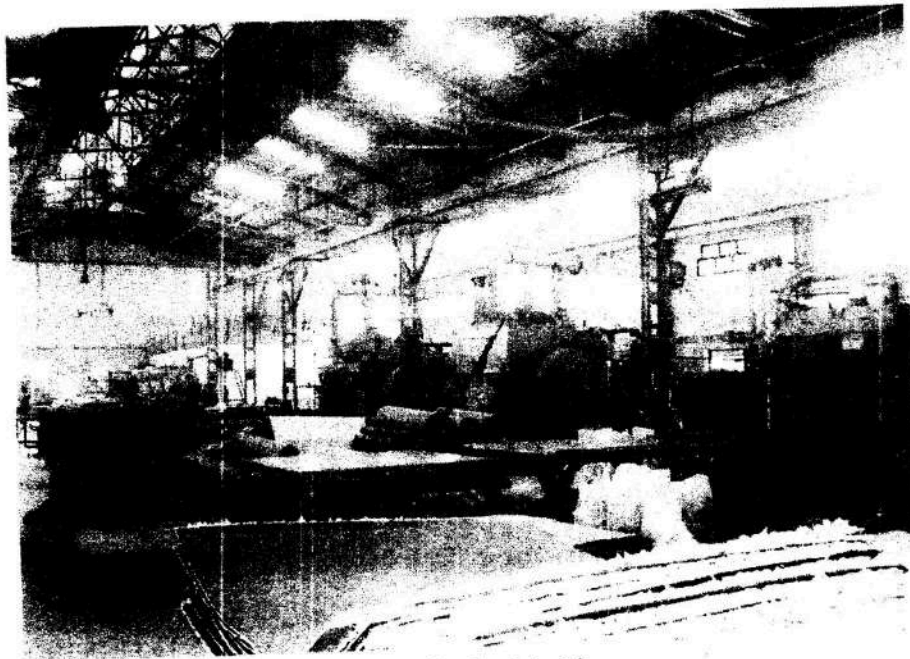
Feeding machine connecting to dust collector



Feeding Machine Connecting To Mixer



Mixing With Gyro Mixer



Calender 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 **Dr. G. Vivekanand** and the Andhra Pradesh Industrial Development Corporation 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 to 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% to 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.

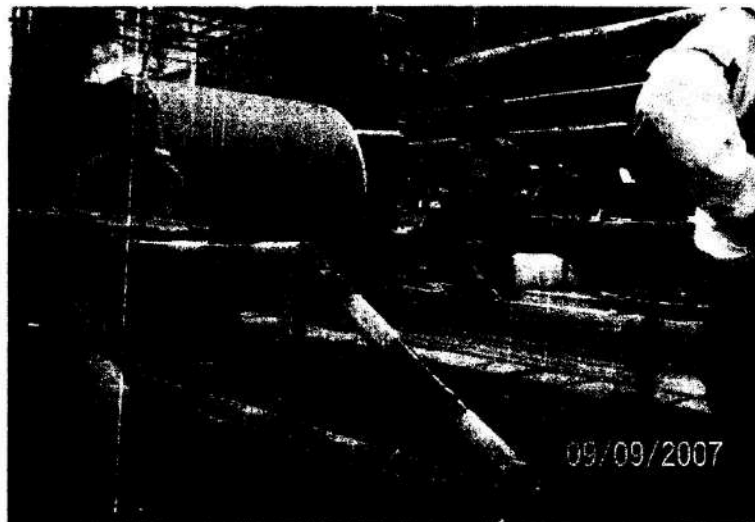
9. **Inspection**

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 temp 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

