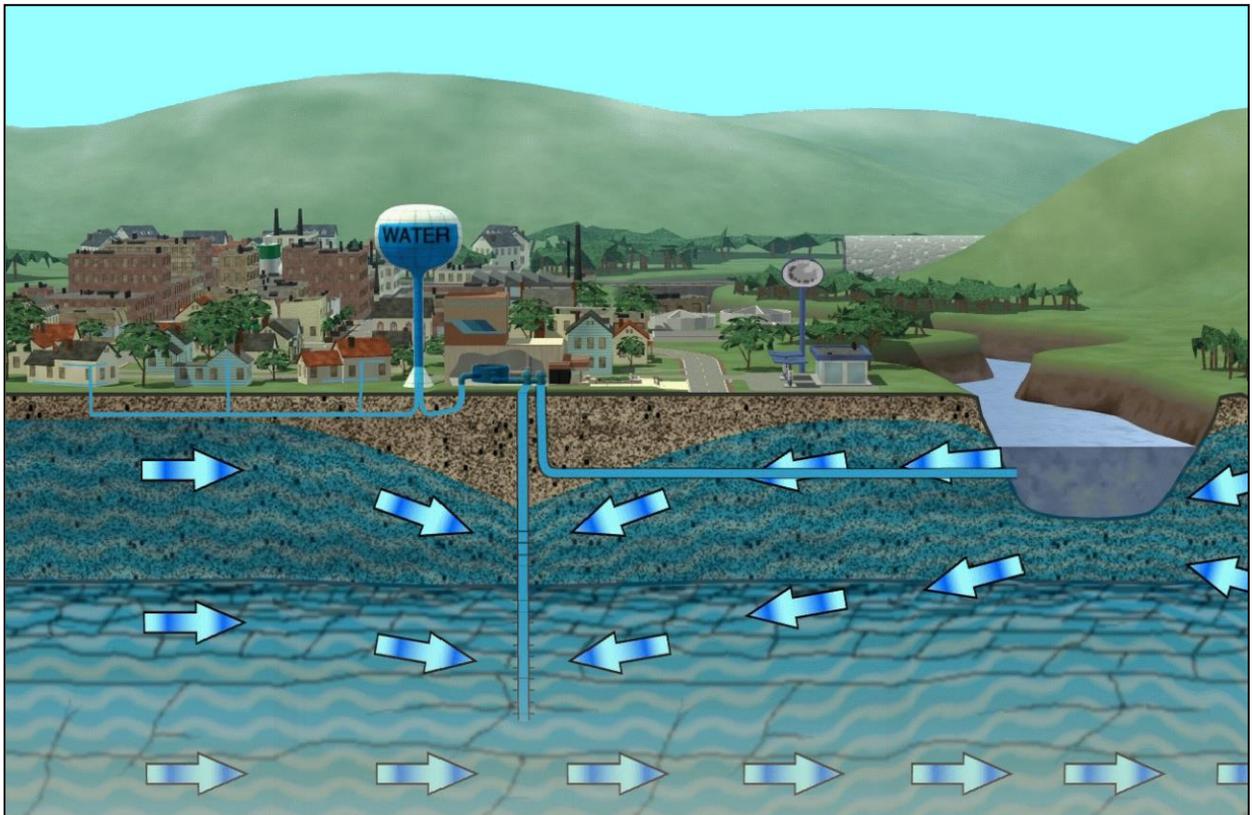


Ground Water Susceptibility Process Manual



Division of Drinking and Ground Waters
Source Water Assessment and Protection Program
Revised December, 2014

Ohio EPA Source Water Assessment and Protection Program Susceptibility Analysis Process Manual

1.0 INTRODUCTION

As part of the Source Water Assessment and Protection (SWAP) Program, Ohio EPA has developed process manuals for completing the three steps necessary to complete a Drinking Water Source Assessment for each public water system (PWS) in the state that uses ground water as its primary source of drinking water. These three steps are:

1. Delineating the area from which a public water system receives its water (drinking water source protection area);
2. Inventory potential significant contaminant sources within the drinking water protection area; and
3. Determine the susceptibility of the source water (aquifer) to contamination.

The purpose of completing the source water assessment is to provide information that each PWS can use to develop a plan to protect their drinking water source from contamination. The development of a Drinking Water Source Protection Plan is strongly recommended by Ohio EPA, and in some cases, required by statute (OAC 3745-91-10). This process manual outlines the procedures necessary to conduct a susceptibility analysis for a public water system using ground water.

2.0 WHAT IS A SUSCEPTIBILITY ANALYSIS FOR GROUND WATER SYSTEMS?

Ohio's Source Water Assessment and Protection (SWAP) Program defines susceptibility to be the likelihood for the source water(s) of a public water system to be impacted by contaminants at concentrations that would pose a concern. The purpose of a susceptibility analysis is to suggest actions a public water system and a community may take to further define and reduce the susceptibility to their drinking water source. The susceptibility analysis will evaluate information collected in the delineation and inventory steps, identify the levels and types of protective actions that may be needed, and determine if further assessment is warranted.

