Control and Prevention of Asbestos Exposure from Construction in Naturally Occurring Asbestos

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Construction projects in Fairfax County, Virginia, routinely disturb amphibole mineral deposits causing actinolite asbestos and tremolite asbestos fibers to become airborne. These same mineral formations exist extensively on the east and west coasts of the United States. Asbestos is regulated by federal, state, and local authorities as a proven human carcinogen. The air-monitoring data presented in this paper show that construction projects in naturally occurring asbestos can produce asbestos exposures to workers and the public. These construction projects can be monitored using standard airborne fiber sampling and analysis techniques, National Institute of Occupational Safety and Health (NIOSH) 7400, and the Occupational Safety and Health Administration (OSHA) reference methods. Exposure to asbestos can create a significant, long-term, liability problem unless prudent actions are taken by responsible parties to prevent asbestos fibers from becoming airborne. The regulations created by the Fairfax County Air Pollution Control Division (APCD) and OSHA 29 CFR 1926.58 are reviewed. The Fairfax County Air Pollution Control Division Control Requirement Directives 1 and 2 are designed to control fugitive dust, establish air monitoring, and require safe disposal and covering of soil. The effective work practices used to control fugitive asbestos emissions from the construction projects are discussed. Construction projects can safely be completed if these regulations and work practices are followed.

The presence of naturally occurring asbestos mineral deposits in Fairfax County, Virginia, was brought to the attention of the Fairfax County Air Pollution Control Division (Fairfax APCD) in 1987. During the building boom of the late 1980s, the first deposits of asbestos rock were discovered at a construction project for an underground parking garage. This project encountered a large vein of tremolite asbestos. As a result of the rock being drilled and crushed, dust covered the entire construction project. Several air drill operators began experiencing itching and skin irritation. After medical and geological investigations, it was determined that the irritation was caused by tremolite asbestos fibers.

State and local agencies are treating the actinolite or tremolite minerals as asbestos-containing material because significant fibrous constituents coexist in a heterogeneous mix with the nonfibrous portion of the rock. The rock produces airborne fiber particles as a result of mechanical deformation. Air-monitoring data, obtained from different construction sites, reflect actual exposure to asbestos fibers during documented work activities. The monitoring data presented in this paper reflect both personal and ambient conditions under which the standards are exceeded.

In addition to a number of construction projects in the county, there are currently several projects involving actinolite or tremolite mineral deposits. The construction and development in these deposits have presented significant challenges to public and employee safety. Air-monitoring data confirm that, as a result of the construction activity, a potential health hazard to the public and workers exists. Violations of the ambient and personal asbestos exposure standards have occurred even while using good wet control methods to control dust. Consequently, employees must have personal protective equipment to avoid asbestos exposure. The violations have necessitated the control and prevention of asbestos exposure from naturally occurring asbestos construction projects.

NATURALLY OCCURRING ASBESTOS: A NATIONAL PROBLEM

Large areas of the United States have asbestiform mineral deposits. These deposits exist as serpentine or amphibole in greenstone and ultramafic rock formations and vary greatly in concentration of their asbestos. California has large land areas of serpentinite formations. These areas contain quarries that have serpentine, chrysotile asbestos. The East Coast contains veins of serpentine and amphibole rock formations that stretch from Canada to Georgia (*1*).

In Fairfax County actinolite and tremolite minerals exist in massive rock formations. The soil layer for these areas runs only 2 to 3 ft deep before striking bedrock. These same conditions may not exist in all areas of the United States. The concentration of asbestos fiber in these mineral deposits can vary from 0 to more than 95 percent as determined by several bulk analysis methods including polarized light microscopy (PLM), X-ray diffraction (XRD) and transmission electron microscopy (TEM). The Fairfax County Soil Science Office conducted a study of randomly selected rocks along the 28.2 km^2 (10.9 mi^2) vein, identified as the Piney Branch Complex (*2*). The average asbestos fiber concentration of the rock, as determined by PLM and TEM analysis, was 38 percent. Thirty-three samples were collected, which ranged from 85 percent to 0 percent. Other samples collected during the last 3 years and analyzed by TEM, XRD, and PLM have yielded comparable, significant asbestos fiber contents.

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In an undisturbed natural environment, these fibers are locked in place within the rock and represent no health hazard. However, when disturbed, for example during construction, these fibers are released as a fine dust that can readily be inhaled into the respiratory system. Long-term exposure to such conditions could lead to debilitating or fatal diseases. Dry, windy conditions could carry this hazardous dust beyond the boundaries of a construction site. Individuals, whose only connection with the site is their proximity to it, could be exposed to a serious health hazard.

