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ACTIVITY-BASED AIR SAMPLING FOR ASBESTOS

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1.0 SCOPE AND APPLICATION

As a result of a directive issued by the United States Environmental Protection Agency (U.S. EPA) Office of Solid Waste and Emergency Response (OSWER Directive 9345.4), estimating asbestos exposures resulting from suspension of soils is an area of increased importance to the Superfund Program. Such exposures may be estimated via monitoring and/or modeling methods. At present, models are not available to accurately estimate asbestos exposure associated with the disturbance of contaminated soil. Therefore, personal monitoring in the form of activity-based sampling (ABS) is the most appropriate technique to estimate exposure. Personal exposure is influenced by the activities performed, the duration of the activity and the site-specific soils of interest.

At a number of diverse sites across the county (Clear Creek Management Area, San Benito County, California (CA), El Dorado Schools, North Ridge Estates, Klamath Falls, Oregon, Slodusty Road, Garden Valley CA, Ambler Alaska), the U.S. EPA has demonstrated that disturbance of soil with low levels of asbestos (including soil concentrations less than 1.0 percent (%) as measured by Polarized Light Microscopy) can potentially result in significant concentrations (>0.1 structures per cubic centimeter) of respirable asbestos fibers in the breathing zone of individuals engaged in various physical activities. This may result in a cancer risk in excess of Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial objectives.

Since personal monitoring is more representative of actual exposure than samples obtained from a fixed downwind location (McBride 1999, Rodes 1995, Hildemann 2005), personal monitoring results are generally most relevant to CERCLA risk characterizations. Thus the best measure of actual exposure to an individual would be through the collection of personal air samples over the exposure period of interest (NIOSH 1977). However, at CERCLA sites, it is neither always possible nor practical to do so. EPA has thus developed a sampling procedure called ABS, designed to mimic the activities of a potential receptor.

As part of ABS, U.S. EPA or contractor personnel trained in hazard recognition and mitigation, serve as surrogates for the potentially exposed populace of interest. ABS simulates routine activities in order to mimic and evaluate or predict personal exposures from disturbance of materials potentially contaminated with asbestos. Similar sampling approaches have been used to assess exposures to pesticides and lead (U.S. EPA 2000) and this technique has long been a cornerstone of industrial hygiene wherein workplace exposures are routinely assessed via personal exposure monitoring.

This document provides guidance for ABS for a particular set of activities or scenarios. Personal monitoring may be conducted during various activities such as raking, All-Terrain Vehicle (ATV) riding, rototilling, digging, a child playing in the dirt, weed whacking, lawn mowing, walking with a stroller, bicycling, and playing basketball.

These are standard (i.e., typically applicable) operating procedures which may be varied or changed as required, dependent upon site conditions, equipment limitations or limitations imposed by the procedure. In all instances, the ultimate procedures employed should be documented and associated with the final report.

This document is not intended to be used as a substitute for a site-specific Quality Assurance Project Plan (QAPP) or a detailed Sampling and Analysis Plan (SAP). This document is intended to be used as a reference for developing site-specific QAPPs and SAPs.



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Mention of trade names or commercial products does not constitute U.S. EPA endorsement or recommendation for use.

2.0 METHOD SUMMARY

There are two types of ABS that can be employed in the field: generic ABS and site-specific ABS. Generic ABS can be used with potentially contaminated soil and utilizes a rake to disturb the soil over a known area in conjunction with the collection of air samples to characterize potential exposure. Site-specific ABS is also used with contaminated soil; however, it utilizes site-specific activities to disturb the soil, such as riding ATVs, jogging or riding bikes. Although site-specific ABS provides a more realistic measure of fiber release, it can also be more resource intensive and it is recommended to be used after the generic ABS, if results deem necessary.

For all ABS events, asbestos samples should be collected from the breathing zones of the subjects at an appropriate flow rate. Special consideration should be given to characterizing exposure to children as it has been hypothesized that children are more prone to exposure than adults (U.S. EPA 2000) because they tend to be closer to the source. Sample flow rates, duration and final volume will need to be weighed against the number of grid openings that must be counted (cost factor) to obtain the needed sensitivity. Sampling periods should be of sufficient durations (averaging time) to facilitate collection of a representative sample and achieving the required level of sensitivity.

3.0 SAMPLE PRESERVATION, CONTAINERS, HANDLING AND STORAGE

3.1 Sample Preservation

No preservation is required for asbestos samples.

3.2 Sample Handling, Container, and Storage Procedures

1. Place a sample label on the cassette indicating a unique sampling number. Do not put sampling cassettes in shirt or coat pockets as the filter can pick up fibers or a static charge that could disturb the dust deposited on the filter media.
2. Samples should be handled gently with the filter inlet facing upward to avoid disturbing the particulate deposited on the filter and to minimize the potential of imparting a static charge to the cassette, which might alter the particulate deposition on the filter media.
3. Place the cassette individually in a manila-type envelope or other appropriate container that will not relay a static charge to the cassette. Under extremely low humidity conditions (less than 10% relative humidity), plastic bags such as Ziploc® or Glad® can develop a static charge that may affect the particle distribution of the filters. Each envelope should be marked with the sample identification number, total volume, and date.
4. To the best extent possible, the sampling cassettes in the manila envelopes should be placed right side up so that the cassette inlet cap is on top and cassette base is on bottom



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(ISO 10312, Section 8). Place samples into a shipping container and use enough packing material (e.g., bubble wrap) to prevent jostling or damage. Samples must be handled gently so as not to disturb the dust deposited on the filter media. Do not use vermiculite or any other type of fibrous packing material for samples. If possible, hand carry to lab.

5. Provide appropriate documentation with samples (i.e., chain of custody and requested analytical methodology).

4.0 INTERFERENCES AND POTENTIAL PROBLEMS

4.1 Area Selection

When selecting areas for ABS, consideration should be given to the potential for off-site migration of contaminants and possible exposure of the public. Within the constraints of ABS, to the degree practical, particulate generation migration off-site should be minimized, and constraints or mitigation protocols established to minimize public exposure. These constraints/mitigation protocols may include restricting public access to the area, conducting the ABS in remote areas of the site, dust suppression using water mist, building a containment structure, etc. Air sampling should be conducted to document the airborne concentration of asbestos at the site perimeter during activities.