Because public water supply wells have been constructed in various hydrogeologic settings and have a range of potentially significant contaminant sources, best professional judgment will be important in determining the susceptibility of each of the public water systems. The results of the susceptibility analysis will be summarized in a Drinking Water Source Assessment Report to help the public water system determine the major threats to their drinking water source and prioritize the protection strategies.

3.0 CONDUCTING A SUSCEPTIBILITY ANALYSIS

The following four steps should occur when determining the susceptibility of an aquifer:

- STEP 1. Determine the Hydrogeologic Setting and DRASTIC Index
- STEP 2. Ground Water Quality Evaluation
- STEP 3. Potential Contaminant Source Evaluation
- STEP 4. Determine the Aquifer's Susceptibility

These steps are detailed in the following sections, and are summarized in a checklist in Appendix A.

3.1 STEP 1. Determine the Hydrogeologic Setting and DRASTIC Index:

The DRASTIC method will be the primary tool used to evaluate the hydrogeologic sensitivity of the aquifer to contamination. DRASTIC is a standardized method to systematically evaluate the pollution potential of any hydrogeologic setting (Aller et al, 1985). The method uses a relative ranking scheme consisting of a combination of weights and ratings to produce a numerical value, called the DRASTIC index. The DRASTIC index helps to prioritize ground water resources with respect to their vulnerability to ground water contamination. DRASTIC applies to the uppermost aquifer, which is usually the most vulnerable. DRASTIC maps, published by the Ohio Department of Natural Resources (ODNR) on a countywide basis, are available for most of Ohio (soilwater.ohiodnr.gov/maps/pollution-potential-maps). If a DRASTIC map is not available or well logs indicate that the well is in a lower aquifer, procedures to calculate the DRASTIC index described in Section 3.1.1 should be followed.

3.1.1 Calculating a DRASTIC Index for a SWAP Area:

The DRASTIC parameters are as follows:

- **D**epth to Water
- **R**echarge to the Aquifer
- **A**quifer Media
- **S**oil Media
- **T**opography
- **I**mpact (type) of Vadose Zone Media
- **C**onductivity (Hydraulic) of the Aquifer

1. **Depth to Water (ft)**: This is the depth from the ground surface to the water table in unconfined aquifers, and the depth to the bottom of the confining layer in confined aquifers. Depth to water can be obtained from well logs or potentiometric surface maps. Well logs are available on-line at ODNR's web site: apps.ohiodnr.gov/water/maptechs/wellogs/app/.
2. **Recharge to the Aquifer (inches/year)**: This is the total amount of precipitation that infiltrates into the aquifer. Recharge water can transport contaminants from the ground surface to the aquifer, and it also affects the quantity of water available for dilution and dispersion of a contaminant. If a DRASTIC map is not available, the rate of recharge can be obtained by reviewing existing DRASTIC maps for similar hydrogeologic settings. The state-wide average value for recharge is approximately six inches per year (Pettyjohn and Henning, 1979).

If the glacial drift over bedrock is thin (less than 25 feet), fractures are likely to be present, allowing more recharge to enter the aquifer than indicated by the DRASTIC maps. For public water systems located in areas of thin uplands, the recharge should be increased. For example, if DRASTIC indicates the recharge for a particular setting is 4-7 inches per year, then you should increase the recharge to 7-10 inches per year. DRASTIC mapping techniques, especially in the older maps, do not take into account transport through fractures to the aquifer and increasing the recharge will help to compensate for that.

3. Aquifer Media: This parameter represents the matrix of the aquifer. This information can be obtained from either the well log for the PWS or from nearby logs.

The Ohio EPA, working in conjunction with the U.S. EPA Region V Karst Workgroup, determined that limestone aquifers with less than 25 feet of glacial cover could be potential karst regions. These are primarily located in northwest, west and central Ohio. For these public water systems, the aquifer media should be modified to "Karst."

4. Soil Media: This parameter refers to the upper six feet of the unsaturated zone. The type of soil can influence the amount of recharge and the migration of contaminants into the aquifer. Various soil types have the ability to attenuate or retard a contaminant as it moves throughout the soil profile. If no DRASTIC map is available, the soil information can be taken from the county soils maps produced by the U.S. Department of Agriculture (USDA), Natural Resources Conservation Service (NRCS). An online soil survey browser is available at casoilresource.lawr.ucdavis.edu/soilweb/.
5. Topography: Topography refers to the slope of the land. If no DRASTIC map is available, this parameter can be estimated from the appropriate United State Geological Survey (USGS) topographic map.
6. Impact of Vadose Zone Media: The vadose zone is the saturated zone above the aquifer. The vadose zone should be determined from the well logs log for the PWS or from nearby logs.
7. Hydraulic Conductivity: This is a measure of the ability of the aquifer to transmit water. This can be obtained from the Resource Characterization database, or by using default values from Table 2.0 in the Drinking Water Source Protection Area Delineation Process Manual (Ohio EPA, 2014).

