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TALC / ASBESTOS EDUCATION DOCUMENT (version 1)

- Confidential -

November 2007
[For internal distribution only]

KEY MESSAGES

To be classified under the term "asbestos", a mineral has to have a specific chemical composition and specific asbestiform morphology. Consequently, asbestos minerals are always asbestiform but asbestiform minerals are not necessarily asbestos.
The grinding of a non-asbestiform mineral will never produce an asbestos fibre.
Talc can occur in a fibrous habit but asbestiform talc does not exist.

INTRODUCTION

A number of publications, media reports and rumours have linked talc with asbestos. This association stems from confusion surrounding the morphological features and chemical composition of asbestos and other minerals, including talc. The purpose of this paper is to define what asbestos is and how it is identified, and to provide background information as to how and why this association has arisen.

A. ASBESTOS BACKGROUND

A.1. What is asbestos?

Asbestos is a term that designates six naturally occurring minerals belonging to the serpentine and amphibole groups. Due to their specific morphology, i.e. long, thin, flexible fibres that are easily separable when crushed or processed, asbestos minerals can be woven, are resistant to heat and chemical attack and have good electrical insulating properties.

Three of these minerals – chrysotile* (otherwise known as white asbestos), crocidolite (otherwise known as blue asbestos) and amosite (otherwise known as brown asbestos) have been, and, in certain cases, continue to be commercialised.

Each of these six asbestos minerals has a non-asbestos counterpart which shares the same chemical composition. They differ only in the manner of crystal growth: the asbestos varieties result from crystal growth in one direction only (asbestiform), whereas the non-asbestos varieties, which are far more common, are the product of two- or three-dimensional growth and are therefore non-asbestiform.

Asbestos and non asbestos classification

Group	Chemical Composition	Morphology	
		Asbestiform	Non-asbestiform
		Classification	
		Asbestos Variety	Non asbestos variety
Serpentine	$Mg_3(Si_2O_5)(OH)_4$	Chrysotile*	antigorite, lizardite
Amphibole	$Na_2Fe_3^{2+}Fe_2^{3+}(Si_8O_{22})(OH,F)_2$	crocidolite	riebeckite
	$(Mg,Fe)_7(Si_8O_{22})(OH,F)_2$	amosite	grunerite
	$(Mg,Fe^{2+})_7(Si_8O_{22})(OH,F)_2$	anthophyllite asbestos	anthophyllite
	$Ca_2Mg_5(Si_8O_{22})(OH,F)_2$	tremolite asbestos	tremolite
	$Ca_2(Mg,Fe^{2+})_5(Si_8O_{22})(OH,F)_2$	actinolite asbestos	actinolite

* Chrysotile is the only asbestos mineral to have a tubular morphology. All the amphibole asbestos minerals have a needle-like morphology.

Therefore, to be classified under the term "asbestos", a mineral has to:

a) present the specific asbestiform morphology.
b) have one of the above chemical compositions (see table above)

Asbestos minerals are always asbestiform but asbestiform minerals are not necessarily asbestos!

A.2. How is asbestos identified?

A.2.1. By its morphology

It is generally accepted that asbestiform minerals are mineral fibre (see appendix 1) populations having the following characteristics when viewed by light microscopy:

1) mean aspect ratios ranging from 20:1 to 100:1 or higher for particles greater than 5 µm in length, ~~and having aspect ratios ranging from 20:1 to 100:1 or higher,~~
2) the ability to split down into very thin fibrils:

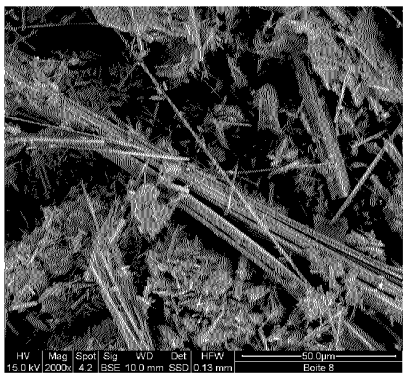

Photo 1(Anthophyllite asbestos)

3) two or more of the following attributes:
   a) parallel fibres occurring in bundles (photos 2 and 3),
   b) fibres bundles displaying splayed ends (photos 2 and 3),
   c) matted masses of individual fibres (photo 4),
   d) fibres showing curvature (photo 5).

