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Review of the Applicability of Published Water Reuse Guidelines for Contingency Operations

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1 SUMMARY

1.1 Purpose

Water is required to sustain Soldiers' health, but transporting water in combat situations is dangerous and expensive. The desire to decrease required resources for water logistics and improve water security drives the Army's interest in water reuse; water recycling is considered to represent a significant reduction in logistical burdens associated with not only provision of water to contingency operations, but also the disposal of wastewaters generated by such operations. While the Army has the technology to make most sources of water, including various types of wastewater clean enough to drink, Soldiers and decision makers instinctively know that deployed personnel do not necessarily require potable-quality water for all water-use activities. The overarching question asks, "Based on health effects caused by microorganisms, chemicals, and physical parameters, how clean does the water need to be for various tasks performed by Soldiers?" When the required water quality is known, treatments and technologies can be matched or developed for the various uses. Such matching will enable the Army to maximize resources and improve water logistics and security.

The purpose of this document is to review the currently available water reuse standards for gray water and assess their applicability to water reuse for specific activities performed in contingency operations. The most common water reuse source stream is comprised of laundry, showering, and dishwashing wastewaters. The resulting assessment is intended to enhance risk analyses and guideline development regarding military water reuse.

This assessment employs the concept of "use cases" to place functional aspects of water use and re-use during contingency operations in realistic context and to structure the assessment. An advantage of the use-case approach is to accommodate the multiple exposure possibilities known to occur within any given use case (such as fire-fighting, dust suppression, laundering of clothes).

Water quality standards are useful to identify health-based allowable concentrations for biological and chemical contaminants post-treatment, as well as desirable physical characteristics. These reuse standards for a given activity (e.g., "fit-for-purpose") can then be used to develop specific goals for technological development and comparison.

The intended audience for this report is personnel who are involved with Army water reuse projects and doctrine development. This population encompasses a wide knowledge base. For example, they may be familiar with how water is used in the field but not necessarily familiar with the technical details of water treatment. This assessment contains summary information on water treatment, risk assessment, and risk management, all of which are fields unto themselves.

1.2 Abstract

This assessment provides a starting place for the development of "use cases" for contingency operations that are relevant for water reuse and reviews currently available standards. The following eight use cases were developed for contingency operations: Laundry, Dust Suppression, Toilet Flushing, Vehicle Washing, Industrial Use (Construction), Fire Fighting, Showering, and Dish Washing. Water reuse in the

context of these eight use cases was described, and human health exposure parameters were identified for each use case. In addition, published nonmilitary water reuse standards for gray water were reviewed for potential applicability to these eight use cases.

Water reuse laws, regulations, and guidelines were researched for three states and three countries: California (CA), Arizona (AZ), and Texas (TX) as well as Australia, The Netherlands, and Israel. These locations were selected because of their involvement (longest initiative for water reuse, most comprehensive documentation, lead areas for public consumption, and most conservative concepts) in water reuse initiatives. In addition, other documents were reviewed (USACE 2014) to confirm the selection of the best references. It is noted that many other states and countries are active in water reuse initiatives (i.e., Hawaii, Washington, Florida) and their guidelines tend to mirror the lead states of CA, AZ, and TX.

It is beyond the scope of this assessment to “pick a standard”; this assessment enhances the development of future risk assessments regarding water reuse. In order to complete a quantitative risk assessment for any given use case, the use-case scenario will have to be validated, the exposure factors will need to be determined, and the approach for characterizing risk will need to be determined. While it is preferable that acceptable risk levels for a scenario are established prior to performing a risk assessment, analysis may proceed without an established acceptable risk depending upon the purpose of the risk assessment. The ability to focus on a particular use case versus general “reuse” may serve to facilitate the implementation of using treated wastewater in the field.

1.3 Recommendations

To support the further advancement of using treated wastewater, the following recommendations are provided:

1. Define and reach consensus on the proposed use cases and relevant exposure parameters to support targeted guideline development.

2. Define and reach consensus on acceptable risk for the selected use cases.

3. Establish (derive) health-based gray water reuse exposure guidelines for target chemical, biological, and physical components of gray water.

4. Develop health-risk based monitoring protocols and techniques, in close collaboration with water quality characterization technology development, to ensure adequate monitoring of water quality for intended (fit-for-purpose) water use.

5. Begin a communication campaign as early as possible (now) to learn about current perceptions and educate users about water reuse applications and benefits.

2 REFERENCES AND TERMS

Appendix A provides the references cited, and the Glossary provides a list of acronyms and terms.

3 BACKGROUND

Water reuse is not a new concept, and there are many countries (e.g., Australia), agencies (e.g., U.S. Environmental Protection Agency (USEPA)), and states (e.g., CA and AZ) involved in quality research to ensure public health protection is maintained when water reuse is employed. There are also other published guidelines such as National Sanitation Foundation/American National Standards Institute (NSF/ANSI®) 350 that establish material, design, construction, and performance requirements for onsite residential and commercial water reuse treatment systems. Previously published water-related standards or guidelines may be applicable for the U.S. Army, which has an interest in water reuse at both fixed installations (USACE 2014) and forward-operating bases (FOBs) (USAPHC 2014a). A formal evaluation of these published guidelines with regard to their applicability to U.S. Army interests is timely, and needed.

3.1 Military Water Reuse Standards and Guidance

The Army Surgeon General is responsible for establishing water quality standards, determining surveillance requirements, evaluating water equipment for possible health hazards, developing test protocols for tactical water purification systems, and providing oversight of operational monitoring to ensure water meets established standards (Army Regulation (AR) 700-136; DA 2009) during military operations. The Army Medical Department coordinated with other military Services to produce Technical Bulletin, Medical (TB MED) 577, *Sanitary Control and Surveillance of Field Water Supplies*; DA 2010), which provides general instructions for the sanitary control and surveillance of land-based field water supplies. In 2010 at the last publication of TB MED 577, water reuse was not widely practiced; therefore, Chapter 9 of the TB MED 577 (“Water Recycle and Reuse”) is limited. However, it does provide a definition for “recycle” (using water again in the process that generated it) versus “reuse” (using water again for a different purpose), information on treatment for recycling water with a focus on laundry and shower water, and gray water standards for recycled water (DA 2010). The TB MED 577 gray water standards are for a limited number of physical (pH, turbidity, hardness, total dissolved solids (TDSs)) and, chemical (free available chlorine (FAC)) parameters as well as generic determination of presence or absence of coliforms. There is no evidence that these standards are health-risk based, and they are not characterized for use cases other than “nonpotable.” These standards do not address chemical hazards that may be present in source waters (e.g., industrial-site runoff; pesticides, insecticides, or chemicals from personal care products, and so forth) or pathogens known to be responsible for performance-reducing levels of gastrointestinal illness in trainee, deployed and garrison units (e.g., Norovirus, *Shigella*; Hyams et al. 1991; Chapman et al. 2011; Arness et al. 2000); (USAPHC 2014 a, b).

Another document, a 2001 information paper generated at the [then] U.S. Army Center for Health Promotion and Preventive Medicine is referenced by TB MED 577. The Medical Issues Information Paper, “Criteria for Recycle of Greywater for Shower Use,” provides criteria for treatment and recycle/reuse of gray water for showers (USACHPPM 2001) and was sourced as a partial basis (along with USACHPPM 2003) for the “Medical Standards on Water Quality Criteria and Treatment Practices for Recycle of Laundry and Shower Wastewater for Shower Use.” This was promulgated by the Office of the Surgeon General (OTSG) for application to all U.S. Army outside Continental United States (OCONUS) and continental (CONUS) field training exercises as well as all U.S. Army OCONUS military field operations (DA 2004). The DA (2004) “Medical Standards…” include recycled gray water quality criteria values for most of the generic physical (pH, color, odor, turbidity, total dissolved solids) and the same generic chemical (free available chlorine (FAC)) parameters as for TB MED 577 while also including selected chemical warfare agents[1], industrial and agricultural compounds such as arsenic and lindane,

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[1] Chemical warfare agents include Hydrogen Cyanide, BZ, Lewisite, Sulfur Mustard, Nerve Agent, and T-2 Toxins.

composite radiological characterization (microcuries per liter (µCi /L)), (BOD_5 (5-day biological oxygen demand)) and coliform concentration (#/100 milliliters (mL)). A significant refinement provided by the OTSG guidance (DA 2004) is its specific use-case application (showering) and characterization of recycled gray water for shower use during training and field operations, as well as its consideration of selected (N = 3) industrial and agricultural compounds. Numerous chemical hazards that may be present in source waters or pathogens known to be responsible for gastrointestinal illness, however, are not addressed.

Between 2001 and 2016, shower and laundry capabilities were developed in order to implement reuse water practices. In 2014, a risk analysis of water reuse in contingency operations was performed by the Army Institute of Public Health (now U.S. Army Public Health Center (APHC)) as the foundation for water reuse guidelines. The USAPHC Technical Guide 364a (*Water Reuse in Contingency Operations, A Strategy for Comprehensive Health Risk Management;* USAPHC 2014a) did not establish numerical water quality standards and did not represent an enforceable regulation of water reuse. The USAPHC (2014a) guidance concluded with the development of a risk management framework and emphasized that future guidelines may be promulgated by the Services or as a Joint technical standard.

With regard to fixed installations, in 2014 the U.S. Army Corps of Engineers (USACE) published a Public Works Technical Bulletin “Applicable Guidelines for Water Reuse at Army Installations” as a guide for Army installations that are considering water reuse. This document is applicable for CONUS installations and lands, as well as outside OCONUS installations and lands under Army Jurisdiction. This USACE document provides a summary of currently available U.S. state and Federal water reuse practices and guidelines but does not directly assess their military-specific applicability to contingency operations. USACE (2014) also provides guidance for Army facility compliance with provisions of AR 200-1 (*Environmental Protection and Enhancement*, DA 2007a) as well as AR 420-1 (*Army Facilities Management*, DA 2012a) and initiatives as set forth in the “Army Vision for Net Zero” (AEPI 2011).

The above military standards and guidance for “nonpotable” water reuse are for a limited number of physical (pH, turbidity, hardness, total dissolved solids), chemical (FAC), and other parameters (arsenic, lindane, coliforms). Furthermore, the existing guidance is insufficient to execute water reuse in the field safely and sustainably (USAPHC 2014a). Enhancement of the above military standards and guidance for “nonpotable” water reuse in a health risk framework is needed for military-specific use cases during contingency operations. Also, enhancement of military water reuse guidance supports the Army Campaign Plan objective to achieve energy security and sustainability and addresses the capability gap for maintaining nonpotable water systems as identified in the Army Water Security Strategy (AEPI 2011; http://www.army-energy.hqda.pentagon.mil/programs/netzero.asp).

3.2 Definitions Related to Wastewater

Water and wastewater treatment have specific vocabularies; some terms used in this document may be used with a meaning different than the reader expects. A glossary is provided at the end of this document defining terms in this risk assessment. The reader is advised to refer to the glossary as health risk assessment, water quality, and wastewater management may use similar terms with different meanings.

