



## **Guidance for Assessment Source Water Monitoring**

Division: DDAGW  
Number: WQ-22-001  
Category: Water Quality – Guidance  
Status: Final  
Issued: 01-14-14

### **I. Purpose**

To provide guidance on Assessment Source Water Monitoring (ASWM) found in rule 3745-81-42 (B) of the Ohio Administrative Code (OAC).

### **II. Background**

Pursuant to 40 CFR 141.402 and rule 3745-81-42 of the OAC, a system with a ground water source may be subject to assessment source water monitoring. ASWM is required when it is necessary to collect additional raw water samples to identify pathogen sensitivity.

### **III. Guidance**

The attached guidance is intended to be used by Ohio EPA staff and/or a person appointed by a public water system to assist in the evaluation of pathogen contamination and pathways for contamination of a ground water source.

### **IV. Attachments**

Attached is the guidance document as developed by the Ground Water Rule Workgroup.

### **V. History**

The Division of Drinking and Ground Waters first issued this guidance on January 14, 2014.

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# Guidance for Assessment Source Water Monitoring

## September 17, 2013

### Introduction

Ohio EPA uses a standard, but flexible approach for evaluating the probability that a local aquifer is or will be contaminated by pathogens under the Ground Water Rule (GWR). The approach developed includes two components:

1. The Hydrogeologic Sensitivity Assessment (HSA); and
2. Assessment Source Water Monitoring (ASWM).

The HSA is produced in a short time frame for a specific public water system (PWS) and uses available data to complete a risk assessment of the pathogen sensitivity of the local hydrogeologic setting. ASWM is utilized to collect additional water quality data to determine the concentrations of *E. coli*, other microbial indicators, and/or select inorganic parameters. This sampling occurs when additional data is needed to determine or refine the pathogen sensitivity at a PWS. For information on the HSA, the reader is referred to the HSA Guidance (WQ-21-001).

Positive microbial samples that may result in requirements for ASWM come from sampling associated with multiple procedures, including:

- *E. coli* positive results from GWR triggered source water samples;
- Total coliform or *E. coli* detections in new well approval samples;
- Evaluation of source water designation issues; and
- Questions concerning wells with persistent total coliform detections.

The reader is referred to GWR standard operating procedures (SOP) for determining when to consider using the HSA and ASWM tools. Section 4.5 of the GWR SOP includes a table that provides a framework for when to require ASWM. This guidance describes the purpose of ASWM, identifies what it is, provides rationale for selecting parameters to include in ASWM, and indicates how to apply the results. In most cases, HSAs are completed before ASWM is initiated, but the data collected is used to confirm or refine the HSA results.

When requested, ASWM is completed as part of an investigation into the causes of confirmed pathogen contamination at a PWS. The PWS will complete the sampling and report the results to Ohio EPA through eDWR and SDWIS. The ASWM results, in conjunction with the HSA and other information will be used to help identify appropriate corrective actions to reduce the likelihood of pathogen contamination and to determine appropriate treatment.

Depending on what corrective actions are installed, assessment source water monitoring may not be necessary. For example, if the PWS well is abandoned and the system ties into a regional PWS, there is no need for ASWM. Thus, initiating ASWM is a case-by-case decision, dependent upon the frequency of *E. coli* detection, local hydrogeologic setting, what corrective actions were implemented, and the need for additional data to evaluate the local pathogen sensitivity or the effectiveness of the implemented corrective action.

## What is ASWM?

Under assessment source water monitoring, additional raw water samples are collected to determine the frequency of detection and/or concentration of *E. coli* and selected inorganic parameters to help determine or refine pathogen sensitivity of a PWS. ASWM is an option for requiring PWSs to collect additional raw water quality data to:

- confirm or refine pathogen sensitivity of a PWS well(s);
- designate the system as a surface water system;
- determine if 4-log treatment for a ground water system is necessary;
- help determine if rapid influx of surface waters influences the aquifer; or
- confirm the effectiveness of implemented corrective actions.

The duration and frequency of ASWM depend on the pathogen sensitivity defined in the HSA, the distribution or presence of fecal sources within the isolation radius or the drinking water source water protection inner management zone (1year TOT), and the corrective actions implemented. The authority for ASWM is included in 3745-81-42 (B).

**Who Monitors** - the PWS is responsible for completing ASWM. In some cases DDAGW staff will collect ASWM samples for special studies or as part of a site visit.

