

The Myth behind the Use of Helium as a Tracer Gas for Leak Detection on Soil Gas Sample Collection Projects

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We have been part of several dozen projects where helium has been used as a tracer gas for soil gas sampling events. Its use at sites is always accompanied by a great deal of extra time and effort on behalf of the consultant and adds significantly to the cost of soil gas investigations. When we ask people why they use helium with all of its problems and expense, we get a variety of answers such as: “The stationary lab requires it” or “DTSC/RWQCB wouldn’t have spent so much time talking about helium as a tracer gas if they weren’t pushing its use” or “The consultant overseeing our project says that if we don’t use helium, we are doing it wrong”. We are sure you have all heard these and many others concerning helium’s use as a tracer gas.

Aha!! You say, “These guys are prejudiced because they have mobile labs” and certainly the use of helium as a tracer is not needed when a mobile lab is on site. We are not advocating that helium as a tracer be discontinued. However, we think everyone should be aware of the problems associated with the use of helium as a tracer gas as well as the use of on-site helium detectors for measuring helium in the field. We will first explain what we believe to be the reason for helium’s use as a tracer gas and then explain why its use should be avoided for many soil gas sampling events. We will present at the end of this discussion a much simpler, cheaper, easier to use and better on-site method for determining leaks in the sampling system. This technique is already being used to collect soil gas samples by many consultants and is described in the April 2012 DTSC/RWQCB soil gas guidance document¹.

On the surface, the use of helium as a tracer gas for leak detection in soil gas sampling events seems like a good one. A shroud can be placed over the sample tubes and sample collection devices, helium is introduced into this confined space and a sample of the soil gas from the sample tube is diverted into a polyvinyl fluoride bag (e.g., Tedlar[®] bag) in the field. The soil gas in the PVF bag is then tested for helium by a hand-held helium detector. Theoretically, if any leak(s) occur anywhere in the system, helium will be detected in this diverted sample. This gives an indication whether or not a leak is present somewhere in the system. The absence of helium gives strong indication that there are no leaks in the sampling system. If helium is detected, the consultant/technician attempts to find the leak and fix it before

proceeding to collect the sample for analysis as prescribed by the 2003 and 2012 ASGI².

The use of helium rather than the less expensive liquid tracers causes less of a problem for laboratory instruments when a leak does occur. The presence of high concentrations of the liquid tracer will contaminate the analytical system and mask any target compounds that have similar chromatographic retention times as the tracer. Because helium is used as the carrier gas for most gas separation methods, helium's use as a tracer does not contaminate analytical laboratory instrumentation.

If the tracer is detected by the stationary lab where field testing for the tracer compound is not performed, it can be several days before the consultant is informed that there was a leak in the sampling system. The consultant will then have to re-mobilize to the site, fix the leak (if they can) and re-collect the sample. This is very time consuming and expensive. Therefore, "Quantitative Leak Testing" has been added to the pending Soil Gas Advisory Document that appeared in March of 2010 in an attempt to remedy this situation³. One of the proposals was to collect a pre-sample and analyze it in the field by either a mobile lab or by a field monitoring device. This pre-sample is used to detect the presence of a leak prior to collecting the sample and performing the analysis. There are no problems when a mobile lab is on site since any leaks can be corrected immediately and the sample re-analyzed the same day. For samples where an on-site monitoring device is required without a mobile lab, the consultant is limited to the use of helium as a tracer since all of the liquid tracers must be first separated from the mixture by a gas chromatograph. No readily available hand-held detectors exist for these liquid tracers. Helium becomes the only choice (except as noted below) as a tracer for samples that must be sent to a stationary lab since hand-held helium gas detectors can be used in the field and are rented from most environmental sampling supply businesses. They are easy to use, simple hand-held monitoring devices similar to PID's, OVA's and methane detectors commonly used by field technicians.

At this point if helium is detected in the field sample by the hand held helium detector, it is assumed that there is a leak in the soil gas probe/sampling system. To avoid the expense of having to re-collect samples that were sent to a stationary lab where tracer compounds were detected, the new guidance document has a section that talks about "quantifying the leak". Here is where we have problems. If a leak occurs as indicated by the presence of a tracer in the sample, the leak should be fixed immediately and the location re-sampled. Quantitating the leak is very bad policy and should be discouraged at all times. The guidance document allows for the concentration of helium in the sample to be divided by the concentration of helium in the shroud to measure the proportion of the sample attributable to leakage. The

document calls this “reasonably quantitative”⁴ when attempting to correct a result for the supposed leak. In all of their methods the EPA does not allow the adjusting of numbers to account for compounds that are found in method or system blanks⁵. Why would they or anyone else allow numbers to be adjusted when there is evidence showing that there was a leak at the time the sample was collected? The next few paragraphs will show why adjusting “numbers” in the case of helium detection in the field is extremely bad policy especially when a simple solution to measuring leaks exists.