The Piney Branch Complex trends northeast to southwest through the county from northwestern Fairfax City to the Occoquan River west of Clifton. The asbestiform minerals found within this portion of the formation form long, strong, flexible fibers that can be separated into bundles or subdivided into progressively finer needle-like fibers. Smaller areas of the Piney Branch Complex occur to the north. The asbestiform minerals in these units may contain chrysotile, as well as actinolite and tremolite. This formation is generally found associated with the soil group referred to as the "orange soil" series. This soil group is formed in weathered materials from mixed basic and acid rock of the Piedmont Uplands creating a plastic clay. The orange soils series serves as a marker for the actinolite and tremolite bedrock beneath the clay (*3*).

The fibrous or asbestos forms of actinolite and tremolite minerals are likely to occur in localized areas along zones of extreme deformation (such as faulting and folding). These localized areas include fibrous veins readily observable with the unaided eye and adjacent bedrock that is generally a heterogeneous mixture of fibrous forms and nonfibrous forms of the parent minerals. Various mineralogical forms are found, including prismatic, acicular, and asbestiform, with dramatic heterogeneity throughout the region and even within individual projects. The localized concentrations are difficult to identify before rock excavation. Therefore, all areas within the Piney Branch Complex are treated as a potential site for asbestos.

Consultations with various professionals including mineralogists, geologists, soil scientists, and petrologists experienced in asbestos mineral study have supported the view that undisturbed soil overlying asbestos-laden bedrock is unlikely to contain appreciable amounts of asbestos. Two fundamental principles provide the basis for this position. First, in the weathering process, actinolite and tremolite minerals, as well as antigorite and chrysolite are known to transform into clay mineral. Second, there is no recognized transport mechanism that accounts for asbestos mineral migration from the underlying bedrock into the upper soil horizons without mechanical disturbance. However, soils in construction areas may contain asbestos if the underlying asbestos-containing rock has been disturbed and incorporated into the soil, or if asbestos-containing rock has been deposited on the site.

Actinolite or tremolite may occur in the transition layers of the soil. These clays have no connection with the traditional Virginia red clay. The reference to "orange" bears no relationship to its actual color, which is a yellow brown to olive. The orange soil series is used as an indicator for the location of the Piney Branch Complex. The rock formation in the Piney Branch Complex is typically olive-green to blue-green in color, with varying degrees of hardness and concentrations of asbestos fibers. The map of major problem soils areas issued by the County of Fairfax (*4*) identifies the location of the orange soil series and where it is assumed the rock formation contains asbestos fibers. These areas are widely dispersed in the northern part of the county bordering Maryland along the Potomac River. A well-defined area of this soil group also runs through the southwestern portion of the county that borders on Prince William County along Bull Run. The Fairfax County soils map makes it possible to accurately predict the potential sites for asbestos-containing areas.

FIBER, CANCER, AND LIABILITY

Originally, the commercial use of asbestos required fiber characteristics of strength and durability. This is reflected in the geological or mineralogical definition of asbestos. The perspective of OSHA and the Environmental Protection Agency (EPA) asbestos regulations has always been based on health effects. NIOSH has stated their position that asbestos has "no safe exposure level." It must be understood that asbestos is one of a handful of substances conclusively proven to be a human carcinogen. OSHA defines fiber in 29 CFR 1926.58 (*b*) as "a particulate form of asbestos, five micrometers or longer, with a length-to-diameter ratio of at least 3 to 1."

Naturally contaminated materials pose a significant threat and there is no technically feasible way to separate "the safe from the bad" during the construction process. Federal, state and local agencies use the term asbestos to determine if a material in question is regulated. Once the material meets the chemical, size, and shape criteria for asbestos, then all the material is treated as asbestos and regulated.

Recent medical research from Europe and the United States documents evidence that tremolite asbestos fiber is a more potent carcinogen than chrysotile asbestos (*5*). It is well known that crocidolite, amosite, and anthophyllite, which are also in the amphibole family of asbestos, are powerful carcinogens. The amphibole fibers are very durable and account for the concern about tumor formation. Tremolite has been found in the lung tissue of tumor victims who were thought to have been exposed only to chrysotile. The victims were exposed to chrysotile contaminated with 1 to 3 percent tremolite (*5*).

