Ohio Environmental Protection Agency

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REPORT ON PROPOSED CYANOTOXIN GENERAL PLAN FOR THE CITY OF TOLEDO

The Cyanotoxin General Plan for the water treatment plant that services the City of Toledo (PWSID: 4801411) was received December 21, 2017 from The Black & Veatch Corporation. with the plan application number 1209467. The Cyanotoxin General Plan was stamped by Nick Burns, P.E., with additional information received through April 24, 2018.

Existing Facility

The City of Toledo Collins Park WTP is the main source of potable water for the City of Toledo, providing treated drinking water from Lake Erie. The City of Toledo utilizes two separate treatment plants housed in the same building utilizing conventional surface water treatment processes, including coagulation, flocculation, sedimentation, lime softening, recarbonation, filtration, and disinfection. A population of 360,000 is served through 133,361 service connections. The combined West and East Plant has an average daily demand of 74.65 MGD (51,800 gpm), a maximum daily demand of 123.82 MGD (85,930 gpm), and an approved capacity of 120 MGD (83,280 gpm). Detail plans were approved on September 13, 2017 to construct Basin 7 and Basin 8 under plan application 1146064. Once the facilities in plan application 1146064 are constructed the East Plant capacity will increase to 80 MGD and the overall approved treatment plant capacity will increase to 140 MGD.

Proposed Plan

The general plan proposes source water protection, avoidance strategies, optimization of existing treatment process for removal of intracellular microcystin (rapid mix/flocculation, sedimentation, and filtration), extracellular microcystins (PAC, Ozone, and Chlorine Contact Time (CT)), and overall harmful algal bloom (HAB) management for the City of Toledo.

Source Water Protection

Due to Lake Erie's historical water quality issues The City of Toledo has implemented several initiatives to mitigate nutrient loading from both point and nonpoint sources. The City of Toledo has enhanced nutrient removal at the water reclamation facility (WRF), the Toledo Waterways Initiative, Storm Water Management Program, and Public Education and outreach programs.

Nutrient Removal at the Toledo Water Reclamation Facility (WRF): The Toledo WRF discharges to the Maumee River, which feeds into Lake Erie. The existing National Pollutant Discharge Elimination System (NPDES) permit phosphorous effluent limitation at the Toledo WRF is 1 mg/L. Iron is added to enhance removal of phosphorus at the WRF.

Toledo Waterways Initiative (TWI): The City of Toledo has combined sewers which can discharge directly into the Maumee River, Ottawa River and Swan Creek during heavy rain events. Toledo is under a Consent Decree with the USEPA to eliminate eight of the 32 Combined Sewer Overflow (CSO) outfalls. The COT launched the TWI in 2002 to eliminate these overflows in order to reduce pollution in the local waterways. This is an 18-year, $527 million program that will reduce the average overflow volume by 80% through a series of deep tunnels and basins. The project is 84% complete to-date and is expected to be completed in 2020.

Storm Water Management Program: The City of Toledo has implemented a Storm Water Management Program in accordance with the Ohio EPA regulations for Municipal Separate Storm Sewer Systems (MS4). This program regulates runoff through the best management practices such as detention basins, filter media barriers, interceptor swales, and construction site drainage controls in order to reduce the pollutant load in storm water runoff. These practices are used to slow the runoff from non-point sources and trap phosphorus before it reaches local waterways.

Agricultural runoff: Phosphorus runoff from fertilizer application on agricultural land surrounding Lake Erie is a major contributor to the nutrient load. There are no governmental regulations on fertilizer applications to-date, but the Natural Resources Conservation Service of Ohio implemented an Environmental Quality Incentives Program, which provides technical and financial assistance for farmers to implement conservation practices to protect the local waterways. This program is voluntary, but it is encouraged and incentivized by the local government.

Public Education and Outreach: The Clear Choices Clean Water Program is actively promoted by The City of Toledo. This program encourages volunteers to help clean up the local waterways and provides educational campaigns to increase awareness for how to protect these waterways through using less fertilizer, managing yard/pet wastes, maintaining septic systems, etc.

