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Standard Guide for Selection of Passive Techniques for Sampling Groundwater Monitoring Wells[1]

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1. Scope*

1.1 This standard provides guidance and information on passive sampling techniques for collecting groundwater from monitoring wells. Passive groundwater samplers are able to acquire a sample from the screen interval in a well, without the active transport associated with a pump or purge technique (**1**).[2] Passive groundwater sampling is a type of no-purge groundwater sampling method where the samplers are left in the well for a predetermined period of time prior to collecting the sample.

1.2 Methods for sampling monitoring wells include low-flow purging and sampling methods, traditional well-volume purging and sampling methods, post-purge grab sampling methods (for example, using a bailer), passive no-purge sampling methods, and active no-purge sampling methods such as using a bailer to collect a sample without purging the well. This guide focuses on passive no-purge sampling methodologies for collecting groundwater samples. These methodologies include the use of diffusion samplers, accumulation samplers, and passive-grab samplers. This guide provides information on the use, advantages, disadvantages, and limitations of each of these passive sampling technologies.

1.3 ASTM Standard D653 provides standard terminology relevant to soil, rock, and fluids contained in them. ASTM Standard D4448 provides a standard guide to sampling groundwater wells, and ASTM Standards D5903 and D6089 provide guides for planning and documenting a sampling event. Groundwater samples may require preservation (Guide D6517), filtration (Guide D6564/D6564M), and measures to pack and ship samples (Guide D6911). Standard D7069 provides guidance on the quality control and quality assurance of sampling events. ASTM Standard D5092/D5092M provides standard practice for the design and installation of groundwater monitoring wells, ASTM Standard D5521/D5521M provides a standard guide for developing groundwater monitoring wells in granular aquifers, and D6452 provides a standard guide for purging methods used in groundwater quality investigations. Consult ASTM Standard D6724/D6724M for a guide on the installation of direct-push groundwater monitoring wells and ASTM Standard D6725/D6725M for a guide on the installation of direct-push groundwater monitoring wells with pre-pack screens.

1.4 The values stated in SI Units are to be regarded as the standard. Values in inches (such as with well diameters) are given in parentheses, and are provided for information. Use of units other than SI shall not be regarded as nonconforming with this standard.

1.5 This guide provides information on passive groundwater sampling in general and also provides a series of considerations when selecting a passive groundwater sampling method. However, it does not recommend a specific course of action, and not all aspects of this guide may be applicable in all field situations. This document cannot replace education or experience and should be used in conjunction with professional judgment. 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 without 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.

1.6 *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.*

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

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Groundwater and Vadose Zone Investigations.

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[2] The boldface numbers in parentheses refer to the list of references at the end of this standard.

*A Summary of Changes section appears at the end of this standard

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
D4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well) (Withdrawn 2010)[3]
D4448 Guide for Sampling Ground-Water Monitoring Wells
D5092/D5092M Practice for Design and Installation of Groundwater Monitoring Wells
D5521/D5521M Guide for Development of Groundwater Monitoring Wells in Granular Aquifers
D5903 Guide for Planning and Preparing for a Groundwater Sampling Event
D6089 Guide for Documenting a Groundwater Sampling Event
D6452 Guide for Purging Methods for Wells Used for Ground Water Quality Investigations
D6517 Guide for Field Preservation of Ground Water Samples
D6564/D6564M Guide for Field Filtration of Groundwater Samples
D6724/D6724M Guide for Installation of Direct Push Groundwater Monitoring Wells
D6725/D6725M Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers
D6911 Guide for Packaging and Shipping Environmental Samples for Laboratory Analysis
D7069 Guide for Field Quality Assurance in a Groundwater Sampling Event

3. Terminology

3.1 For common definition of common technical terms used in this standard, refer to Terminology D653.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *passive environmental sampling, n—in groundwater*, is a group of sampling techniques based on the free flow of analyte molecules from the sampled medium to a receiving phase in a sampling device as a result of a difference between the chemical potentials of the analytes in the two media (**2 and 3**).

