U. S. EPA ENVIRONMENTAL RESPONSE TEAM

DIVER DECONTAMINATION SOLUTIONS

Table 1 lists some decontamination solutions along with their general effectiveness against biological and chemical contaminants and their safety/compatibility for use on divers and dive equipment. The list in Table 1 is not all-inclusive, and other suitable decontamination solutions may be used at the Divemaster's discretion.

The major considerations when choosing a decontamination solution are: (1) effectiveness against the expected site contaminants; (2) compatibility with dry suit materials and other equipment; (3) safety of exposure to both the diver and the tenders; (4) availability and cost; (5) disposal of spent wash solution. Selection of decontamination solutions is at the discretion of the Divemaster, with concurrence of the UDO and the Health and Safety Officer. Decontamination solutions and procedures should be described in the HASP prior to going on-site.

There are numerous decontamination solutions to choose from. Unfortunately, many of the most effective decontamination solutions are very aggressive, corrosive and toxic (LBL 2006). Many disinfectants and sterilants are well suited to cleaning hospital surfaces and equipment, but are not safe to use on divers or dive equipment. The objective of decontaminating the diver is to remove the contamination from the diver's suit so that the suit can be safely removed. There is no necessity to use solutions that are potentially dangerous to the diver or the equipment when other less dangerous solutions will yield satisfactory decontamination. Removing the contaminants from the diver is more important than neutralizing the contaminants. Since some of the contaminants at a site may be unknown, it is necessary to use a decontamination solution that is effective for a variety of contaminants (EPA 1985).

Decontamination solutions prepared from concentrated products (e.g., soap or bleach) should be diluted with potable water and not site water, since site water may negatively impact the final strength of the prepared decontamination solution.

Water

The most important decontamination solution is potable water. A plentiful supply of potable water, preferably from a low-pressure hose hooked up to a municipal water supply or a large water tank is the first and last step of all decontamination procedures. If a large tank is not available, smaller containers (e.g., 5-gallon buckets, collapsible plastic containers, Hudson sprayers) of potable water should be available. Water from a hose should not be under pressure any higher than typical municipal water pressure (40 to 70 pounds per square inch). High pressure hoses (e.g., pressure washers) may damage the diver's suit or force contaminants into seams or contaminate nearby surface support personnel. In some instances a thorough rinse with potable water is all the decontamination the diver needs (e.g., after diving in salt water).

Soap

A strong solution of antimicrobial soap (dish soap typically has more surfactant than hand soap) is the next most commonly used decontamination solution. Soap's surfactant action will remove most organic contamination, and scrubbing with soapy water will remove sediment-associated inorganics (e.g., metals). Soap will also wash away biological contaminants (when biological contaminants are removed, it doesn't matter whether they have been killed). In hand-washing experiments, antimicrobial soap was shown to be more effective at removing biological agents than soap with no antimicrobial additive (CDC 2002). The active ingredient used in most antimicrobial soaps is triclosan. Triclosan works, even at very low concentrations, by blocking enoyl-acyl carrier-protein reductase (ENR), preventing bacteria and fungi from producing fatty acids needed for cell membranes and other vital functions (Senese 2005). Humans don't have the ENR enzyme, and so triclosan is harmless enough for use in a wide variety of consumer goods including cosmetics and toothpaste (Senese 2005). Because of its effectiveness and safety, dish soap is often the solution of choice for decontaminating patients arriving at hospital emergency rooms (USVA 2006; Jagminas 2006). Antimicrobial soap is a preferred decontamination solution because it has wide applicability, ready availability, it is safe for use on both the diver and the diver's suit, and it requires no special PPE or disposal. The leftover soap solution can be used to clean the decontamination zone, the boat or other equipment.

