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Cc: Alessandro Gualtieri
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From: Ann G Wylie (awylie@umd.edu)
Chair, Working group on Asbestos

Date: April 27, 2022

Re: IMA Working Group deliberations and recommendations

During the IMA Congress in 2018, the establishment of the IMA Working Group on Asbestos, asbestiform minerals, and other respirable minerals that pose potential negative health risks was approved. The charge to the Working Group was to clarify issues around nomenclature and classification for minerals posing a potential health risk by inhalation. The group formally got underway in January 2019, more than three years ago.

Because of the pandemic, the work of the committee has been entirely by email, making progress difficult at best. Nonetheless, we worked for more than a year with most of the members participating in the deliberations regularly. Our first task was to agree on a set of definitions that are used by both mineralogists, health scientists, and regulators, with different understandings of their meanings. An interim report was provided to IMA in January 2021. However, we were unable to come to agreement, and in truth, I lost confidence that agreement would be possible given the polarization of views on several key definitions.

Despite these setbacks, given the importance that definitions have in communicating information, we decided to begin again in August 2021 with enthusiastic encouragement from Alessandro Gualtieri that we could come to agreement. We worked through the fall and winter and in February, 2022, the committee leadership decided that it was time to vote and a set of definitions that had been the focus of the discussion for three years was formally proposed to the membership. The subsequent vote was 8 in favor, 3 opposed, one abstains, and one nonvoting (an inactive member).

List of definitions in hierarchical order (approved by the Working Group Feb 14, 2022)

Elongate Mineral Particle
Any mineral particle with a length:width ratio (aspect ratio) of 3:1 or greater assuming the width of a particle to be an apparent parameter defined as the longest dimension of the particle in the plane perpendicular to length and the shortest dimension of the two-dimensional outline of a particle.

Mineral fibre
Any elongate mineral particle that attained its shape during formation in nature with an aspect ratio sufficiently large to impart flexibility to the particle.

Fibril
A single crystal of mineral fibre which cannot be further separated longitudinally into smaller components.

Cleavage fragment
Any elongate mineral particle formed by fragmentation. It may have the same chemical formula of the fibrous or asbestiform variety but it is brittle and cannot separate longitudinally into fibres or fibrils.

Fibrous
The crystal habit that describes particles having the appearance of a mineral fibre.

Asbestiform
The crystal habit displayed by elongate mineral particles composed of bundles readily separable into fibres or fibrils which are aligned parallel to their common fibre axis direction but randomly or semi-randomly in the directions perpendicular. Both macroscopically and microscopically, the fibre bundles can display frayed/splayed ends and can be flexible and bent.

Asbestos
A generic term applied to the asbestiform variety of serpentine (chrysotile) and the asbestiform variety of amphibole group minerals (anthophyllite, cummingtonite-grunerite, tremolite-actinolite and riebeckite), which have been exploited, prospected, described in the literature, traded and sold commercially for their unique physical properties resulting from fibril dimension 0.5 μm or smaller in width.

Below is a summary of the issues raised in the discussion of each term in our list. Despite the fact that there were three negative votes, there is strong support from those who voted yes, including myself. As the attached document shows, several of the concerns expressed asked how the definitions can be applied to particles under an electron microscope or under polarized light microscopy. In the end the committee expressed support for the idea of that criteria for the identification of asbestiform fiber by PLM, SEM and TEM could be developed based on the now vast amount of data we have about the nature of such mineral fiber. This committee, however, voted to discontinue its work.

Discussion of recommended terminology. The terms and definitions in bold were agreed to by a majority of the committee but there were important issues raised during the months of discussion. These issues are summarized below.

ELONGATE MINERAL PARTICLE

Any mineral particle with a length:width ratio (aspect ratio) of 3:1 or greater assuming the width of a particle to be an apparent parameter defined as the longest dimension of the

particle in the plane perpendicular to length and the shortest dimension of the two-dimensional outline of a particle.

DISCUSSION

The term "elongate mineral particle" (EMP) was defined by NIOSH in 2011 and the committee recommends that it be adopted formally by IMA. While fibers form in nature as fibers and fragments form by applying mechanical force to a larger mass, the term elongate mineral particle (EMP) is simply defined by shape, not how it formed.