A drinking water source protection area may extend over more than one hydrogeologic setting. In order to be conservative, the highest DRASTIC index (or most vulnerable setting) should be applied to the drinking water source protection area.

3.2 STEP 2. Ground Water Quality Evaluation

Water quality data must be evaluated to determine if the aquifer has already been impacted. Ohio EPA will use compliance monitoring data from the public water systems. The sampling requirements for a public water system vary depending on the type of system, the source(s) used, and the water quality (i.e., prior detects). Community and non-transient non-community water systems are required to monitor for inorganic (includes nitrates), organic, radiological and microbial constituents. Transient non-community systems, however, are only required to sample for microbiological constituents and nitrate. Sampling frequency varies from monthly to once every

three years according to the type of contaminant and whether or not there have been previous detections. Also, water systems typically only sample treated water (except for a new well); therefore, constituents may be removed or reduced from the raw (or source) water during treatment.

3.2.1 Concentrations of Concern

Table 1 outlines the constituents and criteria that will be used in evaluating water quality. The public drinking water standards for Ohio, including the Maximum Contaminant Levels (MCL's) and the secondary MCL's, can be found in Appendix B.

A few additional details to consider:

- **Wells may have been reconditioned or abandoned.** Public water systems that had early detections of a compound(s) and then no detections may have a well or wells that were abandoned or reconditioned, or may have installed treatment that reduced concentrations. New treatment will not change the susceptibility, but will help to explain trends in compliance water quality data.
- **Known contaminant plumes or contamination should be indicated.** If a known contaminant plume or contamination exists in the drinking water source protection area, but water quality results do not indicate that the PWS has been impacted (or in the case of transients, where you may not know if the PWS has been impacted because they do not sample for organics), it is worth noting in the report that the plume or contamination exists and where it is in relation to the PWS. For transient systems, you may want to recommend a sample be collected and analyzed for whatever contaminants are in the plume to confirm that the PWS is not pumping contaminated water. A known plume in the area indicates a pathway to the aquifer from the land surface, and the susceptibility for the PWS should reflect this.

Table 1. Ground Water Quality Evaluation

	Raw Water Sample	Finished Water Sample
VOLATILE ORGANIC COMPOUNDS (VOCs)	RULE: Two or more detections of related compounds. Does not have to be consecutive.	
Exceptions		
New Well Analyses	If no confirmation sample was collected, evaluate nearby sources and use BPJ in determining an impact.	Does not apply
Disinfection By-Products (Chloroform, Bromoform, Bromodichloromethane, Dibromochloromethane)	Detections of DBPs in raw water may be attributed to backflow of treated water, sampling from an incorrect location, or contamination in the source water. Consult the drinking water inspector in these situations.	Ignore
Dichloromethane	Ignore – common lab solvent	Ignore- common lab solvent
Di(2-ethylhexyl)phthalate, Bis(2-ethylhexyl)phthalate	Ignore – common lab contaminants and plasticizers found in PVC pipe	Ignore – common lab contaminants and plasticizers found in PVC pipe
Di(2-ethylhexyl)adipate	Ignore – common lab contaminant and common plasticizer and rubberizer	Ignore – common lab contaminant and common plasticizer and rubberizer
para-Dichlorobenzene (aka 1,4-Dichlorobenzene)	Consult the drinking water inspector if para-Dichlorobenzene is detected in the raw water.	Ignore – typical component of urinal cakes. If sampling point is the men’s restroom, this value should be questioned.
SYNTHETIC ORGANIC COMPOUNDS (SOCs) (PESTICIDES)	RULE: Two or more detections of related compounds. Does not have to be consecutive.	
Exceptions		
New Well Analyses	If no confirmation sample was collected, a single SOC detection may be considered an impact.	Does not apply
NITRATE	RULE: Two or more detections of nitrate greater than 2 mg/L. Does not have to be consecutive.	
Exceptions		
New Well Analyses	If no confirmation sample was collected, a single nitrate detection may be considered an impact.	Does not apply
INORGANIC COMPOUNDS (OTHER THAN NITRATE)	RULE: Because other inorganic compounds can be either naturally-occurring or source-related, these must be evaluated on an individual basis. Only considered an impact if there are two or more detections of the same compound and the detections are believed to be from an anthropogenic source.	
RADIOLOGICAL DATA	RULE: Only Gross Beta should be evaluated. If a single detection is greater than 15 pCi/L, contact Wendy Sheeran in Central Office to assist in the susceptibility evaluation.	
BACTERIOLOGICAL DATA	RULE: Because the source of the bacteria is usually hard to pinpoint (could be from the raw water or the plumbing), bacteriological results are not used for determining susceptibility.	