Mixing

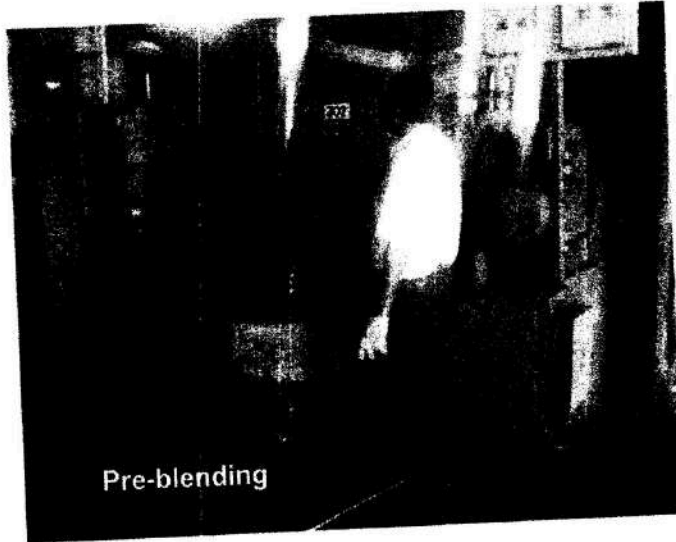
Preforming

Curing

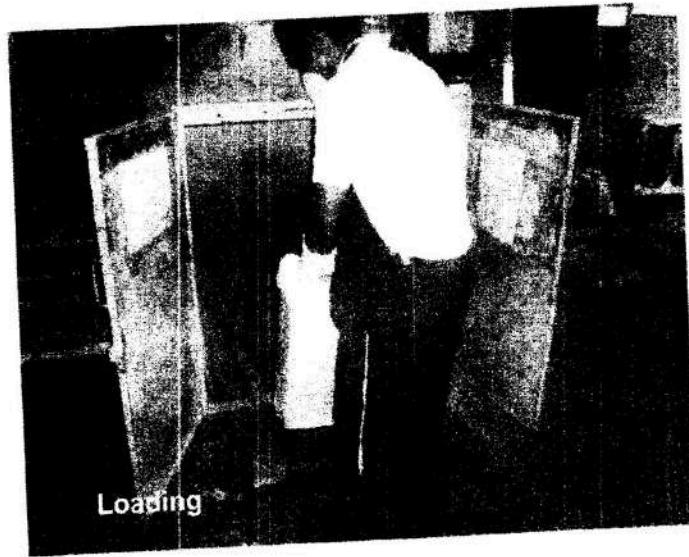
Baking

Finishing

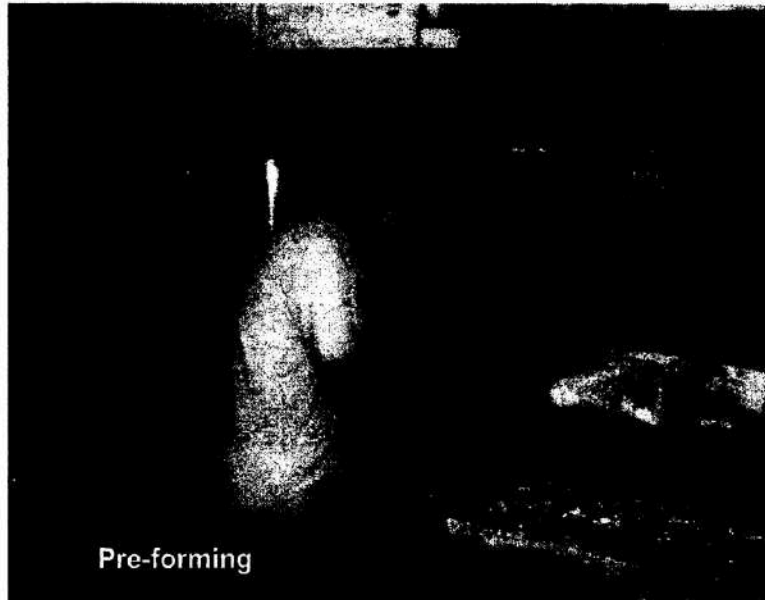
Printing



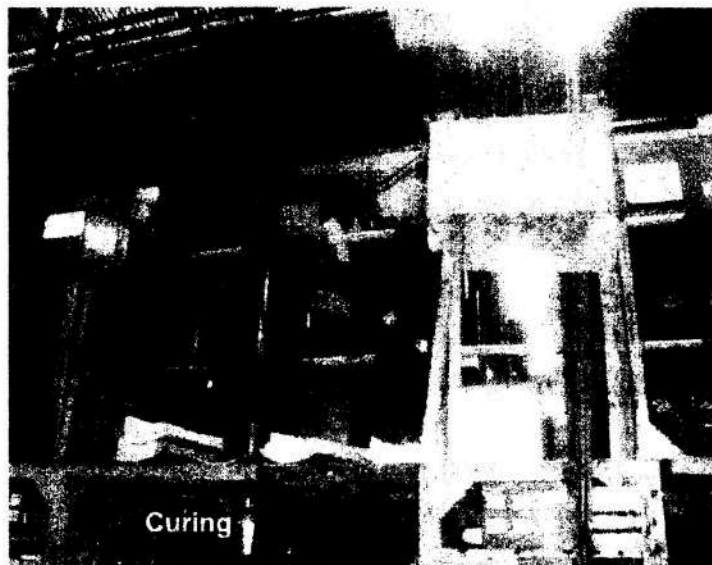
Pre-blending



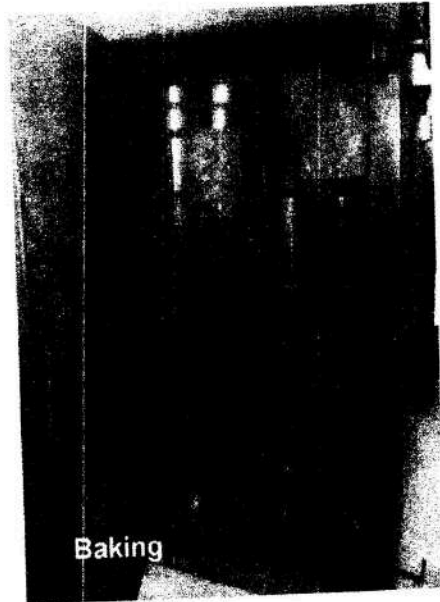
Loading



Pre-forming



Curing





OD grin

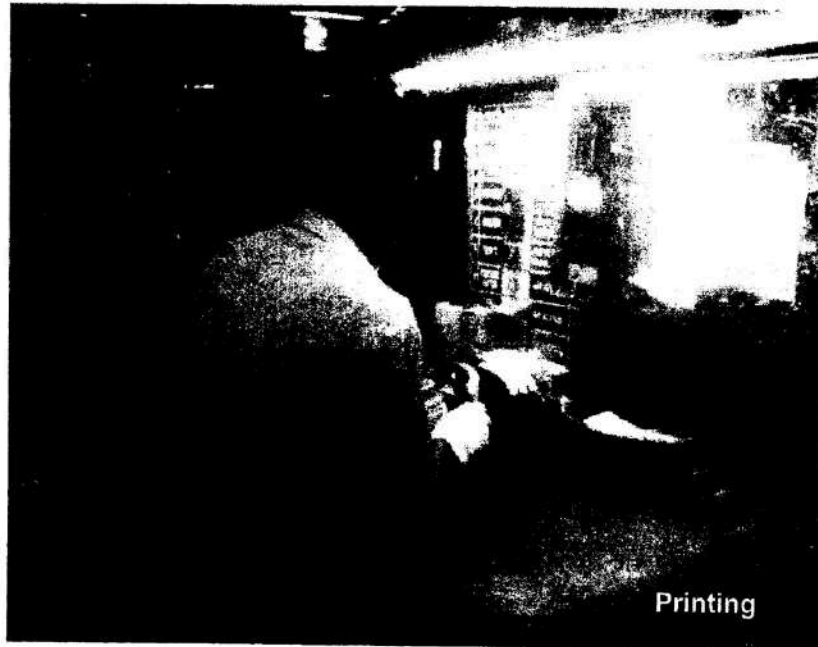


Chamfering





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.