Human communities produce wastewater streams. Wastewater is used as an overarching term that encompasses water, which has been discharged from domestic or industrial sources after a variety of applications. For more specific usage, a qualifier may precede wastewater; examples are *domestic wastewater* and *industrial wastewater*. In this document, reuse will be considered primarily for domestic wastewater, with provisions for reuse of industrial wastewater diluted by other wastewater streams. Wastewater from different sources may have different physical, chemical, and biological characteristics.

In most urban communities, wastewater from the domestic, commercial, and industrial sources are combined into a municipal sewage plumbing system and sent to a treatment facility where it is treated and subsequently discharged to surface or ground water. In some older urban communities, storm-water runoff from streets and other paved areas is also routed to the treatment facility through the same wastewater collection network. Sewage systems capable of handling storm water are known as combined systems.

Generally speaking, waste from toilets, urinals, and kitchens is termed “black water.” Wastewater from bathtubs, showers, sinks, laundry, and dishwashers is called “gray water.” Black water and gray water leaving a residential home are typically combined into one waste stream, and in the wastewater industry this is referred to as “domestic wastewater.” Mixed wastewater, which included industrial and commercial wastewater in addition to domestic wastewater, could be reused; however, it may have more chemical contamination. Mixed wastewater may require more monitoring than gray water or domestic wastewater.

The current assessment is focused on activities associated with the creation of gray water (e.g., laundry, showering, and dishwashing) and does not consider black or mixed wastewater. Black and mixed wastewaters are certainly appropriate topics for such an assessment; however, characteristics of these streams are more complex than gray water and would require further regulatory analysis to perform a comparably detailed assessment. Most states and jurisdictions that have developed water-reuse guidelines have done so for gray water; hence, the current focus of this assessment.

3.3 Fit-for-Purpose Concept

Water is used for a variety of uses in the military including drinking, heat-casualty treatment, personal hygiene (i.e., teeth brushing and shaving), centralized hygiene (i.e., showers), food preparation, washing dishes, laundering, cleaning medical facilities, decontamination, vehicle maintenance, mortuary affairs, construction, and aircraft and vehicle washing (Army Techniques Publications (ATP) 4-44; DA 2015). The concept of “fit-for-purpose” captures the fact that the amount of treatment applied to water is appropriate for the end use, without over treating the water. This concept has previously been applied by the Forces, as evidenced in TB MED 577, Table 2-12, where typical uses of different classes or qualities of water in the field and the associated caveats for each water class are presented (See Appendix B; TB MED 577, Table 2-12, has been wholly duplicated). The use directs the treatment; an activity associated with ingestion of water (i.e., brushing teeth) will require cleaner water than an activity that results in little human exposure, such as making concrete. For example, water that has been primary and secondary treated may be clean enough for dust suppression in a restricted access air field. Water that has been primary, secondary, and tertiary treated may be appropriate for laundry. Water that has undergone primary, secondary, tertiary, and additional advanced treatment may be appropriate for showering (USAPHC 2014a, b). The discussion of specific treatment trains is beyond the scope of this document; Technical Guide 364a provides a review of treatment trains (USAPHC 2014a).

3.4 Acceptable Risk

Knowing the level of acceptable risk helps to determine how best to characterize risk and evaluate risk control options (WHO 2008, NAS 2012). In the context of establishing water reuse standards or guidelines, the risk is a function of the probability of exposure and the probability of a health effect, such as gastrointestinal symptoms in the exposed population.

The APHC performed a risk assessment specifically for treated wastewater used for showering (USAPHC 2014b) and, therefore, investigated the acceptable risk for Civilians and military personnel in that context. For military personnel during deployment, it is Army policy that occupational and environmental health risks are reduced as low as practicable, within the context of operational mission parameters (AR 11-35, DA 2007b). In this context, 'as low as practicable' is generally interpreted to mean that U.S. Civilian standards are met.

For Civilians, a common threshold of acceptable risk used in drinking water as well of other environmental impact assessments is 10^{-6} or 1 in a million chance of developing a specific disease endpoint (such as cancer) or population impact such as disability-adjusted life years (DALYs). Relating this to water reuse, the WHO correlates a 10^{-6} increase in DALYs per person per year with an increase in the frequency of diarrheal illness between 1 in 1,000 and 1 in 10,000 (WHO 2008). As a point of reference, the background level of gastrointestinal illness, specifically diarrheal, is estimated to be between 1 case in 10 people and 1 case per person per year, worldwide (WHO 2008).

The USEPA has set an acceptable microbial risk precedent for drinking water at a risk of 1 gastrointestinal illness in 10,000 people exposed per year (USEPA 2004). The USEPA also provides guidance levels for recreational water exposures based on an acceptable risk of 36 in 1,000 swimmers experiencing gastrointestinal illness per a day of swimming (USEPA 2012).

It is important to note that the meaning of the WHO and USEPA drinking water values differ from the meaning of the USEPA recreational water values. The WHO and EPA drinking water values specify an illness risk *per time*. The USEPA recreational water exposure guideline specifies an illness rate *per exposure*. Therefore, the drinking water and recreational guidelines are not directly comparable.

In the end, there is some degree of risk associated with water reuse. How the individual risks and cumulative risks are managed depends on a number of variables. To address them in a consistent fashion, an acceptable risk threshold must be established. Once acceptable risk thresholds are established they need to be communicated effectively to end users, planners, and leaders.

3.5 Scope

The scope of this effort focuses on the activities associated with using treated wastewater (nonpotable quality) at FOBs. Therefore, the population of interest is deployed personnel serving at FOBs. This assessment focuses on age-appropriate deployed adults; children and elders are not considered in this effort. Using treated wastewater as drinking water is considered direct potable reuse. This use is out of the scope of this evaluation. This assessment is focused on nonpotable reuse.

It is also recognized that any monitoring and immediate forward movement with regard to the use of treated wastewater at FOBs is limited to the current capabilities of both fielded detection kits as well as commercial off-the-shelf equipment considered suitable for field use. The current capabilities are briefly reviewed in Section 5, and because that is a major limitation, the current standards reviewed are presented with the measured parameter first. Likewise, a review of the importance and meaning of the measured parameters can be found in Section 5.

It is not the intent of this document to recommend which standards should be used or to provide a detailed analysis of water quality parameters that can be obtained from cited references and source documents. The intent of this document is to summarize some of the current standards and guidelines used by countries or states who have also wrestled with how to safely implement water reuse. The presentation by use case is intended to help focus any discussions and move from a very general discussion of the available standards to a purposeful discussion; therefore, military-specific decisions can be made based on the most relevant available guidance addressing a particular use.

4 USE CASES FOR CONTINGENCY OPERATIONS

In 1986, a software engineer who was trying to model the complex and dynamic trends of telephone calls introduced the concept of a ‘use case’ (Jacobson 2003). His team had been grappling with multiplicity and diversity and difficulties associated with modeling systems that had a beginning and end, but the middle was not well defined. From this challenge, the concept of ‘use case’ was developed and defined as “a special sequence of transactions, performed by a user and a system in a dialogue” (Jacobson 2003). Over time, the concept has been applied to many different applications. A use case can serve as a bridge between stakeholders of a system and a development team working to provide information. In essence, a use case serves to tell the story of what is needed and places functional requirements into context. A use case contains a flow of events that encompasses how and when the use case starts and ends. There can be multiple exposure possibilities inside a use case.

For any given use case, there are many details that need to be considered. It is impossible to predict or model the exact exposure scenario; therefore, many assumptions and default values are applied to develop a generic use case that captures the essence of an exposure related to a specific activity. For this assessment and effort, the term “treated wastewater” can refer to a variety of qualities of water post-treatment. This assessment does not delve into or specify a specific type of treated wastewater but uses the term generically. If/when a use case is utilized to perform a risk assessment, it is recognized that there is a possibility for large variations in the interactions of personnel (e.g., frequency, surface area contacted, and so forth) with the treated wastewater, in addition to variation in surface characteristics (e.g., smooth vs. rough, solid vs. cracks) of items on which the treated wastewater will be used. These types of details would need to be carefully considered and are not a part of the current effort.

Eight use cases were developed and are listed below. Each use case provides a narrative of the use with some key assumptions, a table of exposure parameters that would need to be considered (actual values are not presented), the identification of possible exposed personnel, and the association of the exposure with personal protective equipment (PPE). The order of the below list is not based on anticipated level of exposure. Figure 1 illustrates the anticipated level of exposure is illustrated in Figure 1.

1. Laundry
2. Dust Suppression
3. Toilet Flushing
4. Vehicle Washing
5. Industrial Use (Construction)
6. Fire Fighting
7. Showering
8. Dish Washing

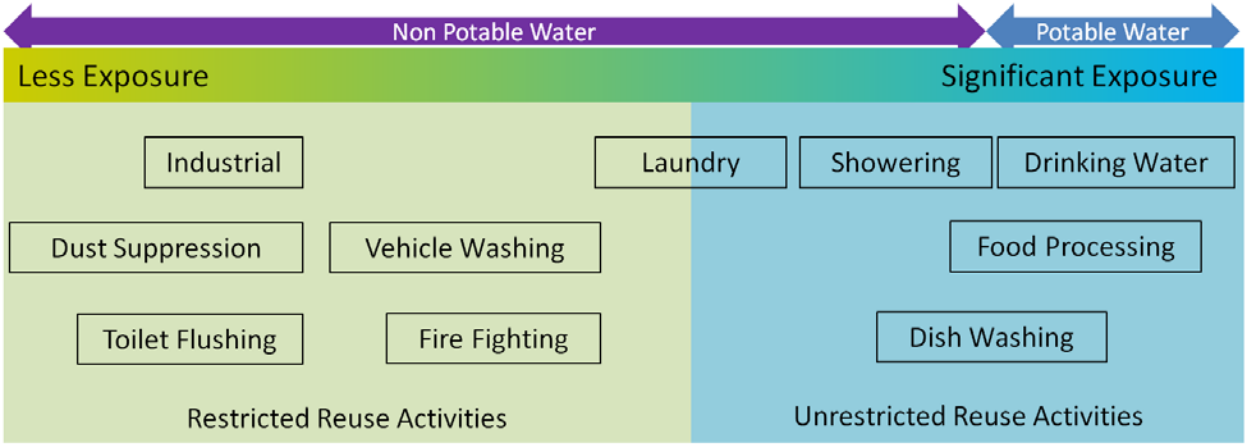

Figure 1. Exposure Continuum for Water Reuse Activities
(Adapted from Figure 9 in USAPHC 2014a)

The three exposure routes that were evaluated (i.e., inhalation of water or aerosolized droplets, incidental ingestion, and dermal contact) are captured in each use case for brainstorming exposure parameters. It is important to note that this is not a risk assessment, *per se*; therefore, not all of the parameter values are defined. The first use case developed was for toilet flushing; in order to find values for the required parameters, extensive resources were expended. Due to available resources, the development of the remaining use cases was limited. If parameter-specific information was not readily available, then the parameter was listed but a value was not provided. The presentation of the necessary exposure parameters provides starting point for if/when a risk assessment is performed.

