Evaluation of Current Water Treatment and Distribution System Optimization to Provide Safe Drinking Water from Various Source Water Types and Conditions

Risk Management Research Project - Addressing Drinking Water Challenges through Science and Innovation

Photo credit: NOAA (by Diane Straw Lake Erie, July 2009)

Dramatically large Cyanobacterial HAB

Background & Problem

Increasingly, drinking water treatment plants (DWTPs) are being challenged by changes in the quality of their source waters and by their aging treatment and distribution system infrastructure. Individually or in combination, factors such as shrinking water and financial resources, climate change, agricultural runoff, harmful algal blooms (HABs), and industrial land utilization increase the probability that contaminants of emerging concern (CECs), such as pesticides, pharmaceuticals, personal care products, endocrine disrupting compounds, and algal toxins will remain after treatment, ending up in consumers' drinking water. In addition, when treating for CECs, disinfection byproducts (DBPs) can form, which may pose health risks as well. This is likely to disproportionately affect small drinking water systems due to, among other factors, limited resources and treatment options.

Purpose of the Studies

Identifying and quantifying the source water and treatment challenges for water systems is an important step towards mitigating present and future risks. An evaluation of potential of water contaminants in the natural environment and during drinking water treatment is needed, particularly as we continue to adapt existing drinking water treatment infrastructure to address CECs. The following studies will help improve our understanding of the propagation of contaminants through drinking water treatment, and identify the best approaches for removal.

Results and Observations to Date

Study 1 The source and finished waters from 26 DWTPs with various treatment configurations were analyzed for the occurrence and treatment viability of estrogens and other CECs, as well as other water quality measures. The results showed concentrations of androgens, estrogens, antibacterial compounds, and atrazine at the source and the finished water at a single time point.

- Of the pesticides, atrazine was highly resistant to removal via conventional water treatment. Advanced treatment, including ozonation and granular activated carbon filtration, appears to be most effective at reducing atrazine concentrations. Trenbolone appears to show a similar trend, but the further study is needed to validate this.
- Of the estrogenic steroid hormones, only estrone (E1) was observed in 10 DWTP source waters with a maximum observed concentration of 0.38 ng/mL and a median of 0.10 ng/mL; however, all of the DWTPs were effective at removing E1 so it was detected in the finished waters.
- Of the antibacterial agents analyzed in the DWTPs source waters, triclosan was detected in 8 and triclocarban (TCC) was detected in 7. They were significantly reduced or removed during treatment at all of the DWTPs. Over 95% removal was observed for triclosan and 90% for TCC at the source and the final product water at a single time point.
- All other androgenic compounds and remaining estrogens, were only detected in the source waters of two DWTPs.

Related Publications:

Schenck K., et al. (2012). Removal of estrogens and estrogenicity through drinking water treatment. *Journal of Water and Health*, *10*(1), 43–55.

Mash H. (2010). Assessing the fate and transformation by-product potential of trenbolone during chlorination. *Chemosphere*, *81*(7), 946-953.

Mash H., et al. (2010). Hypochlorite oxidation of select androgenic steroids. *Water Research, 44*(6), 1950-1960.

Study 2 The propagation of cyanobacteria and associated toxins (nodularin and 8 microcystins) from the water source through the treatment processes of full-scale DWTPs along Lake Erie is being monitored. The study, which began during the 2013 bloom season (Figure 1), takes place between April and November of each bloom season, and is anticipated to continue through the 2015. The concentrations of toxins are being evaluated using Enzyme-Linked Immunosorbent Assay (ELISA) and Liquid Chromatography-Mass Spectroscopy (LC-MS) methods at each stage of the drinking water treatment process, both for the extracellular matrix and the total matrix following cell lysis. In addition, the concentrations of intact cells in suspension are being quantified with chlorophyll analysis. This monitoring regimen should improve our understanding of the dynamics of algal toxin release and removal through drinking water treatment processes. It is anticipated that the results of this study will be submitted for publication in 2015. Some of the preliminary observations are listed below:

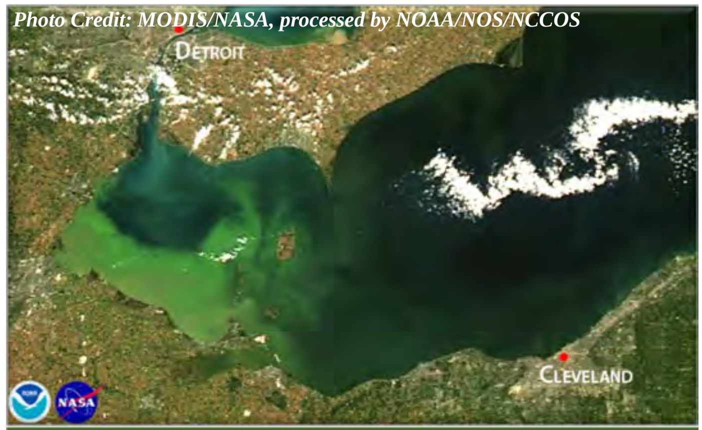

Figure 1. Satellite image of 2013 intense Cyanobacterial HAB, which was concentrated in Lake Erie's western basin.

- The influent water quality, as measured by nitrate, cyanobacteria toxin, and cyanobacteria cell concentrations, is significantly degraded in the western versus the central basin of Lake Erie.
- The bulk of cyanobacterial toxin present in the source water influents is contained within intact cyanobacterial cells. After exposure to permanganate oxidation, a number of cells die and release toxins, which increases the extracellular toxin load as measured by ELISA and LC-MS. The level then drops after additional treatment steps.
- The influent toxin load may be controlled by removing intact cells in the clarification and filtration processes. This observation implies that a facility originally designed for particulate control can, with careful operation, serve as an effective barrier against human exposure to cyanobacterial toxins.

Study 3 The kinetics of oxidation/transformation of biotoxins associated with microcystins, aflatoxins (fungal toxins), and other algal toxins is being evaluated through the treatment processes of full-scale DWTPs along Lake Erie. As the propagation of biotoxins through drinking water treatment was analyzed, one of the primary observations was that the release of toxins from cells following lysis can result in toxin levels in the extracellular matrix, even if earlier treatment steps might have quickly removed toxin from bulk solution. To address this issue, the kinetics of degradation and formation of associated DBPs are being investigated. The current study involves the chlorination of a number of algal toxins and aflatoxins to determine their rates of degradation, coupled with an investigation of the DBPs generated. A number of DBPs were observed, including oxidation and chlorinated substitution DBPs, both of which varied in speciation dependent on chlorine contact time. It is anticipated that the results of this study will be submitted for publication in 2015. Some of the preliminary kinetic results indicate the following:

- Because of reactions centered at the tryptophan moiety, the rate of reaction for the microcystin variants MYC-WR and MYC-LW were approximately 2-3 orders of magnitude faster than the other MYCs studied, which were on the order of hours.
- Chlorine contact time during treatment is an important consideration for toxin removal, although the toxicity of chlorinated DBPs hasn't been established.

Expected Outcomes

The approaches in these studies will develop an improved understanding of the optimal conditions for existing drinking water infrastructure to reduce propagation of HAB-associated toxins and other CECs through drinking water treatment plants. In addition, the evaluations will provide a comparative utility of ELISA and LC/MS assays for cyanobacterial toxin monitoring, and identify parameters most likely to impact the accuracy of the different methods. Such information is critical to the design of effective treatment practices and ultimately helps to prevent waterborne illnesses and safeguard human health.

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