APPENDIX L

BIOHAZARD DIVING OPERATIONS

(including decontamination)

NOTES:

US EPA
STANDARD OPERATING PROTOCOL

BIOHAZARDS OF DIVING OPERATIONS AND AQUATIC ENVIRONMENTS

Prepared in Conjunction
with the

NATIONAL UNDERWATER DIVING SAFETY MANAGEMENT PROGRAM

by

Jerry J. Tulis, Ph.D., Ricky L. Langley, M.D., M.P.H.,
and Amy M. Gitelman, M.P.H.
Occupational and Environmental Medicine
Duke University Medical Center, Durham, NC

for

Office of Administration and Resources Management
Safety, Health and Environmental Management Division

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1. PURPOSE

This Standard Operating Practice (SOP) prescribes the protocols to help safeguard personnel from the Biohazards of Diving Operations and Aquatic Environments recommended under the Environmental Protection Agency's Underwater/Diving Safety Management Program. The user should also reference the EPA's National Biohazard Risk Management Program for additional information and guidance on the more typical biohazards. This SOP document focuses on those biohazards which may be unique to or at higher risk for participants in the EPA's Diving Program.

This SOP sets forth the Environmental Protection Agency's (EPA or Agency) procedures for minimizing its worker's occupational exposure to biohazards in the underwater and diving operations environment. In many cases, the hazards involved in dive operations are the same conditions EPA workers may encounter in land based operations but may also include hazards unique to the aquatic environment. As with any field operation, marine and dive operations involve aspects of physical activity which may result in injury leading to infection. The potential for lacerations or abrasions which may become infected from microorganisms is commonplace in the handling of the diving and marine equipment and supplies. Shore based operations are subject to the typical hazards of animal and insect bites or stings and poisonous plants (e.g., poison ivy) and may be referenced in the National Biohazard Risk Management Program.

Diving operations may also introduce risk of exposure to bloodborne pathogens in conducting first responder activities for and injured diver or the sharing of diving equipment. However small the risk, employers are required to train and make provisions for adherence to the OSHA standard 29 CFR 1910.1030 "Occupational Exposure to Bloodborne Pathogens" promulgated as a final rule on December 6, 1991.

Additional potential for infection exists from the aquatic environment, both fresh and salt water, such as exposure to biohazards from waterborne microorganisms, plants and animals which may be encountered in diving operations. The SOP defines the protocols by which the Agency's policy concerning the protection of its workers from occupational biohazards in diving is effected.

Standard Operating Practices (SOPs), maintained under the National Underwater Diving Safety Management Program in another document, establish the general approaches and work practices which are implemented at the operations level to achieve the various requirements of the Program in laboratory, field, and other settings.

Standard Methods (SMs), maintained under the SOP's in separate documents, detail the specific procedures and techniques which are employed in the conduct of certain work activities.

The Program, and its associated SOPs and SMs, incorporate nationally accepted and consistent means and methods for planning and conducting underwater and diving activities to minimize the potential hazards associated with these activities.

An operating principle of EPA Programs is to demonstrate continuous and measurable improvement in its management and operations, using Total Quality Management (TQM) processes. As such, user of the procedures indicated here may suggest alternative methods for effecting the required outcome. The alternate method, however, should not be implemented until approved and amended by the EPA's Safety, Health, and Environmental Management Directorate.

The purpose of the Biohazards of Diving Operations and Aquatic Environments document is to provide an awareness of potential workplace biohazards to employees and to help protect these employees while performing duties that involve exposure to marine and inland waters and aquatic life, as related to the collection of water, sediment, and sludge samples; acquisition of marine and freshwater specimens; and while conducting various diving procedures.

2. BACKGROUND

Water covers more than seventy percent of the Earth's surface, and numerous vocational activities involve

exposure to these waters and their inhabitants. All oceans, seas, lakes, rivers, and ponds contain a wide variety of indigenous microorganisms, in addition to higher forms of aquatic life. Although the majority of these indigenous organisms are harmless to humans, there are dangerous and life-threatening life forms found in all the waters of the world. Besides these normal inhabitants of marine waters, contamination of "pristine" water from various sources poses an increased hazard to exposed persons. These sources of contamination include human and animal sewage, industrial wastes, agricultural wastes, and other forms of pollution. Numerous species of animal viruses, bacteria, fungi, algae, and parasites are found in sewage effluents, often dumped into oceans and lakes as raw sewage.

The injuries frequently experienced during marine operations, including lacerations and punctures, are readily contaminated with microorganisms, potentially leading to infection. In addition, exposure of mucous membranes of the eyes (i.e., conjunctiva), nose (i.e., rhinal exposure), and mouth; exposure of the ear canal; and the swallowing and aspiration of contaminated water can lead to serious infections and intoxications.

A hierarchy of protective measures can be used to eliminate or significantly reduce exposures to marine biohazards. Included are accepted and proven engineering operations, good work practices, and the use of personal protective equipment. An adjunct to these measures of protection against infectious microorganisms and animal toxins is the use of vaccines and other prophylactic biologicals (preventative medicines).

It is accepted practice that various diving operations involve the use of shared equipment, which can become contaminated with blood and other body fluids due to the frequent lacerations, other traumatic injuries, and the confined space being encountered during diving operations. Consequently, the possibility of transmission of human diseases from one diver to another exists, especially for diseases such as hepatitis B, tuberculosis, herpes, and HIV. Information is provided in this document on the appropriate precautions and other measures that should be practiced to eliminate or reduce the potential for disease transmission when using shared diving equipment.

3. STANDARD OPERATING PRACTICE

a. SCOPE. This Practice applies to all personnel as outlined in the parent policy statement (i.e., National Underwater Diving Safety Management Program) and may apply to the employees or agents of other government agencies or contractors, when performing duties at EPA facilities or at EPA-controlled sites. All personnel are required to comply with:

* the minimum standards of this Practice; and

* the more conservative of this Practice or the employee's organization's procedures.

Contractors, grantees, and organizations with which the EPA has agreements must comply with applicable federal, state, and local laws and regulations pertaining to underwater diving and exposure to biohazards. This SOP is issued in part under OSHA's requirement to 29 CFR 1910.1030. "Occupational Exposure to Bloodborne Pathogens".

b. OPERATIONAL FLEXIBILITY. The provisions for worker safety and health regarding biohazards established by this Practice may be augmented or supplemented by local EPA managers, **but it cannot be deleted, replaced, or superseded.** This clause is intended to provide for a degree of flexibility at the operational level in unique or special non-routine field situations, without compromising or diminishing the level of worker protection afforded by this Practice.

c. BASIC RESPONSIBILITY. Basic responsibility, while carrying out this Practice, rests with the individual. To conduct diving operations in light of the potential of occupational exposure to biohazards, an employee shall demonstrate to the Unit Diving Officer or designee an understanding of the hazards that allows the employee to operate safely. Staff and line management shall be responsible for providing the resources necessary to protect against biohazards.

d. SOP REQUIREMENT. EPA programs frequently involve the need for competent underwater operations even as a potential for exposure to biohazards exists. As the business of the EPA involves investigation of environmental contamination, personnel will occasionally be tasked with these investigations in the underwater environment. The existence of an EPA Diving Program to meet these needs is vital to safe, efficient, and economic operations.

e. SOP PURPOSE. The purposes of the Standard Operating Practice for operating with the understanding of Biohazards of Diving Operations and Aquatic Environments are:

* Safety - to ensure that all diving under the auspices of the Environmental Protection Agency is conducted in a manner most likely to minimize accidental injury or occupational illness;

* Operational Standards - to set forth reasonable rules, regulations and standards for selection, training, certification, supervision, and equipping of EPA divers; and

* Reciprocity - to establish a working reciprocity among staff in various Regional, Unit Offices and Laboratories within EPA; and between EPA and other government agencies, academic institutions, and private concerns involved in diving.

4. SOP COMPONENTS

a. SOP ADMINISTRATION AND MANAGEMENT

1. Health and Safety Office

The responsibility for employee health and safety while performing assigned tasks in the aquatic environment will reside with the regional Health and Safety Office and the Unit Diving Officers, with the collaboration of the EPAs Safety, Health and Environmental Management Division (SHEMD). Information and training will be provided to employees on the presence of aquatic biohazards, especially those indigenous to the U.S. Moreover, training must include information on the cause of potential infectious diseases and envenomations (poisonings), the clinical onset and symptoms of specific diseases, measures for prevention and control of exposure, and accepted treatment modalities (methods of therapy). Specific information on the proper cleaning and disinfection of diving equipment is mandatory.

