Asbestos 1972

ENVIRONMENTAL PROTECTION MONOGRAPH SERIES

ASBESTOS

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ASBESTOS

A) THE CHEMISTRY OF ASBESTOS

Geologists recognize more than thirty asbestiform minerals. However, only six of these are used commercially, namely, chrysotile, amosite, anthophyllite, crocidolite, tremolite and actinolite. Of these, chrysotile accounts for 96% of the asbestos consumed; amosite, 2%; crocidolite, 2%; and the other three total less than 1%. Chemical formulas for these forms of asbestos are given below:

Type	Chemical Formula
Chrysotile (Serpentine group)	$Mg_3Si_2O_5(OH)_4$
Amosite (Amphibole group)	$(Fe,Mg)_7Si_8O_{22}(OH)_2$
Anthophyllite (Amphibole group)	$(Fe,Mg)_7Si_8O_{22}(OH)_2$
Crocidolite (Amphibole group)	$Na_2(Fe^{+2},Mg)_3Fe_2^{+3}Si_8O_{22}(OH)_2$
Tremolite (Amphibole group)	$Ca_2Mg_5Si_8O_{22}(OH)_2$
Actinolite (Amphibole group)	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$

Since chrysotile is by far the most important and widespread form of asbestos, it will be described in some detail.

A typical analysis of chrysotile is the following:

MgO	40.6
SiO_2	39.8
Al_2O_3	0.7
FeO	1.3
Fe_2O_3	2.3
CO_2	0.5
Loss on Ignition	14.0

In addition the mineral usually contains trace amounts of other metals and up to 0.2% organic carbon in the form of oils.

Chrysotile is a fibrous mineral. It is made up of layers of silicon-oxygen tetrahedra condensed onto magnesium hydroxide. The combined silica-magnesium hydroxide network is put together in a manner such that curved sheets 7.3 Angstroms (A) in thickness are formed with the outside (convex) surface always containing OH groups. Twelve to twenty such sheets are mechanically bound together in such a way that round, hollow fibers are produced. The fiber diameter (180-250A) is several orders of magnitude smaller than cotton or wool fibers. The fibers may be very short (a few hundred Angstroms) or up to three inches in length. Normally, many fibers are bound together forming bundles up to 0.03" in diameter. However, it must be borne in mind that asbestos samples may contain dust particles as small as 200 A by 200 A.

Chrysotile is quite resistant to alkali, but is attacked by aqueous HCl, possibly because the outside surface of the fiber is largely $Mg(OH)_2$. When slurried with water enough hydrolysis occurs to produce a pH of about 10, which is also characteristic of $Mg(OH)_2$ in water. The surface of an asbestos fiber in water is positively charged due to loss of OH^-, but the addition of base reduces this charge to zero near pH 12. At low pH (around 3) Mg^{+2} are also lost from the surface reducing the surface charge and exposing SiO_2 to the solution. Strong acids (e.g. 1 N HCl at 95°C. for one hour) completely dissolves away the $Mg(OH)_2$ from the mineral leaving behind amorphous SiO_2 in a fragile fibrous morphology. Asbestos is stable in air and water, and would be

expected to persist in the natural environment. Chrysotile loses its water of hydration at about 450°C., and can be dehydroxylated at 650°C.

B) OCCURRENCE OF ASBESTOS

1) Natural Occurrence of Asbestos - The principal sources of asbestos in North America are Canada and Vermont. The ore generally contains 5 - 10% chrysotile, the remainder being rock of various types. The ore is crushed to release the chrysotile from the rock matrix, and the fibrous material is separated by screening. Amosite and crocidolite are imported from Africa.

2) Background Levels of Asbestos - No data were found.

3) Commercial Uses of Asbestos - Most of the uses of asbestos arise from its unique set of properties; fibrous nature, tensile strength (equivalent to piano wire), thermal and chemical stability.

Uses of chrysotile include: cement reinforcement, insulation, floor and ceiling tile, fire resistant building materials, textiles, paper, diaphragms for the electrolytic production of chlorine and many others. Crocidolite is used for the production of automatic automobile transmissions. Total consumption of asbestos in the U.S. is about 800,000 tons annually. Dow uses for asbestos include insulation, filters, and diaphrams in chlorine cells. Plastic fabricators often use asbestos as a reinforcing agent in plastics.