3.2.1.1 *Discussion*—These passive sampling devices are usually based on diffusion through a diffusion barrier or permeation through a membrane into a sorptive membrane or medium (**2 and 3**). Uptake of analytes follows a standard uptake curve where uptake initially is linear, followed by a period of time where uptake is no longer linear (that is, becomes curvilinear), and finally equilibration is reached. Analytes are retained in a suitable medium within the passive sampler, known as a reference or receiving phase, which can be a solvent, chemical reagent, or a porous adsorbent (**2 and 3**). There are two main accumulation regimes, kinetic and equilibrium, and these are described based on the device's physical basis of operation as defined below.

3.2.2 *equilibrium samplers, n—in groundwater*, passive samplers that have an exposure time that is sufficiently long to permit the establishment of thermodynamic equilibrium between the sampled medium and receiving phase (**3**).

3.2.3 *integrative or kinetic samplers, n*—passive samplers that work in the linear uptake phase (of a standard uptake curve) where the rate of desorption of analytes from the receiving phase to the sampled medium is negligible (**2 and 3**).

3.2.3.1 *Discussion*—These samplers provide a total mass for the time they are deployed, which can be converted to concentration values in some cases.

3.2.4 *no-purge groundwater sampling, n—in groundwater*, sampling methods that differ from active purging-and-sampling methods for sampling groundwater (as described in Guide D6452) in that there is no requirement to remove water from the well prior to sampling.

3.2.4.1 *Discussion*—No-purge methods can collect a sample using an active method (such as pumping, suction, bailing) or a passive method without purging the well.

3.2.5 *passive groundwater sampling, n—in groundwater*, a type of no-purge groundwater sampling method where the samplers are deployed in the well at one or more target depths within the well screen or open bore hole and are then left in the well for a period of time prior to collecting the sample (rather than collecting a sample immediately).

3.2.5.1 *Discussion*—These sampling methods do not use pumping, suction, or bailing to collect the sample and thus do not induce stress on the aquifer (Guide D4448).

3.2.6 *passive-groundwater samplers, n—in groundwater*, devices deployed in a well for the purpose of passive groundwater sampling.

3.2.6.1 *Discussion*—These devices provide a sample from a specific location within the well screen or borehole. Spatial integration, which is likely, is a result of natural ambient flow and mixing of the sampled medium within the monitoring well (**4**). These samplers can be classified by the mechanism used to collect the sample and include: diffusion samplers (**5 and 6**), accumulation samplers (**1, 7**), and passive-grab samplers.

3.2.7 *diffusion samplers, n—in groundwater*, usually contain deionized (DI) or distilled water inside a membrane and rely on diffusion of analytes through the membrane to reach equilibrium with concentrations in the well.

3.2.7.1 *Discussion*—These samplers are an equilibrium type of passive sampler (as defined in 3.2.2.1). The length of the equilibration period depends primarily upon the types of analytes, the membrane material, the rate of exchange of water in the well, and temperature of the well water.

3.2.8 *accumulation samplers, n—in groundwater*, typically consist of a liquid or solid sorbent medium, contained in a permeable membrane or in direct contact with the water sample, and rely on diffusion and sorption to accumulate analytes in the sampler.

3.2.8.1 *Discussion*—Although, these samplers can be used as either an integrative or equilibrium sampler, adsorptive samplers are prone to saturation effects and other reactions

[3] The last approved version of this historical standard is referenced on www.astm.org.

which make them less suitable for equilibrium sampling (**8**). When these samplers are used in the integrative (or kinetic) mode, the sampling time must be within the linear portion of the uptake curve.

3.2.9 *passive-grab samplers, n—in groundwater*, grab samplers that collect a whole water sample and require an equilibration period prior to sample collection. Passive-grab samplers should not disturb the water column during sample collection, should be able to collect a sample at the target depth(s) in the well, and should be able to isolate the sample inside the sampler prior to removing it from the well.