4.2 Flow Rate Considerations

For activities that generate a large quantity of dust (i.e., particulates), sample flow rates may need to be reduced accordingly to avoid overloading the filters. For example, a sampling pump flow rate of approximately 3.0 liters per minute (L/min) was found most effective at one site for monitoring for asbestos while riding ATVs on dusty soils while high soil moisture and reduced particulate generation at another site permitted a 5.0 L/min flow rate.

High flow rates may result in filter damage due to failure of its physical support associated with increased pressure drop, leakage of air around the filter mount so that the filter is bypassed or damage to the asbestos structures (breakup of bundles and clusters) due to increased impact velocities (ISO 10312). High flow rates can also tear the filters during initial pump startup due to the shock load placed on the filter when the pump is first started.

Sampling larger volumes of air and analyzing greater areas of the filter media can theoretically lower the limit of detection indefinitely. In practice, the total suspended particulate (TSP) concentration limits the volume of air that can be filtered as TSP can obscure asbestos fibers. The International Organization for Standardization (ISO) Method 10312 states that the direct analytical method cannot be used if the general particulate loading exceeds approximately 10% coverage of the collection filter. An airborne concentration of approximately 10 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$), corresponding to clean rural air, results in approximately 10% coverage of the filter media based on a 4000-L sample.

The following formula from ISO 10132 may be used to calculate the analytical sensitivity:



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$$S = \frac{A_t}{KA_g V}$$

Where:

S = Analytical sensitivity expressed in structures per liter

A_t = Active area in square millimeters of the collection media or filter

A_g = Mean area in square millimeters (mm^2) of the grid openings examined,

K = Number of grid openings examined

V = Volume of air sampled, in liters

NOTE: 25-millimeter (mm) cassettes have an effective filter area of 385 mm^2 and 37-mm cassettes have an effective filter area of 855 mm^2 . The typical grid opening is 0.0057 mm^2 . Note: Grid size will vary between laboratories and dimensions should be verified prior to calculating the number of grid openings that must be counted to achieve a particular level of sensitivity.

Table 1 provides an example of the minimum number of grid openings that must be counted in order to achieve various sensitivity and detection limits.

It is frequently more efficient to employ co-located samplers to collect a high and low volume of air. This increases the likelihood of at least one of the two samples being readable using the direct analytical method (ISO 10312) than to lose the sample due to overloading or having to analyze by the indirect method (ISO 13794).

4.3 Transmission Electron Microscopy (TEM) Specimen Preparation Methods

It can be argued that direct methods yield an under-estimate of the asbestos structure concentration because other particulate material with which they are associated conceals many of the asbestos fibers present. Conversely, indirect methods can be considered to yield an over-estimate because some types of complex asbestos structures disintegrate during the preparation, resulting in an increase in the numbers of structures counted.

4.3.1 Direct-Transfer TEM Specimen Preparation Methods

Direct-transfer preparation methods are intended to retain all particles in the same relative positions with respect to each other on the final TEM grids as on the original filter. The membrane filter, or a portion of it, is placed on a microscope slide with the sample face upward, and then collapsed by exposure to acetone vapor. The cleared filter is then etched in a low-temperature plasma asher, subsequently coated with carbon in a sputtering device and then peeled from the glass slide. A portion of the collapsed, etched



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and carbon-coated filter is then transferred to an electron microscope grid and then extracted with dimethylformamide, glacial acetic acid and water to remove the filter. Once the process is complete, the particles originally collected on the filter are bound in the carbon film and the grids can be observed on a transmission electron microscope (ISO 1995). Direct-transfer TEM specimen preparation methods have the following significant interferences:

- The particulate density on the filter, which in turn is controlled by the sampled air volume and the total suspended particulate concentration in the atmosphere being sampled, restricts the achievable detection limit.
- The precision of the result is dependent on the uniformity of the deposit of asbestos structures on the sample collection filter.
- Air samples must be collected so that they have particulate and fiber loadings within narrow ranges. If too high a particulate loading occurs on the filter, it is not possible to prepare satisfactory TEM specimens by a direct-transfer method. If too high a fiber loading occurs on the filter, even if satisfactory TEM specimens can be prepared, accurate fiber counting may not be possible.

4.3.2 Indirect TEM Specimen Preparation Methods

In the indirect preparation method the membrane filter, or a portion thereof, is placed on a microscope slide, sample face downward, and ashed in a low temperature asher until complete calcination of the filter is achieved. The ash is then recovered in distilled water and the solution then filtered on a polycarbonate filter. The indirect transfer method redistributes the particulate on a new membrane filter.

Indirect TEM specimen preparation methods have the following interferences:

- The size distribution of asbestos structures is modified (clusters, matrices bundles, etc. may be broken up during sample preparation).
- There is increased opportunity for fiber loss or introduction of extraneous contamination from laboratory glassware, process water, etc.
- When sample collection filters are ashed, any fiber contamination in the filter medium is concentrated on the TEM specimen grid.

The direct analytical method (ISO 10312) is the preferred method and every reasonable effort should be made to prevent overloading of the filter, which would necessitate use of the indirect method. Samples that are overloaded may, at the discretion of the project management team, be analyzed by ISO Method 13794 “Ambient air – Determination of Asbestos Fibres – Indirect-transfer transmission electron microscopy method” (ISO 1999). Results of the ISO 13794 analysis should be reviewed discrete of the ISO 10312 samples and a decision made regarding combining the two data sets.



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4.4 Sampling Cassette Orientation

Air sampling cassettes must be oriented with the open face pointing down to preclude large non-respirable particles from falling or settling onto the filter media.

