Zebra Mussels' Impact on Austin Water Facilities

Written by Olivia Beck, E.I.T.

September 9, 2017

Executive Summary

Zebra mussels are an invasive species that reproduce extremely quickly. The first zebra mussel infestation in Texas was in Lake Texoma in 2009, approximately 90 miles north of Dallas. As of August 2017, zebra mussels have infested Lake Travis and were positively identified in Lake Austin.

Zebra mussels clog pipes, screens, and other intake structures; if mitigation strategies are not implemented, zebra mussels could increase electrical costs associated with pumping raw water and reduce a water treatment plant's ability to treat water. Zebra mussels can also damage equipment, cause taste and odor issues, and significantly alter lake ecosystems.

There are a number of mitigation strategies used against zebra mussel infestations. Generally, mitigation strategies can be classified as preventative (preventing attachment), control (killing/removing zebra mussels), and reactive (removing an infestation of zebra mussels). Any solutions implemented must be NSF/ANSI 60/61 approved and should not negatively impact finished water quality. A multifaceted approach including but not limited to chemical feed systems will likely be most effective for Austin Water facilities.

Water Treatment Plant #4 has a currently unused chemical feed system in place to help control zebra mussel infestations in the raw water transmission main. Ullrich Water Treatment Plant and Davis Water Treatment Plant are monitoring for zebra mussels at their traveling screens, but no systems are in place to mitigate zebra mussel infestations at either facility. Zebra mussels have not yet been identified at any of the three plants by Austin Water personnel.

Austin Water is acting swiftly to minimize the impacts of zebra mussel infestations at its facilities. Even though Lake Austin has not been deemed "infested" with zebra mussels at this time, it will likely become infested in the near future due to zebra mussels' high reproductive rates. Underwater inspections at WTP4, Ullrich WTP, and Davis WTP are expected to occur during the first or second quarter of Fiscal Year 2018 to determine current levels of infestation. An evaluation/feasibility study will be completed to recommend specific zebra mussel mitigation strategies best suited to each facility and to provide cost estimates for those strategies; the Notice To Proceed (NTP) for the study is expected to be issued to a consultant in the first quarter of Fiscal Year 2018, and current projections estimate construction on selected strategies will be complete in the second quarter of Fiscal Year 2022.

Zebra mussels pose a serious threat to Austin Water's water treatment plants. By regularly inspecting its facilities, determining the best mitigation strategies for Austin Water's facilities, and implementing the selected strategies, Austin Water can successfully manage the risk of a zebra mussel infestation and continue to provide excellent service to its customers.

Background and Impacts on Water Treatment Facilities

Zebra mussels are small freshwater mussels native to Russia ("Zebra Mussels: *Dreissena Polymorpha*," 2017). Since arriving in the Great Lakes system during the late 1980s, zebra mussels have spread across the country (Benson, Raikow, Larson, and Fusaro, 2017). The first zebra mussel infestation in Texas was in Lake Texoma in 2009 ("Zebra Mussels: *Dreissena Polymorpha*," 2017), approximately 90 miles north of Dallas. As of August 2017, zebra mussels have infested Lake Travis and were positively identified in Lake Austin (Texas Parks and Wildlife, 2017). Currently, eleven lakes in Texas are classified as infested by the Texas Parks and Wildlife Department, including Lake Travis and nearby Lake Belton and Canyon Lake, and eight lakes have been positively identified for zebra mussels ("Zebra Mussels: *Dreissena Polymorpha*," 2017). Zebra mussels in Texas are mostly in the Dallas/Fort Worth (DFW) area and along the IH-35 corridor between DFW and San Antonio.

