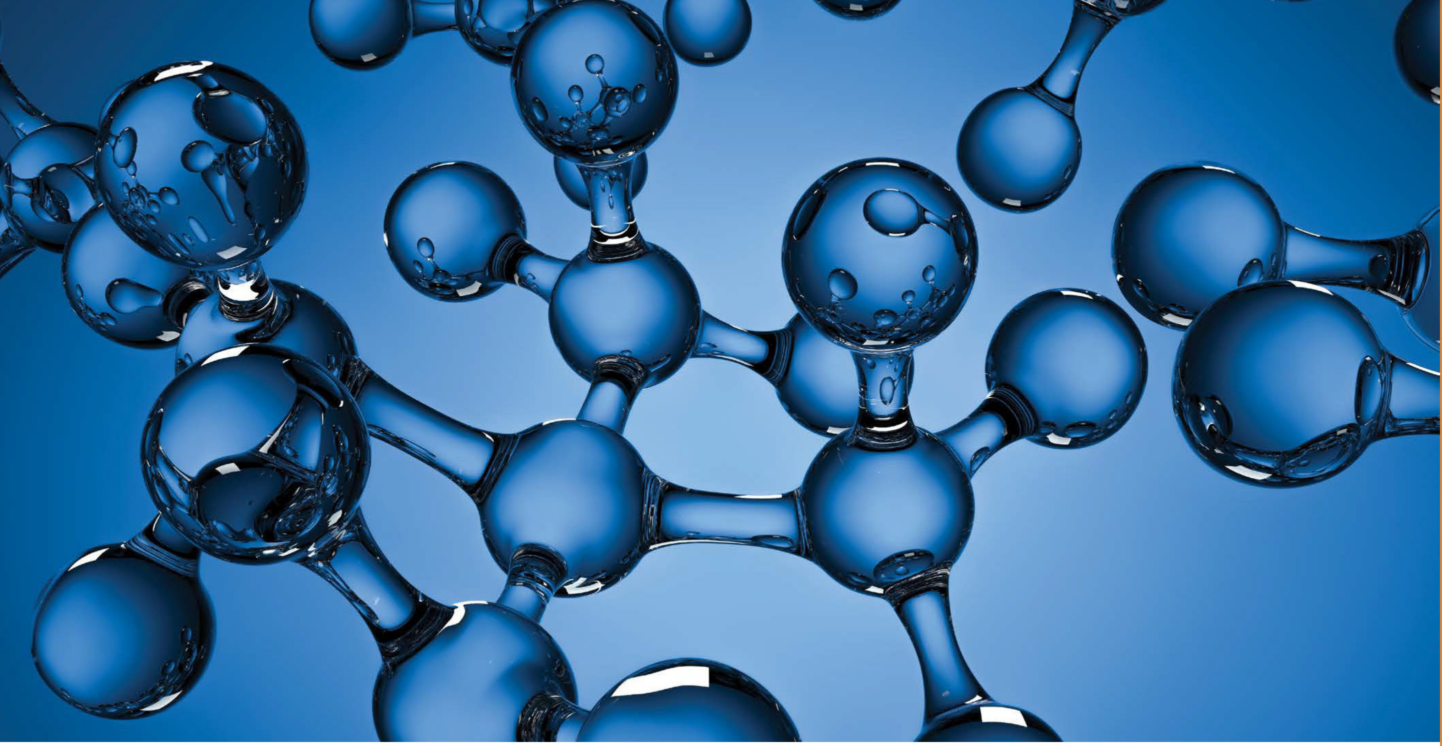

Practical Guide for PFAS Sampling

NGWA WHITE PAPER

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Introduction

Per- and polyfluoroalkyl substances (PFAS) are a class of thousands of synthetic compounds manufactured since the 1940s. PFAS are formed from the carbon-fluorine bond, one of the shortest and strongest bonds known, and organofluorine chemistry is extremely complex. PFAS have been used in a wide variety of industrial and commercial products such as fire-fighting foams, stain-resistant carpet and fabric treatments, non-stick cookware, food packaging, and many other consumer and industrial products. The presence of PFAS in so many products, and their presence in municipal and industrial waste streams, can cause PFAS contamination in landfill leachate and sewage treatment plant effluent. Many PFAS dissolve easily in water, are persistent in the environment, and can travel miles in groundwater to wells, wetlands, and streams. PFAS are associated with negative health effects including cancer, reproductive and developmental impacts, thyroid disease, and immune suppression. Despite an 80-year manufacturing history and its widespread use, our understanding of PFAS health effects, their environmental fate and transport, and effective treatment technologies are still being researched.

