U.S. ARMY PUBLIC HEALTH CENTER

TIP No. 31-112-0722

Water Supply Systems – Water Storage

1. Purpose and Role of Water Storage.

Water storage facilities within the water supply systems provide a critical control mechanism and a barrier that prevents compromise of water quality while it travels to the points of consumption or use. Storage tanks often provide the only visible evidence of this critical utility to the general population and/or those travelling along the highways. These facilities comprise a critical element of this important infrastructure system.

A storage facility is "defined as a reservoir from which water, without further treatment, is supplied directly to the distribution piping system for domestic use" (reference 1). Particularly, the water obtained from any source(s) generally receives some form/degree of treatment prior to entering the general distribution piping network. Distribution storage is intended to meet peak flow requirements within the supply system, maintain system pressures, and meet emergency water and/or fire flow needs, which would normally exceed the water production and pumping capability within the system. If the water systems did not have storage tanks, the water treatment facilities would have to be sized larger and/or extend operating hours to meet the peak water demands placed on the system by domestic, commercial, and industrial use and to provide sufficient flow for fire suppression. These practices would prove very inefficient and uneconomical for normal water system operations (reference 2).

2. Public Health Considerations.

Since water storage tanks comprise an integral part of water supply systems, it is important that the installation Public Health (PH) authorities are cognizant of the operation, maintenance, and inspection of these structures. Water quality entering the distribution system from these facilities must also remain unaffected. Extended residence time of water within a storage tank may significantly impact the water quality within the tanks and the water delivered to consumer's downgradient. The water emanating from storage tanks should be incorporated into the PH's routine sampling matrix. Although water sampling ports are seldom incorporated into the design and structure of storage facilities, water entering the network piping downgradient from storage facilities should be evaluated for free available chlorine (FAC)/combined available chlorine (CAC) residual and total coliform bacteria once per month to ensure proper facility operation and water quality. The PH personnel may complete the heterotrophic plate count assessment to assist in the determination of possible bacteriologic regrowth within the storage tanks. The PH personnel should also remain aware of possible security breaches (e.g., open gates or access hatches, unauthorized access to altitude valves and Supervisory Control and Data Acquisition (SCADA) equipment/controls, access ladders, broken mesh covering vents and overflow portals, etc.). Whenever it appears that anything is amiss, as noted during their routine travel and operations on the installation, the PH authority should contact the Directorate of Public Works (DPW)/operating contractor office immediately. The PH authority should also remain available to support the DPW/operating contractor whenever any storage facility is scheduled to be inspected, repaired, or maintained. The PH authority should sample the water in the tank, or exiting the tank, for FAC/CAC residual and total coliform. All coliform samples must be negative prior to placing any storage tank back into service. If a positive coliform presence is identified and confirmed, the DPW/operating contractor should consult with the PH authority and/or regulatory authority to develop a plan of remedial action.

3. Potential Water Quality Issues Associated with Water Storage.

Water quality problems emanating from within storage facilities can be classified as microbiological, chemical, or physical. Many of the water quality concerns identified within water storage facilities are most frequently caused, or exacerbated by, excessive water age. Water held in a quiescent storage tank causes the disinfection residual (i.e., chlorine or chloramine) to rapidly dissipate. Extended detention times, resulting in increased water aging, can be conducive to significant microbial growth and chemical changes, thus affecting the biological and physical character of the water supply (references 3 and 4). The extended water age is generally caused by an underutilization of water resources being added into the supply system—causing stagnant water zones within the distribution system and insufficient withdrawal of water from the storage tanks during routine daily use cycles. Further, there may be short-circuiting of the water system within the storage reservoir, depending on design and construction, limiting mixing and withdrawal of the general water supply held in the storage facility.