JWP Note: The suggested revised wording of #1) above, matches the original quote from Ann Wylie (see attached document compiling the evolution of the "Wylie definition of asbestos").. The difference between the replaced wording and the actual quote is subtle but important in defining asbestos:

Replaced: "particles greater than 5 µm and having an aspect ratio of 20:1 to 100:1 or higher"
vs.
Proposed: "mean aspect ratios of 20:1 to 100:1 or higher for particles greater than 5 µm"

The actual quote indicates that the expected aspect ratio range for fibres in the size range readily measured by light microscopy is 20:1 to 100:1 or higher. Some methods mandate counting fibers greater than 5 µm (ISO 14966, NIOSH 7400, 7402, etc.) while others require counting fibers less than 5 µm (ISO 10312, EPA 40 CFR Part 763, ASTM 5756, etc.). The difference is mainly a matter of resolution of the instrumentation being employed.

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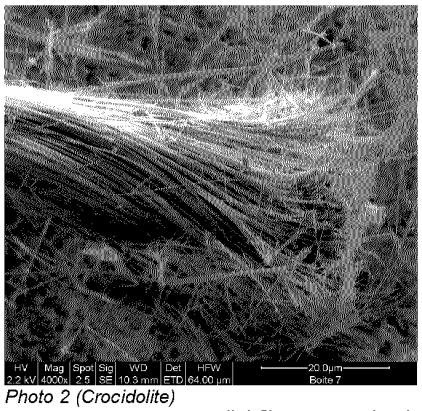


Photo 2 (Crocidolite)

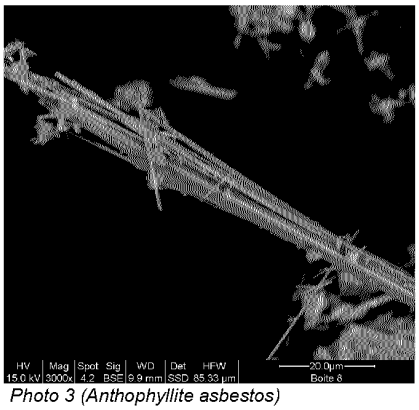


Photo 3 (Anthophyllite asbestos)

parallel fibres occurring in bundles and displaying splayed ends

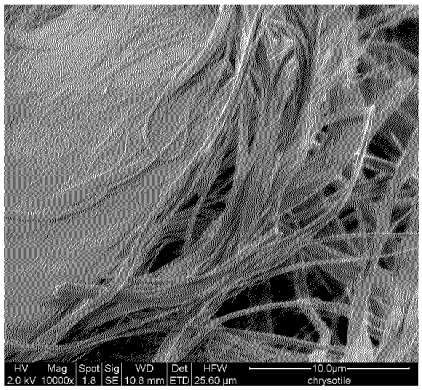


Photo 4 (Chrysotile)

matted masses of individual fibres

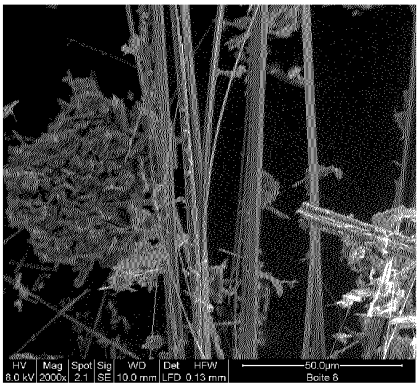
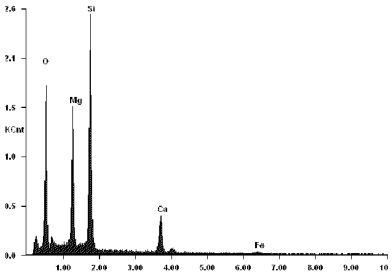


Photo 5 (Anthophyllite asbestos)