As groundwater professionals, we may be called on to sample for PFAS analysis and to interpret PFAS laboratory data. The presence of PFAS in many products, potentially including products commonly used in environmental field sampling efforts, should be considered when planning a PFAS sampling program. Understanding the actual risk, versus perceived risk, that any material or process may present is a key component of developing a sound Sampling and Analysis Plan or Quality Assurance Project Plan (SAP/QAPP). This guidance document is intended to provide a practical guide to PFAS sample collection for those familiar with industry-standard environmental field sampling practices.

Sample Bias and Contamination

Sample bias in water quality assessment is the error associated with any deviation from in-situ values of water quality parameters caused by the process of sample collection, transport, and analysis. Sample bias can affect achievement of Data Quality Objectives (DQOs) that underpin decisions on site management. Positive bias is the overestimation of analyte concentration and can result from contamination of samples by field equipment, materials, and sampling procedures used during sample collection, storage, and transport. Negative bias is the underestimation of analyte concentration and can result from improper field sampling procedures, using materials to which the contaminant sorbs, or sample storage conditions that could result in analyte degradation prior to analysis. To reduce the risk of biasing the sample results, strict sampling protocols are defined in the project-specific SAP/QAPP. The SAP/QAPP details the equipment, material, and procedures for sample collection, storage, and transport that will minimize the potential for sample bias. Sources of bias in a water quality sampling program can come from:

- Field equipment and supplies – the type of equipment used to sample groundwater in the field
- Field sampling methods – procedures for monitoring well purging and sampling
- Sample preservation and storage – the temperature, use or lack of preservatives, and time samples are stored or in transit prior to analysis

Field equipment and supplies including sampling pumps, packers, tubing, bailers, rope, passive sampling tools, and sample bottles are used to collect groundwater samples. They can bias the results if this equipment contains fluorinated materials that have been demonstrated to leach PFAS and comes into direct contact with the sample water. However, using standard protocols and QA/QC sampling can mitigate these impacts.

Pre-Project Planning

When designing a sampling plan, the level of quality assurance required should be considered in light of the project goals. One project may require highly conservative sampling methods with quantitation of target analytes at the low part-per-trillion level, while another project may only need to determine the presence of a half dozen compounds at concentrations above a regulatory limit. For example, if a sampling program is conducted to determine whether PFAS are present in a municipal drinking water wellfield that has never been characterized for PFAS, a highly conservative approach to materials and procedures may be appropriate because even at low levels, false detections could lead to unwarranted public concern and trigger additional sampling. Conversely, if a sampling program is being performed in a well-characterized PFAS source area which is known to have parts-per-billion concentrations of a known suite of compounds, a highly restrictive sampling program may not be needed as the level of PFAS imparted by sampling materials is not likely to make a difference in the program results. A formal DQO process may be desired depending on the project goals and site operator requirements, but a basic determination of DQOs is a helpful starting point for a PFAS sampling plan.

The Need for PFAS-Specific Sampling Considerations

Due to the potential presence of PFAS in consumer products and materials that may be used for sampling, and the low concentrations at which PFAS are analyzed, the possibility of contaminating samples during or after sample collection is a concern. The level of caution that must be taken to avoid biasing PFAS environmental samples has been a matter of debate among environmental professionals. As of the end of 2022, published interference studies (Rodowa et al., 2020; Denly et al., 2019; Diguiseppi et al., 2014) indicate that many commonly used materials are not likely to affect sample integrity. However, whether sampling materials will impart PFAS to samples may vary among materials from different manufacturers and even among different batches of the same product from the same manufacturer. These studies have shown that sampling materials could act as sources of PFAS bias by imparting PFAS to sample media. Atmospheric deposition of PFAS is also a possibility (ITRC, 2022) and may be evaluated by collecting field blanks. Additionally, PFAS analytical methods are continually developing, particularly for non-drinking water matrices. Analyte lists and reporting limits may vary between analytical methods and laboratories.