EPA has mandated that state and local air pollution agencies conduct particulate sampling based on the PM-10 Standard, 40 CFR 50.6 (c). This standard measures particles with an aerodynamic diameter less than or equal to a nominal 10 μm according to the method required in 40 CFR 50, Appendix *J*, and 40 CFR 53.40. Research has shown that particles that are 10 μm or smaller pose a greater health risk because of their ability to penetrate and remain in the lung (*6*). Serpentine and amphibole asbestos particulate with an aerodynamic size of 10 microns or less should therefore be considered a respiratory hazard.

REGULATORY APPROACH IN FAIRFAX COUNTY, VIRGINIA

Construction in the asbestos soil regions of Fairfax County involves a two-stage approach. The Fairfax County Health Department, Fairfax APCD is concerned with the potential public exposure to asbestos fibers during construction. They enforce the Fairfax APCD Control Requirement Directives 1 and 2 for Construction Activities in Actinolite/Tremolite

Soil Sources (CRD 1 and 2). The Virginia Department of Labor and Industry (VDLI), Occupational Health Division, regulates the interior of the construction site as it pertains to employee exposure. The interior of the construction site is regulated by the Asbestos Standard, 29 CFR 1926.58. These two agencies work in concert to control the emissions of asbestos fibers during work activities.

Contractors are required to comply with the Fairfax APCD standards in CRD 1 for construction work in areas of Fairfax County that contain actinolite or tremolite mineral deposits. The following is a summary of the Fairfax APCD CRD 1, which is the heart of the regulatory approach to protecting the public health.

1. Dust control must be practiced at all times.
2. Air monitoring of the construction site must be conducted during all phases of earthwork involving actinolite- or tremolite-containing material, and comply with the ambient air concentration standard for asbestos.
3. An appropriate, safe, disposal site must be used to dispose of actinolite- or tremolite-contaminated spoils whether removed or not removed from the construction site. All final disposal areas and the finished grade of the developed land shall be covered with 6 in. of clean compacted material.
4. Sufficient notice of asbestos shall be given to all employees and contractors on the site in compliance with the OSHA Asbestos Standard (29 CFR 1926.58).

Personal and ambient air monitoring are conducted according to the NIOSH 7400 method. The personal air monitoring required by OSHA regulation 29 CFR 1926.58 (*f*) measures the concentrations of asbestos particulate in the direct breathing zone of the employee. The OSHA regulation 29 Part 1926.58 (*c*) states that no employee may be exposed to an asbestos fiber concentration of greater than the personal exposure limit (PEL) of 0.2 fibers/cm^3 (f/cm^3) of air in an 8-hr time-weighted average. These personal samples are used in evaluating the fiber releases from specific work activities. The ambient air monitoring is required by Fairfax APCD CRD 1 and is used to determine the public's exposure to asbestos beyond the construction project boundaries. The ambient air concentration standard for asbestos is expressed as a 24-hr average that is not to exceed 0.020 (f/cm^3) of air. These samples are measured by monitors at points demarcating public areas from the construction site.

Employees must be informed when the potential for asbestos is present at their work site, and they must be given asbestos awareness training. Employers must establish regulated areas where asbestos fibers can reasonably be expected to exceed the OSHA PEL for workers. Warning signs must be posted to identify regulated areas and warn the public of potential hazards. Employers with a regulated area on multiemployer work sites must inform all employers of the nature and requirements of their regulated areas.

CONTROL PRACTICES

Asbestos mineral formations are encountered by construction activities other than the mining and stone industries. The mining and stone industries choose to work low asbestos content formations, whereas the construction industries are working in these asbestos formations for purposes unrelated to the asbestos content of the excavated spoils. The OSHA Construction Industry Standards are not limited to the mining or stone industries. The VDLI regulation for Licensed Asbestos Contractor Notification, Asbestos Project Permits and Permit Fees Section 1, Definitions, define "construction" as

> . . . all the on-site work done in buildings or altering structures from land clearance through completion, including excavation, erection, and the assembly and installation of components and equipment.

Construction has not been banned in the Piney Branch Complex because it has been demonstrated that commonsense controls can prevent asbestos exposure. Although it is not practical to create a negative pressure enclosure over naturally occurring asbestos construction sites, it is possible to

1. Implement dust control practices that use water;
2. Establish regulated areas where there is a potential to exceed the PEL;
3. Establish an additional controlled area to limit access to the construction site by the "competent person";
4. Implement decontamination procedures for workers and equipment;
5. Establish positive and documented notification procedures among owners, employers, employees, contractors, and subcontractors in regulated and controlled areas; and
6. Post proper signs so that workers and the public are positively notified of the potential hazards for regulated and controlled areas.

