Chrysotile Asbestos In Industry

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The six major forms of asbestos (1332214) were reviewed and then the most widely used form, chrysotile (12001295), was examined in more detail. The three largest industries using chrysotile include the asbestos/cement pipe industry, the asbestos friction products industry, and the asbestos textiles industry. A discussion was given for the production operations and products made in each of these industries. A brief comparison was included of the optical and electron microscopy techniques used in asbestos exposure evaluation. Since the invention of the steam engine, the uses for asbestos in the modern world have dramatically increased. Asbestos/cement pipe has become commonplace for water and sewage piping. The purpose of the asbestos mixed with the cement was to provide more strength and flexibility. The friction products industry involved the manufacture of brake linings, clutch facings, and transmission bands. In the asbestos textile industry both asbestos cloth and tape were produced. The United States Public Health Service, in 1964, initiated a comprehensive industrial hygiene study of these three industries to characterize the exposures to chrysotile asbestos and to establish a new sampling and analytical methods. Some recent research based on samples collected during this study was reviewed as well. In comparing the usefulness of phase contrast microscopy and electron microscopy, it was determined that the phase contrast microscopy technique provided relatively good indications of asbestos fibers greater than 5 micrometers in length.

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ABSTRACT

This paper reviews the six major forms of asbestos and then focuses on chrysotile, the most widely used variety of asbestos. The use of chrysotile in the three largest industrial users of asbestos is studied. These three industries, in the order of usage, are the asbestos - cement pipe, the asbestos friction products, and the asbestos textile industries. The production operations and products involved in each industry will be discussed. Chrysotile asbestos fiber size data representative of each of the three industries will be presented along with a brief comparison of the optical and electron microscopy techniques used in asbestos exposure evaluation.

INTRODUCTION

Asbestos has been used for over 2,500 years.[1] Originally it was used for cremation cloths and lamp wicks and recently as a thermal insulating material. The use of asbestos has increased dramatically over the last 150 years since the invention of the steam engine.[2] The term asbestos is a generic term used to describe a number of naturally occuring fibrous mineral silicates that have economic siginficance. There are six types of asbestos that have TLV's established by OSHA.[3] These six can be divided into two mineral classes based upon their crystal structure; serpentines and amphiboles.[4] Chrysotile is the only one in the serpentine class. The amphiboles include crocidolite, amosite, anthophyllite, tremolite and actinolite. The amphiboles anthophyllite, tremolite, and actinolite are of very little commerical value today. They are found largely as unwanted contaminants in other mineral products such as some industrial grade talcs. Amosite (cummingtonite-grunerite) accounts for about 2% of the total U.S. consumption and is used mainly for pipe and boiler insulation.[5] Crocidolite accounts for about 3% of the total U.S. consumption and is used in certain asbestos-cement products. Chrysotile accounts for about 95% of the total U.S. consumption and is used for a wide variety of products. These include fire resistant cloth, brake linings, clutch facings, asbestos-cement pipe, boards, and shingles, and certain asbestos paints and roof coatings.[5] The use of chrysotile asbestos is generally confined to three major industries. These three are the asbestos-cement products industry, the friction products industry, and the asbestos textiles industry.[4] The various processing steps involved for each industry will be described with the aid of some slides that depict most of the major operations.

CHRYSOTILE ASBESTOS PRODUCTS AND PROCESSES

The asbestos-cement products industry will be described first because it is the largest consumer of chrysotile asbestos in the United States. Latest figures estimate that over 60% of the chrysotile used in the U.S. is used in the manufacture of cement products. The products included in this industry are asbestos-cement pipe, boards, and shingles.[5] The process steps for all three products are similar. However, since asbestos-cement pipe production is much greater than the others, that process is the one that will be described.

Asbestos-cement pipe is used commonly for water and sewage piping. The asbestos is added to the cement pipe to give it greater strength and flexibility. In the manufacture of asbestos-cement pipe, chrysotile is first blended with silica flour and portland cement in a dry mixer. (Slide #1 shows an asbestos storage area with storage and mixing tanks). Then water is added resulting in a wet mix. The wet mix is then filtered onto a moving felt to form a thin film of stock. (Slide #2 shows the wet mix being placed onto the felt). This felt passes over a vacuum box to remove excess water. This asbestos-cement mix is rolled onto a rotating steel mandrel to form the pipe. (Slide #3 shows a pipe forming operation). After the desired thickness is achieved, an electric current is passed through the mandrel which vaporizes the thin film of water surrounding it. This loosens the pipe and the mandrel is then pulled out easily. The pipe is then placed in an air-cure area to dry. (Slide #4 shows an air-curing line). After drying, the pipe is autoclaved at high pressure to form calcium silicates in the pipe which provide stability, and resistance to corrosion. The pipe is then trimmed at the ends to fit coupling sections and grooves are cut in these sections to accomodate packing materials. (Slide #5 shows a pipe end cutting operation). (Slide #6 shows a pipe being cut to make pipe couplings). (Slide #7 shows a pipe trim lathe; this lathe is for the pipe I.D.). (Slide #8 shows another pipe trim lathe; this lathe is for the pipe O.D.). (Slide #9 shows a pipe coupling mill). (Slide #10 shows a pipe finishing operation where the couplings are fastened to the end of pipes).