Avoidance Strategies

While Toledo has no alternative source currently The City of Toledo placed two sondes, one on a buoy near the Intake Crib for the Collins Park WTP in Lake Erie, which is equipped with a sonde at a depth of two feet and another at a depth of 10 feet inside the intake crib. A third sonde was placed in the screen well. Each sonde contains six probes, which take measurements for pH, temperature, specific conductivity, phycocyanin, chlorophyll, and turbidity every 10 minutes. The results of these measurements are available to the public online through the Great Lakes Observing System website. In addition to the measurements taken by the water system, the National Oceanic and Atmospheric Administration (NOAA) has several buoys placed throughout Lake Erie. Each buoy contains sondes that are capable of the same water quality measurements taken at the buoy near the Intake Crib.

Existing Treatment Optimization

The first step in addressing HAB control for any utility would be to optimize their existing treatment process. The City of Toledo has already enacted a program to address HAB contamination through the water treatment plant. Each treatment process that can be optimized to treat elevated concentrations of microcystins including differentiation between intracellular and extracellular levels. Treatment optimization is described in general context and is revised based on the location of the toxin. E.g. if the toxin is intracellular, use of oxidants (permanganate, chlorine dioxide, free chlorine) may be delayed as a potential impact of chemical addition is lysing cells making the toxin more difficult to remove.

Potassium Permanganate:

During an HAB event, the permanganate dose is set to the level that would normally treat zebra mussels and other organics. This requires that a permanganate residual between 0.3-0.5 mg/L to reduce cell lyses while still performing its designated purpose.

Powdered Activated Carbon (PAC):

The original PAC feed ahead of the low service pump station (LSPS) has the capability to feed up to 40 mg/L of PAC and at least 10 ppm for a minor bloom, 15 ppm for a moderate bloom and 20 ppm for a severe bloom. The redundant PAC feed at the third pass of the flocculation basins can also be implemented at a maximum rate of 1-2 mg/L during a bloom event, but even at a low dose, the PAC accumulates in the filters.

A jar test done for raw water at Lake Erie using varying influent extracellular MC concentrations (42.2 µg/L, 36.5 µg/L, and 21.5 µg/L, etc.) at 0 mg/L PAC dose, and the effluent MC concentration after treatment with the indicated PAC dose. The results of this test show the direct impact that a range of PAC doses have on MC concentrations. With the addition of 5 mg/L of PAC alone, and a 5-hour contact time which is representative of the time it takes for the water to travel from the LSPS to the plant, PAC was able to reduce 42.2 µg/L of MC to 5.5 µg/L. A low dose of 5 mg/L reduced MC concentration by 87%. With the capability of adding 8 times that dose, PAC is a significant treatment barrier for MC.

Based on several monitored water quality parameters, the LSPS PAC dose will be increased. For example, as pH increases, a possible sign of an oncoming HAB event, PAC is proportionally increased even before an ELISA test can confirm the concentration of MC to be proactive in the treatment of MC.

The primary location for PAC feed at the plant is at the LSPS. When the PAC feed rate is ramped up at the pump station, there is time for the PAC to settle out of the water during sedimentation prior to the filters. Sweep coagulation is currently used to provide high levels of PAC removal during sedimentation.

The settled water PAC feeding system was added to the WTP in 2015 to provide an additional barrier to MC. During an HAB event, the plant has ability to feed up to an additional 6 mg/L of PAC to the third pass of the flocculation basins. When the settled water PAC feed is used, the PAC does not have as much time to settle out of the water prior to entering the filters, which results in high applied water turbidity and reducing the filter run times. The practical dose limit that maintains low filter effluent turbidity is 2 mg/L during HAB season.

Coagulation, Softening, & pH Adjustment:

After preliminary treatment with permanganate and PAC, the water at the WTP is mixed with alum for coagulation, lime to remove hardness, soda ash to remove non-carbonate hardness, and carbon dioxide to decrease the pH. After soda ash, the water is sent through a sedimentation basin which removes much of the intracellular MC. Removal efficiency of the softening process at the WTP. The historical average removal efficiency for intracellular microcystins is 90% for the WTP. Softening practices do not change significantly during a HAB event because the hardness and alkalinity goals of the treatment plant are maintained to ensure a stable water quality in the distribution system. Although the process can be expected to achieve greater than or equal to 90% removal of intracellular MC, it is expected to achieve 0% of extracellular MC.

