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Force Health Protection and Military Drinking Water Supplies

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Introduction

The U.S. Army engages in operations throughout the world and must capitalize on the latest technology and adopt the most appropriate health criteria to ensure safe drinking water in garrison, during deployments, and during humanitarian operations. The Directorate of Environmental Health Engineering and the Directorate of Health Risk Management of the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM) provide technical support on behalf of the Army Surgeon General concerning medical aspects of drinking water issues. The relevance of the USACHPPM programs with respect to all U.S. military operations is demonstrated by the fact that Department of Defense (DOD) Directive 4705.1, which outlines policy, responsibilities, and procedures for management of drinking water supplies during contingency operations, designates the U.S. Army as the DOD Executive Agent for land-based water operations to include: water detection, pumping, purification, storage, distribution, monitoring, and research and development.[1] The Army's responsibility for implementing this Directive is divided among the Corps of Engineers, the Quartermaster Corps, and the Army Medical Department (AMEDD). As a major subordinate command in the AMEDD, the USACHPPM interacts with the Corps of Engineers and the Quartermaster Corps as well as Army Medical Department Center and School's Directorate of Combat and Doctrine Development to effect appropriate changes in field water doctrine.

Fixed Facilities

The U.S. Army bases in the U.S. resemble small civilian cities and towns; to meet the needs of a more sensitive population (infants, the infirm and women of child-bearing age), provision of potable water at these bases must comply with the same regulatory treatment criteria and water quality standards. Several years ago, the Water Supply Management Program (WSMP) of the USACHPPM Directorate of Environmental Health Engineering developed a comprehensive approach, known as the Water System Performance Evaluation (WSPE), to assess Army waterworks and ensure delivery of safe and palatable drinking water at both domestic and overseas facilities.[2] This approach is incorporated in a protocol that addresses water source, treatment, distribution and storage, water quality monitoring and related activities. For domestic facilities, this comprehensive evaluation is a mechanism for identifying deficiencies and recommending improvements to the water systems to ensure provision of safe, quality drinking water that is safe for consumption by the consumer. The evaluation also assists in ensuring compliance with current and future regulatory criteria. These criteria are defined by the National Primary and Secondary Drinking Water Regulations and related state regulations.[3,4] At fixed facilities outside the U.S., the U.S. Army may purchase water from a host nation supplier and provide any necessary additional treatment, or may operate its own waterworks. Criteria for applicability to these facilities are rooted in the Overseas Environmental Baseline Guidance Document or in host nation requirements, whichever are more stringent.[5] Minimum treatment generally consists of chemical coagulation, sedimentation, filtration, and disinfection for surface water sources and disinfection for groundwater sources and purchased water. The WSPE can be applied to any waterworks throughout the world; the WSMP has performed 140 evaluations at U.S. Army and U.S. Air Force installations worldwide since 1995.

While the WSPE addresses the mission of producing and delivering a dependable and safe supply of water to the customer, the challenges inherent in achieving that mission have expanded subsequent to the horrific events of 11 September 2001(9/11) to include water system security. An intentional contamination or attack to deny or disrupt public water supply could have catastrophic effects on force health. In the Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (Public Law [PL] 107-188), Congress recognizes the need for a more comprehensive view of water safety and security relative to drinking water systems.[6] The PL 107-188 amends the Safe Drinking Water Act and specifies actions that owners/operators of community water systems and the U.S. Environmental Protection Agency (EPA) must take to improve the security of the nation's drinking water infrastructure. Specifically, PL 107-188 states that the owner/operator of a

community water system that serves a population greater than 3,300 people must perform a review of the vulnerability of the system to a terrorist attack or other acts intended to substantially disrupt the ability of the system to provide a safe and reliable supply of drinking water. Such reviews shall include, but need not be limited to: (1) pipes and constructed conveyances; (2) physical barriers; (3) water collection; (4) pretreatment and treatment facilities; (5) storage and distribution facilities; (6) electronic, computer or other automated systems that are used by the public water system (for example, supervisory control and data acquisition [SCADA]); and (7) the use, storage, or handling of various chemicals.

The DOD is currently developing policy and specific procedures for full and timely implementation of the requirements of PL 107-188 at DOD installations and facilities. The Assistant Chief for Staff, Installation Management has issued guidance to Army installations through the Installation Management Agency for compliance with the requirements of PL 107-188.