The friction products industry involves the manufacture of brake linings, clutch facings, and transmission bands.[5] There are two basic processes used in the production of these items, a wet process and a dry process. Basically, the wet process is used for brake linings with the dry process being used for clutch facings, automatic transmission bands and disc brake pads. In the wet process, chrysotile is mixed with carbon black litharge and a liquid phenolic resin. (Slide #11 shows a raw materials mixing area). (Slide #12 shows the mixing hoppers located below the raw materials mixing room). The resulting paste is fed into an extruder which forms a continuous tape of the desired width and thickness. After being extruded, the coils that were formed undergo preliminary curing in ovens. (Slide #13 shows a preliminary curing oven). This curing operation gives the tapes some hardness but still allows them to be somewhat flexible. After the preliminary curing, the tapes are cut into linings of the proper length. (Slide #14 shows the extruded brake lining coil being cut). These linings are then placed in curing racks for final curing. Under the pressure of high tension springs, these racks also give proper shape to the shoes. (Slide #15 shows a workman mounting brake linings on the springs). After final curing, rivet holes are drilled and the surface is ground to the proper radius curvature. (Slide #16 shows a drill press used to drill the rivet holes). (Slide #17 shows a brake shoe grinding operation).

In the dry process, chrysotile is mixed with carbon black litharge and a powdered phenolic resin. The mix is then "preformed" which includes placing a preweighed portion into a mold and hot pressing it for one or two hours. (Slide #18 shows a preform station). (Slide #19 shows a hot press where clutch facings are being made). After hot pressing, the blocks are placed in a curing oven to complete the hardening process. After the final curing, the brake pads, clutch facings, or transmission bands are drilled and ground to specifications in a similar manner as previously described in the wet process. (Slide #20 shows a skid of finished brake linings).

The asbestos textile industry involves the manufacture of asbestos cloth and tape.[(5)] The process involved in the asbestos textile closely parallels that of the cotton textile industry. In the production of asbestos cloth and tape, the crude chrysotile asbestos is first opened. (Slide #21 shows a fiber opening area). This means that the large chunks of crude fiber are physically crushed into small bundles of fiber. This operation usually involves two steps, preliminary crushing in a pan crusher and further opening in a fiberizer. After the chrysotile fiber is opened, it is screened to romove the smaller fibers that are not suitable for spinning. Next, the chrysotile asbestos is blended with small quantities of an organic fiber, usually cotton. (Slide #22 shows a fiber blending machine). This is done to overcome the difficulty involved with spinning pure chrysotile and to add strength to the resulting yarn. The mixture of asbestos and cotton is then carded. (Slide #23 shows a carding machine). The carding operation removes any remaining short fibers and arranges the fibers in a parallel position. Usually, two carding machines are used in a series in order to further strengthen the resulting yarn. (Slide #24 shows the fiber web from the carding machine). The fiber web produced by the carding operation is cut into thin strips called rovings. These rovings are rolled onto "Jack" spools for spinning. The unspun rovings are then spun on either a ring spinning frame or a mule spinning frame. (Slide #25 shows a ring spinning frame). In the spinning operation, the roving is twisted as it is wound onto a spool to increase its tensile strength. The spools of single-ply yarn from the spinning frames are next twisted into two or three ply yarns on a twisting frame. For some textiles, a small diameter metal wire may also be twisted in with the asbestos yarn to further increase tensile strength. (Slide #26 shows a twisting frame). The spools of twisted yarn are then mounted on creels in preparation for weaving. Some of the spools of twisted yarn are wound onto bobbins using cop winders for use in the loom shuttles. (Slide #27 shows a cop winder). The number of creels used to feed the weaving loom depends upon the width of the cloth or tape being woven. In the weaving process, the yarns from the creels are woven together by the transverse yarn of the shuttles. (Slide #28 shows a cloth weaving loom). (Slide #29 shows a close-up of a cloth weaving loom). (Slide #30 shows a tape weaving loom). After the asbestos cloth or tape is woven, it is wound onto rolls for distribution. (Slide #31 shows some asbestos cloth ready for inspection).

