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Protection of divers in waters that are contaminated with chemicals or pathogens

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Toxic and anthropogenic wastes are present on the coasts and in the coastal waters of the United States, particularly along the East Coast. Medical and drug-related wastes, such as syringes, crack vials, and hospital dressings washed ashore during the summer and early fall of 1988 from Florida to Massachusetts resulted in numerous beach closings for health and safety reasons. Over 800 bottlenose porpoises died in the coastal waters of the eastern United States during the summer of 1987, most of which showed severe necrotic epidermal lesions. There are abundant accumulations of plastic trash on the beaches of the United States, including tampon applicators, six-pack beverage rings, and Styrofoam drink containers. A "brown tide" which severely damaged the bay scallop industry and the eel grass population occurred in Peconic Bay, NY, during the summers of 1986, 1987, and 1988. A "green tide" which closed the beaches and caused substantial discomfort to the community occurred off Ocean City, NJ, during the summers of 1985, 1986, and 1987. Over one-third of the nation's shellfish beds are permanently or intermittently closed due to bacterial contamination. Numerous beaches on the East Coast of the United States are closed during the summer months due to unplanned discharges or storm sewer discharges of potentially pathogenic sewage. Finally, lobsters caught for human consumption off the northeastern United States had to be discarded due to necrotic tissues.

These events have led to questions by the public and government officials about the health of our coastal waters. Contamination may arise from a variety of sources, such as discharges from industry or municipal outfalls, run-off from nonpoint sources, or spills of hazardous material. Such materials as plastic precursors, synthetic organic chemicals, and pesticides are a common and essential entity of our daily commerce. Many are transported by waterborne tankers, highway tank trucks, and railroad tank cars. Newspapers and television accounts suggest that accidents involving these varied forms of transport are a common occurrence.

EXPOSURE OF DIVERS TO CONTAMINATED ENVIRONMENTS

During the last decade, diving operations in polluted water have increased the range of materials to which divers have been exposed. At first, little consideration was given to the possible effects of such materials on the divers themselves. For example, a number of years ago the National Oceanic and Atmospheric Administration Diving Office was asked to review a research proposal to put divers down to 60 ft in the New York Bight, and then dump sewage sludge on them from a disposal barge to film the dumping action from underwater.

However, the attitude toward exposure of divers to pathogens and chemicals began to change in the late 1970s after NOAA completed a study which showed that pathogenic microorganisms, such as bacteria, viruses, and parasites, clearly posed potential hazards for divers in ocean-dumping areas. The results were corroborated by several incidents, including one in July 1982 when a number of New York City firefighters and police officers contracted amoebiasis after participating in diver training exercises in the Hudson River near a discharge pipe for raw sewage.

Today, divers are often required to enter contaminated waters to assess damage from leaking vessels or pipelines; to locate, contain, or clean up underwater sources of contamination; to recover drums of potentially hazardous substances; or to conduct research studies. Submersion in these situations has resulted in injuries such as chemical burns, both to divers and surface support personnel handling contaminated equipment, as well as in serious illness in divers required to inspect or repair sewage outfall pipes. For example, exposure of rubber-based diving equipment to environments that were contaminated with petroleum products has resulted in diver injury due to equipment deterioration by the petroleum products, and subsequent failure of the equipment.

Clearly, identification of the potential hazards a diver may encounter is critical before the start of any diving effort. The range of hazardous materials is extensive, but most can be categorized into one of four groups: petrochemicals, chlorinated hydrocarbons and related halogenated organic compounds, noxious gases, and strong acids and bases. The toxicity of these materials varies markedly; exposure to halogenated organics in the aquatic environment, for example, can be extremely dangerous because some of these compounds can penetrate both suit materials and the diver's skin.

The identification of the hazardous material in an aquatic discharge may be determined in several ways: from a shipping manifest, by contacting the carrier, or by other direct means. If positive identification cannot be made, sampling and analysis are required. Sampling the chemical hazard directly from its container is preferred. If direct sampling is not possible, samples should be taken directly downstream of the source of the hazard. Similarly, microbiological surveys of areas where diving operations are proposed must be undertaken to provide information on potentially pathogenic organisms, and the virulence of these organisms. It should be borne in mind that it often takes several days to isolate, culture, count, and type the microorganisms; the information will not be available immediately.

A number of frequently transported chemicals are so potentially hazardous that no exposure should be considered. These chemicals have very high demand penetration rates and are systemic or central nervous system poisons. Tables 1 and 2 list chemicals in the aquatic environment to which a diver should never be exposed, and chemicals to which exposure should be absolutely minimal in such extreme situations as to preserve human life or to prevent massive environmental damage. The lists in Tables 1 and 2 are by no means complete, and any chemical encountered in a field situation should be evaluated on an individual basis with the Environmental Protection Agency (EPA) Oil and Hazardous Materials Technical Assistance Data System, which is the responsibility of the Emergency Response Division (WH-548B), Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, DC 20460, and lists, among other parameters, material solubility in water, material corrosivity to various substances, and allowable exposure concentrations.

