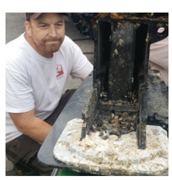
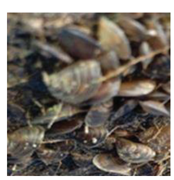
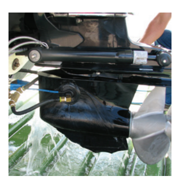
A REVIEW OF CHEMICAL USE ASSOCIATED WITH WATERCRAFT DECONTAMINATION TO ADDRESS AQUATIC INVASIVE SPECIES

A special supplement to the *Uniform Minimum Protocols and Standards (UMPS) for Inspection and Decontamination Programs for Dreissenid Mussels in the Western United States* report







Leah C Elwell and Stephen Phillips, editors

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PREFACE

This document provides supplementary information to the Uniform Minimum Protocols and Standards for Inspection and Decontamination Programs for Dreissenid Mussels in the Western United States (UMPS III; Elwell and Phillips 2016). Previous versions of UMPS (I and II) have discussed the use of chemicals in the watercraft decontamination process. The refinement of decontamination protocols continue to take place and UMPS III focused on the preferred methods of physical removal and hot water to decontaminate watercraft and equipment. A discussion on chemicals was absent from UMPS III in an effort to encourage best practices of decontamination with hot water with a focus on available peer-reviewed science and to emphasize the lack of applied scientific research on chemical decontamination of watercraft. This document is meant to provide information on the primary chemicals that appear in management documents related to decontamination, but also to discourage promotion of their wide-spread use to the public particularly when not supported by peer reviewed science.

INTRODUCTION

Aquatic invasive species (AIS) represent a threat to the ecological function of lakes, rivers and reservoirs. Further, once established AIS can have significant and costly impacts on our economy. To address the spread or introduction of AIS, management efforts have prioritized pathways to reduce this risk. Motorized and non-motorized watercraft have been a primary focus addressed in recent management efforts as they are recognized as a vector in the spread of AIS (Johnson et al. 2001, Mari et al. 2011). In 2017, 31 states had either legal provisions that restrict launching or transporting AIS or a fully operational watercraft inspection decontamination program (Showalter Otts and Janasie 2017). Scientific research has improved the methods available to agencies who implement watercraft inspection and decontamination programs across the nation. Further, increased communication and coordination among managing agencies has improved the success of these programs. Standardizing the techniques utilized in watercraft inspection and decontamination has been a goal among managers and several products support this effort including *Student Training Curriculum for Watercraft Inspectors and Decontaminators to Prevent and Contain the Spread of Aquatic Invasive Species in the U.S.A.* (Brown 2015), and *The Trainer Manual for Aquatic Invasive Species Inspection and Decontamination Courses* (Brown 2015). Model legislation and model regulations that specifically address inspection and decontamination programs have been instrumental in standardizing these programs as well (Showalter Otts and Nanjappa 2014, Showalter Otts and Nanjappa 2016).

Effective techniques implemented consistently are needed to prevent the spread or introduction of aquatic invasive species via motorized and non-motorized watercraft and other water-based equipment. Key research has been conducted on decontamination methods to provide confidence in current methods applied.

> **In general, the use of 140°F water for direct contact and 120°F water for flushing interior compartments coupled with appropriate exposure times are recommended for effective watercraft decontamination.**
> (Comeau et al. 2011, 2015 and see UMPS III 2016)

This technique combined with thorough visual and tactile inspection, physical removal of mussels and dry time greatly reduces the risk that mussels or other invasive species will be spread. The use of hot water and dry time has also been shown to be highly effective in killing other invasive species such as plants and invertebrates (Bayer et al. 2011, Jerde et al. 2012, Anderson et al. 2015).

Historically, chemicals have been a resource that managers, manufacturers and boat owners have turned to for decontamination needs. Often these chemical uses are a reflection of anecdotal experience and unpublished experimentation. Further, chemical use for watercraft decontamination presents its own suite of considerations for efficacy, impacts to the environment, the materials or equipment being treated, associated expense and human health and safety, as well as legal parameters. Finally, exposing watercraft materials to chemicals can alter the integrity of those materials, particularly with repeated use. Because of continued interest in chemical decontamination of watercraft, this document is meant to summarize the common chemicals referenced in watercraft decontamination.

Watercraft inspection staff using hot water to decontaminate a boat. Photo courtesy of Elizabeth Brown,Colorado Parks and Wildlife.

The goal of this document is to outline the current available information on the most common chemicals that are often suggested for use in watercraft decontamination, and provide an overview of the legal use of these chemicals and recommendations for future language in chemical usage for decontamination in management outreach. Presently, there are no peer-reviewed studies that specifically address the use of chemicals in watercraft decontamination. The majority of scientific information on chemicals have been focused on laboratory studies to determine lethal doses for a variety of invasive species, or in closed system experiments to eradicate or control invasive species.

> **The use of chemicals for watercraft decontamination is currently not recommended or suggested for the public or within watercraft inspection and decontamination (WID) programs.**

DECONTAMINATION, CHEMICALS, AND INVASIVE SPECIES

During the 1990s as dreissenids spread throughout the Great Lakes region and Mississippi River Basin, many researchers examined chemical strategies to kill mussels typically with the application of eradication from facilities affected by biofouling such as a power plants (e.g. Claudi and Mackie 1994). At this same time, a wide variety of state and federal agencies released their individual recommendations on "cleaning" watercraft. These recommendations often included chemicals such as vinegar, bleach, quaternary ammonia or table salt. Many of which had been explored previously for eradication or control methods in closed systems.

