Passive Diffusion Bag (PDB) Samplers

Frequently Asked Questions

Passive diffusion bag (PDB) sampling is a cost-effective alternative to standard (or low-flow) purge and sample techniques for collecting concentrations of a variety of volatile organic compounds (VOCs) in groundwater at monitoring wells. Using PDB samplers can result in significant cost savings at sites where VOCs are the constituents of concern and particularly where long-term monitoring of groundwater is required. PDB sampling can also provide inexpensive and precise vertical contaminant concentration profiles that can be used to optimize remedial systems. The Interstate Technology and Regulatory Council (ITRC) Diffusion Sampler Team has gathered the following information about this technology and its uses.

How does a PDB sampler work?

A PDB sampler is a low-density polyethylene bag filled with deionized water, which acts as a semipermeable membrane and is suspended in a well to passively collect groundwater samples. PDB samplers rely on the free movement of groundwater from the aquifer or water-bearing zone through the well screen. VOCs in groundwater will diffuse across the bag material until constituent concentrations within the bag reach equilibrium with concentrations in the surrounding groundwater.

What are the advantages of PDB samplers?

PDB samplers are inexpensive and have the potential to eliminate or substantially reduce the amount of purge water associated with sampling. The samplers are easy to deploy and recover. Because PDB samplers are disposable, there is no down-hole equipment to be decontaminated between wells. PDB samplers require a minimal amount of field equipment. Sampler recovery is rapid. Because of the small amount of time and equipment required for the sampling event, the method is practical for use where access is a problem or where discretion is desirable (for example, residential communities, business districts, or busy streets where traffic control is a concern). Multiple PDB samplers distributed vertically along the screened or open interval may be used in conjunction with bore-hole flow meter testing to gain insight on the movement of contaminants into and out of the well screen or open interval or to locate the zone of highest concentration in the well. As the pore size of low-density polyethylene is only 10 angstroms or less, sediment does not pass through the membrane into the bag. Thus, PDB samplers are not subject to interference from turbidity. Finally, because alkalinity-contributing solutes do not pass through the membrane, the samplers enable collection of VOCs in a nonalkaline matrix, even if the well is in a limestone aquifer. This feature eliminates the VOC losses seen when highly alkaline water “foams” upon attempting to preserve samples by acidificaton.

What are the limitations of PDB samplers?

PDB samplers are not appropriate for all compounds. PDB samplers also integrate concentrations over time, which may be a limitation if the goal of sampling is to collect a representative sample at a point of time in an aquifer where VOC concentrations substantially change more rapidly than the samplers equilibrate. Finally, PDB samplers rely on the free movement of water through the well screen. In situations where groundwater flows horizontally through the well screen, the VOC concentrations in the open interval of the well are probably representative of the aquifer water in the adjacent formation. However, if the well screen is less permeable than the aquifer or the sandpack than under nonpumping conditions, flow lines may be diverted around the screen. In this case, the VOC concentrations in the PDB samplers may not represent concentrations in the formation water because of inadequate exchange across the well screen.

For what constituents can PDB samplers be used?

Field and lab testing have shown that PDB samplers are effective for a number of VOCs, including chlorinated aliphatic compounds and petroleum hydrocarbons. A list of the VOCs evaluated is included in the accompanying table. The majority of VOCs evaluated were shown to readily diffuse into the sample bag.

For which constituents are PDB samplers not suited? What about natural attenuation parameters?

PDB samplers should not be used for the compounds listed at the bottom of the accompanying table (those showing poor replication). They are also unsuitable for inorganic ions and have a limited applicability for non-VOCs and for some VOCs. For example, although methyl-*tert*-butyl ether, acetone, and most semivolatile compounds are transmitted through the polyethylene bag, laboratory tests have shown that the resulting concentrations are lower than in ambient water. The samplers should not be used to sample for phthalates because of the potential for the low-density polyethylene to contribute phthalates to the water sample. They are not useful for inorganic polar molecules because the membrane is nonpolar organic. PDB samplers are also inappropriate for ionic natural attenuation parameters, e.g., nitrates and sulfates. They are effective for the nonionic natural attenuation parameter methane; however, if natural attenuation monitoring is required, a combination of sampling techniques could be considered. For example, annual monitoring of natural attenuation parameters can be performed using a traditional sampling method, while quarterly monitoring of VOCs can be accomplished using diffusion sampling technology.