CHRYSOTILE ASBESTOS FIBER SIZE CHARACTERISTICS

In 1964, The United States Public Health Service initiated a comprehensive industrial hygiene study of these three industries to characterize the exposures to chrysotile asbestos within each one and also to establish a new sampling and analytical method for asbestos.[5] This study resulted in the method for asbestos evaluation being changed from midget impingers where all particulates were counted to the 37mm cellulose acetate filters where only fibers greater than 5µm in length are counted. Most of the exposure data resulting from this long-term study has been previously presented in a variety of forms over the years. In fact, this data served as the basis for the NIOSH asbestos criteria document and its recent revision.[6,7]

Now, I would like to discuss some recent research using the samples that were collected during this study.[8] This research was initiated in response to some recent animal studies that indicate that asbestos fibers of any size can produce the same health effects that only larger fibers were thought to cause in the past.[9,10] This research explores the fiber size characteristics of chrysotile asbestos in those three industries previously discussed. Basically, this research was designed to answer five questions: (1) is there a characteristic mean fiber length for each of these three industries?; (2) is there a characteristic mean fiber length for each operation within each industry?; (3) is there a similarity in the mean fiber lengths between similar operations of the different industries?; (4) how many fibers less than 5µm in length are "missed" by the phase contrast microscopy method of analysis?; (5) using the electron microscope as a reference standard, how well does phase contrast microscopy evaluate the greater than 5µm portion of asbestos exposures?

To carry out this research study, samples taken during the PHS study were selected from the cement pipe, friction products, and textile industries. (Slide #32 shows the distribution of samples for evaluation in this study). Five plant surveys were chosen from each industry. The samples listed under the operation headings were chosen at random from each industry. A total of 179 personal breathing zone samples were selected for evaluation. All the samples were evaluated using both phase contrast and electron microscopy techniques. The phase contrast method used was that described in the NIOSH P&CAM #239 where only fibers greater than 5μm in length were counted. (Slide #33 shows a typical phase contrast microscope). The electron microscopy method used 10,000X magnification and all fibers were sized by length and diameter. (Slide #34 shows out electron microscope).

The next three slides shows the asbestos fiber length expressed as a geometric mean for each operation in each industry. Only the electron microscopy counts were used. The geometric mean and geometric standard deviation statistics were calculated from the cumulative length distributions using the method of probit analysis as described by Mercer[11] in "Aerosol Technology in Hazard Evaluation". The validity in choosing the log normal distribution was verified using the chi square test. (Slide #34 shows the geometric means of the operations in the friction products industry). (Slide #36 shows the geometric means of the operations in the asbestos textile industry). The asbestos textile industry has generally longer fiber length than do the other two industries. (Slide #37 shows the geometric menas of the asbestos-cement pipe industry operations).

The next three slides show the results of the comparison tests between the operations within each industry. To do these comparisons, pooled estimates of varience for the distribution of differences were used. Again, a log normal distribution was assumed and a two-sided "T" test was used for the comparisons. An "S" means the comparisons were siginficant at the 0.05 level of probability. Anything falling between 0.01 and 0.05 was called significant. An "HS" means the comparisons were highly siginficant at the 0.05 level. Anything that fell below 0.01 was called highly significant. An "NS" means not significant at the 0.05 level of probability. (Slide #38 shows the comparisons for the friction products industry). (Slide #39 shows the comparisons for the asbestos textile industry). (Slide #40 shows the comparisons for the asbestos-cement pipe industry). This was the only non-significant finding in all of these comparisons.

The next three slides show the results of the comparisons of similar operations in different industries. The "HS" indicates a highly significant difference and the "NC" indicates that no comparisons were made because the operations are not similar. (Slide #41 shows the comparisons for the raw fiber handling operations). (Slide #42 shows the comparisons for the secondary product forming operations). (Slide #43 shows the comparisons for the product finishing operations). All of these comparisons of similar operations showed a highly significant difference at the 0.05 level of probability. In general, all of the operations were significantly different from the others and, therefore must be considered to be discreet.

