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Standard Guide for Development of Long-Term Monitoring Plans for Vapor Mitigation Systems[1]

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1. Scope

1.1 This guide presents factors to consider when developing Long-Term Monitoring (LTM) Plans for monitoring the performance of both active and passive vapor mitigation systems in buildings. This guide will also assist in developing appropriate performance standards to make sure that vapor mitigation systems remain protective of human health. Active and passive vapor mitigation systems have been used for a number of years on contaminated properties where residual volatile contaminants remain in the ground. This guide discusses a variety of vapor mitigations systems; however, its focus is on the development of long-term monitoring plans for vapor mitigation systems that are designed to remain in place for multiple years.

1.2 A LTM Plan provides clear performance goals for a vapor mitigation system which help to reduce potential confusion and ineffective project management. The LTM Plan also defines performance monitoring time frames to efficiently test the vapor mitigation systems' effectiveness without unnecessary and costly over-testing. This will also promote consistent monitoring. Vapor mitigation systems are often installed without adequate consideration of the long-term monitoring requirements necessary to make sure that they remain protective of human health for as long as the system remains in place. This guidance addresses the requirements of the LTM Plan to monitor a vapor mitigation system's continued effectiveness. Installation verification that the vapor mitigation system was installed correctly is typically addressed in the Remedial Design stage of a contaminated Property Management and is not covered in this document.

1.3 LTM Plan limitations, constraints and potential sources of error are discussed in this standard. This guide does not endorse a mitigation system vendor or testing of vapor mitigation systems. However, this guide does provide a reference for the common procedures for testing vapor mitigation systems and related terms, as appropriate.

1.4 *Units*—The values stated in either International System (SI) units or English units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this standard. The values given in parentheses are provided for informational purposes only and are not considered standard.

1.5 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026. For purposes of comparing a measured or calculated value(s) with specified limits, the measured or calculated value(s) shall be rounded to the nearest decimal of significant digits in the specified limit.

1.6 This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied with consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.

1.7 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.8 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the*

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Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.

2. Referenced Documents

2.1 *ASTM Standards:*

D653 Terminology Relating to Soil, Rock, and Contained Fluids

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D6026 Practice for Using Significant Digits and Data Records in Geotechnical Data

E1745 Specification for Plastic Water Vapor Retarders Used in Contact with Soil or Granular Fill under Concrete Slabs

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *active vapor mitigation system, n—as used in soil gas monitoring/sampling*, uses an electrically-powered fan or other device to induce a pressure differential which in turn causes air and/or vapors to move beyond the building envelope or to pass through a filtration system. (See Table 1 for details.)

3.2.2 *floor sealant, n—as used in soil gas monitoring/sampling*, material, typically liquid, that is spread on the floor that upon curing, inhibits or prevents the migration of vapors into the building.

3.2.3 *heat-exchange system, n—as used in soil gas monitoring/sampling*, an air handling system, which can act as an active vapor mitigation system, that relies on an electrically-powered fan to pass an incoming air stream through a heat exchanger to transfer heat to or from an outgoing air stream.

3.2.4 *indoor air treatment, v—as used in soil gas monitoring/sampling*, process by which indoor air is passed through activated carbon of other absorbent to trap or treat chemical vapors to make it safe for human occupancy.

3.2.5 *heating, ventilation and air conditioning (HVAC), n*—active mechanical systems within a building used to control heating, ventilation, and cooling of the indoor air space.

3.2.5.1 *Discussion*—These systems can change the pressure regime of the indoor space. As such, changes in their configuration and/or operation can have a profound effect on vapor mitigation systems.

3.2.6 *long-term monitoring plan (LTM Plan), n—as used in soil gas monitoring/sampling*, a written plan that establishes the procedures, processes, and benchmarks necessary to monitor and document the effectiveness of a vapor mitigation system designed to remain in place for multiple years so that it remains protective of human health.