In the early 2000s, inspection and decontamination programs were in their infancy and managers were striving to establish methods to effectively kill and remove dreissenid mussels from watercraft. The current watercraft decontamination methods have evolved through the completion of several hundred thousand watercraft decontaminations. The AIS management community has made great strides in developing effective and consistent watercraft decontamination methods with hot water.

Considering that the current watercraft decontamination strategy of using hot water is widely accepted by AIS managers as the preferred method and many chemicals referenced in watercraft decontamination are remnants of control or eradication strategies in closed systems, the use of the current suite of chemicals commonly used in watercraft decontamination is obsolete and is not recommended.

CHEMICALS CAN KILL

Past research on chemicals and invasive species has focused largely on seeking methods that can control or eradicate populations of invasives in primarily closed systems such as power plants or municipal water systems (e.g. Claudi and Evans 1993, Garrett and Laylor 1995, Pucherilli et al. 2014); other studies have examined lethal doses of chemicals with specific species, many with dreissenids (e.g. Martin et al. 1993, Wildridge et al. 1998, Costa et al. 2008).

These types of studies have been instrumental in guiding rapid response preparation and providing managing agencies with potential small scale eradication or control tools when faced with a waterbody discovery of an invasive species.

A variety of chemicals have been examined in their effectiveness to achieve species mortality, typically under a variety of laboratory conditions (Table 1).

> **Effectively killing something with a chemical in the laboratory and applying chemicals during decontamination of watercraft are not the same thing.**

Very few studies exist in the direct application of chemical decontamination of specific equipment (e.g. Hosea and Finlayson 2005, Schisler et al. 2008, Stockton and Moffitt 2013). These studies examined the mortality of New Zealand mudsnails (*Potomopyrgus antipodarium*) when exposed to chemicals such as Formula 409, and Virkon which require immersion of the equipment to be effective. Two recent studies have examined dreissenid mortality to antifreeze. One study suggests propylene glycol-based antifreeze may enhance survival by protecting juvenile to adult mussels from freezing rather than cause mortality (Kelly Stockton-Fiti, personal communication). Whereas, another study observed 100% mortality of veligers and adults depending on concentration and length of time when exposed to propylene glycol-based antifreeze (Donna Kashain, personal communication). The disparity in dreissenid mortality observed between the two studies suggests that results may be influenced by variations in propylene glycol based antifreeze formulation, life stage of dreissenid exposed and other laboratory conditions (i.e. temperature). Therefore it cannot be assumed that all antifreeze formulations will affect dreissenid mortality similarly. Despite these biological investigations into species sensitivity to chemicals, no published studies exist on chemical decontamination of the interior or exterior of watercraft.

There are several important variables that affect the toxicity of chemicals to dreissenids or other AIS. These variables are exposure time, concentration, and water quality parameters (e.g. water temperature, pH, etc.). These variables can be controlled in an experiment where test subjects are collected and retained in laboratory containers. Transferring the results of the laboratory bench to a watercraft decontamination protocol will be a challenge. As indicated previously, there has been limited applied work done to date.

TABLE 1. A Summary of Research Examining Chemicals and Invasive Species Mortality

Research studies that focus on the mortality of dreissenid mussels and other invasive species when exposed to a variety of chemicals.

1 Date	Publication	Summary Results	Chemical
2017	Davis et al. Toxicity of potassium chloride compared to sodium chloride for zebra mussel decontamination. *Journal of Aquatic Animal Health.*	KCl was more effective in achieving mortality of adult mussels and veligers at lower concentrations than NaCl.	sodium chloride potassium chloride
2016	Davis et al. Comparison of three sodium chloride chemical treatments for adult zebra mussel decontamination. *Journal of Shellfisheries Research.*	Exposure to various concentrations of sodium chloride for 24 hours resulted in 97%-100% mortality of adult zebra mussels.	sodium chloride
2016	Moffitt et al. Toxicity of potassium chloride to veliger and byssal stage dreissenid mussels related to water quality. *Management of Biological Invasions.*	Water quality parameters can influence the effectiveness of potassium chloride as a control for dreissenid mussels.	potassium chloride

