REPORTS:

Preventing zebra mussel (*Dreissena polymorpha*) veliger attachment using potassium permanganate

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INTRODUCTION

Zebra mussels (*Dreissena polymorpha*) are a fast colonizing invasive species that were first discovered in North America in 1988 (NOAA 2007) and have since spread across much of the United States. They are considered one of the world’s most economically and ecologically damaging invasive species and have been estimated to cost water treatment facilities $1-5 billion dollars every year (Aldridge 2006). Late stage veligers (juveniles) of the mussels will attach to most rough surfaces, including other zebra mussels, using byssal threads to create strong attachments (D’Itri 1997). This has created problems for any water treatment facility that draws water from a source infested with these mussels. Adherence by mussels within the pipe and the treatment facility will clog the pipe and disrupt water filtration. Their management requires the expenditure of considerable effort and resources.

Zebra mussels were first discovered in Otsego Lake (Otsego County, NY) in 2007 (Horvath 2008). They have since colonized hard surfaces lake wide, including the Village of Cooperstown Municipal Water Works. This facility draws water from the lake via a 0.355m diameter cast iron pipe that extends about 1,310m from its source; water is drawn at about 14m depth (Elliot 2015). Recent efforts to control mussel fouling in the pipe have involved pigging (Elliot 2015), or forcing a flexible plastic plug through the length of the pipe. It requires the assistance of SCUBA divers and the threat exists that the pig may eventually become lodged within the intake pipe.

The water treatment facility currently uses potassium permanganate, an oxidizing agent, to disinfect and improve the potable quality of the water (Elliot 2015). To achieve disinfection, every day about 48mg/L of KMnO₄ is pumped for about an hour, at a rate of about 70 L/minute, through a small pipe that runs along the bottom of the intake pipe. Diffusers at the mouth of the intake pipe distribute the permanganate as water is drawn from the lake. The configuration of the system’s design potentially poses some challenges related to chemically control zebra mussels, primarily in that contact time is limited. It takes about 2 hours for the potassium permanganate-dosed water to reach the mouth of the pipe and about one hour for it to return through the intake pipe to the treatment plant (so the contact time with the permanganate is limited to 60 minutes). The rate of water withdrawal is about 2,100 L/minute. The calculated dose at the pipe mouth is 1.6 mg/L (70 L/minute / 2,100 L/minute*48 mg/l). Water coming into the treatment plant was

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measured contain about 0.62 mg/L permanganate. The difference (~1 mg/L) is presumable lost to reduction as it oxidizes compounds in the raw water. Research conducted by Coyle (2015) indicated that a concentration of 8 ppm would kill about 50% of veligers after a 120 minute exposure. Lower dosing rates and lesser exposure times were not effective at killing veligers.

The goal of this experiment was to determine the concentration of potassium permanganate at one hour contact necessary to prevent zebra mussel veligers from attaching to artificial substrates (which may be substantially lower than that necessary to cause mortality). This oxidizing compound is already used by the Cooperstown facility to treat the lake water, and it has been demonstrated in other studies to control veligers (Claudi and Mackie 1993), making it a candidate for preventing fouling by veligers. These findings could be useful to water treatment operators in that it allows for the determination of dosing rates that are high enough to effectively prevent settling without being excessive. Over dosing not only carries the direct cost of the chemical treatment, but also the cost of removing the permanganate prior to delivery to water users, as permanganate imposes a purple coloration which makes it aesthetically unattractive. Permanganate removal adds to treatment expense as it consumes activated carbon.

METHODS

The original intention of this study was to effectively conduct a semi-controlled experiment using veligers collected directly from the Cooperstown water treatment plant. During the period when veligers were present, the plant operator would adjust the outgoing dose of permanganate in the morning and we planned on running a calculated volume of the return water through a 61 um plankton net. Those veligers would then be transferred to aquaria and cultured to settling stage. This approach would have most closely mimicked the actual treatment scenario. However, we were unable to reliably collect veligers at the treatment plant (possibly due to the intake depth which, at about 14 m, is below the thermocline), so a more controlled approach was undertaken.

Instead zebra mussel veligers were collected from Otsego Lake. A 64 micron zooplankton net was towed between the surface and 5 meters deep for about 10 minutes near the end of July (when veliger numbers were high). After towing, the mussels were brought directly to the lab and their density was determined using an analytical grade digital microscope equipped with cross polarizing filters (Johnson 1995). Once the average number of veligers per milliliter was determined, the sample was diluted with filtered lake water to yield about 100 veligers/mL.