From a microbiological perspective, the regrowth of bacterial populations may occur within the still waters inside a tank if not properly operated and in the absence of a disinfectant residual. Further, degradation of water quality may result from insects, small animals, and birds accessing the tank's interior due to unsecured vents and hatches. These can pose a significant problem, and have proven responsible for adversely impacting installation operations in past years. The Public Health Engineering and Epidemiology personnel worked closely with installation DPW/operating contractor authorities to identify these problems. Pathogenic bacteria and viruses introduced by these creatures, including *E.coli*, Campylobacter, Norwalk virus, Coronavirus, Cocsackieviruses, Hepatitis A, Rotavirus, and Cryptosporidium have been observed in some stored supplies (reference 4). Such issues may be precluded by ensuring that all openings to the reservoirs are closed and appropriate screens for vents and overflows to these facilities are secured in place.

Proper disinfection of water supplies is a critical step in minimizing the risks posed by microbiological contaminants. A sufficient dose should be injected to ensure that a detectable residual of it is maintained through the entire piping network and storage reservoirs to the points of consumption. Frequently, water system personnel must inject sufficient chlorine to achieve a residual at the treatment plant of 1 mg/L to ensure the maintenance of at least 0.2 mg/L throughout the distribution system subsequent to water storage. Care must be taken when adding disinfecting agents (e.g., chlorine), as disinfection by-products may form in water supplies containing naturally-occurring or synthetic organic materials, and there is an extended detention time exposed to chlorine. Disinfection by-products are potential carcinogens if consumed over many years. Therefore, it is critical that disinfection by-products as well as disinfection residuals are monitored, in addition to disinfection residuals, throughout the distribution system. A balance must be achieved to maintain sufficient chlorine residual while minimizing/precluding the formation of disinfection by-products within the water distribution and storage system.

Another possible water quality concern regarding water storage facilities includes the deposition of sediment in the storage tanks. Sediment entering the distribution system from the water treatment facilities and/or wells supplying the system will readily settle out in the quiescent environment provided inside a tank. Operations personnel must remain cognizant of such conditions. If sediment, as well as oxidized iron and manganese builds up in a tank, it may adversely skew the amount of water available to meet the required demands posed upon the supply system and impart water quality concerns (e.g., taste, odor, color). There may be a need to drain a reservoir and physically remove the accumulated sediment if it exceeds 3 inches deep or should such water quality impacts be observed (references 4, 5, and 6).

The corrosive nature of the water supplies has always posed a significant concern for water storage tanks, particularly when addressing steel tanks. For many years, cathodic protection systems have accompanied the installation/operation of steel water tanks. These systems prevent corrosion of the steel tanks by converting all of the “active” sites (steel) to “passive” sites by supplying an external electrical current. These systems must be periodically inspected and maintained. The advent of more effective and advanced chemical coatings meeting National Sanitation Foundation (NSF)/ American National Standards Institute (ANSI) Standard 61 (reference 7) specifications have been used on many newer facilities to prevent corrosion of these structures. The impact of corrosion on the coating materials may also introduce nutrients, which can facilitate the formation of biofilm and further creates a disinfection demand. The integrity of these coatings must be evaluated when the tank interiors are inspected, as described in section 6.

Chemical leaching from inappropriate or incompletely cured coatings may occur. Such actions would cause the potential presence of volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs), which are regulated materials, in the water supply. Synthetic and naturally-occurring organic materials lying dormant in stagnant water, where there is insufficient movement/mixing, may cause resultant bacteria to create tastes and odors that could be transported through the distribution piping to consumers (references 2, 6, and 8). Materials contributing to taste and odor concerns may not possess properties that would be harmful to consumers. However, these characteristics may impede the consumer’s desire to drink or use the water for hydration, cooking, and washing.