5.0 EQUIPMENT/APPARATUS

6.0

- Personal sampling pumps, providing a flow rate from 0.020 L/min up to 4.0 L/min, battery powered
- High flow sampling pumps (i.e., Quik Take 30 or AirCon II), capable of providing a flow rate from 4.0 to 12 L/min, battery or alternating current (AC)
- Mixed cellulose ester (MCE) filter cassettes, 0.45 or 0.8 micrometer (μm), 25-mm diameter, purchased from a certified vendor with appropriate documentation (low filter background counts, consistent filter area, certified leak-free cassettes)
- Sampling setups, Tygon tubing with Luer type adaptor
- Backpacks
- Sampling stands, for perimeter sampling
- Duct tape
- Tools, miscellaneous (e.g., screwdrivers, pliers, cutting tool, etc.)
- Envelopes, manila-type
- Whirlpak bags
- Sample labels
- Chain of custody (COC) records
- Logbook and/or sampling worksheets
- Precision rotameter or primary flow standard appropriate for sampling flow rate
- Personal protective equipment (PPE), including but not limited to respirators, boots, gloves, eye protection, hard hat, to be determined based on type of activity and possible exposure
- Decon equipment (Plastic sheeting, liquinox®, buckets, brushes, water, Hudson sprayers, garbage bags, etc.)
- Power sources, e.g., line power, solar recharging batteries, power inverters, generators, etc.



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6.0 REAGENTS

Reagents are not required for the preservation of asbestos samples.

7.0 PROCEDURES

7.1 Pre-Site Sampling Preparation

1. Determine the extent of the sampling effort (number of locations, repetitions, number of samples, etc.), the sampling methods to be employed, and the types and amounts of equipment and supplies needed.
2. Obtain necessary sampling equipment and ensure it is in working order and fully charged (if necessary).
3. Perform a general site survey prior to site entry in accordance with the site-specific Health and Safety Plan (HASP).
4. Once on-site the calibration is performed in the clean zone. The calibration procedures are listed in Section 7.2.
5. After calibrating the sampling pump, mobilize to the sampling location.

7.2 Calibration Procedures

To determine if a sampling pump is measuring the flow rate or volume of air correctly, it is necessary to calibrate the equipment. Sampling pumps should be calibrated on a routine basis and prior to use.

A rotameter can be used provided it has been calibrated with a primary calibrator. Typically rotameters are calibrated on a yearly basis. Sampling pumps can be calibrated prior to coming on-site in order to expedite on-site calibration. However, calibration must be verified on-site prior to use.

7.2.1 Calibrating a Personal Sampling Pump with a Rotameter

1. Refer to the manufacturer's manual for the Rotameter Operational Instructions.
2. Set up the calibration train using a rotameter, sampling pump and the sampling cassette that will be used during the sampling event. This train may be set up prior to field mobilization and will be checked in the field again prior to use.
3. To set up the calibration train, attach one end of the polyvinyl chloride (PVC) tubing (approx. 2 ft) to the cassette base; attach the other end of the tubing to the inlet plug on the pump. Another piece of tubing is attached from the



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cassette cap to the rotameter. Insure that the tubing and rotameter used to calibrate the pump do not restrict the airflow.

4. Assemble the base of the flow meter with the screw provided and tighten in place. The flow meter should be mounted within 6 degrees ($^{\circ}$) of vertical (Omega 1987).
5. Turn the sampling pump on.
6. Turn the flow adjust screw (or knob) on the personal sampling pump until the float ball on the rotameter is lined up with the pre-calibrated flow rate value on the rotameter. Note: rotameters should be marked with the previous calibration date and corresponding flow rates and scale.
7. A verification of calibration is generally performed on-site in the clean zone immediately prior to the sampling.

7.2.2 Calibrating a Personal Sampling Pump with an Electronic Calibrator

1. Refer to the manufacturer's manual for operational instructions.
2. Set up the calibration train using a sampling pump, electronic calibrator, and the actual sampling cassette or a representative filter cassette. The same lot of cassettes used for sampling should also be used for calibration.
3. To set up the calibration train, attach one end of the PVC tubing (approx. 2 foot) to the cassette base; attach the other end of the tubing to the inlet plug on the pump. Another piece of tubing is attached from the cassette cap to the electronic calibrator.
4. Turn the electronic calibrator and sampling pump on. Select a flow rate to calibrate.
5. Turn the flow-adjust screw or knob on the pump until the desired flow rate is attained on the rotameter.
6. Using the primary calibrator, obtain approximately 10 readings three times until the flow rate of $\pm 5\%$ of the required flow is attained.

7.3. Meteorology

It is recommended that an onsite, portable, 3-meter meteorological station be established. If possible, sample after two to three days of dry weather and when wind conditions are representative for the climatology of the location based on month and time of day. Historical hourly wind speed and wind direction data should be analyzed before mobilization. Wind speed, wind direction, temperature, and station pressure should be recorded on the meteorological station data logger and real-time data should be available for review on the station display panel.



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Suggested meteorological station specifications can be found in Table 2, Appendix A or ERT SOP #2129, *Met One Remote Meteorological Station*. Alternatively, a nearby representative meteorological station, as determined by a meteorologist, may be used to acquire the necessary data.

7.4 General Sampling Information

For all activity-based sampling events, except as noted otherwise, asbestos samples will be collected from the breathing zones of the event participants. The breathing zone can be visualized as a hemisphere approximately 6 to 9 inches around an individual's face. Breathing zone samples provide the best approximation of the concentration of contaminants in the air that an individual is actually breathing. Specific breathing zone heights should be determined on a project-by-project basis based on the anthropometrics for the study population and the participants' positions during the performance of each task.

If it is necessary to relieve a participant from the activity, another sample collector should be suited and ready to participate in the ABS prior to the personnel exchange. The participant will stop the activity, remove the backpack or belt, and pass it to the relief participant similar to the transfer of a baton in a relay race. The original participant will assist the relief participant with donning and adjusting the backpack or belt. The exchange is anticipated to take less than 60 seconds, therefore the sampling pumps and event time clock will not be halted during the exchange. If the exchange requires more than 60 seconds, the pump and event clock will be stopped until activity is re-initiated.

