Gezondheidsraad **Voorzitter**
Health Council of the Netherlands

Aan de Staatssecretaris van Sociale Zaken en Werkgelegenheid

Onderwerp : Aanbieding adviezen herevaluatie bestuurlijke MAC-waarden
Uw kenmerk : ARBO/AMIL/97/00648
Ons kenmerk : U 2706/CB/MP/563-O3
Bijlagen : 18
Datum : 14 december 2000

Mijnheer de staatssecretaris,

Op verzoek van uw ambtsvoorganger bied ik u hierbij de eerste adviezen aan van een reeks over de gezondheidskundige basis van uit het buitenland overgenomen grenswaarden voor beroepsmatige blootstelling aan stoffen. Het verzoek om deze adviezen is in algemene zin vervat in brief nr ARBO/AMIL/97/00648 en in latere stadia door uw departement toegespitst op afzonderlijke stoffen. De adviezen zijn opgesteld door een daartoe door mij geformeerde internationale commissie van de Gezondheidsraad en beoordeeld door de Beraadsgroep Gezondheid en Omgeving.

De beoogde reeks van in het Engels gestelde adviezen zal losbladig worden gepubliceerd onder ons publicatienummer 2000/15OSH en, conform de aan de Gezondheidsraad voorgelegde toespitsingen van de adviesaanvraag, betrekking hebben op 168 stoffen. Het u thans aangeboden eerste pakket bestaat uit een Algemene Inleiding (publicatienummer 2000/15OSH/000) en uit de adviezen genummerd 2000/15OSH/001 tot en met 2000/15OSH/017, respectievelijk betrekking hebbend op:
cesiumhydroxide, cyclopentaan, diboraan, dimethoxymethaan, dipropylketon, fenylfosfine, germaniumtetrahydride, hexachloornaftaleen, methaanthiol, methylcyclohexanol, methylisopropylketon, mica, natriumhydroxide, octachloornaftaleen, silaan, tetrachloornaftaleen, en yttrium en yttriumverbindingen.

Bij afronding van de werkzaamheden van de hierboven bedoelde commissie ontvangt u een Nederlandstalige samenvatting van de in de gehele reeks van adviezen neergelegde bevindingen.

Bezoekadres
Parnassusplein 5
2511 VX Den Haag
Telefoon (070) 340 75 20
email: GR@gr.nl

Postadres
Postbus 16052
2500 BB Den Haag
Telefax (070) 340 75 23

Gezondheidsraad
Health Council of the Netherlands

Onderwerp : Herevaluatie uit het buitenland overgenomen grenswaarden
Ons kenmerk : U
Pagina : 2
Datum : 14 december 2000

De u thans aangeboden adviezen heb ik vandaag ter informatie doen toekomen aan de Minister van Volksgezondheid, Welzijn en Sport en aan de Minister van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer.

Hoogachtend,

prof. dr JJ Sixma

Bezoekadres
Parnassusplein 5
2511 VX Den Haag
Telefoon (070) 340 75 20
email: GR@gr.nl

Postadres
Postbus 16052
2500 BB Den Haag
Telefax (070) 340 75 23

Mica

(CAS Reg. nr: 12001-26-2)

Health-based Reassessment of Administrative Occupational Exposure Limits

Committee on Updating of Occupational Exposure Limits,
a committee of the Health Council of the Netherlands

No. 1999/15OSH/011, The Hague, 14 December 2000

Preferred citation:
Health Council of the Netherlands: Committee on Updating of Occupational Exposure Limits. Mica; Health-based Reassessment of Administrative Occupational Exposure Limits. The Hague: Health Council of the Netherlands, 2000; 2000/15OSH/011.

1 Introduction

The present document contains the assessment of the health hazard of mica by the Committee on Updating of Occupational Exposure Limits, a committee of the Health Council of the Netherlands. The first draft of this document was prepared by C de Heer, Ph.D., S Bosman-Hoefakker, Ph.D. and H Stouten, M.Sc. (TNO Nutrition and Food Research Institute, Zeist, the Netherlands).

The evaluation of the toxicity of mica has been based on the review by the American Conference of Governmental Industrial Hygienists (ACG91). Where relevant, the original publications were reviewed and evaluated as will be indicated in the text. In addition, literature was retrieved from the online data bases Medline, Cancerlit, Toxline, and Chemical Abstracts.* The final literature search has been carried out in June 1998.