It is recognized by the committee that some protocols and laboratory practices record an average width while others measure only the largest dimension perpendicular to length for width. These are analytical protocol issues that should be specified and may vary depending on the specific test method and the purpose of the analysis.

MINERAL FIBER

Any elongate mineral particle that attained its shape during formation in nature with an aspect ratio sufficiently large to impart flexibility to the particle.

DISCUSSION

The first point of discussion was whether there should be two definitions for the term mineral fiber: a mineralogical one and one based only on dimension of a particle that could be used by analytical laboratories. The majority of the committee agreed to propose a mineralogically correct definition that might be helpful to other communities interested in the inhalation of mineral aerosols. There are currently many different dimensional dimensions in use and the committee did not choose to address this issue.

The major issue discussed is the determination of flexibility and if it must be ascertained for each particle for it to be identified as a fiber. In general, the committee believes that mineral fiber will be flexible because mineral fiber has enhanced tensile strength compared to its non-fibrous analogy and/or a high aspect ratio. But like all mineral properties, when observing a particular mineral and mineral occurrence, we gather information from many different grains to draw generalizations about the mineral occurrence, such as its chemical composition, and its habit, e.g., it is fibrous. For example, by optical microscopy, flexibility is most commonly observed where large bundles are evident and splaying fibers are curved. By transmission electron microscopy, only the smallest particles are observed and flexibility is difficult to demonstrate. Several members provided images and observations from their own work demonstrating the difficulties analysts have at the scale of the TEM in recognizing properties that clearly demarcate a riebeckite particle as crocidolite, for example. Analytical issues, however, should not change the fundamental definition of the nature of mineral fiber. The development of criteria that analysis of mineral material by optical and electron microscopy can rely on to identify mineral fiber could be developed in the future.

A member of the committee requested that the phrase "with a width ≤40 µm" be added to specify that that fibers are not visible given the minimum size of an object visible to the unaided eye is 40 µm, but this issue was not made until voting was already underway.

FIBRIL

A single crystal of mineral fibre which cannot be further separated longitudinally into smaller components.

DISCUSSION
The major point of discussion was whether or not this term could apply to any of a group of single crystals independent of size? It was agreed by most that there are no implied size limitations in the definition.

CLEAVAGE FRAGMENT

Any elongate mineral particle formed by fragmentation. It may have the same chemical formula of the fibrous or asbestiform variety but it is brittle and cannot separate longitudinally into fibres or fibrils.

DISCUSSION
One objection raised was the lack of criteria for identify a particle as a cleavage fragment. Currently, such criteria are lacking for analysis by TEM. The development of criteria that analysts using optical and/or electron microscopy can rely on for the identification of cleavage fragments in samples of mineral material could be developed in the future.

FIBROUS

The crystal habit that describes particles having the appearance of a mineral fibre.

DISCUSSION

The major objection raised to this definition was that it is only based on appearance. This makes it very broad, and not as useful as if it also said that it could apply to materials that were actually composed of fibers, no matter how they might look at some scale.

ASBESTIFORM

The crystal habit displayed by elongate mineral particles composed of bundles readily separable into fibres or fibrils which are aligned parallel to their common fibre axis direction but randomly or semi-randomly in the directions perpendicular. Both macroscopically and

microscopically, the fibre bundles can display frayed/splayed ends and can be flexible and bent.

DISCUSSION

Several members wanted to remove the word "readily" from the definition. It was the experience of the committee that asbestiform fibers are easily to separate by hand pressure or a little pressure with a knife, and as such are readily separable.

The issue of whether or not every occurrence has to have some randomness in the crystallographic directions perpendicular to the fiber axis. The published data all demonstrate some randomness at the scale of a visible fiber.

The question of whether or not asbestos fibers found in matted masses lack a fibrillar structure was raised. Experience on this point varies among the committee participants, although most agreeing that all occurrences of asbestiform fibers associated with adverse health effects display a fibrillar structure.

A member suggested that the word "eventually" be added prior to the word "flexible" in recognition that asbestos has been mechanically "fiberized" to free flexile fiber, and that flexibility is enhanced by weather for long periods of geologic time in occurrences reflected in terms such as "paper and leather' but this qualification was not adopted by the committee.