Sample volumes and detection/quantification limits should be specified in the site-specific QAPP with flow rates and sampling periods adjusted accordingly. Typical sensitivity limits that have been employed for risk assessment have been approximately 0.001 S/cc for ABS samples and 0.0001 S/cc for background or reference samples. Based on ISO 10312 Table 1, a sensitivity limit of 0.001 S/cc would require a sample volume of greater than 500 liters to keep the number of grid openings to be counted below 100. Similarly, a sample volume greater than 5000 L would be required to reach 0.0001 S/cc and count fewer than 100 grid openings. For all asbestos sampling, an asbestos sampling train consisting of 0.8- μm , 25-mm mixed cellulose ester (MCE) filter connected to a personal sampling pump will be used. The top cover from the cowl extension on the sampling cassette shall be removed ("open-face") and the cassette oriented face down for all asbestos filters. All samples should be collected open-faced unless a specific requirement for sampling closed-faced exists.

For activity based sampling, a personal sampling pump (or equivalent) or SKC Quick Take 30 will be calibrated to collect between 2 and 12 L/min of air through the filter depending on the capacity of the pump. The flow rate will be based upon the duration of time required to collect a minimum target volume of 560 L and provide a sensitivity limit of 0.001 S/cc.

Generally each activity based sampling event should be repeated a minimum of three times in the same area or if not possible, in an area with similar asbestos soil concentrations to expose trends and demonstrate data reproducibility or assess variability. This can be accomplished by a single participant repeating the activity three or more times or by having a single simulation with three or more participants. If soil moisture or seasonal variability is a concern, then three events for



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each different season or meteorological conditions may be appropriate. The decision to conduct multiple repetitions of an activity in a single area should be based on the data quality objectives of the project and the effect on the decisions that will be made using these data.

The sampling pumps used should provide non-fluctuating airflows through the filter, and should maintain the initial volume flow rate to within $\pm 10\%$ throughout the sampling period. A constant flow or critical orifice controlled pump typically meets these requirements. If the flow rate changes by more than 5% during the sampling period, the average of the pre- and post-sampling rates will be used to calculate the total sample volume. If at any time the measurement indicates that the flow-rate has decreased by more than 30%, sampling should be terminated. Depending on the type of sampling pump used, it may be possible to salvage the sample if sufficient volume was collected; however, it may not be representative of the time it takes for the actual activity to be completed. Depending on the type of sampling pump used, the actual sampling time in hours and minutes before the sampling fault may be displayed and an actual sample volume calculated. If the fault was due to battery failure, it may be possible to check the post-sampling flow.

During certain ABS activities, participants may be fitted with two sampling pumps to collect a high-flow or volume and a low-flow or volume sample. Co-located samples are collected to sample a high and low volume of air to increase the likelihood of at least one of the two samples being readable using the direct analytical method (ISO 10312). Approximately 560 L (40 CFR 763) is collected for the low-flow samples and up to 4000 L for the high-flow samples. The targeted high volume is typically 1200 L, which permits counting approximately 54 grid openings for a sensitivity level of 0.001 S/cc.

7.5 Generic Activity-Based Sampling Scenario / Raking

The raking scenario, also referred to as the generic scenario, is appropriate for all sites with soils potentially contaminated with asbestos. Generic ABS should be employed in a grid pattern to evaluate the potential for fiber release from soil over a portion of the site. If the analytical results are above the criteria that were derived for the site, then remediation or institutional controls should be implemented or additional site-specific ABS should be undertaken. If the analytical results are below the criteria that were derived, then no further action may be necessary.

In this activity or simulation a participant will rake a lawn or garden area to remove debris such as rocks, leaves, thatch and weeds using a leaf rake with a rake width of approximately 20 to 28 inches. Participants should strive to disturb the top half-inch of soil with an aggressive raking motion. This depth will vary based on the objective of the scenario.

Each raking participant donning appropriate PPE will be fitted with a personal sampling pump contained in a backpack with the cassette secured to the shoulder straps near the operator's lapels in the breathing zone. Personnel will rake a lawn or garden area to remove debris for a minimum of 1 to 2 hours (flow rate and sensitivity level dependent). Raking will occur in a measured area with vegetation, soil or rocks/gravel and will occur in an arched motion raking from the left of the participant to the right. The participants will rake the debris towards themselves facing one side of the square for 15 minutes then the participant will turn 90 degrees clockwise and begin a new side. Participants will continue to rake each side of the square and



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rotate 90 degrees. Once several small piles of debris have been made, the participant shall pick up the debris and place it in a trashcan. The sequence of raking, rotating and picking up debris shall be repeated for the duration of the sampling period. The participant should stay in the same plot for the entire sampling period.

7.6 Site-Specific Activity-Based Sampling Scenarios

If site-specific ABS is undertaken, the number and types of activities as well as the types of scenarios should be based on current and potential land use. Reference to current and currently planned future land use and the effectiveness of institutional or legal controls placed on the future use of the land should be evaluated. Probable land use should be selected based on zoning and the existing land use of the site and adjacent areas.

Land use assumptions should be based on a factual understanding of site-specific conditions and reasonably anticipated use. The land use evaluated for the assessment should be based on a residential exposure scenario (i.e., the default worst-case) unless residential land use is not plausible for the site. Future land use assumptions should be consistent with reasonably anticipated future land use based on input from planning boards, appropriate officials, and the public.

7.6.1 ATV Riding

This scenario might be appropriate for recreational areas or other areas where ATVs are typically ridden where asbestos contamination is present. This activity is designed to be representative of two or more ATV participants riding on a course or trail. Riders should maintain their relative position (lead, middle, tail) throughout the activity.

Each ATV rider wearing appropriate PPE will be fitted with two personal sampling pumps set at two distinct flow rates, to collect approximately 560 and 1200 liters of air, because of filter overloading concerns. The cassettes for the personal sampling pumps will be attached to the shoulder straps of the backpack proximal to the riders' lapels in the breathing zone. It may be beneficial to attach a dust monitor (e.g., DataRAM) to the tail ATV to record dust levels and gauge dust loading. The sampling pumps will be carried in a backpack while the dust monitor, if used, will be mounted to the ATV.