C) ANALYTICAL CONSIDERATIONS

Sampling techniques are critical for obtaining meaningful analyses of asbestos. The Environmental Protection Agency has recently prescribed a method of sampling air for asbestos. It involves collecting asbestos in air on a membrane filter and counting the fibers greater than 5 micrometers in length at 400-450 X magnification (4 millimeter objective, phase contrast illumination).

All crystalline forms of asbestos may be identified positively by their X-ray diffraction patterns. Electron miscroscopy and elemental analysis are also of assistance in establishing the identity and quality of the material.

Differential Thermal Analysis has also been used in the identification of asbestos minerals.

The Ecology Council is available for assistance in determining appropriate analytical methodology.

D) TOXICOLOGY

1) Animals - Two distinct diseases result from the inhalation of asbestos, (1) asbestosis, a fibrogenic disease of the lungs and (2) mesotheliomas, cancers of the lining of the chest and abdomen. A great many experimental studies have been carried out on laboratory animals in an effort to demonstrate the fibrogenic and tumorgenic properties of asbestos. Such experimental studies are complicated by many variables including the type and dimensions of the asbestos fibers administered; the contaminants present in the asbestos (e.g. trace metals and hydrocarbons); the route of administration; the species and strain of animal; the dosage; and the time following administration (latency period).

a) Experimental Asbestosis

Asbestotic pulmonary fibrosis (scarring of the lungs) has been produced experimentally in several species of animals, including rats, guinea pigs, hamsters, rabbits and monkeys. In these studies various modes of administration were used, the most frequent being inhalation, and single intratracheal or intrapleural injections. The slowly progressive diffuse pulmonary fibrosis observed in laboratory animals is considered to be the counterpart of the human disease. A striking feature in both animals and man is the very long latency period between exposure and evidence of the disease.

Experimental asbestosis has been produced in one or more species by at least three forms of asbestos (chrysotile, amosite, and crocidolite). The role, if any, played by various contaminants

of asbestos (e.g. trace metals and hydrocarbons) or fiber size, is not clear.

b) Experimental Cancers

Lung cancer has been produced experimentally in several species of animals (including rats, mice, and hamsters) by inhalation, or by single intratracheal or intrapleural injections of asbestos. Chrysotile has been the type of asbestos most frequently cited as the carcinogenic agent, however, other types of asbestos as well as contaminants (e.g. trace metals and hydrocarbons) have been implicated. Generally, the appearance of lung cancer has followed a long latency period, again, paralleling human experience.

In view of the recent human experience, cancers (mesotheliomas) of the pleural surface (lining of the thoracic cavity) are of special concern. Such cancers have been observed in rats and hamsters several months after a single injection of the three most common types of asbestos (chrysotile, crocidolite, or amosite) into the chest cavity.

Pleural and peritoneal mesotheliomas (cancers of the lining of the thoracic and abdominal cavities) have been observed in mice several months following the subcutaneous injection of crocidolite, amosite, or chrysotile. This study is of particular interest, since it provides evidence of migration of asbestos fibers.

c) Mutagenic and Teratogenic Effects

There is no evidence that asbestos is associated with mutagenesis or teratogenesis.

2) Humans - At the present time, approximately five million workers in the United States are exposed to airborne asbestos in occupations involving the industrial production and use of asbestos-containing products. Epidemiological studies have shown that occupational exposures to all commercially used forms of asbestos have resulted in high rates of asbestos-related diseases: asbestosis, cancer of the lung, cancers of the lining of the thoracic and abdominal cavities, and other cancers. The present state of knowledge indicates that once exposure has occurred, asbestos-related disease may appear even though the exposure is discontinued. The disease may be evident after a latency period of 20 years or more; consequently, unless a very careful history is conducted the possible association with asbestos exposure may be missed.

Recently, there has been considerable alarm about asbestos exposure of the general population. The major potential for risk appears to lie in individuals with indirect occupational contacts, household contacts, or residence in the immediate neighborhood of asbestos sources. At present the significance and magnitude of nonoccupational exposures to asbestos are not resolved.

There are many variables in asbestos-related diseases that are not well understood. These include the duration, intensity and continuity of exposure(s); the specific type and dimensions of the asbestos fibers inhaled; the role of cofactors; the contaminants of the asbestos (e.g. trace metals and hydrocarbons); the presence of other concomitant dusts; the latency period; and individual idiosyncrasies.