4. Water Storage Operations.

Water storage systems may be operated using several different methods. Historically, many tanks were constructed to supply water to specific areas for fire protection. This was most frequently found in regions containing significant commercial and/or industrial facilities, but eventually spread to residential and office zones, as well. Such systems are still observed at many of the older depots and ammunition plants within the Army. Often, an elevated storage tank will accompany each separate ammunition product line. The water contained in these facilities supplies the fire hydrants and suppression systems found within each building. In most instances, maintaining a fresh, disinfected water supply is not the primary consideration. Oftentimes, when industrial water is required for mission operations, the water used for fire protection may be provided along with the industrial use water via a designated/segregated distribution system. Potable water within such buildings is either supplied using a distinct/separate distribution system or by bringing in bottled water for employees/personnel.

Currently, most water supply systems are designed to ensure that the storage facilities remain an integral component of the total system. Simply, this means that water in the tanks flow into the distribution system as the demand increases above what is available within the piping network directly from the water treatment plant. Water from storage tanks augment the treated water in the water system's piping to meet the daily peak demands imposed by residential, commercial, and industrial uses. The peak demand periods generally occur in the morning, when people prepare for work and school, and in the evenings, when personnel return to their residences, prepare dinners, wash dishes, and clean themselves and clothing. During the day, the water demand lessens, and the product entering the distribution system from the well(s) and/or treatment facilities often exceeds the demands placed on the system. During these periods, the storage tanks are refilled with fresh, treated water. This cycle often allows most installations to operate on a shorter schedule (i.e., 16 hours per day rather than 24 hours per day), thus saving energy and labor costs (i.e., the need to hire additional operators for the one (unmanned) shift per day).

At many installations, the fire hydrants are adjoined to the potable water distribution system. The same piping network supplies the domestic demands, and may be tapped by firefighters to combat fires throughout the system. Firefighting demands may occur at any time. These demands may coincide with the peak demand periods imposed on the system. Among the design considerations for water systems and storage tank requirements, is the assurance that the water available for domestic requirements and firefighting will be met by the combination of water supplied through the water sources used and the water storage available within the system.

Similarly, water required for emergency purposes must be considered. Emergency circumstances potentially include an interruption in the operation of the water treatment plant or distribution pumps. Army Directive 2020-03 (*Installation Energy and Water Resilience Policy*) states that the Army will plan to sustain energy and water for a minimum of 14 days (reference 9). The need to consider emergency water supplies will depend on the reliability of the system and other measures to safeguard against service interruptions (i.e., interconnections with neighboring community water systems). Please note that the storage tanks within a water system are not drained completely, so that these emergency supply requirements are considered. A specified volume of water may be used before the preset altitude valves will turn off the outflow of water and the valve is opened allowing the tank to be refilled from the water within the distribution system. Overall, water supply systems must be designed to satisfy all anticipated water demands, and storage plays a significant role in this process.

5. Types of Water Storage Facilities.

Finished water storage is frequently segregated into two categories based on construction and siting: ground storage and elevated storage. Ground storage facilities can be located totally below the ground surface, partially below ground and partially above, or completely above the ground located at the surface. Underground storage tanks are the least preferred design alternative due to the high cost and limited technical advantage. Therefore, the use of underground storage tanks should be avoided. Pumps frequently accompany ground-level storage if they are not constructed at elevations that can provide the requisite system pressures, which rely on flow created by gravity alone. Ground storage with pumping capability is frequently more common for systems covering a large area, as the outlying service areas extend beyond the reasonable range of primary pumping capabilities found at the treatment plants (reference 10). Concrete reservoirs are generally built no deeper than 20-25 feet below ground surface. If rock is present, it is usually more economical to locate the storage facilities above the rock level. Therefore, ground-level storage tanks are commonly found in environments where rock or hard clay is observed as a barrier. Further, if ground storage tanks are used within a supply system exhibiting a single water pressure zone, the tank(s) should be sited in the areas displaying the lowest system pressures during the periods of high water use. In systems exhibiting multiple pressure zones, ground-level storage tanks are routinely sited at the interface between pressure zones, where the water from a lower pressure zone would fill the tanks and be passed through pumping stations to the higher pressure zones (reference 3).

