Tracking Vapor Intrusion Pathways – an Active Tracer Gas Test

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ABSTRACT: A tracer gas test has been used to identify active pathways for vapor intrusion at polluted sites where vapor intrusion poses a risk to the indoor air quality. The test methodology has been developed and tested through the Danish EPA Technology Advance Program at six field sites for the Region of Northern Jutland; four where PCE is the contaminant of concern and two where benzene is the contaminant of concern (Loll et al. 2010). The method is based on a controlled (sub slab) release of a tracer gas, verification of the sub slab saturation and subsequent measurement with a fast response hand held leak detector with both audible and visual semi-quantitative indication of the gas level. The methodology has proven itself as a valuable supplemental tool in site investigation; both in identifying vapor intrusion pathways from the subsurface into buildings and internally in the buildings; e.g. between apartment levels. The method requires little (and inexpensive) equipment, yields immediate results, is very flexible/adaptive in use and has a competitive price level compared to other investigation methods.

INTRODUCTION

Background. At sites with vapor intrusion (VI) problems, an efficient tracking of the intrusion pathways can lead to valuable information on how various parts of a building interacts with the soil vapor underneath. In some cases, vapor tracking might allow the choice of a more cost effective remediation strategy. The traditional way to investigate and assess vapor intrusion pathways is to do a thorough building inspection followed by sample collection and analysis at identified potential intrusion pathways. This is an expensive and slow – and often iterative – process.

The proposed method is based on a technology transfer/adaptation of a method used for leak detection in pipe systems, and allows for a once-over investigation of potential pathways. The method should be seen as a supplement to other investigation methods:

- Building inspection.
- Chemical analyses.
- Air exchange measurements for one room/building level.
- Passive tracer gas method between rooms/building levels (Mortensen and Glensvig, 2002, 2003).
- Vapor cover sniffing investigation (Fuglsang, 2004).
- Film enclosure investigation (Fuglsang, 2001 & Fuglsang and Mikkelsen, 2001).
- Leak detection after remediation of intrusion pathways (e.g. by thermography).

Study purpose. The primary purpose of the study is to describe a best practice for the method, based on the application of the method at six field sites. Secondary purposes are to explore the applicability of the method for various investigation strategies and to evaluate pros and cons of the method.

METHODOLOGY

Equipment. The applied tracer gas is a mixture of 5 % hydrogen and 95 % nitrogen with hydrogen as the active ingredient. With a hydrogen content of <5.7 % the gas is considered inert in the Danish handling classification system. The gas has a low density (hydrogen has 1/15 the density of atmospheric air) and is therefore well suited for investigating vertical transport through cracks and other pathways from sub slab level up through the building under investigation.

The tracer gas is released through an adjustable valve (either 0.5-5 L/min or 1-15 L/min) and a flexible tube mounted on an aluminum rod via a Ballofix valve. The rod is the type we use for soil gas sampling (ø12 mm outer diameter). For this application we have shortened it to approximately 40 cm length. Between the rod and the concrete slab we use Teflon tape and applied acrylic sealant.

The leak detector is a Digitron DGS-10 for detection of combustible gasses and with a price tag of about $270. The sensor uses no pump and is placed at the end of a flexible arm to facilitate measurement in places that are hard to reach. The signal is both visual (using a green/ yellow/red scale of LEDs) and audible (clicking noises) with an intensity reflecting the gas level. The sensitivity of the sensor is adjustable and should be set at a background level of three to four clicks pr. second before active measurement. The sensor is somewhat sensitive to high water levels which we accommodate for in the guideline procedures (below).

The results are recorded according to the visual indicator scale:

Green = background level.
Yellow = slightly raised level.
Red = significantly raised level.

Guideline procedure for tracking VI pathways from soil to indoor air.