Zebra mussels are typically less than 1 ½ inches long ("Zebra Mussels: *Dreissena Polymorpha*," 2017) and have an average lifespan of three to five years (USACE, 2013). A female can lay up to 1,000,000 eggs in a spawning season (Benson, et al., 2017); one female will produce an average of 100,000 adult mussels in her lifetime ("Invasive Mussels," 2017). Microscopic larvae, called veligers, drift in water for weeks before settling onto a hard surface using their byssal threads, collectively called a byssus (Benson, et al., 2017). Figure 1 below shows the zebra mussel life cycle. Zebra mussels typically develop to maturity in one to two years (Benson, et al., 2017).

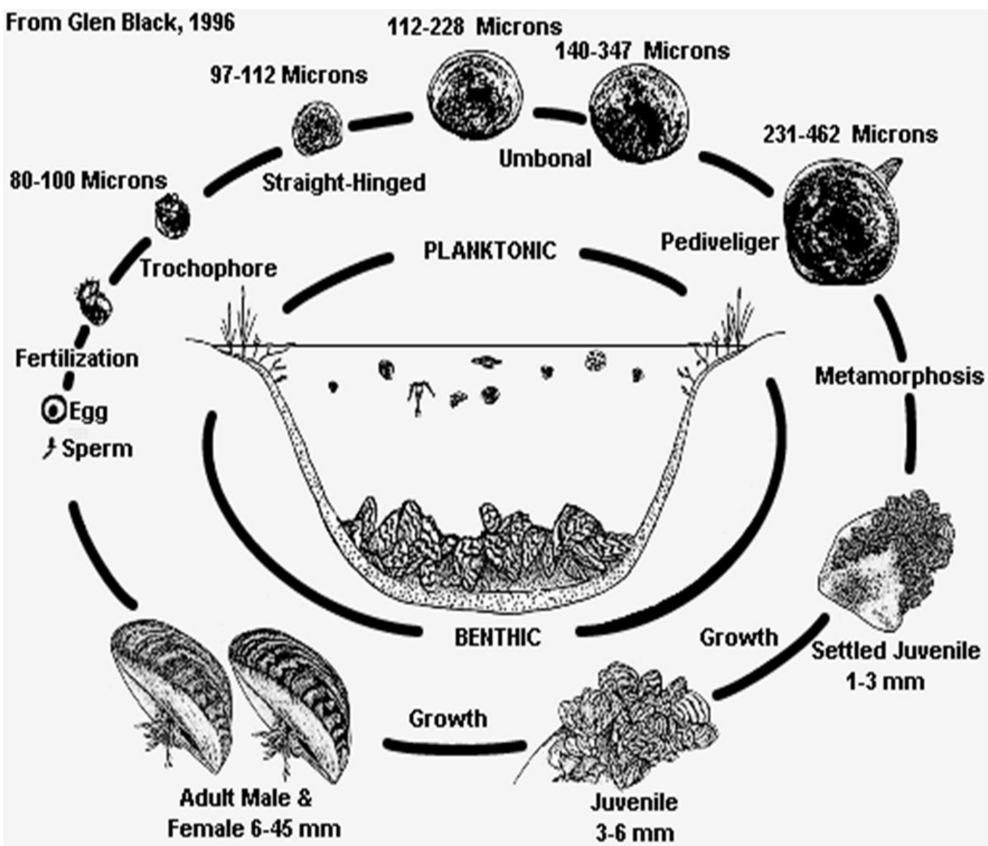

Figure 1: Zebra Mussel Life Cycle (Source: "Zebra Mussel Life Cycle," 2003)

Zebra mussels are generally found at depths between 6 and 45 feet, though they can live in much deeper water ("Zebra Mussels Threaten Inland Waters: An Overview," n.d.). Table 1 below summarizes environmental requirements to sustain a zebra mussel population:

Table 1: Zebra Mussel Environmental Requirements (Source: USACE, 2013)