In February 1999, the President of the Health Council released a draft of the document for public review. The committee received no comments.

2 Identity

name	:	mica
synonyms	:	muscovite
molecular formula	:	-
structural formula	:	$K_2Al_4(Al_2Si_6O_{20})(OH,F)_4$ (muscovite)
		$K_2(Mg, Fe^{+2})_6(Al_2Si_6O_{20})(OH,F)_4$ (phlogopite)
		$K_2(Mg, Fe^{+2})_{6-4}(Fe^{+3},Al,Ti)_{0-2}(Al_{2-3}Si_{6-5})O_{0-2}(OH,F)_{4-2}$ (biotite)
CAS reg nr	:	12001-26-2

Data from ACG91, Lus80, NLM98.

* In a first search, Medline (covering the period 1988 to 6 March 1997 (19970306/UP)) was searched with "(mica AND CI/CT) OR 12001-26-2". In a second MEDLINE search (covering the period 1966 to 18 June 1998 (19980618/UP), the search profile was "(mica OR 12001-26-2 OR vermiculit* OR phyllosilicate#) AND (AE OR PO OR TO)/CT AND (EN OR DE OR FR OR NL)/LA". Cancerlit covering the period 1988 to 5 March 1997 was searched with "12001-26-2 OR mica". In a first Toxline search (covering the period 1988 to 21 February 1997 (970221/ED)) the search profile was "12001-26-2 OR mica". In a second search, Toxline (covering the period 1965 to 24 February 1998 (19980224/ED)) was searched with "(mica OR 12001-26-2 OR vermiculit* OR phyllosilicate#) AND (RISKLINE OR NTIS OR CIS OR EMIC OR ETIC OR TSCATS)/FS" and "(mica OR 12001-26-2 OR vermiculit* OR phyllosilicate#) NOT (IPA OR BIOSIS OR TOXBIB)/FS". Chemical Abstracts covering the period 1967 to 23 June 1998 (980623/ED; vol 128, iss 26) was searched with "(mica and (4 OR 59-5)/SC) OR (mica AND 59/SC (AND lung# OR pneumo* OR respir*))" and "mica AND 59/SC", and "(mica AND vermiculite#) AND ADV/RL". HSDB and RTECS, databases available from CD-ROM, were consulted as well (NIO98, NLM98).

3 Physical and chemical properties

molecular weight	:	797 (muscovite)
boiling point	:	-
melting point	:	-
flash point	:	-
vapour pressure	:	-
solubility in water	:	insoluble
log $P_{oct/water}$	:	-
conversion factors (20^{o}C, 101.3 kPa)	:	-

Data from ACG91, NLM98.

Mica is a colourless, odourless, non-flammable, non-fibrous, water-insoluble silicate of aluminium occurring in plate form, containing less than 1% quartz; it includes nine different species. Muscovite and phlogopite are the major micas of commerce. The former is a hydrated aluminium potassium silicate, often called white mica, whereas the latter is an aluminium potassium magnesium silicate, sometimes called amber mica. Other forms include biotite, paragonite, lepidolite, zimmwaldite, and roscoelite (ACG91, Fei89, Fel90, Sku85).

4 Uses

Mica was previously used as a filler in pharmaceuticals and for decoration purposes. Ground mica is now used as a filler in paints, wallpaper, cement, and asphalt and as insulation material in electric cables. The transparency and high resistance to heat and electricity of mica make it useful for windows in stoves and furnaces. It is also applied as a component of drilling muds in the oil industry. Sheet mica is used in the electrical industry in vacuum tubes and condensators (Fei89, Sku85).

Furthermore, mica is used as a dusting powder to facilitate the release of latex gloves and condoms from their mould during the manufacturing process. It also facilitates the processing and donning of these products.
Mica-containing dusting powders are also used on contraceptive diaphragms, sanitary napkins, and in toiletries (Kan92).

5 Biotransformation and kinetics

Dust samples (50 mg) of different particle size of muscovite were intratracheally instilled in rats. The amount of mica that retained in the lungs or penetrated into the lymph nodes after 7 months, was dependent on the dust particle size; the finer the dust, the smaller the dust mass retained in the lung (Ros90).

Extraction of mineral particles from 7 different regions of the bronchial tree and four regions of lung supplied by these airways from 11 human adult autopsy lungs (right lobe, morphologically normal tissues), revealed an increase in mica, expressed as a percentage of all particles, with decreasing airway diameter (r = -0.27, $p<0.03$). Furthermore, the relative amount of mica was found to be higher in lung parenchyma than in the airways (Chu90).