"When lab testing is conducted, to demonstrate a product or material is 'PFAS-Free', it is important to understand what that designation represents in terms of the analytes tested for and at what reporting limit. As an example, definitions for 'PFAS-Free DI Water' from ITRC and Michigan EGLE describe the term as water that does not contain significant concentrations of any compound in a specific PFAS analyte list that is being analyzed at a project-defined limit."

The significant concentrations depend on project DQOs and could, for instance, be less than the laboratory reporting limit, <1/2 the reporting limit, or other defined criteria for a specific PFAS compound of interest (ITRC, 2022).

Available PFAS Sampling Procedures and Actual Bias vs Perceived Bias

There are a variety of PFAS sampling and analysis guidelines (State of Western Australia, 2017; Environmental Data Quality Workgroup, 2017; Michigan Department of Environmental Quality, 2018; California State Water Quality Control Board, 2020; New York Department of Environmental Conservation, 2021). These guidelines typically stress the potential for PFAS sample contamination by field sampling equipment, materials, and procedures. However, guidelines vary from one organization to another. Many are based on conservative precautionary principles that may unnecessarily restrict field materials, equipment, or procedures that present a minimal risk of biasing sample results. The purpose of this section is to review PFAS sampling guidelines and to assess which ones are based on scientific principles and which ones may include misinformation or unsubstantiated guidance.

Sampling and Analysis Plan (SAP)/Quality Assurance Project Plan (QAPP) – Prior to field sampling program execution, a project-specific plan should be developed for PFAS sampling events. The plan should:

- Describe the study design that will be used to characterize water quality to ensure that the project objectives are met
- Include the project objectives, sampling design and procedures, analytical methods, data assessment procedures, and reporting requirements
- Identify PFAS-specific sampling procedures and preventative measures required to mitigate sample contamination by PFAS sources not related to PFAS in the media sampled

Include a description of any materials and supplies (equipment, clothing, PPE, personal products) that are prohibited from being used during sample collection, storage, and shipment to the analytical laboratory.

General Field Sampling Considerations – A fundamental part of site characterization is the collection of samples that are representative of in-situ surface water and groundwater conditions. Experience has shown that most errors introduced in water quality data results come from the sample collection and handling practices and procedures (CL:AIRE, 2008). It is critical to use precaution in managing all aspects of the collection process to avoid sample contamination when sampling for water quality parameters found in trace quantities. This includes using clean disposable gloves and sampling equipment, decontaminating any reusable equipment between sample points, storing the equipment and sample containers in a clean staging area underlain by dedicated plastic sheeting to avoid accidental contact with contaminated soil or pavement. Samples should be collected in a sequence from the least contaminated area of the site to the most contaminated area of the site (when known), and, if possible, separating field tasks so that one part of the sampling team completes sampling activities while another manages the staging area, equipment, and the sampling process.

Sampling Procedures, Equipment, and Supplies – A variety of field equipment and materials that could contact the sample and act as potential sources of sample contamination are used to collect samples as part of a field sampling investigation. Numerous sampling guidance documents provide guidelines on the type of equipment and supplies that should be used to minimize the potential for sample contamination (State of Western Australia, 2017; Environmental Data Quality Workgroup, 2017; Michigan Department of Environmental Quality, 2018; California State Water Quality Control Board, 2020; New York Department of Environmental Conservation, 2021).