3.3 STEP 3. Potential Contaminant Source Evaluation

The potential contaminant sources need to be evaluated to determine if the susceptibility should be increased because of their presence. The decision to increase the susceptibility should be based on best professional judgment. There are no hard and fast rules regarding this, and therefore the decision is subjective. However, some guidelines as to why the susceptibility should be increased include:

- A large number of potential contaminant sources within the one year time of travel area;
- A history of poor management practices; or
- A source very near to the well.

The reason for increasing the susceptibility must be documented in the report.

3.3.1 Poor Well Construction

Water quality impacts are more likely to occur in sensitive aquifers with potential significant contaminant sources present. If water quality impacts are found in what is thought to be an aquifer with a low sensitivity, it may prompt evaluation of the well integrity (poor well construction may provide a pathway along the well casing for contaminants to enter the aquifer). If water quality impacts are determined, it may be because of well construction problems and not because of a sensitive geologic setting. For example, an aquifer may be considered confined, but water quality results show an impact of benzene. It is possible that the benzene entered the aquifer through a poorly constructed well and not because the aquifer is sensitive. It is also possible to have poor well construction but not have any water quality impacts. This can be especially true for the transient wells, where nitrate is the only chemical analyzed. Reviewing sanitary surveys, discussing the site with the appropriate drinking water staff, and completing site visits may be necessary to evaluate the condition of the wells. ***Uncorrected well construction problems that result in a direct pathway to the aquifer will result in the aquifer being considered susceptible.***

3.4 STEP 4. Determining the Susceptibility of an Aquifer

The DRASTIC index is the most straightforward evaluation. A DRASTIC index ≤ 100 will have a low susceptibility to contamination; a DRASTIC index between 100 and 139 will have a moderate susceptibility; and a DRASTIC index ≥ 140 will have a high susceptibility. However, DRASTIC is not the only criteria in determining the susceptibility. Steps 1, 2 and 3 must be combined to assess the susceptibility of an aquifer.

Adjustments to the susceptibility include:

- Water quality impacts or the presence of a contaminant plume should increase the susceptibility to high, regardless of the DRASTIC index, because they indicate a pathway to the aquifer.
- A large number of sources or highly toxic sources, poor management practices and a history of spills, or direct pathways to the aquifer (such as improperly abandoned wells, quarries and mines) can result in the susceptibility being increased. This will be a best professional judgment call.
- Public water systems located in potential karst areas are highly susceptible to contamination.

4.0 CONSUMER CONFIDENCE REPORT LANGUAGE

The Consumer Confidence Report (CCR) Rules require that a brief summary of each community public water supply's susceptibility to contamination be included in their Consumer Confidence Report. The CCR must include : **(a) the susceptibility rating of the aquifer** as provided in the source water assessment report (high, moderate, low); **(b) the basis of this susceptibility rating;** and **(c) contact information that water consumers can use, if needed, to request more information.** It is also recommended that the CCR contain information on protective strategies, including any that are currently being implemented by the PWS. The PWS may use language drafted by Ohio EPA or they may choose to write their own, as long as they use *equivalent language* to that provided by Ohio EPA. For example, a system cannot change their susceptibility rating (or leave it out completely). This is stated in the CCR rules found in OAC 3745-96-02(B)(2).

6.0 REFERENCES

Aller, Linda; Bennett, Truman; Lehr, Jay; and Petty, Rebecca, 1985. *DRASTIC: A Standardized System for Evaluating Ground Water Pollution Potential Using Hydrogeologic Settings*. EPA/600/2-85/018, Cooperative Agreement CR-810715-01.

Ohio EPA, 2008a. *Creating Source Water Protection Area Delineations and Potential Contaminant Source Inventories*. Division of Drinking and Ground Waters.

Ohio EPA, 2014. *Drinking Water Source Protection Area Delineation Guidelines and Process Manual*, Division of Drinking and Ground Waters.

Pettyjohn, Wayne and Henning, Roger, 1979. *Preliminary Estimate of Ground-Water Recharge Rates, Related Streamflow and Water Quality in Ohio*. U.S. Department of the Interior, Office of Water Research and Technology, Project A-051-ohio.

APPENDIX A

Checklist for Completing a Susceptibility Analysis

STEP 1. Determine the Hydrogeologic Setting and DRASTIC Index (Section 3.1)

- Determine the hydrogeologic setting using ODNR's aquifer maps.
- Locate the drinking water protection area on a DRASTIC map and record the most conservative (highest) DRASTIC index.
- Modify the DRASTIC index if necessary based on site-specific conditions.

STEP 2. Ground Water Quality (Section 3.2)

- Review available water quality data.

Concentrations of Concern (follow guidelines in Section 3.2.1):

- Multiple nitrate detections ≥ 2 mg/L
- Multiple VOCs and SOCs (pesticides) above detection
- Other inorganic compounds evaluated on a site-specific basis

STEP 3. Potential Contaminant Source Evaluation (Section 3.3)

- Identify any known or potential well construction problems and other activities that breach the confining layer (if present).

