Photo courtesy of the Pennsylvania Department of Environmental Protection

Getting the Most Out of Your TOC Information

by Phil Consonery

With the recently enacted Stage 1 Disinfectants/Disinfection By-products (D/DBP) Rule and the proposed Stage 2 D/DBP regulations, the potential health effects of disinfection by-products (DBPs) in drinking water have received extensive coverage in the media. Likewise, total organic carbon (TOC), used to measure precursors to DBP formation, is now deep-seated in regulations affecting large and small water suppliers across the United States.

Lebanon Water Authority, like many utilities that rely on surface water, must deal with natural organic matter in its source water, which can be a precursor to disinfection by-products.

Because long-term exposure to DBPs could cause cancer, both the long- and short-term health effects of DBPs are currently under scrutiny. Some studies suggest the potential that by-products such as total trihalomethanes (THMs) may be associated with spontaneous abortions in humans. THMs may also negatively affect laboratory animal reproduction and fetal development.

The volatile nature of THMs could increase inhalation exposure in situations such as showering, depending on the concentrations in the water and air, as well as the amount of time a person spends in the bathroom after showering. There are unknown factors now, but future research will improve our understanding of DBPs and any linkages to adverse health effects.

Rather than wait on the sidelines while the scientific community continues its debate about DBP health effects, the nation's water suppliers, state regulatory agencies, and US Environmental Protection Agency have taken a progressive approach by jointly agreeing to implement Stage 1 D/DBP Rule provisions and the more recently proposed provisions of the Stage 2 D/DBP Rule. The Stage 1 D/DBP Rule focused on low-cost steps to optimize treatment, thus lowering DBPs. USEPA's guidance says the most cost-effective approach to controlling DBPs may involve the removal of precursors that eventually lead to by-product formation.

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Understanding the Terms

The Stage 1 D/DBP Rule contains a requirement for *precursor* monitoring and removal. The precursor provisions apply to water suppliers using conventional filtration to treat surface water sources or sources under the direct influence of surface water. Water suppliers may operate with *enhanced coagulation* to achieve a specific percent removal of TOC. Or, if that percent of TOC removal cannot be achieved, the supplier can meet at least one of the *alternative compliance criteria*. Under the regulations, surface water suppliers serving at least 10,000 people started monitoring TOC in January 2002; all other affected suppliers were to start monitoring in January 2004.

Let's backtrack for a minute and get a clear idea of these terms. *Webster's Dictionary* defines "precursor" as "a substance that precedes and is the source of another substance." The Stage 1 D/DBP Rule pertains particularly to precursors to THM and haloacetic acid (HAA) formation, which likewise should impact precursors to other by-products that currently are not regulated. The precursors are naturally occurring organic matter found in rivers, lakes, and reservoirs. However, natural organic matter (NOM) is difficult and expensive to measure, so TOC is used as a substitute and indicator of precursors. TOC, then, is considered a precursor to disinfection by-products.

Enhanced coagulation is a method of removing THM and HAA precursors.

The Drinking Water Dictionary defines "enhanced coagulation" as "the addition of excess coagulant or the adjustment of pH levels to improve precursor removal." The Stage 1 D/DBP Rule does not require conversion to optimized coagulation practices, but rather the enhancement of existing processes to remove specific percentages of TOC from the source water, based on influent water quality. This part of the removal requirement is referred to in the USEPA regulation as *Step 1*. Remember, this process only applies to conventional filtration systems.

Regulated precursor removal and TOC reduction falls under the category of *treatment technique* instead of maximum contaminant level (MCL). Treatment techniques are included in regulations when a contaminant of concern is difficult to measure. For example, turbidity is regulated with a treatment technique because it has no direct health impact and cannot be practically regulated by establishing an MCL, but it serves as an indicator for the presence of *Cryptosporidium*, *Giardia*, and viruses. The TOC treatment technique substitutes for monitoring for unregulated by-products.

To recap, a water supplier is fulfilling the requirements of Step 1 if it

- meets the TOC removal requirements through the treatment technique of the Stage 1 D/DBP Rule, which is usually accomplished by practicing enhanced coagulation, or
- meets one of the alternative compliance criteria.