Date	Publication	Summary Results	Chemical
2016	Stout et al. Efficacy of commercially available quaternary ammonium compounds for controlling New Zealand mudsnails (*Potamopyrgus antipodarum*). *North American Journal of Fisheries Management.*	Various quaternary ammonium compounds were examined for efficacy, and suggest that a bath of 0.4% solution for 10 minutes to achieve mortality of mudsnails.	quaternary ammonium (including Quat 4, Green Solutions Hi Dilutions Disinfectant and Super HDQ Neutral)
2015	Davis et al. Distilled white vinegar (5% acetic acid) as a potential decontamination method for adult zebra mussels. *Management of Biological Invasions.*	Exposure for four hours + to 100, 75, 50 or 25% vinegar (5% acetic acid) resulted in 100% mortality of adult zebra mussels.	acetic acid
2015	Moffitt et al. Efficacy of two approaches for disinfecting surfaces and water infested with quagga mussel veligers. In: *Biology and Management of Invasive Quagga and Zebra Mussels in the Western United States.*	Solutions of pH 12 created at two temperatures, and 3 concentrations of Virkon and exposed to veligers which were all effective in killing the veliger.	NaOH Ca(OH)2 Virkon
2014	Pucherelli et al. Quagga mussel contamination of fish haul trucks by fish and development of effective potassium chloride and formalin treatments. *Journal of Applied Ecology.*	Fish were exposed to standard chemical aquaculture transfer protocols and suggest 12 hours of KCL at 1,500 mg/L plus 2 hour 50 mg/L dose of formalin was 100% effective. Veligers can attach to fish mucous membranes externally or on gills.	potassium chloride formalin
2013	Barbour et al. Biosecurity measures to reduce secondary spread of the invasive freshwater Asian clam, *Corbicula fluminea. Management of Biological Invasions.*	Virkon achieved 93% mortality of *Corbicula fluminea* when used at 2% concentration for 5 minutes. Mortality rates were much lower for bleach and salt solutions at 60 minutes exposures.	virkon bleach salt
2013	Stockton KA and CM Moffitt. Disinfection of three wading boot surfaces infested with New Zealand mudsnails. *North American Journal of Fisheries Management.*	Felt, neoprene, rubber wading boots with attached mudsnails were exposed to Virkon. Authors advise bath disinfection as spray disinfection did not reliably achieve mudsnail mortality.	virkon (composed of potassium monpersulphate, sufamic acid, malic acid and other compounds)
2013	Watters, Gerstenberger and Wong. Effectiveness of EarthTec® for killing invasive quagga mussels (*Dreissena rostriformis bugensis*) and preventing their colonization in the Western United States. *Biofouling.*	100% mortality of adults was achieved after 96-h with 17 and 5 ppm, and 100% mortality of veligers within 30 min at 3 ppm	EarthTec® (copper sulfate formulation)
2012	Takeguchi, Liang and Yates. Evaluating potential quagga mussel control measures in Colorado River water. *Journal of American Waterworks Association.*	Chlorine is an effective molluscicide for adult and juvenile quagga mussels, and decisions to use other chemicals tested will need to address efficacy, cost, side effects and permits in contrast.	chlorine chloramine chlorine dioxide ozone alum ferric chloride polyDADMAC
2011	Britton and Dingman. 2011. Use of quaternary ammonium to control the spread of aquatic invasive species by wildland fire equipment. *Aquatic Invasions.*	Quagga mussel veligers exposed to 3% solution of Sparquat 256 for 5 and 10 minutes, only 10 minute exposure experienced 100% mortality.	3% solution sparquat
2008	Hedrick RP, TS McDowell and K Mukkatira. Effects of freezing, drying, ultraviolet irradiation, chlorine, and quaternary ammonium treatments on the infectivity of myxospores of *Myxobolus cerebralis* for *Tubifex tubifex. Journal of Aquatic Animal Health.*	Treatments of bleach and quaternary ammonium, and drying inactivated myxospores, further exposed host *T.tubifex* did not display symptoms of infection to inactivated myxospores. Myxospore viability was inactive at freezing temperatures lower than -20°C.	quaternary ammonium bleach

Date	Publication	Summary Results	Chemical
2008	Schisler GJ, NKM Vieira and PG Walker. Application of household disinfectants to control New Zealand mudsnails. *North American Journal of Fisheries Management.*	100% solution of Formula 409, and Sparquat 256 solution of at least 3.1% for 10 minutes resulted in 100 mudsnail mortality.	Formula 409 Sparquat 256
2002	Edwards et al. Field testing of protocols to prevent the spread of zebra mussels *Dreissena polymorpha* during fish hatchery and aquaculture activities. *North American Journal of Aquaculture.*	1-h pretreatment with 750 mg/L KCl followed by 25 mg/L formalin resulted in 100% veliger mortality and no loss of fish.	potassium chloride formalin sodium chloride
2000	Edwards et al. Prevention of the spread of zebra mussels during fish hatchery and aquaculture activities. *North American Journal of Aquaculture.*	NaCl was most effective treatment for veligers but caused high fish mortality. 25 mg/L solution formalin with KCl was effective against veligers and safe for fish. KCl + formalin + NaCl is not recommended.	sodium chloride potassium chloride calcium chloride formaldehyde TFM
1998	Waller and Fisher. Evaluation of several chemical disinfectants for removing zebra mussels from unionid mussels. *The Progressive Fish Culturist.*	Effective disinfection of unionid mussel shells will require the use of chemical treatment followed by a quarantine period to completely remove zebra mussel larvae and juveniles.	formalin hydrogen peroxide calcium chloride potassium chloride
1996	Brady et al. Chlorination effectiveness for zebra and quagga mussels. *Journal of the American Waterworks Association.*	Chlorination trials with adult zebra and quagga mussels indicate significantly higher mortality for quagga compared to zebra mussels.	chlorine
1996	Matisoff et al. Toxicity of chlorine to adult zebra mussels. *Journal of the American Waterworks Association.*	The success of any treatment protocol depends not only on the exposure time but also on the water temperature at the time of application.	chlorine dioxide
1996	Waller et al. Prevention of zebra mussel infestation during aquaculture operations. *The Progressive Fish-Culturist.*	Zebra mussel veligers and settlers experienced mortality to various treatments.	benzalkonium chloride chloride salts
1995	Van Benschoten et al. Zebra mussel mortality with chlorine. *Journal of the American Waterworks Association.*	A kinetic model allowed for the prediction of the mortality of adult zebra mussels as a function of chlorine concentration, temperature and contact time.	chlorine
1993	Claudi R and DW Evans. Chemical addition strategies for zebra mussel *(Dreissena polymorpha)* control in once-through service water systems. In: *Zebra Mussels: Biology, Impact and Control.*	A thorough summary of oxidizing and non-oxidizing treatments of hydropower systems.	oxidizing chemicals non-oxidizing chemicals
1991	Klerks and Fraleigh. Controlling adult zebra mussels with oxidants. *Journal of American Waterworks Association.*	Three chemicals were compared for their effectiveness against attached adult zebra mussels. KMnO4 is a reasonable alternative to chlorine for treatment of attached mussels. Mussels attached in the lab on average detached 17 hours after death from exposure to oxidant treatments.	hypochlorite permanganate peroxide with iron