4.1 Use Case #1: Laundry

4.1.1 Narrative

The Laundry use case characterizes the laundering and wear of "normal" field-work day clothes (e.g., conservatively estimated as 16-hour wear, changing all garments at least once every 5 days). The extended wearing of clothes (more than 5 days before changing) would be a different use case. Incidental ingestion, direct dermal contact, and dermal absorption exposure routes are considered; off-gassing or particle resuspension from laundered clothing is not considered in this assessment. While it is expected that most dermal pathogens would not survive the washing and drying cycles, this health-protective evaluation considers dermal absorption exposure but acknowledges that this route is not expected to drive risk. The protective assumption is that there exists a theoretical potential for residual cleaning products to remain in clothing fabrics and/or a potential for certain residuals to become available for dermal contact absorption when the fabric becomes wet; under appropriate conditions, either scenario may lead to adverse dermal effects.

While exposures are expected to occur both indoors and outdoors (wherever the clothes are worn), the assumption is that the laundry facility is enclosed indoors. The expected percentage of gray water that the reuse laundry system would use is another factor to take into consideration. For example, if the reuse system could not meet the laundry needs and a traditional system was also used, that mix of source waters would need to be appropriately factored so as to estimate exposure and risk.

4.1.2 Exposed Individuals

Two groups of exposed individuals are defined for the Laundry use case. The primary group expected to sustain the largest exposures (incidental ingestion and direct dermal contact) is made up of the staff of the laundry room (washers of clothes). The secondary group is comprised of people wearing laundered clothes. For this use case, it is assumed that the laundry staff also wears the laundered clothes, so they would be expected to have the highest exposure.

4.1.3 Exposure Factors

The following exposure factors should be considered with performing an exposure assessment (Table 1).

It is noted that there are other non-health-related parameters for acceptable laundry water, for example hardness and pH. The quality of wastewater may also be a function of soaps and detergents used.

Table 1. Exposure Parameters for the Laundry Use Case

Exposure Route	Exposure Factors
All	Frequency (wearer of clothes = general population)
	Frequency (washer of clothes = laundry room staff)
	Duration (wearer of clothes)
	Duration (wearer of clothes)
Incidental Ingestion	Surface area touched
	Hand-to-Mouth Events
	Splash to Face
	Number of Splash Events
	Transfer Coefficient
Inhalation	Breathing Rate
	Volume of Aerosolized Water
	Ventilation Rate
Dermal	Surface Area

4.1.4 Consideration of Personal Protective Equipment

The users will not be protected by any PPE because they are wearing the clothes; therefore, dermal is expected to be the most important exposure pathway. Laundry staff may have limited protection during their tenure in the laundry room (gloves or dust masks) but may also experience dermal exposure from the clothes they are wearing. The design of washers and dryers may provide an engineering control for exposure to the laundry. For example, a high-efficiency bulk washer has a tightly latching door that may contain any aerosols that are generated during washing; some of the aerosols may be released when the door is opened. A forced-heated air laundry dryer uses an external exhaust that will expel air outside the building. The specific design of a military laundry facility will need to be considered when evaluating requirements for reuse water quality.

4.2 Use Case #2: Dust Suppression

4.2.1 Narrative

The focus of the Dust Suppression use case is on using treated wastewater to control dust on dirt (unsealed surfaces) roads. The treated wastewater is being applied by a dedicated water tanker truck. Outdoor exposure is assumed. The concern regarding the establishment of a microbial presence in the dirt (environmental contamination) is beyond the scope of this effort. Likewise, the dust suppression practice is expected to not be performed where surface water impacts groundwater (i.e., near wells or over a shallow water table). Exposure is assumed to be immediate, upon or during application and drying. Future exposure after the application has dried is not considered. Only treated wastewater is applied to the dirt road, there are no chemical additives. While the dust suppression practice can be performed on helicopter landing pads and airstrips, the focus of this effort is on the dirt road application.

4.2.2 Exposed Individuals

Five groups are identified: (1) filler of the tank, (2) driver of tank vehicle, (3) pedestrian walking along the side of the road, (4) driver of a vehicle on the road, and (5) person in the immediate area, but not on the road. It is expected that the most likely to have the highest exposure would be a pedestrian walking along the road either while spraying is occurring, or soon thereafter.

4.2.3 Exposure Factors

The following exposure factors should be considered when performing an exposure assessment (Table 2).

Table 2. Exposure Parameters for the Dust Suppression Use Case

Exposure Route	Exposure Factors
All	Time of Day of Application
	Environment Desiccation
	UV
	Temperature
	Humidity
	Evaporation Rate
	Time between Applications
	Volume Delivered (Truck Spray Characteristics)
	Flow Rate
	Nozzle Type
	Speed of Truck
	Rate of Application (Water)
	Estimated Service Life (Time water remains on surface)
	Soil Type
	Degree of Saturation
Incidental Ingestion	Surface area touched
	Hand-to-Mouth Events
	Transfer Coefficient
Inhalation	Breathing Rate
	Volume of Aerosolized Water
	Wind Speed
Dermal	Surface Area

4.2.4 Consideration of Personal Protective Equipment

It is anticipated that the filler and driver mitigate potential exposure with PPE (gloves and possibly a mask). The other three groups would not be expected to wear PPE.

4.3 Use Case #3: Toilet Flushing

4.3.1 Narrative

Treated wastewater can be used to flush a toilet. The simplest system involves capturing treated wastewater elsewhere in a container such as a bucket and pouring it into the toilet bowl to provide the water level difference to initiate the siphon effect that discharges the toilet into the drain. A more elaborate system will have a pipe system, which is separate from the drinking water system, supply treated wastewater to the tank (also known as a water closet) on the toilet. This use case does not consider a urinal to be a toilet. This use case only considers a single toilet bathroom; a facility with multiple toilets would be expected to have a different aerosol generation rate. After flushing, it is assumed the toilet water will enter a wastewater system that will undergo treatment.

Aerosols generated are assumed to be evenly distributed within confines of the bathroom (Gerba et al.1975; Johnson et al. 2013). Due to even distribution of aerosols, it is also assumed that surface areas (walls, counters, and floors) will also be evenly coated (Gerba et al. 1975). The generation of aerosol and the coating of surface area would occur regardless of the employment of reuse water.

There are multiple types of toilet, as summarized by Johnson et al. 2013. Each will have different aerosol generation characteristics. A gravity-fed toilet has a water closet or cistern that holds water; when the toilet is flushed the force of the new water entering the bowl removes waste. Some toilets are wash-down construction, where the water is released along the rim of the bowl so it washes the sides as the water flushes. A siphonic toilet uses a submerged jet to push the waste from the base of the bowl for discharge. As toilets become more efficient and use less water per flush, the energy of the water used to flush the toilet increases, as does the potential for aerosol generation. Newer toilets use a canister system to pressurize an air-water mixture where the air helps propel waste out of the bowl.

[NOTE: The estimated average concentration of total bacteria deposited into a toilet as a result of use is very high ($1x10^6$ to $3x10^{13}$ bacteria/L toilet bowl water) compared to the expected bacterial load in treated wastewater (values to estimate average concentration from Connell et al. 1965; Rose et al. 2015). The flushing of the toilet is the action that generates the bioaerosols that ultimately deposit microbial content on the surfaces in a bathroom. The relative cleanliness of the treated wastewater is much greater when compared to the “dirty water” in the toilet after use. Therefore, the added risk from using treated wastewater to flush a toilet will probably be negligible.]

4.3.2 Exposed Individuals

Two groups are expected, people who use toilets (user) and people who clean toilets (custodian). The toilet-user scenario is expected to be protective of the custodian due to the anticipated higher exposure experienced by the user (use the restroom more than one time/day).

Under normal use, a toilet will have a torso length separating the water surface in the bowl from the breathing zone of the user. If the user is standing when the toilet is flushed, there will be even more distance from the water surface to the breathing zone when aerosol generation will be highest. If someone is on their knees in front of the toilet, such as for a vomiting event, their breathing zone will be in contact with the water surface in the toilet bowl. Other than a user inadvertently dropping an item into the toilet and needing to retrieve it (such as a cell phone), direct dermal contact with the water in the bowl is not expected.

The personnel who clean toilets will need to reach down or bend down to use a toilet brush to clean inside the bowl of the toilet, as well as use some sort of disinfectant or soap spray and a rag, sponge, or towel to clean the seat and the outside surfaces of the toilet. The actions to clean the toilet will put the breathing zone close to the water in the toilet bowl.

4.3.3 Exposure Factors

Consider the following exposure factors when performing an exposure assessment (Table 3).

Table 3. Exposure Factors for the Toilet Flushing Use Case

Exposure Route	Exposure Factors	Value(s)	Units	Reference
All	Frequency (user)	6 (range 4–8)	Uses/day	Professional judgment
	Frequency (Custodian)	1[a]	Cleaning/day	Professional judgment
	Duration (user)	34.5 (mean, age 18 to 64 years)	Minutes per day	USEPA, Exposure Factors Handbook, 2011
	Duration (Custodian)	8	Minutes per cleaning	Weegles and van Veen 2001
Incidental Ingestion	Surface area touched	326	cm^2 (Palm of hand)	TG 312 (USACHPPM 2009)
	Hand-to-Mouth Events	6	Events/day	Professional judgment
	Transfer Coefficient	.4	unitless	TG 312
Inhalation	Breathing Rate	6.68	L/min	Multiple-Path Particle Dosimetry Model (MPPD)
	Volume of Aerosolized Water	Unknown		
	Ventilation Rate	8	Air Exchanges per hour	http://www.hvi.org/publications/bathroom_ventilation.cfm
Dermal	Surface Area	500	cm^2 (uncovered skin in contact with toilet seat)	Professional judgment

Legend:
cm^2 = square centimeter
L/min = liters per minute
Note:
[a] The exposure for a Custodian cleaning multiple toilets per day needs to be considered.

4.3.4 Consideration of Personal Protective Equipment

It is expected that users will not utilize PPE while using toilets. Cleaning personnel would be expected to have gloves to protect their hands from dermal exposure.

4.4 Use Case #4: Vehicle Washing

4.4.1 Narrative

The vehicle-washing use case is described by two people using a pressure washer to spray down a vehicle. The washing occurs in an outside open bay. The size of the vehicle and level of water pressure will influence the exposure because it is expected that a larger vehicle would require a larger volume of water.

4.4.2 Exposed Individuals

Three groups were identified: (1) vehicle washers, (2) pedestrians walking by where vehicle washing is occurring, and (3) users of vehicle while still wet. It is expected vehicle users may experience high exposure due to the potential to complete for all three exposure pathways (dermal, ingestion, inhalation). Vehicle washers may also experience a large exposure if a high-pressure nozzle is used and results in "blowback."

4.4.3 Exposure Factors

The following exposure factors should be considered when performing an exposure assessment (Table 4).