General guidance for PFAS sampling includes:

- Decontaminating all reusable equipment that contacts sample media, using PFAS-free water;
- Washing hands with PFAS-free soap and donning new, clean nitrile gloves prior to collecting each sample;
- To avoid impacts on the analytical process, using sampling methods that minimize disturbance of the water in the monitoring well;
- Using sample containers demonstrated to be PFAS-free by the supplier; and,
- Following QAPP protocols to collect QA/QC samples.

"Recent research has shown that only sampling equipment that contacts the water samples such as pump components, tubing, bailers, sleeves and liners, samplers, filters, and sample containers represent plausible pathways for PFAS sample contamination from equipment (Rodowa et al., 2020)."

Thus, it is not necessary to avoid all use of equipment that may contain fluorinated compounds. These precautions should be applied to equipment that directly contacts the media that is being sampled.

Cleaning and Decontamination of Field Equipment – Field equipment contacting sample media should be clean to prevent potential contamination during sample collection. Prior to mobilization to a field site, proper safety precautions should be reviewed and observed when field cleaning or decontaminating sampling equipment. All reusable sampling equipment that contacts the sample should be decontaminated with PFAS-free water and a laboratory grade, phosphate- and PFAS-free detergent prior to use and between sampling locations. To assess the adequacy of the decontamination process, equipment blanks should be collected following the guidelines in the SAP/QAPP.

Sample Collection Techniques – Sample collection methods depend on project-specific constraints such as DQOs, sampling infrastructure, and location accessibility. To obtain representative groundwater samples, subsurface disturbance and sample handling should be minimized, including reducing sample agitation and aeration during sample collection. The way in which a well is purged and sampled can significantly impact sample quality. This has led to the preferred use of methods known to reduce sample turbidity, such as low-flow purging/sampling and passive sampling. Other field procedures that are to be completed during the investigation (e.g., hydraulic conductivity testing, depth-to-bottom measurements) should be conducted after sample collection to minimize disturbance of the water column in the well prior to PFAS sampling.

Sample Turbidity and PFAS Sample Filtration – Turbidity in PFAS samples could potentially bias PFAS concentrations in samples due to PFAS adsorption to solids in the sample. Proper filter pack, screen slot design, and well development are important to reduce turbidity for new or redeveloped wells intended for PFAS sampling. Turbidity can also interfere with laboratory sample preparation by clogging the media used for sample extraction. If sample turbidity is elevated, filtration should be avoided due to the potential for sorption of PFAS onto the filter media, and lab centrifugation is the preferred means for separating the solids from the aqueous phase (ITRC, 2022). If field filtration is necessary, an evaluation of which filter is appropriate to use will be necessary. A study of four commonly used filter media (Chandramouli et al., 2014) showed that glass fiber and polyethersulfone (PES) filter media showed the lowest sorption of PFAS from samples, while nylon and PTFE filters should be avoided due to higher sorption rates. PES is commonly available as a groundwater sample filter as both disposable cartridges and replaceable filter media.

Field Clothing and Personal Protective Equipment (PPE) – Field clothing has limited potential as a pathway to affect PFAS samples when standard field protocols are followed (Rodowa et al., 2020). The safety of field personnel is paramount and therefore if essential PPE contains PFAS and must be used during sample collection, then protocols must be developed to minimize PFAS-containing PPE contact with sample media. Their use should also be documented, and field notes should describe refined sampling protocols that were used. Recommended material for field clothing and PPE may include waterproof clothing that contains polyurethane, polyvinyl chloride, wax-coated fabric, rubber, or neoprene.

Food Packaging – While health and safety requirements typically prohibit consuming food and drink during sampling, it should be noted that food packaging may be treated with water and oil repellents containing PFAS. Most guidelines suggest not bringing food on-site in any paper packaging (paper plates, containers, bags, and wrappers).

Personal Care Products (PCPs) – Numerous sampling guidance documents recommend that PCPs, including those for biological protection (e.g., sunscreen, insect repellent), are not to be used to avoid potential sample contamination. As noted by Bartlett et al. (2018), many personal care products once suspected of containing PFAS compounds may not pose a risk of sample contamination. Prudent testing before use can verify specific commercial products are free of PFAS target analytes. To further control any potential transfer of PFAS from PCPs to samples, field personnel should don a new, clean pair of nitrile gloves immediately prior to sample collection.