3.2.7 *passive vapor mitigation system, n—as used in soil gas monitoring/sampling*, a passive vapor mitigation system relies on naturally induced pressure differentials to cause the movement of air beyond the building envelop, or on barriers that prevent the advective or diffusive transport of chemical vapors into the indoor air space.

3.2.8 *sub-membrane, n—as used in soil gas monitoring/sampling*, refers to the area under a concrete slab having an associated vapor barrier (membrane).

3.2.9 *sub-slab sample, n—as used in soil gas monitoring/sampling*, a soil-gas sample collected from beneath a building slab with or without an associated vapor barrier.

4. Summary of Guide

4.1 Development of an LTM Plan for a vapor mitigation system is a process which needs to be based on project-specific details. This guide, however, presents a generalized process, which can be used as a template for LTM Plan development.

5. Significance and Use

5.1 There are two primary types of vapor mitigation systems: Active and Passive (Table 1). Active vapor mitigation systems include: Sub-Slab Depressurization (SSD), Sub-Membrane Depressurization (SMD), Sub-Membrane Pressurization, Block-Wall Depressurization, Drain-tile Depressurization, Building Pressurization, Heat-Exchange Systems, and Indoor Air Treatment. Passive vapor mitigation systems include: Passive Venting, Floor Sealants, Vapor Barriers, and Increased Ventilation. Vapor mitigation systems may also consist of a combination of active and passive technologies.

5.2 Development and implementation of a LTM Plan is important for ensuring the long-term protectiveness of the mitigation systems.

5.3 The approach presented in this guide is a practical and streamlined process for establishing long-term monitoring requirements, monitoring time frames, and factors needed to determine when the use of a vapor mitigation system is no longer needed.

5.4 This guide is intended to be used by environmental professionals including: consultants, building managers, local or regional governing or regulatory agencies, that are installing vapor mitigation systems, conducting monitoring of the vapor barriers, or developing LTM Plans for vapor mitigation systems. Vapor mitigation system installation and LTM activities should only be carried out by environmental professionals who are trained in the proper application of vapor mitigation systems and experienced in the monitoring described in this guide, as applicable.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

TABLE 1 Example Monitoring Programs for Active and Passive Vapor Mitigation Systems

