Kimley»Horn

January 28, 2022

Jason Debrincat, P.E.
Town of Palm Beach
951 Old Okeechobee Road, Suite A
West Palm Beach, FL 33401

RE: *TTHMs in Public Drinking Water*

Dear Mr. Debrincat,

This document is intended to provide residents of The Town of Palm Beach some of the available published information on total trihalomethanes (TTHM) present in the Town drinking water supply. The focus of this document is the effects of TTHM on human health. Two (2) articles are included which present an abbreviated description of the issue and widely accepted impacts on human health. The attached articles are “Chemicals in Drinking Water Fact Sheet, Total Trihalomethanes” by Florida Department of Health, Bureau of Environmental Health (FDOH) and “Disinfection By-Products” by Centers for Disease Control and Prevention (CDC).

Formation of TTHM compounds is predominantly the result of disinfecting the drinking water, in this case using chlorine. This is a world-wide practice and consequently the presence of TTHM compounds is world-wide. As stated in the CDC article, “Chlorine revolutionized water purification, reduced the incidence of waterborne diseases across the western world…”.

Regulations limit the concentration of TTHM present in drinking water to values as low as 1/1,000 of the level that may cause cancer or other health effects. The regulation values for concentration of TTHM are based on many years of continuous consumption of TTHM. The FDOH article states “Because the standards are based upon lifetime exposure, drinking water with levels slightly above the standards for a short period of time does not significantly increase the risk of illness.”.

West Palm Beach prevents levels of TTHM greater than the standard by using chloramine, a combination of chlorine and ammonia, to disinfect the water. Generally, the chloramine treatment must be changed to free chlorine by stopping the addition of ammonia in order eliminate the growth of certain non-toxic bacteria in the piping systems. This process occurs generally twice per year and creates higher levels of TTHM for approximately two weeks. The occurrence in May of 2021 was due to the sudden presence of the cyanotoxin cylindrospermopsin which was treated by switching the water treatment process to using free chlorine.

A notice is issued by West Palm Beach stating the dates a free chlorine maintenance will occur and customers can anticipate the possibility of TTHM levels being higher than normal.

Communication is through the Town and Civic associations to allow customers to choose to continue using the water or consider other options. As described above the FDOH states "Because the standards are based upon lifetime exposure, drinking water with levels slightly above the standards for a short period of time does not significantly increase the risk of illness."

If you have any additional questions or comments, please contact me to discuss at (561) 840-0847.

Sincerely,

KIMLEY-HORN AND ASSOCIATES, INC.

By: John E. Potts, P.E.

Attachment:

- Chemicals in Drinking Water Fact Sheet, Total Trihalomethanes by Florida Department of Health, Bureau of Environmental Health (FDOH)
- Disinfection By-Products by Centers for Disease Control and Prevention (CDC)

Chemicals in Drinking Water
Fact Sheet
Florida Department of Health, Bureau of Environmental Health

This fact sheet discusses possible health risks from exposure to low levels of total trihalomethanes typically found in drinking water.

Total Trihalomethanes (TTHMs)

What are Total Trihalomethanes?

Trihalomethanes are a group of chemicals that can form when organic matter in water is treated with halogen disinfectants such as chlorine. The most common of these chemicals is trichloromethane (also called chloroform), but others, such as dibromochloromethane, bromodichloromethane, or bromoform can also be found. The sum of these four chemicals is referred to as total trihalomethanes (TTHMs).

How might exposure to TTHMs in water occur?

TTHMs are present at low levels in most chlorinated water supplies. Chlorine is added to these drinking water supplies to control microbes such as *E. coli* or *Salmonella* that can cause serious illness.

What is the standard for TTHMs in drinking water?

The Florida Department of Environmental Protection's drinking water standard for TTHMs is 80 micrograms per liter (80 µg/L). Utility companies are required to test for TTHMs every quarter and this standard is compared to a one-year running average of samples.

How can TTHMs affect my health?

Depending on risk factors stated below, health effects from drinking high levels of TTHMs can include: liver, kidney, or central nervous system damage. Drinking water every day with concentrations of TTHMs at or below the standard for your entire lifetime is unlikely to cause illness. In addition, any risk from disinfection byproducts is much lower than the risk of illness from drinking water that has not been disinfected.

How likely are TTHMs to cause cancer?

EPA has set standards for TTHMs in water because there is a slight possibility of an increased risk of bladder or colorectal cancer over a lifetime of drinking water with TTHMs above 80 parts per billion (ppb). The slight risk occurs after decades of drinking water with high levels of TTHMs. This risk is small compared to the risk of potentially deadly infectious diseases in drinking water that is not disinfected.

How do scientists determine drinking water standards?