**Where to Sample** - ASWM requires collection of raw water samples, thus, the sample tap must be located prior to any treatment. For minimum treatment systems, collection of distribution samples is acceptable if no wellhead tap is available. ASWM samples should be reported as directed by Ohio EPA. If the PWS has multiples wells ASWM samples need to be collected from each well.

**Monitoring Frequency** - For pathogens, ASWM sampling includes monthly samples of raw water over an annual cycle to evaluate pathogen concentrations under a range of conditions. For pathogen non-sensitive sites, where there is a high confidence that implemented well construction corrective actions removed the pathway for pathogen migration, ASWM frequency for pathogens can be reduced to quarterly sampling. Inorganic parameters are sampled on a quarterly basis, unless the setting is pathogen sensitive and inorganic parameters are collected to document pulses of surface water recharge.

**Parameters Monitored** - *E. coli* monitoring directly measures the pathogen sensitivity by determining

### Difficulty of Sampling Bacteria

Bacteria in water are suspended particles and, as a result, are not easy to sample accurately in small volume samples, like MMO-MUG sample volumes of 100 mL. The number of bacteria in a volume of water may vary at individual sampling sites due to normal biofilm processes, temporal nature of contaminant sources and pulses of recharge. Consequently, ASWM increases the sampling frequency and spreads the sampling over a year to increase the chance of capturing water with suspended bacteria. In most cases, Quanti-Tray (or other methods that provide bacteria counts - counts/volume, cfu/100mL, most probable number (MPN)/100 mL) is required to provide an estimate of the number of *E. coli*. ASWM provides sufficient data to identify the variation of *E. coli* concentration in source water over an annual cycle as well as providing a mean annual concentration.

the concentration of pathogen indicators (cfu/100 mL, MPN/100 mL). Inorganic parameters are included to evaluate redox conditions as indicators of isolation from the atmosphere or the presence of an influx of surface water recharge. The parameters are discussed in more detail below. The HSA will include recommendations for ASWM. ASWM requires the use of approved analytical methods as documented in rule 3745-81-27.

**Sample Timing** - ASWM is typically monthly sampling for a year. Within this schedule, the PWS operators must attempt to sample PWS wells at vulnerable times. For example, sampling raw water shortly after a large rainstorm or in association with periods of turbidity in raw water evaluates the source water when it is most likely to be affected by rapid surface recharge events. Sampling will be suspended and corrective actions implemented if early results indicate fecal contamination.

### **Microbiologic Parameter Selection and Analytical Requirements**

Ohio EPA has selected to use *E. coli* as the fecal indicator for the GW Rule. This is logical and practical, as the presence of *E. coli* has clear human health consequences and accepted analytical procedures.

It is expected that most triggered source water monitoring and Total Coliform Rule (TCR) samples will be analyzed using MMO-MUG tests, which indicate the presence or absence of *E. coli* but do not provide *E. coli* counts. Consequently, additional data needs to be collected to quantify *E. coli*. Quanti-Tray analysis (MMO-MUG methodology to produce a most probable number, Colilert, Method 9223B) or other methods that provide numeration of *E. coli* may be required. An estimate of the number of *E. coli* per unit volume is necessary to determine source designation and is helpful for correlating pathogen concentrations to physical parameters and identifying appropriate treatment options. The Quanti-Tray method can also provide MPN values for total coliform and enterococci and ASWM is expected to include these microbial parameters.

### **Inorganic Parameters and Rationale for Use**

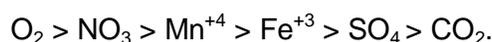
Inorganic parameter data are used as indirect measures of oxidation-reduction (redox) conditions or to document changes in water quality associated with significant recharge events. Nitrate, manganese, iron, and sulfate concentrations are sensitive to redox conditions. Due to systematic changes of redox conditions in the saturated zone, these parameters are useful indirect measures of redox conditions (see Box – Microbial Mediation of Redox Conditions). More reduced conditions indicate isolation from the atmosphere and thus, help confirm pathogen non-sensitive local hydrogeologic settings determined by an HSA.

Inorganic parameters that may be used as proxies for redox conditions or as chemical tracers to help identify pathogen sensitivity of PWS source water include:

- Nitrate may be used as a proxy for oxidized conditions indicating interaction with the atmosphere and the possibility of rapid recharge of surface water elevated in nitrate.
- Elevated iron, manganese, and/or arsenic indicate reduced geochemistry and suggest the aquifer is isolated from the atmosphere and rapid recharge.
- Lower sulfate concentrations can indicate strongly reduced conditions. The reduction of sulfate is associated with production of hydrogen sulfide.