Table 4. Exposure Factors for the Vehicle Washing Use Case

Exposure Route	Exposure Factors
All	Frequency of washing a vehicle
	Duration of wash
	Total wash-water volume
Incidental Ingestion	Ingested volume
Inhalation	Breathing rate
	Aerosol generation rate
	Ventilation rate
Dermal	Surface area of receptor not covered by clothing

4.4.4 Consideration of Personal Protective Equipment

The vehicle washers are expected to have access to PPE (gloves and Tyvek® coveralls) while the vehicle users are not likely to utilize PPE.

4.5 Use Case #5: Industrial Use (Construction)

4.5.1 Narrative

The construction activity is designated as treated wastewater being used to mix concrete. Concrete is a construction material that is widely used by military and civilian contractor personnel. Concrete is used in buildings and transportation applications, as well as for water diversion and treatment. Concrete is made by mixing cement and water together with various inert materials (aggregates). The water is required to initiate the chemical process, which results in the desirable property of the concrete. Source wastewater should be free from acids, alkalis, oils, and organic impurities and needs to meet other required water quality parameters (see Technical Manual (TM) 3-34.44, DA, 2012b). The ratio between cement and water will determine the concrete's strength and application; the less water the stronger. It is assumed that once the concrete is cured, then biological organisms are sequestered or dead. The exposure is expected to occur outdoors while the concrete is being mixed and poured.

4.5.2 Exposed Individuals

A single group is considered—construction workers who add the water, mix, spread, and form the concrete.

4.5.3 Exposure Factors

The following exposure factors should be considered when performing an exposure assessment \ (Table 5).

Table 5. Exposure Factors for the Construction Use Case

Exposure Route	Exposure Factors
All	Frequency of mixing concrete
	Duration of mixing activity
	Water to cement ratio
	Total water volume
Incidental Ingestion	Ingested volume
Inhalation	Breathing rate
	Aerosolization of water
	Ventilation rate
Dermal	Surface area not covered

4.5.4 Consideration of Personal Protective Equipment

It would be expected that the construction worker is wearing gloves (PPE) while performing the mixing and possibly a dust mask.

4.6 Use Case #6: Fire Fighting

4.6.1 Narrative

The Fire Fighting use case is defined as an individual at the end of a fire hose pumping treated wastewater to suppress fire. It is assumed that fire and water damage restoration occurs prior to reoccupation of the burned structure. For this use case, the exposure could occur either indoors or outdoors.

4.6.2 Exposed Individuals

Due to the assumption that appropriate restorative cleaning will occur prior to reoccupation, only firefighters are considered for this use case.

4.6.3 Exposure Factors

The following exposure factors should be considered when performing an exposure assessment (Table 6).

Table 6. Exposure Factors for the Fire Fighting Use Case

Exposure Route	Exposure factors
All	Frequency of fighting fire
	Duration of fire fighting
	Total water volume
	Nozzle type/characteristics
Incidental Ingestion	Ingested volume
Inhalation	Breathing rate
	Aerosolization of water
	Ventilation rate
Dermal	Surface area not covered

4.6.4 Consideration of Personal Protective Equipment

Due to the nature of firefighting, it is expected that the receptor will be in PPE consisting of at least turn-out gear (outer protective clothing of firefighters), gloves, helmet, and boots.

4.7 Use Case #7: Showering

4.7.1 Narrative

All population members are expected to shower daily. A shower involves complete wetting of the skin, hair, and face. Incidental ingestion is expected. Showers will be cleaned by cleaning personnel. For showering, the driving risk is expected to be from incidental ingestion of pathogens; for cleaning, the driving risk is expected to be dermal contact.

In 2014, USAPHC performed a risk assessment for showering in treated wastewater (USAPHC 2014a). [Note: authors of that assessment are also co-authors of this document.]

4.7.2 Exposed Individuals

Two exposed groups are expected: people who use showers (users) and people who clean showers (custodian). The user scenario is expected to be protective of the custodian due to the more frequent exposure by the user and ingestion being the route for pathogens of concern. However, in a deployment setting a custodian would also likely be a shower user. In that case, the user/custodian might then represent the highest exposed subpopulation.

4.7.3 Exposure Factors

Consider the following exposure factors when performing an exposure assessment (Table 7).

Table 7. Exposure Factors for the Showering Use Case

Exposure Route	Exposure Factors	Value(s)	Units	Reference
All	Frequency (user)	1	Shower per day	NSRDEC 2009
	Frequency (Custodian)	1[a]	Cleaning/day	Professional judgment
	Duration (user)	10	Minutes per shower	NSRDEC 2009
	Duration (Custodian)	8	Minutes per cleaning	Professional judgment
Incidental Ingestion	Volume Ingested	10	mL	PNNL 1995

Legend:
NSRDEC = Natick Soldier Research Development and Engineering Center
PNNL = Pacific Northwest National Laboratory
mL = milliliter
Note:
[a] The exposure for a Custodian cleaning multiple showers per day needs to be considered.

4.7.4 Consideration of Personal Protection Equipment

Users will not have PPE while showering. Cleaning personnel would be expected to have gloves to protect their hands from dermal exposure.

4.8 Use Case #8: Dish Washing

4.8.1 Narrative

This case is very similar to direct potable water reuse. Generally, dish washing involves three tubs of water (the wash line): the wash tub, the rinse tub, and the sanitize tub. The bulk of the food residue removed is removed from a dish by being scraped into a waste can; the dish is then immersed in the wash tub. The dish is then cleaned in the rinse tub. The dishes are then dipped into the sanitization tub prior to drying.

Standard procedures call for the sanitize tub to be made with fresh (from the potable tap) water and a prescribed amount of sanitization soap (DA 2015b). When the rinse tub becomes too dirty, the standard procedure is to move it to the wash tub position with the prior wash tub water discarded. The sanitize tub then moves to the rinse position, and a new sanitize tub is drawn. The sanitization tub water is the last water to touch plates, bowls, flatware, kitchen containers, and other food cooking and service implements; therefore, it is important that the sanitize tub water is clean.

In contingency operations, it is possible that the wash tub could be filled using recycled water from previous dishwashing steps. In such a case, the primary risk is expected to be to dishwashing personnel responsible for completion of the dishwashing step via dermal exposure. A secondary risk is expected to be from incidental ingestion by the same personnel.

Due to the expectation that the sanitize water is “fresh water,” it appears that the standards associated with the sanitization step of dishwashing align most closely to drinking water standards and would, thus, be governed by existing drinking water requirements.

4.8.2 Exposed Individuals

A single exposed group comprised of dishwashing personnel responsible for completion of the dishwashing step is expected.

4.8.3 Exposure Factors

The following exposure factors should be considered when performing an exposure assessment (Table 8). Due to available resources, further development of this use case was limited. In Table 8, if parameter-specific information was not readily available, the parameter was listed, but a value was not provided. The presentation of the necessary exposure parameters provides a starting point for if/when a risk assessment is performed.

Table 8. Exposure Factors for the Dishwashing Use Case

Exposure Route	Exposure Factors	Value(s)	Units	Reference
All	Frequency (dishwashing personnel)	4	events per day	Church et al. 2015
	Frequency (number of tub changeouts/dishwashing event)	TBD	changeouts/dishwashing event	TBD
	Duration (user)	TBD	Minutes of access per dishwashing tub use	TBD
Dermal	Uncovered skin surface area	TBD	TBD	TBD
Incidental Ingestion	Volume Ingested	1	mL	Church et al. 2015

4.9 Use Case Exposed Personnel Summary

Use case	Exposed Individuals
Laundry	User (Clothes wearer); Laundry room staff
Dust Suppression (Dirt Roads)	Tank filler, truck driver, pedestrian, driver of vehicle on road, person in vicinity
Toilet Flushing	User; Custodian
Vehicle Washing	Washer, Pedestrian, user in vehicle before dried
Construction (Concrete Mixing)	Construction worker
Fire Fighting	Fire fighter
Showering	User, Custodian
Dish Washing	Personnel responsible for dishwashing step

5 REVIEW OF PERTINENT INFORMATION FOR PRESENTATION OF AVAILABLE STANDARDS

Historically, and for over a century, the goals of water treatment in the United States have been to produce water that is not only chemically and biologically safe but is also noncorrosive and nonscaling for potable and nonpotable uses. The framework developed to meet these goals consists of legal mandates as well as public concerns and environmental considerations. The specific standards, guidelines, or criteria to meet these goals are aligned with maintaining water quality for the intended use and based on legal criteria (Clean Water Act (CWA), Safe Drinking Water Act, and state regulations) and/or operational criteria. The CWA was enacted in 1972 and is the primary Federal law protecting water quality, with the stated goal of restoring and maintaining the physical, chemical, and biological integrity of the Nation's waters. The USEPA is charged with administering the CWA, which includes a pollution discharge permit program and other water quality provisions. The 1986 Safe Drinking Water Act (SDWA) authorizes USEPA to select the best available technologies to comply with current National Primary Drinking Water Regulations. These SDWA regulations are legally enforceable standards that apply to public water systems for potable water. These primary standards protect drinking water quality by limiting levels of specific contaminants that are known to occur in water and that can adversely affect public health. In addition, National Secondary Drinking Water Regulations recommended by USEPA are nonenforceable guidelines for contaminants that may cause cosmetic or aesthetic effects (such as altered taste, odor, or color) in drinking water. Many states and jurisdiction chose to adopt these as enforceable standards for potable and nonpotable applications; it is noted that individual states also have the jurisdiction to establish state-specific water quality standards.

5.1 Basis for Standards and Guidelines

The U.S. domestic guidelines, standards, or criteria for chemical, biological, and physical constituents were established to meet water quality parameters deemed necessary to support a specified intended use. Water treatment and purification technologies required to attain these guidelines, standards, and criteria have subsequently been developed and employed; capabilities of these technologies are directly related to the requirement specifications meeting the intended water use. An overview of key water quality parameters or measurements is discussed below (Section 5.1.1 to 5.1.5). Subsequent sections address analytical test procedures utilized by civilian (Section 5.2) and military (Section 5.3) jurisdictions to monitor water quality. Source documents cited in the following text have been quoted where noted. This section is intended as a review for a broad audience and assumed that they may need an overview of water characterization to assist with understanding the available standards.

Specific categories of standards and guidelines evaluated in this section parallel those reflected in the nonpotable use case-specific standards summarized in the following Sections 7.0 through 14.0.

5.1.1 Disinfection (as measured by chlorine residuals and/or number of coliforms/100 mL)

The first applications of chlorine in potable water occurred in the 1830s as a means of taste and odor control. It was not until the advent of "germ theory" in the 1890s that the importance of disinfection in potable water was more fully understood. Federal authority to establish standards for drinking water were enacted in 1883 by the U.S. Public Health Service to establish and enforce regulations to prevent the introduction, transmission, or spread of communicable disease (Spellman 1999; USEPA 2000).

Because chlorine is a strong oxidant, it is an effective disinfectant for most pathogenic microorganisms provided there is direct contact between the pathogen and chlorine. Bacteria and viruses may be masked by particles of suspended and colloidal matter, such that the disinfection process is hindered.