3.2.10 *equilibration period, n—in groundwater*, the suggested deployment period for passive-grab samplers, diffusion samplers, and accumulation samplers when they are used as equilibrium samplers.

3.2.10.1 *Discussion*—The appropriate deployment period depends upon one or more of the following factors: the time needed for environmental disturbances caused by sampler deployment to dissipate and ambient conditions in the well to return, the time needed for equalization of analyte concentrations with surrounding concentrations in the well water, and the time needed to reduce losses due to sorption of the analytes by the sampler materials to negligible levels.

3.2.11 *deployment time, n—in groundwater*, Deployment time is the period required for an accumulation sampler to achieve quantitative levels of uptake of the target analytes when being used as an integrative (or kinetic) sampler.

4. Significance and Use

4.1 *General*—Passive groundwater sampling has increased use since the polyethylene diffusion bag sampler was first introduced (**5**). As defined above, different types of passive samplers are now available with different functions and usages. The Interstate Technology Regulatory Council (ITRC) has provided several technical and regulatory documents on the use of passive groundwater sampling methods (**1, 5-7**). Collectively, these documents have provided information and references on the technical basis for their use, comparison of sampling results with more traditional sampling methods, descriptions of their proper use, limitations, and a survey of their acceptance and use by responding state regulators. However, the ITRC documents are older and do not include more recent assessments and publications. This Standard seeks to provide newer information on current practice and implementation of passive groundwater sampling techniques.

4.1.1 Because of the large number of passive samplers that have been developed over the years for various types of environmental sampling, it is beyond the scope of this standard to discuss separately each of the methods that could or can be used to sample groundwater. Extensive literature reviews on diffusion- and accumulation-passive samplers can be found in the scientific literature (that is, **3, 8-14**). These reviews provide information on a wide variety of passive sampling devices for use in air, soil vapor, and water. A review paper on the use of diffusion and accumulation-type passive samplers specifically for sampling volatile organic compounds (VOCs) in groundwater (**15**) includes information on other passive samplers that are not included in the ITRC documents (**1, 7**) and discusses their use with respect to measuring mass flux.

4.2 *Use*—Passive samplers are deployed at a pre-determined depth, or depths, within a well for a minimum or pre-determined period of time. They should remain submerged at the target depth for their entire deployment period. All of the passive technologies described in this document rely on the sampling device being exposed to the groundwater during deployment and the continuous flushing of the open or screened interval of the well by ambient groundwater flow ((**4**), (**5-7**), **16**) to produce water quality conditions in the well bore that effectively mimic those conditions in the aquifer adjacent to the screen or open interval. For samplers that require the establishment of equilibrium, it is important that the equilibration period be long enough to allow the well to recover from any disturbance caused by placing the sampler in the well and to prevent, or reduce, losses of analytes from the water sample by sampler materials due to sorption. For kinetic accumulation samplers (used as kinetic samplers), it is important that the deployment time is long enough that quantitative uptake can occur but not so long that uptake is no longer in the linear portion of the uptake curve (that is, has become curvilinear).

4.2.1 As with all types of groundwater sampling methods, the appropriate use of passive methods assumes that the well has been properly located (laterally and vertically), designed, constructed, and was adequately developed (as described in Guide D5521/D5521M) and maintained (as described in Practices D5092/D5092M and D6725/D6725M, or Guide D6724/D6724M). These measures are necessary so that the well is in hydraulic communication with the aquifer.

4.2.2 Each type of passive sampler has its own attributes and limitations, and thus data-quality objectives (DQOs) for the site should be reviewed prior to selecting a device. For wells in low-permeability formations, diffusive flux may become more important than advective flow in maintaining aquifer-quality water in the well.

