

FOR RESOURCE ADVISORS

PREVENTING SPREAD OF AQUATIC INVASIVE ORGANISMS COMMON TO THE INTERMOUNTAIN REGION

2014 TECHNICAL GUIDELINES FOR FIRE OPERATIONS

The following guidelines were developed for fire personnel to help them avoid the spread of aquatic invasive species during fire management and suppression activities. These *technical* guidelines are intended for use by Resource Advisors, biologists, and other resource specialists and supplement the five page “*Operational Guidelines for 2014 Fire Activities*” prepared for fire managers. The amount of detail and technical information presented here is necessary to document the science behind the protocols, and to keep a record of sources of information.

Because of the large expanses over which fire crews and their equipment travel, the potential for firefighters to serve as vectors for invasive species is significant. The aquatic invasive species considered here were selected based on their current significance in the intermountain area and do not include fish. These guidelines are based on what we know about prevention methods for common species and are refined and revised over time as needed.

All documents are available on the Region 4 Aquatic Invasive Species website

http://www.fs.usda.gov/detail/r4/landmanagement/resourcemanagement/?cid=fsbdev3_016101

The **NEW 2014 Appendix** (*AQUATIC INVASIVE SPECIES of Concern to Firefighters NATIONWIDE and Methods of Control*, pg. 7) outlines specific, updated disinfection treatments for each species and the sources of information.

ABOUT THE SOURCES OF INFORMATION USED IN THIS GUIDANCE

The methodologies and decontaminants recommended in this guidance derive from primary data sources, either peer-reviewed or published original studies, research studies that are in press or review, or in some cases, personal communication with researchers from established institutions who are currently working with a particular invasive species. Sources of information for each species are listed in the new 2014 *Appendix* (pg 7) and under References. Information was not borrowed or passed on from other protocols without first tracing it to its source of origin and assuring its validity.

USING HOT WATER

As the 2014 operational guidelines show, the preferred method for equipment decontamination has become spraying or flushing with hot water. Chemical disinfectants, while effective, are problematic to handle, purchase, and are corrosive to aluminum parts in aircraft. Disposal of large volumes of used quat solution is difficult because of their toxicity to aquatic life and regulations that vary by state.

USING CHEMICAL DISINFECTANTS

SAFETY

- Use protective, unlined rubber gloves and splash goggles or face shield when handling the cleaning solution and take extra precautions when handling undiluted chemicals. Have eye wash and clean water available on-site to treat accidental exposure.
- Consult the product label and Material Safety Data Sheet for additional information. MSDS data sheets are provided at:
http://www.fs.usda.gov/detail/r4/landmanagement/resourcemanagement/?cid=fsbdev3_016113

- *Using Chlorine Bleach: Mixing any chlorine-containing compounds (including any form of household bleach or dry form of chlorine) with any ammonia-containing compounds (including fire retardant mixes or residues, and quaternary ammonium compounds) can lead to extreme health and safety hazards, including the release of chlorine gas.*

QUATERNARY AMMONIUM COMPOUNDS

Quaternary ammonium compounds, or ‘quats’, are common disinfectants with an array of uses, from killing algae in swimming pools to sanitizing workout equipment at the gym. They are relatively nontoxic and do not damage fabric, metals (but see below), or gaskets. Solutions of quat compounds retain their effectiveness over days and can be reused if not excessively diluted. These compounds exist as a family with various ratios of carbon to nitrogen and chlorine. There are hundreds, but much of research for their effectiveness against aquatic invasive species has focused so far on one of the alkyl dimethyl benzylammonium chlorides, abbreviated as ADBAC, the active ingredient in Formula 409[®]. Formula 409[®] was selected to test against whirling disease and New Zealand mudsnails because it was thought to be easy to

obtain for anglers, but this household product is not practical for land management use. However, ADBAC, along with other quaternary ammonium compounds, also occurs in *Sanicare Quat 128*[®] (Buckeye International), *Sparquat 256*[®] (Spartan Co.), *Green Solutions High Dilution 256*[®] (Spartan Co.), *BioGuard Algicide 28-40*[®], and other commercial disinfectants.

Another quaternary ammonium compound, diacyl dimethyl ammonium chloride, or DDAC, was tested against chytrid fungus and found to be effective (see below). DDAC also occurs in *Sanicare Quat 128*[®], *Sparquat 256*[®], *Green Solutions High Dilution 256*[®], and *BioGuard Algicide 28-40*[®].

New Quaternary Ammonium Products

Some new formulations of quat compounds are now on the market that have disinfective properties comparable to older products. Recently *Sparquat 256*[®] was discontinued by the manufacturer, and it is no longer possible to obtain it. *Sparquat* was replaced, however, with *Green Solutions High Dilution 256*[®], a disinfectant with the identical blend of quaternary ammonium compounds as *Sparquat* but at a higher concentration (and without some of the additives). Consequently, the Methods of Control table has been updated to include recommended dilutions for *Green Solutions*. Another product, *HDQ*[®] (Spartan Co.) is a quat formulation identical to *Sanicare Quat 128*[®] and can be used interchangeably with it. A more concentrated version, *Super HDQ*[®], is twice as concentrated as *HDQ*[®].

Corrosive properties

Quaternary ammonium compounds are useful in that they do not damage plastics, canvas, or rubber gaskets and seals. However, in 2012 quat compounds did not meet corrosion requirements for aluminum and **should not be used in aircraft** (e.g. fixed-tank helicopters or air tankers) until further review by manufacturers has occurred. Quat compounds, nevertheless, are safe for helicopter buckets and ground-based tanker equipment. See ['Effects of the Quaternary Ammonium Disinfectant Green Solutions High Dilution \(1.8%\) on Metals and Non-Metallic Materials used in Fire Operations'](#).