Filter Operation:

Currently at the beginnings of a HAB event, changes are made to the frequency of filter backwashes. If algae build-up is seen on the top of filters, backwashing occurs more frequently: every 40-90 hours as opposed to 80-120 hours with no backwash recycle currently being practiced. Chlorine is also applied prior to the filters if there is algae build-up. Somewhere between 0.5 mg/L and 1.0 mg/L of chlorine is added for a 24-hour period if algae is seen in the filters.

Chlorine Disinfection:

Chlorine is increased based on the MC concentration so that a chlorine residual of at least 1.3-1.7 mg/L remains at the tap. While the chlorine residual does not exceed the 4 mg/L EPA limit, between 2.0-2.5 mg/L of chlorine is fed after sedimentation when high concentrations of MC are measured. If MC is still present at a significant concentration in the clearwell, more chlorine is dosed at the clearwell without exceeding EPA limits based on the existing residual.

The CyanoTOX calculator version 2, approved by the EPA, was used to predict the effects of chlorine on 100 μg/L of MC. Inputs to the calculator included a pH of 9.8 and temperature of 29 °C. The CT that was used for this evaluation was the historical minimum of the daily minimum CTs measured during previous HAB seasons: 146.3 mg-min/L. This CT is calculated based on one reservoir in operation while in reality the reservoirs work in series. There is no flow meter between the East and West reservoir so CT credit is not calculated for the West reservoir. The CT of 146.3 mg-min/L is divided by 2 to represent the current CT operations resulting in a CT of 73.2 mg- min/L. A safety factor of 2 is applied to this value when using the CyanoTOX calculator which results in a CT of 36.6 mg-min/L. At this CT and the above stated temperature and pH, the CyanoTOX calculated that chlorine could reduce 100 μg/L of MC to 74.9 μg/L, a reduction of 25.1%.

A more rigorous study will be undertaken by the City to evaluate potential changes to the current reservoir operational strategy to optimize CT and Microcystin treatment. The study will evaluate the feasibility of installing flow metering devices to monitor flow in the filtered water conduits, evaluate parallel reservoir operation as an alternative to the current operational strategy, and determine the improvements necessary to implement any proposed changes. The City anticipates completing the study by September 30, 2019.

Currently at the WTP, the water height at the clearwell is increased to optimize CT during an HAB event, so the removal efficiency of chlorine alone can be maximized. In addition, chlorine is the final treatment barrier for MC which means that, when the prior treatments are optimized as well, chlorine acts as a polishing barrier.

Future Treatment Barrier – Ozone

The long-term alternative to treat microcystins in the water supply was to install intermediate ozone facilities at the WTP. The ozone treatment facilities at the Collins Park WTP are currently in the design phase, but ozone will be added to the WTP after recarbonation and before filtration.

Bench-Scale Study:

Multiple rounds of bench-scale testing were conducted at different water qualities to determine the ozone dose required to overcome the initial oxidant demand while also treating microcystins. The main water quality constituent that competes for ozone is TOC. The bench-scale tests used waters with a range of TOC concentrations to select the design ozone dose of ozone needed to treat MC.

The bench-scale testing performed in 2014-2015 tested water with varying water qualities. Temperature, pH, and TOC were varied to determine what ozone dose would be required to treat 50 µg/L of microcystins. Though the microcystins concentrations tested did not reach levels as high as expected, the test results did provide value in understanding how ozone reacts under varying TOC conditions. In the water used for bench-scale testing, TOC ranged from the 30th to the 90th percentile in historically observed settled TOC.

In 2017, further bench-scale testing was completed to test ozone treatment of higher concentrations of microcystins. The microcystins concentrations were upwards of 80 µg/L, an applied ozone dose of even 1 mg/L reduced the microcystins concentrations to non- detect levels. Though the TOC levels were not quite as high (the highest was the 80th percentile of historical settled water TOC), even a 1 mg/L ozone dose was able to surpass the TOC demand and treat high MC levels.