6 Effects and mechanism of action

Human data

Inhalation exposure of workers to mica powder may cause irritation of the respiratory tract (NLM98).

There have been many reports of disease related to the inhalation of mica, especially muscovite. In most of these reports, however, exposure to other substances, especially silica and/or asbestos, has been involved so that a definite relationship between pure mica inhalation and disease has not been well established. Pleural calcifications and thickening, for example, have never been shown to occur in mica exposure without asbestos inhalation (Fei89). Moreover, the significance of pleural thickening, as was reported in persons exposed to mica for long periods, is unclear (Cul90).

Hepatic and pulmonary granulomas were observed in a worker exposed to muscovite dust for 7 years. Diffuse thickening of interalveolar septa due to formation of reticulin and collagen fibers and proliferation of fibroblasts and histiocytes were seen. In the liver, focal or diffuse swelling of sinusoidal lining cells, sarcoid-type granulomas, and perisinusoidal and portal tract fibrosis were observed (Pim78) case-report describes a worker who had developed progressive massive fibrosis in his lungs after a nine-year exposure to mica dust (concentrations not indicated) (Bab95). A 65-year-old man, who had experienced extensive exposure to mica while working in the rubber industry

for 40 years, developed severe interstitial pulmonary fibrosis. Pulmonary function testing revealed restrictive lung function (reduced total lung capacity and diffusing capacity of carbon monoxide). Bronchoalveolar lavage revealed 20% neutrophils in the lavage fluid. Elemental and crystallographic analysis indicated that mica was present in the alveoli and lung parenchyma, suggesting a causative role for mica (Lan91).

The radiographic findings in patients with significant mica exposure consist of fine nodules that are diffuse or appear in both lower pulmonary fields. Reticular interstitial infiltration, again favouring the lower pulmonary fields, may also occur. Lymph node enlargement probably will not occur unless silica has also been inhaled. It is not clear whether mica is a causative agent for fibrosis or pulmonary destruction (Fei89).

After several years of exposure, nodular fibrotic pneumoconiosis may occur after exposure to pure mica dust (Dav83, NLM98). In mica grinders, symptoms of pneumoconiosis appeared between the 10th and 19th year of exposure (Lus80). A case of mild interstitial fibrosis has been described in a young woman exposed to pure mica dust through her husband's occupation (Lap82).

Eight out of 57 workers exposed to dust associated with mica-scrap grinding developed pneumoconiosis. Three workers had been exposed to levels of 18 mineral particles per cubic foot (mppcf)* for 18-26 years, 3 workers to 40 mppcf for 10-23 years, and 2 workers to 50 mppcf for 24-26 years. Five out of 6 men exposed to more than 25 mppcf during more than 10 years showed evidence of pneumoconiosis. No pneumoconiosis was seen in 5 workers exposed to less than 10 mppcf. Only 1 out of 6 workers exposed to mica dust for more than 10 years at concentrations in excess of 25 mppf failed to show evidence of pneumoconiosis. Although the signs and symptoms in these cases resembled those of silicosis, the X-ray pattern of the lung field markings differed somewhat, and tuberculosis was not a complication in any of the mica patients. No cases were found among workers exposed to mica dust in concentrations averaging 3 mppcf or less (study from 1940, cited in ACG91, Lus80). Indian workers occupationally exposed to 20 mppcf mica (3 mg/m^3) for 18 years showed mild evidence of pneumoconiosis as documented by the results of chest X-rays (Hei53).

Twelve workers exposed to mica during mining and processing of slate (containing 38-40% muscovite) had developed pneumoconiosis. X-ray diffraction analysis demonstrated that the majority of the mineral particulates

---

* In 1979 ACGIH adopted a method to convert million particles per cubic foot to a mass limit of milligrams per cubic meter. A good approximation is 6.37 particles per cubic foot as being equal to 1 milligram per cubic meter (Lus80)

present in lungs of these workers were crystalline quartz and muscovite (Cra92). In another study, 17 cases of ‘talc pneumoconiosis’ were examined pathologically and mineralogically to ascertain whether a true talc pneumoconiosis existed. In several cases, significant quantities of mica and kaolin were found within lung tissues in addition to talc (Gib92).

