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INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

Polyethylene Diffusion Bag Samplers

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Notice

IDEM Technology Evaluation Group (TEG) completed this evaluation of Polyethylene Diffusion Bag (PDB) Samplers based on review of items listed in the "References" section of this document.

This evaluation does not approve this technology nor does it verify its effectiveness in conditions not identified here. Mention of trade names or commercial products does not constitute endorsement or recommendation by IDEM for use.

Passive diffusion bag samplers as a group are sometimes referred to as "PDB Samplers." Documents listed in the "References" section describe several different types of passive samplers and passive diffusion samplers. However, for the purpose of this document, a "PDB sampler" is specifically a polyethylene diffusion bag sampler.

Background

"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 waterbearing zone through the well screen. VOCs [volatile organic compounds] *in groundwater will diffuse across the bag material until constituent concentrations within the bag reach equilibrium with concentrations in the surrounding groundwater."* (ITRC 2002)

PDB samplers are not appropriate for measurement of inorganic ions, most non-volatile organics, and certain VOCs (see list below) in groundwater, because these analytes do not effectively diffuse across the bag material.

There are several different makes/models of PDB samplers, and deployment procedures vary. Some come prefilled, while others require the user to fill the samplers with laboratory grade deionized water immediately prior to deployment. PDB samplers are buoyant, so they must be weighted before they are lowered on a line to the desired depth in the screened interval of the monitoring well. Once deployed, PDB samplers typically remain in place for a minimum of two weeks prior to removal to ensure that the deionized water in the bag has reached equilibrium with the surrounding groundwater.

After removal from the well, the user opens the sampler, drains the water into appropriate sample containers, and sends the samples to the laboratory for analysis. PDB sampler suppliers can provide more specific installation and recovery instructions.

PDB samplers have been available for several years and have undergone testing at numerous sites and under a variety of site conditions. For reasons described below, PDB samplers typically offer cost savings when compared to conventional purge or low-flow purge groundwater sampling equipment and techniques.

Section 3.3 of the IDEM *Remediation Closure Guide* (RCG) states that PDB samplers "and other types of passive sampling devices *may* also be acceptable for long-term ground water monitoring at sites that meet a strict set of criteria." IDEM technical staff will use the information and references in this guidance document to determine whether PDB samplers are acceptable for groundwater monitoring projects on a site-specific basis.

Advantages

When compared to conventional purge or low-flow purge and sample techniques, PDB samplers offer the following potential advantages:

- PDB samplers are relatively inexpensive, compared to re-usable sampling pumps and some bailing equipment.
- PDB samplers may eliminate or substantially reduce the amount of purge water associated with sampling.
- Unlike some low-flow purge and sample equipment, PDB samplers are relatively easy to deploy and recover.
- Because PDB samplers are disposable, in most cases there is no down-hole equipment to be decontaminated between wells. Re-usable weights added to a PDB sampler can be dedicated to a well and/or decontaminated between sampling events.
- PDB samplers require a minimal amount of field equipment, and the time required to retrieve the sampler from each well is relatively brief. Consequently, PDB samplers are 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).
- Some PDB samplers can be connected in a series prior to deployment for vertical distribution along the screened or open interval, 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.
- *"Because alkalinity-contributing solutes do not pass through the membrane, the samplers enable collection of VOCs in a non-alkaline 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 acidification."* (ITRC 2002)

Limitations

When compared to conventional purge or low-flow purge and sample techniques, PDB samplers have the following potential disadvantages:

- PDB samplers are not effective for inorganics, SVOCs and some VOCs. A list of VOCs that have been tested, with good correlation between PDB sampler and traditional sampler results, appears in the "Conclusions" section of this document. PDB samplers are not effective for sampling acetone, methyl-*tert*-butyl-ether (MTBE), methyl-isobutyl-ketone (MIBK) and styrene.
- PDB samplers integrate concentrations over time, which may be a limitation if the goal of sampling is to collect a short term sample in an aquifer where VOC concentrations substantially change more rapidly than the samplers equilibrate.
- Not enough data are available to determine whether PDB samplers work in low-permeability formations. Wells with sustained yields of less than 100 mL/minute have not been tested using PDB samplers, but all existing technologies have shortcomings in such environments. (See Low-Yielding Wells)
- *"In wells with screens or open intervals with stratified chemical concentrations, the use of a single PDB sampler set at an arbitrary (by convention) depth might not provide accurate concentration values for the most contaminated zone."* (Vroblesky 2001)
- For projects that do not meet a strict set of criteria, IDEM may ask for a show of equivalency with conventional sampling procedures before approving the use of PDB Samplers. When required, additional testing may add considerable overall cost to a project.
- Two mobilizations to the site are needed – one time to deploy the samplers and a separate time to retrieve the samplers.

Practical Considerations

Cost Comparison

ITRC developed a cost model spreadsheet to allow site-specific evaluation of cost implications of PDB samplers. This PDB Cost Model is available on the ITRC Diffusion/ Passive Samplers Resources & Links page (see https://itrcweb.org/teams/projects/diffusion-passive-samplers and may be useful for long-term monitoring projects.

"The largest cost savings related to the use of PDB samplers are in (1) personnel time on site and (2) the collection and disposal of purge water and the handling and disposal of decontamination fluids used on portable sampling systems. The size of the groundwater sampling operation will affect the cost savings." (ITRC 2004)

Acceptance of a "Non-Standard" Sampling Method

Because of the way PDB samplers function and the length of time needed to reach equilibrium within the well screen, regulatory agencies (local, state, and Federal) have been hesitant in some cases to approve the use of PDB samplers. Regulators familiar with the concept of collecting a grab groundwater sample and sending it off to the laboratory for results with a short turn-around time may have difficulty understanding an

integrated sample of the groundwater contamination that has a different matrix than the typical grab sample. There is concern that the PDB samplers will bias the results high or low and lead to inappropriate characterization of site contamination. In order to promote confidence in the PDB sampler results, IDEM may request side-by-side comparison with conventional or low-flow sampling methods at some point(s) during long-term monitoring.

The following scenarios may occur when reviewing side-by-side comparison results:

- If both PDB and conventional sampling produce concentrations that agree within a range deemed acceptable and meet the site-specific data quality objectives, then a PDB sampler may be approved for use in that well to monitor VOC concentrations.
- If concentrations from the PDB sampler are higher than concentrations from the conventional method, it is probable that concentrations from the PDB sampler adequately represent ambient conditions. Therefore, a PDB sampler may be approved for use in that well.
- If the conventional method produces concentrations that are significantly higher than those obtained using the PDB sampler, then it is uncertain whether the PDB sampler concentrations represent local ambient conditions. In this case, further testing can be done to determine whether contaminant stratification and/or intra-borehole flow is present.

Appropriate Sampling Interval and Time

Achieving equilibrium depends on temperature, flow rate, contaminant concentration, and other factors in and around monitoring wells containing PDB samplers. Without time-consuming and sometimes expensive pilot tests, it can be difficult to determine an appropriate level in the well screen to hang the PDB sampler and an appropriate length of time to leave the sampler in the well before sample retrieval. It is critical that a PDB sampler be fully submerged during the sampling period -- contact with soil gas or air allows an exchange of VOCs between the PDB sampler and the surrounding gases. Furthermore, both ITRC 2004 and Vroblesky 2001 recommend a minimum deployment period of 14 days to achieve equilibration, but no maximum deployment period was listed. PDB samplers have routinely been deployed for three-month periods and longer with no reported loss of sampler integrity. However, for consistency in evaluation, IDEM will not generally approve deployment for longer than 120 days, without site-specific justification. If these criteria are met, IDEM can approve somewhat arbitrary deployment depths and times, without pilot tests.

Low-Yielding Wells

Recommendations for using PDB samplers in low-yielding (less than 100 mL/min) wells were not found. ITRC 2004 gave the following explanations.