Ozone Demand:

Ozone demand is useful for the selection of the design ozone dose as the ozone to TOC ratio can be applied to waters with differing levels of TOC. The range of ozone demand was between 0.1 to 0.56 mg/L for the range of tests performed, which translates into an ozone to TOC ratio of <0.1 to 0.28 mg ozone per mg TOC.

The demand figures are used to predict initial dissolved ozone residual for any given ozone dosage. When additional ozone is applied, only a fraction of it is observed as an increase in dissolved ozone residual. The slope of the lines in Figure 5-2 shows for every additional 1 mg/L ozone applied, the increase in dissolved ozone residuals is 0.5 to 0.7 mg/L. This is useful in establishing the design ozone dosage, since process control will rely on obtaining an initial dissolved-ozone residual.

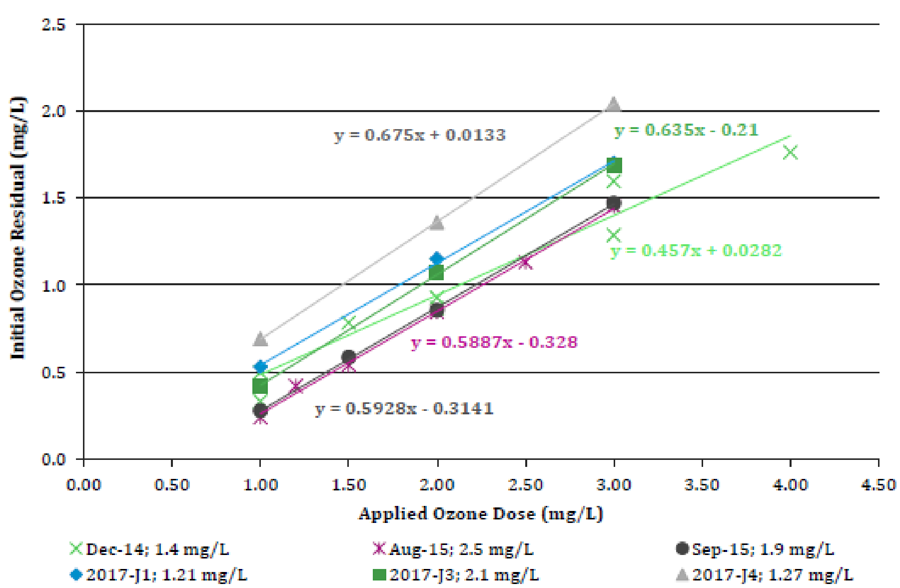

Figure 5-2 Initial Ozone Residual Based On Ozone Dose; (date of testing; settled water TOC)

Design Ozone Dosage:

The settled water ozone dose for the Collins Park WTP was calculated using the following equation:

$$Ozone\ Dosage = TOC \times 0.34 + \frac{C_i}{0.6}$$

Where:
Ozone Dosage = Transferred Ozone Dosage, mg/L
TOC = Settled water TOC, mg/L
0.34 = Ozone to TOC ratio, mg ozone per mg TOC
Ci = Target initial dissolved ozone residual, mg/L
0.6 = Ratio of ozone residual to the ozone applied, unitless

Design Ozone Dosage Assumptions:

- The 99th percentile settled water TOC concentration from the entire 2001-2017 dataset during HAB season is 3.1 mg/L. To incorporate a safety factor, a settled water TOC of 3.5 mg/L was used for the design ozone dosage calculations. This is representative of the TOC concentration if the PAC feed system were offline, even though this system includes redundancy.

- The maximum observed ozone to TOC ratio during bench scale testing (0.28) plus a 20 percent safety factor resulting in a ratio of 0.34.

- A 0.3 mg/L dissolved ozone residual, which requires an additional 0.5 mg/L transferred ozone. The ratio of 0.3 mg/L to 0.6 (unitless) represents the amount of ozone that will need to be added to achieve the desired residual (see Section 5.2.1.2 for further explanation).

$$Ozone\ Dosage = 3.5\text{ mg/L} \times 0.34 + \frac{0.3\ mg/L}{0.6} = 1.69\text{ mg/L}$$

The applied ozone dosage will be 1.8 mg/L assuming a transfer efficiency of 95 percent. At this dose, a firm production capacity of 2,400 ppd would be required at a plant operating capacity of 160 MGD. At this production capacity and a flow of 140 MGD, the applied dose would be 2.05 mg/L and the transferred dose would be 1.95 mg/L.

