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Monitoring of Potable Water Systems

1. General.

One of the most basic tenets of public health involves the provision of a safe drinking water supply. Standards and regulations have been established to ensure that a high-quality water supply reaches consumers obtaining potable water from all public water systems. All of these standards are based on the continued health and welfare of the consumers, and associated treatment and operational practices are requisite to maintain these safe supplies. The primary purpose of this paper is to distinguish the types of water system monitoring required to ensure that safe water supplies are provided to all personnel utilizing public water supplies at installations within the DoD. While technical and operational personnel are responsible for much of this monitoring, the role of the public health authority remains critical, in both monitoring and oversight. Each group must work interactively and openly to achieve the public health and safety goals.

This text will briefly address the system monitoring requisite to meet the compliance requirements imposed by Federal/state regulations. Further, water system personnel must perform routine operational monitoring to ensure that all processes are functioning optimally and that the highest water quality is maintained. The last type of monitoring to be addressed is performed by the local/installation public health (PH) authorities. Their assessment and review of data is accomplished to ensure water quality and the safety and welfare of all consumers. Individually, each type of monitoring serves an important function and fulfills a critical role in assessing the quality and potential public health risks of the potable water supply provided to all on an installation. Combined, the data produced from this monitoring allows regulatory agencies and Installation Medical Authorities to assure the Installation Commander (IC) that safe drinking water supplies are provided to all consumers. Coordination between all responsible parties on an installation will facilitate assurance that the water system performs at its optimal level, and that all anomalies are addressed immediately to achieve and maintain a safe and healthy water supply.

2. Compliance Monitoring.

Public policy is focused on the right of every human being to have safe, clean, affordable, and accessible water adequate for human consumption, cooking, and sanitation. Generally, the federal agency for CONUS installations and territories that is responsible for promulgating drinking water regulations is the U.S. Environmental Protection Agency (EPA). The primary drinking water regulations were established pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (SDWA) (PL 93-523) and related regulations applicable to public water systems. This law is responsible for implementing national drinking water standards/requirements and overseeing the state's water agency enforcement of federal law. Regulations addressing all aspects of potable water supplies have been codified in the Code of Federal Regulations (CFR), Part 40, Section 141-149 (40 CFR 141-149). The standards imposed protect the health and welfare of consumers by establishing guidance regarding the sources, treatment, distribution, storage, and monitoring of water supplies. Water

monitoring can be defined as repeated (with a defined frequency) analysis of water quality at permanent points, accompanied by data processing and prognosis of trends to support action focused on interception and remediation of adverse impacts on the potable supply provided. Compliance monitoring assures that the water supplies meet or exceed the National Primary Drinking Water Regulations (NPDWR) delineated in the cited standards.

An important aspect of these regulations require that oversight of this critical resource is passed to the individual states/territories, who can more closely control and understand each aspect of these local systems. The states can impose their own regulations and standards; however, they must be at least as stringent as those promulgated and developed by the EPA. Often, the states will insert many, if not all, of the Secondary Drinking Water standards into the listing of parameters to be required for sampling and analysis, along with the National Primary Drinking Water Regulations (NPDWR) standards. The states rely on various organizations for regulating aspects of the potable water supplies. In many cases, the states have a designated department for environmental protection or regulation; while in others, the primary agency responsible may be associated with the public health agency or health department. Whichever is the case in a particular state, water quality control and transmission require critical oversight from both technical/engineering and public health perspectives. All DoD installations within the Continental U.S. (CONUS) and associated territories will fully comply with all applicable Federal, State, and local standards and regulations. Should there be evidence of an inability to comply with pertinent standards, a notice of non-compliance with the standards would be sent from the regulatory authority to indicate that a potential health threat exists. Then, the installation/water system would be responsible for either additional monitoring or some type of remedial measure to be undertaken.