STEP 4. Determine the Susceptibility of an Aquifer (Section 3.4)

- Highly sensitive aquifers will have a high susceptibility.
- Low sensitive aquifers will have a low susceptibility unless sources exist that breach the confining layer, water quality impacts are present, or well construction issues are noted.
- Moderately sensitive aquifers will have either a moderate or high susceptibility based on the number and types of potential contaminant sources present and the presence of water quality impacts. Identified well construction problems will result in the aquifer being highly susceptible.
- PWSs located in potential karst areas are highly susceptible.

APPENDIX B

PUBLIC DRINKING WATER STANDARDS FOR OHIO



Drinking Water Standards for Ohio Public Water Systems
November 26, 2010

I. Primary Standards (Ohio Administrative Code Chapter 3745-81)

Inorganic Chemicals	Maximum Contaminant Level (MCL, mg/L)
Antimony	0.006
Arsenic	0.010
Asbestos	7 million fibers/liter (longer than 10 µm)
Barium	2
Beryllium	0.004
Cadmium	0.005
Chromium	0.1
Cyanide	0.2
Fluoride	4
Mercury	0.002
Nitrate (as N)	10
Nitrate-Nitrite (as N)	10
Nitrite (as N)	1
Selenium	0.05
Thallium	0.002
Pesticides and Other Synthetic Organic Chemicals	MCL (mg/L)
Alachlor	0.002
Atrazine	0.003
Benzo[a]pyrene	0.0002
Carbofuran	0.04
Chlordane	0.002
2,4-D	0.07
Dalapon	0.2
Dibromochloropropane (DBCP)	0.0002
Di(2-ethylhexyl)adipate	0.4
Di(2-ethylhexyl)phthalate	0.006
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene dibromide (EDB)	0.00005
Glyphosate	0.7
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05

Lindane	0.0002
Methoxychlor	0.04
Oxamyl (Vydate)	0.2
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated Biphenyls (PCBs)	0.0005
Simazine	0.004
2,3,7,8-TCDD (Dioxin)	3x10 ⁻⁸
2,4,5-TP (Silvex)	0.05
Toxaphene	0.003
Organic Disinfection Byproducts (DBPs)	MCL (mg/L)
Total Trihalomethanes (TTHMs): the sum of the concentrations of Bromodichloromethane, Dibromochloromethane, Bromoform and Chloroform	0.080
Five Haloacetic Acids (HAA5): the sum of the concentrations of Monochloroacetic acid, Dichloroacetic acid, Trichloroacetic acid, Monobromoacetic acid and Dibromoacetic acid	0.060
Inorganic Disinfection Byproducts (DBPs)	MCL (mg/L)
Bromate	0.010
Chlorite	1.0
Volatile Organic Chemicals (VOCs)	MCL (mg/L)
Benzene	0.005
Carbon Tetrachloride	0.005
o-Dichlorobenzene	0.6
p-Dichlorobenzene	0.075
1,2-Dichloroethane	0.005
1,1-Dichloroethylene	0.007
cis-1,2-Dichloroethylene	0.07
trans-1,2-Dichloroethylene	0.1
Dichloromethane	0.005
1,2-Dichloropropane	0.005
Ethylbenzene	0.7
Monochlorobenzene	0.1
Styrene	0.1
Tetrachloroethylene	0.005
Toluene	1
1,2,4-Trichlorobenzene	0.07
1,1,1-Trichloroethane	0.2
1,1,2-Trichloroethane	0.005
Trichloroethylene	0.005
Vinyl Chloride	0.002
Xylenes (total)	10

Radiological		MCL (pCi/L)
Beta particle and photon radioactivity		4 mrem/yr (based on calculated levels for 168 possible contaminants)
Combined Radium-226 and Radium-228		5
Gross Alpha particle activity		15
Uranium		30 µg/L
Microbiological		MCL
Total coliform	Public water systems monitoring with at least 40 samples per month	No more than 5% total coliform positive samples per month (<i>monthly MCL</i>)
	Public water systems monitoring with fewer than 40 samples per month	No more than 1 total coliform positive per month (<i>monthly MCL</i>)
<i>E. coli</i> and fecal coliform		A routine sample and a repeat sample are total coliform positive, and one is also <i>E. coli</i> or fecal coliform positive (<i>acute MCL</i>)
Lead and Copper		Action Level
Lead		Greater than 0.015 mg/L in more than 10% of tap samples in a compliance period
Copper		Greater than 1.3 mg/L in more than 10% of tap samples in a compliance period

II. Secondary Standards (Ohio Administrative Code Chapter 3745-82)

Parameter	Secondary Maximum Contaminant Level (SMCL, mg/L)
Aluminum	0.05 to 0.2
Chloride	250
Color	15 color units
Corrosivity	Non-corrosive
Fluoride	2.0
Foaming agents	0.5
Iron	0.3
Manganese	0.05
Odor	3 threshold odor number
pH	7.0-10.5
Silver	0.1
Sulfate	250
Total dissolved solids (TDS)	500
Zinc	5