Properties of Helium:

Currently, the only commercially feasible source of helium is its extraction from natural gas.⁶ Helium is formed in the ground due to the radioactive decay of elements where alpha particles are created. Helium is found in natural gas in concentrations up to 2% in some areas. It dissolves readily in natural gas or is trapped under shale as it percolates upward in soil. As the result of its collection from natural gas, tech grade helium will contain traces of C1-C6 hydrocarbons that were not removed from the collection process. This is why analytical labs must use ultra-high grade helium for their analytical systems. Tech grade helium is used by curio shops for the purposes of filling toy balloons. Unfortunately, this is the source of most of the helium used as tracer gas in the environmental field since it is cheaper.

Helium has a density much less than air so it will rise not sink (Density of air is 1.161g/L⁷ versus 0.1785g/L for helium⁸). On two occasions we have drilled a boring to 5 feet and either left it open or placed dry bentonite in the boring without hydrating leaving an open conduit to the surface. It is difficult to get helium to diffuse downward in these situations except by applying pressure on a sealed system or providing a vacuum in the subsurface. We were unable to measure helium below about 4 feet in these open borings at atmospheric pressure. Helium also diffuses faster than any gas other than hydrogen. Its tendency is to diffuse into the formation rather than go where it is supposed to during soil gas sampling. One of its duties is to act as a tracer to determine if the sample tubing has been installed properly. Its tendency not to diffuse downward is problematic when using it for this purpose. Another simple way to determine if the boring has been installed properly will be discussed later.

Helium also presents a safety hazard when transporting it in a vehicle. Leaks of any kind in the confined space of an automobile could create an unsafe environment by displacing oxygen. In addition, helium is stored under pressure in metal canisters and, if dropped, could break open and create other problems for the person handling it.

Hand-held Helium Devices:

Commercially available hand-held helium detectors come in two varieties. The first utilizes a mass spectrometer (MS) type detection system. This system uses a single mass detector set at mass 4 which is the mass of a helium atom. These mass detectors typically range from mass 1 to 8 so they will measure any molecule that has a mass in this range. This makes this detector sensitive to hydrogen as well as helium but, by-and-large, these detectors tend to be highly selective to both helium and hydrogen to the exclusion of most others. The MS detector is used by most analytical testing laboratories to determine helium leaks in their carrier gases. Instrument manufacturers such as Agilent, Varian, Perkin Elmer and Beckman all carry this type of hand-held detector. The drawback with these types of detectors is their output reading is not digital (i.e., not quantitative).

The second type of helium detector utilizes a thermal conductivity detector (TCD). This type of detector is a universal detector and will detect any gas/vapor/compound that comes in contact with it. The principle behind these detectors is a difference in thermal conductivity of a gas entering the detector versus a reference gas. Water presents a problem with these detectors since it has a high thermal conductivity and will significantly dampen the signal (the higher the water concentration in the gas, the lower the signal response). These detector systems are not specific for helium and require some sort of filter to filter out hydrocarbons and water. This is the most common hand-held detector used by consultants including the MGD-2002 helium detector quoted in the pending 2010 ASGI document⁹. Both of the helium detectors given here require some sort of filter system to remove excipient hydrocarbons and water in the samples. The filters used in the TCD detectors will not remove methane so any samples containing methane will register as a false positive. It cannot be over emphasized again that high water vapor in the form of moisture in sub-surface conditions and/or humidity or hydrocarbons from either naturally occurring sources or anthropogenic contamination will produce a significant negative/dampening response of the signal or create false positives unless frequent water and hydrocarbon filter changes are made.

In addition to the other problems posed by hand held TCD helium detectors discussed above, these detectors lack the sensitivity to detect small leaks. It is rare to find a TCD detector that will measure compounds below 100ppm and typically they are used to measure gases/compounds whose concentrations are between 500ppm and 100%. Small leaks in the sampling system will not be detected by the TCD detector. Unfortunately, small leaks comprise most of the leaks seen in sampling systems.

