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RESPONSE TO SCIENTIFIC/TECHNICAL REQUEST

Trihalomethanes in drinking water

March 26, 2019

[redacted]

Key Findings

- Individual THMs are classified as 'possibly carcinogenic to humans' or 'not classifiable as to carcinogenicity to humans' by the International Agency for Research on Cancer.
- There are some studies that have associated exposure to THMs with adverse reproductive effects; however, this association is not consistently found and a dose-response pattern of increasing risk with increasing THM concentrations has not been established.
- The formation of THMs in drinking water systems may vary significantly on a seasonal basis. The running annual average guideline accounts for variation in concentrations over the year.

Request and Scope

Treatment of the Tottenham drinking water system has resulted in elevated levels of trihalomethanes (THMs), a group of chemicals formed as disinfection by-products. As a group, THMs consist of chloroform, bromoform, dibromochloromethane (DBCM), and bromodichloromethane (BDCM).[1] In 2007, the Simcoe-Muskoka Health Unit (SMDHU) became aware of this issue and since this time has been engaged with the Town of New Tecumseth and the Ministry of the Environment and Climate Change. In 2015, changes in the operation of the Tottenham drinking water system lowered the running annual average of THMs below Health Canada's[2] maximum acceptable concentration (MAC) of 100 µg/L. In the last few years, it has been noted that concentrations of THMs in Tottenham periodically exceed 100 µg/L; however, the running annual average of THMs continues to be below the MAC. To assist with

their understanding of this issue, and to help address concerns from the community, SMDHU has asked the following:

- What are the health effects associated with exposures to THMs in drinking water?
- Although the running annual averages of THMs in the last few years are below the MAC, how are periodic spikes of THM concentrations considered?

Methods

A literature search was conducted by Public Health Ontario's (PHO) library services in Fall 2017 based on the following research questions: health effects associated with THMs (including cancer and reproductive health outcomes), advisories regarding exceeding limits in drinking water, and corrective actions that have been/can be taken if levels exceed guidelines in drinking water. The search was conducted in the MEDLINE, Embase, Environment Complete and Scopus databases and yielded a total of 1,724 unique results. As the focus was on the current science around THMs, publications from the last two years (2015 – 2017) were reviewed.

At the request of SMDHU, an update to the literature search was performed in winter 2019 to identify new peer-reviewed publications between 2017 and March 2019. The update returned 338 unique results. Titles and abstracts were screened for relevance to human health effects from THMs in drinking water, and 10 original research articles and systematic reviews were identified for full-text review.

Health Effects

Cancer

The International Agency for Research on Cancer (IARC) has completed comprehensive reviews on individual THMs and on chlorinated drinking water.[3,4] IARC has classified chloroform as "possibly carcinogenic to humans (Group 2B)" due to inadequate evidence in humans, stating that the epidemiological evidence for cancers including urinary bladder, rectum, and possibly colon are confounded by a number of factors.[3] BDCM has also been classified by IARC as possibly carcinogenic (Group 2B), as sufficient evidence for carcinogenicity in the colon, kidney, and liver of experimental animals has been observed.[4] In contrast, Health Canada classified BDCM as "probably carcinogenic" and had set a drinking water guideline of 16 µg/L for BDCM in 2006, before rescinding it in 2009.[2] IARC considers bromoform and DBCM "not classifiable as to carcinogenicity to humans (Group 3)" due to inadequate evidence of carcinogenicity in humans and limited evidence of carcinogenicity in experimental animals.[4] Chlorinated drinking water is also listed in Group 3, as IARC has determined there is inadequate evidence for the carcinogenicity of chlorinated drinking water in humans and in experimental animals.[4]

A review of epidemiological studies looking at exposures to chlorinated disinfection by-products (DBPs) in drinking water and bladder cancer by Hrudey et al. in 2015, concluded that studies with a positive association have methodological weaknesses.[5] Further evidence is needed to establish a causal link between DBP exposure and bladder cancer. Similarly, a more recent multicountry ecological study by

Cotruvo and Amato in 2019 concluded that causal drinking water-related bladder cancer risk remains questionable, and likely small compared to other risk factors such as smoking, type 2 diabetes, sex, and ethnicity.[6]