Note, however, that enhanced coagulation comes at costs, both financial and operational, that you must consider. You will have additional expenses associated with increased coagulant dosages, and additional safety considerations and expenses associated with acid addition. The change in pH will affect other treatment properties and contaminant behaviors. You will have to evaluate whether you need to change your disinfectant dosage or process. These changes may also bring about changes in your current compliance status with the Lead and Copper Rule. You cannot tweak one operational process without thinking about the consequences for the overall treatment strategy. So, it is important to contact your regulatory agency and a qualified consultant to discuss strategies before changing treatment.

TOC Removal

TOC removal must occur between the raw water sampling point and the treated water monitoring point, which is located at the combined filter effluent. (The source water must be sampled prior to any treatment.) But, because sampling site availability may be limited at some treatment plants, water suppliers should consult their regulatory agency if they have questions about proper TOC

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TOC Removal (from page 11)

Source Water TOC (*mg/L*)	Source Water Alkalinity (*mg/L* as $CaCO_3$)		
	0 to 60	> 60 to 120	> 120
> 2.0 to 4.0	35.0%	25.0%	15.0%
> 4.0 to 8.0	45.0%	35.0%	25.0%
> 8.0	50.0%	40.0%	30.0%

Table 1. The 3-by-3 matrix shows required TOC removal percentages depending on source water parameters.

monitoring locations.

The required removal of TOC ranges from a 15 percent reduction to as high as a 50 percent reduction. These percentages depend on the source water TOC and the source water alkalinity levels at the time of sampling. Table 1, on page 12, also called the "3-by-3 matrix," shows the acceptable TOC removal percentages for these parameters.

To use the table, consider this scenario: During July 2004, a conventional filter plant obtains raw water samples from a reservoir with a TOC level of 4.2 mg/L and an alkalinity concentration of 62 mg/L. To determine how much TOC must be removed from the raw water, find the source water TOC level in the ranges on the left and the alkalinity level at the top; the intersection of these two points shows that at least a 35.0 percent removal of raw water TOC must occur. In other words, the treated water TOC sample must be 35.0 percent lower than the raw water TOC sample at this treatment plant in July 2004.

The percentage of TOC removal must be calculated monthly. Because source water conditions change throughout the year, removal requirements will likely change from month to month.

Other Benefits of TOC Removal

TOC is used to measure the NOM in water. NOM places a high demand on coagulant doses. Generally, water suppliers that use high coagulant doses do so because of high NOM concentrations in their surface water source. For maximum public health protection, regulations and research efforts have focused on the reactions between NOM and chemical disinfectants. However, a water supplier should consider enhancing existing treatment for NOM removal for several other reasons as well:

- The biodegradable form of organic matter is food that promotes bacterial growth in the distribution system. NOM may be related to the occurrence of coliform bacteria in the distribution system.
- Organic matter can react with harmful metals and synthetic organics, thus allowing these contaminants to proceed through treatment processes that are not designed to remove NOM.
- Organic matter affects water taste, odor, and color.
- Organic matter creates a demand for disinfectants and other oxidants, and it can affect residual disinfectant stability and corrosion.
- NOM competes with other organic compounds that are amenable to removal with treatment methods such as the use of powdered activated carbon or granular activated carbon.

Tips for TOC Removal Requirements

The precursor removal requirements under the Stage 1 D/DBP Rule are complex. The following three-part plan will help you to gather the right data and determine if your treatment plant meets the regulations.

Plan A

Once a month, you must collect samples for source water TOC and alkalinity analysis, as well as a sample of the treated water for TOC analysis. You will calculate the actual TOC removal percentage between the raw water and treated water TOC sample results. Calculate the required TOC removal by comparing your raw water TOC and alkalinity levels to the 3-by-3 matrix.

If your actual TOC removal is at least as much as the required TOC removal in the matrix, the calculation will — at a minimum — result in a "1.00" as the monthly "performance ratio" for your system. Here's how to calculate this performance ratio:

The actual monthly TOC percent removal is determined as follows:

Removal (%) = 1 – (treated water TOC ÷ by raw water TOC) × 100

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TOC Removal (from page 12)

Photo courtesy of the Pennsylvania Department of Environmental Protection

Adsorption clarifiers, which help reduce TOC concentrations before filtration, are backwashed at a surface water treatment plant operated by the State College Borough Water Authority.

The required monthly TOC percent removal is determined using the 3-by-3 matrix. The regulations also allow qualifying water suppliers to establish site-specific removal percentages, using a process called Step 2, which is beyond the scope of this article but is in USEPA's Enhanced Coagulation and Enhanced Precipitative Softening Guidance Manual.

