

Erskine Environmental Consulting

Geologic Investigations Hazardous Materials Naturally Occurring Asbestos

TECHNICAL MEMORANDUM

January 15, 2020

Subject: Comments: Regulations of Asbestos Minerals RJ Lee Group Project Number: LLH901997, dated November 25, 2019; Transmittal of Qualitative Geologic Survey Report, Rock Hill Quarry, Hanson Aggregates Pennsylvania LLC, SMP # 7974SM1, East Rockhill Twp., Bucks Co., PA.

This memorandum provides comments and recommendations regarding the following documents:

- Transmittal of Qualitative Geologic Survey Report, Rock Hill Quarry, Hanson Aggregates Pennsylvania LLC, SMP # 7974SM1, East Rockhill Twp., Bucks Co., PA, and
- Regulations of Asbestos Minerals RJ Lee Group Project Number: LLH901997, dated November 25, 2019.

These comments are supplementary to and augment comments provided in four previous memoranda prepared by Erskine Environmental Consulting (EEC):

1. Review of Qualitative Geologic Survey Sampling Plan, Rockhill Quarry, East Rockhill Township, Bucks County, PA: Erskine Environmental Consulting dated June 6, 2019.
2. Review of Asbestos Test Results, Rockhill Quarry, East Rockhill Township, Bucks County, PA: Erskine Environmental Consulting dated September 1, 2019.
3. DEP Comment Regarding Heavy Equipment Loadout and Review of DEP Reanalysis of Asbestos Test Results by TEM Methodology, Rockhill Quarry, East Rockhill Township, Bucks County, PA: Erskine Environmental Consulting dated September 23, 2019.

4. Review of Response to PADEP September 20, 2019 Letter, Rock Hill Quarry, Hanson Aggregates Pennsylvania LLC, SMP # 7974SM1 East Rockhill Twp., Bucks Co., PA, prepared by the RJ Lee Group: Erskine Environmental Consulting, dated October 13, 2019,

These comments are intended to be a brief summary of findings. The basis for many of the findings and opinions have been discussed in detail within the four previous memoranda submitted by EEC, and the recipients of this memo are referred to those documents where additional explanation is needed.

The observations and conclusions represent the opinion of the author. The opinions are derived as a result of document review, interviews with relevant experts, and in some cases, inferences gained from the review of laboratory data and details provided in the two documents under review. A review of this document by PA DEP, Hanson Aggregates, EARTHRES, and the RJ Lee Group is encouraged, and EEC welcomes comments or rebuttals to the opinions provided.

Section 1: Summary of Findings and Recommendations

The Qualitative Geologic Survey Report (QGSR) presents the field sampling procedures and test results, and argues, directly and indirectly, that the concentrations of reported asbestos are not high enough to be actionable. The opposite is true: asbestos is present in concentrations that may produce an adverse exposure to the public who live off of the site. When the sampling procedures, testing protocols, reporting of concentrations and comparison with regulatory thresholds are considered, the QGSR presents a protocol that through its design, systematically leads to the under reporting of asbestos concentrations, and then dismisses by implication that the results as not actionable by regulators.

The systematic deviation from general Standard of Practice for Professional Geologists and laboratories begins with the scope of the survey. The survey is precisely what its title states: a qualitative survey that is not designed to meet Standard of Practice. There is no reference to any standard or guideline that was followed, nor is there any reference to limitations that are normally expressed as part of a qualitative, preliminary or limited investigation. The survey appears to have as its basis the Qualitative Geologic Survey described in the NSSGA Mineral Identification and Management Guide. This guide, and the procedures found within, were developed by the mining industry to meet mining industry objectives, and uses definitions and procedures that are not commonplace or in accordance with normal Standard of Practice. It follows that the survey was not designed with the health and safety of the public nor general regulatory and testing standards in mind.

The laboratory procedures that were used by the RJ Lee Group were not included in the report, but a review of the laboratory bench sheets and testing reports, combined with references included in RJ Lee Group's summary of regulations of asbestos minerals,

indicate that the methodologies deviated significantly from the protocols established through the National Voluntary Laboratory Accreditation Program (NVLAP). In particular, the RJ Lee Group appears to deviate from standard testing protocols in EPA Method 600/R-93/116, which was cited as the basis for testing. Two significant deviations appear to have been applied. The first is the elimination of fibers that would normally be reported by selectively removing particles that were deemed non-asbestiform, using fiber morphology and the optical property of inclined extinction as a basis. Neither are allowed by the EPA method and proficiency testing associated with the NVLAP accreditation. The second deviation appears to be related to the elimination of particles on the basis of fiber population dimensions. This also is not allowed by any test method. This was verified by a review of regulations and test methods, combined with interviews of two Pennsylvania-based laboratories and a laboratory inspector for the NVLAP program (see EEC's review of regulations and test methods, later in this memorandum). In addition, the relatively few numbers of particles counted in the Rockhill samples (less than 50) preclude this type of analysis, even if allowed by the test methods. The result is a significant under-reporting of asbestos that would normally be reported.

A further reduction in asbestos concentrations is reported by averaging, using a volumetric weighted average technique, the asbestos concentrations in the observed actinolite veins with the asbestos content in the diabase. A diluted asbestos content is reported for the drill cores as a whole. Dilution by compositing, whether it be by field sample compositing, laboratory sample compositing, or averaging of test results, is not allowed by EPA or OSHA. Considering that the original results were likely under reported, the final averaged result is highly misleading.

Finally, the various results are compared with regulatory thresholds that are described as Federal and State of California limits. The characterization of these values (1% Federal and 0.25% California) as actionable thresholds is misrepresented. OSHA regulates asbestos in any amount in the workplace. The State of California regulates asbestos in any amount on earthen construction sites. EPA regulates at the 1% level for applied asbestos in building materials, but not for NOA. The representation that the concentrations at the Rockhill site are below these thresholds are not actionable or worse, not a potential adverse exposure impact, is dangerously misleading.