## Microbial Mediation of Redox Conditions

Redox conditions in ground water are generally controlled by the transfer of electrons between electron donors and receptors in processes referred to as Terminal Electron Accepting Processes (TEAPS - McMahon and Chapelle, 2008). In ground water, organic carbon is usually the electron donor with the result that the organic carbon is oxidized in these reactions. The electron acceptors are various inorganic constituents that are reduced during reactions. The reactions are mediated by microbial metabolism based on energies required for microbial reduction. This is an orderly process. As ground water is reduced, the following constituents are progressively consumed by the TEAPS reactions:



Thus, redox conditions can be identified by the presence and absence of the reactants and products. For example, if ground water exhibits detectable nitrate, it indicates that the water is oxidized; however, if the water includes dissolved iron ( $\text{Fe}^{2+}$ ), it suggests that the ground water is reduced and that iron oxide ( $\text{Fe}^{3+}$ ) has been reduced. This analysis assumes the ground water approaches equilibrium conditions, which of course is not always the case.

At the water table, ground water is exchanging oxygen with the atmosphere and, thus, is oxidized. The water table surface is also more likely to receive rapid recharge of oxidized surface water with surface contaminants. At depths below the water table, dissolved oxygen concentrations are lower because the dissolved oxygen is consumed by microbes or interacts with surrounding earth materials as controlled by the TEAPS reactions, resulting in more reduced conditions. In Ohio, the depth to reduced ground water is generally 70-80 feet below the land surface (based on nitrate data from AGWQMP sampling), but the depth to this transition is site-specific. An aquifer that demonstrates consistent reduced conditions indicates isolation from the oxygen-rich atmosphere and thus, supports the lack of rapid recharge pathways from the land surface to the aquifer. The GW Rule Pilot: Ground Truth for Hydrogeologic Sensitivity Assessment and Assessment Source Water Monitoring (Ohio EPA Ground Water Rule Pilot Report, 2012) collected water quality data from 20 sites. The analysis confirmed that these inorganic parameters can be used effectively as proxies for redox conditions and that pathogen-sensitive settings are associated with oxidizing conditions.

The USGS has developed a web page on redox processes based on work by McMahon and Chapelle (2008). The purpose is to present a decision-support tool for determining aquifer vulnerability based on redox conditions and to highlight publications on redox conditions using this tool. A framework was developed that allows for an analysis of redox processes in ground water using dissolved concentrations of  $\text{O}_2$ ,  $\text{NO}_3^-$ ,  $\text{Mn}^{2+}$ ,  $\text{Fe}^{2+}$ , and  $\text{SO}_4^{2-}$ . This approach documents the progressive reduction that occurs with increased residence time. This work supports the use of redox conditions to evaluate the pathogen sensitivity of an aquifer as utilized here. The web site is located at:

<http://oh.water.usgs.gov/tanc/NAWQATANCRadox.htm>

The inorganic parameters to be collected will be determined based on the HSA results and generally, will be collected on a quarterly basis. Pathogen-sensitive settings often exhibit nitrate detections indicating oxidized conditions and pathogen non-sensitive sites are expected to show elevated manganese or iron, indicating reduced conditions. If a well has a history of turbidity associated with surface recharge, this is a significant sign of pathogen sensitivity. Total dissolved solids (TDS) may be included with the inorganic lab parameters as a means to monitor a physical parameter to document sudden changes in water quality associated with a sudden flux of surface sourced recharge. At PWSs in pathogen-sensitive settings the inorganic parameters may be required on a monthly basis to document rapid recharge causing changes in water quality.

In the most pathogen sensitive settings, an optional approach for documenting changes in water quality associated with rapid recharge is collecting field parameters (temperature, pH, conductivity, TDS, and ORP) with ASWM. Significant water quality changes associated with recharge events help document rapid recharge which may transport pathogens to the aquifer. Small PWSs probably do not have this capability so field parameters will not be required except in special cases.

### **Interpretation of Water Quality Results**

In most cases, ASWM is a yearlong process triggered by confirmed detections of *E. coli*, which led to evaluation of the PWS and decisions about implementing corrective actions. Once the monitoring is complete the results need to be evaluated in conjunction with the corrective actions implemented. Responses to ASWM *E. coli* results are provided below.

#### **Microbial Parameters**

The lack of *E. coli* detections in ASWM suggests implemented corrective actions have addressed the pathogen contamination problem or the site is not pathogen-sensitive. For intermediate pathogen sensitivity settings at which no corrective actions were required, the lack of *E. coli* detections suggests corrective actions are not required, and TCR sampling will monitor the system for future pathogen contamination.