Water Quality Parameter	Survival Range	Preferred Range
Temperature	50-90° F	68-79° F
Calcium	$\geq$ 8 mg/L as Ca	$\geq$ 20 mg/L as Ca (reproductive) $\geq$ 30 mg/L as Ca (optimal)
Alkalinity, total	$\geq$ 30 mg/L as $CaCO_3$	100 - 280 mg/L as $CaCO_3$
Hardness, total	$\geq$ 30 mg/L as $CaCO_3$	100 - 280 mg/L as $CaCO_3$
pH	7.0 - 9.5	8.2 – 8.8
Dissolved Oxygen	$\geq$ 3 mg/L ($\geq$ 25% saturation)	$\geq$ 8 mg/L ($\geq$ 75% saturation)

Based on these requirements, Lake Travis and Lake Austin will both support large zebra mussel populations. Zebra mussels firmly attach themselves to hard surfaces such as boats, pipes, screens, rocks, turtles, and even other mussels. As filter-feeders, zebra mussel populations can significantly increase the clarity of a body of water, which can drastically reduce the amount of algae available as a food source to native species. By clarifying the water, out-competing native mussels, and selectively feeding on only some species of algae, zebra mussels can cause major changes to the ecosystem of the body of water (USACE, 2013).

Zebra mussels clog pipes, screens, and other intake structures, as is shown in Figure 2. If mitigation strategies are not implemented, zebra mussels can increase electrical costs associated with pumping raw water and reduce a water treatment plant's ability to treat water. Zebra mussels can also damage equipment and cause taste and odor issues for water treatment facilities.

Figure 2: Zebra Mussels in Small-Diameter Pipe (Source: Associated Press, 2014)

Regulations

Any zebra mussel treatment/mitigation method must meet all applicable regulations. In accordance with the Safe Drinking Water Act, drinking water treatment chemicals and components must comply with NSF/ANSI 60/61. Drinking water must meet the Texas Commission on Environmental Quality's (TCEQ's) rules and regulations for public water systems as established in Title 30 Texas Administrative Code (30 TAC), Chapter 290; any changes to the treatment process must be thoroughly evaluated and approved by TCEQ prior to implementation to ensure the changes will not negatively impact drinking water quality. Treatment methods impacting Lake Travis or Lake Austin will likely involve coordination/permitting with the U.S. Army Corps of Engineers, the U.S. Fish and Wildlife Service, and the Texas Parks & Wildlife Department.

Mitigation Strategies

There are a number of mitigation strategies used against zebra mussels. Generally, mitigation strategies can be classified as preventative (preventing attachment), control (killing/removing zebra mussels), and reactive (removing an infestation of zebra mussels).

- <u>Preventative</u>
  - *Repellent construction materials:* Zebra mussels will not attach to copper, brass, or galvanized metals (Boelman, Neilson, Dardeau, and Cross, 1997).
  - *Coatings:* Coatings can also be used to prevent zebra mussel attachment; however, the environmental impacts of using a particular coating need to be fully considered before a coating is applied.
  - *Filters and screens:* Filters and screens can be effective at preventing a zebra mussel population from spreading into an intake structure; however, the slot size would need to be smaller than is practical at a water treatment plant to prevent the veligers from passing through.
- <u>Control</u>
  - *Chemical treatment:* Oxidizing and non-oxidizing chemicals can be used for zebra mussel control. Zebra mussels can sense the presence of oxidizing chemicals and close their valves for up to two weeks to avoid the chemical (or simply detach and attach to a different object in a safer environment), meaning an oxidizing chemical might need to be applied for a minimum of two weeks to achieve results (USACE, 2013).
    - Chlorine, including free chlorine and chloramines, is one of the most common oxidizing chemicals used in mussel control. However, formation of disinfection byproducts (DBPs) as a result of chlorination is a major concern.
    - Although bromine, ozone, hydrogen peroxide, and sodium chloride have also been evaluated, they are not recommended for zebra mussel control at this time due to the environmental and health concerns (bromine), cost impacts (ozone and hydrogen peroxide), and inefficiency (sodium chloride).
    - Potassium permanganate and sodium permanganate are both used to control zebra mussel populations. While potassium permanganate is more commonly used and is less costly, sodium permanganate is becoming increasingly popular due to ease of use; potassium permanganate is delivered dry and must be mixed on-site to feed as a liquid, while sodium permanganate is delivered as a solution and can be fed as-is.