Bleach

Sodium hypochlorite, in the form of chlorine bleach, is a biocide that is readily available in most supermarkets. Household bleach is approximately 6% sodium hypochlorite (Clorox 2005). A 5% solution of bleach (approximately six ounces mixed into a gallon of water) will kill most bacteria, fungi and viruses on a hard, non-porous surface after a five minute contact time (Clorox 2006). In order to overcome the consumption of free chlorine by organic matter in the site water, a 10% solution of bleach (12 ounces in a gallon of water) should be used for diver decontamination. Contact time, in this case, is defined as the length of time the wet solution is in contact with the surface to be cleaned. Contact time should be adjusted to at least ten minutes to adjust for the differences between dive equipment and hard surfaces. It is difficult to keep the diver wet for the entire contact time so bleach is not the best choice to decontaminate the diver's suit. However, it is quite simple and effective to soak the diver's fins, harness, BCD, etc. Care must be taken when using bleach as a decontamination solution, since it will burn eyes and mucous membranes in a 10% solution. Bleach straight from the bottle can burn unprotected skin and can damage clothes and dive equipment with sufficient exposure. Proper PPE (e.g., disposable rain suits, face shield, surgical gloves) is mandatory when using bleach as a decontamination solution.

Calcium hypochlorite is also used as a biocide, and it is readily available in powder form (e.g., swimming pool chlorine granules). A 10% calcium hypochlorite solution has greater available chlorine than a sodium hypochlorite solution. However, the powder is not readily soluble in water, and should be mixed thoroughly in warm, preferably soft to moderately hard water prior to use. This makes it difficult to achieve a desired concentration. Calcium hypochlorite granules can burn unprotected skin and can damage clothes and dive equipment with sufficient exposure. The powder also poses an inhalation risk (Arch Chemicals 2002). Proper PPE (e.g., disposable rain suits, face shield, respirator mask, surgical gloves) is mandatory when using calcium hypochlorite as a decontamination solution.

Betadine

Betadine is a brand name for a 10% povidone-iodine solution commonly used in hospitals to disinfect wounds and prepare skin for surgery. Undiluted Betadine will kill most pathogens after ten minutes of contact time. Contact time, in this case, is defined as the length of time the wet solution is in contact with the surface to be cleaned. The diver must effectively be kept wet with undiluted Betadine for the entire contact time to prevent the solution on the suit from drying. Iodophors such as Betadine use povidone to slow the release of iodine, while using surfactants to increase penetration (Abedon 2003). Since the solution is reddish-brown, it is easy to see if any areas of the diver's suit have been missed. Care must be taken when using Betadine as a decontamination solution since prolonged contact of large skin areas can lead to excessive absorption of iodine (Purdue 2005). Betadine will also burn eyes and mucous membranes, and will stain clothing, dive equipment, and boats. Proper PPE (e.g., disposable rain suits, face shield/eye protection, gloves) is mandatory when using Betadine, and it is recommended that all surrounding surfaces be covered with disposable plastic sheeting to prevent permanent staining.

Simple Green

Simple Green is the trade name for a widely used all-purpose cleaner. Simple Green and other similar surfactant-based cleaners can be used as a decontamination solution for dive sites at which there is little concern of biological agents. Simple Green is a multi-use cleaner/degreaser that can be diluted or used straight from the bottle (Sunshine Makers 2006). Simple Green is biodegradable and has no antimicrobial additives. The product is not harmful to diver's skin, eyes, or equipment, and no PPE or special disposal is required.

Quaternary-Ammonium Compounds

Many commercial and household cleaners are based on quaternary-ammonium compounds (quats). These products (e.g., Zepamine A) are designed primarily for deodorizing and sanitizing general household areas, kitchens, cafeterias, food processing equipment/utensils. Additional uses include algae control in pools and cooling systems (Zep 2006). Quats are highly toxic to fish and aquatic plants, and care should be taken not to allow decontamination fluids to enter any body of surface water. If quats are mixed with chlorine bleach, the exothermic reaction is potentially explosive and the resultant chlorine gas may be hazardous. Quats are also corrosive to skin and eyes, and proper PPE and disposal of wash fluid is required.