2. Healthcare Provider

The healthcare provider will give medical assistance to injured and ill workers, maintain injury and infection records of the employees, immunize employees as indicated and keep vaccination records, provide periodic serologic testing to establish immune status and infectivity, conduct skin testing to monitor exposures to certain infectious agents (e.g., tuberculosis), and conduct periodic physical examinations on employees.

3. Management

The employer maintains the full responsibility for assuring that all employees whose assignments require exposure to aquatic environments in the performance of their duties are provided the optimal protection possible against exposure to both indigenous pathogens and those associated with polluted waters.

b. PRACTICE ELEMENTS

1. Occupational Biohazards of Aquatic Environments

Numerous potential health hazards affect individuals performing marine operations. These hazards

can be segregated into four categories, namely,

a) hazards associated with the process of diving, due primarily to the effect of external pressure on gases within the body,
b) hazards associated with the environment, including biological agents, toxins, and dangerous marine life,
c) hazards associated with the equipment, e.g., contaminated air supply, equipment contaminated with biological fluids and exudates, and allergic responses to diving equipment materials, and
d) hazards associated with the collection and processing of environmental samples and aquatic specimens.

It is important that the individual involved with diving or specimen collection and processing be cognizant of the potential hazards involved in these operations and that they always perform their tasks as safely as possible to reduce or eliminate injury or illness. While this document deals primarily with the biohazards associated with diving and other aquatic operations, brief mention will be made of the potential adverse medical problems related to diving per se and from the equipment being used.

a. **Infectious Microorganisms**

All bodies of water worldwide, including saltwater and freshwater, contain numerous species of microorganisms. Some of these microorganisms represent indigenous organisms and others represent contaminating organisms, from sewage, industrial and agricultural wastes, and human and animal shedding. Both the indigenous and contaminating microorganisms contain species associated with human disease (i.e., pathogenic for man), including viruses, bacteria, fungi, algae, and parasites. Among the many species of microorganisms found in aquatic environments are the psychrophilic organisms (temperature range of -5 to 30C), mesophilic organisms (temperature range of 10 to 45C), thermophilic organisms (temperature optimum of 50 to 60C), nonhalophilic organisms (ability to grow in both fresh and saltwater), and halophilic organisms (require saline environment for growth).

Human exposures to waterborne pathogenic and opportunistic microorganisms most often result in illnesses such as gastroenteritis (i.e., inflammation of the stomach and intestines), respiratory disease, wound infections, otitis externa (infection of the external ear canal), conjunctivitis (i.e., infection of the conjunctiva of the eyes), and sinusitis. However, more serious sequelae (consequences) and life-threatening complications can occur. In addition, during "diving operations" workers may be exposed to the blood or body fluids of coworkers as a result of sharing equipment, thereby facilitating the transmission of disease agents. Exposure of workers in the aquatic environment most often occurs through contact (i.e., skin, eyes, ears), penetrating injuries, and respiration, especially during aspiration of contaminated water. A schematic of possible modes of disease transmission while working in the aquatic environment is presented as Figure 1. A listing of the biohazards encountered during diving operations are presented in Table 1. Some of the more important viruses, bacteria, fungi, algae, and parasites associated with waterborne disease or diving operations are briefly discussed in this document, other less important pathogens are presented in the Appendices.

1. **Viruses**

Numerous viruses can be found in marine and inland waters, especially when polluted with sewage. More than 100 different viruses are found in human and animal wastes that can contaminate aquatic environments. Enteric viruses (i.e., those viruses originating from the intestinal tract) are found at concentrations of 1 million virus particles per gram of feces. Sewage levels of approximately 7,000 viruses per liter are common, with levels in parts of the world reaching more than 500,000 virus particles per liter of sewage. Viruses contaminating the oceans, seas, lakes and other bodies of water through the dumping or release of sewage possess a variable survival in these aquatic environments, i.e., viruses are obligate intracellular parasites and cannot replicate without specific animal host cells. Survival of free viruses in seawater is a function of both the specific virus and the environmental conditions. Studies have indicated that survival is enhanced significantly by lower water temperature and the presence of sediments. Enteroviruses such as polio and Coxsackie have been shown to survive from 1 to 3 months in seawater, depending on the season, i.e., summer or winter, respectively. The bacteria found in seawater also affect the survival of viruses by releasing antiviral metabolites that rapidly inactivate viruses. In sewage treatment plants, the use of chlorination is only moderately effective in viral inactivation.

The knowledge that viruses can survive for many weeks upon release to marine or fresh waters is important for the understanding and application of exposure and infection control practices. Moreover, besides the viruses that are associated with shedding and the release of sewage that contribute to the pollution of aquatic systems, there are viruses that inhabit marine life as either indigenous commensals (an intestinal symbiont) or pathogens that can infect man or contaminate seafood.

The virus groups recognized as sewage-associated waterborne organisms that pose a risk to humans are the following:

* adenoviruses
* enteroviruses
* hepatitis viruses
* parvoviruses
* reoviruses
* rotaviruses
* astroviruses
* calciviruses

Viruses that are transmissible through blood and other body fluids could potentially pose a risk to divers sharing equipment that becomes contaminated with these fluids. Included are:

* hepatitis B (HBV)
* hepatitis C (HCV)
* human immunodeficiency virus (HIV)
* cytomegalovirus (CMV)
* Epstein-Barr virus (EBV)
* hemorrhagic fever viruses

A brief discussion of the more important sewage-associated viruses (i.e., adenoviruses, hepatitis A, and polio) and bloodborne pathogens (i.e., HBV and HIV) found in aquatic environments and marine operations follows; a complete list of relevant viruses and the diseases caused is found in Appendix I.

a. **Adenoviruses** are primarily associated with infections of the conjunctiva, respiratory system, and intestinal tract. There exist in excess of 40 serotypes of human adenoviruses.

The transmission of adenoviral infections is primarily through the fecal-oral route and by contact, with fecal shedding continuing for months or years after initial infection. Ocular infections have been associated with exposure to fecally-contaminated water, resulting in sporadic or epidemic outbreaks of pharyngo-conjunctival fever (PCF). Disease onset is abrupt, with sore throat, fever, and conjunctivitis; accompanying headache, malaise, nausea, and diarrhea are common. In adults, the disease is milder than among children, and primarily involves the eyes. Complete recovery occurs in several weeks.

b. **Hepatitis A** is usually spread through the fecal-oral route, i.e., through sewage-contaminated water and food, including seafood, and by contact. The virus can survive in both salt and fresh water. Clinical symptoms include fatigue, fever, nausea, malaise, and jaundice. The disease is self-limiting, with a fatality rate of less than 0.1%. No chronicity (i.e., associated with cirrhosis and carcinoma of the liver) or carrier state develops, as can occur with hepatitis B and C infections. Prophylaxis with immune globulin is recommended for travel to endemic areas; a vaccine is currently in clinical evaluation.

c. **Hepatitis B** is usually spread through contact with contaminated blood or body fluids or as a sexually-transmitted disease. Clinical disease presents with fever, malaise, and jaundice. Serious sequelae include liver disease and cancer; a carrier state may develop. Risks for divers and other marine workers include exposure to contaminated diving equipment and working in polluted waters. Highly effective vaccines are available that are mandated by the OSHA Bloodborne Pathogen Standard for workers at risk of exposure to blood or body fluids.

d. **Human Immunodeficiency Virus** is responsible for the clinical condition recognized as Acquired Immunodeficiency Syndrome (AIDS). HIV is transmissible in the occupational setting by accidental needlestick, mucous membrane exposure, or viral contact with broken skin (e.g., eczema). Infections usually remain latent for many years, ultimately leading to a variety of life-threatening AIDS-defined clinical conditions, including opportunistic infections (e.g., candidiasis, pneumocystis) and cancer. Among employees whose tasks involve diving operations with the use of shared equipment, the opportunity for exposure to the blood and/or body fluids of coworkers exists, unless the equipment is scrupulously cleaned and disinfected after each use. No vaccine or proven chemotherapy are available.

e. **Enteroviruses** include the virus responsible for human poliomyelitis, which is transmitted through the fecal-oral route. During the gastrointestinal phase of infection, copious quantities of poliovirus are shed in the feces; this phase of infection may last for months. With proper sewage management, the poliovirus is inactivated; where sewage management is minimal or absent, the poliovirus remains viable in the environmental setting for months. Transmission takes place through consumption of contaminated water or food, or exposure to virus-contaminated vectors (e.g., flies). Most infections remain asymptomatic, with approximately one paralytic case for every 100-150 infections. Highly effective live and inactivated vaccine preparations against poliomyelitis are available. In less developed regions of the world, poliomyelitis remains a serious public health problem.