Each month, the *actual* removal is divided by the *required* removal to obtain a performance ratio. *A higher performance ratio is better* — all other performance objectives being equal.

To test your understanding of the performance ratio calculation, use the information we identified for the conventional plant in the above scenario. We know that July's raw water TOC level is 4.2 mg/L and the alkalinity concentration is 62 mg/L. We also know that at least a 35.0 percent removal of raw water TOC must occur in the plant. Now, let's say the treated water TOC level is 2.6 mg/L in July. What is the ratio for the month?

Answer: Actual removal (%) = 1 – (2.6 mg/L ÷ 4.2 mg/L) × 100 = 38.1%

Performance ratio = 38.1% ÷ 35.0% = 1.09

Operating under Plan A, we know the performance value for the month is at least 1.00, so our treatment plant meets the TOC removal requirements for the month. If the performance ratio had been less than 1.00, then you should go to Plan B.

Even if your performance value is within the appropriate range, you should keep your guard up by continuing to properly monitor for TOC — and perhaps monitor specific ultraviolet absorbance (SUVA) as well. SUVA is an alternative criterion for demonstrating compliance with TOC removal requirements under the D/DBP Rule because waters with low SUVA values contain primarily nonhumic matter and are not amenable to enhanced coagulation. Also, keep your raw and treated water TOC results in a convenient location, because you may need them later, if you have to resort to Plan C.

Plan B

You should only use Plan B if Plan A fails. In addition to raw and treated water TOC samples, you may optionally collect monthly raw and finished samples for SUVA analysis. If you collect TOC and SUVA samples at the proper locations each month, you will have four opportunities to meet the regulations.

If your raw water or treated water TOC results are less than 2.0 mg/L for the month *or* your raw water or finished water SUVA results are 2.0 L/mg-m or less, the regulations allow you to receive a 1.0 performance ratio for that month. If not, you will need to stay with the actual performance ratio calculated in Plan A for the month. The regulations allow you to choose the higher value of

- the performance ratio calculated in Plan A if the percent removal provides credit for a ratio of greater than 1.00, or
- a 1.0 as determined under Plan B.

Plan C

You should only use Plan C if the running annual average (RAA) of your monthly performance ratios is less than 1.00. Plan C allows you to recalculate some of the same data you might already have at your fingertips. However, rather than the monthly calculations you completed in Plans A and B, you will have to wait until the end of each quarter, when you examine the separate running annual averages for monthly TOC and SUVA values. This means you need at least 12 months of data. One way to calculate an RAA is to add, at the end of each quarter, the three performance ratios for that quarter (one each month) and divide by three. At the end of the year, add the four quarterly averages and then divide by four.

If the RAA of your

- raw or treated water TOC levels is less than 2.0 mg/L, or
- raw or treated water SUVA results is 2.0 L/mg-m or less, or
- total THM samples are 0.040 mg/L or less *and* the RAA of your HAA samples is 0.030 mg/L or less *and* your system uses *only* chlorine,
- then your system is likely in compliance with the enhanced coagulation treatment technique. If you answered "no," your filter plant does not comply with this treatment technique.

An RAA only includes 12 months of data, so when data collected during a new quarter is included in the calculation, data from the initial quarter is dropped from the calculation. Contact your state agency to determine if you should calculate your RAA by averaging the four quarterly averages or by adding the monthly levels and dividing by 12. The results may differ depending on how values are rounded in your state.

You should discuss compliance options, such as the Step 2 provision of the D/DBP Rule, with your regulatory agency *well before* exhausting the alternatives under Plans A, B, and C.

For More Information

The Pennsylvania Department of Environmental Protection (DEP) has a website, <www.dep.state.pa.us>, that links to a variety of resources, including manuals, guidance, instructions and templates. To find information about the TOC removal requirements, type "filtration" into the search box and select "New Drinking Water Regulations," which will bring you to the D/DBP Rule and other rules. Also, USEPA's guidance manual is online at <www.epa.gov/safewater/ mdbp/coaguide.pdf>.

Photo courtesy of the Pennsylvania DEP

The Kemmerer sampler is used to collect samples from beneath the surface of the water when information is needed about various water depths. The sample bottles in the photo are not acceptable for TOC analysis at a laboratory, but can be used for collecting many types of raw water samples.