The next set of data we compared was the concentration of asbestos fibers greater than 5µm in length evaluated by both the phase contrast and electron microscopy techniques. This was done by using the phase contrast microscopy concentrations greather than 5µm as the X coordinates and the electron microscopy concentrations greater than 5µm as the Y coordinates in a least squares linear regression. The comparisons are in the form of correlation coefficients with a perfect fit being equal to one (1). The electron microscope was used as the reference standard for these comparisons. (Slide #44 compares the counts for the operations in the friction products industry). (Slide #45 compares the counts for the operations in the asbestos textile industry). (Slide #46 compares the counts for the operations in the asbestos-cement pipe industry). With only two exceptions, all of these correlations had a value of 0.8 or better.

Finally, proportions of asbestos fibers greater than 5μm in length were calculated for each operation. (Slide #47 shows these proportions). Generally, the asbestos textile industry has a larger proportion of asbestos fibers greater than 5μm in length than do the other two industries.

CONCLUSION

Concerning the asbestos fiber lengths in the various operations, there can be no general conclusion drawn. It appears that there is no characteristic fiber size of an industry or of similar operations in different industries.

With regard to the comparison between the phase contrast microscopy and electron microscopy concentrations of asbestos fibers greater than 5μm in length, however, there can be some general inferences made. The correlation coefficients of the fiber concentrations indicate that, with few exceptions, the phase contrast microscopy technique gives us a relatively good indication of asbestos fibers greater than 5μm in length. However, the proportion of asbestos fibers greater than 5μm in length varies greatly from operation to operation within the industries and between similar operations in different industries. The proportions vary from a low of 4.5% in the finishing operation of the asbestos-cement pipe industry to a high of 20.6% in the fiber preparation operation in the asbestos textile industry. This indicates that the phase contrast microscopy technique that only includes asbestos fiber greater than

5μm in length probably does not give an adequate indication of total asbestos exposure for the asbestos industry as a whole. A general industry asbestos standard allows the workers involved with some operations to be exposed to a greater number of total asbestos fibers than other workers in other operations. Take for an example, a finishing operation worker in the asbestos-cement pipe industry that is exposed to asbestos fibers of which only 4.5% are greater than 5μm in length. There are another 95.5% that are shorter than 5μm in length and, therefore, not evaluated by the phase contrast microscopy technique. At the other extreme, a worker in the fiber preparation operation in the asbestos textile industry is exposed to asbestos fibers of which 20.6% are greater than 5μm in length. This leaves 79.4% that are shorter than 5μm in length. However, assuming that both operations were meeting the current OHSA standard for asbestos, the finishing operator in the cement pipe industry would have approximately a five (5) times greater total asbestos fiber exposure based on the results of our study.

Future research is planned to further document these fiber size characteristics, especially the diameter vs. length relationship of asbestos fibers.

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APPENDIX

SLIDE #32

DISTRIBUTION OF SELECTED ASBESTOS
SAMPLES FOR EVALUATION

FRICTION PRODUCTS INDUSTRY				
PLANT	MIXING	FORMING	FINISHING	TOTALS
A	4	7	4	15
B	6	4	4	14
C	9	3	-	12
D	1	2	9	12
E	2	2	3	7
TOTALS	22	18	20	60

ASBESTOS TEXTILE INDUSTRY				
PLANT	FIBER PREPARATION	TWISTING	WEAVING	TOTALS
F	4	4	4	12
G	4	4	4	12
H	4	4	4	12
I	4	4	4	12
J	4	4	4	12
TOTALS	20	20	20	60

ASBESTOS CEMENT PIPE INDUSTRY				
PLANT	MIXING	FORMING	FINISHING	TOTALS
K	3	3	4	10
L	6	6	2	14
M	4	3	5	12
N	2	4	5	11
O	5	4	3	12
TOTALS	20	20	19	59

ASBESTOS FIBER LENGTH FOR EACH OPERATION IN EACH INDUSTRY EXPRESSED AS A GEOMETRIC MEAN IN µm

SLIDE #35

FRICTION PRODUCTS INDUSTRY		
OPERATION	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION σg
MIXING	1.33 µm	2.87
FORMING	1.40 µm	2.69
FINISHING	1.79 µm	2.82

SLIDE #36

ASBESTOS TEXTILE INDUSTRY		
OPERATION	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION σg
FIBER PREPARATION	2.20 µm	2.72
TWISTING	1.78 µm	2.96
WEAVING	2.04 µm	2.97

SLIDE #37

ASBESTOS CEMENT PIPE INDUSTRY		
OPERATION	GEOMETRIC MEAN	GEOMETRIC STANDARD DEVIATION σg
MIXING	1.63 µm	2.97
FORMING	1.66 µm	2.52
FINISHING	1.01 µm	2.58