The most common types of elevated storage tanks seen at Army installations are elevated steel tanks and standpipes. Standpipes are tall, cylindrical tanks generally constructed of steel or reinforced concrete. The lower portion of the structure provides support to the portion providing system storage. The lower portion of the structure may also be used as a source of an emergency water supply. Elevated water storage tanks are overall more economical and effective for the purposes of meeting peak water demands placed on a water system and for maintaining equalized pressure throughout the system. These structures may be located some distance from the pumping stations and may augment supplies for wide areas of the installations.

Originally, many tanks were bolted together, using organic gaskets or sealants to seal the seams and minimize fluid loss. These tanks have been in use since the early 1900s and were used primarily for crude oil and brine containment systems. Use of bolted tanks for water was advanced by the development of standards by American National Standards Institute (ANSI) and the American Water Works Association (AWWA). Interest in these tanks was reprised when new standards were established by ANSI/AWWA in the late 1970s, which allowed for a lighter gauge of steel to be used for steel panels. These tanks may be dismantled and moved, if necessary, though are currently seldom found in water supply systems. Subsequent water tanks were constructed using riveted panels of steel. Around the 1930s, welded-steel tanks were developed and used. Welded tanks replaced the riveted structures by the 1950s. This 20-year transition period was necessary because the industry had to train enough skilled welders to perform the work, and construction contractors were reluctant to replace their skilled riveter workforce. In 1935, the ANSI and the AWWA developed guidelines/standards supporting the use of welded-steel tanks. The greatest advantage of welded tanks over the riveted tanks was the development of smooth structures with far reduced maintenance costs than was possible with lapped, riveted seams. Elevated steel tanks using the welded seams may hold as much as several million gallons of water. Storage tanks of varying sizes are routinely found on Army installations. Often, tanks holding as little as 10,000 to 25,000 gallons may be used to supply isolated housing, commercial, or industrial areas. Tanks holding up to several million gallons of water may also be found serving larger installations.

Composite-elevated tanks have been used since the 1970s. These tanks display a welded-steel tank for watertight containment. Different materials and designs may be used for the construction of the pedestal. The design and performance of these structures are subject to specific standards and guidelines developed by ANSI/AWWA in 2010.

Clearwell storage is typically a ground storage tank maintained at the water treatment plant. The clearwell is filled with treated water from the plant. This water has received the final chlorination, and the clearwell serves the role of providing the residence/contact time required to ensure deactivation of all harmful microorganisms within the water supply before it enters the distribution system. Clearwell storage is also used to provide a reservoir for use in the plant, such as a supply for filter backwash and when plant production is stopped for short periods because of failure or replacement of some component or unit of treatment. If water were to be routinely allowed to enter directly into the distribution system without the clearwell, the requisite contact time may be circumvented. Therefore, clearwell storage is considered part of the treatment process and is not included in computing the water supply system's storage requirements (reference 3).

Water storage tanks will possess altitude control valves to control the level of water in the tanks. The valve closes at a preset maximum water level or air pressure to preclude the entry of water from the distribution piping system to prevent overflow. Conversely, the valves will open at a preset level to refill when the water level in the tank or reservoir lowers. The water level valves may work on air pressure in the tank. As the tank fills up with water, the weight of the water will begin to compress the air. As the air continues to compress, the pressure within the tank builds. When the tank reaches a certain internal pressure, it signals to the feed source to cease delivery. For many water tanks, the altitude control valves are generally located in a valve pit located at the base of the tank structure. At many sites, a steel sheet covers the valve pit. Doors may be lifted, which allows the workers access to ladders down to the valves located on the water line interconnections. These access points must remain locked to ensure that unauthorized personnel do not access these valves. Someone intending on harming the water system could cause a significant disruption to system operations by accessing and altering the valve settings. Often, this valve pit also includes connections to the electronic SCADA system that monitors water levels and resulting pressures in the water system. If the water levels in the tank reach the capacity of the facility, water will be purged through the overflow vent to the exterior. Normal water levels may vary, but are generally maintained at a level somewhat below the tank capacity (e.g., perhaps 80-85% of tank capacity).