2. **Bacteria**

Although certain bacterial species exist as indigenous microflora in the aquatic environment, the primary sources of waterborne bacteria associated with human infection comes from sewage effluents. Raw and treated sewage contains numerous species of bacteria, some of which are human pathogens. The majority of bacteria found in aquatic environments are enteric organisms (i.e., gram-negative species). Other contaminating bacterial species are comprised of the gram-positive organisms (e.g., staphylococci and streptococci) and the acid-fast organisms (i.e., the mycobacteria).

In addition to the bacteria that are found in the aquatic environment, there are other potentially infectious organisms that could be associated with the sharing of diving equipment. Among these bacteria are the causative agents of tuberculosis, *Mycobacterium tuberculosis*, which is readily liberated in the expelled air of clinically ill individuals, and *Pseudomonas aeruginosa*, an opportunistic bacterium associated with otitis externa and other potentially serious infections.

A brief discussion of the more important bacterial pathogens associated with aquatic environments and marine operations follows, including *Aeromonas*, *Campylobacter*, *Erysipelothrix*, *Mycobacterium*, *Pseudomonas*, *Vibrio*, *Salmonella*, *Leptospira*, and *Legionella*. A complete list of aquatic bacterial pathogens and the diseases caused is found in Appendix II.

a. ***Aeromonas*** species are comprised of gram-negative rod-shaped bacteria found as natural inhabitants of freshwater, where they are responsible for infection among cold-blooded animals (e.g., frogs). They can survive in both fresh and salt water, and have been isolated from many harbor waters. The motile species, i.e., *A. hydrophila*, *A. caviae*, and *A. sobria*, are associated with human diseases such as soft tissue infections and gastroenteritis by either penetrating trauma or ingestion, aspiration may result in respiratory infection and septicemia (blood poisoning). Puncture wounds contaminated with *Aeromonas* can develop cellulitis within 8 hours, with erythema (reddening), edema (swelling), and a purulent discharge (pussing). Localized pain is considerable; fever, chills, and lymphangitis (inflammation of the lymph nodes) may occur. *Aeromonas* infections are treatable with a variety of antimicrobials; therapy for serious infections should include an aminoglycoside.

b. ***Campylobacter*** species are found worldwide as commensals (intestinal symbiont) in a large number of wild and domestic animals. Species responsible for human infection include *C. jejuni*, which has the broadest animal reservoir, *C. coli*, and *C. fetus*. Outbreaks of disease have been associated with the consumption of contaminated food or water, and the fecal-oral route has been implicated in person-to-person spread. The disease is diagnosed more frequently in children than adults, and may account for about 9% of all diarrheal cases. Several clinical forms of *C. jejuni* disease exist, from the most common enteritis of 1-7 days duration with fever, headache, abdominal pain, and diarrhea, to an acute colitis with fever, abdominal cramps, and bloody diarrhea. *C. fetus* presents less frequently with enteric disease, more often as an acute bacteremia. Most *C. jejuni* infections are self-limiting; effective antimicrobial therapy is available.

c. ***Erysipelothrix rhusiopathiae*** is the causative bacterium of erysipeloid in humans, where it occurs primarily as an occupational disease. Common names for erysipeloid are fish-handler's disease, crayfish poisoning, speck finger, and blubber finger. *E. rhusiopathiae* is a gram-positive organism found as a normal inhabitant of many wild and domestic animals, birds, and fish. The organisms are found in the surface slime of both saltwater and freshwater fishes. Human infections usually occur on the hands

at the site of skin injury as nonsuppurative purplish erythematous lesions (purple-red rashes), associated with pain and itching. Most infections are self-limiting, although complications including endocarditis (inflammation of the heart's interior lining) can occur. Antibiotics provide effective treatment.

d. ***Mycobacterium marinum*** is an acid-fast, rod-shaped mycobacterium that is responsible for granulomatous skin lesions, which occur primarily at skin sites associated with prior abrasions, e.g., elbows, knees, toes, and fingers. The organism is widely distributed in nature, occurring in soil, water, and fish. The clinical infection begins several weeks after exposure, as small papules that enlarge and ulcerate with a purulent discharge. Complete healing, which is spontaneous in most cases, requires several months to two years. Antimicrobial therapy is available.

e. ***Mycobacterium tuberculosis***, the causative bacterium of tuberculosis, is spread from person-to-person by contaminated aerosols released through the coughing of clinically-ill individuals. Expelled sputum and phlegm can contaminate the interior surfaces of diving equipment. The dried deposits of these body fluids could become aerosolized, thereby contaminating the captive air within the diving suit with the tubercle bacillus. The microorganisms in these potentially-infectious aerosols remain viable for long periods of time, and with the infectious dose of tuberculosis being extremely small, i.e., 1-10 organisms, the situation could theoretically occur whereby infection of coworkers would occur. Active tuberculosis is characterized by pulmonary involvement, with persistent cough, night sweats, weight loss, and enlargement of lymph nodes. Chemotherapeutic regimens are available and recommended. Periodic tuberculin skin testing should be used to determine the prevalence and incidence of tuberculosis among at-risk workers.

f. ***Pseudomonas aeruginosa***, a gram-negative bacillus, is the primary cause of otitis externa (i.e., swimmer's ear) after exposure to water. The disease is common among divers as a result of altered flora of the ear canal due to prolonged water exposure, and will prevent workers from diving. Dermatologic and eye infections occur; pneumonia and urinary tract infections have been reported. Treatment for otitis externa generally involves the use of antibiotic-steroid ear drops. Serious complications can occur in compromised individuals.

Vibrio species are ubiquitous inhabitants of both saltwater and freshwater, with at least 34 identified species, 11 of which are human pathogens. The majority of human infections are generally caused by the following three species:

V. cholerae
V. parahemolyticus
V. vulnificus

Vibrio species responsible primarily for gastroenteritis resulting from fecal-oral transmission or ingestion of polluted water include:

V. cholerae
V. parahemolyticus
V. mimicus
V. hollisae
V. fluvialis
V. furnissii

Vibrio species responsible for soft-tissue infections, otitis, and sepsis resulting from penetrating trauma or contact include:

V. vulnificus
V. alginolyticus
V. damsela
V. metchnikovii
V. cincinnatiensis

Although the vibrios do exist naturally in the aquatic environment, the contribution of fecal contamination from infected individuals and carriers is difficult to ignore in endemic and epidemic regions of the world, especially where sanitation is inadequate or absent.

g. ***Vibrio cholerae***, a nonhalophilic organism, has been associated with seven pandemics of cholera since 1817, with epidemics underway in several parts of the world today. Enteric infections occur primarily through the consumption of or exposure to contaminated water or food, especially uncooked seafood. Clinical disease typically includes severe diarrhea with dehydration; possible serious sequelae include coma, convulsions, and death. The disease is endemic and epidemic in Southeast Asia, Africa, India, the Middle East, Southern Europe, Central and South America, and the Oceanic Islands. A short-lived and moderately effective vaccine is available and may be required by certain countries.

h. ***Vibrio parahemolyticus***, a halophilic organism, is found worldwide as a major cause of gastroenteritis from the consumption of seafood (e.g., Japanese summer diarrhea). The organism has been isolated from seawater, sediment, suspended particulates, and marine life. The majority of infections worldwide occur during the warm summer months. Human infections result primarily from the eating of raw seafood (e.g., oysters and sushi) or undercooked seafood (e.g., crabs, shrimp, and lobsters). Wounds exposed to the marine environment can become infected with *V. parahemolyticus*, resulting in a cellulitis, and ocular and ear infections have been reported. Serious sequelae such as septicemia, pneumonia, and osteomyelitis are rare. Recovery is usually spontaneous after several days; antimicrobial therapy is available.

i. ***Vibrio vulnificus***, a halophilic organism, is an insidious and highly invasive marine pathogen, that causes three distinct clinical disease syndromes, namely,

(1) wound infections from contact with seawater or the handling of shellfish; these infections, either from the contamination of pre-existing wounds or injury in the marine environment, may become edematous (swollen) and erythematous (red) within hours, accompanied by lymphadenopathy. Intense pain occurs at the infected site, with fever, chills, and nausea; complications, especially in persons with underlying disease, result in a fatality rate of 7-22%. Antibiotic treatment should be administered promptly.
(2) a primary septicemia, with malaise, fever, chills, vomiting, diarrhea, prostration, and a mortality rate of 50%, especially among individuals with pre-existing liver disease that consume raw seafood; antibiotic treatment should be administered promptly, and
(3) an acute, self-limiting diarrhea from the consumption of raw seafood.