TESTS OF SIGNIFICANCE ON ASBESTOS
FIBER LENGTH IN DIFFERENT OPERATIONS
OF THE SAME INDUSTRY

SLIDE #38

FRICTION PRODUCTS INDUSTRY			
OPERATION	GEOMETRIC MEAN	COMPARISONS	
MIXING	1.33 μm	S	
FORMING	1.40 μm	HS	HS
FINISHING	1.79 μm		

SLIDE #39

ASBESTOS TEXTILE INDUSTRY			
OPERATION	GEOMETRIC MEAN	COMPARISONS	
FIBER PREPARATION	2.20 μm	HS	
TWISTING	1.78 μm	HS	S
WEAVING	2.04 μm		

SLIDE #40

ASBESTOS CEMENT PIPE INDUSTRY			
OPERATION	GEOMETRIC MEAN	COMPARISONS	
MIXING	1.63 μm	NS	
FORMING	1.66 μm	HS	HS
FINISHING	1.01 μm		

HS = Highly significant at the 0.05 level of probability
S = Significant at the 0.05 level of probability
NS = Not significant at the 0.05 level of probability

TEST OF SIGNIFICANT ON ASBESTOS
FIBER LENGTH IN SIMILAR OPERATIONS
IF DIFFERENT INDUSTRIES

SLIDE #41

RAW FIBER HANDLING OPERATIONS			
INDUSTRY	OPERATION	GEOMETRIC MEAN	COMPARISONS
FRICTION PRODUCTS	MIXING	1.33 µm	HS
ASBESTOS TEXTILE	FIBER PREPARATION	2.20 µm	HS — HS
ASBESTOS CEMENT PIPE	MIXING	1.63 µm	

SLIDE #42

SECONDARY PRODUCT FORMING OPERATIONS			
INDUSTRY	OPERATION	GEOMETRIC MEAN	COMPARISONS
FRICTION PRODUCTS	FORMING	1.40 µm	HS
ASBESTOS TEXTILE	TWISTING	1.78 µm	HS — HS
ASBESTOS CEMENT PIPE	FORMING	1.66 µm	

SLIDE #43

PRODUCT FINISHING OPERATIONS			
INDUSTRY	OPERATION	GEOMETRIC MEAN	COMPARISONS
FRICTION PRODUCTS	FINISHING	1.79 µm	NC
ASBESTOS TEXTILE	WEAVING	2.04 µm	NC — HS
ASBESTOS CEMENT PIPE	FINISHING	1.01 µm	

HS = Highly significant at the 0.05 level of probability
NC = No comparison (operations are dissimilar)

CORRELATION OF GREATER THAN 5µm
ASBESTOS FIBER COUNTS BY OPTICAL AND
ELECTRON MICROSCOPY

SLIDE #44

FRICTION PRODUCTS INDUSTRY		
OPERATION	REGRESSION CONSTANTS	CORRELATION COEFFICIENT
MIXING	Y = 0.03 + 0.75X	0.54
FORMING	Y = 0.32 + 0.96X	0.88
FINISHING	Y = 0.67 + 1.21X	0.83

SLIDE #45

ASBESTOS TEXTILE INDUSTRY		
OPERATION	REGRESSION CONSTANTS	CORRELATION COEFFICIENT
FIBER PREPARATION	Y = 3.84 + 0.88X	0.77
TWISTING	Y = 0.28 + 0.99X	0.89
WEAVING	Y = 0.83 + 1.14X	0.95

SLIDE #46

ASBESTOS CEMENT PIPE INDUSTRY		
OPERATION	REGRESSION CONSTANTS	CORRELATION COEFFICIENT
MIXING	Y = 0.13 + 0.99X	0.94
FORMING	Y = 0.26 + 0.95X	0.89
FINISHING	Y = 0.83 + 0.56X	0.62

X = Fibers > 5µm/cc by optical microscopy
Y = Fibers > 5µm/cc by electron microscopy

SLIDE #47

PROPORTION OF AIRBORNE ASBESTOS FIBERS GREATER THAN 5μm IN LENGTH BY INDUSTRY AND OPERATION

INDUSTRY	OPERATION	PROPORTION > 5μm
FRICTION PRODUCTS	MIXING	0.098
FRICTION PRODUCTS	FORMING	0.092
FRICTION PRODUCTS	FINISHING	0.172
ASBESTOS TEXTILE	FIBER PREPARATION	0.206
ASBESTOS TEXTILE	TWISTING	0.167
ASBESTOS TEXTILE	WEAVING	0.188
ASBESTOS CEMENT PIPE	MIXING	0.131
ASBESTOS CEMENT PIPE	FORMING	0.099
ASBESTOS CEMENT PIPE	FINISHING	0.045