Drinking water standards are set at very low levels. To set drinking water standards, scientists review laboratory experiments and study reports of people exposed to high levels of chemicals when available. Then they use this information to estimate the risk of illness.

For chemicals that cause illness other than cancer, scientists find the level that is not thought to cause any harmful effects. Then, to be on the safe side, they set drinking water guidelines hundreds or thousands of times less than this "no-effect level." For chemicals believed to cause cancer, the technique is different. Scientists use worst-case assumptions to work out the lifetime risk of cancer at various concentrations of the chemical. They then set the level where the risk becomes so small it is practically zero. The worst-case assumptions used ensure that any errors are on the side of safety.

Because the standards are based upon lifetime exposure, drinking water with levels slightly above the standard for a short time does not significantly increase the risk of illness. The risk of illness, however, increases as the level of chemical increases and the length of time you drink the water increases.

How chemical exposures may affect someone can range widely from one person to the next. A number of personal factors also determine health effects. These include:

- How old is the person?
- What gender are they?
- Does the person have other health problems?
- What are their health habits? (For instance, do they drink alcohol or smoke tobacco?)

Is there a medical test for TTHM exposure?

There are special tests that can determine if you have been exposed to TTHMs. There is no reliable test to determine how much you have been exposed to and these tests cannot tell you whether harmful health effects will occur.

Is it safe to keep drinking water with TTHMs in it?

Citizens have the right to know about the quality of their drinking water. They should be aware of problems that may cause an immediate health problem and of those problems that are a concern when exposure occurs over many decades. That being said, levels of TTHMs less than the drinking water standard are not likely to cause illness. Drinking water with levels slightly above the drinking water standard for a short time does not significantly increase the risk of illness either. However, because health risks increase as the levels of a chemical (or how long a person drinks it) increases, it is best to drink water that meets standards.

For additional health information, please call the Florida Department of Health at 850-245-4240 or visit us online at www.floridahealth.gov/environmental-health/drinking-water/Chemicals-HALs.html

For more information about the health effects from exposure to TTHMs and other disinfection byproducts, please see the US CDC Safe Water Page at https://www.cdc.gov/safewater/chlorination-byproducts.html

Disinfection By-Products

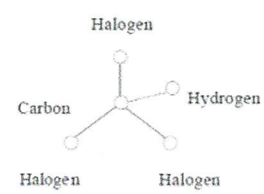
Introduction

Chlorine was discovered in 1774 by the chemist Karl Scheele [1]. One of the first known uses of chlorine for disinfection was not until 1850, when Snow used it to attempt to disinfect London's water supply during that now-famous cholera epidemic. It was not until the early 1900's, however, that chlorine was widely used as a disinfectant [2]. Chlorine revolutionized water purification, reduced the incidence of waterborne diseases across the western world, and "chlorination and/or filtration of drinking water has been hailed as the major public health achievement of the 20th century" [3]. Chlorine remains the most widely used chemical for water disinfection in the United States [2]. However, close to 1 billion people in the world still lack access to safe drinking water, and new questions about health effects from chlorine by-products formed during disinfection have led to questions about the advisability of using chlorine to provide safe water for this population. This page summarizes information about the production, and health effects, of disinfection by-products (DBPs).

These guidelines must be evaluated in context of the WHO Guidelines which state: "Infectious diseases caused by pathogenic bacteria, viruses, protozoa, and helminths are the most common and widespread health risk associated with drinking-water" [10] (Chapter 7, Microbiological Aspects; Section 7.1, pg 118). Additionally, a previous version of these guidelines states: "Where local circumstances require that a choice must be made between meeting either microbiological guidelines or guidelines for disinfectants or disinfectant by-products, the microbiological quality must always take precedence, and where necessary, a chemical guideline value can be adopted corresponding to a higher level of risk. Efficient disinfection must *never* be compromised" [9] (Chemical Aspects; Section 3.6.4, pg 49/65).

In disinfection, gaseous chlorine (Cl_2) or liquid sodium hypochlorite (bleach, NaOCl) is added to, and reacts with, water to form hypochlorous acid. In the presence of bromine, hypobromous acid is also formed. Both chlorine and bromine are in the "halogen" group of elements, and have similar chemical characteristics. Hypochlorous and hypobromous acid form strong oxidizing agents in water and react with a wide variety of compounds, which is why they are such effective disinfectants.

In 1974, Rook [4] discovered that hypochlorous acid and hypobromous acid also react with naturally occurring organic matter to create many water disinfection by-products, including the four primary trihalomethanes:



- Chloroform – $CHCl_3$
- Bromodichloromethane (BDCM) – $CHCl_2Br$
- Dibromochloromethane (DBCM) – $CHClBr_2$
- Bromoform – $CHBr_3$

At the center of each of the four trihalomethanes is a carbon atom, and it is surrounded by and bound to four atoms: one hydrogen and three halogens. These four compounds are collectively termed trihalomethanes and are abbreviated as either THM or TTHM (for total trihalomethanes).