III. Disinfection Requirements (Ohio Administrative Code Chapters 3745-81 and 3745-83)

Disinfectant Residuals		Maximum Residual Disinfectant Level (mg/L)	
Total Chlorine (as Cl ₂) in Distribution		4.0	
Chlorine Dioxide (as ClO ₂)		0.8	
Disinfectant Residuals		Minimum Required Free or Combined Chlorine*	
		Free Chlorine	Combined Chlorine
Community & Major Noncommunity, Distribution (3745-83-01)		at least 0.2 mg/L (unless superseded by the Director)	at least 1 mg/L (unless superseded by the Director)
Surface Water System (3745-81-72)**	Entry Point	not less than 0.2 mg/L for more than 4 consecutive hours	not less than 1 mg/L for more than 4 consecutive hours
	Distribution	not less than 0.2 mg/L in more than 5% of the samples for two consecutive months	not less than 1 mg/L in more than 5% of the samples for two consecutive months
Disinfection Efficacy		Treatment Technique Requirement	
Surface Water System / Ground Water (4-log)		Actual CT ≥ Required CT (Daily Verification)	

* Only have to satisfy either the free or combined chlorine residual. However, monitoring for both is required.

** Surface water systems that would also be classified as either a community or major noncommunity public water system also have to comply with minimum required free or combined chlorine residual levels in the distribution system, as cited above for rule 3745-83-01. Failure to meet the requirements in rule 3745-83-01 would be an operational violation while failure to meet the requirements in rule 3745-81-72 would be a treatment technique violation.)

IV. Turbidity Requirements (Ohio Administrative Code rules 3745-81-73 to 3745-81-75)

Turbidity (Finished Water)	Treatment Technique
Conventional filtration or alternative filtration technology	Less than or equal to 0.3 NTU in at least 95% of samples per month and shall not exceed 1 NTU
Slow sand filtration	Less than or equal to 1 NTU in at least 95% of samples per month and shall not exceed 5 NTU
Turbidity (Individual Filter Effluent)	Actionable Requirements per Event*
Surface Water System Population ≥ 10,000	Individual Filter Events A, B, C, D
Surface Water System Population < 10,000	Individual Filter Events A, B, C

* Events and Actionable Requirements are defined in Appendices A and B to the Surface Water Plant MOR Instructions (Form 5109), <http://epa.ohio.gov/ddagw/reporting.aspx#Forms>.

Note: To determine compliance with the drinking water standards listed in this document, please see rules associated with each section.

Unit Abbreviations

mg/L: milligrams per liter (parts per million, ppm) = 1,000 µg/L

NTU: nephelometric turbidity units

pCi/L: picocurie per liter

µg/L: micrograms per liter (parts per billion, ppb)

µm: micrometers

mrem: millirem

APPENDIX C

Organic Compound Groupings

BTEX Group

Compound	DP (%)	Specific Gravity	Solubility (mg/L)	MCL (µg/L)
benzene	0.90	0.899	1800	5
toluene	4.33	0.867	526	1000
ethylbenzene	0.84	0.867	206	700
total xylenes	2.43	0.862	175	10,000
m-xylenes	1.53	-----	-----	-----
o-xylenes	1.14	-----	-----	-----
p-xylenes	1.05	-----	-----	-----

- Indicative of petroleum and its by-products. Trimethylbenzenes are sometimes found with this group. Benzene and toluene are in common use individually as industrial chemicals, and may be found by themselves.
- Toluene is the most commonly detected group member, followed by total xylenes, then benzene, and then ethylbenzene. Toluene is the most commonly found VOC for those Ohio systems with only a single detect in their compliance history, as of 10/2/2001. Toluene is found in substances commonly used in PWS distribution facilities such as paints (used on floors, water lines, etc), machine oils and greases (possibly associated with rehab, rebuild, or replacement of pumps, valves, line joints, etc). Also found in WD-40 and Liquid-Wrench, the popular release/de-rusting sprays.
- BTEX components (primarily toluene) have been associated with new well analyses, perhaps due to volatilization during the drilling process. Also, toluene has been associated with some “pipe dope” compounds, perhaps used on well casing threads.

- Rarely do [migrated] ground water samples in Ohio PWS have all four components together, but it is common to find ethylbenzene and total xylenes together. This possibly indicates an older spill already degraded in the more mobile benzene and toluene fractions. The reverse occurs with BTEX in soils. Toluene, ethylbenzene and xylenes are preferentially retained by soil relative to benzene; ethylbenzene and xylenes are also more resistant to degradation than benzene or toluene.
- Work in environmental forensics has shown that for [mainly free-product] BTEX-impacted groundwater, if the ratio of benzene plus toluene to ethylbenzene plus xylene is between 1.5 to 6.0 and near a suspected source, the release probably occurred within the last five years. This ratio decreases exponentially with time because of the preferential transport of benzene and toluene, which increases the less soluble ethylbenzene and xylene concentrations. The [preferential] degradation of benzene and toluene with time also results in a reduction of the BTEX ratio.

