The health risk of chrysotile asbestos

David M. Bernstein

INTRODUCTION

The word asbestos is associated with health risk and controversy. However, it is a poorly attributed term, as it refers to two very different minerals with very different characteristics. One is the serpentine mineral of which the white asbestos, chrysotile, is the most common. The other is the amphibole asbestos, which includes the blue asbestos crocidolite and the brown asbestos amosite. Although today chrysotile is the only type used commercially, the legacy of past use of amphibole asbestos remains. This review clarifies the differences between the two mineral families referred to as asbestos and summarizes the scientific basis for understanding the important differences in the toxicology and epidemiology of these two minerals.

Although mineralogists have long been aware of the structural and chemical differences between serpentine and amphibole asbestos, these characteristics have only more recently been taken into consideration by the toxicological and epidemiological literature.

CHrysOTile AND AMPHIBOLE ASBESTOS

The most important characteristics that influence the toxicology of chrysotile are that it is soluble in acid [1] and formed as rolled or concentric thin sheets (7.3 Å thick) composed of silicate and brucite layers with the magnesium hydroxide part of each layer closest to the fiber surface [2–5]. The magnesium on the outside of the role is readily attacked by the acid milieu such as occurs inside the alveolar macrophage (pH 4–4.5), and dissociates from the crystalline structure, leaving an unstable silicate sheet. This process results in the thin rolled sheet of the chrysotile fiber breaking apart and decomposing into smaller pieces. These pieces can then be readily...

Keywords
amphibole asbestos, biopersistence, chrysotile, epidemiology, inhalation toxicology, lung, pleura
Diseases of the pleura

KEY POINTS

- Asbestos is a poorly attributed term referring to two very different minerals.
- Chrysotile is an acid-soluble rolled thin sheet silicate with little biopersistence.
- Amphibole asbestos (crocidolite, amosite) are solid silicate fibers with negligible solubility and high biopersistence.
- Chrysotile produces little effect, and with controlled use it can be used safely.
- Amphibole asbestos is highly pathogenic and quickly initiates disease even after short-term exposure.

Biopersistence

Recent studies have shown that chrysotile fibers are rapidly cleared from the lung and do not reach the pleural cavity and do not result in a pathological response in either the lung or pleural cavity. This is in contrast to the amphibole asbestos fibers such as amosite and tremolite, which because of their insolubility at both neutral and acid pH are very biopersistent in the lung, result in the formation of interstitial fibrosis even after short-term exposure and quickly translocate to the pleural cavity [12**].

As cited above, Kobell [1] in 1834 reported that one of the most important characteristics that differentiated chrysotile was that it was soluble in acid. The importance of this was not recognized until the 1990s when studies were performed to determine why newly developed high aluminium synthetic vitreous fibers were rapidly cleared from the lung [16]. The investigators found that under the acid conditions of the alveolar macrophage, the fiber quickly dissolved and broke apart. This combined with the fact that chrysotile is a rolled sheet silicate with a sheet thickness of 7.3 Å provided a basis for understanding why the long chrysotile fibers clear rapidly from the lung [12**]. The rapid clearance of chrysotile is thought to be characterized not by congruent dissolution as with many synthetic vitreous fibers but rather with the loss of structural integrity of the serpentine sheet silicate and the subsequent disintegration into smaller pieces. Suquet [17] reported on the assessment of the structural damage produced by grinding or acid leaching
of chrysotile. The author reported that ‘Acid leaching transformed chrysotile into porous, noncrystalline hydrated silica, which easily fractured into short fragments. If the acid attack was too severe, these fragments converted into shapeless material.’

Biopersistence studies of chrysotile have shown that it is not biopersistent in the lung and that it does not produce a pathological response following short-term exposure in either the lung or the pleural cavity [18–21,22].

Inhalation toxicology
The early inhalation toxicology studies of asbestos have been often difficult to interpret. These studies were performed prior to the current understanding of animal physiology and the factors that influence fiber toxicology. The paradigm that has evolved concerning fiber toxicity is based upon three criteria: dose, dimensions and durability. Rodents, which are routinely used in toxicology studies, are mandatory nasal breathers and as such can only inhale fibers less than approximately 1 μm diameter. In addition, they are susceptible to lung overload, under exceedingly high exposure concentrations to relatively insoluble particles [23–27]. The fiber preparation procedures used in most early studies involved the use of heavily milled asbestos samples [28–31], which were then aerosolized using a procedure that involved grinding of the fibers as well [28], both of which greatly reduced the number of longer fibers present. Exposure was standardized based upon a gravimetric concentration of 10 mg/m³, without consideration of the number of particles and longer fibers present. As a result, the exposure concentration in these studies has been calculated to range from 200 000 to 8600 000 fibers/cm³, well in excess of what would be considered lung overload [12**].