Rook's discovery of THMs in drinking water led to research on other chemicals formed when chlorine is added to water, and to the health effects of these chemicals. Richardson [5] identified greater than 600 water disinfection by-products in chlorinated tap water, including haloacetic acids (HAAs). THMs, and to a lesser extent HAAs, are currently used as indicator chemicals for all potentially harmful compounds formed by the addition of chlorine to water. In many countries the levels of THMs and HAAs in chlorinated water supplies are regulated based on this assumption.

Humans are exposed to DBPs through drinking-water and oral, dermal, and inhalational contact with chlorinated water [6]. In populations who take hot showers or baths, inhalation and dermal absorption in the shower accounts for more exposure to THMs than drinking water [7].

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World Health Organization (WHO) Research and Guideline Values for DBPs

The World Health Organization (WHO) International Agency for Research on Cancer (IARC) reviews research conducted on potential carcinogens and develops monographs that summarize the research and classify the compound. Links to the monographs for BDCM, DBCM, bromoform, and chloroform are available below (see Additional Resources). As can be seen in Table 1 (below), chloroform and BDCM are classified as possible human carcinogens. The classifications of possible human carcinogens come from data that is extrapolated from research on animals that may or may not be relevant to human cancer. DBCM and bromoform are not classifiable, indicating there is no evidence supporting these two compounds as carcinogens, but there is not enough research to classify them as non-carcinogenic. There is inadequate epidemiological evidence of carcinogenicity in humans for all four compounds.

Table 1: IARC Classification of THMs

	Humans	Classification
Chloroform	Inadequate evidence for human carcinogenicity.	Possible human carcinogen (Group 2B)
Bromodichloromethane	Inadequate evidence for human carcinogenicity.	Possible human carcinogen (Group 2B)
Dibromochloromethane	Inadequate evidence for human carcinogenicity.	Not classifiable as to its carcinogenicity in humans (Group 3)
Bromoform	Inadequate evidence for human carcinogenicity.	Not classifiable as to its carcinogenicity in humans (Group 3)

WHO states that "all people, whatever their stage of development and their social and economic conditions, have the right to have access to an adequate supply of safe drinking water" [8]. To this end, WHO has developed guideline values for many contaminants in drinking water. It is important to note that these guideline values are not standards. "It must be emphasized that the guideline values recommended are not mandatory limits. In order to define such limits, it is necessary to consider the guideline values in the context of local or national environmental, social, economic, and cultural conditions and waterborne disease occurrence" [9].

To develop the guideline values for drinking-water, WHO reviewed the literature for well-designed and documented studies showing health effects from exposure to each of the THMs [8]. A safety factor of 1,000, an average adult human weight of 60 kilograms, and an average drinking water consumption of 2 liters per day were incorporated into the development of each guideline value. The chloroform, bromoform, and dibromochloromethane guideline values were all obtained using a total daily intake calculation. It was assumed that 50 percent of total daily intake of chloroform came from drinking water, and 20 percent of total daily intake of bromoform and dibromochloromethane came from drinking water (in areas with no showers, this assumption leads to a conservative estimate of risk). The models developed for bromodichloromethane and chloroform were based on an excess cancer risk of 10^{-5}, or one extra cancer per 100,000 people at the guideline value for 70 years [9].

- The *chloroform* guideline value was developed from a study showing hepatotoxicity in beagle dogs ingesting chloroform-laced toothpaste for 7.5 years. (A linearized multi-stage model based on observed increases in kidney tumors in male rats supports this total daily intake calculation).

- The *bromoform* guideline value was developed from a study showing lesions on the livers of rats exposed to bromoform for 90 days.
- The *dibromochloromethane* guideline value was developed based on the absence of histopathological effects in rats exposed for 90 days.
- The *bromodichloromethane* guideline value was developed using a linearized multi-stage model based on observed increases in kidney tumors in male mice.

The WHO Guideline Values [9] for the THMs are shown in Table 2. WHO also considers potential health effects caused by exposure to the four compounds simultaneously. In addition to the individual guidelines, there is an additional guideline that states the following: the sum of each individual THM concentration divided by its guideline value cannot be greater than one. This is depicted in the following equation:

$$\frac{\text{Chloroform}}{\text{Chloroform GV}} + \frac{\text{BDCM}}{\text{BDCM GV}} + \frac{\text{DBCM}}{\text{DBCM GV}} + \frac{\text{Bromoform}}{\text{Bromoform GV}} < 1.0$$

Table 2: WHO Guideline Values for Trihalomethanes in Drinking Water (WHO, 1996)

	WHO Guideline Value
Chloroform	200 µg/L
Bromodichloromethane	60 µg/L
Dibromochloromethane	100 µg/L
Bromoform	100 µg/L

These guidelines must be evaluated in context of the WHO Guidelines which state: "Infectious diseases caused by pathogenic bacteria, viruses, protozoa, and helminths are the most common and widespread health risk associated with drinking-water" [10] (Chapter 7, Microbiological Aspects; Section 7.1, pg 118).