Personnel will ride the ATVs around a course at the same time until a sufficient volume of air has been collected to achieve the required sensitivity limit of 0.001 S/cc of air. The riders, one lead rider and one following rider, will vary the vehicle speed between 5 and 30 miles per hour (mph). Riders will strive for an average speed of 10 mph. The average speed is a target speed only; vehicle speeds will be adjusted to meet track conditions. Vehicles will be equipped with a speedometer and odometer to record speeds and distance traveled. ATV riding and sampling should be conducted for 30 to 120 minutes in duration, depending on dust loading and required detection limits.

ATVs and ATV tires should be selected as appropriate for the area being studied. Specifically, the size (i.e., weight, horsepower, etc.) of the ATV should be appropriate for the study area. The vehicle tires should have a tread pattern that is representative of



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those typically used in the area. Local ATV shops or ATV clubs should be consulted for guidance.

7.6.2 Child Playing in the Dirt

This scenario might be appropriate for sites where schools, playgrounds, parks or residential areas, etc. are contaminated with asbestos; the overarching criteria being areas where a child might be expected to play or dig in the dirt. This scenario was designed to be representative of a child playing in the dirt with a shovel and pail.

The event participant wearing appropriate PPE will be fitted with a personal sampling pump; the inlet to the filter will be at a height of approximately 1 to 3 feet above the ground to simulate a child's breathing zone. The actual pump unit should be secured in a backpack or on a belt.

A participant should sit on the ground while digging or scraping the top 2 to 6 inches of surface soil, placing it in a small bucket or pail and dumping it back on the ground. The activity will be paced such that soil will be placed in the bucket and dumped approximately every two to five minutes, regardless of the amount of material in the bucket. The bucket should be emptied rapidly from a height of approximately 12 inches, based on observations of two to four-year-olds playing in a sandbox.

A sampling period and flow rate to collect a sufficient volume of air will be determined as to achieve the project-specific detection/quantification limit. The sampling period will be divided into equal sub-periods to facilitate having the participant face each compass direction for an equal amount of time during the activity. This approach is designed to mitigate the effect of wind direction on potential exposure. Random head and body movement during the activity should further mitigate the impact of wind direction on exposure. Ideally, the participants will face each compass direction at least twice during the sampling event. For example, during a two-hour or 120-minute event, the participant might face North for 15 minutes, rotate to the East for 15 minutes, then South for 15 minutes, then West for 15 minutes and return to the North to repeat the cycle. Participants should move to a fresh patch of soil after the completion of each cycle (360 degree rotation).

7.6.3 Gardening/Rototilling

This scenario might be appropriate for sites where gardening or surface disturbance to a depth of approximately one foot is anticipated. This activity is designed to be representative of individuals participating in gardening activities using a rototiller.

Each rototilling participant donning appropriate PPE will be fitted with a personal sampling pump. The actual pump unit will be contained in a backpack with the cassette secured to the shoulder straps near the operator's lapels in the breathing zone.

Personnel will operate a rototiller for a minimum of two hours to loosen soil in the yard to a depth of approximately 12 inches. The depth chosen is area-specific and will need



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to be determined on a case-by-case basis. A rear tine rototiller in the six to eight horsepower range will be selected. Other types or sizes of tillers may be appropriate based on the soil conditions and type of gardening being conducted.

A 100 to 720-square-foot plot of land will be selected to till. The average size of a community garden in New Jersey was 720 square feet based on a survey conducted by Rutgers University in 1991 (Patel 1991). The edges will be delineated. Square plots are preferred. The rototiller operator will conduct typical associated activities such as removing rocks and debris from the tilled area. To account for the effects of varying wind direction on potential exposure, the operator will till the soil back and forth towards each side of the square continuously for 10 minutes, shut down the machine or place it in neutral, and rake or sort through the material for five minutes. The operator will then turn 90 degrees in a clockwise direction and repeat the previous 15-minute procedure. The operator will continue to rotate 90 degrees clockwise every 15 minutes until the two-hour sampling period is complete. The participant should stay in the same plot for the entire sampling period.

7.6.4 Weed Whacking/Cutting

This scenario might be appropriate for sites where lawn maintenance might be conducted such as in residential and commercial areas. This activity is designed to simulate a person trimming weeds and grasses.

Each weed-whacking participant will be fitted with a personal sampling pump. The actual pump unit will be contained in a backpack with the cassette secured to the shoulder straps near the operator's lapels in the breathing zone. Personnel wearing appropriate PPE will operate a gas or electric-powered string trimmer. A 25 to 35-cc gas or electric-powered trimmer with a 16 to 18- inch cutting swath will be selected. Trimming and edging will occur in a measured area with thick vegetation (typically 100 to 720-square feet, based on a typical residential garden) (Patel 1991). Trimming will be done using a side to side sweeping motion with the operator moving in a series of straight lines back and forth towards one side of the selected area for 10 minutes, resting five minutes, and turning 90 degrees in a clockwise direction before repeating this 15-minute procedure for the duration of the sampling period. The participant should stay in the same plot for the entire sampling period.

7.6.5 Digging

Digging might be appropriate for sites where construction projects are likely to occur or where plants might be planted. Digging will occur in a measured area with vegetation, soil or rocks/gravel.

Each digger participant donning appropriate PPE will be fitted with a personal sampling pump contained in a backpack with the cassette secured to the shoulder straps near the operator's lapels in the breathing zone. The participants will dig a hole to approximately two feet deep and two feet (representative of planting a small shrub or digging a fencepost; site-specific dimensions should be specified in the QAPP/SAP) in diameter



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(Vodak 2004) and will place the soil next to the hole. The participants will then refill the hole with the soil that had been removed. Participants will then rotate 90 degrees in a clockwise direction and continue to dig and refill additional holes until the sampling period is complete. The sequence of digging, filling and rotating shall be repeated for the duration of the sampling period.

7.6.6 Lawn Mowing

Lawn mowing might be appropriate for sites where lawn maintenance might be conducted such as residential and commercial areas.