The conclusions and recommendations that were submitted in the previous EEC reviews remain unchanged. The following are the key recommendations that are relevant for this discussion:

1. The QGSP and its implementation did not conform to the Standard of Practice that is normally followed by a Professional Geologist. The procedures for sampling and testing should follow standard protocol, discussed in EEC's previous memoranda. The geologist should not have a relationship with, and therefore a

conflict of interest as a result, the mining industry and particularly, the permit applicant. The geologist should report directly to the PA DEP.

2. Samples that have not been processed should be submitted by PA DEP to a third-party laboratory. The laboratory should have significant experience testing for NOA, and experience with EPA projects. The laboratory should not have a significant relationship with the mining industry or the permit applicant. All additional samples should be submitted to this lab.
3. Whether or not asbestos at the Rockhill site may produce an adverse exposure by asbestos to the public can be assessed only through air monitoring. It is recommended that activity-based sampling (ABS) be conducted at the site, and if permitted, the mining operation should include perimeter and local air monitoring as described in EEC's previous memoranda. Third-party monitoring should be conducted by a consultant that reports directly to the PA DEP.
4. Consider using a different supplier of aggregate for the turnpike project. All of the potential impacts to the Rockhill Township residents would be eliminated.

Section 2: Review of the two documents

This memorandum is divided into two components:

1. A review and opinion regarding: Transmittal of Qualitative Geologic Survey Report, Rock Hill Quarry, Hanson Aggregates Pennsylvania LLC, SMP # 7974SM1, East Rockhill Twp., Bucks Co., PA. The focus is whether or not the sampling plan, procedures for sampling, analysis and reporting of data, and conclusions are in conformance with Standard of Practice for Professional Geologists and asbestos testing laboratories. Some of the comments, opinions and conclusions draw from information provided in the review of the regulations and test methods, as specified in (1), above.
2. A review and opinion regarding the regulatory definitions of asbestos and test methods cited by the RJ Lee Group. The focus is whether the elimination of particles that are referred to as cleavage fragments using "differential counting" is or is not procedurally specified in the test methods. The discussion draws upon the specific rules and definitions of fibers that must be counted, references to policy by EPA and NIOSH as stated in several official communications, and personal communications with representatives at NIOSH and several NIST-accredited asbestos testing laboratories located in Pennsylvania.

All comments and conclusions are the opinion of the author of this memorandum. The opinions are based on a review of relevant regulations, test methods, guidance documents, and more than 30 years of direct experience with regulatory compliance,

asbestos testing, field investigations, and interactions with the NOA scientific community.

Part 1: Transmittal of Qualitative Geologic Survey Report, Rock Hill Quarry, Hanson Aggregates Pennsylvania LLC, SMP # 7974SM1, East Rockhill Twp., Bucks Co., PA.

The RJ Lee group document focuses on the regulatory definition of asbestos provided in several asbestos regulations and test methods. It is assumed that the purpose of the document is to justify the practice of selectively, or differentially, excluding particles that appear to have originally crystallized in the non-asbestiform habit (“cleavage fragments”) from those that appear to have originally crystallized in the asbestiform habit (“asbestos”).

To assess this issue in a broader context, it is instructive to review the actual criteria that the test methods specify for analysis and reporting, particularly in regard to excluding particles that appear to have originally crystallized in the non-asbestiform habit. It is also instructive to consider verbal comments from two Pennsylvania-based testing laboratories that are accredited by the National Institute of Testing and Technology (NIST) under the National Voluntary Laboratory Accreditation Program (NVLAP), and an assessor who conducts laboratory site inspections for laboratory accreditation and recertification. These subjects are explored below.

QGSR Section 1.0: Introduction

Comment 1.0-1

The EARTHRES Group, Inc. report (EGI report) is titled: “Qualitative Geologic Survey Report”. The identification of this report as a qualitative report is, by itself, problematic. This subject was raised by EEC in the review of the Qualitative Geologic Survey Sampling Plan (QGSSP) prepared previously, but the term “qualitative” persists.

Consider the definition of *Qualitative*: “Relating to, measuring, or measured by the quality of something rather than its quantity”.

Unlike the term “preliminary”, which suggests that the investigation will be followed by a more comprehensive investigation, or “limited”, which implies that the investigation is not comprehensive, the use of “qualitative” in the report title suggests that the scope of the investigation is not designed to adequately quantify the concentration and distribution at the site.

Why is this terminology important? It may allow the Professional Geologist who conducted the investigation to lower or deviate from the Standard of Practice for a geologic NOA site investigation. It also may allow the Professional Geologist to accept

laboratory results that were derived from non-standard test methods and do not quantify the asbestos concentration as would normally be reported following standard and approved test methodologies. Consider: would a Qualitative Soils Survey report delivered by a Professional Engineering Geologist be acceptable, and would there be confidence that the report has provided the data necessary to design a road or building on the soil materials?

Comment 1.0-2

The report does not identify the standard by which the investigation was conducted, nor does it state that the investigation was conducted in conformance with the Standard of Care for geologic investigations. Was the investigation conducted in conformance with the internal mining industry procedures outlined in: NSSGA Mineral ID and Management Guide (NSSGA 2009), which outlines the procedures for a Qualitative Geologic Survey? If so, the report should state it, and provide a limitations section that the investigation was designed for the purposes stated in the NSSGA document. Those purposes should then be stated. For example, one purpose of the NSSGA Qualitative Geologic Survey is listed as: “The program outlined in the Identification Guide is intended to be tailored by geologic personnel or consultants such that it is appropriate for the geologic and production realities of a particular site”.