Additionally, some organisms are resistant to chlorination, such as spore-forming pathogens like Giardia. Therefore, the presence of measured chlorine residual could still be associated with a viable microbial population in source waters. The effectiveness of chlorine disinfection is further dependent on a number of variables, such as mixing, contact time, source water pH, and temperature, as well as the resilience of some pathogenic organisms (USAPHC (Provisional) 2008).

In 1975, the California (CA) Wastewater Reclamation Criteria were promulgated for the use or discharge of reclaimed water in which significant human contact was likely. The disinfected wastewater was required to have median total coliform levels not exceeding 2.2 most probable number (MPN) per 100 mL. If these criteria were met, the reused water would be considered "virtually pathogen free" (NWRI 2012). In evaluation studies conducted by seeding with a vaccine strain of poliovirus, it was determined that a concentration-time (CT) of 450, applied to disinfection of the effluent, met the coliform standard and concomitantly would reduce the virus level by 5 logs. The CA Department of Public Health wastewater chlorination requirement of a CT equal to 450 (milligrams per minute per liter (mg/min/L)) originated from this seeding study (NWRI 2012).

Coliform bacteria have been used to measure the microbial quality of water; two of the more commonly used tests are total coliforms and *Escherichia coli* (*E. coli*). Total coliforms is a measure of closely related, mostly harmless bacteria that live in soil, water, and the intestines of warm-blooded animals. Total coliforms is a common indicator of possible pollution and is often used to determine the effectiveness of potable water disinfection. The USEPA has listed the *E. coli* species as a more accurate indicator of harmful microorganisms that cause intestinal illness.

In an Army medical issues paper, it has been stated that, "The almost certain presence of pathogens in shower wastewater is the most significant element of risk for shower water recycle. The coliform test, or its equivalent, provides the best available measure of disinfection" (USACHPPM 2001).

Additional text from USAPHC (Provisional) 2008) states, "Disinfection can be accomplished by adding a chlorine product in sufficient quantity to kill microbial pathogens. The general goal of disinfection is to produce a detectable chlorine residual (total) in the source water 30 minutes after chlorine addition. Total chlorine residual is defined as the sum of free and combined chlorines present in the water after the chlorine demand has been satisfied. Chlorine demand is that amount of chlorine that is consumed by particles and microorganisms in the water. As a general rule, the higher the turbidity, the more chlorine will be needed to satisfy the chlorine demand and produce a residual. If the turbidity is too high, the solids in the source water can overwhelm the chlorine addition, and chlorine residual will not be maintained."

5.1.2 Total Dissolved Solids (TDS)

The TDSs test is used as an indicator test to determine the general quality of the water. TDSs represent inorganic salts (e.g., calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and small amounts of organic matter that are dissolved in water. TDSs can result from naturally occurring organic and inorganic materials, residual chemicals used in the water treatment process, sewage, runoff, or from the plumbing used to distribute the water.

The TDSs concentrations represent the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the TDSs test provides a qualitative measure of the amount of dissolved ions but does not provide information on the ion relationships.

The impacts of TDS are "adverse effects of a high TDS level would be the decrease in lathering potential and possible higher disinfectant demands. However, TDS buildup is important as a general indicator of contaminant accumulation and has been found to be highly dependent upon the quality of soap or detergent utilized, as measured by the buildup of soap solids" (Schmidt et al. 1989) (USACHPPM 2001).

5.1.3 Turbidity

Turbidity is a critical water quality parameter in that microbial inactivation by chlorine (or equivalent disinfectant) is less effective in turbid waters. Higher-effluent turbidity levels were a useful indication of system failure (USACHPPM 2001).

The impacts of total suspended solids (TSS) are "High-suspended solids and measured turbidity generally translate into higher concentrations of microorganisms in the source water. Viruses and bacteria tend to attach themselves to the solids. As a result, there is a greater risk of coming into contact with disease-causing organisms when individuals are exposed to turbid waters. Reducing turbidity through filtration usually reduces the microbial population. In addition, suspended solids (SS) tend to interfere with the disinfection process, shielding the viruses or bacteria from deactivation. Thus, turbid waters require larger amounts of disinfectants to kill pathogens and provide less certainty regarding pathogen destruction" (USAPHC (Provisional) 2008).

5.1.4 Color

The water property known as "color" refers to the presence of dissolved and/or suspended pigmented components. Examples include dissolved tannins from tree bark or humus (brown or yellow color) or suspended ferrous iron (color shades of orange or rust-red) and clay (soil runoff; yellows and reds and browns). The decreasing ability of light to transmit through highly colored waters is a measure of increasing color. Increasing color would indicate a deterioration of water quality and may make disinfection more difficult (USACHPPM 2001).

5.1.5 pH

The pH is a measure of water acidity and alkalinity. The range of pH units is from 0–14, with 7 being neutral. The pH values of less than 7 indicate acidity; whereas, a pH of greater than 7 indicates a base. It is possible that the pH of water outside the range of 5–9 pH units could be irritating to the skin and eyes (USACHPPM 2001).

The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, and so forth). For example, pH determines the survival and health of aquatic life and affects how much and what form of phosphorus is most abundant in the water. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble (USGS 2016). The pH is also important to the disinfection reaction because it controls the speciation and ratio of chlorine in the more effective hypochlorous acid form.

5.2 Water and Wastewater Analytical Methods Utilized by Civilian Jurisdictions

Respective regulations from various civilian jurisdictions presented in this document make use of standard analytical methods for detecting and measuring components of water and wastewater. In the United States, many state regulatory authorities utilize standard analytical methods as documented by the—

- USEPA (Clean Water Act Analytical Methods[2]);
- U.S. Geological Survey's Techniques of Water-Resources Investigations[3]; and
- Standard Methods for Examination of Water and Wastewater developed by the American Public Health Association (APHA) in collaboration with the American Water Works Association (AWWA) and the Water Environment Federation (WEF)[2].

Each parameter and method includes a specific protocol for sampling methods and storage as well as equipment care and use. These methods have been specifically developed to ensure the safe application of particular water uses under consideration; short summaries of these standard methods are provided below. Operational details regarding necessary equipment, reagents, and procedures can be obtained from the documents and/or Web sites provided in the respective footnotes and reference citations. It is important to note that field capabilities to monitor various water and wastewater parameters would need to be aligned with, or calibrated to, a the standard method for the parameter of interest.

5.2.1 Total Residual Chlorine

Total residual chlorine is a measure of the level of water disinfection (with chlorine or chlorine-containing compounds) performed to kill, destroy or otherwise inactivate pathogenic organisms (DA 2015a). Multiple standard methods are available for residual chlorine determination (APHA/AWWA/WEF 2016): iodometric methods I and II, the amperometric titration method, the low-level amperometric method, the DPD ferrous titrimetric and colorimetric methods, the syringaldazine method, and the iodometric electrode method.

Region 4 USEPA has established and documented methods and considerations for conducting field screening of total residual chlorine in wastewater effluent ("Field Screening of Total Residual Chlorine" Science and Support Division, Athens, GA; 20 Aug 2015). The protocol incorporates use of the Hach Company Pocket Colorimeter utilizing a DPD colorimetric method.

5.2.2 Five-Day Biochemical Oxygen Demand (BOD_5)/ Five-Day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$)

The test for BOD is a bioassay procedure that measures the oxygen consumed by bacteria from the decomposition of organic matter; the BOD assay is a measure of the amount of oxidizable material that can lower dissolved oxygen in the receiving water body. Determining how organic matter affects dissolved oxygen concentrations in the receiving water body is an essential component of water quality management (Delzer and McKenzie 2003).

The change in dissolved oxygen concentration is measured over a given time period in water samples at a specified temperature. The BOD is usually measured in a laboratory environment. Delzer and McKenzie (2003) and the USGS Web site[2] provide details on equipment, supplies, chemical reagents, and preparation of dilution water and chemical solutions used to determine the BOD_5.

Iodometric titration or amperometric (dissolved oxygen meter) methods used to measure dissolved oxygen are often employed for the BOD_5 test procedure. The results are reported as carbonaceous BOD (CBOD) or as $CBOD_5$ when a nitrification inhibitor is added to the sample before analysis.

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[2] Available at: http://www.epa.gov/cwa-methods, https://www.epa.gov/cwa-methods/approved-cwa-microbiological-test-methods and https://www.epa.gov/cwa-methods/approved-cwa-chemical-test-methods as well as others on these sites, the Standard Methods for Examination of Water and Wastewater (APHA/AWWA/WEF 2016; http://www.standardmethods.org/).

[3] Available at: https://pubs.er.usgs.gov/search, accessed 16 April 2016.

Most relatively unpolluted streams have a BOD_5 that ranges from 1 to 8 milligrams per liter (mg/L). If the BOD_5 value of a sample is less than 7 mg/L, sample dilution is not needed. A BOD_5 value greater than 7 mg/L requires sample dilution. Dilution is necessary when the amount of dissolved oxygen consumed by microorganisms is greater than the amount of dissolved oxygen available in the air-saturated BOD_5 sample; sample dilution tables are provided in Delzer and McKenzie (2003).

5.2.3 Fecal Indicator Viruses (FIV)

More than 100 types of human pathogenic viruses may be present in fecal-contaminated waters, but only a small number of them can be detected by currently available methods. Coliphages are used as indicators of fecal contamination and of the microbiological quality of the water (Bushon 2003 and the USGS Web site[2] provided above). Sterile techniques must be followed and documented when collecting and processing samples for FIVs; specific equipment and supplies needed to collect and analyze samples for FIVs are detailed in Bushon (2003). Quality control in sterilization procedures is mandatory (Bushon 2003).

For sample sites suspected of being highly contaminated with fecal material, sample dilution will be required. Determination of virus concentrations may require the use of concentration techniques, three of which are recommended as standard methods by APHA/AWWA/WEF (2016): absorption and elution from microporous filters, aluminum hydroxide adsorption-precipitation, and polyethylene glycol hydroextraction-dialysis. If there is a need to recover viruses from solids in (small) volumes of water, alternate techniques are also available (APHA/AWWA/WEF 2016).

Two methods described by USGS for the detection of FIVs are the single-agar layer (SAL) method and the two-step enrichment method. The host bacteria recommended for use by these methods is *E. coli* CN-13 for the detection of somatic coliphage and *E. coli* F-amp for the detection of F-specific coliphage. Analytical protocols are available in more detail from the USGS Ohio District Microbiology Laboratory (U.S. Geological Survey[4]). The quantity of coliphage in a sample analyzed by the methods outlined in this protocol is expressed as plaques per 100 mL. These methods appear to be able to detect a single coliphage.