        - Non-oxidizing chemicals still pose the risk of killing non-target organisms, but are generally considered to be safer. BioBullets – tiny capsules of vegetable fat containing potassium chloride – might be a viable solution to controlling zebra mussel population; however, BioBullets have not yet been tested in the United States or received EPA approval (Aldridge, Elliott, and Moggridge, 2006).
    - *Biological treatment:* Although zebra mussels have some natural predators, natural predators have not been able to keep up with zebra mussel population growth. The most promising form of biological treatment is Zequanox, a highly effective commercial product that uses dead bacterium as its active ingredient ("EPA Approves Zequanox® for Invasive Mussel Control in Open Water," 2014). Zequanox is not NSF 60 approved at this time.
- <u>Reactive</u>
    - *Mechanical removal*: Zebra mussels can by physically removed by hand, scraping, and pigging. Two downsides of mechanical removal are 1) mechanical removal must be completed regularly, and 2) mechanical removal requires removing the zebra mussels from the body of water, so they don't reattach to the structure.
    - *Pressure washing:* To remove zebra mussels, pressure washing is recommended at pressures between 4,000 and 10,000 psi (Boelman, et al., 1997). Care must be taken to avoid damaging the existing structure, and pressure washing will also need to be done periodically.
    - *Dewatering:* Adult zebra mussels can survive for more than ten days out of water, depending on air temperature and humidity (USACE, 2013). Removing a structure from water for at least two weeks, manually removing the dead zebra mussels, and replacing the structure would likely be an effective method of removal; however, like mechanical removal and pressure washing, dewatering will also need to be completed regularly.

Other forms of treatment include acoustic treatment, electromagnetic treatment, thermal treatment, CO2 injection, ultraviolet light, and anoxia/hypoxia. The chart in Appendix A provides additional information on a number of mitigation strategies.

Mitigation at Austin Water's Water Treatment Plants

The City of Austin has three major water treatment plants (WTPs): Water Treatment Plant #4 (50 MGD), Davis Water Treatment Plant (118 MGD), and Ullrich Water Treatment Plant (167 MGD). Of the three WTPs, WTP4 is the only plant supplied by Lake Travis. WTP4 has three large intake structures at varying elevations in the lake, each sized for the plant's eventual buildout of 300 MGD. Each intake structure has a screen with a 1-inch slot size, and the design flow approach velocity is $\leq$0.5 ft/s, ideal for mussel attachment. From the intake structures, the water flows down a common riser to a 9-foot diameter, 4,300 ft tunnel that terminates at the access shaft of the Low Service Pump Station.

WTP4's intake and tunnel are likely prime locations for a zebra mussel population; however, WTP4 has a chemical feed system in place to protect the facility against zebra mussel infestations should the need arise. The chemical would be stored at the Low Service Pump Station and fed through PVC lines in the intake riser. The chemical feed system on its own might not be sufficient to protect WTP4 against zebra mussels, especially since it leaves the intake screens themselves unprotected, but a multifaceted approach including chemical feed might be appropriate.

Ullrich WTP and Davis WTP are supplied by Lake Austin. Although Lake Austin has only been positively identified for zebra mussels and has not yet been deemed infested, it is expected to be classified as infested in the near future due to zebra mussels' rapid reproduction. The raw water intake structures at Ullrich WTP and Davis WTP do not have any systems currently in place to protect against zebra mussel infestations. Ullrich and Davis WTPs have similar intake structures; both intake structures have traveling screens, sluice gates, bar screens with upper and lower plates, and six raw water pumps. The traveling screens are currently being used to monitor for zebra mussels at Ullrich WTP and Davis WTP; zebra mussels have not been detected at either facility by Austin Water personnel. Similar to WTP4, a multifaceted approach including chemical feed would likely provide the most complete protection for Ullrich WTP and Davis WTP without impacting Lake Austin.