From applying the test method at six test sites we have developed and applied the following 11 step guideline procedure for tracking VI pathways from soil to the indoor air:

1. Establishment of an injection point (IP) by drilling an ø14 mm hole through the concrete slab. The IP should be placed in an area where the soil vapor is assumed to contribute to the indoor air, e.g. in the hotspot. Often times, previous sampling points can be used. Installation of the injection rod with connection to the sub slab soil gas phase. Teflon tape and an acrylic sealant are used to seal around the injection point.

2. Establishment of ø10 mm control points (CPs) at strategic points. The CPs are used to check that sufficient tracer gas levels are reached on the source side of the concrete slab; especially near areas that are included in the VI pathway tracking. The CPs are temporarily sealed with conical rubber stoppers.

3. (*Optional*) Establishment of CPs with access to presumed internal VI pathways; e.g. hollow wall structures, hollow floor separations, old (not used) chimneys etc. Other open VI pathways include passive or inactive ventilation flues, cabling tubes and more.

4. Background level check at CPs and in planned study areas. Points/-areas with yellow or red background levels are noted as points with uncertain results. Through application at the six sites, elevated background levels have been found in areas of storage of household chemicals (e.g. gasoline, white gas etc.), areas with newly applied building foam and sealants or in water saturated environments (e.g. toilet bowls, floor and sink drains and condensation drains).

5. (*Optional*) Check detector sensitivity to materials used during the test (preferably out doors); e.g. elastic sealants, building foams etc. There is a risk of raising the background levels in the test areas.

6. Tracer gas injection with a flow that reflects the permeability and flow resistance of the soil. The higher the soil permeability, the larger the unsaturated zone and the larger an area that needs to be saturated with tracer gas, the higher the injection flow. We have used injection rates between 0.5 and 9 L/min at the six test sites.
7. Investigate for leaks at the IP (gas valve, tube and the IP sealing).

8. Check gas levels at the established CPs. Red gas levels are preferred in the CPs, so a distinction between red and yellow identified VI pathways can be made. The CPs are sealed with conical rubber stoppers when not used.

9. Detection in designated building areas, where the sub slab gas levels are red (cf. point 8); e.g. on floor surfaces, along visible cracks and construction joints, radiator pipes, floor drains, CPs with access to presumed internal VI pathways (cf. point 3) etc.

10. Keep a running log with injection times and flows and keep a record of IPs and CPs (cf. point 12). The results (red/yellow/green) are recorded on a floor plan. For more complicated jobs/sites it might be advantageous to use colored crayons to mark gas entrance points for possible later remedy. Use digital photos and film for later documentation.

11. The IP can be moved in order to accomplish a better coverage of tracer gas (red level) in other parts of the building. Former CPs can be used as new IPs and vise versa.

A similar procedure is provided for tracking VI pathways across floor separations in (Loll et al. 2010).

RESULTS AND LESSONS LEARNED

From application at the six field sites we have collected some useful information regarding the application of the technology and identified VI pathways. Some of these results and lessons learned are described in the following.

The six field sites. At four of the sites PCE was the contaminant of concern (COC) while benzene was the COC at two sites. Five of the sites were multi level buildings whereas one site was a one storey house. At two of the sites, the tracer test has been applied as a part of the early site investigation effort and at three sites in order to assess the effectiveness of remedial actions already in place. At one site, tracer tests have been carried out both before and after remedial efforts. At five sites we have investigated VI pathways both from the subsurface into buildings and internally in the buildings; e.g. between apartment levels.

Suited for identification of advective pathways. For most applications test durations will be within 2 hours for injection at any one IP, and within these time frames the method will be best suited for identifying VI pathways of an advective nature (i.e. cracks) whereas VI pathways of a diffusive nature will not be identified. For instance, we have used the test for identifying VI pathways between a basement and a ground floor level where the floor separation consisted of carpeted wooden planks (one layer) with visible cracks between the individual planks. In this case, no gas was detected above the carpet (within 30 minutes) even though the carpet can in no way be considered impermeable to diffusion. In contrast, there was a pipe running through the planks and carpet at one wall (se picture). At this pathway, the gas was detected within 2 seconds of a release under the basement ceiling. Also, we have seen that linoleum works in the same manner as carpets.