COMPOUNDS SHOWING GOOD CORRELATION IN LABORATORY TESTS
(average differences in concentration of 11 percent or less between diffusion sampler water and test vessel water)

Benzene	1,3-Dichlorobenzene	Naphthalene
Bromodichloromethane	1,4-Dichlorobenzene	1,1,2,2-Tetrachloroethane
Bromoform	Dichlorodifluoromethane	Tetrachloroethene
Chlorobenzene	1,2-Dichloroethane	Toluene
Carbon tetrachloride	1,1-Dichloroethene	1,1,1-Trichloroethane
Chloroethane	*cis*-1,2-Dichloroethene	1,1,2-Trichloroethane
Chloroform	*trans*-1,2-Dichloroethene	Trichloroethene
Chloromethane	1,2-Dichloropropane	Trichlorofluoromethane
2-Chlorovinyl ether	*cis*-Dichloropropene	1,2,3-Trichloropropane
Dibromochloromethane	Dibromochloromethane	Vinyl chloride
Dibromomethane	*trans*-1,3-Dichloropropene	Total xylenes
1,2-Dichlorobenzene	Ethyl benzene	

COMPOUNDS SHOWING POOR CORRELATION IN LABORATORY TESTS
(average differences in concentration greater than 20 percent between diffusion sampler water and test vessel water)

Acetone* Methyl-*tert*-butyl ether MIBK* Styrene

Source: Compounds tested under laboratory conditions for use with passive diffusion bag samplers (Vroblesky and Campbell, 2001).
*T. M. Sivavec and S. S. Baghel, 2000, General Electric Company, written communication.

In what types of aquifers or water-bearing zones can PDB samplers be used?

PDB samplers can be used in most formations, but they are not currently recommended for use in low-permeability formations because the flow of water through the well screen is restricted if the rate of VOC change in the well (by volatilization) is less than the rate that the VOCs are replaced by movement into the well screen. In this case, the VOC concentrations in the well water may not be representative of the VOC concentrations in the formation. PDB sampling relies on self-purging of wells to maintain concentrations within a well that are representative of the surrounding aquifer conditions. However, it should be noted that sampling of low-yielding wells is problematic for any currently available groundwater sampling method. PDB samplers work on the principle of diffusion. In low-permeability formations, diffusion is major mechanism for contaminant transport. Under these conditions, PDB samplers may indeed represent a viable sampling approach compared to other more conventional methods, but not enough data are currently available to support their use in low-permeability formations. Wells often do not adequately self-purge within a two-week period in low-permeability aquifers to allow diffusion sampling to be effective. As a general rule, diffusion sampling should not be used in water-bearing zones with a hydraulic conductivity of less than 1×10^{-6} cm/s.

How are PDB samplers deployed?

PDB samplers can come prefilled or can be filled in the field with laboratory-grade deionized water immediately prior to deployment. Appropriate weight, connectors, and line are attached to the sampler, and it is set at the desired depth in the screened interval. Licensed diffusion bag suppliers can provide more specific installation and recovery instructions. See below for information on using these samplers in wells with varying screen lengths.

How much time is required to collect a PDB sample?

It takes about 10 minutes to collect a groundwater sample from a diffusion bag and about the same amount of time to install a new bag. If quarterly sampling is being done, another bag can be installed immediately after the sample is collected. If annual or semiannual sampling is being done, another bag can be installed immediately after the sample is collected in some situations. PDB samplers have successfully been left in place for a year with no obvious loss of bag integrity. The longevity of PDB samplers in a variety of potentially hostile groundwater environments has not yet been tested, however, so the user should be alert for potential losses of bag integrity during recovery. If a single event is being done, a separate trip will be required to install the bags at least two weeks prior to sample collection.

PDB samplers should be left in place for a minimum of two weeks prior to sample collection to ensure that the deionized water in the diffusion bag has reached equilibrium with the surrounding groundwater. Under low-flow conditions, the PDB should be left in place longer prior to sample collection.

How much do the samplers cost? And where do I get them?

Cost information is available from vendors. There currently are two authorized distributors from whom passive diffusion bags can be obtained. EON Products (www.eonpro.com, 1-800-474-2490) are filled in the field. Columbia Analytical Services (www.caslab.com, 1-800-695-7222) samplers come prefilled with deionized water. PDB samplers employ patented technology (U.S. patent number 5,804,743) and therefore require that the user purchase commercially produced samplers from a licensed manufacturer or negotiate a nonexclusive license for sampler construction from the United States Geological Survey (USGS).