QGSR Section 2.3: Previous Site Investigations

Comment 2.3-1

The report states that water was analyzed by EPA Method 100.2 for fibers ≥ 0.1 micron in length. It reports that no asbestos was detected for fibers ≥ 10 microns, but did not report the concentration of fibers that are less than this length. It states that the concentration is below the EPA drinking water standard for fibers ≥ 10 microns. It also states that there is no corresponding regulatory limit for NOA detected in the ≥ 0.5 micron to less than 10 micron size range.

This conclusion belies the true issue. The water at the site is not tap water, and is not intended to be used for potable water. The issue is that if asbestos is present, and whether it may or may not contribute to a health risk. Consider these issues:

- EPA regulates fibers and structures that are ≥ 0.5 microns in air.
- If the impounded water is to be used for dust control, could asbestos that is ≥ 0.5 microns entrained in fine water droplets be released through evaporation, and migrate off site?
- Could there be an inadvertent release of water off of the site?

Asbestos, including that which may occur naturally in earthen materials, is a hazardous substance under the Comprehensive Environmental Response,

Compensation, and Liability Act (CERCLA) (United States Code: Title 4,2 Chapter 103). Therefore, EPA under CERCLA authority could require response actions when construction activities release naturally occurring asbestos to the environment, including to air, water or soil.

QGSR Section 2.4: Current Site Investigations

Comment 2.4-1

Paragraph 2 of the report states: “Field sampling efforts were completed by professional geologists from EARTHRES”. The report should state that the work plan and investigation was conducted in accordance with the professional Standard of Care that was in effect at the time of the investigation, and clearly indicate what guidance documents were used as the basis of the work plan and investigation. If the investigation followed the qualitative protocols found in the NSSGA Mineral Identification and Management Guide, the report should state this.

Comment 2.4-2

Paragraph 3 of the report states: “Although the literature assessment and site observations indicate that NOA is not present in the diabase matrix, four (4) diabase core samples were collected and analyzed to quantitatively assess the potential presence of NOA in the diabase matrix”.

The statements, and others within the report, seems to rely on the previous absence of reporting as useful data. There are three key references that the report cites as an indication that asbestos is not likely to be present. One investigation conducted in 1931 and another in 1959 are irrelevant. The vast majority of new reports of asbestos are in rocks that have been previously studied by geologists where the crystal habit was of no concern to their specific research. Another reference is the absence of asbestos on Van Gosen’s list of occurrences on the USGS map. The USGS includes only asbestos localities where reported; it does not actively investigate for asbestos. Thus, the references to the absence of previously reported asbestos can only bias, and not enlighten, the recipient of the report, and should not be used to support a finding one way or another.

QGSR Section 3.1: Diabase Geology Literature Assessment

This section reviews published scientific literature that is related to the diabase unit at the site, and provides an assessment with conclusions regarding the potential for NOA to be present. It relies heavily on a regional mineral resource investigation conducted in 1959, as well as other studies that were not designed to detect NOA. It is important to note that the referenced studies conducted prior to the development of NOA investigation

procedures did not report asbestos, whereas several studies conducted after modern NOA inspection and testing was established did, in fact, report asbestos.

The conclusions in the Section states: “The diabase at the Site has not undergone metamorphism upon which asbestos could materialize from the primary minerals of the igneous rock”. This statement is incorrect. Hydrothermal alteration and veining that is reported in the report is, in fact, a record of a metamorphic event that may have altered the primary amphiboles through recrystallization, or induced growth of an overprint of amphiboles that would coexist with primary amphiboles. Both mechanisms are common in rocks that have experienced hydrothermal alteration. See Figure 5, below, for an example.

QGSR Section 4.4 Rock Core Vein Volume Determination.

The method used to estimate the percentage of asbestos in a rock core is an inappropriate method to report asbestos concentrations, and is not in conformance with OSHA and EPA regulations and test methods that prohibit the compositing of samples.

1. The volumetric measurement of veining includes only veins that are observable in the field. It does not include micro veining that is likely to be present throughout the diabase unit (see Figure 5, below for an example). There may be thousands of micro veins for every macro vein at the site.
2. The reporting of an asbestos concentration using a volume-weighted method of two units is a form of compositing that is not allowed by OSHA and EPA. This approach effectively dilutes the asbestos concentrations and will provides a misleading analysis. OSHA requires each material to be sampled and analyzed independently, and does not allow compositing to arrive at a concentration to drive response actions or respiratory protection. Asbestos is regulated in any amount. EPA, under the Federal NESHAP regulations for building demolitions, allow compositing in only one case: sheetrock and joint compound wall systems.

QGSR Section 5.1 Surface Water Sampling

The testing and reporting of asbestos misuses the protocols required under EPA Method 100.1. The method requires a filter pore size of 0.45 microns to eliminate the loss of particles above this fiber length, and states: “Fibers less than 0.5 μm in length will not be incorporated in the fiber concentration calculation”, meaning that all fibers that are greater than or equal to 5 microns shall be reported. The report states that only fibers that were greater than 5 microns were reported, which is not compliant with the reporting requirements. Because most fibers in water are generally below 5 microns in length, the exclusion of the short fibers significantly under report the concentration of asbestos.

QGSR Section 5.2 Aggregate Stockpile Sampling

This section, and repeated in QGSR Section 6.3: Conclusions, misstates and misuses concentration thresholds that are cited in several regulations. It refers to the 1.0% in EPA and OSHA regulations as a Federal limit, and references the 0.25% threshold for surfacing applications. The 1.0% is not a Federal limit, and the 0.25% threshold has a very restricted utility. For example:

- OSHA: The 1.0% threshold is used to require additional and mandatory controls personal protection, and monitoring. The threshold that triggers OSHA controls, personal protection and monitoring is: asbestos in any amount.
- EPA: The 1.0% threshold is a threshold that differentiates building materials where asbestos was applied as a commercial product from those where asbestos was not applied. This is not the threshold that EPA uses for health risk assessments on NOA sites, and its position is that adverse exposures may occur from soil with concentrations of asbestos well below one percent.
- CARB: In the CARB Asbestos Airborne Toxic Control Measure (ATCM) for construction, the 0.25% threshold is applied to roads on NOA materials and post-construction stabilization of disturbed areas. Dust control measures are triggered when asbestos is present in any amount. The stated purpose of the surfacing threshold requirement is to prevent visible dust by wind stripping.