Several studies were performed in workers involved in the mica processing industry in India (Gan93, Gan94a, Gan94b). In the first study, significantly increased respiratory ailments and restrictive and obstructive impairments of lung function were observed in 119 female workers, when compared to 43 unexposed female controls. Exposure levels ranged from 0.9 to 36.4 mppcf (<0.76-1.98 mg/m^3, >96% of respirable particle size, silica content up to 3%), and showed variation between seasons and the type of process. Occupational exposure to mica dusts had occurred for <5 to 15 years. Complaints on cough and breathlessness were significantly more reported in exposed workers. Radiological examination of the chest revealed one case of pneumoconiosis, and two cases of pleural thickening (Gan93). In the second study, 463 male mica processing workers and 123 male controls were studied. The mean mica dust concentrations in different processes ranged from 1.12 to 2.29 mppcf (>90% of respirable particle size, silica content up to 3.7%), whereas the mean duration of exposure ranged from approximately 9 to 16 years. The subjective complaints significantly increased in exposed workers were cough, expectorations, pain in the chest, and low back pain. Also, clubbing and abnormal breath sounds (including crepitations) were observed in a significantly larger proportion of the exposed group. Pulmonary function tests indicated that restrictive, obstructive, as well as mixed-type impairments were significantly increased in exposed workers. Radiological examination of the chest revealed pneumoconiosis and pleural thickening in 5.26 and 4.09% of the exposed workers, respectively (Gan94a). In the third study including 162 exposed male and female mica processing workers and 152 unexposed controls, mean dust concentrations ranged from 8.65 to 228.26 mppcf (1.14 to 79.37 mg/m^3, >90% of respirable particle size, silica content up to 1.49%), whereas the mean duration of exposure ranged from approximately 3 to 10 years. Results were comparable to the earlier studies (Gan94b).

Analysis of 41 lung tissue samples comprising 22 non-cancer silicotics, 9 silicotics with lung cancer, and 10 accidental deaths without lung fibrosis at autopsy (control group), showed significantly higher lung dust concentrations and larger particle diameters of silica, feldspar, clay, and mica in the pooled silicotic group, when compared to the control group. The non-lung cancer

group displayed higher, although not significantly, geometric mean concentrations of total particles when compared to the lung cancer group ($0.6x10^6$ versus $0.4x10^6$) (Loo95).

Epidemiologic surveys of mica workers have largely supported a role for mica in causing pneumoconiosis. In a survey of muscovite and biotite workers in North Carolina, 10 out of 57 workers involved in the grinding of quartz-free mica had chest radiographs consistent with pneumoconiosis. Symptoms of cough and dyspnea were related to the severity of lung involvement as determined by chest radiography (NLM98). In another chest radiographic survey of mica miners and workers, it was found that 11.4% of those exposed to pure mica had pneumoconiosis (NLM98).

From a literature review comprising 368 cases of pneumoconiosis associated with mica exposure, it was concluded that only 66 cases could definitely or probably be attributed to mica exposure. Of these 66 cases, only 26 were caused by exposure to mica alone. Pure exposures had mainly occurred in the packing and grinding of mica. In 6 of the cases, the diagnosis was based on clinical examination, radiography, and lung biopsy or autopsy results. Information on the length of the exposure period and the level of exposure was provided in 28 cases, of which 16 cases had an exposure time exceeding 20 years (Sku85).

In a study on 4772 British coalminers and ex-miners, the incidence of progressive massive fibrosis was clearly associated with average concentrations of quartz and of kaolin plus mica in respirable dust (Mac89).

There has been no cohort or other epidemiological survey of respiratory cancer in mica exposure, although a single case of a peritoneal mesothelioma in a mica worker has been reported (Cha82). Mica has been observed along with other minerals in the lung tissue in cases of lung cancer (Sku85).

Animal data

Three studies in which experimental animals were exposed to mica by inhalation were summarized by Skulberg *et al* (1985). In the first study, lung pathology and mineral dust content were examined in environmentally exposed mammals and birds in a zoo. Fifteen percent of the animals had mild fibrosis, while 5% had severe fibrosis at autopsy. Mineral analysis revealed a mica content of 70% and quartz content of 5-10%. In the second study, combined exposure of guinea pigs to tubercle bacilli and mica dust was investigated. Increased morbidity was observed among animals exposed to both. In the third

inhalation study, rats exposed to an atmosphere heavily charged with muscovite for 3 to 15 days, developed pulmonary granulomas (Sku85). No inhalation studies under controlled laboratory conditions have been performed with mica.