Each lawn-mowing participant will be fitted with a personal sampling pump contained in a backpack with the cassette secured to the shoulder straps near the operator's lapels in the breathing zone. Personnel wearing appropriate PPE will operate a gas-powered lawn mower. Mowing will occur in a measured area with thick vegetation and will occur in a shrinking square pattern. Participants will divide the area into a number of squares that decrease in size towards the center of the square by the width of the mower swath. Mower blades will be set at approximately 2 to 2.5 inches. A bag-less side discharge 3- to 5-horsepower lawn mower will be used for this exercise.

7.6.7 Walker with Stroller

This scenario might be appropriate for sites such as parks, paths or open-space. The actual pump unit will be secured in a backpack. The cassette for the personal sampling pump will be attached to the shoulder straps of the backpack proximal to the walker's lapel in the breathing zone. A second pump will be placed in the stroller at a child's breathing zone height.

During these events, walkers wearing appropriate PPE pushing a stroller will walk back and forth along a portion of a path until a sufficient volume of air has been collected to achieve the required detection limit. The walkers will vary their speed between 1.5 and 4 mph. Walkers will strive for an average speed of 2 mph. The average speed is a target speed only; speeds will be adjusted to meet trail conditions. Walkers should be equipped with a global positioning system (GPS) unit to estimate average speed and distance traveled.

7.6.8 Jogging

This scenario might be appropriate for sites such as parks, paths or open-space. The actual pump unit will be secured in a backpack. The cassette for the personal sampling pump will be attached to the shoulder straps of the backpack proximal to the jogger's lapel in the breathing zone.

During these events, joggers wearing appropriate PPE will run/jog back and forth along a portion of a path until a sufficient volume of air has been collected to achieve the required detection limit. The joggers will vary their speed between 2.5 and 5 mph. Joggers will strive for an average speed of 4 mph. The average speed is a target speed



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only; speeds will be adjusted to meet trail conditions. Joggers should be equipped with a GPS unit to estimate average speed and distance traveled.

Two or more joggers can participate in this activity. When multiple joggers participate, they should maintain their relative position throughout the event (lead, middle, tail). Joggers should be spaced five feet apart.

7.6.9 Two Bicycles

Bicycling might be appropriate for sites such as parks, paths or open-space. Two bicyclists wearing appropriate PPE will ride back and forth with one leading and one following along the length of the site portion of a path or ride around a site (no trail) until a sufficient volume of air has been collected to achieve the required detection limit.

The bicycling participants will each be fitted with personal sampling pumps. The actual pump units will be contained in backpacks with the cassettes secured to the shoulder straps near the cyclists' lapels in the breathing zone.

During these events, the bicycle riders will vary their speed between 3 and 15 mph. Riders will strive for an average speed of 8 mph. The average speed is a target speed only; bicycle speeds will be adjusted to meet trail conditions. Bicycles will be equipped with a GPS to estimate average speed and distance traveled. Riders should maintain their relative position (lead, tail) throughout the activity.

7.6.10 Basketball Scenario

This scenario might be appropriate for sites where basketball courts are present. The basketball scenario was developed to simulate a group of recreational basketball players gathering to play a casual game of basketball for 120 minutes on an outdoor concrete or macadam court. Between four and 10 players wearing appropriate PPE can participate in this exercise.

- From 0 to 15 minutes, two of the players will sweep court with push brooms from the perimeter of the court to the center. While these two people are sweeping the court, the remaining personnel should mill about under the basket and take a few shots.
- From 15 to 30 minutes, shot practice participants stand around the key as for a free throw, with the exception that one of the participants is positioned under the basket to retrieve the ball after each shot. The player closest to the basket on the left side (facing the basket) takes two shots and the ball/shooter rotates counter clockwise after those two shots. Each person shoots consecutively until everyone has taken two shots. The entire group then rotates clockwise. This sequence should be repeated until time expires. Ideally, each player should shoot from each key position and take a turn retrieving the ball under the basket.



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- From 30 to 45 minutes, each player takes turns practicing lay-ups. All players line up on the left side of the basket (facing the basket) and shoot one after another. The first person shoots then retrieves the ball for next person in line and so on. Players should use two basketballs with the second person bouncing the ball outside of the key as the first person shoots. Players should run a full cycle from left then a full cycle from right; repeating the left, right cycles until the interval time is up.
- From 45 to 60 minutes, shot practice as described in the 15 to 30 minute interval above will be conducted.
- From 60 to 75 minutes, a half-court game will be played to the degree practical.
- From 75 to 100 minutes, shot practice as described in the 15 to 30-minute interval above will be conducted.
- From 100 to 120 minutes, a lay-up drill as described in the 30 to 45 minute interval above will be conducted.

7.7 Cumulative Exposure Scenario

A cumulative exposure study might be appropriate for sites where individuals move about a site during the course of a day, with varying levels of exposure at multiple indoor and outdoor locations. The objective is to estimate aggregate and cumulative exposure to asbestos over the course of a day. Cumulative exposure studies should be conducted in order to increase understanding of linkages between sources of asbestos and subsequent exposure and dose to humans for use in mitigating risk and reducing exposure and disease.

Over periods of weeks, years or decades, exposures to environmental agents such as asbestos occur intermittently rather than continuously. Yet long-term health effects, such as cancer, are routinely projected based on an average dose over the period of interest (typically years), rather than as a series of intermittent exposures. Consequently, long-term doses are usually estimated by summing doses across discrete exposure episodes and then calculating an average dose for the period of interest (e.g., year, lifetime).

For the cumulative exposure studies, representative members of the population of interest should be selected for 24 hour sampling. The volunteers should be instructed to go about their day as usual. That is, they should not modify their schedule or activities just because they will be wearing a sampling pump.

A minimal description of exposure for a particular route must include exposure concentration and the duration. This is the method of choice to describe and estimate short-term doses, where integration times are of the order of minutes, hours or days. When projecting long term exposures, on the order of years or a lifetime, since it is typically impractical to sample for the entire exposure period, short-term exposure estimates are assumed to be representative of long-term periods and are integrated to estimate long-term exposures, typically with a safety factor to account for variability.