Part 2: Regulations of Asbestos Minerals RJ Lee Group Project Number: LLH901997, dated November 25, 2019.

The RJ Lee group document focuses on the regulatory definition of asbestos provided in several asbestos regulations and test methods. It is assumed that the purpose of the document is to justify the practice of selectively, or differentially, excluding particles that appear to have originally crystallized in the non-asbestiform habit (“cleavage fragments”) from those that appear to have originally crystallized in the asbestiform habit (“asbestos”).

To assess this issue in a broader context, it is instructive to review the actual criteria that the test methods specify for analysis and reporting, particularly in regard to excluding particles that appear to have originally crystallized in the non-asbestiform habit. It is also instructive to consider verbal comments from two Pennsylvania-based testing laboratories that are accredited by the National Institute of Testing and Technology (NIST) under the National Voluntary Laboratory Accreditation Program (NVLAP), and an assessor who conducts laboratory site inspections for laboratory accreditation and recertification. These subjects are explored below.

OSHA Polarized Light Microscopy of Asbestos of Bulk Materials, Method ID-191, October 1992, Revised February 1995 (“OSHA Method”).

This method was cited as a controlling method by the RJ Lee Group. The OSHA method provides a descriptive context for differentiating cleavage fragments from true asbestos. However, this test method is not relevant to geologic investigations relating to the potential risk to the public that resides off of the construction site. OSHA regulates worker exposure only, and all decisions, protocols and procedures related to site workers are the responsibility of the employers of the workers. In regard to asbestos, worker safety compliance should remain between the employer and OSHA. EPA regulates potential public exposure, which is the primary interest of the residents of the Rockhill Township. EPA’s testing criteria and policies are discussed following this subsection.

A few comments regarding the applicability of the OSHA test method are in order.

1. The OSHA method carries the following warning: DISCLAIMER: These procedures were designed and tested for internal use by OSHA personnel.¹ Therefore, this method should not be used for OSHA compliance, and should never be used for geologic investigations when a potential exposure to the public is of concern (see discussion regarding EPA’s methodology, below).
2. The OSHA method provides no specific procedure for crystallization habit differentiation. If OSHA has a procedure for differential analysis, it has not been provided to the public for use, and any attempt by a laboratory to design its own procedures would likely be inconsistent with OSHA’s protocol. This test method also carries a disclaimer: “A great deal of experience is required to routinely and correctly perform differential counting. It is discouraged unless it is legally necessary”. It is not clear what is meant by “legally necessary”, and a differential counting procedure is not included within the method. This reference suggests that OSHA does not endorse the practice of differential counting.
3. Section 1.4.1, Method Performance states: “NIST has conducted proficiency testing of laboratories on a national scale”. As will be discussed below, proficiency testing that is conducted for laboratory certification under the Federal NVLAP accreditation, does not include crystallization habit differentiation.

EPA Method 600/R-93/116, July 1993, Method for the Determination of Asbestos in Bulk Building Materials (EPA Method).

This method was referenced by the RJ Lee Group as a controlling method. The EPA method is the primary test method used to characterize building materials, and because EPA has not developed a separate method for NOA, it is also used for site

¹ <https://www.osha.gov/dts/sltc/methods/inorganic/id191/id191.html>).

characterization. The method does not provide a protocol that can be used for crystal habit differentiation, and the protocol that is published does not allow a laboratory to exclude a particle from reporting based on the optical extinction angle². It is apparent that both RJ Lee Group and EMSL have used the presence of an extinction angle to define and exclude a particle as not being asbestos. However, Table 1 of the EPA Method states that actinolite-tremolite asbestos can be differentiated from other amphiboles by its oblique extinction at an angle of up to 21 degrees. Thus, actinolite particles cannot be excluded from reporting on the basis of the absence of parallel extinction.

As pointed out by the RJ Lee Group, the method describes some general properties of asbestos, and similar language has been adopted across test methods, regulations and fact sheets. It also refers to differential analysis using mean aspect ratios, stating “These characteristics refer to the population of fibers as observed in a bulk sample. If a sample contains a fibrous component of which most of the fibers have aspect ratios of < 20:1 and that do not display the additional asbestiform characteristics, by definition the component should not be considered asbestos”. However, there are several problems with using this passage for the development of differential counting procedures, one related to aspect ratios, and another related to the analysis of populations. Each are discussed below.

Mean length and aspect ratios cannot be used as a criterion to differentiate crystal morphology in Naturally Occurring Asbestos.

The description of asbestos in regulations and test methods refer to the properties of commercially exploitable asbestos that was mined and incorporated in building materials. Certain asbestos deposits were targeted for commercial mining because the asbestos was present in large quantities and had the characteristics (long fibers, etc.) that were attractive for their use for fire proofing and other purposes. This definition is not entirely applicable to the large range of asbestos occurrences in the United States. As an example, consider the glaucophane³ asbestos found in blueschists throughout California and likely throughout the world (see Erskine and Bailey, 2018). Figure 1 shows two scanning electron photographs of the glaucophane asbestos, showing its asbestiform habit. However, this asbestos does not have all of the classic properties that are described for asbestos in building materials. In particular, the mean length of the fibers is 2.8 microns. The relatively short mean length of the fibers translates into a reduced mean aspect ratio (length divided by width), as reflected in the mean aspect ratio of 10.5 microns for the glaucophane asbestos. If the description of asbestos that was applied to building materials was used to infer that particles could be eliminated from reporting based on

² Extinction angle, defined as the angle between a crystallographic direction and a light vibration direction, is a diagnostic property used to identify the different amphibole species. It is sometimes assumed that fibers that crystallized in the asbestiform habit will always exhibit parallel extinction (extinction angle at or near zero), and therefore, amphiboles that exhibit inclined extinction must have originally crystallized in the non-asbestiform habit, and therefore, should be excluded from reporting.