Disposal

Use caution when disposing the used cleaning solution and follow all federal, state, and local regulations. Do not dump treated water into any stream or lake, or on areas where it can migrate into any water body. Do not dispose large volumes of diluted quat chemicals in municipal sewer systems. While wastewater treatment plants can process small volumes of used quat solutions, large volumes (hundreds of gallons) of quat solutions could overwhelm a treatment facility, especially ones in small towns (Ron Cook, Spartan Chemical Co., pers. comm.). Consult the facility operator/manager prior to disposal.

Whirling disease and quaternary ammonium compounds

The effectiveness of quaternary ammonium compounds against whirling disease spores is based on research by Ronald Hedrick of University of California-Davis (Hedrick et al. 2008). He tested the active ingredient in Formula 409[®] (ADBAC), and found it to efficiently kill spores in 10 minutes at a concentration of 1500 ppm. The commercial quaternary ammonium products recommended in this guidance contain ADBAC as well as other quaternary compounds which may be quite good at killing spores but that have not been tested. Hedrick (pers. comm.) assumes that the other compounds would function similarly with respect to damaging the

spores and thus provide an additive effect in a mixed formulation such as *Sanicare Quat 128*[®] or *Green Solutions High Dilution 256*[®], but because his testing was limited specifically to ADBAC, there is currently no proof that the other compounds would have the same effects as ADBAC.

Chytrid fungus and quaternary ammonium compounds

The quaternary ammonium compound used as the active ingredient against chytrid fungus was a different one than was tested for whirling disease. For chytrid, Johnson et al. (2003) used DDAC. Both DDAC and the compound tested for whirling disease and New Zealand mudsnails, ADBAC, occur together in *Quat 128*[®], *Sparquat 256*[®], and *Green Solutions High Dilution 256*[®] (the latter two have some other quat compounds as well). Consequently, the technical information and calculations for chytrid fungus are derived from DDAC and are shown separately on the spreadsheet.

Didymo and quaternary ammonium compounds

The only evidence we have about the effectiveness of quat products for didymo decontamination comes from New Zealand's *National Institute of Water and Atmospheric Research* (NIWA). Though NIWA did not study quat compounds directly, they reference a small study that suggested that a quat compound similar to one found in *Quat 128*[®] is very effective against didymo. However, neither *Sanicare Quat 128*[®], *Sparquat 256*[®], nor *Green Solutions High Dilution 256*[®] was tested directly. A white paper from Vermont Agency of Natural Resources (see [Matthews 2007](#)) rationalizes the probable effectiveness of quaternary ammonium compounds for didymo and proposes additional research.

How to Test the Concentrations of *Sanicare Quat 128*[®], *Sparquat 256*[®], or *Green Solutions High Dilution 256*[®] Solutions [NOTE: this recipe was corrected in 2013!]

When a large volume of quat solution (as in a pumpkin) has been used repeatedly and possibly diluted with excess water or mud, the solution can lose its effectiveness.

To determine if the solution is at the correct strength, use “Quat Chek 1000” Test Papers, which function like Litmus paper (see below for suppliers). The cleaning solution needs to be diluted before it can be tested with these papers. To do this:

For *Sanicare Quat 128*[®], *Sparquat 256*[®], or *Green Solutions High Dilution 256*[®]:

- Add ¼ cup (2 oz) of the quat solution to a gallon of water. Mix. Test the diluted solution with “Quat Chek 1000” Test Paper. Match up the color of the paper with the ppm's on the color chart. For optimal disinfection, the diluted *Sparquat 256*[®] or *Green Solutions High Dilution 256*[®] solution should have a concentration of between **400 and 600 ppm**; the diluted *Sanicare Quat 128*[®] solution should have a concentration between **600 ppm and 800 ppm**.



Storage and Shelf-Life

Sparquat 256[®], *Green Solutions High Dilution 256*[®], and *Sanicare Quat 128*[®] can be stored at least 2 years in unopened containers without losing their effectiveness. They should be stored in a cool, dry place, out of direct sunlight. Temperatures can range from 32 to 110 F.

Once the quat solution is made up, it can be used repeatedly for up to a week unless heavily muddied or diluted. To monitor the solution's effectiveness, use *Quat Chek 1000 Test Papers* (see above). Solutions kept in sealed containers, free of contamination by foreign materials, remain more stable and can be effectively used for longer timeframes (Ron Cook, Spartan Chemical Co., personal communication).

CHLORINE BLEACH

Important note: Mixing any chlorine-containing compounds (including any form of household bleach or dry form of chlorine) with any ammonia-containing compounds (including fire retardant mixes or residues, and quaternary ammonium compounds) can lead to extreme health and safety hazards, including the release of chlorine gas.

Liquid bleaches, such as household bleach, are a 5—8% solution of sodium hypochlorite, a stabilized form of chlorine. Chlorine products are not emphasized for use in these guidelines because of their corrosiveness to fabrics, plastics, rubber, and metal; the rapid dissipation of disinfectant properties when exposed to air, and their limited effectiveness against New Zealand mudsnails. However, bleaches are extremely effective against certain invasive organisms (see Appendix—*Aquatic Invasive Species of Concern to Firefighters Nationwide and Methods of Control*), and are relatively inexpensive.

