5 ALTERNATIVE FIBRES

5.1 ALTERNATIVE FIBRES

There is a wide range of alternative fibres that can readily be used to replace asbestos in the manufacturing of materials and products that currently contain asbestos[56]. These include:

- Natural organic fibres:
    - Cellulose
    - Cotton
    - Jute
- Synthetic organic fibres:
    - Aramid
    - Polyvinyl alcohol (PVA)
    - Polyamides and polyacrylonitrile
- Natural minerals:
    - Aluminium oxide
    - Carbon/graphite fibres
    - Fibrous clays
    - Steel wool
    - Wollastonite
- Man-made mineral fibres (MMMF):
    - Ceramic fibres (ceramic textile fibres and refractory ceramic fibres)
    - Glass fibre (i.e. glass wool or fibreglass, continuous glass filaments and special purpose glass fibres)
    - Kevlar
    - Mineral wool (rock wool and slag wool)
    - Silicon carbide fibres and whiskers

The following steps should be taken when identifying new or replacement uses for asbestos[57]:

- Identify the alternative/substitute product
- Compare the risks of using chrysotile asbestos against available non-asbestos alternatives/substitutes
- In comparing, consider:
    - The direct effect on human health of exposure to chrysotile asbestos compared with the non-asbestos material
    - The balance of risks, i.e. If the technical performance of the alternative/substitute is inferior to chrysotile asbestos, compared failure may result, leading to accidents and danger to human health, safety or the environment

Each case should be considered on its merits. Where, in exceptional circumstances, it is still not practicable to replace asbestos, a continuous review of new alternative fibres and substitute products should be maintained.

5.1.1 Performance Characteristics

In most instances, alternative fibres provide acceptable performance levels as compared to asbestos. However, in the case of certain very high temperature and high-pressure applications, alternative-fibre formulations may not provide acceptable sealing and/or insulation performance.

Metal, carbon and refractory ceramic fibres have a narrow range of specialist applications. Initially, the use of such alternative fibres may have led to a reduction in technical performance. However, many of these technical deficiencies have now been overcome and these alternative fibres now provide acceptable performance levels as compared to asbestos.

There are other speciality fibres, such as silicon carbide whiskers, which may be used for special, high-tech applications, for example in aircraft engines. These special-use applications have specific requirements for particular fibre characteristics and the fibres used are thus not strictly a replacement for asbestos.

5.1.2 Cost Differences

In general, alternative fibres are more expensive that asbestos. The direct cost-per-kilogram premiums vary from 50% to 1,000%. However, in many instances, material/product formulations can be varied so that the comparative cost differences at the end-user/customer level can be restricted to 10% to 50% price premiums.

5.2 THE HEALTH EFFECTS OF ALTERNATIVE FIBRES

The potential for adverse health effects related to the production and use of substitute fibres, and in particular man-made mineral fibres (MMMF), is still being studied. Based on the available information, there is evidence of biological activity, and that the effects will vary according to the different types of substitute fibres.

Because of the similarity of the chemical composition and morphology of, especially MMMF materials to those of asbestos, questions have been raised about their health implications, and in particular if these substitutes pose a carcinogenic risk.

Before considering the health effects of substitute fibres, the main determinants of toxicity should be clarified. The primary factors related to potential for toxicity due to exposure to fibres are:

- Fibre dimension
- Fibre durability and
- Dose.

According to the "Stanton hypothesis" (as determined by animal implantation studies), the carcinogenic potential of fibres is related to their dimension and durability[58]. Fibres that are long and thin (but of a respirable size) are considered to have the greatest potential for causing adverse health effects, if delivered to the lungs in sufficient concentration.

5.2.1 Fibre Dimension

The dimension of fibres dictates what is inhaled, what is deposited and which fibres will reach the target tissue. Fibres of a respirable size are those that are less than 3.0 to 3.5 μm in diameter and less than 200μm in length – according to the ILO, "a respirable fibre is a particle with a diameter of less than 3 m and with an aspect ratio of 3:1 or greater".