Photos courtesy of (left to right): Colorado Parks and Wildlife; Utah Division of Wildlife; Utah Division of Wildlife; Utah Division of Wildlife




CHALLENGES TO CHEMICAL USAGE

The anatomy of the watercraft will influence the outcome of the chemicals in use. As the complexity of boat increases, it decreases the human ability to adequately address all parts of the boat to remove AIS. There are four areas of watercraft inspection:

- H = hull and trailer (exterior)
- E = engine or motor
- A = anchor, anchor rope, and other equipment
- D = drain interior compartments

If we examine these four areas in the context of chemical application, several issues arise. First, effective exposure time and concentration are not easily achieved by spraying a chemical on the hull, anchor, and/or anchor rope. Second, some interior compartments are often designed with little visual access let alone access for tactile observation, therefore limiting any ability to determine chemical concentration during exposure time. It is difficult to determine the appropriate exposure time or volume of chemical needed for watercraft ballast tank decontamination to achieve a level of confidence in decontamination.

<u>The effectiveness of chemicals can also be influenced by biological factors of the target AIS.</u> Every chemical will have a different impact on the target species. For example, dreissenids can close their shells for extended periods when exposed to chemicals (Claudi and Evans 1993), microbes can be resilient to chemical exposure (Hedrick et al. 2008), and plants will vary in their susceptibility to chemical exposure. These and other biological factors highlight the fact that no single chemical is suited for effective decontamination for the full suite of aquatic invasive species of plants, animals and microbes.

The effectiveness of chemicals is influenced by water quality parameters or other physiochemical factors. Factors such as pH, water quality profile and temperature will affect how the chemical impacts the target AIS. Recent research by Moffitt et al. (2016) suggests that water quality variables influence the effectiveness of potash as an effective molluscide. Further, early research by Van Benschoten et al. (1995) modeled chlorine effectiveness and found it was correlated to water temperature, concentration and exposure time.

A variety of information on agency webpages or outreach documents suggests to the recreationists that the use of chemicals is acceptable, but often this information is provided with little direction on appropriate disposal or use. Proper use and disposal of chemicals is a concern in watercraft decontamination. All chemicals should be used and disposed of in accordance to their label. (See section "Proper Use and Compliance" below). Many watercraft manufacturer warranties specify that the use of chemicals in association with watercraft may invalidate that warranty. A variety of chemicals (e.g. bleach) can damage, corrode, or otherwise alter the integrity of the product depending on the construction materials. Thorough understanding of product warranty and care of product is advised.

The use of chemicals to decontaminate watercraft does not absolve watercraft operators or transporters from state or federal watercraft inspection and decontamination programs.

> **Watercraft operators must comply with local jurisdictions watercraft inspection regardless of any previous decontaminations performed or chemicals that may have been used by the watercraft operator.**

IMPORTANT NOTE: There are well established standards and protocols for chemical use in decontamination of laboratory and field equipment. Where field activities take place in known habitats where invasive species are present, then a decontamination protocol is often followed particularly when conducting sampling at multiple locations in one sampling effort. The same issues of exposure time, concentration and water quality parameters will still influence the effectiveness of sampling equipment decontamination.

Many agencies have developed decontamination strategies for internal agency use over the past decade. Some of these strategies include materials produced by the Army Corps of Engineers, Department of Defense, and the Bureau of Reclamation (Armed Forces Pest Management Board 2017, Cofrancesco et al. 2007, DiVittorio et al. 2012), which in many cases instruct the use of pressurized water. Most recently, the National Interagency Fire Center developed recommendations for decontaminating firefighting equipment to prevent the spread of AIS with the use of chemicals in the *Interagency Fire Team Operational Guidelines and Interagency Fire Team Technical Guidelines* (Interagency Standards Group 2016). Many state agencies have adopted chemical equipment decontamination protocols that are used internally by field staff and contractors, for example Wisconsin's Department of Natural Resources *Best Management Practices for Boat, Gear and Equipment Decontamination* (2017), and Washington Department of Fish and Wildlife *Invasive Species Management Protocols* (2012).

TABLE 2. Decontamination Chemical Profiles

The following chemicals have been highlighted here as they are commonly referenced for use in watercraft decontamination or equipment decontamination applications.

2 Chemical Name and Various Forms	Application	Registered Uses	Decontamination Comments	Chemical Considerations
Chlorine bleach (sodium hypochlorite)	■ Very common disinfectant used in the medical and scientific community to kill organisms. ■ Chlorine has been used for over a century in the disinfection of municipal water facilities. ■ Chlorine has been one of the dominant chemicals utilized in the control of dreissenids at a variety of facilities such as power plants or water treatment facilities.[1]	**Not labeled for use in decontamination of watercraft.** Chlorine that is typically purchased by the public is not labeled as a molluscicide, but commonly is labeled as a disinfectant of surfaces.	Readily available to the public and inexpensive. Regulating or enforcing any private household use is challenging.	Difficulty in determining/achieving an appropriate exposure time or volume of chemical needed to ensure mortality of all AIS which minimizes confidence in watercraft decontamination. Bleach may damage watercraft materials.
Quaternary ammonia (e.g. Formula 409, Sparquat, Virkon)	■ Used as a household cleaning product. ■ Commonly used in the disinfection of field equipment.	**Not labeled for use in decontamination of watercraft.** These products are typically labeled as disinfectants, virucides and fungicides.	These products are readily available to the public. Quaternary ammonia is commonly used in the disinfection of equipment such as waders, other field equipment.	Difficulty in determining/achieving an appropriate exposure time or volume of chemical needed to ensure mortality of all AIS which minimizes confidence in watercraft decontamination. Quaternary ammonia may damage watercraft materials.
Vinegar (Acetic acid)	■ Common household product for cooking and cleaning. ■ 20-30% acetic acid solutions are marketed as an herbicide.	**Not labeled for use in decontamination of watercraft.** Horticulture vinegar is labeled as an herbicide.	Vinegar has been referenced repeatedly in the decontamination of watercraft by various entities. This product is readily available.	Difficulty in determining/achieving an appropriate exposure time or volume of chemical needed to ensure mortality of all AIS which minimizes confidence in watercraft decontamination.
Antifreeze (propylene glycol	■ Used in the maintenance and winterization of watercraft.	**Not labeled for use in decontamination of watercraft.** Labeled for automotive engine use.	Antifreeze is readily available to the public. Formulations of antifreeze vary widely.	Proprietary formulations of antifreeze vary widely which does not allow generalizations on decontamination effectiveness.