³ Glaucophane is the aluminous end-member of the Riebeckite (Crocidolite)-Glaucophane solid solution series. Because glaucophane was not mined for the use in building materials, it is not named as a regulated amphibole, even though it is essentially the same mineral as crocidolite.

mean length and aspect ratios, the reporting of “no asbestos detected” would occur, resulting in no requirements for personal protection and monitoring for workers and no perimeter monitoring requirements designed to protect offsite receptors.

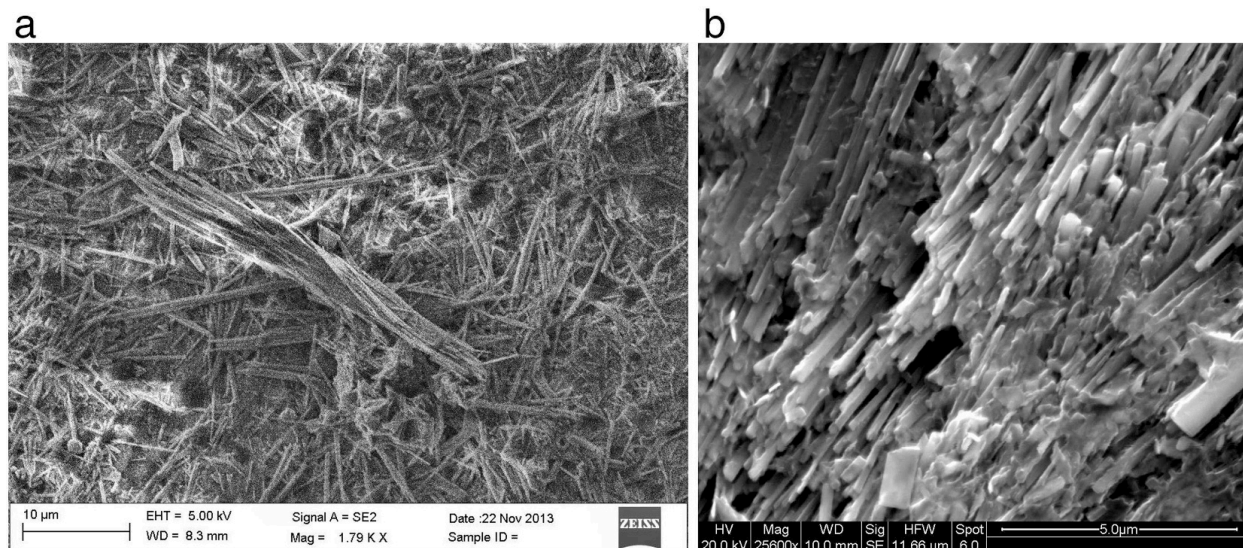


Figure 1: Scanning electron photomicrographs of asbestiform glaucophane in blueschist.

Although the mean length is short and mean aspect ratio of this material is low, there are sufficient numbers of long fibers to produce exceedances of the OSHA PEL by more than 20 times, and routine exceedances of the risk-based threshold that was calculated for the Calaveras Dam project.

The reporting requirements of particles as asbestos in other standard test methods.

The analysis and reporting of particles as asbestos is defined by the procedures specified in various test methods. The following is a survey of several standard and frequently used test methods for asbestos analysis in air.

- International Standards Organization (ISO) released the ISO 10312 method. This TEM (Transmission Electron Microscopy) method is used primarily for health-based exposure risk calculations. It counts structures and fibers greater than 0.5 µm in length and greater than 0.002 µm in width. The procedure is used with a minimum aspect ratio of 5:1, but allows for using 3:1 when performing risk assessments. The method does not allow for selectively removing particles on the basis of crystallization habit or dimensional analysis.
- EPA Level II (Yamate) method. This method was drafted in an attempt to standardize various laboratories' TEM methods for airborne asbestos, and has been largely replaced with the AHERA method, described below. The method counts structures greater than 0.5 µm in length with a 3:1 or greater aspect ratio.

The method does not allow for selectively removing particles on the basis of crystallization habit or dimensional analysis.

- Asbestos Hazard Emergency Response Act (AHERA). This method was developed specifically for air clearance in schools, but has been adopted universally for air sampling and analysis for assessments related to non-worker exposures. The method uses TEM and counts structures greater than 0.5 μm in length with a 5:1 or greater aspect ratio. The method does not allow for selectively removing particles on the basis of crystallization habit or dimensional analysis.
- NIOSH 7400 method. This method, using Phase Contract Microscopy (PCM), is routinely used for personal exposure sampling of workers. It defines fibers as particles greater than 5 micrometers (μm) in length and with a length to width ratio (aspect ratio) of 3:1 or greater. All particles are counted, including fibrous glass, gypsum, cellulose. The method does not allow for selectively removing particles on the basis of crystallization habit or dimensional analysis.
- NIOSH 7402 Method. This method, using TEM, is a companion to the NIOSH 7402 method, designed to selectively adjust the concentration reported by NIOSH 7400 by eliminating particles that are not chrysotile or not one of the five regulated amphiboles. Particles such as fibrous glass are removed from the reported concentration. The method does not allow for selectively removing particles on the basis of crystallization habit or dimensional analysis.