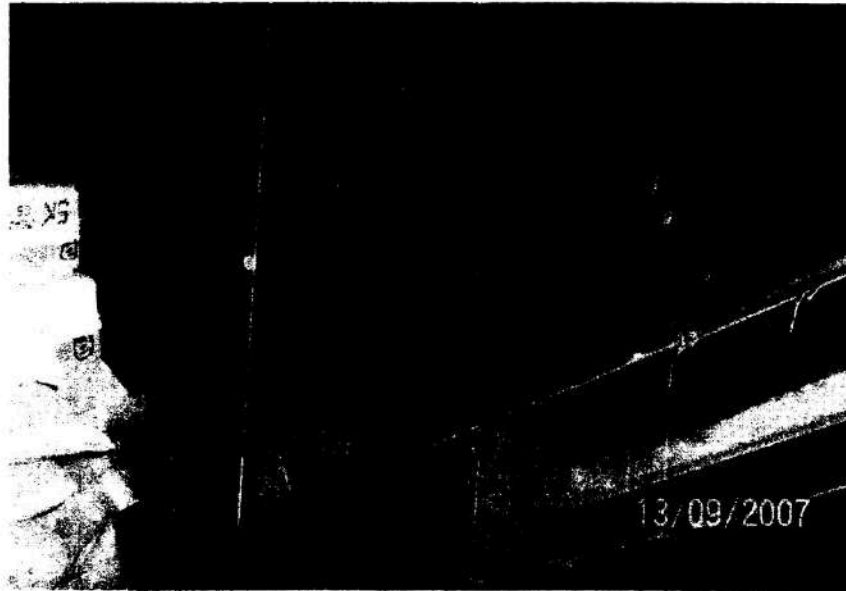


Figure 1:Asbestos fibres bags transported through conveyor belts



Figure 2:Mixing of asbestos fibres



Figure 3:Slurry taken to steel mandrels

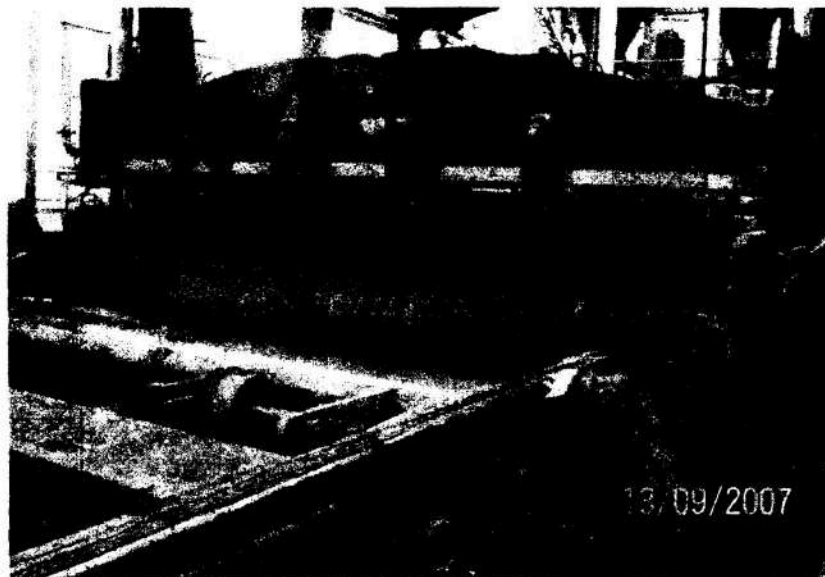


Figure 4:Pipes are being manufactured through continuously laid layers of slurry

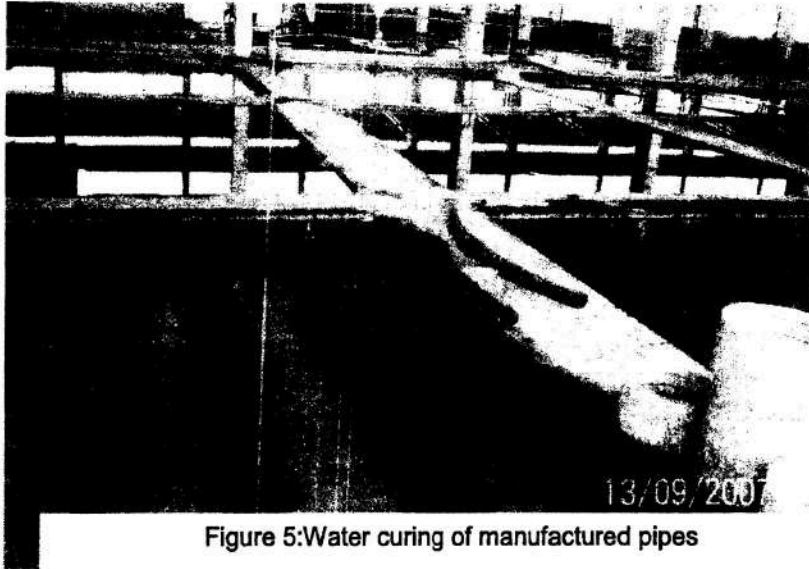


Figure 5:Water curing of manufactured pipes



Figure 6:Finishing work on manufactured pipes

Objectives

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

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. Thus 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 1122 subjects, which comprise of 625 asbestos workers, 362 community subjects residing in the vicinity of asbestos sheet manufacturing factory and 135 end-users of chrysotile asbestos product. 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 though all the sixty workers were covered due to incomplete information the final analysis included only 59 subjects. The details of the study participants are as follows:

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 factory	362
End-users of chrysotile asbestos products	135
Total	1122

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 workers.

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 different flow volumes like FEV₁, FEV_{1%} 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. Pulmonary function test values were predicted from the standard prediction equation of the Kolkata normal subjects (Chatterjee et al). The instrument was calibrated every day before starting the experiment.