Water is the key to controlling the fugitive dust and thus asbestos emissions from these operations. Application techniques vary from a sophisticated spray system attached directly to the rock-cutting or drilling equipment, to strategically aiming a water hose at a work activity or employing a water truck to spray the entire work area and haul roads. All exposed and excavated material must be kept damp to prevent the release of asbestos fibers into the air. The variable rate fogger nozzles employed in fighting petroleum fires are an excellent tool for this purpose. The fogger nozzle produces a wet mist that knocks down airborne fibers, and water consumption can be controlled by the operator.

The operation of tracked air drills and rock saws in an actinolite or tremolite mineral deposit has great potential to cause the OSHA PEL to be exceeded. Therefore, these work areas must be designated as regulated areas with proper implementation of the Asbestos Standard. Other activities that have produced high airborne fiber concentrations include truck loading, excavating, blasting, grading, and vehicle movement on interior project dirt roads.

Contractors must therefore establish a regulated area where asbestos fibers can reasonably be expected to exceed the PEL. Employees in a regulated area must wear personal protection equipment provided by the employer, including properly fitted and tested respirators and clothing. There must be facilities for decontamination of workers before they leave the regulated areas at the construction site. Decontamination trailers with showers and changing rooms have been installed on construction sites. Here, workers can dress in personal protective equipment before entering the site and can remove personal protective equipment and shower before going home for the day. This prevents contamination of street clothing and reduces secondary exposure. Disposal of contaminated Tyvek suits and other items are handled in the same manner as they are at abatement projects. Items are placed in approved sealed containers with proper signage and deposited in approved landfills.

The creation of controlled areas prevents unauthorized or uninformed individuals from entering the construction site and risking accidental exposure to asbestos. If an individual did enter the site and allege exposure, the owner and contractors could be held liable and subject to civil suit. This is the reasoning for the notifications in Items 5 and 6 previously listed and required by 29 CFR 1926.58 (*d* and *k*). The certified industrial hygienist or consultant would control access to the construction project, provide awareness training, and determine the employee's level of personal protection equipment. Tyvek suits or suitable protective clothing, along with appropriate respiratory protection, should be worn by workers inside project boundaries if earth and rock have been disturbed, even though they will not be entering a regulated area.

In addition, all tools, vehicles, and equipment should be thoroughly decontaminated before they leave the construction site. Appropriate methods of employee decontamination are similar to those for other asbestos abatement projects. Construction equipment should be decontaminated using fire hoses before removal from the construction site.

Large amounts of asbestos-contaminated rock spoils are generated during construction in the asbestos soil areas. Disposition and transport of these spoils is of particular concern because of the potential release of fugitive asbestos dust and future development of the disposal or fill areas. Identification of safe disposal sites for contaminated material presents challenges for the construction industry as well as landfill operators. Landfill operators have been reluctant to accept spoils because they contain asbestos and occupy large volumes of landfill space. During recent construction of an Interstate access ramp, more than 25,000 m^3 of highly contaminated material were moved to a large, tree-covered interchange median. A small hill was created among the trees, covered with clean fill and planted with covering grasses. On another construction project aesthetic berms and changes to the final grade solved the problem of disposal. Construction planning and design should include the disposal of prior spoils.

Trucking of contaminated spoils can be handled in a safe manner. Water or other wetting and binding agents can be used to successfully transport these spoils in a dust-free way. Developed lots should have an additional layer of clean fill to seal the actinolite or tremolite asbestos, soil, and rock. The depth of the fill should be sufficient to provide a factor of safety to ensure that exposure will not occur. The recommended depth is at least 6 in. of clean, compacted soil, as practiced by landfills. A cover planting (sodding, hydroseeding) can be applied to ensure that the fill maintains the seal.

AIR-MONITORING RESULTS

The project monitoring reports submitted to the Fairfax APCD by contractors are the source of the data presented in this paper. The reports include a daily description of work activities, weather conditions, and diagrams of the project that indicate the location of work activities and monitors. The air-monitoring results are listed by sample time, volume, and fibers/cm^3 of air. Compliance with the significant ambient air concentration (SAAC) is determined by converting the raw data into a 24-hr average concentration. The equation preshented in the Fairfax APCD CRD 2 for calculating the 24-hr average concentration is as follows:

$$\frac{(W \times S) + (2 \times \mathrm{MDC}) + \{[24\,\mathrm{Hr} - (W + 2\,\mathrm{Hr})] \times \mathrm{BGC}\}}{24\,\mathrm{Hr}}$$

where

W = work day in hours,
S = sample results in fibers/cm^3,
MDC = mean decay period concentration (concentration decays to background levels during the 2 hr following the end of the workday), and
BGC = background concentration is approximately 0.005 fibers/cm^3.

$$\mathrm{MDC} = \frac{\text{Start Concentration} + \text{End Concentration}}{2} = \frac{S + \mathrm{BGC}}{2}$$

(NOTE: Because $2 \times \mathrm{MDC} = 2 \times \frac{(S + 0.005)}{2} = S + 0.005 \approx S$ S may be substituted for $2 \times$ MDC as a simplification.)