It is worth noting that Austin Water operates two additional water treatment plants: River Place Water Treatment Plant and Emma Long Water Treatment Plant. River Place WTP serves the River Place neighborhood in northwest Austin, and Emma Long WTP serves Emma Long Metropolitan Park. Although the expected impact of zebra mussel infestations at these two WTPs is considerably less than the anticipated impact of infestations at the three primary WTPs, Emma Long and River Place WTPs will also be considered when evaluating zebra mussel mitigation strategies.

Austin Water's Action Plan

Austin Water is acting swiftly to minimize the impacts of zebra mussel infestations at its facilities. The intake structures at Ullrich WTP, Davis WTP, and WTP4 will be inspected on a regular basis to monitor for zebra mussel infestation. To this end, an existing contract including diving inspection services at WTP4 has recently been amended to include the other WTPs for zebra mussel inspection; the initial inspections are expected to occur during the first or second quarter of Fiscal Year 2018.

An evaluation/feasibility study will be completed to recommend specific zebra mussel mitigation strategies best suited to each facility and to provide cost estimates for those strategies. A Project Charter has been initiated within Austin Water's Facility Engineering group, and a Notice To Proceed (NTP) is expected to be issued to a consultant in the first quarter of Fiscal Year 2018. Following completion of the study, additional authorization will be required to design and construct the facilities selected to mitigate zebra mussel infestations; construction is currently estimated to be complete in the second quarter of Fiscal Year 2022. In the interim, the diving inspection contract will also include mechanical removal/pressure washing to remove any mussels that might settle on Austin Water structures and impair operations.

Conclusions

Zebra mussels pose a serious threat to Austin Water's water treatment plants. By regularly inspecting its facilities, determining the best mitigation strategies for Austin Water's facilities, and implementing the selected strategies, Austin Water can successfully manage the risk of a zebra mussel infestation and continue to provide excellent service to its customers.

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Appendix A

METHOD	Primary TARGET AGE	Potential EFFICACY	CONTACT TIME /CONCENTRATION	COMMENTS
Thermal shock	All	100%	13 hours @ 33 °C (winter) 1 hour @ 37 °C (summer)	Lethal to most aquatic species
Freezing	Juveniles Adults	100%	2 days @ 0 °C 5-7 hours @ –1. 5 °C under 2 hours @ –10 °C	Must dewater system
Oxygen starvation – stripping water of oxygen	All		2 weeks + @ 0 mg/L	Must isolate population
Oxygen Starvation - Benthic mats	Juveniles Adults	Up to 99%	9 weeks	Initial tests promising for limited infestations
Desiccation	Juveniles Adults	100%	Immediate @ 36 °C 5 hours @ 32 °C 2. 1 days @ 25 °C	Must dewater system for several days
Manual removal	Juveniles Adults	Variable	N/A	Ongoing efforts in Lake George, New York and Lake Powell
Predation	All	Low	Continuous	Harvest of potential predatory species should be limited
Acoustic Deterrents Cavitation	Veligers	Not commercially available	veligers in seconds @ 10–380 kHz juveniles in minutes adults in a few hours	May affect other species, reduced success in high flows, needs power source
Acoustic Deterrents Low frequency sound	Veligers	Not commercially available	4 to 12 min @ 20 Hz–20 kHz Inhibits settling	Not lethal, needs power source
Acoustic Deterrents Ultra sound	All	Not commercially available	veligers in seconds @ 39–41 kHz adults in 19-24 hours	May impact other species, needs power source
Acoustic Deterrents Vibration	Veligers Juveniles	Not commercially available	intermittent @ 200 Hz & 10–100 kHz	Structural integrity may be threatened
Acoustic Deterrents Plasma pulse technology	Veligers	Prevents settling – Not commercially available	intermittent high energy pulses	Not lethal, private technology
Electrical Deterrents Low voltage electricity	Veligers	Not commercially available	immediate results @ 8 volt AC Prevents settling	Not lethal, needs power source
Filtration Media filters	Veligers, translocators	100%	Removal of all particles greater than 80 microns	Removes all plankton, high total suspended solids may be a problem
Filtration Self-cleaning mechanical filters	Veligers, translocators	100%	Removal of all particles greater than 80 microns	Removes all plankton, high total suspended solids may be a problem
UV radiation	Veligers	100% prevention of settlement		Lethal to many species, effectiveness may be limited by turbidity and suspended solids
Bacterial toxin *(Pseudomonas fluorescens)*	All	95%	6 hours	Low toxicity to other organisms, few treatments needed, not yet available in commercial quantities.