TSP

TSP is an acronym for tri-sodium phosphate, a strong cleaner/degreaser. However, in the 1970s use of phosphate-containing products was limited. Some products on the market today that are sold as TSP may contain other ingredients and can be less than half TSP (Savogran 2001a). Other products sold as TSP or TSP-substitutes may contain no phosphate and may be acutely corrosive to skin and eyes (Red Devil 2006, Savogran 2001b). TSP products are commonly used to prepare surfaces for painting, remove mildew from home siding, and remove stains from patios or driveways. While TSP is a common household cleaner, it is not appropriate for some materials. TSP will stain metals and can etch glass and fiberglass. When using TSP solutions, care should be taken to cover the surrounding area with plastic sheeting and the decontamination fluids should not be allowed to enter any body of surface water. Proper PPE and disposal of wash fluid is mandatory when using TSP products.

Alcohol

Isopropyl alcohol (IPA) is also a good biocide (NIH 2006), and while it is not appropriate for decontaminating the diver's entire suit and/or equipment, it is ideal for wiping down the areas under the seals of the diver's AGA mask (the latex seal around the diver's face where the mask meets the dry suit), or around the area where the diver's helmet mates to the dry suit. IPA is readily available in supermarkets as a 70% IPA/30% water solution, or as individually packaged wipes. Contact time is immediate. Care should be taken not to get IPA on the diver's face or in the diver's eyes. The readily available 70% IPA solution should not be diluted further before use. Tenders should wear at least eye protection and gloves when working with IPA.

Other Decontamination Agents

The list of decontamination agents above is not all-inclusive, and other suitable cleaning agents may be used at the Divemaster's discretion. For crude oil/grease on a dry suit or other dive equipment, a variety of cleaning solutions or wipes impregnated with cleaning agents/degreasers are available (e.g., citrus wipes). For disinfecting the area under a diver's AGA mask seal or where the helmet mates with the dry suit a variety of individually sealed wipes are readily available (e.g., Saniwipes, benzalkonium chloride wipes, etc.). For chemical and biological agents from terrorism-related incidents, the National Institute of Justice lists other decontamination solutions that may be investigated for suitability (NIJ 2001). Before using any cleaning solvent, its safety for skin contact and compatibility with dry suit and equipment materials must be assessed.

TABLE 1. Decontamination Solution Effectiveness/Safety

Decontamination Solution	Use Against Biological Contaminants	Use Against Chemical Contaminants	Safety for Diver Skin Contact	Dive Gear Compatibility
Potable Water	C	C	1	1
Antimicrobial Soap	A	A	1	1
Bleach	A	B	2	3
Betadine	A	C	2	2
Simple Green	B	B	1	1
Quaternary Ammonium	A	B	3	2
TSP	B	A	3	3
Alcohol	A	C	3	2

	Effectiveness:	Safety/Compatibility:
	A = Very Effective	1 = Not Harmful
	B = Effective	2 = Potentially Harmful
	C = Somewhat Effective	3 = Harmful if other precautions
		are not followed

NOTES:

1. This list is not all-inclusive. Other suitable decontamination solutions may be used at the Divemaster's discretion.
2. Effectiveness includes both contaminant removal and neutralization.
3. Safety includes both physical harm to the diver and degradation/staining of equipment.
4. Dive gear compatibility is generalized based on normal decontamination solution concentrations and common dive gear materials. It is recommended that specific gear manufacturers be contacted to determine compatibility.
5. Mention of trade names does not imply product endorsement.

REFERENCES

Abedon, S.T. 2003. Sterilization and Disinfection - Chapter Review for Micro 509 course at Ohio State University. Available at www.mansfield.ohio-state.edu/~sabedon/black12.htm.

Arch Chemicals, Inc. 2002. Material Safety Data Sheet: HTH Dry Chlorine Granular. Arch Chemicals, Inc., Norwalk, Connecticut. MSDS prepared February 2002.