Full responsibility of compliance with the various provisions of the State and Federal drinking water regulations is a function of the IC and the officials responsible for the management of the public water supply (government and/or the designated operating contractor). Compliance monitoring helps verify a consistent, high-quality water supply for all personnel. Most every state's regulatory authority requires that the purveyor of all public water systems must develop a monitoring plan to check the water quality at locations throughout the water supply system that would be representative of the potable water reaching all consumers within the system. The plan should be developed by the water purveyor and PH personnel at an installation, and they will work closely with the state primacy regulatory authorities who must concur with such monitoring plans. The parameters to be analyzed and reported, as well as the frequency of sampling, are defined by the regulatory authorities. The water distribution system supplying housing, offices/administrative areas, commercial, and industrial facilities must be incorporated into this plan. Historically, samples were collected by either water supply providers, external contractors, or PH personnel. More recently, sampling is often conducted by personnel from the accredited laboratory performing the analyses. The sampling of "critical" areas of the installation can be augmented by the PH authorities supporting the installation; this will be discussed in greater detail section 4 of this paper.

The types and number of samples acquired will be dependent upon the source(s) of water used, the chemical/radiological/biological quality of the water supply, the treatment provided, and the numbers and types of populations served. Sampling techniques are generally provided by the EPA, and the analytical techniques used are defined in the latest revision of Standard Methods

for the Examination of Water and Wastewater (Standard Methods). The appropriate sampling containers required for each set of parameters, along with preservatives (if warranted), will be provided by the certified laboratory to be used and are defined in the Standard Methods text.

The installation must submit the compliance monitoring results to the regulatory authority on the prescribed basis (e.g., monthly). An individual position will be tasked by the IC to coordinate and communicate specifically with the regulatory authorities. With many installations now using privatized water systems, the Site Manager for the contractor has often been designated to provide this service. It is important that one individual routinely corresponds with the regulatory authority to ensure that accurate information and data are forwarded in both directions and can convey information to the IC as soon as possible. Many Community Water Systems (CWSs) must submit data monthly; however, the reporting frequency may be less depending on the source water used and the population served. For example, a system supplied solely by groundwater may be required to submit samples every 6 months for review and approval. Compliance data should also be made available to the local/installation PH authority monthly for review to assure that the water remains safe for its intended uses.

The IC must ensure that the water supplier issues an annual Consumer Confidence Report (CCR) to installation residents/employees. The CCR is usually published in June for the preceding calendar year. The report identifies the source of installation water, treatment, testing results, possible health effects if contaminants are detected, and points of contact if consumers have additional questions or concerns. The CCR is often made available to personnel via a public domain such as a library or online at an installation website. The CCR is also submitted to the installation major command for information and tracking.

In the civilian domain, oversight of small public water supplies and/or water supplies provided to individual facilities or small groups of buildings may be delegated to local county health departments or the lowest level of local government. At DoD installations, the PH authority and/or Installation Medical Authority (IMA) may oversee the health and safety of such small water systems — which may include National Guard armories, trailer parks, golf courses, or individual wells for training facilities. These facilities may fall under the scope of the local county health departments if the sale or transfer of the facility/property is undertaken. The local government agency may require minimal testing for the incoming occupants (coliforms and nitrates) to ensure the safety and welfare of future occupants. Non-transient, non-community (NTNC) water systems are observed on many DoD installations in the form of schools, training areas, and ranges. Compliance monitoring, once again, should at least meet the minimal standards required. Water quality data should be collected by installation water supply personnel and shared with the installation PH authority to discern potential adverse health concerns/risks.

3. Operational Monitoring.

Although compliance monitoring for water quality is the only type of surveillance that is mandated by law for a utility to comply with the applicable standards, operational monitoring of the water system is likely the most critical form of surveillance to be undertaken. Water treatment systems are designed to remove all unwanted characteristics and contaminants, based on preliminary water quality assessments. Under normal circumstances, it is assumed that the treatment processes are operating properly, and the distribution system is conveying the water supplies as

designed. Verification that these facets of the water supply system are functioning properly and there are no unforeseen interruptions of service or sources of contamination introduced can only be ensured through the performance of crucial operational monitoring of the system. Please note that water sampling provides only a snapshot of the conditions in time. The conditions prevalent in the samples collected at a given time and place may change at any time, which is a key reason why operational monitoring must be accomplished on a regular/routine basis. This type of surveillance allows the responsible personnel to quickly recognize changes in water quality or quantity due to an issue in the system and correct it before there are persistent threats to system degradation or human health.