SUPPLY SOURCES

The recommended chemicals are available through GSA (<https://www.gsaadvantage.gov>) or through local janitorial chemical suppliers.

Green Solution High Dilution 256[®] (replaces *Sparquat 256*[®])

Spartan Chemical Company

GSA (NSN No. 3508-1) = \$68 per case (4 gal) = \$17 per gal

EPA registration #1839-169-5741. Additional info at <http://www.spartanchemical.com>

Sanicare Quat 128[®] (Buckeye)

Buckeye International Inc.

EPA registration # 47371-130-559 Additional info at <http://www.buckeyeinternational.com>

Bell Janitorial Supply 801-394-5559 <http://www.bellclean.com> = \$20 per gal

HDQ[®] (identical to *Sanicare Quat 128*[®])

Spartan Chemical Company

GSA (No. 101-1202) = \$52 per case (4 gal) = \$13 per gal

EPA registration # 10324-155-5741 Additional info at <http://www.spartanchemical.com>

Super HDQ[®] (twice as concentrated as *Sanicare Quat 128*[®])

Spartan Chemical Company

GSA (No. 1204-04) = \$64 per case (4 gal) = \$16 per gal

EPA registration # 10324-141-5741 Additional info at <http://www.spartanchemical.com>

pHydrion[®] Quat Test 1000 Papers (0-1000 ppm Hi-Range)

(These papers are NOT available from GSA. GSA only has the papers for low concentrations)

- Microessential Labs (<https://www.microessentiallab.com/ProductInfo/W20-QUATT-QUATCK-SRD.aspx>) \$47 for 10 kits. Each 'kit' provides 150 tests.
- Grainger, Inc. (<http://www.grainger.com/Grainger/items/3UDF5?Pid=search>) \$51 for 10 kits. Each 'kit' provides 150 tests.

Liquid household bleach

Grocery stores, prices and strength vary

NEW 2014 Appendix:

AQUATIC INVASIVE SPECIES of Concern to Firefighters NATIONWIDE and Methods of Control —the species fire operations are most likely to encounter, their distributions, all disinfection methods, and references.

Zebra & Quagga Mussels

Dreissena polymorpha &
Dreissena rostriformis bugensis



Photo credit: The Nature Conservancy

Zebra & Quagga Mussels

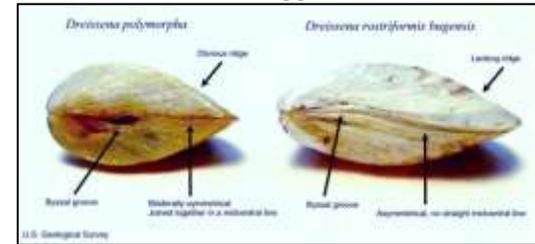


Photo credit: U.S. Geological Survey

General Information:

- **Quagga Mussel Distribution:** CA, NV, UT, AZ, CO, NM, OK, TX, midwest, Great Lakes region and NE US. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/>
- **Zebra Mussel Distribution:** CA, UT, CO, OK, KS, NE, SD, ND, LA, AR, MO, IA, MN, MS, TN, AL, KY, IN, other midwest and Great Lakes regions and NE US. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/taxgroup/mollusks/zebramussel/>
- **Habitat:** Both mussels attach to hard surfaces in temperate lakes and slow rivers. Microscopic mussel larvae are released into open water where they swim about for several days before settling.
- **Fire Activities Posing Risk:** Most concern is with microscopic larvae present in water column. Larvae can survive for 5 days in internal tanks with residual water (summer months). Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water
- **Environmental Impacts:** Zebra and quagga mussels colonize water supply pipes and biofoul hydroelectric and nuclear power plants, public water plants, and industrial facilities. These species remove nutrients in aquatic ecosystems and litter beaches with sharp-edged shells.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p>HOT WATER SPRAY <u>To kill Quagga or Zebra mussel adults</u> ≥ 140°F (60°C) for 5 to 10 seconds</p> <p><u>To kill Quagga/Zebra mussel free-swimming larvae</u> ≥ 140°F (60°C) likely to be ‘instantly lethal’</p> <p>HOT WATER IMMERSION: <u>To kill Quagga/Zebra mussel adults and free-swimming larvae</u> ≥ 120°F (50°C) for 1 minute</p>	<p>Comeau et al. 2011 (quagga adults); Morse 2009 (zebra adults)</p> <p>R. McMahon, pers. comm. (2014)</p> <p>Beyer et al. 2011</p>	

Zebra & Quagga Mussels

Methods of Control for Firefighters	Details of Method	References	Notes
	<p>FREEZING ≤ 32°F (0°C) for 48 hours or more for adults</p>	<p>McMahon 1996</p>	
<p>Drying</p>	<p>In summer, 5 days survival time for larvae in internal tanks with residual water; in cooler months; 28 days</p>	<p>Choi et al. 2013</p>	
<p>Mechanical</p>	<p>Scraping, brushing, hot water pressure washing to flush larvae</p>	<p>Comeau et al. 2011 and multiple sources</p>	
<p>CHEMICALS</p>			
<p>Quaternary ammonium Compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; dicyl dimethyl ammonium chloride [DDAC])</p>	<p><u>To kill Quagga mussel larvae:</u></p> <p><i>3.1% Sparquat256® solution</i> Mixing instructions: 4.3 oz per 1 gallon water 3.4 gallons per 100 gallons water Contact time = 10 minutes</p> <p>OR</p> <p><i>1.8% Green Solutions High Dilution 256® solution</i> Mixing instructions: 2.5 oz per 1 gallon water 1.9 gallons per 100 gallons water Contact time = 10 minutes</p>	<p>Britton and Dingman 2011</p> <p>Britton and Dingman 2011</p>	<p>Quat compounds methods are specifically for larvae likely found in the water column.</p> <p>Quat Compounds can corrode aluminum; not for use on aircraft equipment</p>
<p>Bleach (e.g. Clorox®) 6% sodium hypochlorite</p>	<p><i>0.5% bleach solution</i> (250 ppm sodium hypochlorite) Mixing instruction: 0.6 oz bleach per 1 gallon water 1.1 Tablespoons of bleach per gallon water ½ gallon bleach per 100 gallons water Contact time = rinse only, no time specified.</p>	<p>Modovski 2011 (Based on Cope et al, 2003 which cited Gatenby 2000.</p>	<p>Bleach is corrosive to gear and metals</p>