Less evidence is available for other cancers, and no recent reviews were identified. Villanueva et al.'s multicentre case-control study in 2017 found no clear evidence of an association between total THM exposure and colorectal cancer.[7] Likewise, Jones et al.'s retrospective cohort study in 2019 found no clear association between years exposed to greater than 40 µg/L of total THMs and either colon or rectal cancers; however, they did find a weak positive association between rectal cancer and BDCM.[8] A Spanish multicentre case-control study looking at long-term exposure to THMs in drinking water and breast cancer concluded that at levels common in Europe, there was no association with breast cancer.[9]

Reproductive and Developmental Effects

Nieuwenhuijsen et al. conducted a review of DBPs (including THMs) and their association with reproductive effects and found that although various studies point towards an association of DBPs with low birth weight, the evidence was not conclusive.[10] Other studies reviewed showed a weaker association for DBPs with spontaneous abortions, stillbirth and birth defects, although the authors noted that higher quality studies are needed to confirm or refute these findings.[10] In 2009 and 2010 updates to the review, little to no evidence for associations between DBPs and adverse birth outcomes including fetal growth restriction, prematurity, and congenital anomalies was found, with the possible exception of small for gestational age (SGA).[11,12] A critical review conducted in 2015 examined 40 studies that attempted to quantitatively assess population health impacts and health risks associated with exposure to DBPs. The findings of the review revealed that many of the studies were generated with estimates of generic cancer and non-cancer risks based on toxicological data and methods designed for regulatory purposes (which are often designed to overestimate risks), and extrapolating health impacts from these studies presented imprecise and biased estimates.[13]

In 2016, Kogevinas et al. examined exposures to THMs in drinking water during pregnancy and birth outcomes. The cohort study was conducted between 2002 and 2010, and included 14,005 mothers and their children from across Europe. No association between birth outcomes (including birth weight, SGA, and preterm births) and THM exposure during pregnancy was found.[14] More recently, Mashau et al.'s systematic review in 2018 found no clear association between maternal exposure to THMs in drinking water and adverse pregnancy outcomes. They found less than one-third of 29 included studies reported evidence of an association; the most consistent evidence was for a possible increased risk of SGA.[15]

Specific to chloroform, Williams et al. conducted a systematic review in 2018 of development outcomes including birth defects, preterm birth, low birth weight, and SGA. The review concluded that human epidemiology studies provide only weak evidence for an association with developmental outcomes and fail to establish a causal role for chloroform with adverse outcomes at environmentally relevant concentrations.[16] They also scoped reproductive outcomes such as altered menstruation, pregnancy loss, and stillbirth, but noted literature on these endpoints is generally sparse.[16] A 2018 American case-control study examined maternal exposure to DBPs and risk of stillbirth. There was no association with

THMs overall, and while a positive association was detected with chloroform and BDCM exposure, the authors saw no evidence of any exposure-response relationship.[17] This study also did not perform statistical adjustments for multiple testing.

Although various studies have associated exposure to THMs with adverse reproductive effects, neither a clear evidence of a threshold, nor a dose-response pattern of increasing risk with increasing THM concentrations has been established.[2]

Running Annual Average

The formation of THMs in drinking water systems is dependent on several factors including: temperature, pH, water source, natural organic matter present in source water, chlorine contact time, and water system distribution factors. As such, concentrations of THMs within a drinking water system may vary significantly over time. A study conducted in Quebec found that during summer months, the average THM concentration within the water distribution system was 2.5- to 5-times the concentration during winter months.[18]

To account for variations in THM concentrations, Health Canada's MAC for THMs in drinking water is measured as running annual average of quarterly (at a minimum) samples. Health Canada has stated that "although individual measurements may exceed the guideline value, this would be of concern only if they caused the running average of quarterly samples to exceed the guideline value." [2] Although Health Canada's guideline value for THMs is 100 µg/L, they do recommend that THM "concentrations be kept as low as reasonably achievable without compromising the effectiveness of disinfection." [2]

As there are no established adverse health effects associated with short-term variation in THM concentrations, using the annual average of THM concentrations as the measure of compliance with standards and guidelines appears to be supported by the best evidence currently available.

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