Within an installation, the drinking water provider ensures that the water supply system provides customers with a continually safe and adequate supply of drinking water that is compliant with the various provisions of state and Federal (or Host Nation) standards. However, it is generally the certified waterworks operators who are responsible for the daily operation and maintenance of all water facilities, water treatment plants, distribution systems, intake structures, storage tanks, pumps, control systems, and other related appurtenances of the public water systems. The subsequent discussion will segregate operational monitoring associated with treatment and distribution system activities prior to returning to general operational concerns.

Generally, the operators must ensure that pumps and all treatment processes are working well and as designed. Routine monitoring of all processes and equipment assists in the identification of potential problems at an early stage so that corrective action(s) may be initiated quickly and efficiently. Operators must develop and document a set of standard operating procedures (SOPs) to routinely update all activities required to efficiently operate and maintain all components of the water system. Authorities responsible for the water system should review and approve these SOPs to ensure that all critical information is obtained and presented. Included in this assessment is the monitoring of all system components and processes, observing and recording data provided by treatment and monitoring equipment, and the sampling and testing of water at various points along the system for different parameters. Water treatment personnel must remain vigilant regarding chemical addition and the monitoring of concentrations leaving the treatment plant and entering the distribution system. These SOPs should correspond to a detailed monitoring plan, recording all chemicals added and potential changes in water quality noted, which would require the amendment of such treatment operations. Operational water monitoring reflects the water quality throughout the treatment processes to ensure that treatment is functioning at its optimal efficiency and design effectiveness, and to report to consumers and regulatory authorities that the supplies reaching consumers is safe and poses no underlying health risks. Such monitoring may be performed through the recording of equipment measurements and readings (e.g., water levels in tanks, meter readings on pumps and chemical injection systems, and system pressures), the collection and analysis of grab samples from within the system, and/or the use of Supervisory Control and Data Acquisition (SCADA) systems frequently employed to provide automatic monitoring and/or control of operations throughout the water system. In addition, operations personnel maintain disinfection residuals and treatment chemical tanks/injection systems; inspect and maintain water intake points and wells; and ensure that all pumps remain operational and in good working condition. It is critical that operations personnel maintain detailed records of all monitoring via logs or automatic recording devices. These data will facilitate the detection of trends that may indicate system upsets or changes in water quality over time.

Operations personnel also retain responsibility for the quality of water throughout the distribution system to the points of use/consumption. This includes the monitoring of water quality characteristics, the proper pressurization of water within the distribution system, and the routine integrity of all water piping and appurtenances. It is critical that disinfection residuals remain present at all points throughout the distribution system, to minimize or preclude the potential for consumers to become exposed to bacteria or viruses in the supply. The presence of a disinfectant residual in the water supply reduces the possibility of harmful bacteria or viruses. Therefore, operations personnel must evaluate the residual concentrations at multiple locations daily to ensure that a detectable residual is maintained throughout the water supply system. These data, combined with the data augmented by the PH authority, allows the water supplier to accurately maintain an appropriate dosing of chlorine (and ammonia, if chloramines are used). Similarly, proper pressures must be maintained throughout the distribution system to eliminate the risks of backflow/back siphonage of contaminants into the piping network. If system pressures remain inconsistent or are low, the DPW/operating contractor and facility engineers may need to consider additional pumps or the frequent cleaning of the piping network.

Operational monitoring of the distribution system should also encompass a periodic review of the water's corrosivity to discern the continued integrity of the system's piping and joints. Corrosion control chemicals can be injected at the water treatment facility or at the point of entry into the building in question, as necessary, to counteract deterioration of piping and joints due to corrosion. The pH of the water supply must be assessed frequently, as well. This parameter serves as an indicator of the chemical water quality. A changing pH may notify operations personnel that an alteration in water quality has occurred (either through addition of an external chemical or a changing condition within the water system). The site or source of change can be tracked, and the problem situation readily corrected.