Field Documentation – A vital component of a field investigation is the documentation of procedures, results, and conditions encountered during sample collection and storage. Numerous guidelines recommend avoiding waterproof pens, paper, and notepads. As noted by Rodowa et al. (2020), with the lack of a plausible pathway, if new, clean nitrile gloves are donned immediately prior to sample collection, the risk of sample contamination from field documentation materials is low.

Sample Containers and Handling – Sample containers and preservatives may also affect PFAS concentrations in water samples. It is recommended that HDPE or polypropylene containers be used for PFAS sample collection. Once the sample bottle is capped, it is unlikely that PFAS can contaminate the sample from an external source. Field blanks or trip blanks may be used to assess the integrity of the sample through transport. Sample storage and preservation requirements such as temperature and holding time vary by analytical method. Samples should be stored and handled according to the specific analytical method being applied.

Samples are packed in a cooler after collection and shipped to the laboratory for analysis. Research data specific to the potential for sample contamination from the packaging and transport of PFAS samples is lacking. In the absence of empirical data, the following describes a conservative approach. For transport from the field site to the laboratory, samples are packed in a cooler to achieve temperature preservation requirements as specified in the analytical method. Sampling guidelines suggest that the coolant should be real ice, double-bagged in LDPE bags, and to avoid the use of chemical freezer packs. Field blanks will also serve as trip blanks, providing data about the integrity of samples through the shipping process.

Overview of Available PFAS Sampling Materials and Fact Sheets – Materials Guidance

Fluoropolymers have been commonly used in the manufacture of groundwater sampling equipment such as pumps, tubing, bailers, and passive samplers. Regulatory guidance on PFAS sampling often recommends against the use of any fluoropolymers in sampling equipment due to the concern that these materials could leach PFAS into samples. Materials testing (Rodowa et al., 2020; Denly et al., 2019; DiGuiseppi et al., 2014) has shown that many fluoropolymers do not leach PFAS while other fluoropolymers may leach PFAS into sample media. Sampling equipment and supplies that could contact the sample should be demonstrated to be free of materials that could leach PFAS into samples. Many equipment suppliers offer products that have been tested and demonstrated to be PFAS-free. Equipment blank samples or soak test samples can also be used to determine if equipment is PFAS-free prior to use. Where existing sampling equipment is dedicated for use in a single well or sampling point, testing for PFAS can determine if the existing equipment can be used. If PFAS is detected, sampling the same source with a known PFAS-free sampling system can be used to determine if the source of the PFAS is the equipment or if PFAS is present in the water being sampled.

Determine if a material is suitable for PFAS sampling

Testing new equipment and materials – New sampling equipment such as bailers and bailer cord, pumps, disposable tubing, and any other components that will contact the well or the samples collected should be determined PFAS-free prior to first use. If the PFAS leaching potential is unknown, collect an equipment blank or generate soak samples and analysis before any groundwater sampling event to determine if equipment is sufficiently free of target PFAS. If equipment comes from more than one source or vendor, testing should be conducted for every identifiable manufacturing lot.

Testing existing sampling systems:

- For portable/reusable equipment, use equipment blanks before first use and after each decontamination event or on a frequency required by the SAP/QAPP protocol
- For dedicated sampling systems, select a subset of wells (e.g., 5%) and sample from the well.

a. If all results are non-detect or below an acceptable threshold for PFAS, the equipment should be suitable for PFAS sampling if it meets all regulatory materials requirements or restrictions.

b. Where results are mixed or positive, resample the same, or a subset of, wells with a known PFAS-free sampling system and compare results to determine if sampling equipment is the likely source or if PFAS is present in the groundwater.

c. If sampling equipment is the source, determine if there are materials or components that could be replaced to eliminate the source (e.g., PTFE thread tape or ETFE-insulated wire)

- Manufacturer certification of PFAS-free materials and sampling equipment – Many equipment manufacturers and distributors offer sampling equipment and materials that have been tested for PFAS leachability and determined not to leach measurable or reportable PFAS into samples. To determine if this type of equipment will meet your PFAS sampling program requirements, ask the following questions of the supplier:

a. What is the testing protocol? Are materials soak tested for an extended period (several hours or more), or is an equipment blank sample test used?

b. Is every piece of equipment or manufacturing lot of bulk material (tubing, bailer cord, etc.) tested, or is a subset or percentage tested to represent the entire lot?

c. Does the list of PFAS analytes include those in the sampling program requirements?