Most importantly, the WHO specifically states in the 2nd edition of the Guidelines that: "Where local circumstances require that a choice must be made between meeting either microbiological guidelines or guidelines for disinfectants or disinfectant by-products, the microbiological quality must always take precedence, and where necessary, a chemical guideline value can be adopted corresponding to a higher level of risk. Efficient disinfection must *never* be compromised" [9] (Chemical Aspects; Section 3.6.4, pg 49/65). In the 4th edition of the Guidelines, the WHO states: "In all circumstances, disinfection efficiency should not be compromised in trying to meet guidelines for DBPs, including chlorination by-products, or in trying to reduce concentrations of these substances" [10] (Chapter 8 Chemical Aspects, Section 8.5.4, pg 188).

Thus, waterborne pathogens pose a real and more immediate threat to health; water disinfection by-products are certainly the lesser of these two evils.

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USEPA Standards for DBPs

The disinfectant/disinfection by-products (D/DBP) rule that regulates DBPs in the United States was designed to be implemented in three stages (Table 3) [11, 12]. The US Environmental Protection Agency (USEPA) does not regulate THMs or HAAs individually – there is only a standard for total THMs and total HAAs.

Table 3: D/DBP Rule Implementation, USEPA

Stage	TTHM Standard	HAA Standard
Initial	100 µg/L	
Stage 1	80 µg/L	60 µg/L
Stage 2	80 µg/L	60 µg/L

The USEPA has calculated cancer potency factors for the four THMs, which can be used to calculate the probability of cancer for varying exposure levels (Table 4). As can be seen, DBCM has the highest factor, and bromoform is an order of magnitude lower.

Table 4: USEPA Cancer Potency Factors

Compound	Cancer Potency Factor
Chloroform	insufficient data [13]
Bromodichloromethane	0.062 mg/kg/day
Dibromochloromethane	0.084 mg/kg/day
Bromoform	0.0079 mg/kg/day

Thus, the extra cancer from chloroform was calculated to be negligible.

Other countries in the developed world, particularly in Europe, have established much stricter standards for DBPs in drinking water. These countries have the resources to follow the precautionary principle, which advocates the avoidance of chemicals until they are proven safe. These low standards are met, in part, by researching and implementing alternative disinfection methods (such as the use of ozone, UV light, and chloramines) and water treatment strategies (such as filtration before disinfection).

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DBPs and the Safe Water System

Addition of chlorine to untreated water will lead to the formation of DBPs. A significant amount of energy and time has been invested in the United States and Europe to determine the human health effects of these DBPs and how to restructure water treatment processes to prevent DBP formation in order to minimize the slight risk of cancer from long-term exposure to DBPs. However, diarrheal disease in the developing world is still a leading cause of infant and under-5 mortality and morbidity. In these populations, the risk of death or delayed development in early childhood from diarrheal disease transmitted by contaminated water is far greater than the relatively small risk of cancer in old age.

CDC has tested Safe Water System water to measure the concentration of THMs in the finished water. In that study, household chlorination of turbid and non-turbid waters did not create THM concentrations that exceeded health risk guidelines [14, 15]. In addition, ceramic filtration, sand filtration, cloth filtration, and settling and decanting were not effective mitigation strategies to reduce THM formation. Since this finding may not hold for all source waters worldwide, reducing organic matter in turbid source water may reduce the potential for DBP formation [15]. To do this:

- Let the water settle for 12-24 hours and then decant water into a second bucket. Chlorinate this decanted water, and/or
- Filter the water through a cloth or filter before chlorination.

The Safe Water System is a proven intervention that consistently reduces diarrheal disease incidence among users in the developing world. This disease reduction leads to healthier children and adults. There is a slight risk to the ingestion of THMs at the WHO guideline value level. Although the risk from THMs is important to address, until centrally treated, piped water can be delivered to every family, the initial critical need is the provision of microbiologically safe drinking water to reduce the incidence of diarrhea and other waterborne disease.

If you have any questions or comments on this page or the Safe Water System, please email healthywater@cdc.gov.

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References

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Additional Resources

- Monographs for BDCM, DBCM, and bromoform
- Monograph for chloroform [PDF – 52 pages]

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