Pulmonary fibrotic lesions and many cholesterol cleft like structures were observed at 210 days after intratracheal injection of 5 mg of mica dust in mice. The lymph nodes showed marked density of mica in the cortico-medullary zone and medullary cords where swollen macrophages were fully packed with mica (Sah90).

Intratracheal administration of 10 mg mica in 1 ml saline to female Wistar rats caused a 3-fold increase in the number of alveolar macrophages in broncho-alveolar lavage (BAL) fluid by day 8. However, the percentage of macrophages in BAL fluid was decreased, and the isolated macrophages displayed reduced phagocytic and metabolic activity, and adherence to glass (Dix90). In another rat study, using a similar experimental protocol, biochemical markers of BAL fluid were examined. On day 8, elevated levels of proteins, sialic acid, and phospholipids, and increased activity of lactate dehydrogenase were observed. β-glucuronidase activity was not affected by mica exposure (Baj92).

In rats, 25 mg of mica dust by intratracheal injection produced small compactly arranged fibrotic lesions in lung parenchyma at 330 days, and lymph nodes were markedly increased in size with fibrosis in the medullary region (Sah85, Sah90). Dust samples (50 mg) of different particle size of muscovite all caused fibrogenic reactions 7 months after intratracheal instillation in rats. The greatest reaction was observed after instillation of the finest dust fraction. The dust masses that were retained in the lungs or penetrated into the lymph nodes were depended on the dust particle size; the finer the dust, the smaller the dust mass retained in the lung. After instillation of muscovite, the hydroxyproline content in the lungs increased with the increasing coefficient of permeability, and the total lipids consent in the lungs correlated with the surface tension of the tested dust suspensions (Ros90). Pulmonary responses to mica samples of respirable size were evaluated in a rat model system over a period of 360 days after intratracheal injection of 50 mg mica in 1.5 ml saline per animal. Two mica Indian mine samples and one factory sample induced an initial mild pulmonary reaction (cellular infiltration, oedema). At later time points, varying sized granulomatous foci developed in the parenchyma, and after 360 days a cellular reaction, comprised of predominantly mononuclear

cells, was still present. The factory sample induced a characteristic abscess formation at 180-360 days (Gar87).

In Guinea pigs, 75 mg of mica dust after intratracheal injection provoked fibrotic lesions with thick reticulin fibres in the lymph nodes at 365 days. It was concluded that the poor fibrogenic response of mica dust may not produce severe adverse effects at an early stage, but that prolonged inhalation may interact with the exposure to other environmental chemicals and/or complicate infections (Sah90).

Several other animal studies using intratracheal instillation of mica in various species were summarized by Skulberg *et al*. (Sku85). These studies did not provide additional information. The results from intratracheal instillation studies do not give an unanimous conclusion as to whether pure mica is fibrogenic or not.

Ninety days after intraperitoneal injection of 5 mg of mica dust in mice, thick dense reticulination together with excessive lymphoid hyperplasia in omental tissue was observed. In draining lymph nodes, slight reticulinosis was seen in the medullary region corresponding to deposition of particles (Sah90). Seven days after intraperitoneal administration of 0.1 and 0.5 g mica in saline to female Wistar rats, severe adhesions were observed in all animals. No adhesions were seen in rats exposed to 0.02 g mica. Deposits of powder were found in all treatment groups, whereas ascites was not observed after mica exposure (Kan92). Guinea pigs, once administered 2 ml of a 5% suspension of mica dust in saline by intraperitoneal injection, showed nodules on the anterior abdominal walls. These nodules became flattened with irregular edges as the interval between injection and gross examination increased from 14 to 90 days (ACG91). In rats, direct intraperitoneal injection of biotite or haematite dust suspended in saline solution did not produce tumours, in contrast to injection of several fibrous dusts (Lus80).

Male and female Fischer 344 rats were fed diets containing 0, 1.0, 2.0, or 5.0% titanium dioxide (TiO_2) coated mica (mica content of the test substance 72%) for up to 130 weeks. This dosage regimen resulted in exposure levels of 0.43, 0.86, and 2.16 mg mica/kg bw/day, respectively (based on average food consumption of 60 g/kg bw/day). In this study, no consistent or biologically important changes in survival, body weight gains, haematologic or clinical chemistry parameters, or histopathology were observed. There was no evidence that TiO_2-coated mica produced either toxicologic or carcinogenic effects at dietary concentrations as high as 5.0% (Ber90).