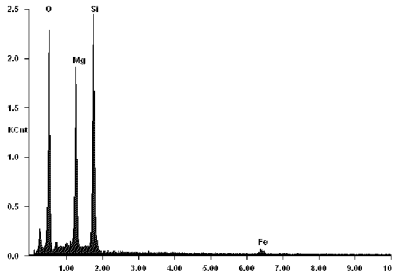
fibres showing curvature

A.2.2. By its chemical composition

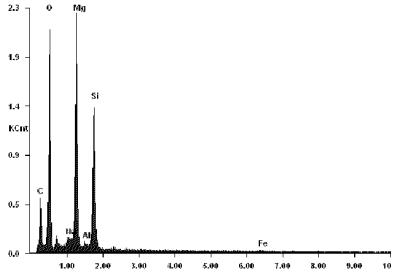
A mineral's chemical composition is determined by an EDX spectrum. As shown in the charts below, all asbestos minerals share the same spectrum as their non-asbestos counterparts:



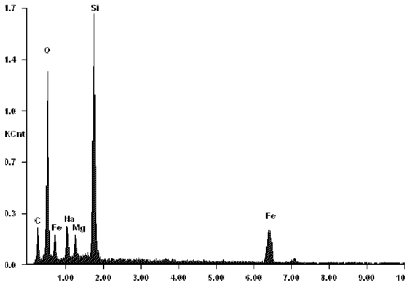
Characteristic peaks of Actinolite or Actinolite Asbestos: Mg, Si, Ca



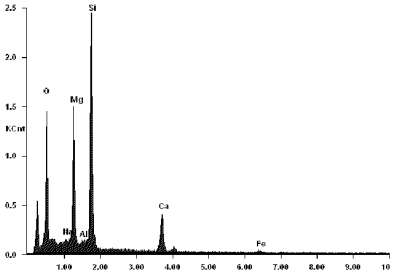
Characteristic peaks of Anthophyllite or Anthophyllite Asbestos: Mg, Si, Fe



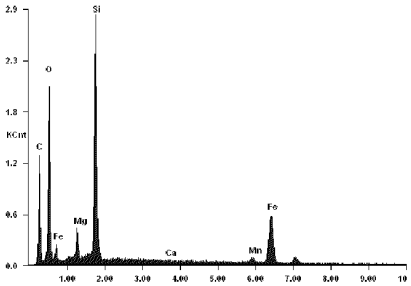
Characteristic peaks of Antigorite or Chrysotile: Mg, Si



Characteristic peaks of Crocidolite or Riebeckite: Na, Si, Fe



Characteristic peaks of Tremolite or Tremolite Asbestos: Mg, Si, Ca



Characteristic peaks of Amosite or Grunerite: Mg, Fe, Si

A.3. How can we distinguish between asbestiform minerals and non-asbestiform minerals?

Asbestiform and non asbestiform minerals break down differently.

Due to their one directional crystal growth, asbestiform minerals separate systematically along their privileged axis of growth, resulting in thin fibrils. When an asbestiform mineral is milled, the predominant particle shape will always be a fibril or a bundle of fibrils. No matter how finely they are ground, asbestiform particles will retain high ~~have the same~~ aspect ratios, but bundles may ~~will~~ become disaggregated producing increasingly thinner fibres (photos 6 and 7 below).

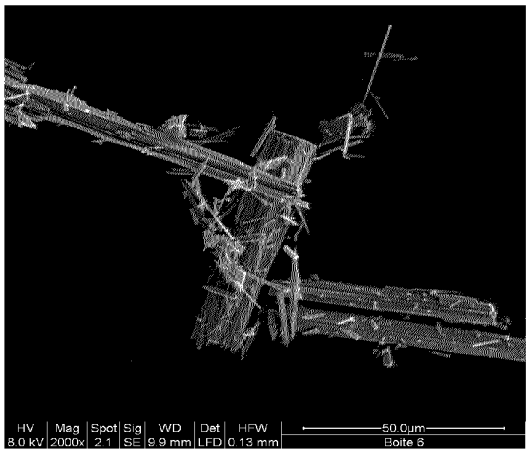


Photo 6 (Tremolite asbestos)

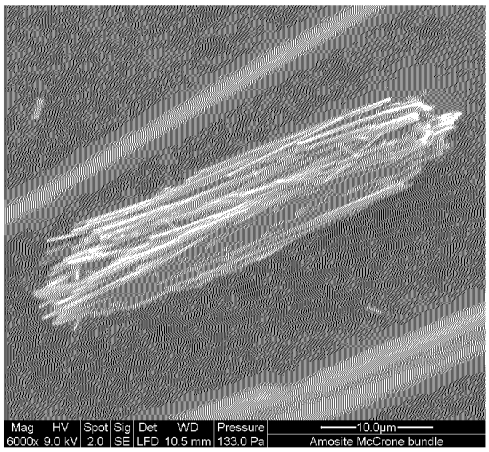


Photo 7 (Amosite)