Problems with the use of hand-held Helium detectors in the field:

The biggest problem when attempting to measure helium in the field is that the field measuring devices being used are not selective just for helium. If you use any of the common TCD helium detectors, you will find a one-to-one correlation between helium detection and hydrocarbon concentrations. That is, the higher the hydrocarbon concentration in the soil, the higher the response on the helium detector. This is why most analytical laboratories use a much more expensive MS type leak detector that is more selective. However, most of these devices are not digital and are also sensitive to hydrogen. Hydrogen is given off in trace amounts during the anaerobic degradation of hydrocarbon materials including vegetation so false positives are likely with these devices as well. Water also contains some hydrogen so its removal is required for either detector.

Any time there is naturally occurring natural gas present at a site such as is found at many locations in southern California, you will get false positives from both the hydrocarbons and the helium found naturally occurring in the natural gas using the TCD type detector. The MS type detector will give false positives when hydrocarbons are present under anaerobic conditions by measuring hydrogen as well as positive detection for the helium naturally occurring in natural gas. If natural gas is suspected to be present at a site, helium should not be used as a tracer even with stationary laboratory samples given the reasoning mentioned above (i.e., Helium's natural presence in the subsurface).

If you have made it this far, you should have the feeling by now that helium is not a very good tracer for many sites when you are attempting to measure its presence in the field. This is especially true for sites where hydrocarbons are suspected, vegetative degradation is occurring, high water vapor is present or where natural gas is present. It should be noted that most stationary labs analyze helium using a separation technique and can identify helium selectively. However, we have just eliminated helium for most applications where hand-held TCD-type helium field devices are used. If you are collecting soil gas samples via passivated stainless steel canisters (e.g., SUMMA[®] canisters) or PVF bag and sending them to a stationary lab, helium can be used as a tracer compound although one should be careful with samples deeper than 5 feet because of helium's tendency to rise. Unfortunately, there are many situations where helium cannot be used as a tracer because of its penchant for false positives. It is impossible to determine beforehand whether hydrocarbon compounds or water vapor may be present that will give false positives or false negatives with hand-held helium leak detectors at a given site. This problem is eliminated by using a mobile lab or using the leak check technique described below.

Other problems associated with the use of Helium as a tracer gas:

Let's now take a look at the other problems associated with the use of helium as a tracer. First, one must set up a confinement system to keep helium at the sampling interface. Several designs have been devised using small bell jars or similar containers that fit over the sample tube(s). If passivated stainless steel canisters are to be used as sample collection devices, a bigger containment system must be used. Most of these larger containers are the clear Rubbermaid file storage containers adapted to be used as glove boxes. These can be quite elaborate and will leak around fittings and always where the container touches the ground. This interface between the container and the ground cannot be made vacuum tight without putting grout, weights around the outside or some other means to lessen the release of the helium atmosphere you are trying to create. On windy days it is nearly impossible to maintain a constant helium atmosphere inside one of these sample collection systems. This is what makes us nervous about trying to quantitate the leak. If it is difficult to maintain a constant concentration of helium in this enclosure (usually 10%), it is going to be difficult determining the helium concentration appropriate for adjusting the results when helium is detected, that is if it is helium you are detecting!

In order to get close to consistent concentrations of helium in the sampling shroud, a technician must be present all of the time to continuously adjust the helium pressure inside the shroud. This is an added cost to the project over the additional cost for the helium, PVF bags, shroud, shroud construction and helium detector rental. This is not counting all of the extra time needed to set up the shroud and sampling equipment associated with its use. Each additional fitting or tube added to this system will potentially increase the likelihood of more leaks. All of this is unnecessary.

On top of these issues, consultants are adjusting analytical results based on the concentration of helium detected in the sample when helium is detected. This should make everyone very nervous about what is being reported for soil gas investigations where helium is used as a tracer considering its many false positives and false negatives (with high moisture content) in field analyses especially with the TCD-type detector.

Uses of a shut-in test as a leak check technique:

Now we promised you an easy technique to determine if a leak is occurring within the sampling tube and collection apparatus. Our observation is that 90% or greater of all leaks occur in the above ground sample collection equipment. Very few leaks occur at the soil/sample tube interface. Bentonite or Portland cement provide good seals most of the time if properly hydrated and allowed to set for some period of time

before sampling. The most important area to check is from the end of the sample tube to the collection device. The soil gas collection devices can be a glass syringe, glass bulb, PVF bag or stainless steel canister with quick disconnect valves or 2-way or 3-way valves being the most common interfaces between the end of the sample tube and the sampling device. Much more complex sampling systems are used when helium is the tracer.