The TOC values would be expected to still achieve greater than 99% MC oxidation were calculated using the original dosage selection calculation as well as a ratio of two of the bench-scale tests that had the highest level TOC. Eliminating the demand safety factor and applying the above equation to solve for TOC using the true transferred ozone dosage at 140 MGD, 1.95 mg/L, a TOC of 5.1 mg/L should still provide very high level (>99%) MC removal.

The two best bench-scale data sets from which to extrapolate the TOC data to illustrate high level MC removal are also included in Table 5-5. The result of those calculations illustrates a settled water TOC level of 4.1 mg/L. Even at TOC levels above, 4.1 mg/L, MC will continue to be removed; however, the data is not available to mathematically demonstrate what level of treatment will be achieved. Some level of treatment would continue to be achieved at higher settled water TOC.

Table 5-5 Calculated TOC level while Achieving Greater Than 99% MC Reduction

BENCH-SCALE TEST SAMPLE	DESIGN APPROACH*	RATIO OF TOC AUG. 2015	RATIO OF TOC 2017-J3
Transferred Ozone Dose	1.95 mg/L	1.2 mg/L	1.0 mg/L
Settled Water TOC	Calculated	2.5 mg/L	2.1 mg/L
Percent MC Removal	>99 percent	> 99.7 percent	> 99.6 percent
Design Transferred ozone dose (at 140 mgd)	1.95 mg/L	1.95 mg/L	1.95 mg/L
Calculated TOC Capable of 99% MC removal at the Design Ozone Dose:	5.1 mg/L	4.1 mg/L	4.1 mg/L
Calculation:	$\frac{1.95\ mg/L - (0.3\ mg/L\ /\ 0.6)}{0.28\ \frac{mg\ O3}{mg\ TOC}}$	$\frac{1.95\ mg/L}{1.2\ mg/L} \times 2.5 \frac{mg}{L} TOC$	$\frac{1.95\ mg/L}{1.0\ mg/L} \times 2.1 \frac{mg}{L} TOC$

*Safety factors were removed to illustrate difference between the design value (3.5 mg/L) and the value supported directly by bench-scale testing results.

<u>General Plan Implementation Schedule</u>

Ozone	Date
Final Design – Completed by early May 2018, including OEPA review and approval	May-18
Construction Contract Bid and Award	May-Sept. 2018
Construction Notice to Proceed	Sept. 2018
Development of HAB Treatment Optimization Protocol and Ozone Manual O&M	Apr-20
Ozone System Substantial Completion (without Basins 5 and 6)	Aug-20
Completed	June-21
Reservoir Operation Study to Optimize CT	
Completed	Sept. 30, 2019

The Plans are to be approved at this time under normal conditions and the following special conditions of the director:

(a) The enclosed report contains a description of the facilities approved which may include information regarding approved operating rates, capacities, and requirements, and is incorporated herein.

(b) In accordance with Ohio Administrative Code (OAC) 3745-90-05(B), the owner shall implement the approved cyanotoxin general plan in accordance with the approved schedule and continue to monitor for microcystins in accordance with OAC 3745-90-03 to demonstrate treatment effectiveness.

(c) In accordance with OAC 3745-90-05(C), if the owner fails to comply with item (b) of this plan approval, it is a violation of the treatment technique requirement of the HAB rules and the owner shall issue a tier 2 notification in accordance with OAC 3745-81-32.

(d) If there are any substantial changes to either source water or treatment, as defined in OAC 3745-91-01, the owner shall contact the Division of Drinking and Ground Waters, northeast District Office to determine if a revision to the Cyanotoxin General Plan is needed.

(e) The Cyanotoxin General Plan shall be reviewed annually and updated as needed. Any revisions to the general plan shall be submitted to the Division of Drinking and Ground Waters, northeast District Office for review.

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Engineering & Infrastructure
Division of Drinking and Ground Waters