Studies taking into account both the animal physiology and the fiber characteristics that influence potential toxicity have shown that chrysotile even at exposure concentrations of 500 fibers(WHO)/cm³ produces no pathological response [32].

Epidemiology
Several important limitations underlie epidemiological studies of chrysotile. Although chrysotile is currently used largely in high-density cement products, the epidemiological and regulatory evaluation of chrysotile is based upon a cross-section of all uses in the past. The studies characterized as chrysotile only have been reviewed recently and provide further understanding of the difficulty in using these studies to evaluate chrysotile as used today [12**]. As a result of the measurement techniques used at the time, there was little or no quantitative exposure information available on the types of fibers to which the workers were exposed. In addition, fiber exposure was estimated based upon the extrapolation from gravimetric or total particle number of samples without information available as to fiber diameter or length. The nature of industrial processes was used to suggest the type of fiber to which the workers were exposed. However, in many applications, chrysotile and amphibole asbestos were often used interchangeably depending upon availability, cost and effectiveness in the process. Equally important, work histories of employees were not as well documented as might occur today [33].

Etiology
Although early studies correlated severity of illness in ‘asbestos’-exposed workers with the duster jobs [34–41] providing an exposure–response relationship, owing to the state of occupational hygiene measurements at the time, none of the studies were able to use exposure measurements that included fiber number or fiber type or the size distribution of the fibers [33].

As not only fiber biopersistence but also fiber length influences the relative potency of fibers, understanding the relative potency requires a precise measurement of the type of fiber exposed and the bivariate length and diameter size distribution of the fibers.

Taking into account these factors, the chrysotile epidemiology studies are often difficult to interpret. The importance of identifying even short-term exposure to amphibole because of the differential potency of chrysotile as compared with amphibole asbestos as well as the importance of the fibers longer than 20 μm in fiber pathogenesis was not taken into account in the studies.

The epidemiology studies characterized in the review by Hodgson and Darnton [42] as predominately chrysotile exposure [43–48] have been reviewed in light of current data, and information has been learned from the toxicology studies on the importance of fiber type and fiber length in producing a pathological response in the lung and pleural cavity. Most of the studies have been shown not to be chrysotile-only studies, but to have had compounding exposures to amphibole asbestos as well as other methodological difficulties in evaluating the results [12**].

An evaluation of epidemiological studies of workers exposed to chrysotile as used in the production of high-density cement products, which provided as well differentiation as to when amphibole asbestos exposure also occurred, has shown that
chrysotile can be used safely when exposures are controlled. Studies of chrysotile as used in the production of high-density cement products are summarized in Table 1 [49–54].

Studies that have been interpreted as studies on chrysotile asbestos are, after careful review and understanding of the conditions and data presented, not representative of chrysotile exposure alone, but rather have numerous other elements as described above that were not fully taken into consideration.

CONCLUSION

The use of the common term asbestos has long obscured our understanding of the health effects of the exposure to chrysotile in comparison to amphibole asbestos such as crocidolite and amosite asbestos.

Chrysotile, the only type currently used, has been shown to have little biopersistence in the lung and to produce no pathological response in both short-term and sub-chronic inhalation toxicology studies in either the lung or pleural cavity. In contrast, similar exposures of amphibole asbestos are highly pathogenic quickly producing interstitial fibrosis with fibers translocating to the pleural cavity and initiating pathological response there as well.

Most epidemiological studies have historically not well differentiated exposure to these very different fiber families due in part to the state of industrial hygiene measurements at the time the exposures took place. When taking into consideration the importance of even short-term exposure to amphibole asbestos, the studies of chrysotile cement workers clearly demonstrate that under controlled use of chrysotile, it can be used safely.

Acknowledgements

D.M.B. has appeared as an expert witness in litigation concerned with alleged health effects of exposure to chrysotile.

Conflicts of interest

There are no conflicts of interest.

REFERENCES AND RECOMMENDED READING

Papers of particular interest, published within the annual period of review, have been highlighted as:

* of special interest
** of outstanding interest

The health risk of chrysotile asbestos

Bernstein DM


This is a comprehensive review of the toxicology and epidemiology of the relative potency of chrysotile in comparison to amphibole asbestos.