The best way to test for leaks above ground is the use of a shut-in test. A description of the shut-in test is given in the 2012 Soil Gas Advisory document¹⁰ (**Figure 1**) The use of a Magnehelic vacuum gauge is recommended but any differential vacuum gauge can be used. We use a 3-way valve with the flared end of the valve going inside the ¼ inch sample tubing but a quick disconnect valve can also be used. The Magnehelic is placed into or on one of the other valve positions and the sampling device is placed on the third position. A vacuum of approximately 100 inches/H₂O is created by closing off the valve attached directly to the sample tube. A vacuum is created and the system is allowed to sit for approximately 1-2 minutes. If there are any leaks in the system you will see the vacuum slowly (or fast for large leaks) decrease. Any leaks can be isolated, fittings adjusted, leaky valves replaced or different tubing used until all leaks have been removed. This takes less than 3 minutes to set up and test with no added technician, no need for tracer and no need to re-mobilize back to the site at a later time to re-collect samples. A liquid tracer will still need to be placed at the soil/tubing interface to determine if there are leaks from the surface down to the first probe tip. **No adjustment of results for leaks is necessary whether you are using a mobile or stationary lab when the shut-in test is used!!!**

As indicated earlier, leaks from the ground down are rare. If they do occur, the driller can be asked to re-drill the boring the same day that the probes were installed. The shut-in test is simple without the hassle of dealing with helium or the inadvertent cross contamination of the valves or sampling device with liquid/gas tracer on the hands or clothes of the sampling technician.

Checking for proper installation of nested probes:

This same technique can be used to determine if there are leaks between different levels of a nested set of samples in a given boring. We call this method the Dodge method after John Dodge who had us do this for him at one of his sites. The Dodge technique involves putting an additional Magnehelic gauge on the end of the sample tube at an adjacent depth in a nested soil gas boring (**Figure 2**). Leaks are determined by pulling a vacuum at one depth and looking for the formation of a vacuum on an adjacent depth. For instance, if you are sampling at a 5 foot depth, the

second Magnehelic is placed at the end of the sample tube at the 15 foot depth. (Note: The second Magnehelic should be more sensitive. We recommend no more than 5 inches/H₂O as a maximum). A vacuum is pulled at the depth that the sample is being taken and watching the more sensitive Magnehelic at the adjacent depth. If there is movement, it strongly suggests that there is a leak or a pathway between the two boring depths and the possibility of improper hydration between depths has occurred. There are situations where a pathway can exist other than through the boring, for instance in a sandy soil, so each situation should be considered on its own merit.

Conclusion:

There is a lot of information to absorb here but the bottom line is that before you choose a tracer gas, you need to consider the problems that each can cause as well as the limitations of the tracer and the measuring devices used for its detection. As you can see, helium's use as a tracer gas is not the panacea that everyone was expecting it to be. Anyone who has used helium as a tracer gas on soil gas sites is familiar with the frustration of helium detections using hand-held helium detectors on systems they know are leak free. Trying to determine the location of the leak can be more frustrating. Liquid tracers also have their problems so I encourage everyone to use the shut-in test for determining leaks in the sampling system when collecting soil gas samples. In addition, the use of the Dodge method for determining leaks between boring depths can quality control drilling operations without a great deal of time or expense. Everyone is looking for less expensive ways of doing things these days so give it a try.

Thanks for reading.

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References:

1. Advisory – Active Soil Gas Investigation, California EPA, March 2010, Appendix D.
2. Advisory – Active Soil Gas Investigations, DTSC/RWQCB, January 28,2003, section 2.4.4
3. 2010 Advisory, Appendix C
4. Advisory – Active Soil Gas Investigation, California EPA, March 2010, Appendix C, page 57.
5. See EPA Method 8000 section 8.2.6.6, SW-846
6. “How Products are Made”, Volume 4
7. Handbook of Chemistry & Physics, 74th ed., 6-1.
8. Lange’s Handbook of Chemistry, 11 ed.
9. Advisory - Active Soil Gas Investigation, California EPA April 2012, Appendix D, page 62.
10. Advisory – Active Soil Gas Investigation, California EPA April 2012, Appendix D, page 61.