**GW Rule** - Since ASWM is initiated after confirmed detections of *E. coli*, any detection of *E. coli* in ASWM documents pathogen sensitivity and requires implementation of corrective actions under the GW Rule. Review of the HSA, ASWM results and other available information will help identify appropriate corrective actions, including required treatment. In cases where ASWM is being used to confirm that an implemented corrective action is effective, *E. coli* detections document that pathways for pathogen migration to the production aquifer are still present and that additional corrective actions are needed.

**New Wells** - If TC or *E. coli* was detected in new well samples after disinfection, ASWM was probably required during the first year of production, along with a requirement of 4-log treatment capability. *E. coli* detections in ASWM during the first year of operation at a new well will result in a requirement for 4-log treatment and compliance monitoring. If the annual average of *E. coli* is greater than 10 MPN/ 100 mL the PWS will be redesignated surface water.

**Source Designation** - The use of *E. coli* as the GW Rule pathogen indicator makes the use of the LT2 crypto equivalency possible. The LT2 crypto equivalency (10 *E. coli*/100 mL = 0.075 oocysts/L) allows an association between *E. coli* and crypto concentrations (U. S. EPA LT2ESWTR Source Water Monitoring Factsheet, 2006). The importance of the LT2

equivalency is that it provides a number that identifies a well as surface water (SW) source based on *E. coli* counts. If the source water samples record the annual mean *E. coli* concentrations above 10 *E. coli*/100mL, the PWS well will be considered a SW system. If the raw water samples detect *E. coli* at annual mean concentrations below 10 *E. coli*/100 mL, it indicates that the PWS is a ground water system. If additional evaluation suggests that a PWS with *E. coli* detections below 10 *E. coli*/100 mL is characterized by rapid recharge pathways that significantly compromise the local hydrogeologic barriers, including the possible transport of crypto cysts or giardia, the system may be designated as a SW system by action of the director.

The data collected from the GW Rule Pilot project documents that only four Quanti-Tray samples have recorded a most probable number (MPN) result of 10 *E. coli* /100mL or greater (4 of 233 samples), and none of the 20 sites come close to an annual average of 10 *E. coli*/100 mL. (Ohio EPA, 2012) Thus, it appears that previous source designation efforts worked, and few PWSs will have their source designation changed as a result of ASWM and application of the LT2 equivalency.

**Persistent Total Coliform** - Total coliform (TC) is not a reliable human health indicator when using the MMO-MUG methods, but it has been used as one for some time, with justification based on the lack of better alternatives. Under the revised TCR, the MCL for total coliforms has been eliminated and replaced with a treatment technique for TC. In the revised TCR, TC serves as an indicator of a potential pathway of contamination into the distribution system. If the PWS exceeds the new TC treatment technique triggers, an assessment must be conducted to determine if any sanitary defects exist and to correct any found.

ASWM is used to collect additional data to evaluate pathogen sensitivity. If the PWS has no *E. coli* detections, has detections of TC but is considered pathogen non-sensitive or exhibits intermediate pathogen sensitivity with no chemical water quality impacts, then the PWS may be allowed to install disinfection to address the presence of total coliform. Problems with persistent TC positive results are the one situation where an HSA and ASWM can occur when *E. coli* detections are not confirmed. The use of these tools may allow the PWS to address the TC issue by installing simple disinfection. Detection of *E. coli* in ASWM moves the PWS into 4-log disinfection or other corrective options based on the GW Rule.

### **Inorganic Parameters**

The results for the inorganic parameters are interpreted to indicate the redox conditions and to document changes in water quality associated with recharge events. This information is used to support the pathogen sensitivity determined by the HSA. The following statements identify inorganic parameters that may be used as proxies for redox conditions or documentation of sudden changes in water quality characteristics associated with recharge events:

- Elevated nitrate may be used as a proxy for oxygen concentration indicating interaction with the atmosphere, which suggests the presence of rapid recharge of surface water elevated in nitrate. If nitrate exceeds 2.0 mg/L, the aquifer can be considered impacted by surface land use.
- Elevated iron, manganese, and/or arsenic indicate reduced geochemistry and suggest the aquifer is isolated from the atmosphere and rapid recharge.
- Low sulfate in conjunction with odors of hydrogen sulfide indicate strongly reducing conditions.

- Rapid changes in total dissolved solids may indicate a sudden recharge event.
- Turbidity associated with surface recharge is a significant sign of pathogen sensitivity.