Many authors have emphasized the gravity of the asbestos hazard and the need for stringent controls.

a) Pulmonary Asbestosis

Asbestosis, the first recognized disease associated with the prolonged inhalation of asbestos (all types), is a disabling or fatal scarring disease of the lungs (progressive diffuse pulmonary fibrosis). The risk varies directly with the length of exposure and the dust concentration. The chief symptoms of advanced asbestosis are a non-productive cough, shortness of breath, substernal chest pains, decreased chest expansion, weakness, emaciation, clubbed finger tips, and curved finger-nails. X-ray findings show a fibrosis of the lung fields which is usually, but not exclusively, basilar, mid-lung field adhesions, pleural plaques and calcifications.

b) Neoplasms from Inhalation of Asbestos

Lung Cancer

Many studies over the past twenty-five years have definitely confirmed an association between occupational exposure to

asbestos (all types) and a higher than expected incidence of lung cancer (bronchogenic carcinoma). The latent period between exposure to asbestos and evidence of lung cancer may be even longer than for asbestosis; however, there is very little information on the dose-time relationship. While lung cancer is the most common complication of asbestosis, cases of lung cancer apparently induced by asbestos have been reported unaccompanied by asbestosis.

Cigarette smoking vastly enhances the chances of asbestos workers developing lung cancer. In view of the continued poor outlook following removal from exposure to asbestos, the discontinuance of cigarette smoking is a paramount prevention measure.

Cancer of the Pleural and Peritoneal Surfaces

Very little serious consideration was given to asbestos as an etiological factor in mesothelial malignancies prior to 1960. Since then, many reports have been published supporting a relationship between asbestos and pleural and peritoneal mesotheliomas. An outstanding feature has been the long period, commonly over 30 years, between the first exposure to asbestos and the appearance of a tumor. As with lung tumors, there is no good correlation between the severity of asbestosis and the occurrence of mesotheliomas.

There are some epidemiological data indicating that crocidolite and, to a much lesser degree amosite, produce mesotheliomas, while anthophyllite and chrysotile do not; however, much more data are needed in this regard.

Other Cancers

Association between asbestos inhalation and malignancies of the gastrointestinal tract (stomach and colon) and other sites has been suggested.

c) Neoplasms from Oral Ingestion of Asbestos

Recently, controversial epidemiological evidence has been published indicating that the asbestos-contaminated talc on rice in the diet is the carcinogen or cocarcinogen responsible for the high incidence of Japanese stomach cancer. This opens up many areas of concern over the deleterious effect of orally ingested asbestos. Since asbestos-containing filter pads are commonly used in the food and beverage processing industries, it is very likely that many foods and beverages contain asbestos fibers. In fact, asbestos fibers have been identified in beer and occur naturally in rivers when the water runs over asbestos containing rock. No doubt, there will be considerable research activity in this area in the immediate future.

3) Fish and Other Aquatic Organisms - No evidence has been found to indicate that asbestos is toxic to aquatic organisms No references

were found to studies of asbestos toxicity to aquatic organisms. Bottom life could be affected if solids were to accumulate to the extent that the organisms become isolated from their normal environment, e.g., food sources, light, oxygen and pH.

4) Plants - No evidence has been found to indicate that asbestos is toxic to plant life. Accumulation of solids on foliage interferes with sunlight availability for photosyntheses.

5) Biotransformation - Fiber size is critically important in determining respirability, deposition, retention, and clearance from the pulmonary tract and is probably an important determinant of the site and nature of biological action. Little is known about the movement of fibers within the body, including their potential for entry through the gastrointestinal tract.

No data were found which indicate that asbestos is bioconcentrated or biomagnified.

E) ESTABLISHED STANDARDS

1) Air

a) Occupational

(1) The American Conference of Governmental Industrial Hygienists recommends the following Threshold Limit Value (TLV) as a time-weighted concentration for workmen exposed 7 to 8 hours per day, 40 hours per week.

Asbestos (all types) 5 fibers/ml $>5\mu$ in length as determined by the membrane filter method at 400-450 X magnification (4 mm objective) phase contrast illumination. Concentrations 5 fibers/ml but not to exceed 10, may be permitted for 15 minute periods each hour up to five times daily.

(2) The British Occupational Hygiene Society recommended the following criteria for limiting exposure to chrysotile asbestos assuming a 1% risk of contracting asbestos disease during a 50 year working exposure.