System Type	Initial Verification (System Startup)[A]	Operational Monitoring[B]	Long-Term Monitoring[C]	Additional Testing[D]	Comments
Active Mitigation Systems (continuously motorized)					
Active vapor mitigation system including: SubSlab Depressurization (SSD), Sub-Membrane Depressurization (SMD), Block-Wall Depressurization (BWD), Drain-Tile Depressurization (DTD)	Sample IA & SS within 30-60 days of system startup. Collect vacuum readings from riser manometer & subslab vacuum reading from 3 or more locations.	Repeat initial verification. One of the first-year sampling events should be during heating season or during the season or time of the year determined to most likely have a positive sub-slab to indoor air pressure. Verify vacuums quarterly. In some cases, continuous sampling may be used for verification testing. See 6.3.3.4 for details.	Every year - Verify manometer & subslab vacuum readings. Every 5 years - Conduct 5-year review. As appropriate based on sampling and/or monitoring data, discuss decommissioning strategies with regulators.	Repeat IA & SS sampling & concurrent vacuum readings if: 1) mitigation system is modified; 2) part of building is demolished or extended; 3) HVAC system is modified; 4) change in vacuum at riser manometer >20 %; 5) subslab pressure is higher than –0.004 inches water at any location. If IA exceeds acceptable levels due to inadequate mitigation or invalid test, make necessary changes and retest.	The monitoring/sampling frequency for the initial verification, operational and long-term monitoring is for sites with documented vapor intrusion exposure. A less frequent sampling schedule may be appropriate for other sites.
Building Pressurization	Sample IA & SS within 30-60 days of system startup. Collect indoor/outdoor pressure differential readings from multiple points within building.	Repeat initial verification. One of the first-year sampling events should be during heating season or during the season or time of the year determined to most likely have a positive sub-slab to indoor air pressure. Verify pressure differentials quarterly. Monitor closely to ensure that HVAC operation is not modified. More frequent reviews of HVAC operation may be advisable	Quarterly - Verify pressure readings and continuation of HVAC operation. Every 5 years - Conduct 5-year review	Repeat IA & SS sampling & concurrent pressure readings if: 1) HVAC use is changed; 2) part of the building is demolished or extended; 3) HVAC system is modified; 4) indoor/outdoor pressure differential change >20 %. If IA exceeds acceptable levels due to invalid test results or inadequate mitigation, make necessary changes and retest.	*Building Pressurization … may not be appropriate when the concentrations of contaminants in the soil gas are high.* MA DEP 2016 VI Guidance p 49 (1). This method is more appropriate for characterizing vapor intrusion than mitigation …IN DEM 2016 TGM Mitigation Systems, p 5 (2). Frequent rebalancing may be necessitated by changes in HVAC operation due to seasonal temperature changes, and other causes. May not be suitable for HVAC operation changes during weekends or other downtime. Pressure differential could potentially be monitored with an alarm system.
Heat-Exchange Systems	Sample IA & SS within 30-60 days of system startup.	Repeat initial verification. One of the first-year sampling events should be during heating season or during the season or time of the year determined to most likely have a positive sub-slab to indoor air pressure. Verify blower operation and check for clogging quarterly.	Every year - Verify blower operation and check for clogging. Every 5 years - resample IA & SS; verify screening levels, building use, configuration, & HVAC. More frequent checks for clogging of air inlet is advisable.	Repeat IA & SS sampling if: 1) mitigation system is modified; 2) part of building is demolished or extended; 3) HVAC system is modified. If IA exceeds acceptable levels due to invalid test results or inadequate mitigation, make necessary changes and retest.	*"…it is notoriously difficult to balance the flows properly to control air quality for mitigation approaches involving increased ventilation (for example, air-toair heat exchange systems.) Additionally, these types of systems usually are not cost-effective because of increased heating and airconditioning cost."* USEPA 2012 02, VI FAQs, p 36. Generally, only suitable for lowlevel VI.

TABLE 1 *Continued*

System Type	Initial Verification (System Startup)[A]	Operational Monitoring[B]	Long-Term Monitoring[C]	Additional Testing[D]	Comments
Indoor Air Treatment	Indoor-air treatment is generally only suitable as a temporary measure. Sample IA & SS within 30-60 days of system startup.	Sample IA & SS every quarter. Verify blower operation and check for clogging quarterly. Change filters regularly.	Sample IA & SS twice per year. Verify blower operation and check for clogging quarterly. Change filters regularly.	Increase frequency of filter changes or add treatment systems if IA exceeds target levels. Sample IA immediately prior to first three filter changes to determine adequacy of replacement schedule.	Carbon-filtration systems, if used, require periodic filter replacement. Test air prior to filter change, and if target compounds exceed target levels, replacement frequency probably needs to be increased. Indoor-air treatment is generally only suitable as a temporary measure.
Passive Mitigation Systems (not continuously motorized)					
Passive Venting, with or without wind turbine	Sample IA & SS within 30-60 days of system setup.	Sample IA each quarter	Sample IA & SS annually	Repeat IA & SS sampling if: 1) mitigation is modified; 2) part of building is demolished or extended; 3) HVAC System is modified. If IA exceeds acceptable levels due to invalid test results or inadequate mitigation, make necessary changes.	
Floor Sealants	Because this technology is not typically used as the primary mitigation technology (see Comments), follow the Initial Verification requirements of the primary mitigation technology.	Conduct Primary VI Mitigation testing	Conduct Primary VI Mitigation testing	NA	Not typically used as a standalone technologyTypically epoxylike floor coatings, possibly combined with sealing cracks and openings. *"... experience shows that in existing structures sealing alone reduces radon levels only 0 % - 50 %..."*, ITRC 2007
Barrier without active or passive venting	Because this technology is not typically used as the primary mitigation technology (see Comments), follow the Initial Verification requirements of the primary mitigation technology.	Conduct Primary VI Mitigation testing	Conduct Primary VI Mitigation testing	NA	Not typically used as a standalone technologyIncludes plastic sheeting & asphaltic sprays. *"experience shows that in existing structures sealing alone reduces radon levels only 0 % - 50 %..."*, ITRC 2007.
Increased Building Ventilation	Sample IA & SS within 30-60 days of system setup.	Conduct Primary VI Mitigation testing	Conduct Primary VI Mitigation testing	NA	