4.3 *Advantages*—While passive methods are not expected to replace conventional pumped sampling in all situations, they often offer a faster alternative "tool" for sampling groundwater monitoring wells because purging is eliminated from the pre-sampling procedure. Other advantages include that these samplers can be used in most wells and typically have no depth limitation. These samplers are either disposable or dedicated to a well. This eliminates or reduces the need for decontamination. Passive samplers typically reduce the logistics associated with sampling and are especially useful at sites where it is difficult to bring larger equipment (such as pumps and compressors) to the well location.

4.3.1 Passive groundwater sampling techniques typically provide a lower "per-sample" cost than conventional pumped sampling methods (**17-26**). This is primarily because the labor associated with collecting a sample is substantially reduced and waste handling and disposal is substantially reduced. Eliminating handling and disposal of purge water is an environmental benefit and advantage.

4.3.2 If there is interest in identifying contaminant stratification within the well, multiple passive samplers can be used to characterize vertical contaminant distribution with depth.

Baffles or packers can be used to segregate the sampling zones and often provide better characterization of each zone. Profiling contamination with depth in a well can be informative when trying to decide where to place a single passive sampler within the well screen for long-term monitoring; placing a sampler at the mid-point of the screen may not yield a sample with the highest contaminant concentrations or one that agrees best with previous low-flow concentrations (for example, **26**).

4.4 *Disadvantages*—As with any groundwater sampling method, rapid or rigorous deployment of the sampler(s) can increase turbidity in the well. For passive groundwater samplers, this can be reduced or eliminated if the equilibration time is long enough to allow the return of the natural ambient turbidity in the well. In many cases, passive samplers are deployed at the end of a sampling event and left in the well until the next scheduled sampling event; this practice provides more than enough time for equilibration to occur. Some methods require dedicated equipment purchase which may increase the cost for the initial sampling event in order to obtain the overall cost advantage.

4.5 *Limitations*—There are three primary limitations with passive samplers: analyte capability, sample volume, and physical size with respect to well diameter. For the diffusion and accumulation samplers, the membrane and or sorbent, respectively, determine the analyte capability of the sampler. In contrast, passive-grab samplers collect whole water samples and can be used for any analyte, subject to sample volume and physical size limitations.

4.5.1 Analyte capability is often unique to individual passive samplers. In the case of diffusion-based passive samplers, the user should verify that the membrane is suitable for the analytes to be tested. ITRC (**5-7**) describes the analyte capability of diffusion-bases passive samplers. Two or more individual types of passive samplers can be used simultaneously to sample for a broader spectrum of analyte types.

4.5.2 Passive-grab and passive-diffusion samplers collect a finite sample volume. Total sampler volume may limit the number and type of analytes that can be practically collected. Additional samplers or larger volume samplers may be available and can be used to meet the volume requirements. Also, because laboratories typically use only a small portion of the sample collected, it may be possible to provide the laboratory with a smaller sample volume. Table X1.1 provides suggested minimum volumes for several analyte classes. The laboratory should be consulted to confirm adequate sample volume during the method selection process.

4.5.3 Regarding physical sizes of the sampler(s), the diameter of the sampler or combination of samplers must be able to fit in the well or multi-level sampler.

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. 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.

5. Considerations for Passive Groundwater Sampling

5.1 *Planning a Passive Sampling Event*—As with all sampling activities, it is essential that all parties involved in planning the use of any sampling method identify and agree on the sampling and data-quality objectives, data-evaluation criteria, end use of the data, target analytes, and hydrogeologic concerns before the sampling method is selected. The appropriateness of any method is determined by the data-quality objectives (DQOs) for the sampling event and overall site monitoring program, and by the ability of the sampling method to meet them accurately and reliably. Considerations when selecting a passive sampling method can include sampler design, ability of the sampler to collect the target contaminants, well construction (including well diameter, screen and filter pack length, and proper slot size for the screen and filter pack design as described in Practice D5092/D5092M), vertical and horizontal flow patterns within the well, and contaminant stratification. Additional guidance on the selection of a passive sampling method can be found in Table X2.1.