Clorox (The Clorox Company). 2005. Clorox Regular Bleach, Material Safety Data Sheet. The Clorox Company, Oakland, California. MSDS prepared May 2005. Available at www.clorox.com.

Clorox (The Clorox Company). 2006. Clorox Bleach, Frequently Asked Questions. The Clorox Company, Oakland, California. Information downloaded February 2006. Available at www.clorox.com.

CDC (Centers for Disease Control and Prevention). 2002. *Guideline for Hand Hygiene in Health-Care Settings: Recommendations of the Healthcare Infection Control Practices Advisory Commitee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force*. Morbidity and Mortality Weekly Report, volume 51, number RR-16, October 25, 2002.

EPA (United States Environmental Protection Agency). 1985. *Interim Protocol for Diving Operations in Contaminated Water*. Author, R.P. Traver, U.S. EPA Office of Research and Development, Hazardous Waste Engineering Research Laboratory, Cincinnati, Ohio. EPA/600/2-85/130.

Jagminas, L. and D.P. Erdman. 2006. Chemical, Biological, Radiological, Nuclear and Explosives (CBRNE) - Chemical Decontamination. Available at http://emedicine.com/emerg/topic893.htm.

LBL (Lawrence Berkeley National Laboratory). 2006. *Biosafety Manual: Decontamination*. Lawrence Berkeley National Laboratory, Environment, Health and Safety Division, Biosafety Program. Available at www.lbl.gov/ehs/biosafety/Biosafety_Manual/html/decontamination.shtml.

NIH (National Institutes of Health). 2006. *Guide to Biodecontamination*. National Institutes of Health, Division of Safety, Office of Research Services. Available at: www.nih.gov/od/ors/ds/pubs/biodecontamination/index.html.

NIJ (National Institute of Justice). 2001. *Guide for the Selection of Chemical and Biological Decontaminatioin Equipment for Emergency First Responders*, NIJ Guide 103-00. National Institute of Justice, Law Enforcement and Corrections Standards and Testing Program, National Law Enforcement and Corrections Technical Center, Rockville, Maryland. October 2001.

Purdue (Purdue Products LP). 2005. Betadine Solution (10% povidone iodine), Material Safety Data Sheet. Purdue Products LP, Stamford, Connecticut. MSDS prepared July 2005.

Red Devil. 2006. Material Safety Data Sheet: TSP-90 Heavy Duty Cleaner. Red Devil, Inc., Union, New Jersey. MSDS prepared January 2006.

Savogran. 2001a. Material Safety Data Sheet: TSP. Savogran, Norwood, Massachusetts. MSDS prepared August 2001.

Savogran. 2001b. Material Safety Data Sheet: Liquid TSP Substitute. Savogran, Norwood, Massachusetts. MSDS prepared September 2001.

Senese, F. 2005. What are triclocarban and triclosan (ingredients in some antiseptic soaps)? Frostburg University's General Chemistry Online, http://antoine.frostburg.edu/chem/senese/101/faq/triclosan.shtml, updated September 20, 2005.

Sunshine Makers. 2006. Material Safety Data Sheet: Simple Green, *also for*: Simple Green Scrubbing Pad. Sunshine Makers, Inc., Huntington Harbour, California. MSDS prepared January 2006.

USVA. (United States Department of Veterans Affairs). 2006. Chemical Terrorism General Guidance Pocket Guide. US Department of Veterans Affairs, Office of Quality and Performance, Clinical Practice Guidelines. Available at www.oqp.med.va.gov/cpg/cpg.htm.

Zep (Zep Manufacturing Company). 2006. Product Specification Report: Zepamine A: Concentrated, Water-Based Deodorant/Sanitizer. Zep Manufacturing Company, Atlanta, Georgia. Product number 1823. Information downloaded March 2006. Available at www.zep.com.