Mica dusts (0.25-5 mg/ml, particle size <5 µm) were tested *in vitro* for induction of haemolysis of sheep erythrocytes, for enzyme release by rat alveolar macrophages (release of lactic dehydrogenase (LDH), β-glucuronidase and β-N-acetyl-glucosaminidase), and for induction of reactive oxygen metabolites in human polymorphonuclear leukocytes. The mica dust samples tested, viz., phlogopite and muscovite, are physically comparable but displayed marked differences in cytotoxicity. Phlogopite induced marked haemolysis, LDH release, and reactive oxygen species, whereas muscovite induced these phenomena to a much lower extent (Hol90). Mica dust haemolysis was inhibited by the antisilicotic compound polyvinylpyridine N-oxide. Human lymphocytes were more sensitive to mica dust as compared to sheep cells. Less than half of the amount of dust was needed to haemolyse the same volume of erythrocyte suspension of human than that of sheep (Kaw73). Other studies indicated that the haemolytic effect of mica may be qualitatively related to the rate of dissolution of silica from mica dust (Nar77).

The *in vitro* concentration of mica (biotite, phlogopite, and muscovite) causing 50% cell death (CD_{50}) in Chinese hamster V79 cells was higher than 100 µg/ml (Pig83). In Rhesus monkey kidney cell monolayers, the production of interferon by influenza virus was inhibited by mica (muscovite) (Jau90).

No data on mutagenicity, genotoxicity and reproduction toxicity of mica have been found.

7 Existing guidelines

The current administrative occupational exposure limit (MAC) for mica in the Netherlands is set at 5 mg/m^3, 8 h TWA for total dust, and 2.5 mg/m^3, 8 h TWA for respirable dust.

Existing occupational exposure limits for mica in some European countries and in the USA are summarized in the annex.

8 Assessment of health hazard

Exposure to mica powder may cause irritation of the respiratory tract. There are neither data available on irritating effects of mica to skin and eyes, nor on sensitization.

There are many reports of disease in humans related to the inhalation of mica, especially muscovite. Contamination of mica dust with other minerals is

very common, particularly during mining. Therefore, in most reports exposure to other substances, especially silica or asbestos or both, has been involved so that a definite relationship between pure mica inhalation and disease has not been well established. Pleural calcifications and thickening, for example, have never been shown to occur in mica exposure without asbestos inhalation.

In the epidemiologic studies on workers in the mica processing industry in India cases of pneumoconiosis are ascribed to relatively pure exposures to mica (Gan93, 94a/b). Also significantly increased respiratory ailments and restrictive and obstructive impairments of lung function were observed. However, comparison of these studies showed conflicting results regarding effects on the lungs and exposure. An inhalation dose-response relationship could not be established. Interference from confounding factors could not be excluded. Therefore, the committee considered these studies not suitable as a basis for an health-based occupational exposure limit.

No controlled inhalation studies have been performed in laboratory animals.

The present epidemiological and toxicological evidence indicates that the cytotoxic and fibrogenic potential of mineralogically pure mica is low.

Data on mutagenicity, genotoxicity and reproduction toxicity of mica are not available. Epidemiological studies do not indicate carcinogenic effects of mica.

The committee concludes that the data base is too poor to justify recommendation of a health-based occupational exposure limit for mica

Considering the data from the mica-processing workers, the committee concludes that the current MAC value of 2.5 mg/m^3, 8 h TWA as respirable dust, may be too high.

As a warning it is noted that mica is often contaminated with quartz and/or asbestos.

References

ACG91 American Conference of Governmental Industrial Hygienists (ACGIH). Documentation of the threshold limit values and biological exposure indices. 6th ed. Cincinnati OH, USA; ACGIH, 199: 1047-8.

ACG00 American Conference of Governmental Industrial Hygienists (ACGIH). 2000 TLVs® and BEIs®. Threshold Limit Values for chemical substances and physical agents. Biological Exposure Indices. Cincinnati OH, USA: ACGIH, 2000.

Arb96 Arbejdstilsynet. Grænseværdier for stoffer og materialer. Copenhagen, Danmark: Arbejdstilsynet, 1996 (At-anvisning nr 3.1.0.2).

Bab95 Baban NK, Dralle WM, Roy TM. Accelerated progressive massive fibrosis and mica dust. J Tennessee Med Assoc 1995; 88: 430-2.