5.2 *Analytes of Interest*—When deciding whether to use passive sampling or which passive sampling method to use, consideration should be given to the contaminants of concern (COCs) for the site and other analytes or parameters that may be used to evaluate the geochemical processes of interest. Some passive samplers collect only specific analytes, whereas other devices can be used for a broader suite of analyte types.

5.2.1 Some samplers collect a limited volume of sample, and this may limit the use of these samplers. The sample volume that can be collected will be determined by the type of passive sampler, the diameter of the well, and the length of the desired sampling interval in the well. A larger total sample volume can be obtained by increasing the number of samplers used within the sampling interval (at the same depth or in series with depth) or, in some cases, by increasing the size of the sampling device (that is, using a longer or wider diameter sampler). However, when samplers are deployed in series with depth, concentrations in the samplers will reflect any stratification that exists in the sampling zone. Also, as mentioned previously, consulting with the analytical laboratory may make it possible to reduce the minimum volume of sample. (See Table X1.1 for suggested minimum volumes.)

5.2.2 More specific information on the capabilities of particular sampling devices can be found in 6.1, 6.2, and 6.3, and in Table X2.1. For devices that are available commercially, current information can also be obtained by contacting the sampler manufacturer(s) or supplier(s).

5.3 *Site Considerations*—In general, passive groundwater samplers can be used in a wide variety of hydrogeologic settings. Site considerations can include: accessibility of the wells, well diameter, screen length, saturated thickness, the hydraulic connection between the well and aquifer, and the hydraulic gradient that generates flow. Passive samplers are particularly well suited for conditions where active sampling methods can be problematic. These conditions can include low-yield formations where excessive drawdown is unavoidable even at low flow rates, locations where purge methods result in large volumes of purge water that must be disposed, locations that are difficult to access with a vehicle, or where low-turbidity samples are needed but cannot be obtained using other sampling methods such as with a bailer or a pump.

5.3.1 However, there can be situations that preclude the use of any sampling method, including standard purged methods. Both passive and active sampling methods may inadvertently collect non-aqueous phase liquid (NAPL). For example, this can occur when a sampler or pump passes through a NAPL zone during deployment or when droplets are drawn down or entrained while pumping the well. In these cases, collection of water samples from wells containing NAPL may overestimate dissolved-phase concentrations and may complicate data interpretation. Therefore, the practical effect of this bias on the sampling objectives and project DQOs should be evaluated, and continued collection of the water sample may not be warranted.

5.4 *Acceptability of Passive Groundwater Sampling Methods*—Numerous studies have shown that passive-groundwater sampling methods collect representative concentrations of groundwater constituents of concern and are appropriate alternatives to purged sampling methods. Studies illustrating representativeness and comparability to purge sampling approaches are listed for each type of sampling device in 6.1, 6.2, and 6.3.

5.4.1 Questions about the "need to purge" have been largely answered over the course of the last few decades (**16, 27, 28**). In properly designed, developed, and maintained monitoring wells, hydraulic communication exists between the aquifer and well. With adequate hydraulic gradient, aquifer water flows into and out of the screened or open sections of a well. Passive sampling devices set in such screened or open zones will collect aquifer water that is in dynamic equilibrium with the aquifer without purging. As with pumping, the hydraulics within the well, well bore, and the formation will determine what the sample represents. The same factors are at play with the different available passive sampling methods.

5.4.2 There are conditions where a passive sample does not collect a sample from the entire screened zone of a well. This may be due to, for example, vertical flow in the well, contaminant stratification, poor hydraulic communication, or a low hydraulic conductivity in the formation (creating a long residence time in the well). However, these conditions can also be problematic for purged sampling methods (**29, 30**). These conditions do not necessarily make passive sampling an unacceptable alternative, rather, passive sampling may simply represent the adjacent aquifer differently than a pumped sampling method. Recommendations on how to deal with differences between analyte concentrations when comparing passive vs. active sampling methods are given in Appendix X3.