Sampling from points within the distribution system provides a good indicator of the water quality reaching the consumers throughout the system. Unfortunately, the water within the piping network does not exhibit a uniform quality, even within relatively small supply systems. The quality of potable water may change due to several reasons. Operations personnel should be cognizant of the following:

- The duration of time within the system and resulting decay of disinfectant residuals;
- The mixing of water from multiple water sources or storage facilities;
- Chemical reactions and biological processes (e.g., corrosion, nitrification, regrowth);
- Changing alkalinity and pH; and
- The introduction of foreign materials through cross-contamination, backflow, or infiltration in the piping network.

These are all reasons for sampling at repeated, fixed locations over time. Operations personnel can account for anomalies encountered by assessing these parameters at key locations. Collecting and analyzing samples manually, as has been the norm historically, is giving way to "in-line" monitoring systems, which can collect samples and record data on a regular basis (timed or whenever a designated concentration is reached). In-line monitoring systems (frequently associated with SCADA systems) can identify contamination incidents, report water quality data

or detect any deviation from normal conditions over time, and report the information to operations personnel for further investigation.

Water operations personnel must develop the programs to assess, inspect, and maintain the integrity of the piping network within the distribution system. This includes responding immediately to any reported leaks within the system to properly repair all leaks/breaks, assure continued high-water quality, and return the supply to full service. Appurtenances (e.g., valves, hydrants, and cross connection control devices) within the supply system must also be routinely inspected, maintained, and repaired/replaced (as needed). The prescribed frequencies of such programs are defined in the Unified Facilities Criteria (UFC) 3-230-02 and pertinent American Water Works Association (AWWA) guidance.

Water system operators must also ensure that all water facilities and equipment remain secured from unauthorized access. Operations personnel/authorities must ensure that personnel are available 24 hours a day to address potential problems as they occur within the system. Similarly, they must have personnel available, and a program established to respond to customer complaints and investigate/resolve problems that may affect water quality or quantity. Generally, operations personnel/authorities should maintain an inventory of supplies, chemicals, and equipment to properly operate the water supply system and address many of these issues as they arise. Critical aspects of the program which supports operation and maintenance of water systems will be incorporated into the water system SOPs and emergency response plan (which is required by several standards established within the SDWA).

The inspection and maintenance of storage tanks also fall within the realm of operational monitoring. Operations personnel scan these facilities for cracks, leaks, or notable corrosion during their routine/daily activities. Also, they will ensure that all doors and vent covers remain secured. Further, access to altitude control valves, corrosion control devices, and SCADA controls must remain locked and restricted. Aberrant anomalies must be dealt with immediately. Further, UFC 3-230-01 and AWWA standards require that all steel tanks be drained and thoroughly inspected, internally and externally, every 5 years, at a minimum. Tank interiors must be properly cleaned and disinfected prior to being placed back into service.

Operations personnel must possess the appropriate certification required by their state to perform their assigned work duties (for CONUS installations). Certified operators are the only personnel qualified to amend treatment or storage tank controls. A portion of this certification process mandates that the individuals display a capability to perform basic chemical sampling and analyses as well as the operation and calibration of several meters used to assess many parameters requisite to ensure that the water processes are achieving the desired water quality. The collection and analysis of water samples for operational considerations augments the compliance assessment identified in section 2 of this text. Sampling and testing water at various points along the system for different parameters demonstrates that the water quality remains consistent and has not been compromised through a break or intentional contamination. The operators must use the appropriate containers and preservatives (per Standard Methods and the pertinent SOPs). Use of SCADA to measure chemical addition and concentrations within treatment and distribution systems is becoming more prevalent as technology improves and costs for electronics decrease. SCADA is a computer-based system for gathering and analyzing real-time data to monitor and control equipment that deals with critical and time-sensitive

materials or events. Readings may be taken every few minutes to track the changing water quality, if needed. The sensors are low-cost, easy to deploy and operate, and can provide hydrologic and water quality data almost immediately, or near real-time, via graph or computer read-out.

It has been repeated throughout most references and discussions involving operational monitoring that record-keeping is one of the most important parts of a water operator's responsibilities. Tracking the status of records for chemical addition, operational gauges and readings, and analytical results facilitates the quick recognition of any problem developing within the system. Chemicals may be added and/or equipment and valves adjusted to amend problems as they arise. Many problems can be corrected before there is any permanent damage or threats posed to consumer health. Operators, therefore, must maintain adequate data and maintenance records to allow for a continuous assessment of all treatment, storage, and distribution systems. A review cycle of records should be established to verify operational control requirements addressing water quality, laboratory operations, and mechanical equipment are being satisfied.