Baj92 Bajpai R, Waseem M, Gupta GSD, *et al*. Ranking toxicity of industrial dusts by bronchoalveolar lavage fluid analysis. Toxicology 1992; 73: 161-7.

Ber90 Bernard BK, Osheroff MR, Hofmann A, *et al*. Toxicology and carcinogenesis studies of dietary titanium dioxide-coated mica in male and female Fischer 344 rats. J Toxicol Environ Health 1990; 29: 417-29.

Cha82 Chahinian AP, Pajak TF, Holland JF, *et al*. Diffuse malignant mesothelioma. Prospective evaluation of 69 patients. Ann Intern Med 1982; 96: 746-55.

Chu90 Churg A, Wright JL, Stevens B. Exogenous mineral particles in the human bronchial mucosa and lung parenchyma. I. Nonsmokers in the general population. Exp Lung Res 1990; 16: 159-75.

Cra92 Craighead JE, Emerson RJ, Stanley DE. Slateworker's pneumoconiosis. Hum Pathol 1992; 23: 1098-105.

Cul90 Cullinan P, McDonald JC. Respiratory disease from occupational exposure to non-fibrous phyllosilicates. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 161-78 (NATO ASI Series Vol G21).

Dav83 Davies D, Cotton R. Mica pneumoconiosis. Br J Ind Med 1983; 40: 22-7.

DFG99 Deutsche Forschungsgemeinschaft (DFG): Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe. MAK- und BAT-Werte-Liste 1999. Maximale Arbeitsplatzkonzentrationen und biologische Arbeitsstofftoleranzwerte. Weinheim, FRG: VCH Verlagsgesellschaft mbH, 1999; Mitteilung 35.

Dix90 Dixit R, Khanna AK, Waseem M, *et al*. Alterations in in vitro functional activities of alveolar macrophages exposed in vivo to mineral dusts. Vet Hum Toxicol 1990; 32: 517-20.

Fei89 Feigin DS. Misconceptions regarding the pathogenicity of silicas and silicates. J Thorac Imaging 1989; 4: 68-80.

Fel90 Felius RO. The mineralogy of phyllosilicates. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 3-14 (NATO ASI Series Vol G21).

Gan93 Gangopadhyay PK, Majumder PK, Bhattacharya SK, *et al*. The health status of mica processing industrial female workers. Indian J Ind Med 1993; 39: 1-8.

Gan94a Gangopadhyay PK, Bhattacharyya SK, Mazumdar PK, *et al*. Occupational health problems of mica processing male workers. Indian J Ind Med 1994; 40: 8-19.

Gan94b Gangopadhyay PK, Majumder PK, Bhattacharya SK, *et al*. Highly dusty mica processings and occupational health problems. Indian J Ind Med 1994; 40: 124-34.

Gar87 Garg AN, Wankhade HK, Dogra RKS, *et al*. Neutron activation analysis of respirable mica samples and their pathological effects in lungs of rats. Sci Total Environ 1987; 67: 165-76.

Gib92 Gibbs AA, Pooly FD, Griffiths DM *et al*. Talc pneumoconiosis: a pathologic and mineralogic study. Hum Pathol 1992; 23: 1344-54.

Hei53 Heimann H, Moskowitz S, Harihara CR *et al*. Note on mica dust inhalation. Arch Ind Hyg Occup Med 1953; 8: 531-2.

Hol90 Holopainen M, Vallyathan V, Hedenborg M, *et al*. Toxicity of phlogopite and muscovite in vitro. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 349-60 (NATO ASI Series Vol G21).

HSE99 Health and Safety Executive (HSE). EH40/99 Occupational Exposure Limits 1999. Sudbury (Suffolk), England: HSE Books, 1999.

Jau90 Jaurand MC, Pairon JC. Review on short-term tests used for the toxicological evaluation of phyllosilicates. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 331-47 (NATO ASI Series Vol G21).

Kan92 Kang N, Griffin D, Ellis H. The pathological effects of glove and condom dusting powders. J Appl Toxicol 1992; 12: 443-9.

Kaw73 Kaw JL, Gupta GSD, Narang S, *et al*. Hemolytic activity of mica dust and its relation to polyvinylpyridine N-oxide. Exp Pathol 1973; 8: 349-53.

Lan91 Landas SK, Schwartz DA. Mica-associated pulmonary interstitial fibrosis: case report. Am Rev Respir Dis 1991; 144: 718-21.