***Asbestiform particles** separate vertically into strands*

When a non asbestiform mineral is milled, no matter how coarse or fine, the majority of the particles break down irregularly or into their three dimensional cleavage fragments (photo 8 and 9 below). However a few elongated fragments, resembling fibres, may appear and be incorrectly identified as asbestiform fibres.

If an asbestiform amphibole is milled, individual fibrils may be produced from disaggregation of bundles. Conversely, if a non-asbestiform amphibole is milled, particles may be produced that meet the definition of "countable" asbestos, as defined by the method being employed. Unfortunately, single fibres, taken individually, cannot be distinguished as having originated by growth (asbestiform) or by breakage (cleavage fragment), especially if only trace amounts are present. Therefore, it is important to maintain documentation pertaining to macroscopic growth habit prior to milling if amphiboles are present. This information may become necessary in proving the phase is non-asbestiform if "countable" fibres are detected during third party analysis of the product.

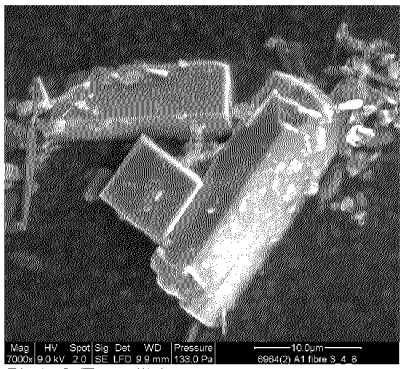


Photo 8 (Tremolite)

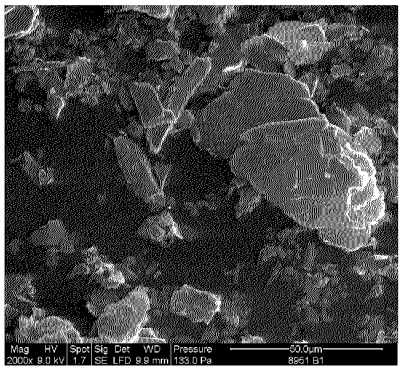


Photo 9 (Talc)

Non-asbestiform particles *break down either into their three dimensional cleavage fragments or irregularly.*

The grinding of a non-asbestiform mineral will never produce an asbestos fibre.

B. HOW CURRENT METHODS OF ANALYSIS CAN ADD TO THE CONFUSION

The most widely used methods are based on optical microscopy (Polarized Light Microscopy (PLM), Phase Contrast Microscopy (PCM)…) and on Electron Microscopy (Transmission Electron Microscopy (TEM) or Scanning Electron Microscopy (SEM)).
The methods first consist in searching fibres and then in identifying the nature of the fibres.
[Unfortunately, in most methods, whatever the technique, the asbestiform morphological criteria are not taken into account so amphibole or serpentine particles complying with the fibre definition are misidentified as asbestos fibres.]

JWP note: I would be in favour of deleting this last sentence. The asbestiform morphological criteria as defined by Wylie may not apply to fibers that have been aggressively milled and are of the size range below the resolution of the light microscope (see following quote by Wylie et al.). I do not know of any outside electron microscopy method that uses the Wylie definition. The confusion in identification arises from the limitation inherent in microscopy for determining the original growth habit of individual fibers (the type likely to be present in air or dust samples):

> "Morphological properties are difficult to apply to single particles when classifying them as a cleavage fragment or a fiber. Distinctions on morphology are most reliably made on populations. Furthermore, in air and water samples, in which particles are often less than 5 um in length, the presence of asbestos should be verified in bulk material at the source before identification of particles as asbestos…" – Bailey, K.F., Kelse, J., Wylie, A.G., and Lee, R.J.

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C. TALC & ASBESTOS

C.1. What is talc?

Talc is a hydrated magnesium silicate with the following chemical composition:
$Mg_3\ Si_4\ O_{10}\ (OH)_2$

The crystal growth of talc elementary crystals is three dimensional. Talc particles are platy (photo 10).