Dust Category	Chrysotile concentration* Fibers/ml**
Negligible	< 0.5
Low	0.5-2.0
Medium	2-10
High	> 10

*Averaged during a three-month period.
**Greater than 5μ in length.

From these criteria, a limit of 100 fibers/ml-years was proposed, hence a limit of 2 fibers/ml averaged over a 50-year period.

(3) The National Institute of Occupational Safety and Health (NIOSH) has recommended to the Labor Department that the Occupational Safety and Health Regulations by the Labor Department be amended within two years and prescribe a limit of no more than 2.0 asbestos fibers/ml of air based on a count of fibers greater than 5μ in length, determined as a time-weighted average exposure for an 8-hour work day, and no peak concentration to exceed 10.0 fibers determined by a minimum sampling time of 15 minutes. The two-year delay is to allow time for the installation of necessary engineering control. In addition, medical surveillance will be required.

b) Ambient Air Quality - No numerical standards for asbestos have been found. However, the U. S. Environmental Protection Agency has proposed in 40 CFR Part 61 that "no visible dust" will be the criteria and control will be based on elimination at the source of emission.

c) Emission Levels - The U. S. Environmental Protection Agency has proposed the limitation of all airborne asbestos by requiring suitable collection devices for the airborne asbestos on all operations that may generate airborne asbestos. Suitable collection devices are specified (40 CFR Part 61.23 & .24).

2) Water

a) Potable - Neither the U.S.P.H.S. nor any other group appears to have set a standard for asbestos in drinking water.

b) Stock and Wildlife - No standards have been found.

c) Aquatic Life - No standards have been found.

d) Irrigation - No standards have been found.

e) Industrial Effluent - No standards have been found.

3) Soil - No standards have been found.

4) Food, Drugs and Food Additives - No standards have been found.

F) CONSIDERATIONS FOR ESTABLISHED GUIDES FOR A GIVEN LOCATION

1) Inhaled asbestos is a potent carcinogen. It has been receiving much attention lately. Some states have banned certain uses of asbestos including the spraying of insulating material in building construction.

2) Orally ingested asbestos in water or food is now under scrutiny as a possible causative factor in cancer of the gastrointestinal tract.

3) The effect of asbestos on aquatic life has not been studied.

4) The goal should be to avoid the exposure of all individuals to asbestos dust since the actual no-effect level is still unclear. Adequate control methods must be implemented. Stringent medical follow-up studies on these asbestos workers will be required.

5) Due to lack of knowledge of the effects of asbestos in water, and the possible emotional factor associated with potential carcinogens, discharge to the water environment should be minimized.

6) Cigarette smoking vastly enhances the chances of asbestos workers developing lung cancer.

G) SUGGESTED DOW GUIDES

All local and national regulatory requirements must be met. The following guides should be used in the absence of such regulations or if the Dow Guide is lower than the legal requirements.

1) Total Plant Emissions - Less than 0.01 kg/day total emission of asbestos to air as finely divided asbestos may present a health hazard in certain local situations.

Release to soil in such a way that there is no possibility of asbestos becoming airborne presents much less of a problem.

2) Air

a) Occupational - Time-weighted average concentration for repeated 8-hour period, 40 hours/week:

Asbestos (all types) -

2 fibers/ml of air based on a count of fibers >5μ in length, with peak concentrations not to exceed 10 fibers/ml of air as determined by a minimum sampling time of 15 minutes, and using the membrane filter method of collection and analysis at 400-450 X magnification (4 mm objective) phase contrast illumination. In addition, medical surveillance will be required for those employees who are exposed to asbestos at time-weighted average levels greater than 1 fiber/ml of air or peak concentrations greater than 5 fibers/ml of air.

b) Ambient Air Quality - Averaged over a 24-hour period: Asbestos (all types) - 0.1 fibers/ml of air >5μ in length as determined by the EPA method.

c) Emission - Emission must be controlled so that all ambient guides are met.

In addition there are limitations on the uses and criteria for emission controls for asbestos stipulated by the Environmental Protection Agency in the Code of Federal Regulations, Title 40, Part 61, Subpart B.

3) Water - Asbestos must be considered in the limit for total suspended solids of 15 mg/l. There is at the present time no other basis to establish a specific standard.

4) Soil - Asbestos may be disposed of in landfill areas, but it must be done in a manner such that it cannot become resuspended in air.

5) Food, Drugs and Food Additives - Contamination of foods, drugs and cosmetics with asbestos must be avoided.

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