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Observations of activities should be recorded throughout each cumulative exposure study, together with the other relevant factors including locations and activities during the study.

Samples will be collected using a personal air pump with a flow rate of approximately 3.5 L/min. Samples shall be collected open-faced with the inlet facing downward at a personal breathing zone height of 4 to 6 feet for 24 hours. Because the battery life for a personal monitor is typically eight to 10 hours, the pump shall be changed out at approximately 8-hour intervals (keeping the same filter cassette). Each pump shall be pre-calibrated to 3.5 L/min prior to use. Each monitor shall be worn at normal breathing height during all waking hours. During sleep, the monitor will be placed in the same room as the sleeping individual. The sampling cassette will be placed proximal to the breathing zone of the reclined participant.

Should a study subject participate in a high dust generating activity such as riding an ATV, the 24 hour sampling cassette event should be paused and a short term exposure sample should be collected on a separate cassette with an appropriately calibrated sampling pump. Once the high dust activity has been terminated, the original 24-hour cassette and pump should be resumed for the remainder of the sampling period. Results of the 2 or more samples, depending on the number of high dust generating events should be summed to derive the total 24-hour exposure data.

7.8 Background Sampling

Background samples should be considered for all sampling events and should be addressed in a site-specific Quality Assurance Project Plan. Background samples are strongly recommended for all outdoor sampling and encouraged for any indoor sampling. A background or sample is defined as a sample collected upwind at a distance sufficient to prevent being influenced by the simulated activities and may be on or off the site. To the degree practical, the area selected for background sampling should be free of known asbestos contamination. For outdoor sampling, consider collecting samples outdoors in a manner consistent with Asbestos Hazard Emergency Response Act (AHERA) clearance sampling as per 40 Code of Federal Regulations (CFR), Appendix A to Subpart E of part 763. The background level should reflect the concentration of asbestos in air for the environmental setting on or near a site or activity location and can be used to evaluate whether or not a release from the site or activity has occurred. Background level does not necessarily represent pre-release conditions or conditions in the absence of influence from source at the site. A background level may or may not be less than the detection limit, but if it is greater than the detection limit, it should account for variability in local concentrations. Background samples should be collected concurrent with ABS using stationary sampling pumps. Sampling and analytical parameters (sample volume grid opening count, etc.) should be prescribed to permit a detection limit approximately an order of magnitude below that of the ABS detection limit.

An Aircon II sampling pump (or equivalent) will be calibrated to collect 10 L/min for on-site and off-site air samples through the filter. The flow rate will allow a minimum target volume of 4000 L and will provide a sensitivity limit of 0.0001 S/cc. Lower volume air samples will be collected concurrently at the ambient air sampling locations. Personal sampling pumps will be utilized in the same manner with the same media at a flow rate between 2- and 3- L/min in order to collect a



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sample volume of approximately 1000 L. The target sensitivity of these samples is also 0.0001 S/cc when additional grids are counted in accordance with the method. Co-located samples are collected to sample a high and low volume of air to increase the likelihood of at least one of the two samples being readable using the direct analytical method (ISO 10312).

7.9 Perimeter Sampling

Perimeter samples are defined as samples collected upwind, downwind or crosswind of a specific activity. When selecting areas for ABS, consideration should be given to the potential for off-site migration of contaminants and possible exposure of the public. Within the constraints of ABS, to the degree practical, particulate generation migration off-site should be minimized, and constraints or mitigation protocols established to eliminate public exposure. These constraints/mitigation protocols may include conducting the ABS in remote areas of the site, dust suppression using water mist, building a containment structure, etc. Air sampling should be conducted to document the airborne concentration of asbestos at the site perimeter during activities. Perimeter air monitoring should be conducted to:

- Document air quality during ABS and establish background or upwind levels of asbestos during site activities
- Monitor and document air quality during site activities near sensitive receptors
- Provide risk management information and address public confidence
- Reduce possible liabilities associated with ABS

Perimeter air sampling should be performed to ensure that ABS activities do not result in excessive airborne asbestos emissions from the site. Air samples should be collected and analyzed to determine the concentrations of asbestos at the site perimeter.

An Aircon II sampling pump (or equivalent) will be calibrated to collect 10 L/min for on-site and off-site air samples through the filter. The flow rate will allow a target volume of 4000 L and will provide a sensitivity limit of 0.0001 S/cc. Lower volume air samples will be collected concurrently at the perimeter sampling locations using personal sampling pumps, if loading is an issue. These pumps will be utilized in the same manner with the same media at a flow rate between 2- and 3-L/min in order to collect a sample volume of approximately 1000 L. The target sensitivity of these samples is also 0.0001 S/cc when additional grids are counted in accordance with the method. Co-located samples are collected to sample a high and low volume of air to increase the likelihood of at least one of the two samples being readable using the direct analytical method (ISO 10312).

7.10 Soil Sampling

A sufficient number of soil samples should be collected to characterize the study area. Since particulates are expected to be released from the entire study area, the primary objective of the soil sampling is to estimate the populations mean concentration. Composite samples are appropriate for characterizing study areas and a sampling design program such as Visual Sampling Plan is recommended for calculating the number and location of samples with the appropriate confidence intervals. Soil sampling should be conducted in accordance with ERT SOP #2012, *Soil Sampling*.



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Soil characteristics should be documented in conjunction with the activity-based personal exposure monitoring using American Society of Testing and Materials (ASTM), Method D2488 - 00: *Description and Identification of Soils (Visual-Manual Procedure)*, soil moisture by ASTM Method D2216-05: *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* and grain size by ASTM Method D6913-04e1: *Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis* or Method D422-63 (2002): *Standard Test Method for Particle-Size Analysis of Soils*.

Soil samples should be representative of the soil being disturbed or used during ABS activities. Table 3 provides examples of soil sampling depths, which may be disturbed by the activity being performed.

The relationship between the concentration of asbestos in a source material (typically soil) and the concentration of fibers in air that results when the source is disturbed is very complex, depending on a wide range of variables. To date, no method has been found that reliably predicts the concentration of asbestos in air given the concentration of asbestos in the source. Because of this limitation, this SOP emphasizes an empiric approach, where concentrations of asbestos in air at the location of a source disturbance are measured rather than predicted.