EQUIPMENT CONSIDERATIONS

In 1-atm diving, the diver is enclosed in a rigid suit that contains air at the surface pressure of 14.7 psi. Recent developments in 1-atm suits have concentrated on articulated metal suits, which allow divers to work in a 1-atm environment at depths exceeding 1000 ft. However, such suits are too bulky and unmaneuverable for most underwater efforts.

In ambient diving, the diver is subjected to the ambient pressure of the water depth to which he or she has descended. Ambient diving is divided into two subgroups: self-contained diving and surface-supplied diving. Self-contained diving utilizes scuba, and is widely used in scientific research. The diver's air supply is provided from a regulator held between the teeth, so the diver's mouth is constantly exposed

TABLE 1
CHEMICALS TO WHICH DIVERS SHOULD NEVER BE EXPOSED

Acetic anhydride	Chlordane
Acrylonitrile	Epichlorohydrin
Bromine	Methyl parathion

TABLE 2
CHEMICALS TO WHICH EXPOSURE SHOULD BE ABSOLUTELY MINIMAL

Benzene	Methylmethacrylate
Carbon tetrachloride	Naphthalene
Cresol	Perchloroethylene
Dichloropropane	Polychlorinated biphenyls
Ethyl benzene	Styrene
Hydrogen sulfide	Toluene
Methylene chloride	Triochloroethylene
	Xylene

to the water. In addition, the inhalation of contaminated microscopic water droplets from the exhaust valve of a scuba regulator provides a direct passage of the contaminant to the lungs, and thus to the bloodstream. Further, the only way for a scuba diver to clear condensation from inside the mask is to flood it with surrounding water, thus exposing the nose and eyes to the water. The limitations of scuba in contaminated waters for ocular. nasal, and oral exposure are obvious. The standard scuba dive systems are inadequate to protect divers in contaminated waters.

Surface-supplied diving consists of a rigid helmet attached to a waterproof suit. There are many variations of helmets and suits on the market today. Surface-supplied diving provides a major advantage over self-contained diving: the diver's air supply is provided through an umbilicial hose, and thus the diver is not limited by the amount of air carried in a tank on his or her back. Since there must be an umbilical to supply the breathing gas, surface-supplied diving has the additional advantage that a heating (or cooling) water hose that feeds the diver's suit can be established in parallel with the air hose. In addition, a hard-wire link for constant communication between the diver and the surface tenders and a safety lifeline are married to the umbilical for retrieval of the diver in case of incapacitation.

A diver's protective suit should have strength, flexibility, ease of decontamination, and, most important, chemical resistance. The material from which a suit is constructed will have a considerable effect on the amount of pollutant that will be absorbed or passed through the suit. Several types of protective suits are available, ranging from foam neoprene rubber, such as a standard scuba wet suit, to smooth neoprene rubber suits, such as the Draeger suit, to suits made by the Viking Rubber Corporation, to the recently developed suit-under-suit (SUS).

Foam neoprene is a poor choice for diving in chemically contaminated environments because it can act as a sponge and absorb large amounts of contaminated water. In addition, certain contaminants can degrade foam neoprene and pass through to the diver. This is particularly true during decontamination procedures, when high pressure sprayers, used in the initial cleaning of the diver and the suit, may force the contaminant through the foam neoprene. Smooth neoprene suits, such as the Draeger suit, do not absorb contaminants and are more easily decontaminated than foam neoprene suits. However, the suits are fairly thin, provide no thermal protection from hot or cold aquatic environments, and have a tendency to tear or puncture. Suits made by the Viking Rubber Corporation are made of heavyweight rubber bonded to a polyester fabric. The suit is fully waterproof but, like the Draeger suit, provides no thermal insulation. The diver must wear insulated underwear for warmth and protection against chafing from the inner fabric of the suit. In warm aquatic environments or in the case of maximum exertion by the diver, the Viking suit can be a substantial disadvantage because there is no way to coo! the diver inside the suit. The Viking suit has a major advantage over the Draeger suit because it is very resistant to tearing: in addition, it is more easily decontaminated than a foam neoprene suit.

The SUS dive system, developedjointly by EPA and NOAA, provides substantially improved protection for divers (1). This positive-pressure dive suit provides an innovative solution to two problems associated with contaminated water diving: thermoregulation and leakage. The SUS consists of an inner, thin-rubber dry suit with attached boots. A second, looser, modified Viking Suit with exhaust valves on both ankles and on one arm is worn over the inner suit. A neck dam on the outer suit is mated to a similar device on the inner suit, thereby creating a closed cavity between the two suits and separating the diver's head from the two suits. Clean water of the appropriate temperature is pumped through one of the umbilical hoses into the cavity between the two suits to warm or coo! the diver. The water exits through the ankle and arm exhaust valves in the outer suit. Since the cavity between the suits is filled with water under a pressure slightly greater than that of the ambient water, any puncture or leak in the outer suit results in clean water leaking out, rather than outside water leaking in, as would be the case in air-filled suits such as the Draeger or nonmodified Viking.