5.2.4 Turbidity

Turbidity is “an expression of the optical properties of a liquid that causes light rays to be scattered and absorbed rather than transmitted in straight lines through a sample” (ASTM 2003). While not an inherent property of water (such as pH), turbidity measurements serve as a combined measure of suspended and dissolved silt, clay, fine organic matter, plankton, microbes, dyes, and other components and is, therefore, a means of quantifying a level of water clarity for the intended use. Because there are multiple approved protocols and instruments for measuring turbidity, Anderson (2005) recommends that turbidity values always be reported on the basis of individual instrument design (e.g., for colored particles, dissolved color, particle density, and so forth). Standard equipment designs based on number of light source beams and their wavelengths as well as choice of turbidity unit are summarized in Anderson (2005).

The U.S. Federal regulations measuring turbidity are established only for drinking water and include the three USEPA-approved methods listed below. The applicable range for these three methods is 0 to 40 turbidity units (Anderson 2005).

1. EPA Method 180.1 (USEPA, 1993a), based on white-light nephelometric instrument designs.

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[4] http://oh.water.usgs.gov/micro/lab.html#am

2. GLI Method 2 (USEPA, 1999; Great Lakes Instrument Company, undated), which uses a dual-beam and dual detector technology with an 860-nanometers light-emitting diode light source to compensate for color and reduce erratic readings.

3. Hach Method 10133 (USEPA, 2002), an inline process-stream method (as provided in Anderson 2005).

5.2.5 Suspended Solids

Total suspended solids are fine particles that are not "settleable" and are made up of sands, clays, aquatic organisms such as plankton and algae, decomposing organic matter, and bacteria. The TSSs are considered a principal component of water clarity. The TSS measurement is thus important information for controlling fouling of water distribution systems as well as serving as an indicator of potential organic and/or bacterial load.

Standard and approved sample handling and preservation methods (e.g., drying at 103–105°Celsius (C) as well as USEPA-approved laboratory gravimetric measurement protocols (where water samples are filtered through glass filters and then weighed) are summarized in APHA/AWWA/WEF (2016); these protocols are also available online from APHA (www.standardmethods.org/store).

5.2.6 Dissolved Solids

Dissolved solids are made up of organic matter in solution as well as inorganic salts of calcium, magnesium, and sodium as well as potassium cations and anions of chlorine, carbonate, sulfate and nitrate (WHO 2003). TDSs originate from natural sources as well as sewage, urban and road runoff, and other forms of wastewater. Therefore, TDS measurements can be used as indicators of wastewater load and hardness in the sampled waters. However, TDS and hardness do not necessarily correlate. Hardness is the result of multivalent ions, such as calcium and magnesium. If water passes through a softener, there may be little change in TDS, but there will be a significant change in hardness. Depending on the water solubility of individual components, TDS concentrations in natural waters can vary from <30 mg/L to 6000 mg/L (WHO 2003).

The WHO (2003) considers that TDS concentrations <1000 mg/L are usually acceptable but that concentrations >500 mg/L may be objectionable due to excessive scaling in the water distribution system and taste. Certain TDS components, such as chlorides and sulfates, affect water corrosivity.

Standard and approved sample handling and preservation methods (e.g., drying at 180°C) as well as laboratory measurement protocols are summarized in APHA/AWWA/WEF (2016); these protocols are also available online from APHA (www.standardmethods.org/store).

5.2.7 Enteric Bacteria

The sanitary quality of water is indicated by the presence and density of enteric, or "fecal indicator" bacteria. Although many intestinal bacteria do not typically cause human disease, their presence is an indicator of the possible presence of waterborne pathogens that can result in gastrointestinal illness or disease (Myers et al. 2007). Enteric bacteria density in water (# bacteria /100 mL) is considered a measure of water safety for consumption or body-contact recreation, and is, thus, regulated by Federal and state authorities (Myers et al. 2007). For the purpose of the present analysis, the levels of water ingestion and immersion assumed for body-contact recreational waters are considered comparable to those encountered during showering (USAPHC 2014b).

Sterile techniques must be followed and documented when collecting and processing samples for enteric bacteria; specific equipment and supplies needed to collect and analyze samples for *Enterococci* and *E. coli* are detailed in Myers et al. (2007). Quality control in sterilization procedures is mandatory (Myers et al. 2007). Sample preservation procedures, container materials and maximum allowable sample holding times are all regulated (USEPA 2007a).

In the United States, *Enterococci* and *E. coli* density monitoring data are federally mandated for coastal beaches of the Great Lakes and oceans; inland beaches are subject to state requirements. Criteria vary according to whether fresh or marine waters are considered, as well as choice of sampling strategy (e.g., geometric mean of five samples or single-sample maximum based on use category such as "moderate use full-body contact" to "infrequent use full-body contact."). For fresh waters, *E. coli* requirements range from a geometric mean (GM) of 126/100 mL to a single-sample maximum for infrequent full-body contact of 576/100 mL. For *Enterococci*, the span for the same parameters is 33/100 mL to 151/100 mL (Myers et al. 2007; USEPA 1986).

Standard and approved methods for measuring *E. coli* and *Enterococci* density include membrane filtration followed by media-specific culture as well as defined enzyme substrate tests (Brenner et al. 1993; AOAC1995; ASTM 2000; USEPA 2002, 2006a, b, c, 2007a; APHA/AWWA/WEF 2016).

5.2.8 Nitrogen

Nitrogen exists in water in many forms due to the high number of oxidation states it can assume. In the environment and water, changes from one oxidation state to another can be accomplished by chemical and biological processes. The most prevalent forms in water and those that require treatment are organic-N, ammonia-N, and nitrate-N. All of these forms of nitrogen impact water quality: (1) ammonia is toxic to organisms, (2) ammonium ion or ammonia is an oxygen-consuming compound, which will deplete dissolved oxygen concentrations in waters, (3) all forms of nitrogen can be available as a nutrient leading to eutrophication, and (4) nitrate is a public health hazard in drinking water. Nitrogen entering water treatment systems in the organic or ammonia form can be either removed or transformed. Removal of nitrogen is obtained by assimilation and by conversion to nitrogen gas through nitrification and denitrification. Under appropriate or controlled conditions, microorganisms oxidize ammonia in the presence of oxygen to form nitrates (nitrification). Nitrates may be transformed to nitrogen gas through a process called denitrification in the absence of oxygen.

Based on composition and concentration of nitrogen forms in influent water, the nitrate-nitrite-ammonia content is controlled by optimizing chemical and microbiological processes in wastewater treatment systems to meet water effluent requirements.

The USEPA-approved methods for measuring all inorganic forms of nitrogen (total nitrogen) in (drinking) waters for CWA compliance are provided online[5]. Standard and approved methods for sampling and measuring total nitrogen by persulfate as well as by untraviolet (UV)/persulfate digestion and oxidation methods are summarized in (APHA/AWWA/WEF 2016). Automated colorimetric phenate methods (Kjeldahl) have been approved by USEPA and are reported to measure total nitrogen within the range of 0.05 to 2.0 mg/L (automated phenate; USEPA 1978) and 0.1-20 mg/L TKN (total Kjeldahl nitrogen) (semi-automated; USEPA 1993b); the range can be extended with sample dilution. Some industrial nitrogenous compounds (such as amines and oximes) may not be detected by the semi-automated Kjeldahl method outlined above (USEPA 1993b).

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[5] https://www.epa.gov/cwa-methods/approved-cwa-test-methods-inorganic-non-metals

Standard and approved methods for sampling and measuring ammonia nitrogen, organic nitrogen, and nitrate nitrogen by multiple methods are summarized in (APHA/AWWA/WEF 2016). An approved semi-automated colorimetric method for measuring ammonia nitrogen is available (USEPA 1993c). In addition, a spectrophotometric method for measuring nitrate nitrogen has also been approved by USEPA (USEPA 1971), and an approved combination method that can measure Nitrate + nitrite nitrogen utilizes an automated colorimetric method (USEPA 1993d).

5.2.9 pH

As a primary factor governing chemistry of water systems, pH is a routine measurement of water quality. Since water pH directly affects physiological functions of plants and animals, pH values are an important indicator of water system integrity, corrosivity and safety (Ritz and Collins 2008).

Standard procedures most frequently utilize an electrometric method; equipment requirements (primarily related to type of ion selective electrode employed) are based on the expected chemical condition of test waters (e.g., dominance by base ions; elevated concentrations of sulfur, and so forth) as summarized in Ritz and Collins (2008) and APHA/AWWA/WEF (2016). The use of pH indicator paper is no longer supported. Expected pH measurement ranges are from 2 to 12, with a preferable instrument range of 1 to 14 (Ritz and Collins 2008).

Variables affecting measurement include temperature, buffer solution quality, cleanliness and integrity of the electrode, and the need to measure pH in still (nonrunning) water.

5.3 Current Military Detection Capabilities

Water quality surveillance in the deployed environment, “the field,” consists of operational monitoring by Quartermaster Corps, or contractor operators, as well as quality assurance monitoring by Medical Service Corps preventive medicine (PM) officers and technicians. The water test kits fielded to the operators and PM staff are the Water Quality Analysis Set-Purification and the Water Quality Analysis Set-Preventive Medicine [WQAS-PM] respectively. The kits contain an assortment of water quality instruments for measuring various parameters

The water quality parameters relevant to nonpotable water reuse that can be measured in the field by Soldiers include turbidity, TDS, total and FAC, pH, and microbiological indicators (total coliforms and *E. coli*).

Equipment for microbiological testing in water is currently fielded only to PM units. According to the requirements of TB MED 577, only presence/absence testing of total coliforms and *E. coli* are conducted (DA 2010). While a method for field-enumeration of bacteria exists, it is seldom used and may soon be phased out. The membrane-filtration technique is considered too cumbersome and time consuming for successful adoption within a new monitoring scheme for water reuse.

To be able to better characterize reclaimed water, specifically to more efficiently enumerate bacteria, the procurement of additional equipment will need to be considered. One commercial off-the-shelf technology example is the IDEXX Quanti-Tray®, which provides a most probable number measurement of total coliforms and *E. coli*.

6 REVIEW OF SOURCE DOCUMENTS FOR AVAILABLE STANDARDS

Laws, regulations, and guidelines were researched for three states and three countries: CA, AZ and TX, as well as Australia, The Netherlands, and Israel. These locations were selected because of their involvement (longest initiative for water reuse, most comprehensive documentation, lead areas for public consumption, and most conservative concepts) in water reuse initiatives. In addition, other documents were reviewed (USACE 2014) to confirm the selection of the best references. It is noted that many other states and countries are active in water reuse initiatives (i.e., Hawaii, Washington, Florida), and their guidelines tend to mirror the lead states of CA, AZ, and TX. Multiple uses that correspond to the use cases described in this document were considered to include fire suppression, dust control, vehicle washing, irrigation of nonfood items, as well as use of showers and laundries.

The regulations and guidelines are very diverse. In addition to the quantitative values discussed further below, there are qualitative requirements that address cross connections, signage in areas where gray water is used, the design of gray water systems and piping, water-planning requirements that include the use of gray water, use restrictions and safeguards for recycled water, and area use requirements (i.e., distance of use from a water supply).