Salmonella species found as waterborne pathogens may cause three distinct clinical diseases, namely,
(1) a self-limiting gastroenteritis,
(2) a septicemia, and
(3) an enteric fever (i.e., typhoid fever).

The salmonellae can survive in seawater for several weeks. Several thousand serotypes of *Salmonella* exist; the most relevant serotypes associated with human infections are:

S. serotype typhi, responsible for typhoid fever
S. serotype typhimurium, causes gastroenteritis
S. serotype enteritidis, causes gastroenteritis, and
S. serotype choleraesuis, causes septicemia.

j. ***Salmonella* serotype typhi** is solely carried by humans; it is spread through the fecal-oral route, and by the consumption of contaminated water and food. In the US and other developed countries, the control of carriers, chlorination of water, sewage management, and prophylactic vaccination have kept typhoid fever under control, with approximately 70% of US cases acquired during travel to endemic areas outside of the US. Among the developing countries, waterborne transmission represents the major route of infection. Typhoid fever may be prolonged, lasting about three weeks, with fever, malaise, lethargy, constipation, diarrhea, and bacteremia. The mortality rate is 2-10%, with a relapse rate of 20%. Antimicrobial therapy is available. A recently developed live oral vaccine is considered efficacious and should be used for prophylaxis against typhoid fever.

k. ***Leptospira interrogans***, the causative bacterium of leptospirosis, is contracted by contact with infected animals or contaminated water; the bacteria enter the body through a skin break or through mucous membranes. Numerous wild and domestic animals act as reservoirs, and may represent the major source of human infection. Swimming, wading, bathing, diving, or other contact with water in ponds, streams, and reservoirs that are contaminated with animal urine from infected animals is frequently the source of human infections, sometimes resulting in outbreaks of illness. Onset of clinical disease is abrupt and influenza-like; serious sequelae include liver, kidney, and central nervous system involvement. The disease occurs worldwide, especially during the summer months in temperate climates and as an endemic disease in the tropics. Effective antimicrobial therapy is available; prophylactic use of antimicrobials among high-risk occupational groups is recommended.

l. ***Legionella***, the causative bacterium of legionellosis and Pontiac fever, is comprised of at least 29 species, although approximately 70% of human infections are due to *L. pneumophila*. Legionnaires' disease has been reported worldwide, both as endemic outbreaks and sporadic cases. The natural habitat for the legionellae is water, including ponds, lakes, water cooling towers, showers, nebulizers, whirlpools, etc., with transmission occurring primarily from contaminated aerosols. The legionellae can survive and multiply in tap water for longer than one year; hyperchlorination is required for microbial inactivation. This opportunistic pathogen generally afflicts individuals with specific risk factors (e.g., elevated age, smoking, alcohol consumption). Two distinct clinical conditions have been described, namely, (1) legionnaires' disease, an influenza-like illness that can lead to systemic disease, with extensive pulmonary involvement, respiratory failure, and death, and (2) Pontiac fever, a self-limiting influenza-like illness without pneumonia. No vaccine is available; antibiotic therapy is recommended.

3. **Fungi**

The most common fungal infections associated with the aquatic environment are the dermatophytoses, caused by a large group of fungi collectively known as dermatophytes or "ringworm" fungi. Another less frequently encountered fungal infection associated with polluted waters is pseudallescheriasis.

a. ***Epidermophyton***, ***Microsporum***, and ***Trichophyton*** are the fungal genera responsible for the dermatophytoses; 24 species are currently recognized. Tinea pedis is ringworm of the feet or athlete's foot, particularly affecting the interdigital webs and soles. Infection can occur by contact with wet floors or decks, e.g., in communal showers and bathing facilities. The infection typically results in a nuisance infection, although if untreated, can progress to lymphadenitis. Antifungal medications are readily available, many as nonprescription drugs.

b ***Pseudallescheria boydii*** is the causative fungal agent of pseudallescheriasis. The fungus has been isolated from various environmental sources, including soil, polluted water, sewage, waterlogged pastures, swamps, algae, and animal manure. Numerous local and systemic diseases have been attributed to *P. boydii*, including sinusitis, meningitis, cerebral abscess, pulmonary involvement, endocarditis, arthritis, and cutaneous granulomata. Invasive disease from near drowning due to aspiration of polluted water has been documented; most infected patients experienced brain abscesses and a fatal outcome. Traumatic implantation of *P. boydii* in healthy individuals has resulted in chronic, localized infections of soft tissue, bone, and the cornea. Chemotherapy with the imidazoles appears effective.

4. **Algae**

Protothecosis is an uncommon algal infection caused by two species of the genus *Prototheca*, namely, *P. zopfii* and *P. wickerhamii*. Although rare, cases have been reported from all regions of the world, including the southeast US. Species of *Prototheca* have been isolated from both marine and fresh water, aquatic sediments, soil, and foods contaminated with polluted water, soil, or animal feces. Infections involve the soft tissues of the extremities resulting from penetrating trauma and exposure of existing lesions with contaminated water or soil. The course of infection is extremely indolent (slow to occur), lasting months or years, with little evidence of self-healing. Chemotherapy is available.

5. **Parasites**

Various human and animal parasites are found as contaminants of both marine and fresh

waters worldwide. The majority of parasitic infections from exposure to the aquatic environment are the result of contact with or ingestion of fecally-contaminated water or food. A brief discussion of some of the more important parasitic infections of humans that are associated with fecally-polluted water, namely amebiasis, giardiasis, schistosomiasis, and cryptosporidiosis, follows. Additionally, information on amoebic meningitis, a serious waterborne disease caused by exposure to a free-living pathogenic amoebae is presented. A complete listing of aquatic parasites associated with human disease is found in Appendix III.

a. ***Entamoeba histolytica*** is the protozoan parasite responsible for amebic dysentery or "Montezuma's revenge." About 400 million persons worldwide are infected; 100 million have acute or chronic disease. Thus, the majority of infected persons have asymptomatic disease. *E. histolytica* normally lives and multiples in the large intestine of infected humans, but may assume a more pathogenic form and invade the tissues. Clinical disease is associated with acute diarrhea, abdominal pain, fever, chills, and headache. Cysts are the only infective form; they are excreted with the feces and remain somewhat tolerant of environmental conditions (e.g., they survive in feces and cool water for 1-2 weeks). Transmission is primarily through fecally-contaminated water and food; insects often act as carriers of the infective cysts. The prevalence of amebiasis varies, with 5% infectivity in the US and 40% in tropical areas of the world. Drug treatment is available.

b. ***Giardia lamblia*** is the parasitic protozoan responsible for giardiasis, an intestinal infestation that occurs worldwide, especially in warmer climates. The disease is readily transmitted to others, especially where sanitary conditions are not observed. The route of transmission is fecal-oral, and one index case can infect hundreds of individuals through the contamination of food or water. Several animals, including dogs and beavers, act as reservoirs of disease, and may be responsible for the contamination of streams and other inland waters. Clinical disease is associated with foul-smelling stools and anorexia, and although not fatal, the disease can prove extremely discomforting. Drug treatment is available and recommended for symptomatic cases.

c. ***Schistosoma*** species, including *S. haematobium*, *S. mansoni*, and *S. japonicum*, have been recognized as human parasites since antiquity. The clinical disease, schistosomiasis, occurs worldwide in tropical regions of Africa, the Caribbean, South America, the Middle East, Southeast Asia, and India. In excess of 200 million people worldwide are infected. The larval fluke (i.e., worm) responsible for schistosomiasis is transmitted from contaminated freshwater to humans by penetrating the "unbroken" skin; a freshwater snail acts as the intermediate host. After penetration, the larvae mature and the host experiences a rash, fever, malaise, cough, abdominal pain, and nausea; bloody diarrhea and enlargement of the liver can occur. The deposition of human waste in bodies of water containing the intermediate snail host is the single most important epidemiologic finding. Drug treatment is available.

d. ***Cryptosporidium*** is the protozoan parasite responsible for cryptosporidiosis, which is transmitted by contact and through the ingestion of contaminated water. Outbreaks and epidemics have been reported, with fecal-oral transmission implicated. Animals can act as reservoirs. Clinical symptoms include watery diarrhea, fever, abdominal pain, and anorexia. The parasite is found worldwide, with normal water chlorination proving ineffective in its destruction. Treatment is supportive and includes rehydration therapy and maintenance of proper electrolyte balance.

e. ***Naegleria fowleri*** is a pathogenic free-living amoeba that causes a disease called primary amebic meningoencephalitis (PAM) or amoebic meningitis among previously healthy individuals. The amoebae enter the nasal passages while individuals are submerged (i.e, swimming or diving) in warm freshwater harboring *N. fowleri*; only a few amoebae are required for infection to occur. The amoebae migrate up the nasal mucosa, penetrate the cribriform plate, and enter the cranium, where a rapidly fatal encephalitic disease ensues. Symptoms include fever, severe headache, vomiting, confusion, delirium, and coma. Although these amoeba are ubiquitous, infections remain rare. Diving in suspect warm and polluted freshwater should be avoided; hyperchlorination destroys the amoebae.

b. **Dermatoses**

Various microscopic and macroscopic aquatic animals are responsible for the initiation of dermatologic problems among persons exposed to marine life while swimming, wading, or diving in fresh or seawater. A list of the recognized aquatic animals responsible for dermatitis is found as Appendix IV; several of the more important organisms associated with dermatologic reactions in humans are discussed below.