Among the records to be maintained by operations personnel are updated water system maps, with sampling locations denoted, and laboratory reports, from both certified laboratories and in-house operational assessments. Further, maintenance schedules and records, correspondence with regulatory authorities and interconnected utility systems, manufacturer's catalogs, and instruction manuals for all installed equipment should be maintained. The sampling sites should represent all areas of the distribution system where potable water is used/consumed, to include residential, administrative, and industrial areas. This approach will allow operational authorities to be assured that disinfection residuals are maintained, and microbiologic growths are impeded throughout the entire piping network. Also, such areal sampling allows operators to track the integrity of the distribution and storage systems to monitor for potential leaks or breakage in piping/appurtenances. The location, cause, and frequency of all system leaks/breaks should be noted and assessed by operations authorities to determine if further action should be initiated to minimize future interruptions or water loss. Maintenance schedules and records would include hydrant flushing programs, valve inspection and maintenance activities, and cross-connection control programs, as well as replacement and repair.

Operations authorities must establish a mechanism to receive and respond to consumer complaints. Ideally, such a program should have the ability to receive consumer input at any time (24 hours a day, 7 days a week (24/7)). This may be accomplished by connecting with an already-available system—such as an emergency services system (e.g., installation police/security force). As an alternative, the water provider may establish a designated phone line to receive calls from the public. They could, then, designate an operations employee to check this line for messages every 2 hours (maximum). Situations involving a potential for water loss or contamination require immediate investigation/action. The appropriate engineering or contractor personnel may be contacted by the on-call assessor and are expected to respond immediately at any time of day or night. If the initial assessor deems the complaint/situation to be non-critical, the caller can be assured that they will receive a response from the appropriate water provider personnel within the next 24–48 hours. Subsequently, the water provider (engineering/operations contractor) must follow-through and investigate the complaint situation within the designated timeframe. A proper consumer complaint program can be helpful to identify

problems within the water supply system prior to them becoming serious and facilitates goodwill with the installation population/consumers.

4. Public Health/Environmental Health Monitoring.

From a drinking water perspective, DoD's primary goals are to consistently provide safe, aesthetically pleasing potable water at adequate pressures and quantities to protect the health and quality of life of people living and working on the installations. The roles of the government and operating contractors providing the water supply are to acquire, treat, and distribute the potable water to these personnel. The role of the public/environmental health authorities at the installation level is just as critical. These personnel assess exposure to potential environmental hazards, including those found in the drinking water supply; evaluate the threats and risks; and communicate environmental health solutions to the operations and installation authorities. The DoD public/environmental health programs should optimize Service-member protection and readiness in all situations and protect the health of personnel, military families, and other relevant populations potentially exposed to environmental hazards, including the installation potable water supply.

According to Service guidelines and policies, the installation public health authority maintains public health oversight, quality assurance, and technical assistance for the installation's drinking water supply systems" (DA 2020b). From an oversight perspective, the installation PH authority represents the IMA, or medical commander, when reviewing all analytical results and operational information provided by installation, operational, and laboratory contract organizations regarding the potable water system. Recommendations are provided to the IC addressing any non-compliance issue or system upset that may cause harm to consumers. The PH authority should not only note the problematic issue but also perform an assessment of risk for command action. It is, therefore, important that the installation PH authority is supplied with all data regarding the water supply system, along with copies of operational anomalies reported by the drinking water provider. In turn, the PH authority will coordinate all assessments performed with these organizations.