8.0 CALCULATIONS

The sample volume is calculated from the average flow rate of the pump multiplied by the number of minutes the pump was running (volume = flow rate X time in minutes). The sample volume should be submitted to the laboratory and identified on the chain of custody for each sample (zero for lot, and field blanks).

The concentration result is calculated by dividing the number of asbestos structures reported after the application of the cluster and matrix counting criteria by the sample volume (concentration = number of asbestos structures / sample volume).

9.0 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

The following general QA procedures apply:

1. All data must be documented on field data sheets or within site logbooks. Record the following: date, time, location, sample identification number, pump number, flow rate, and cumulative time.
2. All instruments/equipment must be operated in accordance with operating instructions as supplied by the manufacturer, unless otherwise specified in the work plan. Equipment checkout and calibration activities must occur prior to sampling/operation and they must be documented.
3. Field blanks should be collected at a rate of one per twenty samples or one per sampling event, whichever is greater
4. Lot blanks should be collected at a rate of at least two per lot



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5. Collocated samples should be collected at the frequency of one per sampling event

For TEM analysis, the following QC procedures apply:

1. Examine lot blanks to determine the background asbestos structure concentration.
2. Examine field blanks to determine whether there is contamination by extraneous asbestos structures during specimen preparation or handling.
3. Examine laboratory blanks to determine if contamination is being introduced during critical phases of the laboratory program.
4. To determine if the laboratory can satisfactorily analyze samples of known asbestos structure concentrations, reference filters shall be examined. Reference filters should be maintained as part of the laboratory's Quality Assurance program.
5. To minimize subjective effects, some specimens should be recounted by a different microscopist.
6. Asbestos laboratories shall be accredited by the National Voluntary Laboratory Accreditation Program.
7. At this time, performance evaluation samples for asbestos in air are not commonly available for Removal Program Activities; however, they should be considered on a case-by-case basis.

10.0 DATA VALIDATION

Results of QC samples will be evaluated for contamination. This information will be utilized to qualify the environmental sample results accordingly with the project's data quality objectives.

11.0 HEALTH AND SAFETY

When working with potentially hazardous materials, follow U.S. EPA, OSHA, and corporate health and safety procedures. More specifically, when entering an unknown situation involving asbestos, a powered air-purifying respirator (PAPR) (full face-piece) is necessary in conjunction with high-efficiency particulate air (HEPA) filter cartridges. See applicable regulations for action levels, permissible exposure levels (PEL) and threshold limit values (TLV). If previous sampling indicates asbestos concentrations are below personal health and safety levels, then Level D personal protection is adequate.

For all ABS, appropriate PPE, including Tyvek coveralls, protective gloves and foot wear, and a respirator with HEPA filter cartridges (P-100 or equivalent) should be worn to protect participants. Details regarding PPE and other protective measures should be specified in the site-specific Health and Safety Plan. Special consideration should be given to the physical safety of the event participants as well as heat stress associated with performing vigorous activities in impermeable clothing.

12.0 REFERENCES

40 CFR Part 763 Asbestos Worker Protection



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13.0 APPENDICES

TABLE 1. Minimum Number of Grid Openings Required To Be Counted to Achieve a Given Analytical Sensitivity and Detection Limit. (Adapted from ISO 10312)



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TABLE 2. Suggested Meteorological Station Specifications

TABLE 3. Soil Sampling Depth Based on Activities Performed



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TABLE 1. Minimum Number of Grid Openings Required To Be Counted to Achieve a Given Analytical Sensitivity and Detection Limit. (Adapted from ISO 10312)

Analytical Sensitivity Structures/cc	Limit of Detection Structures/cc	Volume of Air Sampled (Liters)					
		500	1000	2000	3000	4000	5000
0.0001	0.0003	1066	533	267	178	134	107
0.0002	0.0006	533	267	134	89	67	54
0.0003	0.0009	358	178	89	60	45	36
0.0004	0.0012	267	134	67	45	34	27
0.0005	0.0015	214	107	54	36	27	22
0.0007	0.0021	153	77	39	26	20	16
0.001	0.003	107	54	27	18	14	11
0.002	0.006	54	27	14	9	7	6
0.003	0.009	36	18	9	6	5	4
0.004	0.012	27	14	7	5	4	4
0.005	0.015	22	11	6	4	4	4
0.007	0.021	16	8	4	4	4	4
0.01	0.030	11	6	4	4	4	4



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TABLE 2. Suggested Meteorological Station Specifications

Variable	Accuracy	Resolution
Wind Speed (horizontal and vertical)	$\pm (0.2 \text{ m/s} + 5\% \text{ of observed})$	0.1 m/s
Wind Direction (azimuth and elevation)	$\pm 5 \text{ degrees}$	1.0 degrees
Ambient Temperature	$\pm 0.5^\circ \text{ C}$	0.1° C
Precipitation	$\pm 10\% \text{ of observed or } \pm 0.5 \text{ mm}$	0.3 mm
Pressure	$\pm 3 \text{ mb (0.3 kPa)}$	0.5 mb
Solar Radiation	$\pm 5\% \text{ of observed}$	10 W/m ²

m/s = meters per second

°C = degrees Centigrade

mm = millimeters

mb = millibar

W/m² = watts per square meter

kPa = kilopascal



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TABLE 3. Soil Sampling Depth Based on Activities Performed

Activity Based Sampling Scenario	Soil Sampling Depth
Raking (metal garden rake)	Surface to 3 inches
Raking (leaf rake)	Surface to 2 inch
ATV riding	Surface to 2 inch
Rototilling	Surface to 12 inches
Digging	Surface to depth of excavation
Child Playing in the dirt	Surface to 3 inches
Weed Whacking	Surface to 2 inches
Lawn Mowing	Surface to 2 inch
Walking with Stroller	Surface to 2 inch
Two Bicycles	Surface to 2 inch
Activities on solid surfaces such as asphalt or concrete	Microvacuum ASTM D 5755