All the study subjects were evaluated by radiological examination as per ILO guidelines. Chest X rays (PA view) were obtained with the subject in inspiration. These X rays were examined by three readers independently using ILO Classification of Pneumoconioses Radiographs. The median value of the profusion reported by three readers is presented in the analysis.

Statistical analysis:

Collected data were analyzed by using Epi Info 5 and SPSS software.

Environmental Study

Fiber concentrations in the workplaces was evaluated using SKC personal samplers with a flow rate of 1-2 ltr./min. The membrane filter method using phase contrast microscopy was used. Samples were collected on cellulose acetate membrane filters (diameter –25mm, 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 $<3 \mu\text{m}$ and aspect ratio $\geq 3:1$) were counted using Walton-Becket graticule 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)

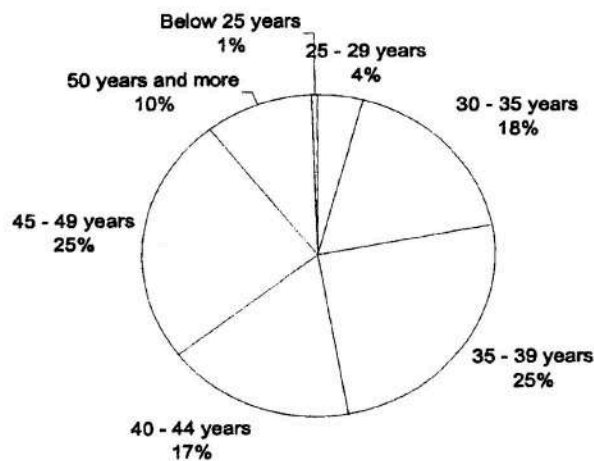
Fibre levels were then compared with the permissible levels mentioned in the Indian Factories Act, 1948⁵⁷ (1 fibre/ml) and the recommended exposure levels of OSHA⁵⁸ (0.1 fibre/ml), NIOSH⁵⁹ (0.1 fibre/ml), and ACGIH⁶⁰ (0.1 fibre/ml).

Results

Asbestos cement sheet-manufacturing unit of Kolkata

Mean age of the study subjects was 40.5 (\pm 6.9) years. Only 1% of the workers were below 25 years of age. Ten percent workers were of 50 or more years age. Twenty two percent workers were in 25-35 years age group, 42% workers were in 35-44 years age group and 25% workers were in 45-49 years age group (Fig. 1). 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.

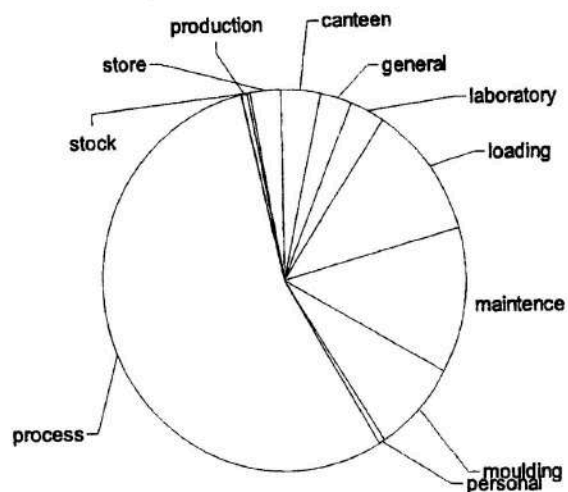
Fig.-1: Age wise Distribution of the workers