Significant fiber levels above the PEL have been observed at construction sites. Fiber levels generated are dependent on work activities, control methodologies, weather conditions, individual worker performance, and mineralogical form and concentration of the actinolite and tremolite deposits encountered on the construction project. High-fiber air-monitoring levels in the actinolite or tremolite mineral deposits have even been encountered independent of visible asbestiform formations. The construction projects listed in Table 1 are within the orange soils group areas and have tested positive for the asbestos forms of actinolite and tremolite. The air monitoring results in Tables 2 through 5 are from these sites. Shown in these tables are areas in which standards have been exceeded and a potential to exceed the worker PEL and the public SAAC for many different work activities. They do not include the majority of the air-monitoring data that reflect compliance with the standards.

The bulk of the monitoring reports submitted show that the fugitive dust-control methods attenuate the exposure problem. When no fugitive dust-control methods were employed there have been dangerously high levels. During dry caisson drilling for asbestos soil Project 3, TEM analysis indicated an airborne asbestos concentration of 1.145 f/cm^3 (Table 2, Project 3) near the property line. On the same project, a caisson inspector recorded a breathing zone concentration of 0.278 f/cm^3 (Table 3, Project 3). Another project experimented using dry drilling methods with a tracked air drill to determine possible exposure for the employees. The fugitive dust was so dense that the experiment was stopped after 30 min. The air-monitoring results showed 0.3 f/cm^3 (Table 2, Project 14).

TABLE 1 Natural Asbestos Soil Construction Projects

Project	Type of Project
1	Commercial Office High Rise Complex
2	Public Secondary School
3	Commercial Office High Rise Complex
4	Commercial Office High Rise Complex
5	Addition of Interstate Interchange Ramps
6	Expansion of Existing Fleet Garage
7	Residential Subdivision Project
8	Municipal 48 Inch Water Line Tunnel
9	Installation of Small Water Line
10	Residential Subdivision Project
11	Largest Residential Subdivision Project
12	Residential Subdivision Project
13	Small Shopping Center
14	Expansion of Existing Parking Decks.
15	Enlargement of Secondary Road Intersection
16	Widen an Existing Road to Four Lanes
17	Small Commercial Building
18	Religious Temple and Associated Buildings
19	Residential Neighborhood Utility Work
20	Addition of Interstate Interchange Ramps

TABLE 2 Air Monitoring Data from Caisson Drills, Air Drills, and Other Compressed Air-Driven Equipment.