If the pathogen sensitivity of a site determined in the HSA is not consistent with the ASWM data, it is necessary to revisit the HSA or to reevaluate the well integrity. For instance, if the well construction is determined to be good and the HSA identifies the PWS aquifer as pathogen non-sensitive, then the ASWM data should have no *E. coli* detections and water quality parameters should exhibit low nitrate and possibly elevated iron indicative of reduced water in the aquifer. In contrast, if the raw water ASWM data exhibits elevated nitrate (> 2.0 mg/L) and/or *E. coli* detections, a critical pathway appears to have been overlooked or misinterpreted in the HSA.

The optional field parameters can provide documentation of rapid recharge in the more sensitive pathogen-sensitive settings.

- Of the standard field parameters, oxidation reduction potential (ORP) is a good indicator of redox conditions. ORP greater than 200 mV indicate oxidized conditions and values below 100 mV indicate reduced conditions.
- Field parameters (temperature, pH, conductivity, and TDS) also are valuable to document geochemical stability of the ground water. If the field parameters document significant trends or spikes in values over the sampling period this suggests variation associated with recharge events and points to pathogen sensitivity.

### **Incorporating ASWM into HSA Investigation**

ASWM results will be evaluated on a case-by-case basis because the data needs to be interpreted in relation to the HSA previously completed and in the context of what corrective actions were required. Some examples of expected water quality associated with the pathogen sensitivity categories help to put the use of the ASWM data in context.

**Pathogen Sensitive** – As discussed in the Federal Ground Water Rule Preface, the density of fecal sources is the first concern when evaluating source water in a sensitive aquifer. Significant fecal sources within the isolation radius or inner management zone of the Drinking Water Source Protection Area (one year TOT) are red flags. The type of sensitive aquifer, density of the fecal sources, and corrective actions initiated will determine the need for ASWM and what parameters are selected. The first question in any evaluation of an *E. coli* or a TC positive sample is: “is it in a pathogen-sensitive aquifer?” If the answer is ‘yes,’ then all samples must be critically evaluated and the source of the TC should be treated as likely to be fecal. The inorganic results should help to confirm the sensitive nature of the local aquifer with documentation of oxidizing conditions.

**Pathogen Non-Sensitive** – Typical wells in a pathogen non-sensitive aquifer will have a thick protective layer or an aquifer setting where pathogens die off because of long travel time to the well. Wells located in a non-sensitive aquifer with proper well construction and no fecal sources within the isolation radius or one year time of travel indicate that the likelihood of a positive *E. coli* sample from a fecal source is low or non-existent. ASWM should include inorganic parameters to help document water quality that indicates the aquifer is reduced and isolated from the atmosphere. Historic sample data

may show that the rate of surface water recharge is low (for example: non-detect for nitrate and elevated iron or arsenic). Thus, if TC is detected, it suggests the occurrence is from natural occurring bacteria in the aquifer or may be associated with bioslimes in the well and not from a fecal source. PWSs with a positive TC history in pathogen non-sensitive settings should be instructed to investigate well construction or bioslimes in the well to evaluate the source.

**Intermediate Pathogen Sensitivity** – Many of the wells throughout the state will fall into an intermediate category based on locations outside of regional pathogen-sensitive areas and the lack of multiple hydrogeologic barriers as determined by the HSA. ASWM will be required for up to one year to supplement existing data to determine if the source water shows characteristics of a pathogen-sensitive or non-sensitive aquifer. If the ASWM water quality data documents:

- Confirmed *E. coli* detections, the well will be considered pathogen-sensitive;
- That nitrate, iron or arsenic levels fluctuates suddenly as a function of recharge to the aquifer (due to intense rainfall or other local recharge events), but no *E. coli* is detected, then it can be concluded that recharge flowing to the production well is sufficiently slow that pathogens are dying off before they reach the well.
- No unusual fluctuation in water chemistry and no detection of *E. coli*, then the well should be treated as pathogen non-sensitive.

If a PWS operator chooses to install disinfection on pathogen non-sensitive wells (may get infrequent TC detections, but no *E. coli*), then Ohio EPA's recommendation is to install disinfection to meet 4-log inactivation in case future triggered source water monitoring results produce an *E. coli*- positive. With 4-log capacity installed, there is no need to request approval for 4-log treatment until *E. coli* is detected. PWSs that do not request approval of 4-log treatment will be required to complete GW Rule triggered source water monitoring whenever TC is detected in routine TCR samples.

### References Cited

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