It is apparent that neither EPA, NIOSH nor the international scientific community endorses particle differentiation on the basis of crystallization habit. All reporting, and subsequent health risk determinations, are based on fiber length and width only. It is further apparent that these organizations feel that it is the particle dimensions, and not the mechanism by which the particles became reportable, is of primary importance to exposure assessments.

An EPA method that specifies a protocol for differential counting, with limitations.

EPA method 100.1 to determine the asbestos concentration in water is the only commonly used standard method that provides a protocol to differentiate a fiber population that may have originally crystallized in the asbestiform habit from a population that originally crystallized in the non-asbestiform habit. Section 7.5: Index of Fibrosity, provides a procedure to “discriminate between amphibole asbestos fibers and amphibole cleavage fragments on the basis of the distribution of their aspect ratios”. Using a statistical approach, a fibrosity index of a population is calculated. According to the method, “The fibrosity index as defined above has values exceeding 100 for waterborne dispersions of asbestos- Values below 50 indicate a distribution characteristic of cleavage fragments, or one from which the high aspect ratio fibers have been selectively removed.” The method further states: “Meaningful values of the index of

fibrosity can be obtained for most waterborne fiber dispersions if more than 50 fibers have been measured” (the significance of this passage is discussed in the following subsections). However, under Section 8: Reporting, the method does not allow the fibrosity index to be used to eliminate fibers from inclusion into the reporting asbestos concentration. All particles that meet the definition of an asbestos fiber (a particle of chrysotile and/or the five regulated amphiboles which “has parallel or stepped sides, an aspect ratio equal to or greater than 3:1, and is greater than 0.5 μm in length”) are to be reported as asbestos, regardless of crystal habit.

The importance of obtaining a statistically significant fiber population for differential counting analysis.

The RJ Lee review of regulations and test methods provides characteristics of asbestos and states: “These characteristics refer to the population of fibers as observed in a bulk sample”. A reference to fiber populations is included in several of the test methods cited. The only reference to the minimum size of a significant population is provided in EPA method 100.1 as 50 fibers. This value may not be sufficient if the range of fiber dimensions is large.

To illustrate this concept, consider a study by the RJ Lee group that was conducted to characterize the size distributions of amphibole asbestos fibers and non-asbestos amphibole particles to determine differences and similarities between the populations (Van Orden et al., 2016). Figure 2 is a bivariate distribution graph of asbestiform riebeckite (on the left) and non-asbestiform riebeckite (on the right), showing the population distributions of each when aspect ratio is plotted against width. Note that the population of fibers used in the study was high: in this case, 3,835 non-asbestiform fibers and 22,397 asbestiform fibers were included in the data set. The red box is the field for commercially exploitable asbestos that was presented at a conference in 2010 (reference cited in the Van Orden paper: Chatfield, E. “A Procedure for Quantitative Description of Fibrosity in Amphibole Minerals,” presented at the ASTM Michael E. Beard Asbestos Conference 2010, San Antonio, TX, January 2010). The two specimens were selected on the basis of being “visually characterized as asbestos or non-asbestos”. Note that there is considerable overlap between the two populations within the asbestos and non-asbestos field, indicating that the two populations cannot be unequivocally differentiated without a significant number of particles present in the data set. The low number of particles that are point counted in rocks with asbestos concentrations of less than 10%, such as the rocks at the Rockhill quarry, are not sufficient to use this criterion, even if allowed by the test methods.

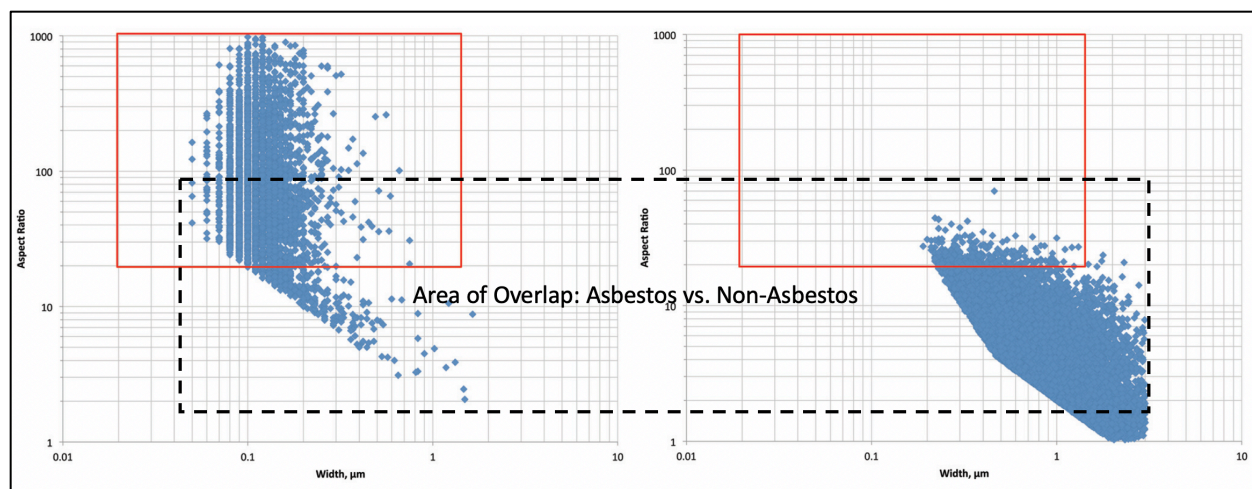


Figure 2: Bivariate distribution graphs of commercially exploitable riebeckite asbestos (“crocidolite”- left) and visually-selected non-asbestiform riebeckite (right). Aspect ratio- y-axes; width- x-axes; red box- asbestiform field from Chatfield, 2010. Plots from Van Orden, 2016.