Additional topics where PH authorities provide oversight and coordination include the development of sampling and analysis plans and the review of system and equipment design improvements. In such cases, these authorities can ensure the safety and protection of personnel and integration of plans into the installation's protocols and procedures. Also, the PH personnel perform an annual sanitary survey of all facilities within their area of responsibility (AOR). They are also responsible for ensuring that all water systems within their AOR and required data has been input to the Defense Occupational and Environmental Health Readiness System – Industrial Hygiene (DOERHS-IH). This knowledge and understanding may help PH personnel in assisting the water providers to perform the annual updates to the installation Water System Vulnerability Assessments and Water System Emergency Response Plans. Further, PH personnel may represent the IMA in assisting the IC with developing public notices and consumer advisories regarding water quality. This most commonly occurs when bacteriological samples are reported as positive in the water supply system. Subsequent water sampling would be conducted according to regulatory guidance, and the PH authorities will help to develop "Do not drink" or "Boil water" advisories for dissemination throughout the affected population. Public health coordination and input would also prove very helpful when developing notices and

interacting with installation personnel regarding consumer complaints about the water supply system.

The installation PH authority plays a critical role in the assessment of disinfectant residual and microbiological quality throughout the system. They develop a sampling program to augment the routine sampling accomplished for compliance monitoring and by operations personnel. Sampling is often conducted at key locations within the distribution system that may not routinely be included in the assessment program used for compliance or operational control. Public health monitoring may, instead, focus on areas representing potentially compromised individuals or "weak" areas of the distribution system. For example, the PH sampling plan may incorporate activities such as schools, child development centers, home daycare activities, hospitals, and clinics. Further examples include areas of the distribution system traditionally exhibiting "dead-ends" (where piping displays interconnection from only one direction) or low-flow/low-usage zones. Such areas of the distribution system are considered "weak" because of the limited amount of water flowing through these zones, facilitating the decline of disinfectant residuals and the potential proliferation of debilitating bacterial populations.

The PH authority maintains a capability to evaluate water for free available chlorine (FAC) residual, combined available chlorine (CAC) residual (if chloramines are used for system disinfection), and pH. The latter value, pH, can be obtained using a meter and is important in the determination of whether the system may have been compromised by unauthorized personnel. Unknown, or unauthorized chemical addition may adjust the pH outside of normal operating ranges. The PH authority must also maintain a laboratory and equipment capable of evaluating the water supply for total coliform and fecal coliform. Bacteriological testing is used to verify the absence of coliform organisms and is generally accepted as verification for the disinfection of the pipeline. The presence of coliform bacteria in the water supply must be reported immediately to the system operators and the installation command. In support of installation operations, the PH authority should also work closely with the water provider to confirm that proper disinfection procedures are utilized during and after the installation and repair of drinking water treatment, storage, and distribution system equipment and facilities. They can assist with disinfection actions and the assessment of bacteriological water quality to verify that the water supply is potable and safe for use.

In addition to the required parameters identified above, the PH authority/installation medical commander may conduct or request random sampling of the chemical, radiological, and/or microbiological quality of the water supply at any time to support their oversight and quality assurance responsibilities. Their input and health-based understanding should also provide a basis for their contributions in assisting the ICs to develop Memoranda of Understandings (MOUs) and Memoranda of Agreements (MOAs) with external authorities to document relationships regarding this critical resource. All agreements and contracts must ensure the recurring medical surveillance requirements and responsibilities as defined in Service guidelines and regulations. For these reasons, the local PH authority should participate on the installation Environmental Quality Control Committee, Antiterrorism Security Committee, and the installation Emergency Planning Board.

5. Aggregate Monitoring of Water Supply Systems. The total aggregation of data accumulated from all requisite monitoring of the water supply system is in place to ensure that all

treatment, storage, and distribution facilities are operating correctly, as designed, and that the water reaching consumers is plentiful and of the highest quality available. The sampling and analysis performed on the water system for compliance purposes show the regulatory authority that the water system complies with all requisite parameters and that all concentrations fall below the permissible limits of the maximum contaminant levels. The monitoring performed routinely by operations personnel facilitates the adjustment of chemical additions, storage residence times, and distribution system flow to optimize the quality and quantity of water produced. Public health authorities augment the operational data for installations within their AOR and provide a necessary expertise to evaluate the possible health impacts of system anomalies and contaminants upon consumers. The combination of all water supply system monitoring ensures that all processes and facilities are functioning well to provide a safe, healthy, and aesthetically-pleasing product for consumption and use. Assurance of such a water supply is fundamental to continued public health.

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