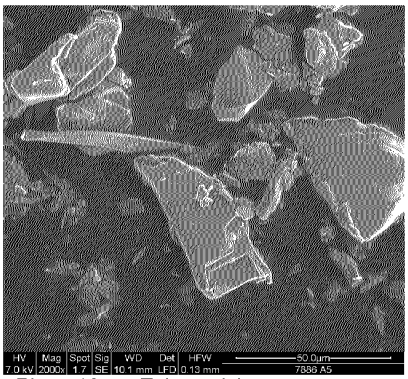

Photo 10 Talc particles

C.2. Does 'asbestiform or fibrous talc' exist?

People often confuse the terms "asbestiform" and "fibrous". It is not the same thing:

Fibrous means having an elongated form with an aspect ratio ranging from 3:1 to 5:1.

Asbestiform refers to particles greater than 5 µm in length, with aspect ratios ranging from 20:1 to 100:1 or higher, with the ability to split down into very thin fibrils and with two or more of the following attributes:

- parallel fibres occurring in bundles,
- fibres displaying splayed ends,
- matted masses of individual fibres,
- fibres showing curvature.

JWP Note: Again, this sentence should read "Asbestiform refers to particles with aspect ratios ranging from 20:1 to 100:1 or higher for fibers greater than 5 µm," rather than implying that only fibers greater than 5 µm are considered asbestiform. There are several methods that define asbestos as less than 5 µm.

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Talc can occur in a fibrous habit but asbestiform talc does not exist, it is a misnomer.

The term 'asbestiform talc' has also been applied to talc 'containing asbestos'. This is a misuse of the term since 'asbestiform' can only ever be used to describe a mineral's morphology. The correct term for this mixture is simply 'talc containing asbestos'.

C.3. Why the talc – asbestos connection?

Historically the primary cause of talc-asbestos association was, in USA, due to the publication of studies that purportedly found asbestos in cosmetic talc and baby powders. Because these studies generated growing public concern, they received widespread media coverage (New York Times, Washington Post,…). Coincidental with these publications, epidemiological studies linking cosmetic talc and ovarian cancer began to appear. They have received extensive media coverage. These two "very public" issues formed the foundation in the public's mind that "most talc contained asbestos", "talc was asbestos like" and 'that talc is a carcinogen".

The talc used in the cosmetic and baby powders was coming from a deposit in the New York State.

In the early 1970s, a series of epidemiological studies on populations working in "talc" mines in the state of New York, US, concluded that there was an increase in the incidence of lung

cancer. One of these deposits featured a rare combination of talc and three potential asbestos minerals: tremolite, anthophyllite, and serpentine. Despite the fact that the end product contained only 25% of talc, it was commonly referred to as 'New York Talc' or 'tremolitic talc'.
The company that owned the mine vehemently defended its product.
A number of other epidemiological studies have been conducted since 1992 with contradictory results. To this day, the issue remains controversial.

Virtually all references to talc and asbestos can be traced back to the NY mine or to deposits in the same area. This, combined with the confusion surrounding asbestos has led to unjustified bad press for the talc industry in general.

D. RIO TINTO MINERALS TALC OPERATIONS APPROACH & TESTING PROTOCOL

The health and safety of customers and employees is Rio Tinto Minerals' prime concern and the company takes its responsibility in these areas very seriously. To this end, rigorous and regular asbestos detection protocol based on best available practices has been part of Rio Tinto Minerals Talc Operations testing for decades.

D.1. Control methods used by Rio Tinto Talc Operations

Rio Tinto Minerals Talc Operations have been using the CTFA J4/1 method, introduced by the American cosmetic industry, since 1978 to detect amphibole asbestos. It is based on X-Rays diffraction technology and optical microscopy. It is accurate to 0.5%.

In line with recent evolutions in legislation and technology, Rio Tinto Minerals Talc Operations are using a more precise and accurate testing method based on electron microscopy (either Transmission Electron Microscopy, based on ASTM D5756 in the USA or Scanning Electron Microscopy based on ISO 14966 in Europe).