However, it is not our experience that an actual advective flow is required at the time of the test - fast diffusion and the buoyant nature of the hydrogen molecules will carry sufficient amounts of hydrogen for detection *against* an advective gradient. Of course, this will not be the case against *any* advective gradient, and the exact pivot point has not been investigated or identified.

Pathways are pinpointed very accurately. When the technology is applied with the equipment described, it is possible to identify advective VI pathways very accurately (< 1/5 inch).

Background levels and detector water sensitivity. As mentioned above, the detector is somewhat sensitive to high concentrations of water vapor which can lead to uncertain results (or results with lowered sensitivity). Also, since we have used a non-specific detector, false positives might arise in areas with household chemicals. Tests can sometimes be performed in such areas by adjusting the detector sensitivity after performing tests in all other areas first. Hence, we stress the importance of performing step 4 in the provided guideline procedure.

Identified VI pathways (sub slab to indoor air). At all sites we have identified VI pathways between poured concrete floors and the outer walls or between poured concrete floors in adjacent rooms. At four sites we found pathways around radiator pipes, water pipes and drains, and in three instances at sampling points previously used for soil vapor sampling. At two sites VI was observed at points where fixed inventory was bolted into a poured concrete floor (hair dresser chairs and a staircase). At one site, VI was observed in an area with no visible cracks while no gas intrusion was observed along several visible cracks. We assume that the floor has been poured in more than one layer (three layers was observed at one of the other sites; see the picture). Hence, while visible cracks might occur in the top layer, no cracks might be present in the bottom layer – or vise versa.

At three sites we have identified sub slab VI to hollow wall structures, from where further spreading is possible through various wall mounts or other points where the wall structure is not intact; e.g. where outlet sockets are mounted. Sometimes VI through hollow walls lead to a direct pathway from the soil vapor to the indoor above the ground floor level. At one of these sites, we identified VI from the soil vapor through foundation blocks and into the hollow wall.

Identified VI pathways (across floor levels). At three sites we identified VI pathways around pipes and other installations. At two of the sites such pathways were identified even though part of the remedial actions at the sites was to separate the indoor air at the two levels by extensive use of acrylic sealant. Hence, the measures were not completely effective, although having some effect.

At two sites, major migration pathways from basements to higher apartment levels were through stair wells. At one site, cracks in the concrete floor separation were visible from the ground level and were highly conductive in transporting vapors to the floor level above.

Identified VI pathways (floor level by-pass). Some of the identified pathways lead to vapors being transported in larger quantities to higher floor levels than to lower levels; e.g. directly from the basement level to the second floor.

At one site, vapors were massively present in the basement and were transported via installation ducts directly to the second floor without being released via this pathway to the first floor. The same was true at one of the other sites (a three level building with a basement) where the building phone and electrical installations were collected in the basement. VI intrusion was present to the basement environment and from there via electrical cabling tubes (see picture) to the indoor environment at the second and third floor through outlets.

At two sites, we observed VI into the bottom of a no longer used chimney. Since the chimney is still open above the roof top at one of the sites, no further VI from the chimney to the indoor air was observed, but at the other site, the old chimney has been knocked down, a new roof has been built, and the top of the remaining chimney is now open (at the top) into the hollow space of the floor separation from where vapors are free to migrate to the indoor air.

CONCLUSIONS

In our opinion, the presented method is a very visual test that yields quite fast results and provides the field personnel with an option to make up and investigate new hypotheses as the test progresses. Hence, it is a very adaptive test that doesn't require desk work between iterative visits to the site. The detector is very robust and doesn't require calibration etc. Also, it has a fast response time which facilitates covering large areas or stretches within a reasonable time frame; a fair size building can be covered by two practiced consultants within one day. The required equipment is cheap: A detector of approx. $ 270, gas for the six tests in this project was approx. $ 400 and standard soil vapor sampling equipment. These are qualities that add value to the method in its present form.

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