Summary of published research on PFAS sampling materials

Research on materials commonly used for groundwater sample collection and handling has been conducted over the past several years. DiGuiseppi et al. (2014) tested a commonly used peristaltic pump with polyethylene and Teflon-lined polyethylene tubing, bladder pumps with polyethylene and PTFE (Teflon) bladders, an electric submersible centrifugal pump with polyethylene tubing, and a disposable polyethylene bailer. Only the Teflon-lined tubing and the electric pump showed PFAS detections above the limit of quantification (LOQ). Denly et al. (2019) conducted soak tests on a wide range of materials used for sample collection (various tubing, bailer cord, PTFE and polyethylene bladders and water level measurement tapes, passive diffusion bag samplers), along with sampling supplies such as disposable gloves, waterproof notebooks, and resealable plastic storage bags. Results showed that low levels of PFAS may leach from different sampling materials, and that "different manufacturers of the same type of tubing (PTFE, HDPE, and LDPE) may yield variable concentrations of different PFAS and different batches of the same product from the same manufacturer may yield variable concentrations of different PFAS due to quality and process variability."

Rodowa et al. (2020) took the approach of grouping commonly used sampling supplies and materials into categories by use (pre-staging, staging, sample collection, and shipping) with an emphasis on "plausible pathways for exposure" to samples collected. Soak testing showed that most of the materials tested did not leach PFAS, including all the materials in the sample collection category, with the authors concluding that the risk of PFAS sample contamination in field samples is very low. The take-away from these studies is that equipment blank samples or soak samples are warranted to determine if equipment that contacts samples is free of PFAS that can bias samples and fail DQOs but following industry standard sampling practices should mitigate sample bias from PFAS.

Introduction to PFAS QA/QC

PFAS present in sampling equipment can leach into samples, thus positively biasing sample results by introducing PFAS into the water sampled. Additionally, PFAS can sorb to sampling equipment and supplies, negatively biasing results. Therefore, quality assurance and quality control (QA/QC) procedures are particularly important in characterizing PFAS in groundwater. QA/QC samples enable samplers, regulators, and other key stakeholders to have confidence in data collected. Field-related quality control samples should be included in a project-specific SAP/QAPP. Depending on the project DQOs, the following should be considered:

Types of Field QA/QC samples

1. *Field Blanks*

Purpose

To assess whether the sampling area environment may contribute PFAS to the sample, the collection of a field blank is recommended to increase confidence in sample integrity. Studies have shown that while most PFAS evaporate into the air at low rates, some types of PFAS can be present in volatile form in ambient air and can come from a variety of sources. Stack test data from North Carolina, New Hampshire, New York, and New Jersey have confirmed that PFAS can be released into the air from industrial smoke or steam stacks and incinerators and can travel many miles downwind of the source (Michigan PFAS Action Response Team, 2022).

Method

To collect a PFAS field blank, in an area representative of the sampling environment carefully pour lab-provided or known PFAS-free water into a new and clean sample container. Close the lid tightly and label after sample collection.

Other Considerations

Consider a field blank collection frequency representative of changes in the sampling environment, including changes in sample collection personnel, distance across the site, or potential impacts from nearby operations.

2. Equipment Blanks

Purpose

To assess whether materials in the sampling system contribute PFAS to samples collected and confirm the efficacy of field decontamination procedures. PFAS can migrate or leach into samples from a wide range of materials commonly used for sampling systems (e.g., tubing, gaskets, bladders, O-rings, etc.).