The cost savings resulting from the decreased time required to collect diffusion samples (relative to standard purge or low-flow purge and sample techniques) often more than offset the cost of the PDB sampler and replacement bags. Prices vary based on volume, hardware, and optional accessories, but the overall cost of a diffusion sampler generally ranges $16 to $35 per bag, plus reusable hardware (approximately $20 to $25).

Do I need to do a field comparison or validation study at my site before they can be used there?

A validation study typically includes conducting a side-by-side test with both PDB samples and conventional sampling (typically low-flow sampling). In wells showing little temporal variability in concentrations, a validation study may not be needed. PDB sampling results can be compared to historical data from samples collected using other techniques, but the results are less conclusive than those of a side-by-side test. The biggest uncertainties associated with PDB sampling are the presence of vertical stratification within the well and vertical flow within the well itself. Stratification can produce PDB sampler results that do not always agree with pumped results because PDB samplers represent approximate points (about 1 foot long) and tend to show the stratification with high precision, while the pumped sample often is a mixture of waters from different parts of the stratification. In this situation, it is advisable initially to delineate the stratification with diffusion samplers to decide on the optimum deployment depth. Vertical flow within the well means that the water may be coming from a horizon not adjacent to the PDB sampler and, therefore, not representative of the formation immediately adjacent to the PDB sampler. In this situation, a validation study should be completed to determine whether diffusion sampling is appropriate for the site conditions.

How can PDB samplers be used for detection monitoring at facilities currently using conventional sampling methods without introducing statistical variability due to the change in sampling method?

It is practically impossible not to introduce statistical variability when you switch sampling methods. For sites that are in compliance monitoring and using statistics to demonstrate a decreasing trend, PDB samplers may not be appropriate. However, if there is already a strong decreasing trend established in the data, switching methodologies would be less critical because there is good evidence that the plume concentrations are decreasing. If good correlation with existing results was obtained, the decision to switch methodologies is not scientifically complex. In a more complicated case

where data do not correlate well, additional work would be required to document why there is poor correlation (e.g., vertical profiling, bore-hole flow testing, review of hydrogeology and well construction information). It should be noted that some of the questions regarding PDB-sample data correlation and use, such as vertical placement of the sampler, also can apply to low-flow samples. PDB samplers have the potential to generate detailed data that may not always agree with the existing database of samples that have undergone some degree of mixing during pumping. The significance of these new data, in terms of contaminant fate, transport, and site management, is a site-specific consideration.

Are any guidance documents or user guides available?

Yes. In collaboration with USGS, U.S. Air Force, U.S. Naval Facilities Engineering Command, U.S. Environmental Protection Agency (U.S. EPA), Federal Remediation Technologies Roundtable, Defense Logistics Agency, and U.S. Army Corps of Engineers, ITRC has published *The User's Guide for Polyethylene Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Concentrations in Wells* (Vroblesky, D. A. March 2001). The document can be obtained at www.itrcweb.org and other Web sites. The purposes of this document are to present methods for PDB sampler deployment and recovery, discuss approaches for determining the applicability of passive diffusion samplers, and discuss various factors influencing interpretation of the data. The intended audience for the methodology sections of the report includes managers and field personnel involved in using PDB samplers. The discussion of PDB sampler applicability and interpretation of the data is suited for project managers, technical personnel, and the regulatory community. Part 2 of the document presents case studies of PDB-sampler field applications.

Is PDB sampler training available?

In collaboration with the U.S EPA/ Technology Innovation Office (TIO) and USGS, ITRC has developed Internet-based training on the *User's Guide*. See www.itrcweb.org for details. In conjunction with U.S. EPA/TIO, ITRC hosts these two-hour training courses via the Internet to reach a geographically diverse audience of regulators, consultants, and other members of the environmental community. The sessions are also archived on the Web at http://clu-in.org/studio/seminar.cfm.

Where can I get more information about PDB samplers?

ITRC has developed a "Diffusion Sampler Information Center" Web site http://DiffusionSampler.itrcweb.org. The site contains information on diffusion samplers, recent news, deployments, cost and performance data, technical documents, lessons learned, technology advances, available training, frequently asked questions, and contacts. The Web site also has links to other sources of information about PDB samplers. There is a growing body of data from numerous facilities comparing the results of diffusion sampling with other techniques such as bailing and low-flow sampling. This information is summarized in numerous technical reports that are being published or produced. The ITRC Web site will track and summarize this technical information on diffusion sampler deployments nationwide.

Whom can I contact for additional information?

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