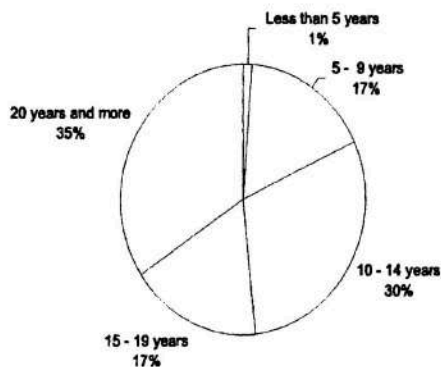
Majority of the workers (54.8%) were from Process Division followed by Maintenance (12.2%), Loading (11.1%) and Moulding Division (8%). Other

workers participated in the study were from Stores, Laboratory, General Pool and other departments.

Fig.-2: Department wise Distribution of the Workers



Mean job duration of the workers was 15.9 ± 6.8 years. Only 1% of the workers had duration of work less than 5 years, whereas 17% workers had duration of work of 5-9 years. Forty Seven Percent of workers were having duration of work 10-19 years and 35% workers had duration of work 20 years or more.

Fig.-3: Distribution of the Workers according to Job Duration

The workers did not have any complaint of cough or dyspnoea. Some workers complained of occasional eye irritation / respiratory 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. 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 1: 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. The workers with exposure of 15 or more years were having higher abnormalities.

Table 2: PFT Status according to duration of work

PFT Status	Duration of Work (years)					Total
	< 5	5 - 9	10 - 14	15 - 19	≥20	
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)

Table 3: PFT Status according to smoking habit

PFT Status	Smoking habit			Total
	Non-smoker	Smoker	Past smoker	
Normal	111 (71.6)	14 (56.0)	3 (37.5)	128 (68.1)
Mixed	6 (3.9)	4 (16.0)	1 (12.5)	11 (5.9)
Obstructive	13 (8.4)	-	-	13 (6.9)
Restrictive	25 (16.1)	7 (28.0)	4 (50.0)	36 (19.1)

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 more workers also had normal features except for prominent broncho-vascular markings in their radiographs and four workers had

radiographs suggestive of interstitial lung fibrosis. 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.

Environmental monitoring was carried out at six sampling locations. Fiber concentrations are shown in table-4. Permissible Exposure level (PEL) in India is 1 fiber/ml where as other agencies like NIOSH, ACGIH and OSHA recommend 0.1 fiber/ml (Table 5). It can be seen from table-4 that fiber concentrations are lower than the PELs.

Table 4: Mean Fiber Conc. (Fibers/ml) at different locations

Location	Fibre Concentration	No. of samples
Cement/Fly Ash Feeding	0.0072 ± 0.0025	6
Fiber Mill	0.0668 ± 0.0027	6
Sheeting	0.0103 ± 0.0026	6
Stripping	0.0068 ± 0.0017	6
Moulding/Filing	0.0066 ± 0.0018	6
Carbo Cutting	0.0088 ± 0.0029	6

Table 5: 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

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

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 1). Among the total number of workers 29(49.2%) were married and the rest were not. Only 16.7% workers had more than secondary level education and about 23% workers illiterate (Table 2).

Table 1: 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 2: 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 ± 2.5 . 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 chewers.

Majority of the workers (41.7%) were 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 3).

Table 3: Department wise distribution of the workers

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

Mean job duration of the workers was 4.5 ± 3.2 years. Minimum experience was 1 year and maximum experience was 13 years. Majority of workers (61.7%) had experience of work up to 5 years, whereas 35% workers had duration of work of 6-10 years. Almost three percent of workers were having experience of more than ten years (Table 4).

Table 4: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=60)
Upto 5	37 (61.7)
6-10	21(35)
Above 10	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 crepitation was present in 6.7% and 10% subjects respectively.

Pulmonary function test revealed that 6.8% workers were having obstructive disorder and rests were normal. No significant effect of age (Table 5) and work experience (Table 6) on pulmonary function test parameters' values was observed.

Table 5: Distribution of pulmonary function test parameters according to age

Age Group (Yrs.)	FEV ₁ /F VC %	FVC	FEF _{25%-75%}
Upto 30	89.19 ± 5.6	4.10 ± 0.67	4.51 ± 1.14
31-40	87.23 ± 6.2	4.14 ± 0.58	4.47 ± 1.22
41-60	93.87 ± 7.9	3.49 ± 0.23	4.78 ± 1.88
Significance (Single way ANOVA)	NS	NS	NS

Table 6: Distribution of pulmonary function test parameters according to job duration

Experience Group (Yrs.)	FEV ₁	FVC	FEF _{25%-75%}
Up to 5	88.83±7.18	4.06±0.69	4.49±1.32
6-10	88.88±2.81	4.13±0.54	4.44±0.84
11 and above	88.93±0.68	4.22±1.12	5.53±0.27
Significance (Single way ANOVA)	NS	NS	NS

On radiological examination, findings suggestive of Koch's infection (Right Middle Zone) were observed in a single worker.

