Session L7: Monitoring and Predicting Cyanobacteria Blooms in Water Supplies

Room C123
8:00 – 9:30 am

0322
L7-1

Fate and Transport of Cyanobacteria-Related Toxins and Taste-and-Odor Compounds from Milford Reservoir and Other Upstream Reservoir Releases in the Kansas River, Kansas 2011

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The Kansas River is the drinking water source for more than 600,000 people in Kansas. Four major reservoirs (Milford, Tuttle Creek, Perry, and Clinton) contribute directly to the Kansas River, and all reservoirs have had occasional cyanobacterial blooms. During 2011, a toxic *Microcystis* bloom closed Milford Reservoir to all recreational activities from July through late fall, and several dog deaths were linked to the bloom. Releases from Milford and other upstream reservoirs on August 31, 2011 caused concern about the fate and transport of cyanobacteria-related toxins and taste-and-odor compounds to the Kansas River. The US Geological Survey, in cooperation with several federal, state, and local partners, collected weekly samples at 14 locations along the Kansas River from September 2 through late fall to evaluate the fate and transport of cyanotoxins and taste-and-odor compounds from Milford and other reservoirs. Field parameters (specific conductance, pH, temperature, dissolved oxygen, fluorescence, and turbidity) were measured during sample collection, and all samples were analyzed for cyanotoxins, taste-and-odor compounds, chlorophyll, and phytoplankton community composition. The cyanotoxin microcystin and the taste-and-odor compounds geosmin and 2-methylisoborneol (MIB) were transported into the Kansas River by the August 31 release from Milford Reservoir and by September 8 the compounds were detected throughout a 250-kilometer reach of the river, from just downstream of Milford Reservoir to Kansas City, Kansas. The Milford outflow was the main source of microcystin, but all reservoir outflows were a source of taste-and-odor compounds to the river. In general, microcystin concentrations were largest just below Milford Reservoir, and decreased downstream; patterns in taste-and-odor concentrations were not as straightforward. Relatively little change in concentrations had occurred throughout the reach by September 12. Microcystin was not detected in finished drinking-water samples. Increases in reservoir releases continued throughout the fall of 2011, and weekly sampling was continued through the duration of release flows. These data demonstrate the influence cyanobacterial blooms in reservoirs may have on downstream water-quality conditions during reservoir release flows and underscore the importance of monitoring networks to ensure public-health protection.

0493
L7-2

Multi-Year Trends in *Microcystis aeruginosa* and Associated Microcystin Toxin in the Klamath River System: Implications for Sampling and Public Health

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Copco and Iron Gate Reservoirs located on the Klamath River in Northern California have experienced consistently large toxigenic blooms of *Microcystis aeruginosa* (MSAE) over the past six years, exceeding World Health Organization (WHO) and State of California (SWRCB/OEHHA) public health guideline levels for both cell density and toxin by 10 to over 1000 times during July-October. Reservoir blooms lead to downstream transport of MSAE cells and microcystin toxin, including accumulation in slow velocity river-edge areas downstream. Low MSAE or toxin values in open-water (collected in mixed areas of higher velocity) Klamath River samples often translated to values exceeding public health thresholds in river-edge areas.

The six year monitoring program allowed for the determination of inter- annual and seasonal bloom dynamics, relationships between MSAE cell density and microcystin toxin, as well as between chlorophyll a and microcystin. For example, the SWRCB/OEHHA public health guidance level of 8 mg/L microcystin had 15% and 20% exceedance probabilities when MSAE cell density was 20,000 cells/ml, and ~25% and ~40% probabilities when MSAE cell density was 40,000 cells/ml for the Jun-Sep and Jun-Aug models, respectively. Likewise, evaluation of WHO low probability of adverse health effect guideline values of 20,000 cells/ml MSAE and 4 µg/L microcystin as utilized in CA Total Maximum Daily Load calculations, showed that at an MSAE cell density level of 20,000 cells/ml that there were ~35% and 50% probabilities of exceeding 4 mg/L microcystin for the Jun-Sep and Jun-Aug models, respectively. The greater frequency of exceedance observed for the Jun-Aug models reflect both higher absolute microcystin values and higher microcystin toxin to MSAE cell density ratios occurring during that time, and thus provide a more conservative indication of risk with respect to public health.