In response to the events of 9/11, the WSMP developed a Water System Vulnerability Assessment (WSVA) protocol that meets the requirements of PL 107-188 and is based upon the best available information from various Federal agencies and professional associations.[7] The WSVA is designed to provide installation commanders and key staff members with a frank, thorough, and risk-based assessment of the vulnerabilities of their drinking water systems and to recommend counter-measures to lower the risk by reducing the probability and severity of these vulnerabilities. The protocol provides for assessment of virtually any Army water system, regardless of size or complexity, including those systems that purchase water from nearby municipal systems; it addresses water system vulnerabilities that, if successfully exploited, could result in (1) the physical destruction of water system assets; (2) the intentional contamination of raw or treated water supplies; and (3) a cyber-attack that could compromise the water system's ability to produce, store, or distribute treated drinking water.

The ultimate goal of a water system is to safeguard the public health and safety, and to reduce the potential for disruption of a reliable supply of pressurized water. The PL 107-188 also requires that water systems update emergency response plans according to findings of the vulnerability assessment within 6 months of its promulgation; the WSMP developed guidance on drinking water emergency planning in 1998.[8] The EPA has developed a document that provides uniform response, recovery and remediation guidance for water utility actions in response to man-made and/or technological emergencies.[9] This document recognizes five different incident types, but should also serve to guide response, recovery and remediation actions for other threatened or actual intentional acts that would affect the safety or security of a water system. The five incident types are: (1) Threat of or Actual Intentional Contamination of the Water System; (2) Threat of Contamination at a Major Event; (3) notification from Health Officials of Potential Water Contamination; (4) Intrusion through the SCADA; and (5) Significant Structural Damage Resulting from an Intentional Act.

Field Facilities

Military field operations, which also include sustainment and support operations such as peacekeeping and humanitarian assistance missions, present significant preventive medicine challenges. Because loss of life, health and mission capability from disease and nonbattle injury has historically exceeded that from combat, assuring an adequate supply of safe drinking water in the field has always been a major concern to the Army. The Army, Air Force, Navy, and Marine Corps are all responsible for providing water to their troops. Each Service performs the task and delegates the various responsibilities according to its own needs. For the Army, the Army Engineer units are responsible for source development, which includes well drilling and construction to support tactical water supply points, and construction of fixed and semifixed water treatment and distribution facilities. The Quartermaster Corps is responsible for the actual production and distribution of potable water on the battlefield. The AMEDD is responsible to ensure the potability and palatability of the drinking water.

Water Quality Doctrine and Standards. The Army Surgeon General sets health standards and provides doctrine and policy governing potable water quality; the Army, Navy, and Air Force surgeons general have adopted unique Tri-service field potable water standards for use in all DOD land-based deployments outside the U.S. These standards were developed to protect against performance-limiting effects that could compromise operational capability, and to that end the standards address acute rather than chronic health effects. Current water quality Tri-service standards address short- and long-term deployments as well as arid and temperate environments. The U.S. Forces must also meet multinational standards when in combined operations with other countries. It must be recognized, however, that perceived threats to water quality are not constant over time or region; because U.S. Armed Forces are increasingly involved in prolonged overseas military operations other than war, studies in progress at USACHPPM expand the Tri-service standards to include more toxic industrial chemicals and to address lifetime health concerns incidental to water contamination.[10] The Tri-service surgeons general have also promulgated standards for individual nerve agents, to be applied when field analytical capability becomes available. In addition, goals have been established for individual nerve agents, corresponding to red blood cell cholinesterase

depression of no more than 25%, in response to recommendations of the National Research Council Committee on Toxicology. [11]

Irrespective of the short- and long-term standards, the decision to accept a water source for potable use lies with the field commander. His decision will be based on the concept and principles of Operational Risk Management (consideration for the health of his troops while considering the overall risk associated with the exigencies of the mission). The command surgeon on the battlefield is responsible for protecting the health of the Soldier; in this role, he is the approving authority for water sources and water treatment methods and alternative measures to maintain the potability of water. Preventive medicine personnel function similarly to local public health departments to perform periodic inspections of water sources, test finished water quality, and inspect water treatment and storage equipment. The unit field sanitation team in each Army company-sized unit is the key link for water quality at the unit level.