Lap82 Lapenas DJ, Davis GS, Gale PN, *et al*. Mineral dusts as etiologic agents in pulmonary fibrosis: The diagnostic role of analytical scanning electron microscopy. Am J Clin Pathol 1982; 78: 701-6.

Loo95 Loosereewanich P, Ritchie AC, Armstrong B *et al*. Pulmonary dust retention in silicotics with and without lung cancer. Appl Occup Environ Hyg 1995; 10: 1104-6.

Lus80 Lusis I. Review of the health effects of micas. US Environmental Protection Agency, Office of Pesticides and toxic substances, EPA-560/3-80-001, EPA publ no PB81-176778, 1980: 513-54. (Proceedings of the national workshop on substitutes for asbestos, Arlington VA, July 14-16, 1980).

Mac89 Maclaren WM, Hurley JF, Collins HPR, *et al*. Factors associated with the development of progressive massive fibrosis in British coalminers: a case-control study. Br J Ind Med 1989; 46: 597-607.

Nar77 Narang S, Rahman Q, Kaw JL, *et al*. Dissolution of silicic acid from dusts of kaolin, mica and talc and its relation to their hemolytic activity - an in vitro study. Exp Pathol 1977; 13: 346-9.

NBO96 National Board of Occupational Safety and Health. Occupational exposure limit values. Solna, Sweden: NBOSH, 1996; Ordinance AFS1996/2.

NIO98 National Institute of Occupational Safety and Health (NIOSH). Registry of Toxic Effects of Chemical Substances (RTECS) [CD-ROM, issue April 1998. SilverPlatter International, 1998 (last update mica file: December 1997).

NLM98 US National Library of Medicine (NLM). Hazardous Substances Data Bank, (HSDB) [CD-ROM], issue April 1998. SilverPlatter International, 1998 (last update mica file: February 1998).

Pig83 Pigott GH, Pinto PJ. Effects of nonfibrous minerals in the V79-4 cytotoxicity test. Environ Health Perspect 1983; 51: 173-9.

Pim78 Pimentel JC, Menezes AP. Pulmonary and hepatic granulomatous disorders due to the inhalation of cement and mica dusts. Thorax 1978; 33: 219-27.

Ros90 Rosmanith J, Hilscher W, Schyma SB. The effect of the surface quality on the fibrogenicity of the phyllosilicates muscovite and kaolinite. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 123-8 (NATO ASI Series Vol G21).

Sah85 Sahu AP, Singh KP, Shukla LJ, *et al*. Choline and mica dust induced pulmonary lesions in rats. Ind Health 1985; 23: 135-44.

Sah90 Sahu AP. Biological effects of mica dust in experimental animals. In: Bignon J, ed. Health related effects of phyllosilicates. Berlin, Germany: Springer Verlag, 1990: 387-93 (NATO ASI Series Vol G21).

Sku85 Skulberg KR, Gylseth B, Skaug V *et al*. Mica pneumoconiosis-A literature review. Scand J Work Environ Health 1985; 11: 65-74.

SZW00 Ministerie van Sociale Zaken en Werkgelegenheid (SZW). Nationale MAC-lijst 2000. The Hague, The Netherlands: Servicecentrum Sdu Uitgevers, 2000.

TRG00 TRGS 900: Grenzwerte in der Luft am Arbeitsplatz; Technische Regeln für Gefahrstoffe. B Arb Bl 2000; 2.

Annex

Occupational exposure standards for mica in various countries.

country -organisation	occupational exposure limit		time-weighted average	type of exposure limit	note[a]	lit ref[b]
	ppm	mg/m^3				
The Netherlands						
-Ministry	-	5[c]	8 h	administrative		SZW00
	-	2.5[d]	8 h			
Germany						
-AGS	-	-				TRG00
-DFG MAK-Kom.	-	-				DFG99
Great-Britain						
-HSE	-	10[c]	8 h	OES		HSE99
		0.8[d]	8 h	OES		
Sweden	-	-				NBO96
Denmark	-	-				Arb96
USA						
-ACGIH	-	3[d,e]	8 h	TLV		ACG00
-OSHA	-	3[d,e]	8 h	PEL		
-NIOSH	-	3	15 min	REL		
European Union						
-SCOEL						

[a] S = skin notation; which mean that skin absorption may contribute considerably to body burden
sens = substance can cause sensitisation

[b] Reference to the most recent official publication of occupational exposure limits

[c] Total inhalable dust

[d] Respirable dust

[e] Particulate matter containing <1% crystalline silica