[1] Claudi and Evans 1993, and US Army Corps 1998

Photos courtesy of (left to right): Elizabeth Brown; Colorado Parks and Wildlife; Colorado Parks and Wildlife; Utah Division of Wildlife; Colorado Parks and Wildlife

PROPER USE AND COMPLIANCE ISSUES

The Environmental Protection Agency (EPA) and associated state agencies are responsible for the registration and approval of specific chemicals for use as a pesticide or herbicide. The primary legislation that guides pesticide use is the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) passed in 1996. FIFRA was followed by the Pesticide Registration Improvement Act of 2003 which enhanced the ability of the EPA in pesticide regulation process. These laws guide the use of chemicals and help define when a chemical use is required to comply with specific actions. A pesticide label is the printed or graphic information attached to the pesticide container. Pesticides are regulated for their use by a label and it is illegal to use a registered pesticide for a use that is not specified on the label. FIFRA defines a pesticide (section 2(u)) as *any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest; any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant; and any nitrogen stabilizer.*

Federal Insecticide, Fungicide, and Rodenticide Act

This legislation is the primary mechanism for the federal government to regulate the distribution, sale and use of pesticides. All pesticides that are distributed or sold in the United States must be registered by the EPA. A licensed pesticide must show that it will not cause unreasonable adverse effects on the environment when used according to pesticide label specifications. The Office of Pesticide Programs regulates the use of all pesticides in the United States. The National Pesticide Information Retrieval System (NPIRS) contains information pertaining to pesticides either currently or previously licensed for distribution and sale in the United States and is provided for informational purposes only (www.ppis.ceris.purdue.edu). There are several types of pesticide registrations.

A. FIFRA Section 3: The EPA can register pesticides for use throughout the United States. There are examples of limited use pesticide registrations for some states. There can be additional restrictions on pesticides determined by tribes or individual states.

B. FIFRA Section 2 (ee): The EPA can grant the use of a pesticide that is currently not labeled for that specific species but the use of the pesticide is allowed on the site as specified on the label.

C. FIFRA Experimental Use Permits: Section 5 FIFRA allows EPA to grant permission to manufacturers to test pesticides under development.

D. FIFRA Emergency Exemptions: Section 18 of FIFRA allows the EPA to grant state or federal agencies to permit unregistered use of a pesticide in a specific geographic area for a limited time if an emergency pest condition exists. This may occur if there are currently no registered pesticides available or a registered pesticide is not labeled for that particular use or site.

E. State-Specific Registrations: Section 24(c) of FIFRA allows states to register a new pesticide for any use or a federally registered product for an additional use as long as there is a demonstrated "local need" and a clearance from Federal Food, Drug and Cosmetic Act.

KEY TERMS

Decontamination: The process of cleansing an object or substance to remove contaminants such as microorganisms.

Disinfectant: Antimicrobial agent that are applied to surface of non-living objects to destroy microorganisms living on that object (chlorine, quaternary ammonium compounds). Measures of effectiveness include high, intermediate and low.

The Clean Water Act and the National Pollutant Discharge Elimination System

The Clean Water Act prohibits anybody from discharging "pollutants" through a "point source" into a "water of the United States" unless they have a National Pollutant Discharge Elimination System (NPDES) permit. The permit contains limits on what you can discharge, monitoring and reporting requirements, and other provisions to ensure that the discharge does not hurt water quality or people's health. The permit essentially translates the requirements of the Clean Water Act into specific provisions tailored to the operations of each person discharging pollutants. If you discharge from a point source into waters of the United States, you need a NPDES permit. If you discharge pollutants into a municipal sanitary sewer system, you do not need a NPDES permit, but should clarify with the local municipality permit requirements. If you discharge pollutants into a municipal storm sewer system, you may need a permit depending on what you discharge. Other laws besides the Clean Water Act may apply to the NPDES implementation and permitting. For example, the National Environmental Policy Act requires that agencies conduct environmental impact reviews for actions that would significantly affect the quality of the human environment. Therefore, the Clean Water Act (Section 511) established that only EPA-issued permits to "new sources" are subject to NEPA's environmental review.

Understanding Current Statements on Boat Decontamination and Chemicals

Some chemicals have such broad use in the workplace or households that they have become deregulated and are not closely monitored for misuse, chlorine is one such chemical. A number of entities have created management regulations or recommendations that suggest the use of chlorine and vinegar as suitable chemicals to use in the decontamination of watercraft. However, are these recommendations legal? How does the label of a chemical affect its use in decontamination of watercraft? Do specific uses of these chemicals when performed in a repeated fashion at a place of business become non-compliant (i.e. boat marina)? Several of these questions have been explored here through consultation with the Environmental Protection Agency.