Zebra & Quagga Mussels

Methods of Control for Firefighters	Details of Method	References	Notes
Other Disinfectants	<p><u>To kill Quagga mussel adults & larvae:</u></p> <p>2% <i>Virkon Aquatic</i>® solution Mixing instructions: 20 g/liter 76g per 1 gallon of water 760g per 100 gallons water Contact time = 10 minutes</p> <p><u>To kill Quagga mussel larvae only:</u></p> <p>0.5% <i>Virkon Aquatic</i>® solution Mixing instructions: 5 g/liter 19g per 1 gallon of water 190g per 100 gallons water Contact time = 10 minutes</p>	Stockton 2011	Virkon is corrosive to soft metals. Although not specifically tested, may not be applicable for use on aircraft equipment

Asian Clam
Corbicula fluminea



Photo credit: Noel M. Burkhead-USGS



Photo credit: Flyforums.co

General Information:

- **Distribution:** Almost all US states except MT, ND and ME. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov//queries/FactSheet.aspx?speciesID=92>
- **Habitat:** Lakes and streams, buried in sediments or larvae and juveniles drifting in currents
- **Fire Activities Posing Risk:** Most concern is with larvae and juvenile clams in swept into water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impacts:** Asian clams can biofoul power plant and industrial water systems. Juveniles secrete a mucousy dragline and can be easily transported in currents. The clams also clog irrigation canals and drinking water pipes.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p><u>To kill Asian clam larvae and small juveniles:</u></p> <p>HOT WATER It is probable that a hot water spray $\geq 140^{\circ}\text{F}$ (60°C) for a few seconds would be lethal. No scientific study reports effectiveness.</p> <p>Flushing equipment with hot water would remove larvae and juveniles, which are easily entrained in flowing water.</p> <p><u>To kill Asian clam adults:</u> $\geq 109^{\circ}\text{F}$ (43°C) for 30 minutes</p>	<p>R. McMahon, pers. comm. (2014)</p> <p>McMahon and Williams 1986</p> <p>Mattice and Dye 1975</p>	

Methods of Control for Firefighters	Details of Method	References	Notes
Drying	Dry gear in air for 14–27 days in cool weather; much shorter dry times in full sun	McMahon and Williams 1984	
Mechanical	Scraping, brushing, remove all plant material	Multiple sources	
CHEMICALS	Though chemicals are used in hydroelectric facilities, Asian clams are resistant to chemicals: decontamination times are lengthy and kill rates < 100%.	For example, Barbour et al. 2013	

New Zealand Mudsnail
Potamopyrgus antipodarum



General Information:

- **Distribution:** WA, OR, CA, ID, MT, WY, UT, NV, AZ, CO, MN, IL, OH, PA, NY, and Canada. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/taxgroup/mollusks/newzealandmudsnaildistribution.aspx>
- **Habitat:** Streams and lakes, occurring on rocky substrates as well as aquatic plants.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental impacts:** Mudsnails reproduce very quickly. It only takes a SINGLE snail can result in a colony of more than 40 million snails in just one year. New Zealand mudsnails can smother a streambed, crowding out the native aquatic species that provide food for fish.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p>HOT WATER: ≥ 122°F (50°C) for 15 seconds</p> <p>FREEZING: ≤ 27°F (-3°C) for 1 to 2 hours</p>	<p>Dwyer et al. 2003</p> <p>Richards et al. 2004</p>	
Drying	<p>Dry gear in full sunlight for ≥ 50 hours</p> <p>Dry gear at 86°F (30°C) for 24hours</p> <p>Dry gear at ≥ 104°F (40°C) for at least 2 hours</p>	<p>Alonso and Castro-Diez 2012</p> <p>Richards et al 2004</p>	

Methods of Control for Firefighters	Details of Method	References	Notes
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; dicyl dimethyl ammonium chloride [DDAC])	<p><u>4.6% Sanicare Quat128[®] solution</u> Mixing instructions: 6.4 oz per 1 gallon water 5 gallons per 100 gallons water Contact time = 10 minutes OR <u>3.1% Sparquat256[®] solution</u> Mixing instructions: 4.3 oz per 1 gallon water 3.4 gallons per 100 gallons water Contact time = 10 minutes OR <u>1.8% Green Solutions High Dilution 256[®] solution</u> Mixing instructions: - 2.5 liquid oz. per 1 gallon water - 1.9 liquid gallons per 100 gallons water Contact time = 10 minutes</p>	Schisler et al. 2008	Quat Compounds can corrode aluminum; not for use on aircraft equipment
Bleach (e.g. Clorox [®]) 6% sodium hypochlorite	Not effective	Hosea and Finlayson 2005	

