

Evaluating Performance Of THM Removal Systems

Important THM Formation Potential Considerations

Initial Disinfectant Byproduct Formation

In free chlorine (not chloraminated) drinking water systems, chlorine reacts with total organic carbon (TOC) to create over 600 disinfection byproducts (DBPs). Humic and fulvic acid derived from dead leaves and wood is the most common form of TOC needed to start the THM creation process.

These first initial DBPs are not trihalomethanes (THMs) but they do contain THM precursors. Over the course of several reactions (2? 30? 60?), some of the carbon material is eventually converted into THMs. So it can be said that THMs are actually byproducts of byproducts of byproducts (and so on, so forth).

The reaction of $CL + TOCs = DBPs$ is relatively fast and steady while the subsequent reactions where THM precursors form actual THMs start fast but then slow down.

THM Formation Over Time

The amount of THMs mostly depend on chlorine concentration, bromine concentration, TOC concentration, temperature and pH.

Only a small percentage of THMs are formed quickly.

Converting THM precursors (often called THM formation potential or THMFP) into actual THMs is one of the slowest set of reactions in the entire water treatment industry and can take 50-80 hours to complete. In fact, it may never actually be completed though it does tend to reach a steady state.

Bromine & Hypobromous Acid

Most surface water contains bromine (upwards of 20 ppb or more). Bromine (like chlorine) is an oxidizer though it is not as "hot" as chlorine.

Chlorine in treated water can form hypochlorous acid (HOCl). Bromine is able to "substitute" for the chlorine in the HOCl and become hypobromous acid (HOBr).

Hypobromous acid is good at participating in the many reactions that convert THM precursors into actual THMs. If the bromine content is greater than 150 ppb, then most of the formed THMs will be the brominated species (dichlorobromomethane, dibromochloromethane, or bromate).

Temperature Effect

Temperature has a large effect on the level of THMFP. For instance, a water sample @ 5°C can result in THMFP of 50 ppb while the same water @ 35°C can result in THMFP of over 200 ppb.

It should also be noted that water tends to warm up as it moves through the distribution system and water storage tanks. This warming can cause an increase in THMFP.

Mixing & Increased Detention Time

Simple physics indicates the mixing provided by the SN Series THM Removal Systems helps all chemical reactions in water to occur; however, the conversion of THMFP into actual THMs is probably more about time than it is about mixing because in laboratories where researchers use continuous mixing and shaking of water samples, it still takes many hours to convert THMFP into THMs. So, the most important part of the mixing component might be its effect on detention time.

To summarize mixing, all of Ixom Watercare's THM Removal Systems are designed to stop incoming water from short-circuiting through the tank. This is accomplished by pulling water off the floor of the tank faster than the incoming flow rate. This has three primary benefits:

1. it ensures all water receives some treatment before it leaves the tank and
2. it ensures the maximum DBPs and THMFPS are formed in the tank and
3. it increases the detention time in the tank so more THMFP can be converted into actual THMs in the tank and then subsequently stripped.

THM Removal Equation

The equation for THM removal is actually quite simple and can be expressed as follows:

$$R\% = 100\% - (\text{THM}_{\text{out}} / \text{THM}_{\text{in,adjusted}})$$

Where:

R% = THM removal achieved.

THM_{out} = the THM out of the tank.

THM_{in,adjusted} = the THM going into the tank, adjusted upward by the amount of THMFP that was converted in the tank into actual THM = THM_{in} + (THMFP_{in} – THMFP_{out})

The following examples will apply this equation to better illustrate THM removal performance and just how easy it can be to arrive at a false conclusion.

EXAMPLE 1- A small amount of THMFP is converted into actual THM in the tank.

$$\begin{aligned} \text{THM}_{\text{out}} &= 31 \text{ ppb} \\ \text{THM}_{\text{in}} &= 40 \text{ ppb} \end{aligned}$$

The amount of THMFP converted into actual THM in the tank, as measured by a lab or AMS analyzer, is THMFP_{in} – THMFP_{out} = 60 ppb – 48 ppb = 12 ppb.

$$\text{Then THM}_{\text{in,adjusted}} = \text{THM}_{\text{in}} \text{ plus THMFP converted} = 52 \text{ ppb}$$

$$\text{Then } R\% = 100\% - (31/52) = 100\% - 60\% = \underline{40\%}$$

Note that if the only comparison was between THM_{out} vs THM_{in}, the calculation would show 100% - (31/40) = 23%. But this would be incorrect because it does not account for some of the THMFP being converted in the tank into

actual THM and then being stripped.

EXAMPLE 2- The same water as Example 1, but a larger amount of THMFP is converted into actual THM in the tank.

$$\begin{aligned} \text{THM}_{\text{out}} &= 38 \text{ ppb} \\ \text{THM}_{\text{in}} &= 40 \text{ ppb} \end{aligned}$$

The amount of THMFP converted into actual THM in the tank, as measured by a lab or AMS analyzer, was THMFP_{in} – THMFP_{out} = 60 ppb – 36 ppb = 24 ppb. Then THM_{in,adjusted} = THM_{in} plus THMFP converted = 64 ppb

$$\text{Then } R\% = 100\% - (38/64) = 100\% - 60\% = \underline{40\%}$$

Note that if the only comparison was between THM_{out} vs THM_{in}, the calculation would show 100% - (38/40) = 5%. But this would be incorrect because it does not account for some of the THMFP being converted in the tank into actual THM and then being stripped.

THMFP Measurement Via The Sample Aging Method

If a lab or AMS Analyzer is not available to determine how much THMFP was converted into actual THM in the tank, then the Sample Aging Method can be used to give an approximation for THM_{in,adjusted} in the above formula:

1. Take a sample of both Tank-Out and Tank-In water, at about the same time.
2. For the Tank-Out water, follow standard lab protocol for adding a preservative to stop further chlorine reactions. Test the THM of the Tank-Out water.
3. For the THM_{in,adjusted}, age the sample first, before adding a preservative to stop further chlorine reactions. The sample should be aged for approximately the same amount of time as the detention time in the tank, plus one day to account for the intense mixing in the tank.

$$\text{Age Time} = (\text{TankVolume} / \text{Flowrate through the tank}) + 1 \text{ day}$$

The THM test of this water will give an approximation of THM_{in,adjusted} in the above formula.