1. **Schistosome Dermatitis**, also called cercarial dermatitis or "swimmer's itch", is caused by the penetration of the skin with nonhuman schistosomes, i.e., microscopic immature larval forms of schistosomal flatworms of birds and other nonhuman animals. Cutaneous infestation occurs worldwide, both from salt and fresh water and in all geographic regions. Cercarial dermatitis primarily affects exposed areas of the body; symptoms include a prickling sensation, itching, and the appearance of a red maculopapular rash. Complications include secondary bacterial infections. Brisk toweling immediately after leaving the water may be helpful in preventing infestation. Niclosamide applied to the skin may prevent cercarial penetration; dimethyl phthalate has been reported as an effective cercarial repellent.

2. **Cymothoidism**, or sea louse dermatitis, is caused by the bite of free-swimming crustaceans or cymothoids, i.e., sea lice that live as parasites on invertebrates and fish. They are found in the shoal waters of both tropical and temperate shore lines, where they are buried in the sandy bottom. The cymothoids will attack any organism near their domain, including humans. Sea lice can quickly attach to any prey and inflict sharp bites that result in hemorrhagic wounds. Cymothoids are commonly found along the southern California coast. Wounds should be cleansed with hydrogen peroxide and an antibiotic ointment should be applied.

3. **Seabather's Eruption**, also known as "sea poisoning," "sea critters," and "ocean itch" is caused by a group of marine animals known as cnidarians that possess tentacles with stinging nematocysts. The majority of outbreaks have been recorded in South Florida and the Caribbean and have been attributed to the larval form of the thimble jellyfish, *Linuche unguiculata*. These larvae are barely visible, appearing like finely ground pepper, and are trapped by bathing suits and diving apparel. Skin lesions range from a barely discernable macular rash to a generalized maculopapular and vesicular eruption; urticarial lesions have been reported. The dermatitis is associated with intense itching; other symptoms include nausea, diarrhea, chills, weakness, difficulty in sleeping, muscle spasms, and general malaise. Treatment includes the use of antihistamines and hydrocortisone creams, with epinephrine for extensive eruptions.

4. **Seaweed Dermatitis** is caused by exposure to the seaweed *Lyngbya majusculata*, a common blue-green algae found throughout the Pacific, Indian, and Caribbean oceans. Swimmers and divers exposed to toxic varieties of *L. majusculata* develop an erythematous dermatitis (reddened skin rash) associated with stinging, burning, and itching. These dermal sensations may develop within minutes to hours after exposure. The rash may progress to an escharotic (burn scabbing) blistering dermatitis, especially in perianal, perineal, or scrotal areas. Oral, ocular, and mucous membrane lesions have been reported, as well as a facial rash and conjunctivitis, possibly associated with exposure to aerosolized seaweed fragments. Seaweed dermatitis is treated symptomatically with cool compresses and topical steroids. Washing with soap and water upon leaving the water may prevent the development of dermatologic problems.

5. **Cutaneous Larva Migrans**, also known as creeping eruption, sandworm, and plumber's itch, is caused by exposure of the skin to the filariform larvae of nonhuman hookworms (e.g., dogs, cats, and raccoons). The sources of human infection include soil and sand contaminated with animal feces; e.g., exposure of bare feet or other body parts to contaminated beach sand above the high water mark or beneath beach houses. Infections occur worldwide, especially in tropical and subtropical areas, e.g., along the coast of Florida and the Gulf of Mexico in the US. Upon penetration of the skin, the nonhuman larvae cannot complete their normal life cycle, although they can remain under the skin for months. Symptoms begin immediately after penetration, with a red papule at the site of entry, which becomes enlarged and vesicular. The embedded larvae can move up to several centimeters per day, leaving torturous tracks with extreme itching. Treatment is both systemic and topical. The wearing of sandals and other protective clothing is recommended in potentially contaminated areas.

c. **Intoxications**

Numerous toxins are produced by dinoflagellates in the marine environment that may cause severe illness in humans; most are the result of injection of the toxin. In addition, bioaccumulation of dinoflagellate toxins occurs in filter-feeding marine animals such as oysters and clams. Consumption of contaminated oysters and other marine animals, especially when eaten raw, can cause intoxication, with symptoms ranging from numbness of the extremities, headache, nausea, vomiting, and diarrhea in milder cases to muscle paralysis, respiratory distress, memory impairment, and occasional death in severe cases.

Exposure of divers and other personnel engaged in marine operations most often occurs through the inhalation of aerosolized dinoflagellate toxins. The unarmored dinoflagellate *Ptychodiscus brevis* is associated with "red tide" outbreaks, with fish kills and human exposures taking place during algal blooms. Ocean waves tend to lyse the dinoflagellates, thereby releasing the toxin which can become airborne along coastal areas. The released toxins possess both a hemolytic and a neurotoxic effect. Symptoms of respiratory exposure include conjunctivitis, rhinitis (runny nose), bronchitis, and respiratory irritation. The use of respiratory protection and goggles should limit exposure. Treatment is supportive.

d. **Envenomations**

Numerous varieties of aquatic animals can envenomate divers and other workers while engaged in marine and fresh water operations. Both vertebrate and invertebrate animals can be involved in envenomation, using different mechanisms and producing different toxins.

1. **Venomous Invertebrates**, such as jellyfish, stinging corals, sea anemones, sea pansies, hydroids, and the Portuguese Man o'War belong to a group of marine animals known as cnidarians, with more than 9,000 species worldwide. They possess stinging nematocysts used to envenomate victims. Nematocysts are triggered by contact, which leads to skin penetration

with the concurrent release toxins that can cause intense pain, inflammation at the sites of exposure, and a urticarial skin rash (hives). Rarely, these envenomations lead to systemic symptoms and death.

a. ***Chironex fleckeri***, known as the "sea wasp", and *C. quadrigatus*, are the most dangerous of the invertebrate coelenterates identified as box-jellyfish. Nematocyst stings from these jellyfish produce immediate discolored wheals that progress to extensive swelling, erythema (reddening), vesiculation (blistering), and necrosis. The victim experiences immediate intense pain which can be incapacitating. Within minutes after tentacle attachment and envenomation, the affected individual may become cyanotic, convulsive, and pulseless. Pulmonary edema is evidenced upon autopsy. First aid is of utmost importance as the victim may die within minutes of being stung. All embedded nematocysts and attached tentacles must be removed immediately to prevent further envenomation, and the affected area should be washed with salt water and a commercial vinegar or 3-10% acetic acid applied to neutralize the toxin. An antivenom for *C. fleckeri* stings is available for cases of "sea wasp" poisoning. Other treatment is supportive.

b. **Echinoderms**, including the starfish and sea urchins, possess hard exoskeletons with spines which can penetrate the human skin and release venom. These toxins cause severe pain, redness, swelling, muscle weakness, paresthesias (i.e., sensations of burning, prickling, or formication), and cardiac arrhythmias. Paralysis and respiratory depression may occur. If spines break and become embedded in the skin, they should be removed, sometimes requiring surgical intervention. Ancillary treatment is supportive.

c. **Mollusks**, including coneshells and cephalopods, may envenomate upon handling. Coneshells envenomate by a radular tooth or dart that produces localized paresthesias, numbness, and paralysis, which may progress to respiratory arrest. Cephalopods such as octopi secrete a toxic saliva which is inoculated into the victim through a bite from its beak. These bites usually produce bleeding and are painful, causing swelling, redness, inflammation, blurred vision, numbness, difficulty in swallowing, and occasional paralysis. Treatment for mollusk envenomation is primarily supportive.

   Several species of polychaete marine roundworms possess biting jaws with venom glands. Bites can cause swelling, pain, and erythema (reddening), with spontaneous healing in several days. Only supportive treatment is indicated.