5.4.3 In instances where there is poor hydraulic communication between the aquifer and the well, rehabilitation of the well or redevelopment often improves the communication between the aquifer and well. This can be necessary for both pumped and passive methods.

5.5 *Implementing Passive Sampling Methods*—There are inherent advantages and limitations in every groundwater sampling method. These differences should be examined within the context of the particular project objectives, data needs, and site conditions for each proposed application. A fundamental concern of regulators is that the sampling method used at a site, or at a particular well, provides results that meet the DQOs for the project.

5.5.1 *Method Selection*—There are different passive sampling systems and these technologies vary in the degree of field validation. Methods that have strong field validation and provide good reproducibility among different users, field conditions, and time frames are best suited for long-term monitoring strategies. Two or more passive sampling techniques may be deployed simultaneously and provide samples for a broader range of analytes and thereby meet the site DQOs. For a broad range of analyte concentrations, it may be necessary to deploy two or more samplers of the same type in a well.

5.5.2 *New Sites*—In cases where new wells or a new site is under consideration, selection of a sampling method does not rely on historical data continuity and thus method selection would rely on an evaluation of the data quality needs for the site. Improved site-characterization methods can yield better designed wells (often with shorter screens) and thereby improve this decision process. Data from passive sampling methods that use multi-level samplers may provide more specific and detailed high-resolution information in terms of aquifer stratigraphy, contaminant fate and transport, and site management.

5.5.3 *Older Sites*—There should be no impediment to switching to a passive method as long as the DQOs of the site can be met by the particular sampling method chosen. A number of field and laboratory studies (listed in 6.1, 6.2, and 6.3) have been conducted to determine the comparability of passive methods with conventional sampling methods. These studies reveal that in most situations, passive methods provide samples that have analyte concentrations that are not significantly different (on a statistical basis) from those collected using other conventional sampling methods such as low-flow purging and sampling. When considering a change in sampling methods, the question arises how the results of the existing and new methods will compare. When converting to a passive sampling method, a side-by-side comparison test with the site's current method or comparison with historical data may be desirable to understand data differences between sampling methods. Further discussion on how to conduct this type of test, how to analyze the data, and how to interpret the data are given in Appendix X3.

6. Types of Passive Groundwater Sampling Devices

The three types of passive groundwater sampling devices—that is, passive-grab samplers, diffusion samplers, and accumulation samplers—vary greatly in how they function and each type has its own specific deployment-time requirements. This section describes these three general types of passive samplers and the supporting validation references.

6.1 *Passive-grab Samplers* are used to collect a whole water sample from a discrete depth or interval within the well or borehole after a recommended deployment period in the well. Residence time allows the well to recover from the disturbance caused by inserting the sampler in the well and thus allows the water in the screened interval to return to the ambient flow conditions that existed between the well and the formation. This reduces the possibility of collecting a sample with an artificially elevated turbidity and thus obtaining falsely elevated concentrations of particle-borne contaminants. Deployment residence time also allows the sampler materials to equilibrate with analyte concentrations in the surrounding well water prior to sample collection, and thereby prevents, or reduces, analyte losses due to sorption by the sampler materials (**31-35**). Sample collection does not occur until the device is triggered or actuated. Passive-grab samplers should not disturb the water column during sample collection, should be able to collect a sample at the target depth(s), and should be able to isolate the sample inside the sampler prior to moving the sampler within the well. These criteria distinguish "passive-grab samplers" from other grab samplers that are used as no-purge samplers, such as various types of bailers including point-source bailers and collapsible bailers (for example, sleeve-type samplers). The ITRC Diffusion/Passive Sampler Team (**1**, **7**) previously categorized grab samplers used in passive sampling as "equilibrated-grab samplers." However, not all of "equilibrated-grab samplers" meet the more restrictive definition for "passive-grab samplers" given in this standard.