- The enforcement of FIFRA is based on the sale and distribution of registered pesticides, not on the use of chemicals labeled for other uses
- All chemicals should be used and disposed of in accordance with the label.
- The act of a recommendation for chemical watercraft decontamination by a managing agency does not put that agency at a legal liability.
- Waste chemicals from repeated chemical watercraft decontaminations on a large scale (e.g. marina) may be subject to NPDES compliance and will be dependent on state laws and regulations.
- Waste chemicals from household chemical watercraft decontamination are not subject to NPDES compliance. However, a courtesy notification to the municipal water treatment center that the waste chemicals will enter is suggested.

Even for casual use of chemicals for decontamination their impacts to local waters or non-target organism should be considered. For example, quaternary ammonium products can persist in municipal water systems (Boethling 1984, Zhang et al. 2015) and chlorine is known to produce the toxic byproduct of trihalomethane. Additionally, many chemicals can negatively impact non-target organisms through their applications (Waller 1993).

Statement on Safety and Disposal of Chemicals

The use of chemicals in any application should have a safety protocol and proper disposal protocols to ensure that harm to human, wildlife, or environment are minimized. A safety protocol should include proper handling, storage, accurate solution mixtures and application measures (e.g. gloves, safety glasses). A proper disposal protocol should include measures of disposal that meet local requirements, and minimize spillage to the environment. In some cases, chemicals may need to be inactivated prior to disposal to meet safety standards (e.g. chlorine solution inactivation with sodium thiosulfate). Material Safety Data Sheets are an industry resource that should be retained for chemical use.

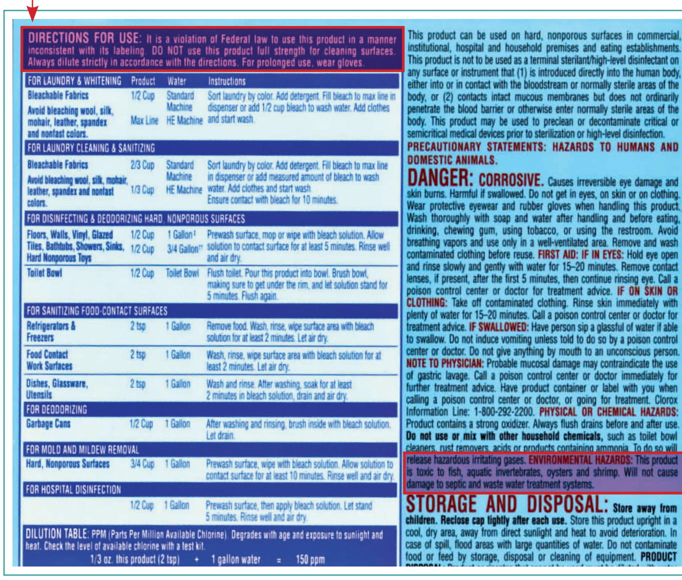
CONSISTENT PRACTICES FOR DECONTAMINATION

The evolution of the issue of aquatic invasive species management has been rapid. With the passage of key invasive species legislation in the 1990s there was a wealth of information provided to the public on invasive species and specific cleaning practices. In many cases that original information is still circulated and available in the public domain or in publications. This information contains a mix of recommendations rather than focusing on consistent preferred methods of hot water decontamination. In order to better serve watercraft owners and operators the use of consistent language and consistent recommendations should be promoted. In most cases, information that refers to chemicals (e.g. bleach, vinegar) for use by the public should be removed from online sources, and documents should be updated to reflect that information. Therefore it is recommended that state, federal and other entities that provide outreach on watercraft cleaning should adopt the following:

> **Watercraft and associated equipment users should practice Clean Drain Dry. The use of chemicals is discouraged for use in most situations to decontaminate watercraft or equipment due to compliance with labeling use, proper handing issues, and potential impacts to the environment. Decontamination with the use of hot water should be conducted by professionals to ensure that protocols are adhered to and safety hazards can be minimized.**

Based on the current studies presented here, the various constraints such as exposure time, concentration as well as knowledge of currently available chemicals, it is strongly suggested that use of chemicals in watercraft decontamination practice by the public are discontinued.

FIGURE 1.Typical Product Label
An example of a chemical that has been mentioned for use in decontamination. Proper use of a chemical is guided by the label; note highlighted areas below including "directions for use" and "environmental hazards".



BIBLIOGRAPHY

Anderson LG, AM Dunn, PJ Rosewarne and PD Stebbing. 2015. Invaders in hot water: a simple decontamination method to prevent the accidental spread of aquatic invasive non-native species. Biological Invasions 8:2287-2297.

Armed Forces Pest Management Board. 2017. Guide for Agricultural Preparation of Military Gear and Equipment for Redeployment. Technical Guide No.31. Office of Assistant Secretary of Defense. Silver Spring MD.

Barbour JH, S McMenamin, JTA Dick, ME Alexander and J Caffrey. 2013. Biosecurity measures to reduce secondary spread of the invasive freshwater Asian clam, *Corbicula fluminea* (Müller, 1774). Management of Biological Invasions 4: 219-230.

Beyer J, P Moy and B DeStasio. 2011. Acute Upper Thermal Limits of Three Aquatic Invasive Invertebrates: Hot Water Treatment to Prevent Upstream Transport of Invasive Species. Environmental Management. 47: 67-76.