Water Treatment Equipment. The earliest military field water treatment system was the mobile water purification unit, which used sand filtration and chlorination and was employed by the American Expeditionary Force in World War I. Subsequently, the ERDLator (named after the Engineering, Research and Development Laboratory at Fort Belvoir, VA), a mobile water treatment unit that combined coagulation, flocculation, sedimentation, diatomaceous earth filtration, and hypochlorite disinfection, became the principal water treatment unit employed by the Army in World War II, the Korean War, and the Vietnam War. It reliably produced safe, pathogen-free drinking water. As the nature of Army operations evolved, the need arose for equipment capable of processing different types of raw water, and in 1979 the ERDLator was replaced by the reverse osmosis water purification unit, or ROWPU, which for the first time, made it practical to purify seawater on a large scale. Reverse osmosis (RO) is the foundation of land-based water production for U.S. Armed Forces in deployments. The 600-gallons-per-hour (gal/hr) ROWPU is trailer-mounted or skid-mounted, air-droppable, and requires a dedicated 5-ton prime mover. It is designed to produce 600 gal/hr (2271 liters per hour [L/hr]) from freshwater sources (1,500 milligrams per liter [mg/L] total dissolved solids [TDS] or less) or 400 gal/hr (1514 L/hr) from saline water sources (35,000 mg/L TDS or more) at a temperature of 25° C. The 3,000-gal/hr ROWPU can be shipped aboard U.S. Air Force aircraft in an 8x8x20-foot (2.4x2.4x6.1-meter [m]) International Standardization Organization (ISO) container with supplies and ancillary equipment. It can be mounted on a standard 30-foot (9.1-m) military trailer, requires a 60-kilowatt (kw) utility diesel generator, and is designed to purify 3,000 gal/hr (11,355 L/hr) from freshwater sources and 2000 gal/hr (7570 L/hr) from saline sources. All ROWPU models incorporate multimedia and cartridge filters ahead of thin film composite RO membranes and are equipped with granular-activated carbon units for treatment of nuclear, biological, and chemical (NBC)-contaminated water. The ROWPU provides a military capability to produce potable water from a raw water source of virtually any quality in a wide range of geographical areas around the world.

Evolving requirements have led to the development of the 1500-gal/hr tactical water purification system (TWPS), as well as the 125 gal/hr lightweight water purifier (LWP), by the U.S. Army Tank Automotive Research, Development and Engineering Center (TARDEC). The TWPS, designed to purify 1500 gal/hr (5678 L/hr) from freshwater sources and 1200 gal/hr (4542 L/hr) from seawater, differs superficially from the 600-gal/hr ROWPU (which it will replace on a one-for-two basis) in that a membrane microfilter replaces the multimedia and cartridge filters of the ROWPU. However, the TWPS (as well as the LWP) incorporates significant technological upgrades in other major components, such as controls, pumps, and membranes. The TWPS is trailer-mounted or skid-mounted, air transportable with accessories in an ISO container, and is deployed with activated carbon and ion exchange resin over packs for additional treatment of water in an NBC environment. According to the Operational Requirements Document, "the TWPS will support combat, combat support and combat service support missions at all echelons."[12] The LWP, designed to purify 125 gal/hr (473 L/hr) from freshwater sources and 75 gal/hr (284 L/hr) from seawater, can be conceptually envisioned as a scaled-down TWPS. It can be disassembled into modules transportable by four-person teams. According to the purchase description, "the LWP System is intended to improve the responsiveness of water support to early entry, highly mobile forces throughout the spectrum of conflict in peace and war, and will provide quality water support to small units and detachments where distribution of bulk water is not feasible or practical."[13]

The USACHPPM has studied the ability of the TWPS and LWP to reduce hypothetical maximum challenge levels of NBC agents to the Tri-service standards.[14,15] Except in a few cases where data are insufficient, USACHPPM is confident that the TWPS and LWP, when equipped with activated carbon and ion exchange over packs, will meet these requirements and will provide safe, palatable water to military personnel and others in the field. The TARDEC is currently carrying out studies of rejection of lewisite, hydrogen cyanide and radioiodine by the TWPS and LWP to resolve remaining uncertainties. However, the question of treatment for removal of many toxic industrial chemicals, volatile organic compounds in particular, has yet to be adequately addressed. There are virtually no standards for biological agents in water, nor in most cases are there data

available to develop such standards, notwithstanding which, USACHPPM believes that contamination of RO product water by either replicating (live) agents or biotoxins could only occur post-treatment.[16]

The most common means of water supply to the individual Soldier is bottled water, which may be shipped from the U.S., purchased locally, or field packaged in 1-L and larger plastic containers using Quartermaster assets.[17] Because field-packaged water need meet only Tri-service standards, while water shipped from the U.S. should meet the U.S. Food and Drug Administration bottled water standards, there can be significant variation in the quality of bottled water provided to the individual Soldier. The single warfighter or small units may also be supplied any of several commercially available individual water purifiers, noting, however, that none of these devices has been subjected to adequate efficacy testing, nor indeed is there yet a suitable health-based protocol for such testing.[18] The TARDEC is presently investigating the practicality of condensing and purifying water from vehicle exhaust, and other studies involve condensing water from the atmosphere.