6. Storage Tank Inspection and Maintenance.

Storage facilities must be routinely cleaned, maintained, and inspected to ensure the integrity of the structure and components and the assurance of operations and public health. The walls, roof, and flooring of each tank must be assessed to ensure that they are not compromised. As a part of this comprehensive assessment, the status of the steel and interior coatings should be examined—to include the type and condition of the coating and an approximation of the coating system's failure. As part of this assessment, the coating thickness and the extent of pitting damage should be estimated. Vents, overflows, access hatches, and roof openings should also be evaluated (references 8 and 11). Any weaknesses should be noted and repaired immediately. Prior to being filled and placed back into service, the tank walls and interior surfaces should be washed using a power water jet and scrubbed with a disinfectant solution, to preclude possible bacterial growth in the water supply. Several methods of chlorination are described in the ANSI/AWWA Standard C652, *Disinfection of Water-Storage Facilities* (reference 1). Once filled with water, the water in the storage tank should be sampled and tested for coliform organisms. The AWWA Standard (C652) (reference 1) states that the methods identified in the *Standard Methods for the Examination of Water and Wastewater, 23rd Edition*, *2017* (reference 12) should be used. If the tests for coliform organisms are negative, the facility can be placed back into service. If the sample results show the presence of coliform bacteria, the Standard recommends that the facility be evaluated by a qualified engineer. Whatever remedial measure is taken, repeat coliform samples should be analyzed until two consecutive samples are negative.

There are no steadfast Federal requirements for the inspection of storage tanks. Many States, however, have identified timeframe requirements for when inspections should be accomplished. Installation personnel should check with their local and State regulatory authorities to ascertain the required timeframe and information required for the inspection of water storage tanks. In the absence of a regulatory requirement, the AWWA Manual M42 (reference 2) and the Unified Facilities Criteria (reference 6), which provides criteria/guidance for all Services, state that tanks should be drained, maintained, and inspected every 3 years.

There are several types of inspections frequently employed. Any deficiency noted during an inspection of the storage tanks should be corrected and documented immediately. Routine inspections may be accomplished daily or weekly by water system personnel. This simply involves a drive-by assessment of the exterior, checking vents, ladders, altitude controls, and access points to ensure that they remain secure (reference 8). Also, the integrity of fencing and locks should be checked. Then, on a monthly or quarterly basis, personnel may perform a periodic inspection. This involves a hands-on assessment to ensure that all appurtenances are secure and have not been tampered with. Finally, the comprehensive inspection, identified previously, is performed every 3 years. All water system storage tanks within the Army/Department of Defense (DoD) must receive comprehensive inspection and maintenance every 3 years. This includes the in-depth assessment using the complete washout and physical inspection of the interior. Alternatively, some commercial companies now use trained divers or remotely operated vehicles (ROVs) to provide a thorough inspection of the tank interiors (reference 13). All inspections, deficiencies, maintenance, and corrective actions should be well documented with records archived by the DPW.

7. Safety Issues.

In addition to sanitary and technical/structural considerations, a number of safety concerns involving the water storage must be inspected as well. Although some water tanks are sited within specified industrial areas at some Army installations (which are routinely fenced in), most water tanks are located within the general cantonment areas of installations, thus making them accessible to anyone on the installation property. This would include personnel or dependent children seeking mischief or to cause intentional damage or harm to the water system. Therefore, storage tank facilities are generally sited within a fence, with locked gates and signs stating, “Authorized Personnel Only.” Key control authorities must ensure that only personnel undertaking authorized work are allowed entry into these sites. All personnel must be instructed to ensure that all locks are secured every time when exiting the site.