Method

To collect an equipment blank, identify potential contributors to characterize. In a clean environment, carefully pour lab-provided or known PFAS-free water over pieces of equipment or equipment components into clean sample containers. Alternatively, pump the PFAS-free water through the pump or tubing if pouring over the equipment would not expose the water to all materials contacting the sample. Close the lid tightly and label after sample collection.

Other Considerations

It is important to be mindful of individual contributions from each piece of equipment. For example, if both an interface probe and sampling pump are used during the sampling procedure, it is advisable to collect equipment blanks from each individual piece of equipment to better characterize potential sample contamination sources.

3. Field Duplicate Samples

Purpose

Two samples collected under identical circumstances, used to evaluate the precision of sample collection, preservation, storage, and laboratory methods (ITRC, 2022). If required in the SAP, refer to the applicable analytical method for procedures and specifications.

4. Trip Blanks

Purpose

To assess whether contamination has occurred during transport. Trip blanks are a bottle of PFAS-free water prepared in the laboratory, which travels from the laboratory to the site, and then gets transported back to the laboratory without sampling procedures (CSWQCB, 2020). Field blanks will also serve this purpose, so collecting both may be redundant.

Summary

Recent research (Rodowa et al., 2020) has concluded that the most likely pathway for sample bias is through direct contact between sampling equipment and the water sample. It may be difficult to generalize these results to similar products used for groundwater sampling, but they lend credence to the practice of evaluating the specific materials and protocols selected for a site-specific SAP/QAPP. Many of the best practices and basic sampling hygiene for groundwater sample collection apply to samples collected for PFAS analysis. With the inclusion of field quality control samples, and an evaluation of materials to be used, many of the concerns around PFAS sample contamination should be minimized or eliminated.

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Appendix 1: Materials Guidance

Fluoropolymers, such as Teflon®, have been used for more than 40 years as preferred materials for groundwater sampling equipment and sample containment. There is a large installed base of dedicated sampling systems and portable or reusable equipment manufactured with fluoropolymers. Fluoropolymers and fluoroelastomers commonly used in well construction, sampling equipment, and supplies include:

- Polytetrafluoroethylaene (PTFE) – trade names Teflon®, Hostaflon®, Polyflon®
- Ethylene Tetrafluoroethylene (ETFE) – Tefzel®
- Fluorinated Ethylene Propylene (FEP) – Teflon® FEP, Hostaflon® FEP, Neoflon FEP
- Perfluoroalkoxy alkanes (PFA) – Teflon® PFA, Hostaflon® PFA, Chemfluor®
- Polyvinylidene fluoride or polyvinylidene difluoride (PVDF) – Kynar®, Hylar®
- VDF-based fluoroelastomers (FKM/FPM) – Viton®, Dyneon®, Tecnoflon®

Fluoropolymers are not manufactured using perfluoroalkyl carboxylic acids (PFCAs) or their potential precursors. However, PFCA (perfluoroalkyl carboxylic acids) homologues may be used as processing aids in the polymerization of some fluoropolymers (Organization for Economic Cooperation and Development, 2013).

There is the potential that some materials could leach PFAS into samples, resulting in a false positive indication of the presence of PFAS in the groundwater. Material testing has shown that some fluoropolymers are more likely to leach PFAS into samples; for example, ETFE has shown potential to leach PFBA, while PVDF testing has shown high concentrations of 6:2 FTS. However, not all fluoropolymers leach measurable or reportable concentrations of PFAS, and not all materials of the same type are always positive for PFAS. For example, PVDF sold under the trade name Kynar® 500 has been formulated without the use of fluorosurfactants, and testing has shown no leaching of PFAS from this version of PVDF.