Environmental monitoring was carried out at six sampling locations. Fiber concentrations are shown in table-7. When compared with the permissible exposure level (PEL) in India⁵⁷, which is 1 fiber/ml, and with recommended levels of other agencies like NIOSH⁵⁸, ACGIH⁶⁰ and OSHA⁵⁸, which is 0.1 fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 7: Fibre concentration (fibres/ml) at different locations

Location	Fibre Concentration (fibres / ml) Mean ± sd	n
Cement/Fly ash feeding	0.014883 ± 0.00358	6
Fibre mill	0.031833 ± 0.02038	6
Sheeting	0.0087 ± 0.00342	6
Stripping	0.008167 ± 0.0026	6
Moulding	0.00771 ± 0.00376	6
Carbo -cutting	0.0114 ± 0.00541	6

Highlights

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

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 (39.3%) 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 1). Among the total number of workers 63 (90%) were married and the rest were not. Only 27.1% workers had more than secondary level education and about 14.3 % workers illiterate (Table 2).

Table 1: 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 (39.3)

Table 2: 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 . 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 3).

Table 3: Department wise distribution of the workers

Department	Frequency (%) (N=70)	Mean experience \pm SD
Maintenance	17 (24.3)	11.76 \pm 8.09
Process	36 (51.4)	11.50 \pm 7.54
Packing / loading	6 (8.6)	8.33 \pm 5.16
Others	11 (15.7)	14.54 \pm 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. Majority 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 4).

Table 4: 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)
Above 10	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.

Pulmonary function test revealed that 11.4% workers were having obstructive disorder, 2.9% were having restrictive abnormality and rests were normal. Significant effect of age (Table 5) on pulmonary function test parameters' values was observed but no such significant effect was observed in relation to work experience (Table 6).

Table 5: Distribution of pulmonary function test parameters according to age

Age Group (Yrs.)	FEV ₁	FVC	FEF _{25%-75%}
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
Significance (Single way ANOVA)	F=5.989; p<0.01	F=3.194; p<0.05	F=4.34; p<0.05

Table 6: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV ₁	FVC	FEF _{25%-75%}
Upto 5	3.19 ± 0.61	3.65 ± 0.71	3.98 ± 1.67
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
Significance (Single way ANOVA)	NS	NS	NS

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.

Environmental monitoring was carried out at 12 sampling locations in fiber feeding and calender machine section and at six sampling locations in Cutting/Finishing and near godown. Fiber concentrations are shown in table-7. When compared with the permissible exposure level (PEL) in India⁵⁷, which is 1 fiber/ml, and with recommended levels of other agencies like NIOSH⁵⁹, ACGIH⁶⁰ and OSHA⁵⁸, which is 0.1 fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 7: Fibre concentration (fibres/ml) at different locations

Location	Fibre Concentration (fibres / ml) Mean ± SD	n
Fiber Feeding	0.0382 ± 0.0224	12
Calender machine	0.0135 ± 0.0128	12
Cutting/finishing	0.0107 ± 0.0071	6
Near Godown	0.0217 ± 0.0114	6

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 factory, Hyderabad

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 1). 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 2).

Table 1: 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	42.98 ± 3.5	37.66 ± 9.5	36.96 ± 9.4

Table 2: 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)	-

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 majority (49.2%) had normal body mass index values (18.5 – 24.99) 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 3).

Table 3: Department wise distribution of the workers

Department	Frequency (%) (N=153)
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 4).

Table 4: 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 5: 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)	-
Bronchial asthma	-	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)	-	-

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 5).

Pulmonary function test revealed that among asbestos sheet workers, 22% workers were having restrictive disorder, 11.9% were having obstructive abnormality, 1.7% were having combined type of abnormality and rests were normal. Similarly in the community individuals 11.6% were having restrictive disorder, 8.3% were having obstructive abnormality, 2.2% were having combined type of abnormality and rests were normal. In the end-users 12.6% were having restrictive disorder, 8.1% were having obstructive abnormality, 1.5% were having combined type of abnormality and rests were normal. No effect of age was observed on FEV₁ and FVC in the three groups (Table 6 & 7). However in the workers the mean FVC values of those employed for >20 years were significantly lower than those employed for 11-20 years (Table 8).

Table 6: Distribution of FEV₁ 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	2.93 ± 0.68
≥40	2.6 ± 0.52	2.4 ± 0.72	2.3 ± 0.78
Significance (Single way ANOVA)	F=0.69; p=0.4	F=11.13; p<0.01	F=10.58; p<0.00

Table 7: 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
Significance (Single way ANOVA)	F=0.91; p=0.34	F=11.13; p<0.01	F=6.47; p<0.002

Table 8: Distribution of lung function parameters according to duration of exposure among asbestos workers

Experience Group (Yrs.)	FEV ₁	FVC	FEF _{25%-75%}
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
Significance (Single way ANOVA)	F=3.07; p=0.08	F=4.37; p=0.04	F=1.09; p=0.29

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.

Environmental study

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 9 while the fibre levels in the village situated near the vicinity of

the factory are shown in Table 10. Permissible Exposure level (PEL) in India⁵⁷ is 1 fiber/ml where as other agencies like NIOSH⁵⁹, ACGIH⁶⁰ and OSHA⁵⁸ recommend 0.1 fiber/ml. It can be seen from table-9 and 10 that fiber concentrations are lower than the PELs.