2. **Venomous Vertebrates** possess venom glands which can inflict serious injury to victims upon accidental exposure. More than 100 species of marine fish possess a defensive venom-injecting apparatus. Although worldwide in distribution, most venomous species are found in tropical and semi-tropical waters around coral reefs. Included are stingrays, scorpion fish, lion fish, weever fish, stonefish, zebrafish, tiger fish, turkey fish, fire cod, toadfish, stargazers, stonelifters, catfish, and surgeonfish. Venom glands are usually associated with spines or barbs in front of the dorsal, anal, or pectoral fins and spines in the tail and gill covers. In the stingray, the venom gland is located at the tip of the long barbed spine.

   Envenomations are associated with immediate and extremely intense pain at the puncture site, with some bleeding from the penetrating wound. Associated symptoms include nausea, vomiting, weakness, respiratory distress, convulsions, numbness, and occasional death. Treatment of stung limbs involves immersion of the limb in hot water (110-120F) for 30-60 minutes. All embedded spines, barbs, or other foreign materials must be removed from the injured site. Antibiotics and tetanus toxoid should be administered to patients stung by stingrays or scorpionfish, where larger penetrating wounds are encountered. Antivenom is available for stonefish envenomations. Supportive therapy is generally adequate.

   Sea snakes possess paddle-shaped tails and multiple fangs and are highly venomous. The bite

is usually painless and results in several small puncture wounds. Generalized rhabdomyolysis (i.e., disintegration or dissolution of muscle) is the dominant feature of sea snake envenomation. Early symptoms include headache, thirst, sweating and vomiting, with generalized aching and tenderness of the muscles within 30 minutes. Trismus or lockjaw is a frequent manifestation. Subsequently, a generalized paralysis occurs with respiratory failure as the muscles become stiff and nonresponsive. Renal failure and cardiac arrest are the result of damage to skeletal muscles. An antivenom is available and should be given immediately upon development of symptoms.

e. **Dangerous Non-Venomous Aquatic Animals** can inflict serious injuries to divers and others inhabiting the aquatic environment because of their aggressive behavior and size.

Many species of sharks are found worldwide in temperate and tropical waters that have attacked divers and swimmers inflicting severe and fatal injuries. Other potentially dangerous marine and fresh water animals include the mantarays, barracudas, moray eels, alligators and crocodiles, electric eels, piranhas, and several snakes such as the cottonmouth moccasin and brown water snake.

Some marine mammals may also be dangerous for humans, including the polar bear, sea lion, hippopotamus, and the duck-billed platypus. All wounds from these animals should be thoroughly debrided and rabies prophylactic vaccination considered.

2. Controlling and Preventing Exposure

a. **General Considerations**

All diving operations are conducted in biologically-contaminated water, the degree of hazard being a function of the type and number of potentially infective or venomous organisms and aquatic life present. Seawater and inland waters are essentially mixtures of numerous different microorganisms, some of which are normal inhabitants of the aquatic environment and others which originate from human and animal excreta and shedding. The majority of microorganisms found as aquatic inhabitants are harmless to humans, they are normal commensals of animals, birds, and mammals. However, certain species of viruses, bacteria, fungi, algae, and parasites are recognized as human pathogens and opportunistic microorganisms; the major sources of these disease-producing organisms being human and animal excreta, especially from infected hosts. The dumping of raw sewage into oceans, lakes, and rivers is the primary source of exposure to potentially infectious and toxigenic microorganisms for both humans and animals, including consumable species such as shellfish.

The appearance of water per se may be misleading for workers, since crystal-clear water can be grossly contaminated with microorganisms, e.g., pristine-appearing water can contain upwards of a million microorganisms per milliliter. However, as the water appearance becomes brackish and foul-smelling, the likelihood of extensive microbial contamination increases significantly, unless the pollution is due to toxic chemicals, which may also be detrimental to microbial life. Clearly, when entering water that has known or potential effluents from sewage disposal, the need to take protective measures is mandated.

The most important preventive strategy to avoid occupational disease while conducting marine operations is "exposure control." When conducting diving operations in known polluted waters, the need for optimal protection from exposure to these waters is indicated. All body parts must be protected by diving apparel and extreme care must be exercised to avoid mucous membrane and oral exposure to even minute quantities of water.

It is imperative that diving personnel with pre-existing wounds, incompletely healed surgical incisions, or underlying disease, completely refrain from entering the aquatic environment.

Numerous pathogenic and opportunistic microorganisms require an easy portal of entry, such as a previous cut, abrasion, or wound, in order to infect. In addition, individuals that have underlying disease or are immunosuppressed are significantly more susceptible to the possibility of serious and life-threatening infection upon exposure. Waterborne microorganisms can cause serious respiratory disease when the normally sterile lung is contaminated through near drowning or accidental aspiration of polluted water.

It is clearly understood that we exist in a world full of health risks, risks that affect us every day of our lives. When operating in the aquatic environment, an awareness of the potential and real risks present is necessary in order to avoid serious consequences; that is the purpose of this document. As Barsky stated in Diving in High Risk Environments, "when diving in contaminated water, ... precautions include obtaining the right equipment, maintaining it according to manufacturer's specifications, completing the initial training, continuing with monthly training dives to ensure competency in the use of the equipment, and maintaining a realistic attitude about what you can and can't do."

Thus, risk reduction is the key. By having an understanding of the biohazards present in the aquatic environment, we can minimize or prevent exposure to these biohazards. Through the deployment of a hierarchy of exposure control measures generally understood and accepted in the management of biohazards, namely, engineering practices, good work habits, medical surveillance and prophylactic vaccination, and the use of appropriate protective equipment and apparel, risk can be reduced. Engineering practices per se (i.e., biocontainment) are of limited use in the aquatic environment for controlling exposure to biohazards, although important for the protection of laboratory personnel handling potentially dangerous samples or specimens, e.g., the use of laminar flow cabinets. Therefore, the application of good work habits in conjunction with medical monitoring and the use of personal protective equipment will be emphasized. Each of these areas will be discussed briefly; additional information is available in Standard Methods for the Handling and Management of Biohazardous Materials, Jerry J.Tulis, Ph.D., Division of Occupational and Environmental Medicine, Duke University Medical Center, February/March, 1994, produced under Cooperative Agreement U60/CCU408717-02 for the EPA's National Biohazard Risk Program.

b. **Good Work Habits**

Workers engaged in operations in the aquatic environment need to adhere to standard procedures of infection control. Exposure to potentially polluted waters must be prevented or limited in order to avoid infection. In the referenced document Standard Methods for the Handling and Management of Biohazardous Materials, the following section is pertinent to marine and diving operations:
Section 5.2.1 Work Practices, specifically (e) the collection of land and marine animals, (f) the collection of water samples, sediments, waste, sewage, and other environmental specimens, and (g) the use of diving and other personal protective equipment.

Diving equipment must be decontaminated after every use in order to prevent exposure of the diver or attending personnel to waterborne hazards, especially toxic materials and pathogenic microorganisms. Decontamination involves the initial cleaning and decontamination of the exterior of the diving equipment, followed by similar procedures for the interior of the diving equipment. Decontamination of the exterior is conducted to remove or destroy any potentially dangerous microorganisms acquired from the aquatic environment, whereas decontamination of the interior is to remove or destroy any infectious microorganisms deposited by the diver during equipment use (e.g., from blood or other body fluids). Moreover, personal hygiene is mandatory; employees must shower immediately upon removal of diving equipment. For information on the selection of disinfectants for use on diving equipment, namely, alcohols, formaldehyde, glutaraldehyde, chlorine-liberating halogens, iodine-liberating halogens, phenolics, and quaternary ammonium compounds, see the document entitled Standard Methods for the Handling

and Management of Biohazardous Materials, Appendix III, Generic Classification of Disinfectants.

1. **Exterior Diving Suit Decontamination**

The decontamination process begins as the diver exits the water. Initially, a high-pressure water spray in a top-to-bottom pattern of washing is used to remove gross contamination. All personnel assisting with decontamination (e.g., tenders) should wear appropriate protective apparel to avoid exposure. Neutralizing agents or disinfectants are then used, depending on knowledge of the potential contaminants. For destruction of microorganisms, a surfactant such as trisodium phosphate is used followed with a spray of betadine, zepamine, or tincture of green soap. Areas that should receive an increased careful disinfection include the helmet/yoke interface, seams, zippers, and the soles of boots. After a minimal 10-minute exposure to these products, decontaminated areas are rinsed with fresh water.