Alternatives to Fluoropolymers

There are several materials listed in regulatory guidance documents that are recommended as acceptable alternatives to fluoropolymers for groundwater sampling. Commonly used materials include:

1. **Polyethylene**– High density polyethylene (HDPE) is widely accepted, while low-density polyethylene (LDPE) is listed as acceptable in some guidance documents or can be used when an equipment blank sample confirms the absence of PFAS, or the manufacturer has tested and certified the material to be PFAS-free. Guidance documents do not address other forms of polyethylene, such as medium-density (MDPE), linear low-density LLDPE) or ultra-high molecular weight (UHMWPE) polyethylene, which are chemically identical to the more common HDPE and LDPE forms but can have other physical properties such as greater flexibility and low coefficient of friction, comparable to fluoropolymers. It is most used to manufacture tubing, bailers, pump bladders, support cable and wire insulation. Sample containers for PFAS are generally made of HDPE.

   a. Advantages of polyethylene include wide availability, low cost, good chemical resistance to organic solvents, fuel components, acids and bases, high strength, and low weight.

   b. Disadvantages of polyethylene include limited flexibility for some formulations, higher gas permeability than fluoropolymers, poor flex life, and density that is less than water (buoyant in water).

2. **Polypropylene**– Polypropylene is more rigid than polyethylene and can be more readily molded and machined. It is commonly used to make parts such as fittings, bailers and bailer cord, soil core sampling tools and other components.

   a. Advantages of polypropylene include wide availability, low cost, good chemical resistance to organic chemicals, acids and bases, high strength and low weight, and lower gas permeability than polyethylene.

   b. Disadvantages of polypropylene include very limited flexibility, especially at lower temperatures, less resistance to solvents, and even lower density than polyethylene, making it buoyant in water.

3. **Silicone Rubber** – Silicone is commonly used for tubing, especially in peristaltic pumps, and less commonly used for seals, gaskets, and O-rings.

   a. Advantages of silicone include good flexibility and elasticity, high flex life, good chemical resistance to organic chemicals, acids and bases, and high temperature resistance.

   b. Disadvantages of silicone include lower tensile strength and high sorption of organic compounds, potentially affecting sample concentrations.

4. **Polyvinyl Chloride**- (PVC, RPVC or uPVC) – PVC is a rigid plastic, commonly used to make well casings, bailers, and pump components.

   a. Advantages of PVC include wide availability, low cost, high strength to weight ratio, easy machinability, good chemical resistance to acids and bases, low gas permeability, and greater density than water.

   b. Disadvantages of PVC include lower chemical resistance to chlorinated solvents and aromatic hydrocarbons, more brittle than PE or PP.

5. **Vinyl (**flexible PVC) – Vinyl or flexible PVC is flexible plastic, made flexible by adding plasticizers to PVC. It is commonly used to make tubing, wire insulation, gaskets and seals and disposable gloves. Commonly known by the trade name Tygon®.

   a. Advantages of vinyl include wide availability, low cost, transparency, and particularly good flexibility, especially at lower temperatures.

   b. Disadvantages of vinyl include low tensile strength, poor UV resistance and the ability to leach plasticizers that can contaminate samples; the most common vinyl plasticizer is bis(2-ethylhexyl) phthalate (DEHP).

6. **EPDM Rubber** – Ethylene Propylene Diene Monomer (EPDM) is a synthetic rubber commonly used to make seals, gaskets and O-rings and wire insulation.
    a. Advantages of EPDM rubber include particularly good flexibility, good UV and weathering resistance, and good resistance to acids and bases.
    b. Disadvantages of EPDM rubber include poor resistance to most hydrocarbons, such as aromatic hydrocarbons and chlorinated solvents.
7. **Nitrile Rubber**– Known as nitrile butadiene rubber, NBR, and Buna-N, it is a synthetic rubber commonly used to make hoses, seals, gaskets and O-rings, and disposable gloves.
    a. Advantages of nitrile rubber include excellent flexibility, resistance to puncture and tearing, good resistance to hydrocarbons, chlorinated solvents, and bases.
    b. Disadvantages of nitrile rubber include poor resistance to acids and the potential to leach carbon disulfide that can contaminate samples.

Acronyms

ITRC: Interstate Technology and Regulatory Council
Michigan EGLE: Environment, Great Lakes, and Energy
QA/QC: Quality Assurance/Quality Control

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