Five 500 mL beakers were half filled with concentrations of 0mg/L, 2mg/L, 4mg/L, 8mg/L, and 16mg/L of potassium permanganate, respectively. Each treatment was conducted in duplicate. Each beaker received a cage, which was constructed of of PVC piping with the top end open and the bottom end closed off by 64 micron mesh. These contained the veligers while being exposed to the permanganate solution. Ten milliliters of the veliger sample was added to each cage using a 1mL Hensen Stempel ten times for each concentration, thus adding approximately 1,000 veligers to each treatment. The veligers were exposed in their respective beaker for one hour, at room temperature, in order to replicate one hour of dosing at the Village of Cooperstown Municipal Water Works. Once the hour was completed, each cage was rinsed off with filtered
lake water and transferred to its respective aquarium. Each aquarium contained 20L of filtered lake water, was equipped with an aerator, and had a ~30x30 cm plexiglass plate suspended vertically in its center. These plates had been pre-treated by having been hung in a local pond (free of zebra mussels) for 7 days prior to the experiment in order to create a biofilm to which the veligers could attach (Davis 2015).

The veligers were left in the tanks for 30 days to allow them time to grow, settle and attach to the plexiglass. They were fed 0.25 mL of Isochrysis 1800™ “instant algae” every Monday, Wednesday, and Friday and the temperature of each tank was taken after feeding. Every Monday, water samples were collected for the determination of ammonia in order to ascertain reasons for mortality should the veligers die. Also weekly, half of the tank’s water was replaced with fresh filtered lake water. To remove the water, a zooplankton sieve with a 61 micron mesh was placed over the end of a siphon tube so that water could be drawn out without drawing out any veligers.

After 30 days, the plexiglass plates were removed from each tank and examined under a cross polarized scope. All of the plates were checked under the scope; however the opacity of the plates, as well as the film on them, made it difficult to see anything. For this reason, the biofilm was scraped from the plates and was added it to 125mL of 70% ethanol. In order to determine how many unattached veligers there were, each tank was siphoned through a 64 micron mesh plankton cup. The filtered water was mixed with 70% ethanol to dilute the solution to 125mL and to preserve the samples. Both the scrapings and the filtered samples were examined under a cross-polarized scope. From each sample, 5mL was inspected and all the [whole] veligers were counted. The number counted was divided by 5mL and then multiplied by 125mL to determine how many were either on the board in the end or in the water.

RESULTS AND DISCUSSION

Over the course of the month long study, temperature across the tanks averaged 21.76°C (SD= 0.74°C). A one-way single factor ANOVA was performed on the temperature data which showed no significant difference between the tanks (F=0.278751, df=9, p=0.978956). Ammonia concentrations averaged 0.43 mg/l (SD= 0.05). A one-way single factor ANOVA was done on the ammonia data which revealed that there was no significant difference between the tanks (F=0.337178, df=9, p=0.95511) or over time (F=9.79208, df=3, p=<.001).

Figure 1 summarizes the attached and planktonic zebra mussels (veligers) among the treatment groups. The “unaccounted for” fraction is the discrepancy between the targeted number of veligers initially added (1,000) and the estimated numbers of veligers and attached mussels recovered (the subsamples of 5 x 1 mL subsamples viewed, considering the total concentrate volume of 125 mL). This fraction could also include veligers not surviving long into the experiment. A chi-squared test showed that there was no difference in the number of attached veligers between tanks (χ²= 15, df=12, p=0.2414). There was no difference in number of attached mussels or veligers between treatment levels. Potassium permanganate does not appear
to be an effective molluscicide for zebra mussels at the concentrations and duration of contact evaluated.

Figure 1. Percent of zebra mussel veligers that were either attached, planktonic, or unaccounted for. A Chi-squared test was done to show no difference in number of attached veligers between tanks.

This project was originally planned to be performed at the Cooperstown Water Treatment facilities; however, we were unable to consistently collect veligers there to represent each of the five trail concentrations. This necessitated the collection of veligers directly from the lake as well as conducting the exposure sequences in the lab rather than that occurring during the water withdraw by the municipal treatment facility. It was also discovered part-way through the experiment that zebra mussel veligers had infested the filtered water system used for culturing at the lab facility (presumably due to a failed filtration system). Therefore, we had to restart the entire project. Also, after this realization, extra care needed to be taken to ensure that veligers were not introduced from this source into the culture tanks, i.e., every time we used the lake water hose we filtered the water through a 61 micron zooplankton net. Lastly, power was lost for several hours halfway through the project. This may have caused a disruption to the aerators in the tanks, but the fact that ammonia concentrations were consistent throughout the experiment implies that oxygen concentrations did not drop meaningfully.
REFERENCES