	Sample							
Proj	Date	Type	Meth	Volume Liters	Min.	Fibers / Cm^3	Notes	TWA
1	7-6-87	BZ	TEM	54.6	39	0.14	DRY AIR DRILLING	
1	7-6-89	BZ	TEM	20.0	28	0.23	DRY AIR DRILLING	
3	7-15-88	AREA	TEM			1.145	CAISSON DRILL	
3	7-15-88	AREA	TEM			0.242	CAISSON DRILL	
3	9-29-88	AREA	PCM	1130	452	0.071	CAISSON DRILL	
3	9-29-88	AREA	PCM	723	289	0.45	INSIDE CAISSON	
3	10-17-88	AREA	PCM	160	64	0.164	CAISSON DRILL	
3	10-20-88	BZ	PCM	363	145	0.096	CAISSON DRILL	
3	10-21-88	AREA	PCM	815	326	0.096	CAISSON DRILL	
4	11-15-88	BZ	PCM		150	0.3	AIR DRILLER	.097
4	11-17-88	BZ	PCM		232	0.13	AIR DRILLER	.032
4	12-05-88	BZ	PCM		340	0.103	AIR DRILLER	.072
4	12-07-88	BZ	PCM		282	0.21	AIR DRILLER	.133
4	12-8-88	BZ	PCM		165	0.11	AIR DRILLER	.047
4	12-10-88	BZ	PCM		270	0.095	BLASTING	.075
5	7-10-89	BZ	PCM	211		0.127	AIR DRILLER	
6	7-17-89	BZ	PCM	1037	415	0.071	THIS PCM AND TEM	
6	7-17-89	BZ	TEM	1037	415	0.164	SAME SAMPLE-DRILLER	
6	10-18-89	BZ	PCM	350	140	0.068	HOE RAM	
6	10-18-89	BZ	PCM	338	135	0.070	HOE RAM	
7	10-25-89	BZ	PCM	252	240	0.126	AIR DRILLER	
7	10-27-89	BZ	PCM	246	240	0.544	AIR DRILLER	
7	10-28-89	BZ	PCM	240	240	0.075	AIR DRILLER	
7	11-2-89	BZ	PCM	240	240	0.296	AIR DRILLER	
7	11-14-89	BZ	PCM	708	354	0.355	AIR DRILLER	
7	11-14-89	BZ	PCM	69	30	0.092	" SAME MAN AS ABOVE	
7	11-15-89	BZ	PCM	445	445	0.279	AIR DRILLER	
7	11-29-89	BZ	PCM	638	425	0.097	AIR DRILLER	
7	11-29-89	BZ	PCM	60	30	0.682	DRY AIR DRILLING, WITH FABRIC FILTER	
7	11-30-89	BZ	PCM	540	360	0.142	AIR DRILLER	
7	11-30-89	BZ	PCM	60	30	0.045	AIR DRILLER	
7	1-19-90	BZ	PCM	473	315	0.092	AIR DRILLER	
7	2-1-90	BZ	PCM	585	390	0.122	AIR DRILLER	
7	2-6-90	BZ	PCM	570	380	0.184	AIR DRILLER	
7	2-8-90	BZ	PCM	488	325	0.106	AIR DRILLER	
7	2-12-90	BZ	PCM	60	30	0.094	AIR DRILLER	
7	2-21-90	BZ	PCM	435	290	0.111	AIR DRILLER	
7	3-19-90	BZ	PCM	581	287	0.129	AIR DRILLER	
9	7-10-89	BZ	PCM	63	35	0.11	AIR DRILLER	
16	10-4-90	BZ	PCM	453		0.40	HAND AIR DRILL	
16	10-4-90	BZ	PCM	247		0.10	HAND AIR DRILL	

NOTE: *Proj.*: Sample collected at this natural asbestos soil project. The number corresponds to that in Table 1. *Type*: *BZ* = employee breathing zone sample for OSHA compliance; *AREA* = sample collected near group of workers or perimeter of construction project. *Meth.*: *TEM* filter was analyzed by transmission electron microscopy, *A* and *B* protocols; *PCM* filter was analyzed by phase contrast microscopy according to NIOSH 7400 method. *Fibers/cm*^{3}: Fibers per cubic centimeter of air as submitted in the air-monitoring report. *TWA*: Eight-hr time-weighted average for OSHA compliance.

OSHA action levels of 0.1 f/cm³ have been exceeded despite implementation of proper dust controls. High risk for exposure to asbestos can be seen from the data in Table 2 for tracked air and caisson drillers. The sample data collected in Table 4 for earth-moving equipment show that they also produce OSHA action levels. The data in Table 3 for construction workers illustrate that even passive activities are at risk for exposure. In one particular case, a surveyor inspecting storm drain structures was exposed to an average concentration of 0.73 f/cm³ (Table 3, Project 16). One drain structure was actually located directly in a vein of actinolite asbestos. Because no other work was taking place during his inspection, the area had not been watered and was dry. Fortunately, the inspector was in the controlled area of this project and was

TABLE 3 Air-Monitoring Data for Construction Workers

Proj	Sample Date	Type	Meth	Volume Liters	Min.	Fibers / Cm³	Notes	TWA
1	8-29-87	BZ	PCM			0.079	GEO. INSPECTOR	
3	9-29-88	BZ	PCM	883	353	0.072	INSPECTOR	
3	9-30-88	BZ	PCM	1020	408	0.091	INSPECTOR	
3	10-7-88	BZ	PCM	213	85	0.278	INSPECTOR	
3	10-12-89	BZ	PCM	750	300	0.199	INSPECTOR	
3	10-14-89	BZ	PCM	100	40	0.260	INSPECTOR	.13
3	10-17-89	BZ	PCM	813	325	0.125	INSPECTOR	
4	5-18-89	BZ	PCM		128	0.12	LABORER	.06
4	5-20-89	BZ	PCM		282	0.10	LABORER	.06
4	7-7-89	BZ	PCM		100	0.72	LABORER	.17
4	7-12-89	BZ	PCM		275	0.15	" PUMPING H2O	.11
4	7-29-89	BZ	PCM		242	0.11	LABORER	.08
4	8-7-89	BZ	PCM		279	0.12	LABORER	.07
4	8-11-89	BZ	PCM		230	0.26	LABORER	.15
4	8-30-89	BZ	PCM		16	0.54	PIPE LAYER	.03
4	10-12-89	BZ	PCM		294	0.09	PIPE LAYER	.06
7	12-18-89	BZ	PCM	60	30	0.090	PIPE LAYER	
7	6-12-90	BZ	PCM	423	315	0.067	CABLE LAYER	
8	5-11-89	BZ	PCM	564	232	0.12	PIPE LAYER	.08
9	7-10-89	BZ	PCM			0.11	PIPE LAYER	
16	10-2-90	BZ	PCM	435		0.73	SURVEYOR	.27