Several researchers have shown that the most important differentiator between asbestiform and cleavage fragments is the distribution of width populations (see Erskine and Bailey, 2018, for example). Figure 3 shows the width populations of fibers in the Van Orden study. Note the significant overlap in width distributions of the asbestiform and non-asbestiform populations, indicating that without a large population data set, the two populations cannot be unequivocally differentiated.

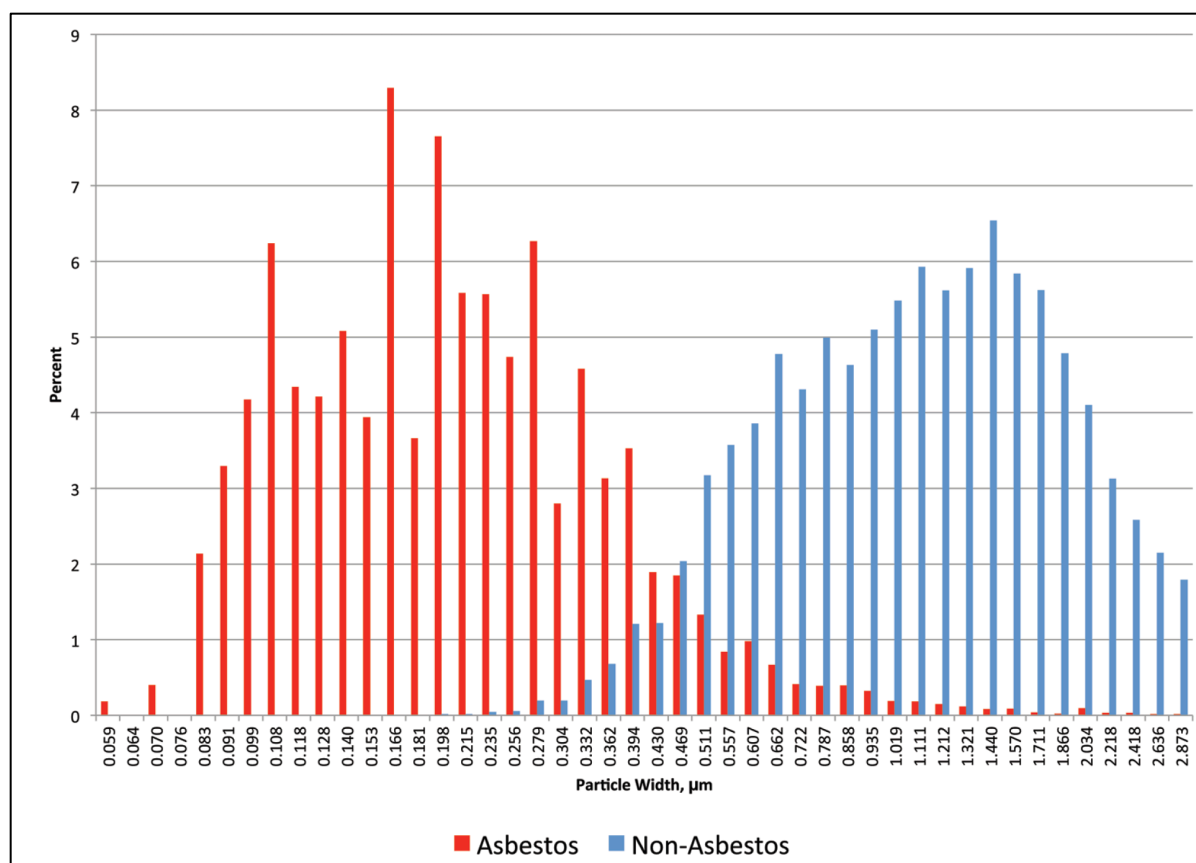


Figure 3: Average width histograms for asbestiform and non-asbestiform particles (From Van Orden, 2016).

A population analysis cannot be conducted for NOA where dual fiber distributions are present.

Even if a population analysis of fiber dimensions were allowed for building materials, it should not be applied to NOA. Asbestos that was exploited for commercial use was targeted because of the properties that is described in the various test methods and regulations. This highly fibrous material was extracted and processed to selectively remove particles that were not desirable, including short and wide particles that may be considered cleavage fragments. Therefore, the asbestos applied to building materials are selectively long and thin. Rocks that contain NOA, however, commonly contain fibers that originally crystallized in the asbestiform and non-asbestiform habit, and generally do not meet the descriptive properties of commercial asbestos. If a population differential analysis was conducted on rocks with a dual population of these two habits, the entire sample could be deemed non-asbestos if the non-asbestiform component was dominant.