2. **Interior Diving Suit Decontamination**

Upon completion of disinfection of the exterior of diving equipment, the suit may be removed. All pieces of diving equipment are placed in individually marked containers as removed, and the containers are sealed appropriately. Information to be included on container labels includes the date of exposure, the identity of the piece, known or suspected contaminants, the duration of exposure, and the decontamination procedure. A record is kept of the use and maintenance of each piece of the diving apparatus. The sealed containers are placed in a designated equipment decontamination area.

Interior surfaces of diving equipment require prompt decontamination to avoid or limit the development of mold growth, i.e., mildew formation, especially if moist from perspiration. Drying the suit while turned inside out, and the use of appropriate germicidal sprays are recommended. Inspection of the surfaces for detection of dried blood from lacerations or cuts is an important cleaning and decontamination procedure to avoid disease transmission. The selection of a high-level disinfectant depends on the types of surfaces to be treated, i.e., plastic, glass, metal, or cloth. High level disinfectants include various formulations of the generic disinfectants glutaraldehyde, sodium hypochlorite, formaldehyde, and phenol. Care must be exercised in order that potentially toxic disinfectant residues are not left on diving apparatus; some pieces may need to be rinsed with fresh water and dried before reuse or storage.

3. **Personal Hygiene**

Immediately following the removal of diving equipment, the diver should shower vigorously for a minimum of 5 minutes, using a disinfectant soap. All undergarments, including bathing suits, underwear, etc., should be placed in a plastic container. Upon completion of the initial showering, the worker should towel-dry, depositing the used towel in a plastic bag. A second showering should then follow, again for 5 minutes, and with the same toweling procedure. A medical evaluation is recommended when symptoms of disease or injury are evident.

4. **Specimen Collection**

Workers engaged in the collection of marine specimens and environmental samples, including potentially polluted water and aquatic sediments, must be cognizant of the presence of pathogenic microorganisms and dangerous marine life. Care must be exercised when handling water samples contaminated with sewage, since numerous enteric microorganisms are present, some of which can cause disease upon exposure of abraded skin or mucous membranes. Touching of the oral cavity, nasal passages, or eyes with contaminated hands, whether gloved or ungloved, can result in localized or systemic infections of these areas, i.e.,

gastrointestinal infections, sinusitis, or conjunctivitis. Injuries from marine animals, including penetrations from barbs, spines, and fins, can become infected when exposed to contaminated water or aquatic sediments. Numerous venomous marine animals can inflict painful stings or bites resulting in envenomation; heavy duty gloves must be worn when handling these marine animals.

Important exposure control measures that need to be considered when collecting aquatic materials include the complete avoidance of water potentially contaminated with pathogenic microorganisms. Should exposure to these waters be required, the use of protective apparel that covers all exposed body parts is required. All previously used protective apparel must be discarded in appropriate biohazard containers if disposable, or properly decontaminated if to be reused. Since most collection will be conducted with the use of the hands, protective gloves and vigorous handwashing are important principles of infection control; these precautions extend to the laboratory where collected specimens are handled, processed, and discarded.

3. MEDICAL MONITORING PROGRAM

a. Physiologic Hazards Associated with Diving Operations

Physiologic injuries associated with diving are usually based on two physical laws, Boyle's Law and Henry's Law. According the Boyle's Law, the volume of a given mass of gas is proportional to the absolute pressure found in that environment. As the pressure increases during diving operations, the volume of gas decreases, and the deeper the dive, the smaller the gas volume. As the diver ascends, the gas volume expands and barotrauma may result, especially during rapid ascent.

According to Henry's Law, the amount of gas in a volume of solvent is proportional to the partial pressure of the gas, and while descending during diving operations, the gases become increasingly soluble in blood and tissue. This condition leads to decompression sickness and nitrogen narcosis, and depending on clinical signs and symptoms, may require recompression therapy.

Other potential physiologic hazards that may affect divers are heat and cold stress. Heat stress is a problem associated with total encapsulation in a diving suit. As the diver engages in activity, cooling which normally occurs through sweating may be insufficient and hyperthermia may develop. Simply monitoring the breathing and heart rates are good indicators that hyperthermia is occurring. Symptoms of heat stress include weakness, dizziness, headache, nausea, and impaired judgement. Muscle cramps, delirium, seizures, and eventually coma may develop if body temperature continues to increase. Appropriate measures such as cessation of work should be undertaken if hyperthermia is suspected. Maintaining the diver in a cool environment during pre-dive and post-dive procedures may be useful.

Cold stress may occur, especially when working in frigid environments. Body heat may be lost by conduction, convection, and radiation. Cold injuries may develop from both freezing or non-freezing of tissues. Injuries of the extremities are most likely to involve the cheeks, nose, external ears, fingers, toes, hands, and feet. Risk factors for cold injury include old age, fatigue, alcohol consumption, smoking, underlying conditions affecting the peripheral circulation, and inadequate insulating clothing. Early symptoms of hypothermia include uncontrolled shivering, confusion, stumbling, disorientation, and skin cold to the touch.

Divers should be closely monitored for symptoms of either hyperthermia or hypothermia. Appropriate equipment for cooling or warming the diver should be available. The Environmental Protection Agency (EPA) and the National Oceanic and Atmospheric Administration (NOAA) developed the suit-under-suit (SUS) diving system to provide improved protection for divers. The

SUS is a positive pressure dive suit that provides thermoregulation and minimizes leakage. It is comprised of two suits, an inner thin-rubber suit with attached boots, and an outer heavyweight rubber suit with exhaust valves on both ankles and one arm. The two suits are mated at the neck dam. An umbilical hose is used to pump clean thermally-regulated water into the cavity between the two suits to warm or cool the diver. The cavity is maintained at a positive pressure, thereby preventing contaminated water from entering the cavity in the event of a puncture or leak in the outer suit.

b. Hazards Associated with Diving Equipment

With certain types of diving equipment, the possibility exists for the contamination of the breathing air supply leading to asphyxial conditions. Improperly functioning surface equipment may introduce noxious and life-threatening fumes to the diver's air supply.

Allergic reactions can develop among workers exposed to diving equipment materials, especially from the mouthpiece, suit, and face mask. Diving equipment is comprised of numerous different chemicals, some of which can cause allergic responses among sensitized divers. Cases of latex allergy have been reported among divers. These reactions are manifested by the appearance of skin irritation, including rashes, vesicle formation, and weeping lesions. A diagnosis of allergic contact dermatitis can usually be made with a case history, physical examination, and patch testing. An investigation to determine the specific cause of contact dermatitis is important, since other materials may be substituted in order to allow continued diving. Treatment includes the use of cold Burow's solution dressings and corticosteroids.

The chaffing of certain body parts, e.g., the toes, knees, wrists, and axillae, can occur from the seams and collar of diving suits. The wearing of a full-body leotard under the diving suit may prevent chaffing.

Residues remaining on diving equipment from the process of decontamination, i.e., disinfection, may cause allergic responses or skin irritation to occur. The thorough rinsing of equipment after disinfection should prevent these problems from occurring.

c. Selection of Personnel for Diving Operations

Not all workers are psychologically or physiologically prepared to handle the numerous challenges that may be encountered during diving. It is not uncommon for divers to experience claustrophobia in totally encapsulated suits while in an aquatic environment, especially when entering confined spaces. Physical challenges such as the weight of the equipment, limited movement, and buildup of body heat, can result in diver discomfort and distress. Diving in highly polluted and dangerous waters can cause undue stress on diving personnel. Thus, the screening of personnel for diving operations per se, and especially in high risk environments, is mandatory; workers need to be aware of potential hazards and trained to respond properly during difficult and emergency situations.

d. Medical Surveillance

Diving operations are associated with numerous potentially dangerous and sometimes life-threatening situations for both the inexperienced and the experienced diver. Because certain identifying medical conditions may place an employee at increased risk of injury, harm, or disease, it is recommended that a thorough medical evaluation and periodic physical examinations are performed. Included are a complete history of illnesses and general health and a comprehensive medical examination. Additional tests may include pulmonary function tests, EKG, EEG, and audiogram. Useful examples of medical history and physical examination forms used by the Recreational Scuba Training Council and Duke University are presented as Appendix V, with contraindications for diving listed and discussed. Additional testing will vary according

to the frequency of diving operations, the depth of the dives, any underlying medical disorders, the presence of known contaminants in diving waters, etc.