Boethling R. 1984. Environmental fate and toxicity in wastewater treatment of quaternary ammonium surfactants. Journal of Water Research 9: 1061-1076.

Brady TJ, JE Van Benschoten and JN Jenson. 1996. Technical Note: Chlorination effectiveness for zebra and quagga mussels. Journal of the American Waterworks Association 107-110.

Britton D and Dingman. 2011. Use of quaternary ammonium to control the spread of aquatic invasive species by wildland fire equipment. Aquatic Invasions 2: 169-173.

Brown, E, editor. 2015. The Student Training Curriculum for Watercraft Inspectors and Decontaminators to Prevent and Contain the Spread of Aquatic Invasive Species. Colorado Parks and Wildlife, Denver, CO.

Brown, E, editor. 2015. The Trainer Manual for Aquatic Invasive Species Inspection and Decontamination Courses. Colorado Parks and Wildlife, Denver, CO.

Claudi R and DW Evans. 1993. Chemical addition strategies for zebra mussel *(Dreissena polymorpha)* control in once-through service water systems. In TF Nalepa and DW Schloesser (eds), *Zebra Mussels: biology, impact and control*, pp 563-574. Boca Raton, FL: Lewis Publishers.

Claudi R and GL Macki. 1994. Practical Manual for Zebra Mussel Monitoring and Control. Lewis Publishers, Boca Raton, FL. ISBN: 0-87371-985-9

Cofrancesco, Jr, AF, DR Reaves and DE Averett. 2007. Transfer of Invasive Species Associated with the Movement of Military Equipment and Personnel. US Army Corps of Engineers – Engineer Research and Development Center.

Costa R, DC Aldridge and GD Moggridge. 2008. Seasonal variation of zebra mussel susceptibility to molluscicidal agents. Journal of Applied Ecology 6:1712-1721.

Comeau S, S Rainville, W Baldwin, E Austin, S Gerstenberger, C Cross and WH Wong. 2011. Susceptibility of quagga mussels (*Dreissena rostriformis bugensis*) to hot-water sprays as a means of watercraft decontamination. Biofouling 27: 267- 274.

Comeau S, RS Ianniello, WH Wong and SL Gerstenberger. 2015. Boat decontamination with hot water spray: Field validation. In: Wong WH and SL Gerstenberger (eds), *Biology and Management of Invasive Quagga and Zebra Mussels in the Western United States,* pp 161-173. Boca Raton (FL): CRC Press.

Davis EA, WH Wong and WN Harman. 2017. Toxicity of potassium chloride compared to sodium chloride for zebra mussel decontamination. Journal of Aquatic Animal Health doi:10.1080/08997659.2017.1388866

Davis EA, WH Wong and WN Harman. 2016. Comparison of three sodium chloride chemical treatments for adult zebra mussel decontamination. Journal of Shellfisheries Research 3:1029-1036.

Davis EA, D Wong, and WN Harman. 2015. Distilled white vinegar (5% acetic acid) as a potential decontamination method for adult zebra mussels. Management of Biological Invasions 4: 423-428.

Divittorio J, M Grodowitz, J Snow and T Manross. 2012. Inspection and Cleaning Manual for Equipment and Vehicles to Prevent the Spread of Invasive Species. US Bureau of Reclamation Technical Memorandum No. 86-68220-07-05.

Edwards WJ, L Babcock-Jackson and DA Culver. 2002. Field testing of protocols to prevent the spread of zebra mussels *Dreissena polymorpha* during fish hatchery and aquaculture activities. North American Journal of Aquaculture doi: 10.1577/1548-8454(2002)064<0220:FTOPTP>2.0.CO;2

Edwards WJ, L Babcock-Jackson and DA Culver. 2000. Prevention of the spread of zebra mussels during fish hatchery and aquaculture activities. North American Journal of Aquaculture 62: 229-236.

Elwell LC and S Phillips, eds. 2016. Uniform Minimum Protocols and Standards for Watercraft Inspection and Decontamination Programs for Dreissenid Mussels in the Western United States (UMPS III). Pacific States Marine Fisheries Commission, Portland, OR.

Garrett WE and MM Laylor. 1995. The effects of low level chlorination and chlorine dioxide on biofouling in a once-through service water system. Proceedings, 5th International Zebra Mussel and Other Aquatic Nuisance Organisms Conference, pp 133-51.

Harrington DK, JE Van Benschoten, JN Jensen, DP Lewis and EF Neuhauser. 1997. Combined use of heat oxidants for controlling adult zebra mussels. Water Research 11: 2783-2791.

Hedrick RP, TS McDowell, K Mukkatira, E MacConnell and B Petri. 2008. Effects of freezing, drying, ultraviolet irradiation, chlorine, and quaternary ammonium treatments on the infectivity of myxospores of *Myxobolus cerebralis* for *Tubifex tubifex*. Journal of Aquatic Animal Health 2: 116-125.

Hosea, RC and B Finlayson. 2005. Controlling the spread of New Zealand mud snails on wading gear. California Department of Fish and Game, Office of Spill Prevention and Response, Administrative Report 2005-02, Sacramento, CA.

Interagency Standards Group. 2016. Interagency Standards for Fire and Fire Aviation Operations. National Interagency Fire Center, Boise, ID.

Jerde CL, MA Barnes, EK DeBuysser and A Noveroske. 2012. Eurasian watermilfoil fitness loss and invasion potential following desiccation during simulated overland transport. Aquatic Invasions 1: 135-142.

Johnson, LE, A Ricciardi, and JT Carlton. 2001. Overland dispersal of aquatic invasive species: A risk assessment of transient recreational boating. Ecological Application 11: 1789-1799.