The greatest risk for developing adverse health effects is associated with fibres less than 0.25μm in diameter and greater than 8μm in length.

The dimensions of natural occurring fibres, such as asbestos, differ from MMMF's. Natural occurring fibres exist in a polycrystalline structure with the tendency to cleave along longitudinal planes, creating thinner fibres with higher length-to-diameter ratios that have a greater potential for toxicity[59]. MMMF's, on the other hand, are non-crystalline or amorphous and will fracture perpendicularly to their longitudinal plane into shorter fibres. This is an important difference between asbestos and man-made fibres.

The dimensions of MMMF's can be manipulated and are manufactured according to specific nominal diameters varying according to fibre type and use. Table 9 indicates that MMMF's in general have larger diameters compared to asbestos fibre[60].

TABLE 9: NOMINAL DIAMETERS OF SOME MAN-MADE MINERAL FIBRES

FIBRE TYPE	NOMINAL DIAMETER (μM)
Refractory Ceramic Fibres	1.2 - 6.0
Glass Wool	0.05 – 15.0
Mineral Wool	6.0 – 9.0

It is believed that the comparatively larger fibre diameters of MMMF's may explain the observed differences in the carcinogenic potential between man-made mineral fibres and asbestos fibres in both animal inhalation and human studies[60]. The larger (in diameter) man-made mineral fibres may be deposited in the respiratory tract and may not reach the lung tissue in the same quantities as the finer asbestos particles.

It may be concluded that the fibre dimension is an important factor in determining whether the inhaled fibres will reach the target organ/s. MMMF's may be considered as intrinsically safer than naturally occurring fibres such as asbestos, due to the fact that the fibre dimensions can be manipulated and controlled during the manufacturing process.

5.2.2 Fibre Durability

There is a collective opinion among researchers that fibres, once inhaled, must be durable and persist for a certain time in order to induce a tumour. There is, however, no precise agreement about the length of time that fibres must persist to alter cells of the bronchial walls or the pleural or peritoneal tissues.

Durability can be defined as the relative resistance of the fibre to dissolution through attack by the body's biological fluids. The durability of fibres deposited in the lung is dependant upon the lung's ability to clear the fibres, as well as the fibres' physical and chemical properties.

Processes such as dissolution, disintegration, elimination or migration through the body may affect the persistence of a fibre in the body.

Research conducted on the ability of different fibre types to dissolve, have shown that there is a direct link between how long it takes for a fibre to dissolve and the likelihood of developing health effects[61]. In general, it can be stated that fibres capable of dissolving in the human body are rendered harmless. On the other hand, fibres that don't dissolve are almost certain to cause adverse health effects, particularly if they are respirable fibres.

The durability of MMMF's (as in the case of the fibre dimension) can be manipulated in the production process according to specific end-use requirements through the addition of certain stabilisers.

It has been stated that the durability of a fibre is dependant on chemical composition. Therefore, the known chemical composition of a fibre can predict the potential with which a fibre may cause disease.

"K-Dis" is a term used to express the relative solubility of a fibre, and is expressed as a number given to a fibre according to its chemical composition[61]. A high K-Dis means that the fibre dissolves easily, and therefore the potential to cause disease is low. A low K-Dis, on the other hand, means that the fibre persists in the lung, with a subsequent high potential for causing disease.

The "ideal' K-Dis rating that can be awarded to a fibre is 100 or more. Fibres that are given a high K-Dis rating can be regarded as "healthy" or safe, as opposed to fibres witha low K-Dis rating, which would be regarded as dangerous.

To provide an example, asbestos has a low K-Dis rating and is therefore harmful if the fibres would be inhaled into the lungs.

In a study conducted by a manufacturer of fibreglass (Owens Corning), it was revealed that fibreglass produced by the company had a K-Dis rating of close to 100, according to its chemical composition. In the event that these fibres would be inhaled, the rapid dissolution will render the fibres harmless.

In general, it has been stated that durability studies indicate that glass and mineral wool fibres are less durable than ceramic fibres, which in turn, are less durable than asbestos fibres.