Table 9: Mean Fiber Conc. (Fibers/ml) at different locations of the asbestos sheet-manufacturing factory

Location	Mean Fiber levels \pm SD
Fiber Mill	0.0081 \pm 0.0042(6)
Sheeting	0.0104 \pm 0.0066 (6)
Carbo Cutting	0.0331 \pm 0.0282 (6)
Moulding	0.0105 \pm 0.0054 (6)
Stripping	0.0127 \pm 0.0140(6)
Outdoor	0.0097 \pm 0.0076 (7)

Figures in the Parenthesis indicate number of samples

Table 10: Mean Fiber Conc. (Fibers/ml) at different locations around the vicinity of factory

Village	Location	Mean Fiber levels \pm SD
Velmala	Indoor	0.0037 \pm 0.0021 (12)
	Outdoor	0.0029 \pm 0.0013 (8)
Sanduguda	Indoor	0.0039 \pm 0.0019 (7)
	Outdoor	0.0034 \pm 0.0013(8)

Figures in the Parenthesis indicate number of samples

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% workers were having restrictive disorder and 1.7% were having combined type of abnormality while in the community individuals 11.6% were having restrictive disorder and 2.2% were having combined type of abnormality. In the end-users 12.6% were having restrictive disorder, and 1.5% 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

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 age. 109 (71.2%) workers were in 31-40 years age group. 33 (21.6%) workers were up to thirty years of age (Table 1). 62 (40.5%) workers had more than secondary level education and only 4 (2.6%) workers were having primary level of education (Table 2).

Table 1: 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 2: 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 ± 3.4 . Majority (55.9%) had normal body mass index values (18.5 – 24.99) 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 3).

Table 3: 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 4).

Table 4: 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.

Pulmonary function test revealed that 3.9% workers were having restrictive disorder, 13.1% were having obstructive abnormality, 0.7% were having combined type of abnormality and rests were normal. Significant effect of age (Table 5) and work experience (Table 6) on Forced Vital Capacity (FVC) values was observed.

Table 5: Distribution of PFT parameters according to age

Age Group (Yrs.)	FEV ₁ %	FVC	FEF _{25%-75%}
Up to 30	87.7 ± 4.76	3.3 ± 0.48	3.46 ± 0.8
31-40	86.6 ± 7.14	3.3 ± 0.48	3.55 ± 1.2
41-60	84.2 ± 9.02	2.56 ± 0.59	2.61 ± 1.45
Significance (Single way ANOVA)	F=1.12; p=0.33	F=11.13; p<0.01	F=3.33; p=0.38

Table 6: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV ₁ %	FVC	FEF _{25%-75%}
Up to 10	87.9 ± 7.32	3.3 ± 0.49	3.7 ± 1.16
11-20	85.9 ± 6.65	3.2 ± 0.5	3.4 ± 1.17
21 and above	89.7 ± 6.3	2.0 ± 0.41	2.37 ± 1.21
Significance (Single way ANOVA)	F=1.57; p=0.21	F=9.59; p<0.01	F=2.13; p=0.12

On radiological examination, findings suggestive of Koch's fibrosis (both Upper Zone) were observed in one worker while one worker showed cardiac enlargement.

Environmental monitoring was carried out at 4-9 sampling locations. Fiber concentrations are shown in table-7. When compared with the permissible exposure level (PEL) in India⁵⁷, which is 1 fiber/ml, and with recommended levels of other agencies like NIOSH⁵⁹, ACGIH⁶⁰ and OSHA⁵⁸, 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 OSHA⁵⁸, NIOSH⁵⁹, and ACGIH⁶⁰.

Table 7: Mean Fiber Conc. (Fibers/ml) at different locations

Location	Mean Fiber levels \pm SD
Fiber Feeding	0.0571 \pm 0.0325 (6)
Curing	0.0395 \pm 0.0194 (6)
Pre-forming	0.1064 \pm 0.0415(6)
Grinding	0.0210 \pm 0.0084 (6)
Drilling	0.0189 \pm 0.0054 (4)
Cutting	0.0300 \pm 0.0120 (4)
Inspection	0.0507 \pm 0.0435(3)
Bag filter	0.0576 \pm 0.0261(7)
Outdoor	0.0088 \pm 0.0111 (8)

Figures in the Parenthesis indicate number of samples

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

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 1). 69 (72.6%) workers had more than secondary level education and only 7 (7.4%) workers were illiterate (Table 2).

Table 1: Age wise Distribution of the workers

Age group (Yrs.)	Number of workers (%) (N=95)
Up to 20	5 (5.3)
21-40	79 (83.2)
≥40	11 (11.6)

Table 2: 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 3).

Table 3: Department wise distribution of the workers

Department	Frequency (%) (N=95)
Production	12 (12.7)
Finishing	52 (54.8)
Maintenance	9 (9.5)
Others	23 (24.2)

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 4).

Table 4: Distribution of Workers according to Job Duration

Experience (Yrs.)	Number of workers (%) (N=95)
< 10	91(95.8)
10-20	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.