All minimum values noted above are suggested.

• In some cases, it may not be possible or preferred to collect sub-slab soil gas (SS) samples. In these cases, riser exhaust gas sampling may be collected in the place of sub-slab air samples. See 6.4.5 for more details.
• Pressures are reported relative to indoor air pressures, such that subslab pressures are lower than indoor-air pressures. For example, a pressure reading of –0.2032 mm [–0.008 in.] H_2O indicates a stronger vacuum than a reading of –0.1016 mm [–0.004 in.] H_2O.
• All testing and verification events will include a visual inspection for clogging of air inlets or outlets, leakage of caulking and seals, and changes to building configuration and occupancy.
• Testing soil gas concurrently with indoor air is useful for interpreting the source of IA constituents, and assists in determining when mitigation may no longer be necessary. If soil-gas sampling is impossible or impractical, additional testing might be appropriate.
• Sampling may begin earlier than 30 days if specified by guidance or regulatory requirements.
• All systems should will undergo a 5-year review, which should include sampling IA (and potentially SS) and reviewing: 1) target levels, 2) changes to mitigation system, 3) changes to building configuration, 4) changes to HVAC configuration or operation, 5) changes in building occupancy.
• Modifications to mitigation system, building, or HVAC system, and failures of the mitigation system will typically require restarting the verification process.
• Analyte list may be limited to compounds found in subslab soil gas.

In H_2O: Millimeters [Inches] - of - water - equivalent pressure. 25.4 mm [1.0 in.] H_2O = 249.1 Pascals or 27.6 g/cm^3 [0.03613 pounds per square inch].
IA: Indoor Air
SS: Sub-Slab Soil Gas

[A]Initial Verification (System Startup)—Period of time immediately following system startup.
[B]Operational Monitoring—Period of time needed to verify that the system is operating within requirements through typically expected annual conditions.
[C]Long-Term Monitoring—Period of time following operational monitoring through system decommissioning.
[D]Additional testing—These are actions that may need to be taken if there is a problem with the system or there is a change to the building/system.

6. Long-Term Monitoring Plan Components

6.1 *Overview of Long-Term Monitoring Plans*—It is a Best Management Practice for the owner or operator of an active or passive vapor mitigation system to develop a Long-Term Monitoring Plan (aka Operation and Maintenance Plan or LTM Plan) prior to or immediately following installation. The LTM Plan provides detailed information on how the system was constructed, and how to monitor and maintain the system to protect human health as long as it is needed. The LTM Plan should also include an organization chart documenting who is responsible for which aspects of the mitigation system.[2] Other local or regional governing or regulatory agencies may have additional information.