Methods of Control for Firefighters	Details of Method	References	Notes
Other Agents	2% <i>Virkon Aquatic</i> ® solution Mixing instructions: 77g per 1 gallon of water 770 g per 100 gallons water Contact time = 15-20 minutes	Stockton and Moffitt 2013	Virkon is corrosive to soft metals. Although not specifically tested, may not be applicable for use on aircraft equipment

Malaysian Trumpet Snail
Melanoides tuberculata

Also called: Red Rimmed Melania, Red Lipped Melania



Photo credit: Alex Kawazaki



Photo credit: Flickrriver.com

General Information:

- **Distribution:** AZ, CA, CO, FL, HI, LA, MT, NC, NV, OR, UT, TX (possible in SD, VA and WY). For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1037>
- **Habitat:** Slow moving rivers and lakes, on mud and plants
- **Fire Activities Posing Risk:** Risks include: helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** This trumpet snail can out-compete native snails and alter ecosystem functions

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p>HOT WATER: <u>To kill snails of all sizes</u> 122 °F (50°C) for 4-5 minutes</p> <p>FREEZING: Freezing in Ice water for 12-24 hours Freezing in salty ice water for 2 hours</p>	<p>Mitchell and Brandt 2005</p> <p>Mitchell and Brandt 2009</p>	
Drying	Very resistant to drying, >20 days	Mitchell and Brandt 2005	
Mechanical	Scraping, brushing, hot water pressure washing	Multiple sources	

Methods of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Mitchell et al. 2007	

Oriental Mystery Snail
Cipangopaludina spp.

Also called: **Chinese Mystery Snail**



Photo credit: Cornell University



Photo credit: Oregon Dept of Fish and Wildlife

General Information:

- **Distribution:** WA, OR, CA, ID, UT, AZ, CO TX, NE, MO, GA, FL, NC, Great Lakes region, and northeastern US. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=1044>
- **Habitat:** Slow moving rivers and lakes, on mud and plants. Readily transported by equipment infested with snails hitchhiking on aquatic plants.
- **Fire Activities Posing Risk:** Helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** These snails form dense populations and outcompete native species for food and habitat. They are intermediate hosts for parasitic worms and can transmit diseases that kill waterfowl. Some mystery snails prey on fish embryos. Snail shells often litter shorelines and clog screens of water intakes.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122 °F (50°C) for 4-5 minutes	J. Havel, pers. comm. (2014)	
Drying	14 to ≥28 days, depending on snail size. Larger snails very resistant to drying.	Havel 2011	
Mechanical	Scraping, brushing, clean off all plant material	Multiple sources	

Oriental Mystery Snail

Method of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	No known studies, but as with other snails with sealing flaps (e.g. New Zealand mudsnails, trumpet snails), likely not effective		

Faucet Snail
Bithynia tentaculata



Photo credit: Amy Benson-USGS

General Information:

- **Distribution:** Great Lakes Region, WI, PA, NY, VT, VA, MD, and MT. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/queries/FactSheet.aspx?speciesID=987>
- **Habitat:** Slow moving rivers and lakes, on mud and plants. Readily transported by equipment infested with snails hitchhiking on aquatic plants.
- **Fire Activities Posing Risk:** Helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** These snails outcompete native species for food and habitat in lakes and streams. They are intermediate hosts for parasitic worms and transmit diseases that kill waterfowl. Where abundant they infest municipal water supplies.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122 °F (50°C) for ≥1 minute	Mitchell and Cole 2008	
Drying	Dry gear for 14 to 21 days	Mitchell and Cole 2008	
Mechanical	Scraping, brushing, clean off all plant material	Multiple sources	
CHEMICALS			
Quaternary ammonium Compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Mitchell and Cole 2008	

Faucet Snail

Method of Control for Firefighters	Details of Method	References	Notes
Other agents	<i>Virkon</i> ® Not effective	Mitchell and Cole 2008	

Spiny Waterflea
Bythotrephes longimanus



General Information:

- **Distribution:** Primarily in the Great Lakes Region of the US. For most up-to-date information on distribution, please see: <http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=162>
- **Habitat:** Waterflea plankton (adults and juveniles) are free-swimming in water column of ponds and lakes; dormant (resting) eggs are in mud or silt.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Impact:** The rapidly reproducing spiny waterflea competes with small fish and fouls fishing gear. Larger fish that feed on waterfleas may die due to punctures from spines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER To kill adults, juveniles, and resting eggs: ≥ 122°F (50°C) for 5 minutes 140°F (60°C) for 1 minute	Branstrator et al. 2013 (resting eggs) Beyer et al. 2011 (plankton)	
Drying	Dry gear for ≥6 hours (planktonic adults and juveniles, and resting eggs)	Branstrator et al. 2013 (resting eggs) Branstrator, D.K., pers. comm. 2014; (plankton)	
Mechanical	Scraping, brushing, removal of organic and plant materials.	Multiple sources	

Spiny Water Flea

Methods of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds	No known studies		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	Not effective	Branstrator et al. 2013	

Didymo

Didymosphenia geminata



Photo credit: USGS



Photo credit: Biosecurity New Zealand

General Information:

- **Distribution:** WA, OR, CA, ID, MT, WY, CO SC, ND, AR, NC, VA WV PA, NY, NH, CT, AK, and Canada. For most up-to-date information on distribution, please see: <http://www.invasivespeciesinfo.gov/aquatics/didymo.shtml>
- **Habitat:** Didymo is a single cell alga that attaches to submerged rocks in cold streams and rivers.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water. Didymo can survive in residual tank water for <2 days in summer but up to 45 days in autumn (Kilroy et al. 2007).
- **Environmental Risk:** Didymo forms dense mats that trail downstream and can completely cover the substrate, smothering native plants, insects, and mollusks..