D.2. Epidemiological studies

Rio Tinto Minerals mills 1,500,000 tonnes of talc a year in its operations worldwide. In addition to the analytical testing conducted on our ore bodies, the health of mill workers has been closely monitored for over 50 years through independent epidemiological studies (see appendix 2).
Indeed, employees from our Italian, French and Austrian operations constitute the largest group exposed to talc in these studies, without other complicating substances being present and the largest data record base in the world.
All of the studies concluded that there is no excess of lung cancer or excess of any other type of cancer amongst these populations. Similarly, pleural or peritoneal mesotheliomas known to be related to asbestos mineral exposure were not found.

D.3. Carcinogenicity of talc in general

Talc has not been listed as a known or suspected human carcinogen by International Agency for Research on Cancer (IARC) in 1987, [Does this sentence need to be updated following the recent IARC ruling on perineal use of talc?] by the European community in 1989, by the National Toxicity Program (NTP) in 2000, by the American Congress of Governmental Industrial Hygienists (ACGIH) in 2001.

Appendix 1: Fibre definitions

Dimensional parameters of fibrous particulates used for atmospheric monitoring purposes:

Agency	Length, µm	Diameter, µm	Aspect Ratio
ASTM			
Practice E 849-82	> 5	< 3	> 5:1
Method D 4240-83	> 5	< 3	> 5:1
National Institute for Occupational Safety and Health (NIOSH)	> 5	< 5	> 3:1
Asbestosis Research Council for Great Britain (ARC)	> 5	< 3	> 3:1
Occupational Safety and Health Admisnistration (OSHA)	< 30	< 3	> 5:1
Mine Safety and Health Administration (MSHA)	> 5	< 3	> 3:1
International Organization for Standardization (ISO)	> 5	< 3	> 5:1
Asbestos International Association (AIA)	> 5	< 5	> 3:1
ASTM Method D5756, 5755, 6281, 6480	>0.5	>0.03	>5:1
EPA 40 CFR Part 763, EPA-600/ J-93/167	>0.5	>0.03	>5:1
NIOSH 7400/7402	>5	>0.3	>3:1
ISO Method 14966	>5		>3:1
ISO Method 10312, 13794	>0.5		>5:1
All methods based on PLM (OSHA, NIOSH, EPA)	>5		

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Appendix 2: Bibliography

Epidemiological studies conducted at Rio Tinto Talc European Operations

Italy

RUBINO G. and Coll., *Mortality Study of Talc Miners and Millers*, J Occup Med, **1976**; 18: 186-193.

RUBINO G. and Coll., *Mortality and Morbidity among Talc Miners and Millers in Italy*, in Dusts and Disease, Pathotox Publishers, **1979**, 357-363.

COGGIOLA M. and Coll. *An update of a mortality study of talc miners and millers in Italy,* Am. J. Indust. Med. 44, **2003**, p 63-69

France

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Springer-Verlag ; Berlin Heidelberg **1990**.

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Occup. Environ. Med **1995**; 52; 470-477.

France and Austria
WILD P. and Coll. *A cohort mortality and nested case-control study of French and Austrian workers*
Occup. Environ. Med **2002**; 59; 98-105.

WILD P. and Coll. *Effects of Talc Dust on Respiratory Health: Results of a Longitudinal Survey of 378 French and Austrian Talc Workers*
Occup Environ Med Published Online First: 10 October **2007**

Studies carried out among industrial users of talc

CATILINA P. et coll., *Risques pulmonaires professionnels liés à l'utilisation du talc dans l'industrie du caoutchouc*
Arch. Mal Prof. **1980** ; 41 ; 363-368.

RAMANAKUMAR A. V. and Coll. *Risk of lung cancer following exposure to carbon black, titanium dioxide and talc: Results from two case-control studies in Montreal*.
Int. J. Cancer, Published Online: 23 Aug. **2007**

MISCELLANEOUS

ENDO-CAPRON S. and coll. *In Vitro* response of rat pleural mesothelial cells to talc samples in genotoxicity assays (sister chromatid exchanges and DNA repair) Toxic. In Vitro **1993**; 7; 7-14.

HUNCHAREK M. A. B. and Coll. Use of cosmetic talc on contraceptive diaphragms and risk of ovarian cancer: a meta-analysis of nine observational studies.
Europ. J. Cancer Prev. **2007** 16 (5) 422-429.