6.2 *Sections of the LTM Plan*—Sections of the LTM Plan should include at a minimum, the following items in the form of text, drawings, cut sheets, photographs, and inspection logs:[3]

6.2.1 *System Overview*—A general description of the contaminants of concern (COCs) to be mitigated, the mitigation system, its location, and a discussion of potential changes that may be made to convert a passive vapor mitigation system to an active vapor mitigation system. The description should discuss or depict:

6.2.1.1 Problems that require mitigation, including the regulatory reason or agreements requiring the mitigation, as applicable

6.2.1.2 The physical address of the system

6.2.1.3 Commissioning date

6.2.1.4 Basic description of the systems components and their intended function

6.2.1.5 A general description of the performance goals

6.2.1.6 An indication of the expected length of time the system will remain operational

6.2.1.7 *Permits*—Check with local and/or regional governing agencies to determine type of air or other environmental construction permits and building codes may be required. The permit requirements should be listed in this section.

6.2.2 *Construction Documents, as applicable:*

6.2.2.1 Final as-built construction drawings and specifications. Updated as-built drawings should be added to the LTM Plan whenever equipment is changed or upgraded.

6.2.2.2 Locations of barriers

6.2.2.3 Locations of electrical connections, shutoffs, and fuses

6.2.2.4 Locations of suction pits, fans, piping and exhaust points

6.2.2.5 Locations of monitoring points

6.2.2.6 Locations of alarms

6.2.3 System operation and maintenance procedures

6.2.4 Inspection procedures, schedules, and reporting requirements including periodic adjustments

6.2.5 Notifications and corrective action procedures

6.2.6 *Decommissioning goals/triggers*—See Annex A1 for details.

6.2.7 Recommissioning procedures and reporting requirements

6.2.8 Decommissioning procedures

6.2.9 *Notification and point of contact (Organizational Chart):*

6.2.9.1 Organization chart should identify the individual/organization responsible for various parts of the vapor mitigation system.

6.2.9.2 Include who to contact in the event of an emergency, for example, when an alarm sounds.

6.2.10 *Manufacturers Recommended Repair Procedures:*

6.2.10.1 *Vapor Barrier Repair*—See Annex A1 for details.

6.3 *General LTM Plan Information*—Long-term vapor mitigation systems requiring a LTM Plan are typically either passive or active. Passive vapor mitigation systems may consist of a floor sealant, and/or piping and risers and may or may not include a vapor barrier material, or a filtration system. An active vapor mitigation system may include many of the same components as a passive system but with an electrically powered fan to create a pressure differential to discharge soil gas to the exterior, increase building pressure, or pass air through a filtration system. Certain manufacturers will provide warranties on the installation and product life expectancy, which should be included in the LTM Plan.

6.3.1 The LTM Plan should include photos and as-built drawings of the vapor mitigation system and documentation that the system meets, or is functioning within the design parameters and regulatory specifications (for example, that sub-slab depressurization monitoring points have sufficient vacuum). The as-built drawings should be updated whenever equipment or materials are changed or updated.

6.3.2 *Required Active Vapor Mitigation System Information*—This information includes engineering diagrams of the mechanical system, acceptable performance specifications, alarm settings, and life expectancy of mechanical elements of the system.

6.3.2.1 *Alarms*—The purpose of an alarm system is to indicate that the vapor mitigation system is not operating correctly, or that vapor concentrations are at unsafe levels. The alarm information in the LTM Plan should include the type of alarm, alarm high and low action levels, and corrective measures. Not all vapor mitigation systems have or require alarm systems.

6.3.3 *Monitoring Requirements*—The LTM Plan should define, among other items, the COCs or other properties that will be tested and their action levels/goals to be reached before the system can be decommissioned. Table 1 presents Example Monitoring Requirements for Initial Verification, Operational Monitoring, Long-Term Monitoring and Additional Testing for both active and passive vapor mitigation systems.

6.3.3.1 Initial verification is the monitoring of the system that occurs immediately after the start-up of the system to ensure that the system is working. This occurs after the installation verification (see 1.2 for more details). Operational Monitoring is conducted during the first year of system operation to ensure that the system is continuing to operate as

[2] USEPA 2001 (3) provide examples of an organization chart and for additional information on LTM Plans.

[3] Michigan 2013 (4) provide examples of these documents as well as VI LTM checklists.