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p>HOT WATER: 113°F (45°C) for 20 minutes 140°F (60°C) for 1 minute</p> <p>FREEZING: 28°F (-2°C) for 4 hours ; 5°F (-15°C) for 2hours</p>	<p>Kilroy et al. 2007</p> <p>Kilroy et al. 2007</p>	
Drying	Dry external surfaces and internal tanks for 48 hours in summer	Kilroy et al. 2007	
Mechanical	Scraping, brushing, removal of organic and plant materials.		
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium)	<p>2.0 % <i>Sanicare Quat128</i>[®] solution</p> <p>Mixing instructions: 2.4 oz per 1 gallon water 1.9 gallons per 100 gallons water</p> <p>Contact time = 1 minute</p>	Matthews 2007, derived from Kilroy et al. 2007	

Methods of Control for Firefighters	Details of Method	References	Notes
chloride [ADBAC]; dicyl dimethyl ammonium chloride [DDAC])	<p>OR</p> <p><i>1.2% Sparquat256[®]</i> solution Mixing instructions: 1.7 oz per 1 gallon water 1.3 gallons per 100 gallons water Contact time = 1 minute</p> <p>OR</p> <p><i>0.7% Green Solutions High Dilution 256[®]</i> solution Mixing instructions: 1.0 oz per 1 gallon water 0.8 gallons per 100 gallons water Contact time = 1 minute</p>		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	<p><i>2.0% bleach solution</i> (800 ppm sodium hypochlorite) Mixing instructions: 1.8 oz bleach per 1 gallon water 3.6 Tablespoons bleach per gallon water 1.4 gallon bleach per 100 gallons water Contact time = 1 minute</p>	Root and O'Reilly 2012	≥90% effective in killing didymo; corrosive to fabric and metals
Other Disinfectants	<p><i>1% Virkon Aquatic[®]</i> 10 g/liter Contact time = 10 minutes</p> <p><i>Greenworks</i> dish detergent: 5% solution for 1 minute</p> <p><i>Dawn</i> dish detergent: 5% solution for 1 minute</p>	Root and O'Reilly 2012	~80% effective ≥95% effective ≥95% effective

Chytrid fungus
Batrachochytrium dendrobatidis



Photo credit: Microbiologybytes



Photo credit: DPIW.fas.gov.au

General Information:

- **Distribution:** Chytrid fungus occurs on most continents
- **Habitat:** Zoospores are free-swimming in water column and can survive in wet mud or silt.
- **Fire Activities posing risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** This aquatic fungus feeds on living vertebrates and primarily affects the skin of amphibians. Because amphibians breathe and take up water through their skin, the disease causes widespread amphibian declines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	HEAT 140°F (60°C) for 5 minutes (tested in incubators)	Johnson et al. 2003	
Drying	Dry gear for ≥3 hours; in sunlight is best.	Johnson et al. 2003	
Mechanical	Scraping, brushing, removal of organic and plant materials.		
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; dicyl dimethyl ammonium chloride [DDAC])	0.15% <i>Sanicare Quat128</i> [®] solution Mixing instructions: 0.02 oz per 1 gallon water 1/8 teaspoon per 1 gallon water Contact time = 30 seconds OR 0.04% <i>Sparquat256</i> [®] solution Mixing instructions: 0.06 oz per 1 gallon water	Johnson et al. 2003.	

Methods of Control for Firefighters	Details of Method	References	Notes
	0.36 teaspoon per gallon of water Contact time = 30 seconds OR <i>0.02% Green Solutions High Dilution 256[®]</i> solution Mixing instructions: - 0.03 oz per 1 gallon water - 0.2 teaspoon per 1 gallon water Contact Time = 30 seconds		
“Regular Clorox [®] Bleach” 6% sodium hypochlorite	<i>22% bleach solution</i> (1.2% sodium hypochlorite) Mixing instructions: 1 part bleach:4 parts water 26 oz bleach per 1 gallon water 20 gallons bleach per 100 gallons water Contact time = 5 minutes	Ultra Clorox [®] Label (EPA Reg #5813-50)	These mixing instructions are approved by EPA specifically for chytrid fungus
“Clorox [®] Germicidal Bleach” 8.25% sodium hypochlorite	<i>22% bleach solution</i> (1.2% sodium hypochlorite) Mixing instructions: 1 part bleach:5.5 parts water 20 oz bleach per 1 gallon water 15.4 gallons bleach per 100 gallons water Contact time = 5 minutes	Germicidal Healthcare Clorox [®] label (EPA Reg. No. 5813-100)	These mixing instructions are approved by EPA specifically for chytrid fungus
Other Disinfectants	<i>0.1% Virkon[®]</i> 1 g/liter Contact time = ≥ 2 seconds	Johnson et al. 2003	

Whirling Disease

Myxobolus cerebralis

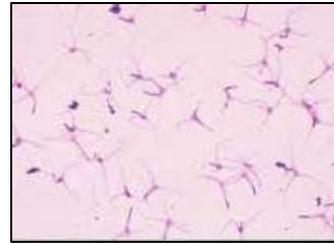


Photo credit: Colorado Parks and Wildlife

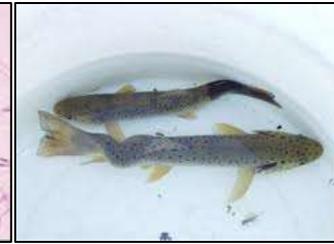


Photo credit: Colorado Parks and Wildlife

General Information:

- **Distribution:** WA, OR, CA, ID, NV, AZ, NM, UT, CO, NE, WY, ID, MT, MI, WI, OH, WV, VA, DE, MD, PA, NJ, CT, NY, MA, VT, NH, AK. For most up-to-date information on distribution, please see: <http://www.invasivespeciesinfo.gov/microbes/whirling.shtml>
- **Habitat:** Free-swimming microscopic larvae occur in water column, resistant spores in mud and bottom sediments. Spores can remain viable in mud for 12 years.
- **Fire Activities Posing Risk:** Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Whirling disease afflicts trout species, causing spinal distortions and population declines.

Disinfection Protocols:

Methods of Control for Firefighters	Details of Method	References	Notes
Temperature	<p>HOT WATER:</p> <p><u>To kill spores</u> 195°F (90°C) 10 minutes</p> <p><u>To kill free-swimming larvae</u> ≥ 167°F (75°C) for 5 minutes</p>	<p>Hoffman and Markiw 1977</p> <p>Wagner et al. 2003</p>	
Drying	Dry gear for 24 hours, drying in sunlight is best to kill spores and larvae	Hedrick et al. 2008	
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds	4.6% Sanicare Quat128® solution	Hedrick et al. 2008	

Whirling Disease

Methods of Control for Firefighters	Details of Method	References	Notes
(e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diethyl dimethyl ammonium chloride [DDAC])	<p>Mixing instructions: 6.4 oz per 1 gallon water 5 gallons per 100 gallons water Contact time = 10 minutes. OR 3.1% Sparquat256[®] solution</p> <p>Mixing instructions: - 4.3 oz per 1 gallon water - 3.4 gallons per 100 gallons water Contact time = 10 minutes OR 1.8% Green Solutions High Dilution 256[®] solution</p> <p>Mixing instructions: 2.5 oz per 1 gallon water 1.9 gallons per 100 gallons water Contact time = 10 minutes</p>		
Bleach (e.g. Clorox®) 6% sodium hypochlorite	<p>1% bleach solution (500 ppm sodium hypochlorite) Mixing instruction: 1.1 oz bleach per 1 gallon water 2.2 Tablespoons bleach per gallon water 0.9 gallon bleach per 100 gallons water Contact time = 15 minutes</p>	<p>Hedrick et al. 2008 (spores) Wagner et al. 2003 (larvae)</p>	

Viral Hemorrhagic Septicemia

Novirhabdovirus sp.

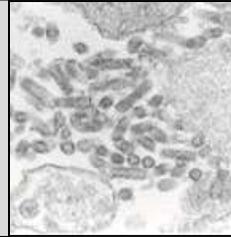


Photo credit: Seagrant.suny.edu



Photo credit: D. Kenyon Michigan DNR

General Information:

- **Distribution:** Great Lakes and St. Lawrence River. For most up-to-date information on distribution, please see: <http://www.invasivespeciesinfo.gov/microbes/vhs.shtml>
- **Habitat:** VHS is carried in the water column and in aquatic invertebrates, such as snails and crustaceans, as well as fish parts.
- **Fire Activities Posing Risk:** Most concern is with virus free floating in the water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Over 50 fish species are susceptible to this disease which causes significant fish die offs.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122°F (50°C) for 10 minutes 158°F (70°C) for 1 minute	Jørgensen 1974, cited in Bovo et al. 2005	
Drying	Dry gear for 4 days at 70°F (21°C)	Pietsch et al. 1977 (for IHNV virus). (Bovo et al. 2005)	IHNV and VHSV are closely related viruses. It is presumed that inactivation studies on one virus may pertain to the other.
Mechanical	Thoroughly wash and dry	Multiple sources	

Viral Hemorrhagic Septicemia

Method of Control for Firefighters	Details of Method	References	Notes
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diethyl dimethyl ammonium chloride [DDAC])	0.4% <i>Green Solutions High Dilution 256</i> [®] solution Mixing instructions: ½ oz per 1 gallon water 0.4 gallon per 100 gallons water Contact time = 10 minutes	EPA label Reg. No. 1839-167 (2010)	These mixing instructions are approved by EPA for closely related viruses in the same family, but not specifically for VHS
Bleach (e.g. Clorox®) 6% sodium hypochlorite	0.2% <i>bleach solution</i> (98 ppm sodium hypochlorite) Mixing instructions: 0.26 oz/1 gallon water ~ ½ tablespoon/1 gallon water 26 oz/100 gallons water 0.2 gal/100 gallons water Contact time: 2 minutes	Ahne 1982, cited in Bovo et al. 2005	
Other Agents	0.5% - 1% <i>Virkon Aquatic</i> [®] 5 g/liter to 10 g/liter Contact time = 10 minutes	Yanong and Erlacher-Reid 2012	

Spring Viremia of Carp

Rhabdovirus carpio

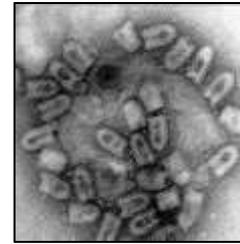


Photo credit: ytponet



Photo credit: USGS

General Information:

- **Distribution:** NC, IL, WI OH, MN, MO, WA, Ontario. For most up-to-date information on distribution, please see: http://www.glerl.noaa.gov/res/Programs/glansis/nas_database.html
- **Habitat:** SVC is carried in the water column and survives long periods in wet mud.
- **Fire Activities posing risk:** Most concern is with virus free floating in the water column. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** This virus is a major cause of disease and death in carp and 50 other fish species.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER: 122°F (50°C) for 5 minutes	Ahne 1976, cited in Bovo et al. 2005	
Drying	>28 days at 70°F (21°C)	Ahne 1982	
Mechanical	Scraping, brushing, washing and removing organics (e.g. mud)	Multiple sources	
CHEMICALS			
Quaternary ammonium compounds (e.g. alkyl dimethyl benzylammonium chloride [ADBAC]; diacyl dimethyl ammonium chloride [DDAC])	<i>0.4% Green Solutions High Dilution 256[®]</i> solution Mixing instructions: ½ oz per 1 gallon water 0.4 gallon per 100 gallons water Contact time = 10 minutes	EPA label Reg. No. 1839-167 (2010)	These mixing instructions are approved by EPA for closely related viruses in the same family, but not specifically for SVC.

Method of Control for Firefighters	Details of Method	References	Notes
Bleach (e.g. Clorox®) 6% sodium hypochlorite	0.1% bleach solution (55 ppm sodium hypochlorite) Mixing instructions: ¼ teaspoon per 1 gallon water 11.5 oz per 100 gallons water Contact time: 2 minutes	Ahne 1982, cited in Bovo et al. 2005	
Other Agents	0.5% to 1% Virkon Aquatic® 5 g/liter to 10 g/liter for 10 minutes 0.1% Virkon Aquatic® 1 g/liter for 30 minutes	Bowker et al 2012	

<p>Port Orford Cedar Root Disease (<i>Phytophthora lateralis</i>) & Sudden Oak Death (<i>Phytophthora ramorum</i>)</p>		
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Photo credit: USDA Forest Service

Photo credit: phytophthoradb.org

General Information:

- **Port Orford Cedar Root Disease Distribution:** WA, OR, CA. For most up-to-date information on distribution, please see: <http://www.issg.org/database/welcome/>.
- **Sudden Oak Death Distribution:** CA, OR. For most up-to-date information on distribution, please see: <http://www.issg.org/database/welcome/>
- **Habitat:** Spores swim in standing water and can be carried large distances in flowing water; they also occur in soil.
- **Fire Activities Posing Risk:** Most concern is with spores carried in untreated water. Risks include: contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Port Orford cedars of all sizes may be killed by the root disease. Sudden oak death affects other trees as well as oaks, leading to widespread forest destruction.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
“Regular Clorox® Bleach” 6% sodium hypochlorite	Add 1 gallon bleach to 1000 gallons of drafted water (~50 ppm sodium hypochlorite). Prepare the mixture at least 5 minutes prior to application for dust abatement, fire suppression, and cleaning vehicles and logging, road building, and maintenance equipment.	Ultra Clorox® Label (EPA Reg. No. 5813-50) AND Southwest Oregon Interagency Fire Management Plan (USDA Forest Service 2013)	¹ See note below for application.

Method of Control for Firefighters	Details of Method	References	Notes
"Clorox® Germicidal Bleach" 8.25% sodium hypochlorite	Add ¾ gallon bleach to 1000 gallons of drafted water (~50 ppm sodium hypochlorite). Prepare the mixture at least 5 minutes prior to application for dust abatement, fire suppression, and cleaning vehicles and logging, road building, and maintenance equipment.	Germicidal Healthcare Clorox® label (EPA Reg. No. 5813-100)	

¹ Locate vehicle washing stations (with chlorinated water) where water will not run into streams. When refilling tenders/engines, fill with water first, pull 150' away from the stream (or where overland flow will not run back into the stream), and then add the chlorine. Avoid dropping buckets of or directly releasing chlorine-treated water into streams or wetlands. Don't treat water from streams that are uninfected with the root rot disease, unless it is for use at washing stations (to avoid unnecessary use of chlorine). (Southwest Oregon Interagency Fire Management Plan 2013)

Aquatic Invasive Plants



Purple Loosestrife Photo credit:universityofconn.com



Parrot feather. Photo credit: Aquariussystems.com



Hydrilla. Photo credit: nwdistrict.ufl.edu

General Information:

- **Distribution:** Varies based on species. For most up-to-date information on distribution, please see: <http://www.invasivespeciesinfo.gov/aquatics/main.shtml>
- **Habitat:** Aquatic plants are usually confined to shorelines and relatively shallow portions of waterbodies, though plant pieces can float throughout.
- **Fire Activities Posing Risk:** Contact with untreated water; helicopter buckets, snorkels, and other drafting gear that capture bottom sediments, mud, or aquatic plants; internal tanks and hoses that retain residual untreated water.
- **Environmental Effects:** Non-native aquatic plants clog waterways and threaten the diversity and survival of native species.

Disinfection Protocols:

Method of Control for Firefighters	Details of Method	References	Notes
Temperature	HOT WATER PRESSURE WASH: ≥140°F (60°C) for 2 minutes; inspect and re-treat as needed.	Blumer et al. 2009	This study is specific to Eurasian watermilfoil, but lethal temperatures likely comparable for other submerged species.
Mechanical	Scraping, brushing, high pressure washing and mud removal. Some seeds may remain viable after washing, so disposal or filtration of treated water is recommended.	Multiple sources	

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