NOTE: *Proj.*: Sample collected at this natural asbestos soil project. The number corresponds to that in Table 1. *Type*: *BZ* = employee breathing zone sample for OSHA compliance; *AREA* = sample collected near group of workers or perimeter of construction project. *Meth.*: *TEM* filter was analyzed by transmission electron microscopy, *A* and *B* protocols; *PCM* filter was analyzed by phase contrast microscopy according to NIOSH 7400 method. *Fibers/cm³*: Fibers per cubic centimeter of air as submitted in the air-monitoring report. *TWA*: Eight-hr time-weighted average for OSHA compliance.

TABLE 4 Air-Monitoring Data from Earth-Moving Equipment

Proj	Sample Date	Type	Meth	Volume Liters	Min.	Fibers / Cm³	Notes	TWA
4	1-24-89	BZ	PCM		190	0.14	LOADERS	.14
4	1-24-89	BZ	PCM		287	0.14	BULLDOZER	.14
4	8-2-89	BZ	PCM		272	0.11	TAMPER	.08
4	8-3-89	BZ	PCM		277	0.11	TAMPER	.10
4	8-9-89	BZ	PCM		415	0.11	ROLLER	.10
4	10-11-89	BZ	PCM		259	0.10	TAMPER	.05
4	8-31-89	BZ	PCM		168	0.09	TRUCK	.03
4	10-16-89	BZ	PCM		572	0.12	OPEN CAB	.10
5	6-26-89	AREA	PCM	214		0.12	TRUCK & LOADER	
5	6-26-89	BZ	PCM	90		0.05	TRUCKS	
5	6-21-89	AREA	PCM	561		0.04	LOADERS	
7	10-16-90	BZ	PCM	75	30	0.036	OPEN CAB BACKHOE	
15	7-5-90	AREA	PCM	365	146	0.075	TRUCK LOADING	

NOTE: *Proj.*: Sample collected at this natural asbestos soil project. The number corresponds to that in Table 1. *Type*: *BZ* = employee breathing zone sample for OSHA compliance; *AREA* = sample collected near group of workers or perimeter of construction project. *Meth.*: *TEM* filter was analyzed by transmission electron microscopy, *A* and *B* protocols; *PCM* filter was analyzed by phase contrast microscopy according to NIOSH 7400 method. *Fibers/cm³*: Fibers per cubic centimeter of air as submitted in the air-monitoring report. *TWA*: Eight-hr time-weighted average for OSHA compliance.

TABLE 5 Air-Monitoring Data from the Perimeter or Nonwork-Oriented Monitors

	Sample							
Proj	Date	Type	Meth	Volume Liters	Min.	Fibers / Cm^3	Notes	TWA
1	8-29-87	BZ	PCM			0.028	NEAR PERIMETER	
2	8-27-87	AREA	TEM			0.0195	NO WORK IN PROGRESS	
2	8-27-87	AREA	TEM			0.0165	NO WORK IN PROGRESS	
2	9-28-87	AREA	TEM			0.035	NO WORK IN PROGRESS	
3	1-20-89	AREA	PCM	315	126	0.144	WEST PERIMETER	
3	1-20-89	AREA	PCM	803	321	0.06	WEST PERIMETER	
4	4-25-89	BZ	PCM		163	0.05	NEAR PERIMETER	.02
5	6-27-89	AREA	PCM	1238		0.23	CLEARANCE	
6	6-5-89	AREA	PCM	1050	420	0.045	WEST END PERIMETER	
6	6-28-89	AREA	PCM	263	105	0.14	EAST OF WORK AREA	
6	6-28-89	AREA	PCM	900	360	0.046	FAR SOUTH WORK AREA	
6	7-10-89	AREA	PCM	1043	417	0.042	SOUTHERN PERIM AREA	
6	7-11-89	AREA	PCM	1075	430	0.042	SOUTHEAST PERIM AREA	
6	9-6-89	BZ	PCM	900	450	0.069	NEAR PERIMETER	
6	9-22-89	AREA	PCM	1060	424	0.060	DOWNWIND	
8	4-25-89	AREA	TEM & PCM	902	384	0.01	0.021 STRUCTURES/Cm^3	
8	4-25-89	AREA	TEM & PCM	1181	455	0.01	0.038 STRUCTURES/Cm^3	
8	4-28-89	AREA	PCM	132	56	0.04	NEAR DECON TRAILER	
9	7-10-89	AREA	PCM	59	58	0.09	DOWNWIND	
10	11-14-89	AREA	PCM			0.06	WEST EDGE	
10	11-14-89	AREA	PCM			0.04	WEST EDGE	
10	11-21-89	AREA	PCM			0.05	EAST EDGE	
15	7-5-90	AREA	PCM	363	145	0.058	PERIMETER	