Source: Heimowitz, Paul, and Stephen Phillips. *Columbia River Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species: Appendix D.1 - Control Options*. Rep. Pacific States Marine Fisheries Commission, 5 Nov. 2013. Web. 5 Mar. 2014. <http://preventinganinvasion.psmfc.org/rapid-response-workgroup/>.

NON- OXIDIZING CHEMICALS	TARGET AGE	EFFICIENCY	CONTACT TIME/ CONCENTRATION	COMMENTS
pH adjustment	Veligers Adults	100% 100% 69. 9% 52. 4%	under 7 or over 9. 5, pH close to limit prevents settlement pH 3 in 96 hours pH 2 in 96 hours ph4 in 96 hours	High pH may cause unacceptable precipitation in water with high scaling index
Potassium salts (KCL)	All	Prevent settlement 50% 95-100%	50 mg/L 48 hours @ 150 mg/L 3 weeks @ 95–115 mg/L	Lethal to other mussel species, non-toxic to fish at required dose rate
Potassium ion (KH2PO4)	All	100%	continuous @ 160–640 mg/L	As above
Potassium ion (KOH)	All	100%	Less than 10 mg/L	As above
Copper ions	Veligers	100%	24 hours @ 5 mg/L 10 15µg/L continuous prevents settlement	Lethal to other aquatic species
Copper-based algaecides	All			Lethal to other aquatic species, efficacy increases with increasing ambient temperature
EarthTec®	adults	100	0. 5mg/L copper equivalent in 96 hours	Equally effective on zebra and Quagga
Captain™	adults	85%	1. 0mg/L copper equivalent in 96 hours	Difference in efficacy between quagga and zebra mussels
Natrix™	adults	85-100%	1. 0mg/L copper equivalent in 96 hours	Difference in efficacy between quagga and zebra mussels
Copper Sulfate	adults	50-99%	0. 5mg/L copper equivalent in 96 hours	Difference in efficacy between quagga and zebra mussels
Endothal based algaecides				
Teton - amine salt of endothal	Adults – Quagga Adult zebra	100% 2% 100% 100% 75%	36 hours of exposure at 1 ppm 24 hours of exposure at 2 ppm 12 hours of exposure at 3 ppm at ambient temperature of 25º C At 20º C ambient water temperature 96 hours of exposure at 1 ppm 84 hours at 2 ppm 24 hours of exposure to 3 ppm. 96 hours at 3ppm at 25º C	Efficacy differs between quagga and zebra mussels. Efficacy increases with ambient water temperature
Cascade – di-potassium salt of endothal	none	0		

Source: Heimowitz, Paul, and Stephen Phillips. *Columbia River Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species: Appendix D.1 - Control Options*. Rep. Pacific States Marine Fisheries Commission, 5 Nov. 2013. Web. 5 Mar. 2014. <http://preventinganinvasion.psmfc.org/rapid-response-workgroup/>.