Chlorinated Solvents Group

Compound	DP	Specific Gravity	Solubility (mg/L)	MCL (µg/L)
Tetrachloroethene (PCE)	10.26	1.631	150	5
Trichloroethene (TCE)	19.33	1.466	1100	5
1,1,1-Trichloroethane (1,1,1-TCA)	12.83	1.346	1500	200
1,1-Dichloroethene (1,1,1-DCE)	3.86	1.25	400-2500	700
cis-1,2-Dichloroethene	9.29	1.27	600-6300	70
trans-1,2-Dichloroethene	2.67	1.27	600-6300	100
Chloroethane	0.77	0.898	5740	none
Vinyl chloride	3.25	0.908	1.1-60	2

- PCE and TCE have been in industrial use over 50 years. Commonly used as degreasing agents (engine cleaners, metals processing). PCE (aka tetrachloroethylene) is a common dry cleaning agent. PCE is used in electric transformers as an insulating and cooling fluid, and in the paper and pulp, and textile industries.
- PCE and TCE can both undergo dechlorination (loses a chlorine) leading to the daughter products 1,1-DCE, cis- and trans-1,2-Dichloroethene, which finally degrades into vinyl chloride. This is the “natural attenuation” sequence for chlorinated solvents. The percentage of individual compounds may be indicative of the “age” of the impact or spill. For example, if only vinyl chloride is found, it may indicate an older spill in which all of the precursors have been degraded and only vinyl chloride is left. Conversely, only PCE may indicate a more

recent spill or impact. However, any of these compounds may be found individually.

- 1,1-TCA can also dechlorinate to produce 1,1-Dichloroethane, cis- and trans-1,2-Dichloroethene, chloroethane, and then vinyl chloride, and so is listed in the table above.
- Under oxidizing conditions, the metabolites may be oxidized and hydrolyzed to produce intermediates such as dichloroacetic acid and formate, with the ultimate products being the mineralized (i.e. inorganic form) end products CO₂, H₂O, and Cl⁻.
- The presence or absence of a particular breakdown product can be argued as evidence that the parent compound was present for a particular period of time. For example, the compound 1,1-dichloroethene is a breakdown product of both TCA and PCE, while chloroethane is a degradation product of only TCA or 1,2-dichloroethane. The presence of chloroform can indicate the presence of carbon tetrachloride; it is not an associated product of either PCE or TCA.

Urinal Cake/ Restroom Deodorant Group

- Paradichlorobenzene (aka 1,4-Dichlorobenzene) is a common volatile component of these products. The other two isomers (orthodichlorobenzene (DP = .11 %), and metadichlorobenzene (DP = 0.24 %)) are rarely found in VOC samples from PWSs. Reasons for this are unclear. If you see this compound in a sample, check to see if the sample was taken in a restroom, or janitor's closet, etc. for potential invalidation.
- Also used in the production of mothballs, moth crystals, and in diapers, toilet bowl deodorizers. Used for disease control on tobacco as a plant bed treatment for blue mold. Widely used in the production of low pressure aerosols because of its insecticidal action and its properties as a solvent. Used industrially to control mildew and molds on leather and fabrics in closed containers. Used in formulations to repel cats and dogs both indoor and outdoors.
- Leaching from hazardous waste disposal areas has occurred and the detection of 1,4-dichlorobenzene in various ground waters indicates that leaching can occur.

Lab Solvents Group

This group contains the most common laboratory contaminants found in Ohio PWSs.

- Methylene chloride (aka dichloromethane, DCM) is a common laboratory solvent used for the extraction of SVOCs (BNAs) from water in method USEPA 624 and methods in SW 846. It is extremely easy to cross contaminate a sample with this compound in the laboratory because of its high volatility. Large quantities of dichloromethane are used by industry each year, primarily in aerosols, paint removers and chemical processing.

When spilled on land, dichloromethane is expected to evaporate from near surface soil into the atmosphere because of its high vapor pressure. Although little work has been done on its adsorption, it is probable that it will leach through subsoil into groundwater. Degradation in

groundwater is unknown.

- Acetone
Very common laboratory solvent, and although it is not commonly analyzed for in VOC scans, it is in the 624 scan. Highly soluble in water.

Acetone is a very common solvent for fats, oils, waxes, resins, rubber, plastics, lacquers, and varnishes.

Acetone is produced in large quantities and may be released to the environment as emissions, in waste water, and in its production and use as a chemical intermediate and solvent. Most acetone used in solvents will be ultimately released into the air.

- Hexane
Another very common laboratory solvent. Not analyzed as part of the VOC compliance program, but analyzed for in 624 (Ambient Monitoring Network). Has replaced methyl chloride as a liquid extraction agent in some methods.