Klerks and Fraleigh. 1991. Controlling adult zebra mussels with oxidants. Journal of American Waterworks Association 12: 92-100.

Mari L, E Bertuzzo, R Casagrandi, M Gatto, SA Levin, I Rodriquez-Iturbe, and A Rinaldo. 2011. Hydrologic controls and anthropogenic drivers of the zebra mussel invasion of the Mississippi-Missouri river system. Water Resources Research 47: 1-16.

Martin ID, GL Mackie and MA Baker. 1993. Control of biofouling mollusk, *Dreissena polymorpha* (Bivalvia: Dreissenidae), with sodium hypochlorite and with polyquaternary ammonia and benzothiazole compounds. Archives of Environmental Contamination and Toxicology 24: 381-388.

Matisoff G, G Brooks and BI Bourland. 1996. Toxicity of chlorine dioxide to adult zebra mussels. Journal of American Water Works 93-106.

Moffitt CM, A Barenberg, KA Stockton and BJ Watten. 2015. Efficacy of two approaches for disinfecting surfaces and water infested with quagga mussel veligers. In: WH Wong and SL Gerstenberger (eds), *Biology and Management of Invasive quagga and zebra mussels in the Western United States*, pp 467-477. Boca Raton (FL): CRC Press.

Moffitt CM, KA Stockton-Fiti and R Claudi. 2016. Toxicity of potassium chloride to veliger and byssal stage dreissenid mussels related to water quality. Management of Biological Invasions 3: 257-268.

Pucherelli SF, DE Portz, K Bloom, J Carmon, S Brenimer and D Hosler. 2014. Quagga mussel contamination of fish haul trucks by fish and development of effective potassium chloride and formalin treatments. Journal of Applied Aquaculture 26: 132-148.

Rajagopal S, G van der Velde and HA Jenner. 2002. Effects of low-level chlorination on zebra mussel, *Dreissena polymorpha*. Water Research 36: 3029-3034.

Schisler GJ, NKM Vieira and PG Walker. 2008. Application of Household Disinfectants to Control New Zealand Mudsnails. North American Journal of Fisheries Management 28: 1172-1176.

Showalter Otts S and P Nanjappa, eds. 2014. Preventing the spread of aquatic invasive species by recreational boats: Model legislative provisions and guidance to promote reciprocity among state watercraft inspection and decontamination programs. National Sea Grant Law Center, University, MS.

Showalter Otts S and P Nanjappa, eds. 2016. Model regulation for state watercraft inspection and decontamination programs. National Sea Grant Law Center, University, MS.

Showalter Otts S, and C Janasie. 2017. From Theory to Practice: A Comparison of State Watercraft Inspection and Decontamination Programs to Model Legislative Provisions. Sea Grant Law Center, NSGLC – 14-05-09.

Stockton KA and CM Moffitt. 2013. Disinfection of three wading boot surfaces infested with New Zealand mudsnails. North American Journal of Fisheries Management 33: 529-538.

Stout JB, NKM Vieira, and PG Walker. 2008. Efficacy of commercially available quaternary ammonium compound for controlling New Zealand mudsnails *(Potamopyrgus antipodarum)*. North American Journal of Fisheries Management 36: 277-284.

Takeguchi W, S Liang and R Yates. 2012. Evaluating potential quagga mussel control measures in Colorado River water. Journal American Water Works Association 104: E162-E172.

US Army Corps of Engineers. 1998. Zebra Mussel Research Technical Notes: Chemical Control Research Strategy for Zebra Mussels. Technical Note ZMR-3-18. US Army Corps of Engineers, Waterways Experiment Station.

Van Benschoten JE, J Jensen, D Harrington, and DJ DeGriolamo. 1995. Zebra mussel mortality with chlorine. Journal of the American Waterworks Association 101-108.

Waller DL and SW Fisher. 1998. Evaluation of several chemical disinfectants for removing zebra mussels from unionid mussels. The Progressive Fish-Culturist 60: 307-310.

Waller DL, JJ Rach, WG Cope, LL Marking, SW Fisher, and H Dabrowska. 1993. Toxicity of candidate molluscicides to zebra mussels *(Dreissena polymorpha)* and selected nontarget organisms. Journal of Great Lakes Research 4: 695-702.

Waller DL, SW Fisher and H Dabrowska. 1996. Prevention of zebra mussel infestation during aquaculture operations. The Progressive Fish-Culturist 58: 77-84.

Washington Department of Fish and Wildlife. 2012. Invasive Species Management Protocols, Version 2.

Watters A, SL Gerstenberger and WH Wong. 2013. Effectiveness of EarthTec® for killing invasive quagga mussels *(Dreissena rostriforumis bugensis)* and preventing their colonization in the Western United States. Biofouling : The Journal of Bioadhesion and Biofilm Research 29: 21-28.

Western Regional Panel on Aquatic Nuisance Species. 2010. Quagga-Zebra Mussel Action Plan for Western Waters.

Wildridge PJ, RG Werner, FG Doherty and EF Neuhauser. 1998. Acute toxicity of potassium to the adult zebra mussel, *Dreissena polymorpha*. Environmental Contamination and Toxicology 34: 265-270.

Wisconsin Department of Natural Resources. 2017. Boat, Gear and Equipment Decontamination and Disinfection Protocol, Manual Code #9183.1.

Zhang C, Cui F, Zeng GM, Jiang M, Yang ZZ, Yu ZG, Zhu MY, and Shen LQ. Quaternary ammonium compound (QACs): A review on occurrence, fate and toxicity in the environment. Science of the Total Environment 518-519: 352-62.