"PDB samplers require sufficient groundwater flow to provide equilibration with the aquifer … With sufficient aquifer flow conditions, groundwater will continually flow through a properly constructed well. Under these conditions, groundwater in the screen interval may be replaced in as little as 24 hours. For water in the well to be representative of the aquifer, the rate of solute contribution from the aquifer to the well

must equal or exceed the rate of in-well contaminant loss, such as by volatilization or convection. This condition may not occur where groundwater velocities are very low or the well has a low yield, which is commonly the result of a very low gradient or a very low hydraulic conductivity. There are currently no data on the performance of PDB samplers in these situations."

"It is difficult to collect a water sample in low-permeability zones using any type of device, and PDB samplers may provide a practical approach if the restrictions are carefully considered. However, PDB sampling is not recommended for wells in which water in the screened interval becomes effectively stagnant. Less suitable wells also include those that are poorly designed, constructed, or developed."

Vroblesky 2001 added:

"In less permeable formations, longer equilibration times may be required. It is probable that water in the well bore eventually will equilibrate with the porewater chemistry; however, if the rate of chemical change or volatilization loss in the well bore exceeds the rate of exchange between the pore water and the well-bore water, then the PDB samplers may underestimate pore-water concentrations. Guidelines for equilibration times and applicability of PDB samplers in low-permeability formations have not yet been established. Therefore, in such situations, a side-by-side comparison of PDB samplers and conventional sampling methodology is advisable to ensure that the PDB samplers do not underestimate concentrations obtained by the conventional method."

Procedures for Side-By-Side Comparisons

IDEM may request side-by-side comparisons between PDB samplers and conventional or low-flow groundwater sampling devices for some projects. IDEM recommends the following procedures when performing such comparisons:

- The well should be sampled by the conventional or low-flow approach soon after (preferably on the same day) recovery of the PDB sampler.
- Low-flow purging and sampling disturbs the local ground water less than conventional purge-and-sample methods. Thus, samples obtained by PDB samplers are likely to be more similar to samples obtained by using low-flow purging than to those obtained by using conventional purge-and-sample methods.
- The water samples obtained using PDB samplers should be sent in the same shipment as the samples collected by the conventional or low-flow approach for the respective wells.
- Utilizing the same laboratory for both sample sets may reduce analytical variability.
- In a well having relatively low temporal concentration variability, comparison of the PDB sampler results to historical concentrations may provide enough information to determine whether the PDB samplers are appropriate for the well.

Differences in analytical results between PDB sampling and other methods should be expected. Section 4.2 of ITRC 2004 includes procedures for evaluating comparisons,

examples of comparison studies, and reasons for poor agreement between PDB and conventional sampling results. For consistency in evaluation, IDEM considers a relative percent difference (RPD) $\leq$ 20 as acceptable variability for side-by-side comparison of results. This standard RPD value may be adjusted according to site-specific conditions and DQOs.

Sample Retrieval

When the PDB sampler is retrieved from the well, the user should examine the surface of the sampler for evidence of algae, iron or other coatings, and for tears in the membrane. If there are tears in the membrane, the sample should be rejected. If the PDB sampler exhibits a coating, this must be noted in the field record and considered when evaluating the sample results.

Protective nets are available which users can place around PDB samplers prior to deployment to help prevent tearing the samplers when they are removed from the well. Some PDB samplers also offer special hangers and release valves to aid in transferring the water sample from the PDB to the sample containers.

Safety Issues

IDEM TEG did not identify any significant safety issues associated with PDB samplers.