When released into the soil, hexane may biodegrade to a moderate extent, and is not expected to leach into groundwater but quickly evaporate. When released into water, hexane may biodegrade to a moderate extent and is expected to have a half-life between 1 and 10 days.

- Dichlorodifluoromethane (Freon 12), Trichlorofluoromethane (Freon 11)
A “freon” is a fluoridated methane. Freons are (were) common refrigerants, oil and grease extraction solvents, replaced by hexane. Used to flash freeze foods, as leak-detection agents, in the manufacture of aerosols for cosmetics, pharmaceuticals, insecticides, paints, adhesives, and cleaners. Not very common; they are unregulated VOCs.

All of the large quantities of these highly volatile compounds produced will eventually be lost as emissions and the levels of this chemical have been building up in the atmosphere. For this reason, they are used to trace ocean mixing worldwide.

These compounds have a 1.6 % detection rate in 1,700 stations recorded in the USEPA data base STORET for groundwater.

Miscellaneous Groups

- Bromomethane, Chloromethane and Chloroethane
Commonly found together in PWS compliance samples, although their source is unclear. Bromomethane is a gas under normal conditions, and so humans are most likely to be exposed to bromomethane in air. Release to air occurs from natural sources (production in the ocean by marine organisms), from industrial point sources, through the use of leaded gasoline, and from its use as a fumigant. This compound may also be generated in drinking water as the result of the chlorination. Bromomethane is highly volatile, and so nearly all releases will be [eventually] to the air, where a rather long half-life of 11 months is

estimated, suggesting that it will widely disperse. On the other hand, this compound is also quite soluble in water, so that some portion of a spill, after evaporation, may partition into rain or clouds, and eventually find its way into the ground water system.

Because of its volatility, very little bromomethane is released to surface water; direct spills would be expected to volatilize quickly. The main consumptive use of bromomethane in the United States is the fumigation of soils, where the residence time is estimated at 1-2 days, limiting its persistence in the soil regime.

Degradation in water occurs slowly by hydrolysis, yielding methanol, bromide ion, and hydrogen ion. Degradation half-life is estimated at between 20 and 38 days, significantly longer than its volatilization half-life (3.1 hours), indicating that most bromomethane will volatilize before extensive hydrolysis occurs.

- Naphthalene

This is an unregulated VOC, but is a relatively common detect. It is the simplest of the polyaromatic hydrocarbons (PAHs). Associated with coke, coal tar, fuel oil, and gasoline. Used in the production of naphthol, mothballs, fungicides, dyes, detergents, wetting agents resins, toilet bowl deodorants, and smokeless powders. Very common as a chemical intermediate in synthesis of organic compounds. PAHs can occur naturally at low levels.

Naphthalene enters the atmosphere primarily from fugitive emissions and exhaust connected with its presence in fuel oil, diesel fuel, and gasoline. In addition, there are discharges on land and into water from spills during the storage, transport and disposal of fuel oil, coal tar, etc. Once in the atmosphere, naphthalene rapidly photodegrades (half-life 3-8 hr). Releases into water are lost due to volatilization, photolysis, adsorption, and biodegradation. The principal loss processes will depend on local conditions but half-lives can be expected to range from a couple of days to a few months. When spilled on land, naphthalene is adsorbed moderately to soil and undergoes biodegradation. Naphthalene is a common contaminant in roadside ditches, presumably from the exhaust of motor vehicles.

- Carbon tetrachloride

Occasionally detected in ground and surface water samples. Has been used as a grain fumigant, and hot spots are found under old grain silos. Other uses: preparation of refrigerants, aerosols, propellants, oil and gas solvent, spot removers. Released to the environment in industrial settings.

Carbon tetrachloride evaporates quickly from surface waters and soil. It does not bind to soil and may leach into ground water. It has a low potential to accumulate in aquatic life. May hydrolyze to form chloroform (trichloromethane) and carbon dioxide, and biodegrade by reductive dechlorination to yield chloroform, dichloromethane, and others.

- Methyl Chloride

Formed in the oceans by natural processes; it has been detected in air all over the world. Methyl chloride is also present in some lakes and streams and has been found in drinking water at very low levels. Other sources of exposure to methyl chloride include cigarette

smoke, polystyrene insulation, and aerosol propellants; home burning of wood, coal, or certain plastics; and the use of chlorinated swimming pools. Occupations that present a higher risk of exposure include building contracting, metal industries, transportation, car dealers, and service-station attendants.

Methyl chloride is used mainly in the production of silicones where it is used to methylate silicon. It is also used in the production of agricultural chemicals, methyl cellulose, quaternary amines, and butyl rubber and for miscellaneous uses including tetramethyl lead. Methyl chloride was used widely in refrigerators in the past, but generally this use has been taken over by newer chemicals such as Freon.

Draft compiled by Michael Slattery and Rich Ciotola, DDAGW, 9/20/2001