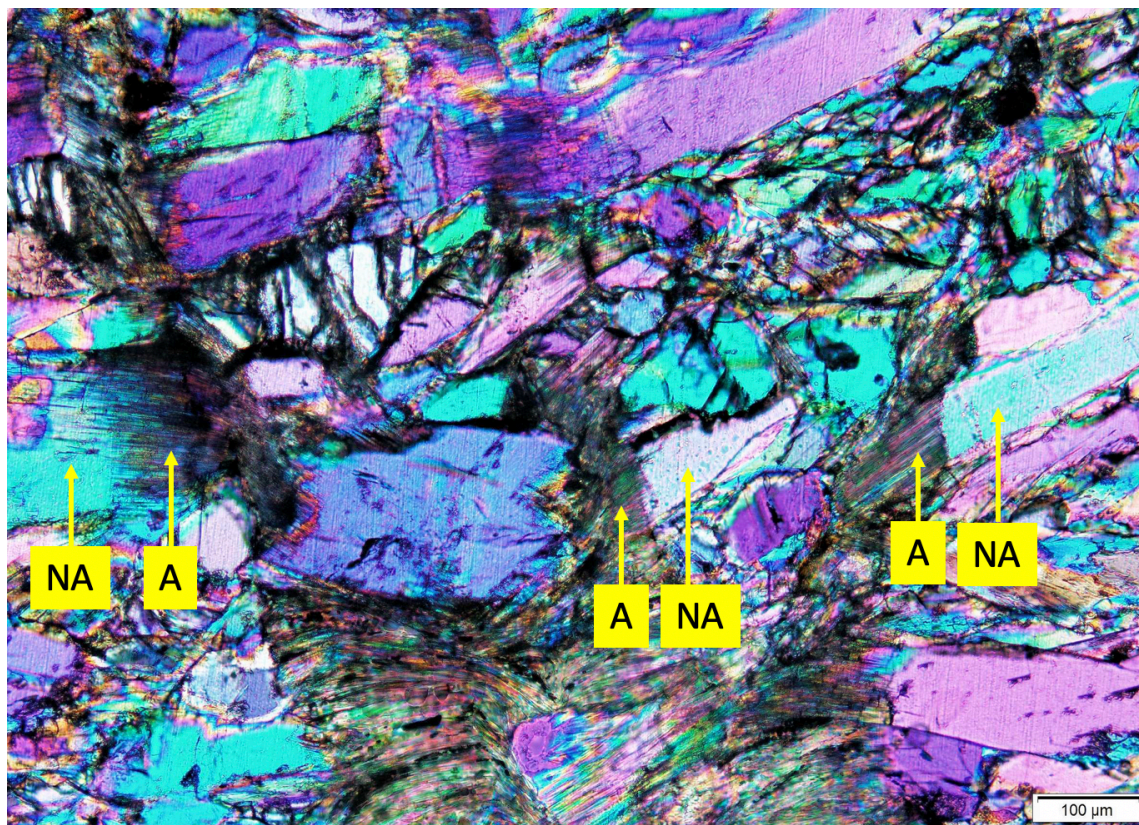
As an example, Figure 4 shows a photograph of a hand specimen of grunerite amphibole selected as an example of non-asbestiform morphology in the Van Orden study. On the right is a sample of common actinolite from the San Bernardino Mountains, southern California. Both exhibit a radial crystal growth morphology that is common for

amphiboles in metamorphic rocks. Thus, the actinolite sample meets the visual criteria used in the Van Orden study. A plot of the aspect ratio vs. width distribution (not presented here) is similar to the non-asbestiform grunerite sample on the left of Figures 2 and 3, and would be considered non-asbestiform with the particles not being reported as asbestos (using a population analysis).



Figure 4: Hand sample of “non-asbestiform” grunerite amphibole (left, from Van Orden et al., 2016) and actinolite from the San Bernardino Mountains, southern California.

However, this sample has a dual occurrence of crystal habits. Figure 5 shows a photomicrograph of a thin section of this sample taken under a polarizing petrographic microscope. Note the three dark-colored zones where the primary non-asbestiform actinolite crystals have been altered along hydrothermal veins to asbestiform actinolite. Because the non-asbestiform component dominates the particle population, and are selectively visible by PLM methodology, the asbestiform actinolite would escape detection and reporting. Thus, visual selection and differential counting protocols cannot ensure that the population of particles are all asbestiform or all non-asbestiform.



*Figure 5: Thin section of common actinolite from the San Bernardino Mountains. The three dark zones in the center of the photo are thin hydrothermal veinlets where the *in situ* conversion of non-asbestiform actinolite to asbestiform actinolite has occurred (the evenly-colored part of the crystals are the original non-asbestiform habit, whereas the thinly banded parts are the asbestiform part of the crystals). For the three crystals shown, NA=non-asbestiform habit and A=asbestiform habit (sample photographed undercrossed polarizers with the compensation plate inserted).*

Standards for asbestos analysis under the NVLAP accreditation for asbestos.

The RJ Lee Group submitted to DEP a NVLAP accreditation certificate as a part of its asbestos testing qualifications. The laboratory represented that it followed EPA Method EPA Method 600/R-93/116, which is the standard test method utilized under the accreditation. To assess whether or not differential counting using particle morphology in a population and/or inclined extinction as a basis for differentiation are procedures that conform to a standard that is utilized across accredited laboratories, EEC contacted a NIST-certified laboratory inspector with many years of accreditation experience and two AHERA-accredited laboratories located in Pennsylvania (contact information will be provided to DEP upon written request). The following is a summary of findings.

1. According to the NIST inspector, the application of differential counting procedures, whether by fiber dimensions of a population or observed

morphological features, is not a part of the analysis and reporting protocols under the AHERA accreditation.

2. According to the NIST inspector, the accurate measurement of extinction angle is a required component for the testing for asbestos, and the presence of an extinction angle to eliminate a particle from reporting is not a part of the analysis under the AHERA accreditation. The extinction angle is used to differentiate the species of amphiboles (actinolite from tremolite, for example), and not to differentiate crystal crystallization morphology.
3. Both laboratories reported that they do not utilize differential particle analysis of a particle population to exclude particles from asbestos reporting.
4. Both laboratories reported that they apply the extinction angle to differentiate between amphibole species, but do not use the presence of an extinction angle to eliminate particles from reporting.

In addition, EEC polled three laboratories at a public forum where the California Air Resource Board (CARB) presented guidelines for its CARB 435 test method, which was developed for aggregate material (Laboratories will be identified to DEP upon written request). All three laboratories were AHERA accredited with experience on EPA NOA projects, and all three companies also had laboratories outside of California. One would be considered a national laboratory with several laboratories located across the United States. When asked if the presence of inclined extinction was used to eliminate particles from asbestos reporting, all three stated that they did not. One of the three laboratories was later asked if differential counting procedures were used and allowed by the EPA method, and the laboratory director stated that it was not.

Please contact me if you have any questions.



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