To relieve the demand for potable water and to reduce wastewater discharges, it is projected that recycle/reuse of shower and laundry wastewater will be practiced at Force Provider facilities, which are mobile tent cities that provide billeting, mess, exercise, and recreational services to Soldiers temporarily relieved from combat and other duty stations. With this effort has come the need to generate human health criteria for the recycled water. These USACHPPM-developed criteria, now undergoing review by the Army Surgeon General, are based on the short-term Tri-service drinking water standards and the EPA Guidelines for Water Reuse, but also include treatment requirements.[19,20] Development of a wastewater treatment scheme capable of meeting these criteria is in progress at the TARDEC.

Storage and Distribution Equipment. The potable water storage and distribution system (PWS/DS) is the primary means for the receipt and storage of bulk water and for its issue to deployed forces. Each PWS/DS can receive and distribute water to and from both hose line and tank truck. The system capacity is dependent on the number and size of fabric tanks used. The PWS/DS can issue water to tank trucks, water trailers, the forward area water point supply system (FAWPSS), or small unit containers. The FAWPSS is a helicopter-transportable, self-contained, gas- or diesel-operated unit that dispenses potable drinking water to troop units from 500-gallon (1892 L) collapsible water storage and dispensing drums. These drums provide water to a 125-gallons-per-minute (gpm) (473 L/min) centrifugal pump that discharges water to four distribution nozzles. Potable water is transported in 3,000- and 5,000-gallon (11-m^3 and 19-m^3) semitrailer-mounted fabric tanks, in 400-gallon (1514-L) water trailers or by means of a collapsible, self-supporting fabric pipeline, known as the tactical water distribution system or TWDS, as much as 10 miles (16 km) in length. Storage equipment includes a variety of containers ranging in size from 5-gallon (19-L) water cans to 50,000-gallon (190-m^3) collapsible tanks.

Water Quality Monitoring. A number of different organizations monitor the quality of drinking water supplied to U.S. personnel and others in the field. Water purification teams are responsible for operational monitoring to ensure the efficacy of water purification equipment and the treatment process. Health monitoring of drinking water supplies in the field is the responsibility of several organizations, including the preventive medicine detachments. Preventive medicine personnel, in addition to approving the raw water source, certify that product water is in compliance with the required field water standards at the point of production, ensure maintenance of the recommended chlorine residual at the unit level, and perform periodic sanitary inspections of the water system(s). The field medical units use the Water Quality Analysis Set - Preventive Medicine (WQAS-PM) or commercial, off-the-shelf replacements and the Water Quality Test Kit, Chemical Agent (M272 Kit) to perform health monitoring. The M272 Kit is not able to monitor the chemical agents to the current Tri-service standards; research is in progress by the U.S. Army Soldier and Biological Chemical Command to field a replacement kit to monitor for biological and chemical agents to required levels of concentration. Also under development, by the U.S. Army Medical Research and Materiel Command, is a rapid bacteriological test kit capable of detecting coliform bacteria at the level of one organism per 100 milliliter (mL) in 4 hours or less. Concerns for possible adverse lifetime health effects from consumption of field potable water have mandated selective sampling and analysis beyond the requirements of the Tri-service standards, and for this purpose the 520th Theater Army Medical Laboratory has more sophisticated analytical capability, such as gas chromatography/mass spectrometry, to perform a much wider variety of chemical analyses. Samples are also collected for complete water analysis at USACHPPM laboratories or other approved domestic or overseas facilities.

Summary and Conclusions

Potable, palatable drinking water is critically vital to our health and well-being, in garrison as well as in the field environment. In garrison, the installation commanders are responsible for providing safe and palatable drinking water to the Army communities. In austere field environments and during military operations, the quality of drinking water becomes even more important in order to minimize disease and

nonbattle injuries. The Army Corps of Engineers is responsible for source development, the Quartermaster Corps has the responsibility for water production and distribution on the battlefield, and the medical community is responsible for ensuring that the water is of the highest quality possible. Field water purification is enabled by means of various reverse osmosis units that can produce potable water from a source of virtually any quality, including seawater. At the level of the individual warfighter, bottled water is available, as well as various individual water purification devices, most of which lack adequate and appropriate medical evaluation. The Army has conducted a number of challenge studies on its reverse osmosis membranes; however, additional studies are still needed to verify that certain toxic industrial chemicals and NBC agents can be effectively removed. Nevertheless, USACHPPM remains confident that the currently fielded reverse osmosis systems with activated carbon and ion exchange over packs, as well as those under development, will produce potable water from virtually any water source.

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