Other than water operations personnel (e.g., DPW/operating contractors), other installation directorates may store large pieces of equipment (e.g., light poles, street light clusters) within the fenced-in areas surrounding water tanks, upon Command approval. Further, many installations use the elevated tanks as a base for antennae used for widespread communication systems. Similarly, installations have frequently leased space on the elevated tanks to commercial communications companies for their antennae. Since the tanks are already significantly elevated, the companies and installations can avoid the costs associated with constructing large towers to site their antennae. Similar safety instructions—to ensure that gates are locked and only authorized personnel enter the sites—must be provided to all additional installation and commercial workers entering these areas.

Additional items to be checked during routine inspection visits to the storage facilities, or during security patrols performed by the installation or DoD Police Force, include ensuring that access ladders to the elevated walkways are folded up and secured to preclude ready access to non-authorized personnel. Also, observers can discern if the boxes housing cathodic protection controls have been disturbed. They are generally attached to the base of an upright spire supporting the elevated tank. Any disturbances of these appurtenances, or notation of access doors remaining open should be reported immediately to the DPW and/or the installation water system operating contractor.

Climbing up to the access doors on an elevated water storage tank poses many safety concerns and risks. Security harnesses must be in place to ensure worker safety while climbing and working at such heights (reference 8). In addition, any entry into a storage tank requires a confined space entry plan. A minimum of two people entering the structure and one individual serving as a "spotter" outside the tank should be involved for safety concerns. Personnel should also retain access to requisite safety equipment for climbing and working within these structures.

8 Point of Contact.

Please contact the Environmental Health Engineering Division, Garrison Water Branch, 410-436-2509 or DSN 584-2509 for additional guidance.

9. References.

1. American National Standards Institute (ANSI)/American Water Works Association (AWWA). 2020. Standard C652, *Disinfection of Water-Storage Facilities*, April 1, 2020.

2. AWWA. 2013. Manual M42, *Steel Water-Storage Tanks*, revised 2013. https://engage.awwa.org/personifyebusiness/Store/Product-Details/productId/39312169

3. Department of the Army (DA). 1985. Technical Manual 5-813-4 [AFM 88-10, Vol 4], *Water Supply, Water Storage*.
https://armypubs.army.mil/default.aspx

4. Department of Defense (DoD) 2021. Unified Facilities Criteria (UFC) 3-230-02, *Operations and Maintenance (O&M): Water Supply Systems, Change 1*, 1 April 2021. https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

5. DoD. 2021. UFC 3-230-01, *Water Storage and Distribution, Change 3*, 1 July 2021. https://www.wbdg.org/ffc/dod/unified-facilities-criteria-ufc

6. USACHPPM. 2002. Water Supply Management Information Paper No. 31-019, *Maintaining High Drinking Water Quality in Finished Water Storage Tanks and Reservoirs, November 200*2.

7. National Sanitation Foundation (NSF)/ANSI Standard 61, *Drinking Water System Components - Health Effects, 2017*.

8. Tobin T. 2015. Water Storage Tank Safety Standards, presented at the PNWS AWWA 2015 Conference, May 1, 2015.

9. DA. 2020. Directive 2020-03, Installation Energy and Water Resilience Policy.

10. U.S. Environmental Protection Agency, Office of Ground Water and Drinking Water, *Distribution System Issue Paper, Finished Water Storage Facilities*, August 15, 2002. https://www.epa.gov/sites/default/files/2015-09/documents/2007_05_18_disinfection_tcr_whitepaper_tcr_storage.pdf

11. “Storage Tank Inspection and Maintenance,” 2021. Illinois Environmental Protection Agency. https://www2.illinois.gov/epa/topics/drinking-water/field-operations/Pages/storage-tanks.aspx

12. Baird R and L Bridgewater. 2017. *Standard Methods for the Examination of Water and Wastewater*. 23rd ed. Washington, D.C.: American Public Health Association.

13. Marine Industrial Tank Diving and Coating. https://www.mitdivingcoating.com/