Pulmonary function test revealed that 3.2% workers were having restrictive disorder, 6.3% were having obstructive abnormality, 2.1% were having combined type of abnormality and rests were normal. Significant effect of age

was observed in all the pulmonary function parameters (Table 5) while the significant effect of work experience was seen on Forced expiratory Volume in first second (Table 6).

Table 5: Distribution of PFT parameters according to age

Age Group (Yrs.)	FEV ₁	FVC	FEF _{0.2-1.2}
Up to 20	3.6 ± 0.65	4.0 ± 0.55	7.1 ± 0.96
21-40	3.3 ± 0.48	3.7 ± 0.51	7.4 ± 1.29
≥40	2.5 ± 0.56	2.9 ± 0.57	6.1 ± 2.43
Significance (Single way ANOVA)	F=14.76; p<0.01	F=10.12; p<0.01	F=4.13; p=0.01

Table 6: Distribution of PFT parameters according to job duration

Experience Group (Yrs.)	FEV ₁	FVC	FEF _{0.2-1.2}
Up to 5	91.2 ± 8.58	3.71 ± 0.53	7.5 ± 1.22
6-10	86.3 ± 7.39	3.46 ± 0.58	6.9 ± 1.8
11 and above	92.8 ± 1.55	3.36 ± 0.56	7.4 ± 1.24
Significance (Single way ANOVA)	F=4.72; p=0.01	F=2.53; p=0.08	F=1.3; p=0.27

On radiological examination, findings suggestive of Koch's infection (Upper Zone) were observed in three workers. One of them had fracture of right 8th rib posteriorly.

Environmental monitoring was carried out at 4-6 sampling locations. Fiber concentrations are shown in table-7. When compared with the permissible exposure level (PEL) in India⁵⁷, which is 1 fiber/ml, and with recommended levels of other agencies like NIOSH⁵⁹, ACGIH⁶⁰ and OSHA⁵⁸, which is 0.1 fiber/ml, it was found that fiber concentrations were lower than the PELs.

Table 7: Mean Fiber Conc. (Fibers/ml) at different locations

Location	Mean Fiber levels \pm SD
Fiber Mill	0.0487 \pm 0.0629(6)
Cement Feeding	0.0270 \pm 0.0078(5)
Lamina Rolling	0.0168 \pm 0.0082 (6)
Finishing	0.0265 \pm 0.0139 (12)
Cutting	0.0346 \pm 0.0238 (4)
Outdoor	0.0039 \pm 0.0020 (6)

Figures in the Parenthesis indicate number of samples

Highlights

- Fiber level in all the workplaces were below national and international standards.
- 3.2% workers were found to have restrictive type and 2.1% had combined type of pulmonary function impairment.
- No worker was found to have radiographic features suggestive of interstitial lung fibrosis.

Conclusions

1. The study included a total of 1122 subjects, which comprise of 625 asbestos workers, 362 community subjects residing in the vicinity of asbestos sheet manufacturing factory and 135 end-users of chrysotile asbestos product.

2. The mean age of the workers was found to be highest in the sheet workers of Hyderabad (42.98 ± 3.50 years) while in the sheet industry at Silvassa it was lowest (27.4 ± 6.5 years). The mean age of the community residing in the vicinity of sheet factory was 37.66 ± 9.5 years while that of end-users was 36.96 ± 9.4 years. Accordingly the mean duration of job was highest among sheet workers of Hyderabad (21.84 ± 2.43 years) while in the sheet industry at Silvassa it was lowest (4.5 ± 3.2 years).

3. The literacy levels of the workers in most of the industries was found to be good. This helps in motivating the workers to use PPEs and in implementing the control measures such as health education for the prevention of diseases related to asbestos exposure.

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

5. The pulmonary function test reveal that out of total 1122 subjects, 119 (10.6%) had restrictive abnormality, 99 (8.8%) had obstructive abnormality and 25 (2.2%) had combined (restrictive +obstructive) type of pulmonary function abnormality.

Rest of the subjects were normal. Further analysis showed that 9.6% asbestos workers had restrictive abnormalities as comparison to 11.6% community subjects. The difference was statistically non-significant ($\chi^2= 0.99$, $df=1$, $p>0.05$).

6. On radiological examination, no subject was found to have findings suggestive of interstitial lung fibrosis. The common findings on radiological examination included suggested old pulmonary tuberculosis in 22(1.9%) subjects and pleural effusion and pleural thickening in one subject each.
7. 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 like OSHA, NIOSH or ACGIH, it was found that except at one process in the brake lining industry, the fibre levels were below the recommended levels. The dust levels in the ambient air as well as under the asbestos sheet roof was also found to much lower that these standards.
8. During the study it was found that most of the factories were using protective measures for the control of occupational and environmental health hazards in the workers as well as the surrounding communities.

Recommendations

1. In the present study the fibre levels were found to be much lower than the national permissible levels. However it requires regular monitoring of the workplace fibre levels 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. However it is recommended that these subjects should be periodically monitored medically so as to detect any adverse health effects particularly those having restrictive and combined type of pulmonary function abnormalities.

3. Most of the industries were using protective measures like use of PPEs, pre-placement, periodic and post retirement medical examination, for the control and prevention of asbestos related health hazards, these measures are to be implemented by all the asbestos using industries to protect the health of the workers.

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