TOC analysis: the best tool in a drinking water facility's toolbox

Total Organic Carbon (TOC) has become an important water quality analysis tool for drinking water plants in recent years due to its link to disinfection byproducts (DBPs). TOC alone is not harmful, but upon its reaction with a disinfectant can produce harmful byproducts. However, TOC's relevance in drinking water applications is not purely for regulatory compliance of DBP limits or meeting TOC monitoring requirements. TOC is also an important parameter for optimizing and thereby reducing costs associated with a treatment process and is an indicator of the health and safety of source water and distribution system water quality. TOC has a range of applicability at a drinking water plant, and therefore any drinking water utility — large or small — can measure TOC in their laboratory or online in their treatment process.

nail the regulations– disinfection byproducts

Regulations like the USEPA's Safe Drinking Water Act attempt to balance the risks presented by microbial pathogens and byproducts from the disinfectant used to destroy these microbes. The byproducts, DBPs, form from the interaction of the naturally occurring organic matter (NOM) in a drinking water plant's source water and its disinfection process. TOC is recognized globally as the parameter used to determine the quantity of NOM in water. DBPs, such as haloacetic acids (HAAs), continue to form as water passes through a plant's distribution system and contact time increases. Trihalomethanes (THMs), another class of DBPs that include chloroform, are formed from the interaction of TOC, naturally occurring bromide, and chlorine (**Figure 1**).

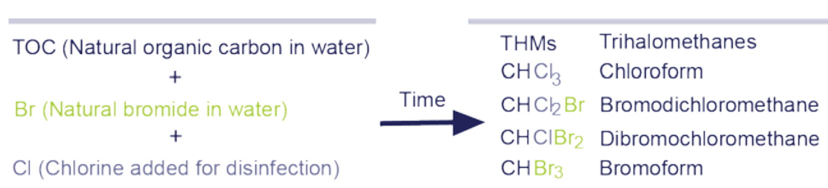

Figure 1. THMs formed from TOC, Bromide, and Chlorine

TOC deemed a DBP precursor by the EPA, can be monitored in a lab or online to predict the DBP levels in the distribution system. A large percentage of TOC should be removed in the drinking water treatment process to reduce DBP levels. Many different processes remove TOC, including coagulation, granular activated carbon (GAC) filters, and anionic exchange.

cut costs– treatment optimization

Drinking water utilities today are experiencing heavy pressure to not only meet increasingly difficult water quality requirements but also to reduce spending in their plant treatment processes. Today many drinking water plants are using TOC monitoring and process optimization to produce high-quality water while also achieving significant cost reductions in different treatment processes.

Coagulation

One of the main treatment processes used to remove TOC is coagulation. Coagulation is typically followed by flocculation and clarification and the combination of these three pre-treatment techniques is termed conventional treatment. Conventional treatment facilities in the USA are required to meet a TOC removal percentage based on their source water alkalinity and TOC level.

Common coagulants are aluminum sulfate, (typically called alum), ferric chloride, ferric sulfate, and polyaluminum chloride (PACl). Selection of the proper coagulant and proper dosage considers many factors such as pH, alkalinity, temperature, and sludge production, in addition to the water quality achieved. Jar testing, pilot testing, or full-scale optimization can test the efficiency of a particular coagulation scheme but must include both TOC and turbidity measurements to effectively gauge its success.

Activated Carbon

Activated carbon is a form of processed carbon made from materials such as wood, peat, coal, and coconut shells. The product is extremely porous, giving it a very large surface area available for adsorption of dissolved organics, taste and odor-causing compounds, and some disinfection byproducts. Activated carbon is most commonly used in drinking water treatment plants in either a granular or powder form.

Powder Activated Carbon (PAC)

PAC is the powder form of activated carbon where fine granules are used for seasonal or short-term problem solving. The powder is available in bulk and typically added directly to a process. Inlets for PAC tend to be raw water intakes, rapid mix basins, and clarifiers. PAC is usually added to the water before the coagulation-flocculation step, and removed with its sludge. PAC is used to solve taste and odor problems or act as a coagulation aid, providing a nucleus for floc to form. When PAC is used to remove TOC, it is important to optimize its addition by understanding how much TOC the PAC is removing.

Granular Activated Carbon (GAC)

GAC has a relatively larger particle size compared to PAC and, consequently, presents a smaller external surface. GAC is typically used in filters in place of sand or anthracite and is a long-term solution to water quality issues. The adsorption efficiency of the GAC decreases over time and eventually needs to be replaced or reactivated. To ensure that the GAC filter effectively removes the contaminants from the raw water source and maintains the desired water quality, water quality monitoring such as TOC is often implemented. If GAC is used to remove dissolved organics, a spike in TOC can indicate a need for replacing or regenerating the activated carbon.

Ion Exchange

Ion exchange uses special resins to remove charged contaminants from water using adsorption. Ion exchange has typically been used for the removal of inorganics, but recently specialized anion resins have been developed for the removal organics, such as humic acids. When water is passed through the resin, it exchanges charged contaminants for the charged ions stored on the resin surface. Ion exchange resins are most commonly regenerated with a salt solution (sodium chloride).

Regardless of the treatment method being optimized or the technique used to test optimization, it is critical to evaluate success using the proper analytical equipment. **Figure 2** shows the many points where TOC analysis can be utilized in a conventional treatment plant.