In general, when divers have open lesions or other wounds, they should not dive. However, simple skin lesions can be covered with a petroleum-based antibiotic ointment and covered; the wound is thoroughly cleansed after the dive, with removal of all dressings and medications. Upper respiratory infections tend to swell the passages of the eustachian tube and the sinuses; diving under these conditions can cause barotrauma of the sinuses or the middle ear. Pre-existing lower respiratory infections can lead to pulmonary barotrauma and serious injury due to mucous plugging of the small airways, thereby preventing the escape of air during ascent. All individuals experiencing systemic illness should refrain from diving until fully recovered.

e. Prophylactic Vaccination

As an important adjunct to the use of personal protective equipment, good work habits, and diver training, the use of specific vaccines will help prevent certain infections associated with the aquatic environment. Although numerous disease-causing agents are found in polluted waters, primarily from sewage effluents, the number of vaccines available to protect the worker is limited. Nevertheless, serious diseases can be prevented with the use of these vaccines, and divers should avail themselves of their protective value. Among the vaccines that are recommended for all personnel engaged in diving and other marine operations are those developed against the viral infections that cause hepatitis A, hepatitis B, and poliomyelitis, and against bacterial infections that cause typhoid fever, cholera, and tetanus. In addition, when workers are engaged in marine operations in semi-tropical and tropical waters, especially where insect vectors of various viral, rickettsial, bacterial, and parasitic diseases are present, the need for additional vaccines, prophylactic medications, and insect repellents needs to be considered. Additional information on vaccinations is provided in the document entitled Foreign Travel and Field Operations Immunologic Readiness Program, Jerry J. Tulis, Ph.D. and Ricky L. Langley, M.D., M.P.H., Division of Occupational and Environmental Medicine, Duke University Medical Center, June, 1993, produced under Cooperative Agreement U60/CCU408717-01 for the EPA's National Biohazard Risk Management Program.

f. Post-Exposure Evaluation

When an employee experiences an accident or potential exposure to hazardous materials, including polluted waters containing pathogenic microorganisms, the worker needs to be promptly evaluated by medical personnel. It may be necessary to evacuate the employee to a facility where hyperbaric oxygen therapy can be administered. When an exposure to infectious agents is suspected, the exposed areas need to be thoroughly cleansed and the worker monitored for the onset of clinical symptoms.

Exposure to nematocysts from jellyfish and other marine animals can be treated with salt water and weak acetic acid (i.e., vinegar) after removal of the embedded nematocysts. Injuries from stingrays and venomous fish should be treated initially to hot water to neutralize the toxin; antivenom and other life support measures may be required. It is mandatory that medical personnel evaluate injuries from envenomations as promptly as possible.

The exposure of diving personnel to the residual blood or body fluids of other divers, i.e., in the use of shared diving equipment, needs to be addressed by application of the bloodborne pathogens standard. For additional information see the document entitled Model Standard Operating Procedure for Compliance with the OSHA Bloodborne Pathogen Standard, Jerry J. Tulis, Ph.D., Division of Occupational and Environmental Medicine, Duke University Medical Center, May, 1993, produced under Cooperative Agreement U60/CCU408717-01 for the EPA's National Biohazard Risk Management Program.

For all occupational exposures, employees involved in diving and other marine operations need to be monitored periodically until the injury has healed or recovery from infection or illness is complete. Diving personnel may need to be restricted from diving operations until the medical provider deems it safe for the employee to resume diving.

g. Medical Recordkeeping

1. **General Considerations**

The proper maintenance of medical records is vital to a medical surveillance program. Certain federal agencies, e.g., OSHA, mandate requirements for the maintenance of medical records. Under OSHA regulations, the following definitions apply:

* employee exposure records mean any information on workplace measurements or monitoring data, biological monitoring data, and material safety data sheets.
* medical record means a record concerning the health status of an employee which is monitored by a health care professional; the results of medical examinations and laboratory tests; medical opinions, diagnoses, and recommendations; first aid records, with descriptions of treatment and prescriptions; and, employee medical complaints.

OSHA regulations specify that employees or their designated representative must be given access to exposure and medical records. However, OSHA does not mandate the form, manner, or process by which an employer maintains a record provided the information contained in the record is preserved and retrievable. Chest roentgenograms must be preserved in their original state.

2. **Medical Records**

The medical record for each employee shall be preserved and maintained for at least the duration of employment plus thirty (30) years, except that the following types of records need not be retained for any specific period:

a. Health insurance claims records maintained separately from the employer's medical program and its records.
b. First aid records (not including medical histories) of one-time treatment and subsequent observation of minor scratches, cuts, burns, splinters, etc. which do not involve medical treatment, loss of consciousness, restriction of motion or work, or transfer to another job, if made on-site by a non-physician and if maintained separately from the employer's medical program and its records.
c. The medical records of employees who have worked for less that one year for the employer need not be retained beyond the term of employment if they are provided to the employee upon termination of employment.

3. **Employee Exposure Records**

Each employee exposure record shall be preserved and maintained for at least thirty (30) years, except for the following:

a. Background data or environmental (workplace) monitoring or measuring, such as laboratory reports and worksheets, need only be retained for one year provided the sampling results, the collection methodology (sampling plan), a description of the analytical and mathematical methods used, and a summary of other background data relevant to interpretation of the results obtained are retained for at least thirty (30) years.
b. Material safety data sheets records concerning the identity of a substance or agent need not be retained for any specified period provided some record of the identity (i.e., chemical name) of the substance or agent, where it was used and when it was used is retained for at least thirty (30) years.

c. Biological monitoring results designated as exposure records by specific occupational safety and health standards shall be preserved and maintained as required by the specific standard.

4. **Analyses Using Exposure of Medical Records**

Each analysis using exposure of medical records shall be preserved and maintained for at least thirty (30) years.

5. **OSHA Bloodborne Pathogen Standard**

The recent OSHA standard on protection of workers against bloodborne pathogens specifies requirements on recordkeeping. Medical records and training record requirements are specified as follows:

a. **Medical Records**

The employer shall establish and maintain an accurate record for each employee with an occupational exposure; this record shall include the following information:

1. The name and social security number of the employee.
2. A copy of the employee's hepatitis B vaccination status including all the dates of vaccination and any medical records relative to the employee's ability to receive immunization.
3. A copy of all results of examinations, medical testing, and follow-up procedures.
4. The employer's copy of the healthcare professional's written opinion.
5. A copy of the information provided to the healthcare professional.
6. The employer shall ensure that employee medical records are kept confidential and are not disclosed or reported without the employee's express written consent to any person within or outside the workplace except as required by this section or as may be required by law.
7. The employer shall maintain the records for at least the duration of employment plus thirty (30) years.

b. **Training Records**

Training records shall include the following information:

1. The date(s) of the training.
2. The contents or summary of the training session.
3. The names and qualifications of the persons conducting the training.
4. The names and job titles of all persons attending the training sessions.
5. Training records shall be maintained for three (3) years from the date on which the training occurred.

4. **Employee Training Program**

a. **General Considerations**

All employees whose job requirements involve potential exposure to waterborne pathogenic microorganisms, aquatic life responsible for dermatoses and envenomations, and dangerous marine and fresh water animals need to receive specialized safety training. Included are all employees whose occupational duties involve diving operations in both seawater and fresh water; the monitoring of estuarine and coastal waters; the collection of water samples, sediments, sludges, and sewage; the collection of marine and fresh water animal and plant species; and the laboratory use and disposal of collected environmental samples and specimens. The training should be provided during orientation after hiring

and annually thereafter, with more frequent specialized training as deemed necessary for compliance with newly issued policies, directives, guidelines, or regulations.

b. **Biological Safety Training**

Included in the biological safety training sessions should be the following de minimus information:

* etiology of waterborne infectious diseases
* geographic distribution of infectious agents and dangerous marine life
* sources of water pollution
* infectivity of microorganisms from aquatic environments
* transmissibility of aquatic microorganisms
* clinical symptoms of relevant diseases
* symptomatic and specific treatment
* vaccine prophylaxis
* exposure incident reporting
* biocontainment practices for laboratory work
* good work practices
* use of protective clothing
* shipment of biologic specimens
* handling of biomedical wastes
* medical surveillance programs
* compliance with OSHA Bloodborne Pathogen Standard
* compliance with consensus guidelines and policies
* other relevant issues

Additional specialized training to be provided to employees whose duties involve diving operations includes the following de minimus information:

* diving in contaminated and polluted water
* selection of safe diving equipment
* decontamination of diving equipment
* personal hygiene after diving
* physical preparedness for diving
* contraindications to diving

The document entitled Standard Methods for the Handling and Management of Biohazardous Materials, Section 6.4, Biosafety Training provides additional information on safety awareness training when coping with occupational biohazards.

Finally, it is not within the scope of this document to provide information on the training requirements of divers from the viewpoint of equipment selection, use, maintenance, and storage; discussion of scuba and surface-supplied diving equipment; diving plans and techniques; equipment checklists; and other important considerations. This document is limited to the biohazards associated with diving and other marine and fresh water operations.