6.1 U.S. Army

Current guidelines for Water Recycle and Reuse for TriService application are documented by the Army Surgeon General as chapter 9 (pp. 89–90) in TB MED 577 (DA 2010). This chapter does not identify any specific method or field kit for determining that the identified general standards for water recycle and reuse (pH: 5 to 9; Turbidity: 1 NTU; Hardness: 500 mg/L; TDS: 1500 mg/L; Coliforms: absent; FAC residual: 1 mg/L after 30 minutes) are met. Specific criteria to be met are found in USACHPPM (2001) and DA (2004), in which USEPA protocols are referenced. Both of these sources for specific standards reference use of the “Water Quality Analysis Set—Preventive Medicine” and the M272 chemical agent test kit for water quality testing.

6.2 California

California adopted water recycling criteria in July of 2015 under Title 22, California Code of Regulations (CCR) Division 4, Chapter 3 (Title 22 CCR). By definition, the regulation established four types of recycled water, based on the treatment streams applied and the resulting disinfection.

California has also promulgated requirements and water quality criteria for "Groundwater Replenishment Reuse Projects” that either directly or indirectly uses recycled municipal wastewater to replenish a groundwater basin for use as a source of municipal and domestic water supply. Standards incorporated for these projects include the USEPA maximum contaminate levels (MCLs) and secondary maximum contaminant levels (SMCLs) as well as standards for the controls of nitrogen compounds and pathogenic microorganisms.

The MCLs and SMCLs are part of the USEPA’s National *Primary* Drinking Water Regulations, which are legally enforceable standards for public water systems (USEPA 2016). These standards are intended to protect drinking water quality by limiting the amounts of specific contaminants. The highest level of a contaminant that is allowed in drinking water is delineated by the National Primary Drinking Water Regulations. The derivation of values considered health risks, technical feasibility of treatment, and cost-benefit analysis.

The National *Secondary* Drinking Water Regulations are a set nonmandatory water quality standards for 15 contaminants (USEPA 2016). The SMCLs are not enforced and serve only as guidelines to assist public water systems in managing drinking water for aesthetic considerations such as taste, color, and odor. At the SMCL, these contaminants are not considered to present a risk to human health.

6.3 Arizona

In Arizona, the use or providing of reclaimed water requires a permit (Arizona Administrative Code (AAC), R18-9-701 *et. seq.)* (Title 18, AAC). The Reclaimed Water Quality Standards[6] establish five classes of reclaimed water expressed as a combination of minimum treatment requirements and a limited set of numeric reclaimed water quality criteria (AAC R18-11-301 *et. seq*.). In addition, the AAC assigns the minimum class of reclaimed water required for a given activity.

6.4 Texas

Texas regulations establish two types of reclaimed water with assigned uses and standards. These standards apply to any organized or municipal system which includes gray water reuse. Onsite reuse of gray water is not subject to these standards but must meet design and operation standards for onsite gray water systems set out in Title 30,Texas Administrative Code (TAC), Chapter 283 (Title 30 TAC).

6.5 The Netherlands

In the Netherlands, almost all of the national legislation for environmental issues is incorporated in the Environmental Management Act (EMA) (VROM 2004). The EMA is based on and incorporates the European Union (EU) legislation. In the area of water reuse, the Netherlands appears to follow the approach of the EU following international guidelines. For water recycling, the EU does not have any numeric standards.

6.6 Israel

In April 2010, Israel's Public Health Regulations “Effluent Quality Standards and Wastewater Treatment Rules” were published to establish standards for wastewater reused only for irrigation of agricultural produce[7]. The Israel Ministry of Health has established rules for *E. coli* levels[8] that are protective of the public and the environment in areas irrigated with treated wastewater. The Ministry requires permits for irrigation with treated wastewater. In addition, barriers are required between the treated wastewater and the fruit. The combination of the barrier and the quality of the treated wastewater is factored into the permitting process. There are five levels of treated wastewater quality, according to the treatment processes they underwent and the treatment quality (biological, chemical, and physical).

Currently, there are proposed reuse standards based on fecal count, turbidity, chlorination, and disinfection with UV radiation. The reuse standards are in a probationary status due to the resistance by the Ministry of Health, State of Israel. The Ministry of Health prefers to see a small treatment plant on each private property. The reuse standards for groundwater are now waiting public reaction and the final approval by the Standard Institutes since extensive work is going on in the area.

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[6] http://apps.azsos.gov/public_services/Title_18/18-11.pdf

[7] http://www.sviva.gov.il/English/Legislation/Pages/WaterAndWastewater.aspx

[8] http://www.health.gov.il/English/Topics/EnviroHealth/Reclaimed_Water/kolchim

6.7 Australia

In Australia, the Federal government does not extend regulation for most environmental matters; instead, the authority to regulate environmental matters is largely left to the individual states. However, Australia has established risk-based guidelines for the safe reuse of recycled water. The guidelines establish a risk-based framework, which includes determining acceptable or tolerable risk, setting health-based targets, and assessing risks. These guidelines use DALYs to convert the likelihood of infection or illness into burdens of disease, and set a tolerable risk as 10^{-6}-DALYs per person per year. The tolerable risk is then used to set health-based targets. The guidelines focus on specific uses. These national guidelines are set out in two documents[9], "Australian Guidelines for Water Recycling: Managing Health and Environmental Risks" and "Australian Guidelines for Water Recycling: Augmentation of Drinking Water Supplies."

Each of the Australian states have issued guidelines for water reuse, each with different uses and users, and some are quite old (i.e., South Australia's guidance is over 16 years old). The guidelines are based on quantitative and qualitative standards and are provided for a variety of uses.

7 SUMMARY OF STANDARDS—USE CASE #1: LAUNDRY

Biological (Table 9), chemical (Table 10), and physical (Table 11) standards specific to laundry were found in guidance from Western Australia, Victoria, and CA. Several of the standards appear to have applicability for the military-defined use case. For example, the standards from Western Australia are for communal washing machines, and CA provides standards for commercial laundries.

Table 9. Biological Standards for Laundry

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Clostridia	Communal use cold tap washing machines	Australia WA[1]	1 CFU[a]/ 100 mL	No details provided.
Coliphages	Communal use cold tap washing machines	Australia WA[1]	1 PFU/ 100 mL	No details provided.
Fecal Coliform or *E. coli*	Multi-Dwelling washing machine	Australia WA[1]	1 CFU/ 100 mL	No details provided.
	Communal use cold tap washing machines	Australia WA[1]	1 MPN or CFU/ 100 mL	No details provided.
	Cold water supply to washing machines	Australia VIC[2]	10 CFU/ 100 mL	No details provided.
	Single Domestic washing machine	Australia WA[1]	1 CFU[a]/ 100 mL	No details provided.
F-specific bacteriophage MS2 (or poliovirus)	Commercial laundries	USA CA[3]	See details.	Use a disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the plaque-forming units of F-specific bacteriophage MS2, or poliovirus in the wastewater. A virus that is at least as resistant to disinfection as

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[9] http://www.recycledwater.com.au/index.php?id=16

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
				poliovirus may be used for purposes of the demonstration
Total Coliform	Commercial laundries	USA CA[3]	2.2 CFU/ 100 mL	Average concentration of last 7 days
			23 CFU/ 100 mL	Highest concentration for any one sample in any 30-day period
			240 CFU/ 100 mL	Maximum concentration for a single sample

Legend:
CFU = colony forming unit
PFU = plaque-forming unit
MS2 = single-stranded bacteriophage (RNA) virus that infects Enterobacteriaceae including *E. coli*
Note:
[a] Unit assumed and added by authors
Sources:
1. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
2. Code of Practice Onsite Wastewater Management, Publication number 891.3, EPA Victoria, February 2013
3. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria

Table 10. Chemical Standards for Laundry

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Chlorine Disinfection (CT)	Commercial laundries	USA CA[1]	See details.	Use a chlorine disinfection process.
Total Chlorine	Communal use cold tap washing machines	Australia WA[2]	0.2-2.0 mg/L	No details provided.

Sources:
1. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria
2. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health

Table 11. Physical Standards for Laundry

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
BOD_5 or $CBOD_5$	Multi-dwelling washing machine	Australia WA[1]	10 mg/L	No details provided.
	Communal use cold tap washing machines	Australia WA[1]	10 mg/L	No details provided.
	Cold water supply to washing machines	Australia VIC[2]	10 mg/L	No details provided.
	Single Domestic washing machine	Australia WA[1]	10 mg/L	No details provided.
pH	Communal use cold tap washing machines	Australia WA[1]	6.5-8.5	No details provided.
SS	Multi-dwelling washing machine	Australia WA[1]	10 mg/L	No details provided.

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
	Communal use cold tap washing machines	Australia WA[1]	10 mg/L	No details provided.
	Cold water supply to washing machines	Australia VIC[2]	10 mg/L	No details provided.
	Single Domestic washing machine	Australia WA[1]	10 mg/L	No details provided.
Turbidity	Communal use cold tap washing machines	Australia WA[1]	2 NTU	95% Confidence interval on average turbidity
			5 NTU	Maximum

Sources:

1. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
2. Code of Practice Onsite Wastewater Management, Publication number 891.3, EPA Victoria, February 2013

8 SUMMARY OF STANDARDS—USE CASE #2: DUST SUPPRESSION

Biological (Table 12), chemical (Table 13), and physical (Table 14) standards specific to dust suppression were found in guidance from Australian Capital Territory, Western Australia, AZ, CA, and TX. All of the standards appear to have applicability for the military defined use case depending on the amount of access to the treated surface post dust suppression.

Table 12. Biological Standards for Dust Suppression

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Enterococci	Dust suppression and Soil compaction	USA TX[1]	35 CFU/ 100 mL	Geometric mean concentration of samples taken over last 30 days
			89 CFU/ 100 mL	Maximum concentration in any single “grab” sample
Fecal Coliform or *E. coli*	Dust control	USA AZ[2]	200/100 mL	Maximum concentration in four of the last seven daily reclaimed water samples taken
			800/100 mL	Maximum concentration in any single sample
	Dust suppression and Soil compaction	USA TX[1]	200 CFU/ 100 mL	Geometric mean concentration of samples taken over last 30 days
			800 CFU/ 100 mL	Maximum concentration in any single “grab” sample
	Dust suppression	Australia WA[3]	10 MPN or CFU/100 mL	No details provided.
Thermo-tolerant coliforms	Municipal dust suppression controlled public access	Australia ACT[4]	1000 CFU/ 100 mL	Median value of concentrations (Restricted access after dust suppression occurs.)
			10 CFU/ 100 mL	Median value of concentrations (Unrestricted public access after dust suppression occurs)
Total Coliform	Dust control on roads and streets	USA CA[5]	23/100 mL	Mean concentration using last 7 days of sampling results

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
			240/100 mL	Highest concentration for any one sample in any 30-day period

Sources:
1. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
2. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards
3. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
4. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007
5. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria

Table 13. Chemical Standards for Dust Suppression

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Total Chlorine	Dust suppression	Australia WA[1]	0.2-2.0 mg/L	No details provided.
	Municipal dust suppression controlled public access	Australia ACT[2]	>1 mg/L	Chlorine residual after 30 min or equivalent level of pathogen reduction
	Municipal dust suppression uncontrolled public access	Australia ACT[2]	>1 mg/L	Chlorine residual after 30 min or equivalent level of pathogen reduction
Total Nitrogen	Dust control	USA AZ[3]	Not required	Nitrogen removal treatment is not required
			10 mg/L	5-sample geometric mean concentration

Sources:
1. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
2. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007
3. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

Table 14. Physical Standards for Dust Suppression

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
BOD_5 or CBOD5	Dust suppression and Soil compaction	USA TX[1]	20 mg/L	30-day average
	Dust suppression	Australia WA[2]	20 mg/L	No details provided.
pH	Dust suppression	Australia WA[2]	6.5-8.5	No details provided.
	Municipal dust suppression controlled public access	Australia ACT[3]	6.5-8.0	90% compliance
	Municipal dust uncontrolled public access	Australia ACT[3]	6.5-8.0	90% compliance
SS	Dust suppression	Australia WA[2]	30 mg/L	No details provided.
Turbidity	Dust suppression and Soil	USA TX[1]	15 NTU	30-day average

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
	compaction			
	Dust suppression	Australia WA[2]	5 NTU	95%
	Municipal dust suppression uncontrolled public access	Australia ACT[2]	2 NTU	No details provided.