NOTE: *Proj.*: Sample collected at this natural asbestos soil project. The number corresponds to that in Table 1. *Type*: *BZ* = employee breathing zone sample for OSHA compliance; *AREA* = sample collected near group of workers or perimeter of construction project. *Meth.*: *TEM* filter was analyzed by transmission electron microscopy, *A* and *B* protocols; *PCM* filter was analyzed by phase contrast microscopy according to NIOSH 7400 method. *Fibers/cm*^{3}: Fibers per cubic centimeter of air as submitted in the air-monitoring report. *TWA*: Eight-hr time-weighted average for OSHA compliance.

wearing personal protective equipment. Normally, this passive work activity would not have been defined as a regulated area by the OSHA Asbestos Standard.

The perimeter of construction sites is monitored to protect the public from asbestos exposure. Perimeter sample results are obtained at the edge of the project boundary and can be more than 300 m or right next to the actual source of the fugitive emissions. In Table 5, high perimeter readings can be confirmed even when no work activities are reported on the site. In this particular case, Project 2, the project was highly contaminated with asbestos and the excavations were violent. Conversely, low readings are not unusual for very large construction projects with a substantial distance and buffer between the work and perimeter.

Because high asbestos levels like those previously mentioned are not easily predicted, it is necessary to be conservative with controls to ensure protection. Certainly, if good dust control and safety are practiced, protection for the public and employees can be achieved.

CONCLUSIONS

Naturally occurring asbestos represents a potential problem nationwide for anyone responsible for construction. Every project involving or potentially involving deposits of asbestiform rock is regulated by OSHA Construction Industry Standard 29 CFR 1926.58. Because asbestos is a proven human carcinogen and NIOSH has concluded "there is no known threshold of exposure to asbestos below which there is no risk," it is imperative to protect everyone from asbestos exposure whether the project is temporary or long term. The presence of asbestos, confirmed by appropriate laboratory analysis, should be dealt with as a hazardous material regardless of its origin or the working circumstances. The asbestos regulations were promulgated to address the health risks associated with asbestos no matter where the exposure might be encountered. It is interesting that insurance companies have required more stringent state-of-the-art standards for naturally occurring asbestos construction projects. They recognize that existing regulations provide only the minimum protection and do not mitigate civil tort.

The air-monitoring data presented demonstrate the potential for asbestos exposure. Construction work can be successfully performed without exposure to employees if good dust controls are practiced. However, compliance with the regulations may require personal protective equipment and other special procedures. Also, dust control and limited access to the site are integral parts of complying with the regulations and reducing owner and contractor liabilities.

REFERENCES

1. Clifton, R. A. *What is Talc? Definitions for Asbestos and Other Health-Related Silicates*. ASTM STP 834 (Benjamin Levadie, ed.), ASTM, Philadelphia, Pa., 1984, pp. 158–174.
2. Johnson, L. K. *Survey of Mineral Deposits in Fairfax County Orange Soils Group*. Fairfax County Soil Science Office, Fairfax County, Va., 1987.
3. Johnson, L. K. *Soils of Fairfax County: General Ratings for Urban Development*. Fairfax County Soil Science Office, Fairfax County, Va., 1989, pp. 7, 11.
4. *Major Problem Soils Areas of Fairfax County Map*. Fairfax County Soil Science Office, Fairfax County, Va., 1979–1980.
5. Mossman, B. T., J.Bignon, et al. Asbestos: Scientific Developments and Implications for Public Policy. *Science*, Vol. 247, Jan. 19, 1990, pp. 294–301.
6. Lee, K. P. Lung Response to Particulates With Emphasis on Asbestos and other Fibrous Dusts. *CRC Critical Reviews in Toxicology*, Vol. 14, Issue 1, pp. 33–86.

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