6.1.1 *Advantages*—The primary advantage of passive-grab samplers is that typically they can be used to collect samples for a wide range of organic and inorganic analytes. This is because sample collection is not limited by the sampler membrane or the collection media inside the device. These devices do not exclude colloidal particles, and thus can be used to collect samples for analyses of total and dissolved concentrations of analytes. Samples collected with these samplers can be used to measure pH, oxidation-reduction potential (ORP), electrical conductivity, and dissolved gases. These samplers can be used for quarterly, semi-annual, or annual sampling events with single mobilizations for sample collection. After collecting each sample, a new sampler or sample bottle is replaced in the well in preparation for the next event, avoiding a second trip to the field. For one type of passive-grab sampler, the samples are sealed in a sample bottle in the well. In some instances the sample bottle can remain sealed until the sample is analyzed; this prevents loss of VOCs during transfer in the field or in the laboratory ((**36**)).

6.1.2 *Disadvantages*—For passive-grab samplers, inadvertently agitating or aerating the well or dislodging particles from the inside of the well casing or well bore during sampler deployment can alter some analyte concentrations including metals subject to oxidation/precipitation reactions, and particle-borne or colloid-borne contaminants. The length of the equilibration period should be sufficient to provide time for the well to recover from any disturbance caused by inserting the sampling device in the well. The extent of recovery in the well depends upon the flow rate in and out of the screened interval and the condition of the well. In instances where entraining extraneous particles is a problem, this can be mitigated in some cases by redeveloping the well.

6.1.3 *Limitations*—The primary limitations with these samplers are their size and the sample volume collected. Typically, these samplers do not fit in wells less than 5 cm (2 in.) in diameter. In instances where a larger sampler volume is needed, a larger sampler may be available or, it may be possible to place several samplers at the same depth in larger diameter wells or in series with depth in smaller diameter wells.

6.1.4 *Additional Information*—There are several field and laboratory studies that have evaluated the performance of these types of groundwater samplers include peer-reviewed reports, papers (**22-25**, **35**, **36**) and other reports (**17**, **37**). Also, several of these reports (**17**, **24**, **25**) include cost analyses that demonstrate the cost savings that can be achieved using these types of passive samplers when compared with conventional pumped sampling methods.

6.2 *Diffusion Samplers* rely on diffusion of analytes of interest through a membrane into distilled or deionized (DI) water contained inside the sampler. Polymeric materials commonly used for the membranes include low-density polyethylene (LDPE), regenerated cellulose (or dialysis membrane), nylon, and polymethylsulfone. While typically a minimum of two weeks is recommended for equilibration (**1**, **5-7**), a longer period may be needed for some analytes such as explosives (**18-20**). Diffusion samplers provide a time-weighted average concentration that is weighted most heavily towards concentrations in the well over the last few days the sampler is in the well. The degree of this weighting depends on the equilibration rates for the analytes of interest for the membrane being used (that is, the type and thickness), the water temperature, and rate of recharge (flow rate) in the well.

6.2.1 *Advantages*—Diffusion samplers are functionally simple and can be quickly deployed and retrieved. Waste disposal is limited to a small amount of unused water from spent disposable samplers. Diffusion samplers are typically disposable so little or no decontamination is required. Most of these samplers can be used for quarterly, semi-annual, or annual sampling events. Depending upon the membrane used in the sampler, it may be possible to collect samples that can be used to measure pH, ORP, electrical conductivity, or dissolved gases. Some diffusion samplers can be used to collect samples for a variety of organic and inorganic analytes, and some membranes provide unique advantages. As an example, the LDPE membrane used in some samplers will prevent alkalinity exchange of the aquifer water with the (DI) water in the sampler (**38**). This can be an advantage when collecting VOC samples from alkaline aquifers where addition of the sample to the acid preservative in the vial (or vice versa) results in effervescence and subsequent loss of VOCs. Several of these samplers are available commercially and generally are relatively inexpensive to purchase. Samplers that are not commercially available (and thus have to be constructed) may still be cost effective (**17-25**).

6.2.2 *Disadvantages*—These samplers exclude all particles bigger than the pore size of the membrane and thus they cannot