PROPRIETARY MOLLUSCICIDES QUATERNARY AMMONIUM COMPOUNDS	TARGET AGE	EFFICIENCY	CONTACT TIME/ CONCENTRATION	COMMENTS
Clam-Trol CT 1	All	100% 48 hours after exposure	1. 95 mg/L @ 11 °C for 12 hours 1. 95 mg/L @ 14 °C for 14 hours 1. 95 mg/L @ 20 °C for 6–14 hours	More toxic to veligers than adults and more toxic to mussels than to trout. Must be deactivated with bentonite clay
Calgon H-130	All	100% after 48 hours	0. 85–1. 12 mg/L	1. 1 mg/L toxic to salmonids, must be deactivated, corrosive, flammable
Macro-Trol 9210	All	100%	5–50 mg/L continuous	Lethal to aquatic organisms, must be deactivated with bentonite clay
Bulab 6002	All	100%	2 mg/L 7–10 days 4 mg/L 5–8 days	Lethal to fish, especially salmonids. Must be deactivated with bentonite clay
PROPRIETARY MOLLUSCICIDES AROMATIC HYDROCARBONS	**TARGET AGE**	**EFFICIENCY**	**CONTACT TIME/ CONCENTRATION**	**COMMENTS**
Mexel 432	Deters veliger settlement		Dose at 1–4 mg/L once a day	96 hours LC 50 for rainbow trout 11mg/L, corrosive
EVAC – endothal formulation	All	100%	0. 3–3 mg/L for 5 to 144 hours	Lethal to fish but rapidly degrades, does not bioaccumulate
Bulab 6009	All	100%	2 mg/L 4 to 10 days 4 mg/L 3 to 8 days	96 hours LC 50 for rainbow trout 1,1 mg/L, corrosive

Source: Heimowitz, Paul, and Stephen Phillips. *Columbia River Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species: Appendix D.1 - Control Options*. Rep. Pacific States Marine Fisheries Commission, 5 Nov. 2013. Web. 5 Mar. 2014. <http://preventinganinvasion.psmfc.org/rapid-response-workgroup/>.

OXIDIZING CHEMICALS	TARGET AGE	EFFICIENCY	CONTACT TIME/ CONCENTRATION	COMMENTS
Chlorine	Veligers Adults	100% 100%	0. 3mg/L TRC (total residual chlorine) settlement prevention 1mg/L TRC 7 to 14 days depending on ambient water temp.	Lethal to many aquatic species , can be detoxified on discharge with sodium metabisulphite
Chlorine dioxide ClO2	All Adults	100%	0. 3mg/L TRC (total residual chlorine) settlement prevention 1mg/L TRC 7 to 14 days depending on ambient water temp.	
Chloramine	All Adults	100%	0. 3mg/L TRC (total residual chlorine) settlement prevention 1mg/L TRC 7 to 14 days depending on ambient water temp.	
Hydrogen peroxide	Veligers Juveniles	100%	6 hours	High dosage rates required. Lethal to other aquatic species. Short half-life in water
Ozone	All	100%	Veligers in 0. 3ppm continuous prevents settlement 5 hours @ 0.5 mg/L total mortality Adults in 7 days @ 0.5 mg/L depending on ambient temp.	Lethal to other aquatic species, very short half-life in water, generally no need to detoxify on discharge
Potassium permanganate	All	100 %	2. 0 mg/L for 48 hours	Lethal to other species, at high doses may turn water pink
Sodium permanganate	All	100%	0. 3 mg/L to 1. 25 mg/L	

Source: Heimowitz, Paul, and Stephen Phillips. *Columbia River Basin Interagency Invasive Species Response Plan: Zebra Mussels and Other Dreissenid Species: Appendix D.1 - Control Options*. Rep. Pacific States Marine Fisheries Commission, 5 Nov. 2013. Web. 5 Mar. 2014. <http://preventinganinvasion.psmfc.org/rapid-response-workgroup/>.