ASBESTOS

A generic term applied to the asbestiform variety of serpentine (chrysotile) and the asbestiform variety of amphibole group minerals (anthophyllite, cummingtonite-grunerite, tremolite-actinolite and riebeckite), which have been exploited, prospected, described in the literature, traded and sold commercially for their unique physical properties resulting from fibril dimension 0.5 μm or smaller in width.

DISCUSSION

The first issue the committee discussed was the primacy of the term asbestos vs that of asbestiform. These terms are defined under the working assumption that asbestiform is primary. There was initial discussion about removing the term altogether but given its history and its wide spread use in public health as well as mineralogy, we agreed to retain this term.

Several members of the committee wanted to apply the term asbestos to both fibrous and asbestiform habits. The committee agrees that the asbestiform habit is a fibrous habit, but all fibrous habits are not asbestiform. The experience of the majority of the committee and the published literature demonstrates that there are fibrous mineral occurrences, including fibrous but not asbestiform occurrences of chrysotile, anthophyllite, cummingtonite, grunerite, tremolite, actinolite and riebeckite, that are fibrous but do not resemble asbestos and are not asbestiform. They often form brittle, wide, single crystals, sometime referred to as prismatic crystals. These EMP fibers lack enhanced tensile strength, are often too wide to penetrate the deep lung, and are not asbestiform. Since the term "fibrous" requires only the appearance of being composed of fibers, without the restriction placed by the term "asbestiform", the term asbestos could be extended to particles that are not composed of separable fibers and that are

not asbestiform. After significant discussion, , the committee did not include the phrase "asbestiform OR fibrous" in the description of asbestos; an occurrence must be asbestiform to be called asbestos.

Several members of the committee wanted the term asbestos to be applicable to any amphibole composition if it is asbestiform, not just the ones listed in this recommended definition, as is consistent with the current IMA definition; this was perhaps the most divisive element we discussed. There are documented occurrences of asbestiform amphibole that have been prospected or described as asbestos in the literature with a composition not specified in this definition and amphibole nomenclature changes over time. Fibrous amphibole at Libby, MT is described as asbestiform but its composition excludes it from the term asbestos today, although it was known as soda tremolite prior to the adoption of the current classification scheme and were that still in use, the term asbestos could apply. However, all major amphibole asbestos mines working during the 20th and 21st century produced an amphibole asbestos with a composition on the list. The definition of asbestos is limited to the six minerals by Chemical Abstracts Service, IARC, NIOSH_OSHA, DPA, NIOSH, among others. For these reasons the majority of the committee agreed to limiting the compositions as we have done.

The committee understands that amphibole compositions must be quantitatively determined to apply amphibole nomenclature precisely and this is not routinely done during TEM or SEM examination. Optical microscopy is limited by some ambiguity between properties and chemical composition. All methods are challenged by very small fibril widths. When there is uncertainty the IMA/MSA recommends the use of terms such as "tremolitic" or actinolitic" when the composition is semiquantitative.

OTHER ISSUES RAISED BY COMMITTEE MEMBERS

A few members wanted to include a definition of the term "acicular." After discussion that described its different widespread uses, committee decided that a new definition was unwarranted at this time, and the standard, widely understood meaning that acicular means "needlelike" should remain.

After final vote was underway, one member of the committee sent a very long document that was not reviewed by the committee before the vote. However, after receiving the document the committee chair did not receive a request to reconsider the vote from a member who had voted in favor of the definitions.

One member of the committee claimed that the definitions the committee voted on were produced by a "subgroup". This is simply not born out by the email record substantiating the long term over which the committee deliberated, the multiple communications about the definitions that circulated among all group members, and the unlimited opportunity for comment over many months. All communications on the substance of the issues were shared to every member throughout the process. There was no hidden subgroup at work. The option of a minority report was made clear to all members of the committee.

A member objected to a vote on all terms together. We had spent several years discussing these terms individually, so the final list was one on which discussion had ceased and all issues had been raised and addressed. It seemed appropriate to put them all up to see if the group was satisfied enough to recommend sending these definitions forward.