These data also showed that there were ~30% and ~25% probabilities of exceeding 20,000 cells/ml MSAE and 4 µg/L microcystin at a chlorophyll a level of 10 µg/L. By demonstrating increasing trends in response variables with either increasing CHL or MSAE cell density, the above relationships provide a robust basis for evaluation of public health guidance values for toxic cyanobacteria in the Klamath River system.

0160
L7-3

A Framework for the Implementation of a Cost Effective Cyanobacteria Harmful Algal Bloom (Chab) Monitoring Program – A Case Study of Hypertrophic Lake Taihu, China

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While long recognized for their human health risks, the toxic metabolites (cyanotoxins) produced by bloom-forming cyanobacteria (blue-green algae) remain surprisingly unregulated, and as a result, few water utilities have surveillance programs in place to monitor for these toxins. Microcystins are the most prevalent cyanotoxins worldwide, and are recognized as potent liver toxins and probable tumor promoters. These toxic metabolites are produced by a variety of cyanobacterial genera and are listed on the EPA's environmental contaminant list. The World Health Organization recommends a provisional guideline of < 1.0 µg l^{-1} total microcystins in finished drinking water. During bloom events, microcystin concentrations often exceed this guideline by several orders of magnitude. Until state and federal regulations catch up with the science, the public health onus for harmful algal bloom surveillance and drinking water remediation falls largely on the water treatment facility. While advanced water treatment processes exist for the destruction or removal of these compounds, they are often prohibitively expensive, especially for smaller utilities. However, the implementation of a cost effective, tailored monitoring program can be used to establish action thresholds in which advanced treatment processes are only enacted for the duration of the health threat.

To demonstrate this approach, a case study of hypertrophic Lake Taihu, China's third largest lake and a drinking water reservoir for millions of citizens, is presented. Every spring and summer the lake is plagued by dense blooms of the toxic cyanobacterium *Microcystis* spp. In 2007, the blooms were so severe that the government had to provide bottled drinking water to millions of local residents until the bloom abated.

The usefulness of monitoring various analytical targets is discussed in relation to toxigenicity and microcystin concentration of water samples based on a three year monitoring study of Lake Taihu. While each drinking water source may have its own unique characteristics, this study will serve as a framework demonstrating how to create a tailored monitoring program for any given reservoir. Improved surveillance and open exchange of monitoring data will greatly advance our collective ability to predict harmful algal blooms, and therefore safeguard the public health of water users.

0337
L7-4

Co-Occurrence of Cyanobacterial Toxins and Taste-and-Odor Compounds in Midwestern Drinking-Water Supply Reservoirs

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Drinking-water supply reservoirs in the midwestern United States commonly have cyanobacterial-related taste-and- odor issues that are a major cause of customer complaints and loss of confidence in drinking-water safety by the general public. Increased public awareness of potential health risks associated with cyanobacterial blooms has exacerbated recreational and drinking-water safety concerns.

Many cyanobacterial taxa are capable of producing toxins (*e.g.*, microcystins) and taste-and-odor compounds (*e.g*, 2-methylisoborneol and geosmin), and some produce multiple compounds simultaneously. With multiple potential producers of microcystins, 2-methylisoborneol (MIB), and geosmin, co-occurrence in mixed assemblage cyanobacterial blooms can be expected; however, few studies have characterized mixtures of toxins and taste-and-odor compounds during blooms.

Recent (2001-2010) multi-year studies in Midwestern (Indiana and Kansas) drinking-water supply reservoirs (n = 4) have documented frequent co-occurrence of microcystins, MIB, and/or geosmin. Depending on the reservoir, microcystin and MIB co-occurred in about

22 to 53% of samples with detectable MIB. Microcystin and geosmin co- occurred in 22 to 63% of samples with detectable geosmin. Similarly, co-occurrence of MIB and geosmin ranged from 51 to 76%.

Co-occurrence of microcystins, MIB, and/or geosmin was most common in blooms dominated by *Aphanizomenon*, *Anabaena*, *Planktothrix*, *Pseudanabaena*, and *Synechococcus*. Cyanobacterial bloom assemblages are a critical determinant of the likelihood of co-occurrence.

While some toxin producers are not known taste-and-odor producers, the majority of known taste-and-odor producers also are known toxin producers. While these studies show that co-occurrence of microcystins, MIB, and/or geosmin was relatively common, there were numerous instances of cyanobacterial-related taste-and-odor events that occurred without accompanying microcystins.