Finally, it should not be assumed that because a diver has received initial training in a dive system he or she is proficient in the use of that system. Continuing retraining is necessary if the diver is to remain proficient in the use of the system under a!! circumstances.

DECONTAMINATION PROCEDURES

After every dive into contaminated or potentially contaminated water, the divers must be decontaminated to avoid danger to themselves or to the personnel handling the equipment. The first step in the decontamination process is to wash the diver down with a high-pressure spray to remove any adhering contaminants or residues; the second is a washdown with a surfactant, such as trisodium phosphate, or with a solvent appropriate to the contaminant to which the diver has been exposed. If the diver has been exposed to water contaminated with pathogens, the second step should be followed by spraying down the diver with a clinical disinfectant such as Betadine surgical scrub solution. Finally, the diver should be sprayed with fresh water to remove the final decontaminant. Areas that need special attention during decontamination procedures include zippers, seams at junctions of suit surfaces, helmet-sealing mechanisms, and the soles of the diver's boots.

In decontaminating a diver, the preferable washdown pattern is top-to-bottom with the sprayer nozzle facing downward; it is also important not to touch the diver with the sprayer nozzle to prevent contamination of the nozzle. An optima! distance of the sprayer from the diver is 1.5-2.0 ft; this distance also reduces the splashback of contaminants that may hit personnel in the decontamination area. Decontamination personnel must also be protected from the contaminants they are washing from the diver. In addition, commercial recovery operations have shown that recovery of sunken chemical drums and containers by divers can often lead to contamination of the dock or the ship's deck and surrounding equipment. Care must be exercised to ensure that surface personnel do not spread the contaminants beyond the immediate decontamination area. Finally, it should be evident that solutions resulting from diver decontamination should not be routinely discarded; such solutions should be treated as diluted portions of the hazardous contaminant, and treated accordingly.

REVISED EPA DIVING SAFETY POLICY

One development that has led to increased diver protection, in safe as we!! as in contaminated and polluted waters, is the recent revision of EPA's Diving Safety Policy (DSP). (The original DSP was incorporated into EPA's Occupational Health and Safety Manual on 18 March 1986; the revised DSP was promulgated and incorporated into the same publication (chapter IO) on 2 September 1988.) This revised policy increases the training requirements and mandatory level of experience to attain various certification levels. The revision is consistent with the regulations of the Occupational Safety and Health Administration (OSHA) and with NOAA's diving requirements. (OSHA Regulations for commercial diving operations are found at 20 CFR 1910, Subpart T. NOAA's diving requirements are found in NOAA Directive 64-23, dated 30 November 1983, issued by the Assistant Administrator for Ocean Services and Coastal Zone Management, National Oceanic and Atmospheric Administration, Rockville, MD 20852.)

The Manual is the responsibility of the Environmental Health and Safety Division (PM-273), Office of Administration, U.S. Environmental Protection Agency, Washington, DC 20460. The new policy accomplishes several main objectives: a) It establishes EPA policy for a!! diving operations, in accordance with the OSHA regulations. b) It ensures that a!! diving operations performed by EPA, or its contractors, are conducted in a safe manner, with uniform procedures, and by sufficiently trained personnel. c) It applies to a!! diving operations carried out by any employee of EPA during the course of official duties. The DSP also applies to any non-EPA employee engaged in a diving operation under the auspices of EPA. d) The DSP establishes an EPA Diving Safety Board (DSB), composed of a!! Unit Diving Officers.

The DSP is responsible for, in part: a) Establishing policy and operating procedures to ensure a safe and efficient diving program; b) reviewing existing policies, procedures, and needs to ensure a continually high level of technical skills and knowledge; c) establishing policy for the initial certification of divers and refresher training of experienced divers; and d) reviewing EPA diving accidents or potentially dangerous situations, and establishing preventive measures to ensure the avoidance or recurrence of such incidents.

The policy establishes qualifications and responsibilities for the Board Chairperson, a Board Technical Director, a Board Training Director, as we!! as Unit Diving Officers, Divemasters, individual divers, and dive tenders. The DSP further establishes certification requirements for diving candidates, trainee divers, working divers, advanced working divers, and senior divers. Finally, the DSP establishes limits on diving operations, as we!! as requirements for certification of a!! diving equipment.

CONCLUSION

Through the work that has been done in recent years by EPA, NOAA, and other agencies, contaminated and polluted water diving has evolved into a distinct form of specialized diving. This evolution is continuing, and more developments can be expected in the future. Increased demands will be put on divers and diving systems by continuing efforts to clean up waters that have been receptacles for chemical, toxic, or pathogenic wastes.

The safety of the diver and support personnel must be the primary concern of any clean-up or emergency response effort. Personnel should be made aware that standard scuba dress offers minima! or no protection for contaminated waters. Every plan for a dive into waters that contain hazardous or contaminating materials must be carefully evaluated and weighed against the short-term and long-term hazards of the particular contaminant involved.

REFERENCE

1. Traver RP. Interim protocol for diving operations in contaminated water. EPA Rep 600/S2-85/130. Cincinnati, OH: Hazardous Waste Engineering Research Laboratory, August 1968.

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