An in vitro durability ranking study conducted by Scholze and Conrad revealed further evidence regarding the durability of different fibres. The study expressed the fibre durability in terms of fibre life years. Excerpts from the results of the study are presented in Table 10.

TABLE 10: COMPARATIVE FIBRE DURABILITY RANKINGS

RANK	MATERIAL	MEDIAN DIAMETER (µM)	DISSOLUTION VELOCITY (NM/DAY)	FIBRE LIFE (YEARS)
1	**Glass wool, TEL**	3.5	3.45	0.4
2	**Glass wool, Superfine**	0.38	1.4	1.0
3	**Slag wool**	4.8	0.69	2.0
4	**Refractory, Fibrefrax**	1.85	0.27	5.0
5	**Chrysotile Asbestos**	0.074	0.005	Approx. 100
6	**Crocidolite Asbestos**	0.17	0.011	Approx. 110

The results of this durability study revealed the differences between man-made and natural fibres. From the above it may be estimated that man-made mineral fibres will dissolve in less than 10 years, compared to natural fibres, such as chrysotile and crocidolite, which may require approximately 100 years or longer to dissolve.

Asbestos fibres have substantially higher residence times in the lungs and, therefore, display a higher potential for causing disease, when compared with man-made fibres.

Because of the differing chemical composition and fibre dimensions of man-made fibre, the potential toxicity is expected to vary, and has to be evaluated on a fibre-type-by-fibre-type basis.

5.2.3 Dose

The extent of physiological response is related to the dose. According to Singh and Coffman, dose is perhaps the most important factor in explaining the observed differences in the carcinogenic potency of asbestos and MMMF's[60].

It was further stated that exposures of workers in man-made mineral fibre industries to airborne fibres are generally lower than exposures in similar processes where asbestos is involved. This may be ascribed to the larger fibre diameters of man-made mineral fibres compared to asbestos.

Unlike asbestos fibres, man-made mineral fibres do not split longitudinally into fibres of small diameter, but tend to break transversely into shorter and thicker segments than asbestos fibres. The result is that the inhaled coarser man-made mineral fibres may not always reach the target tissue to cause comparable damage.

In summary, when considering the primary factors related to potential for toxicity, man-made mineral fibres are thought to have less potential than natural occurring fibrous silicates (i.e. asbestos) for producing adverse health effects, due to the following reasons:

- The non-crystalline state of man-made mineral fibres and the tendency to fracture into shorter fibres and
- Man-made mineral fibres, once inhaled, are generally less durable to attack from the body's biological fluids

5.3 SUMMARY AND CONCLUSIONS

The available information suggests that there are many alternative fibres that could be used as replacements for asbestos fibres in most existing asbestos-containing materials. In addition, there are also substitute products that could be used instead of asbestos-containing products for a number of applications where these products are currently being used.

However, it would also appear as if there are still some asbestos-containing materials and products where replacement may not be possible (or wise), based on the inability of alternatives and substitutes to meet the functional performance requirements and safety standards stipulated by either customers or regulations.

Also, it would appear as if there might be significant cost differences between asbestos and the replacement fibres and products.

With regard to occupational health and safety requirements, there appear to be differing views with regard to the safety of some of the alternative fibres (and even some of the substitute products).

In considering these alternative fibres, the following questions need to be addressed:

- What is the application for which an asbestos-containing product is being used – what is the core functional need that is being satisfied (i.e. insulation, friction-control, sealing, reinforcement, etc.)?
- Is it technologically feasible to replace asbestos with an alternative fibre, does an alternative fibre and/or substitute product exist? And will the alternative/substitute provide an acceptable level of functional performance that satisfactorily addresses the core need?
- Is it economically viable to replace asbestos with an alternative fibre; is the cost of the alternative/substitute acceptable? Can an adequate profit be made? Will the customer be willing to pay the price?

- Is the alternative fibre or substitute product safe – what are the occupational health implications for workers handling these substances/products? And what is the impact on the broader environment and, therefore, other community stakeholders?

The answers to these questions will have a direct bearing on any decision to replace asbestos with an alternative fibre.