Conclusion

Based on review of the documents listed in the References section of this document, IDEM Technical Evaluation Group recommends IDEM technical staff use the following criteria when determining whether PDB samplers are acceptable for groundwater monitoring at a specific site:

- PDB samplers are only appropriate as part of an IDEM-approved, site-specific Sampling and Analysis Plan (SAP), Quality Assurance Project Plan (QAPP), or similar document with established Data Quality Objectives (DQOs).
- PDB samplers are only appropriate for long-term monitoring of certain VOCs in groundwater at sites where the contamination has been characterized and defined.
- Users should follow manufacturers' recommendations with regard to the VOCs monitored and the acceptable concentration ranges for the particular PDB sampler used. PDB samplers are not appropriate at wells with VOC concentrations above acceptable concentration ranges (or free product).
- Sites must have suitable groundwater flow to allow adequate exchange across the well screen. IDEM does not recommend sampling low-yielding wells (See description in Low-Yielding Wells, above) with PDB samplers.
- PDB samplers should be left in the well a minimum of 14 days prior to removal, unless site-specific conditions indicate a different time interval is appropriate. The samplers may remain in the well longer than 14 days to allow for convenience in sampling schedule; however, IDEM will not generally approve deployment for longer than 120 days without site-specific justification.

- The VOCs listed in the table below are acceptable for monitoring using PDB samplers. As noted above, acetone, methyl-*tert*-butyl-ether, methyl-isobutyl-ketone and styrene are NOT acceptable for PDB samplers.

Compounds with Good Correlation between Conventional and PDB Sampling

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-Chloroethyl vinyl ether	*cis*-Dichloropropene	1,2,3-Trichloropropane
Dibromochloromethane	1,2-Dibromoethane	Vinyl chloride
Dibromomethane	*trans*-1,3-Dichloropropene	Total xylenes
1,2-Dichlorobenzene	Ethylbenzene	

Source: Vroblesky 2001

- Side-by-side comparison of results from PDB samplers with results from conventional or low-flow groundwater sampling devices may be necessary to demonstrate that site-specific conditions are suitable for using PDB samplers, or to show that approved PDB samplers have functioned properly during the monitoring period. IDEM considers RPD less than 20 as acceptable variability for side-by-side comparison of results. This standard RPD value may be adjusted according to site-specific conditions and DQOs.

Further Information

If you have any additional information regarding PDB Samplers or any questions about the evaluation, please contact the Office of Land Quality, Science Services Branch at (317) 232-3215. IDEM TEG will update this technical guidance document periodically or on receipt of new information.

References

Interstate Technology Regulatory Council (ITRC), 2002. Passive Diffusion Bag (PDB) Samplers, Frequently Asked Questions; available at: http://www.itrcweb.org/Documents/PDBFAQs2.pdf

Interstate Technology Regulatory Council (ITRC), 2004. Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater (DSP-3) Feb-04; available at: https://connect.itrcweb.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=37de87b8-6ca8-4f8a-b688-5f5a09332d40

LeBlanc, D. and Archfield, S.; 2005. Comparison of Diffusion and Pumped Sampling Methods to Monitor Volatile Organic Compounds in Ground Water, Massachusetts Military Reservation, Cape Cod, Massachusetts, July 1999-December 2002, Scientific Investigations Report 2005-5010; available at: http://pubs.usgs.gov/sir/2005/5010/pdf/sir2005_5010.pdf

Vroblesky, D.; 2001. User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells *Part 1:* Deployment, Recovery, Data Interpretation, and Quality Control and Assurance, U.S. Geological Survey, Water-Resources Investigation Report 01-4060; available at: https://clu-in.org/download/char/passsamp/Users-guide-for-polyethylene-WRIR01-4060.pdf

Vroblesky, D., *editor*; 2001. User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells *Part 2:* Field Tests, U.S. Geological Survey, Water-Resources Investigation Report 01-4061; available at: https://www.itrcweb.org/Guidance/GetDocument?documentID=23

General Passive Sampler Information Sites

USEPA Clean-Up Information (Clu-In.org); Passive (no purge) Samplers, Diffusion Samplers; available at: http://www.clu-in.org/characterization/technologies/default.focus/sec/Passive_(no%20purge)_Samplers/cat/Diffusion_Samplers/

Interstate Technology Regulatory Council (ITRC); Diffusion/Passive Samplers Resources and Links; available at: https://itrcweb.org/teams/projects/diffusion-passive-samplers.