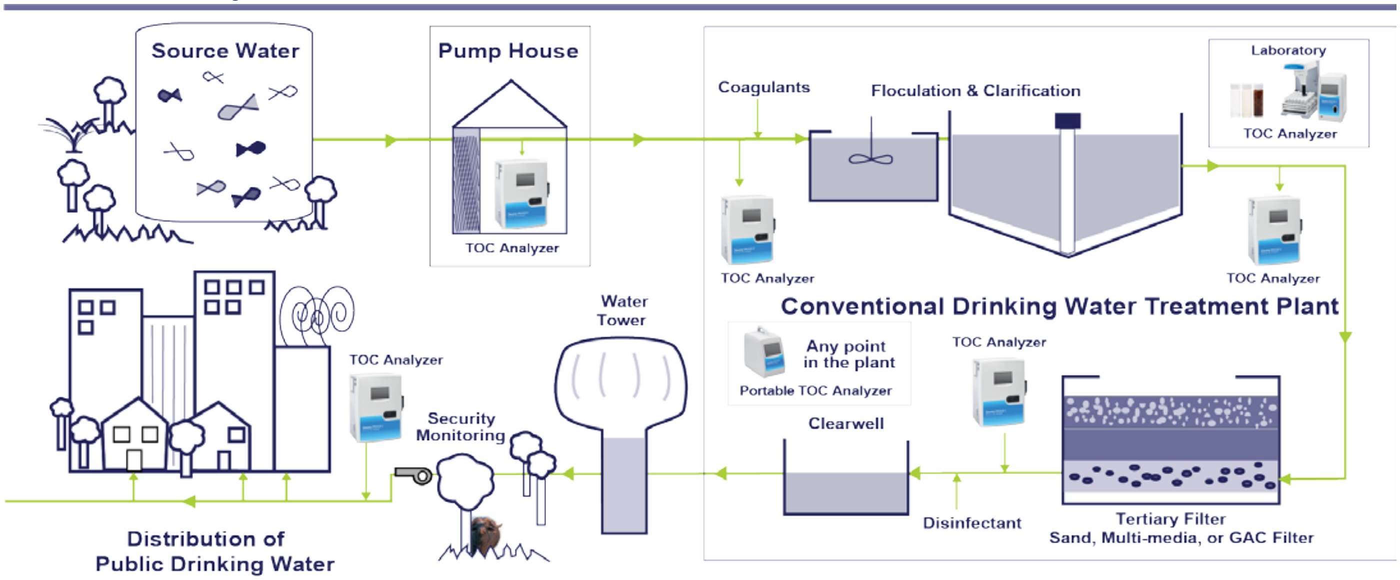

Figure 2. TOC in the Drinking Water System

tighten your process– disinfection techniques

When water has high levels of iron or manganese, a higher feed rate of disinfectant is necessary. TOC is also a disinfectant-demanding substance. Consequently, the less TOC removal achieved in a treatment process, the more disinfectant needed and the more money spent. In fact, the disinfection process competes with the natural oxidant demands of substances such as TOC; therefore, TOC levels must be taken into account while managing inactivation of viruses.

Many plants are also switching from chlorine to chloramines to avoid higher DBP formation. This switch may achieve a decrease in THMs and HAAs but a utility may, in turn, be forming other DBPs that are not yet regulated. Chloramines are known to form many non-halogenated DBPs, such as iodoacids and nitrosamines. Iodoacids are identified as one of the most toxic and DNA-damaging DBPs, while nitrosamines, such as N-nitrososodimethylamine (NDMA), are known to be many times more carcinogenic than THMs.

In addition, TOC still plays a critical role in chloramination processes. If a plant adds their ammonia downstream from their chlorine addition, which is common to reach virus inactivation requirements, they could see nitrification problems if they do not maintain a consistent TOC level in the water. Since TOC is a chlorine- demanding substance, it could affect the proper chlorine to ammonia ratio, and if excess ammonia exists in the water, lead to nitrification.

protect the public–distribution system security monitoring

The USEPA published the *Water Security Initiative: Interim Guidance on Planning for Contamination Warning System Deployment* to help drinking water utilities improve their ability to detect intentional or unintentional distribution system contamination. The USEPA's Interim Guidance document identified TOC, chlorine, and conductivity as the three most important parameters for detecting a contaminant.

To protect the public drinking water, an operator needs a tool that can monitor the change in TOC in the distribution system with limited user interaction.

measure variances– environmental changes to surface water

A major contributor to TOC in drinking water is the decay of naturally occurring vegetation, including algae, sediment, and particles in water. TOC content in water sources varies from region

conclusion

TOC, an operator tool, spans a wide variety of applications, and is widely thought of as a tool to help a utility comply with DBP regulations, but it also assists with cost savings from optimizing a range of plant processes. Beyond these two applications, TOC is useful for monitoring source water or distribution system water quality and maximizing disinfection strategies.

To maximize the use of this important tool, it is critical to have an instrument that is easy to use, runs with limited user interaction, and has reliable, proven technology, such as Sievers TOC Analyzers. They use no external reagents, no carrier gases, offer 12 months' calibration stability, and are currently used in hundreds of municipalities globally. The instruments are offered in online, laboratory, or portable configurations, useful for any combination of water applications. Sievers TOC Analyzers give operators the flexibility to run on-line or perform simple grab samples to ensure proper TOC removal, DBP control, and cost savings.

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