Sources:
1. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
2. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
3. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007

9 SUMMARY OF STANDARDS—USE CASE #3: TOILET FLUSHING

Biological (Table 15), chemical (Table 16), and physical (Table 17) standards specific to toilet flushing were found in guidance from Australian Capital Territory, Western Australia, Victoria, Queensland, AZ, CA, and TX. Some of the standards appear to have applicability for the military defined use case such as communal use toilets from Western Australia or Toilet or urinal flush water from Texas.

Table 15. Biological Standards for Toilet Flushing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Clostridia	Communal use toilets	Australia WA[1]	1 CFU/100 mL	No details provided.
Clostridium perfringens	Domestic toilet flushing	Australia QLD[2]	1 CFU/100 mL	Median sample concentration
			10 CFU/100 mL	95% bound on average concentration
				5 log reduction of protozoan parasites (*Clostridium perfringens* as indicator)
Coliphages	Communal use toilets	Australia WA[1]	1 PFU/100 mL	No details provided.
Enterococci	Toilet or urinal flush water	USA TX[3]	4 CFU/100 mL	Geometric mean concentration of samples taken over last 30 days
			9 CFU/100 mL	Maximum concentration in any single "grab" sample
Fecal Coliform or *E. coli*	Toilet or urinal flush water	USA TX[3]	20 CFU/100 mL	Geometric mean concentration of samples taken over last 30 days
			75 CFU/100 mL	Maximum concentration in any single "grab" sample
	Toilet and urinal flushing	USA AZ[4]	23/100 mL	Maximum concentration in any single sample
			No detectable organisms	No detectable organisms in four of the last seven daily reclaimed water samples taken
	Toilet flushing	Australia VIC[5]	10 CFU/100 mL	No details provided.
	Communal use toilets	Australia WA[1]	1 MPN or CFU/100 mL	No details provided.
	Multi-Dwelling toilets	Australia	1 CFU*/100 mL	No details provided.

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
		WA[1]		
	Single Domestic toilets	Australia WA[1]	1 CFU*/100 mL	No details provided.
	Domestic toilet flushing	Australia QLD[2]	1 CFU/100 mL	Median sample concentration
			10 CFU/100 mL	95% bound on average concentration
				Treatment that results in 5 log reduction of bacteria (*E.coli* as indicator)
F-specific bacteriophage MS2 (or poliovirus)	Flushing toilets and urinals	USA CA[6]		A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the plaque forming units of F-specific bacteriophage MS2, or poliovirus in the wastewater. A virus that is at least as resistant to disinfection as poliovirus may be used for purposes of the demonstration
	Domestic toilet flushing	Australia QLD[2]	1 PFU/100 mL	Median sample concentration
			10 CFU/100 mL	95% bound on average concentration
			See detail.	Treatment that results in 6 log reduction of viruses (bacteriophages as indicators)
Somatic coliphage	Domestic toilet flushing	Australia QLD[2]	1 PFU/100 mL	Median sample concentration
			10 CFU/100 mL	95% bound on average concentration
Thermotolerant coliforms	Residential toilet flushing	Australia ACT[7]	10 CFU/100 mL	Median sample concentration
Total Coliform	Flushing toilets and urinals	USA CA[6]	2.2/100 mL	Average concentration using last 7 days of samples
			23/100 mL	Highest concentration for any one sample in any 30-day period
			240/100 mL	Maximum concentration in any single sample

Legend:
QLD = Queensland, Australia
Sources:

1. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
2. Queensland Water Recycling Guidelines, State of Queensland Environmental Protection Agency, December 2005
3. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
4. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards
5. Code of Practice Onsite Wastewater Management, Publication number 891.3, EPA Victoria, February 2013
6. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria
7. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007

Table 16. Chemical Standards for Toilet Flushing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Chlorine Disinfection (CT)	Flushing toilets and urinals	USA CA[1]	≥ 450 mg-min/L	A chlorine disinfection process following filtration that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 mg-min/L at all times with a modal contact time of at least 90 min, based on peak dry weather design flow.
Total Chlorine	Residential toilet flushing	Australia ACT[2]	>1 mg/L	Residual after 30 min or equivalent level of pathogen reduction
	Communal use toilets	Australia WA[3]	0.2-2.0 mg/L	No details provided.
Total Nitrogen	Toilet and urinal flushing	USA AZ[4]	Not required	Nitrogen removal treatment is not required
			10 mg/L	5-sample geometric mean concentration

Sources:
1. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria
2. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007
3. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
4. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

Table 17. Physical Standards for Toilet Flushing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
BOD_5 or $CBOD_5$	Toilet or urinal flush water	USA TX[1]	5 mg/L	30-day average
	Toilet flushing	Australia VIC[2]	10 mg/L	No details provided.
	Communal use toilets	Australia WA[3]	10 mg/L	No details provided.
	Multi-Dwelling toilets	Australia WA[3]	10 mg/L	No details provided.
	Domestic toilet flushing	Australia QLD[4]	20 mg/L	Median value of samples
	Residential toilet flushing	Australia ACT[5]	20 mg/L	Treatment value for biochemical oxygen demand
	Single Domestic toilets	Australia WA[3]	10 mg/L	No details provided.
pH	Communal use toilets	Australia WA[3]	6.5-8.5	No details provided.
	Residential toilet flushing	Australia ACT[5]	6.5-8.0	90% compliance
	Domestic toilet flushing	Australia QLD[4]	6–8.0	No details provided.
SS	Toilet flushing	Australia VIC[2]	10 mg/L	No details provided.
	Communal use toilets	Australia WA[3]	10 mg/L	No details provided.
	Multi-Dwelling toilets	Australia WA[3]	10 mg/L	No details provided.
	Residential toilet flushing	Australia ACT[5]	30 mg/L	Treatment value for SSs
	Single Domestic toilets	Australia WA[3]	10 mg/L	No details provided.
	Domestic toilet flushing	Australia QLD[4]	5 mg/L	Median value of samples

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Total Chlorine	Domestic toilet flushing	Australia QLD[4]	0.2-0.5 mg/L	For dual reticulation systems, free chlorine residual 0.2-0.5 mg/L on delivery to customer. For other A+ uses, the need for a chlorine residual should be determined as part of the risk assessment
TDS/Electrical Conductivity (EC)	Domestic toilet flushing	Australia QLD[4]	1000 mg/L/ 1600 µS/cm*	Median value of samples
Turbidity	Toilet or urinal flush water	USA TX[1]	3 NTU	30-day average
	Toilet and urinal flushing	USA AZ[6]	5 NTU	filtered effluent does not exceed at any time
			2 NTU	24-hour average of filtered effluent
	Communal use toilets	Australia WA[3]	2 NTU	95% confidence on average of samples
			5 NTU	Maximum for all samples
	Residential toilet flushing	Australia ACT[5]	2 NTU	No details provided.
	Domestic toilet flushing	Australia QLD[4]	2 NTU	95% confidence on average of samples
			5 NTU	Maximum for all samples

Legend:
µS/cm = microSiemen per centimeter
Sources:
1. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
2. Code of Practice Onsite Wastewater Management, Publication number 891.3, EPA Victoria, February 2013
3. Guidelines for the Non-potable Uses of Recycled Water in Western Australia, Environmental Health Directorate, Department of Health, Government of Western Australia, August 2011
4. Queensland Water Recycling Guidelines, State of Queensland Environmental Protection Agency, December 2005
5. Greywater Use, Guidelines for residential properties in Canberra, Australian Capital Territory, Canberra, October 2007
6. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

10 SUMMARY OF STANDARDS—USE CASE #4: VEHICLE WASHING

Biological (Table 18), chemical (Table 19), and physical (Table 20) standards specific to vehicle washing were found in guidance from AZ. The standards appear to have applicability for the military defined use case.

Table 18. Biological Standards for Vehicle Washing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Fecal Coliform or *E. coli*	Vehicle and equipment washing	USA AZ[1]	23CFU/100 mL	Maximum concentration in any single sample
			No detectable organisms	No detectable organisms in four of the last seven daily reclaimed water samples taken

Source:
1. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

Table 19. Chemical Standards for Vehicle Washing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Total Nitrogen	Vehicle and equipment washing	USA AZ[1]	10 mg/L	Geometric mean concentration of the last 5 samples.
			Not required	Nitrogen removal treatment is not required

Source:
1. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

Table 20. Physical Standards for Vehicle Washing

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Turbidity	Vehicle and equipment washing	USA AZ[1]	2 NTU	24-hour average of filtered effluent
			5 NTU	Limit filtered effluent does not exceed at any time

Source:
1. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

11 SUMMARY OF STANDARDS—USE CASE #5: INDUSTRIAL USE (CONSTRUCTION)

Biological (Table 21), chemical (Table 22), standards specific to construction were found in guidance from AZ. The standards do not appear to have applicability for the military defined use case of concrete mixing. There were no physical standards identified.

Table 21. Biological Standards for Construction

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Fecal Coliform or *E. coli*	Soil compaction and similar construction activities	USA AZ[1]	200 CFU/100 mL	Highest concentration in four of the last seven daily reclaimed water samples taken
			800/100 mL	Maximum concentration in any single sample

Source:
1. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

Table 22. Chemical Standards for Construction

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Total Nitrogen	Soil compaction and similar construction activities	USA AZ[1]	Not required	Nitrogen removal treatment is not required
			10 mg/L	Maximum concentration in any single sample

Source:
1. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

12 SUMMARY OF STANDARDS—USE CASE #6: FIRE FIGHTING

Biological (Table 23), chemical (Table 24), and physical (Table 25) standards specific to firefighting were found in guidance from AZ, CA, and TX. Some of the standards appear to have applicability for the military defined use case such as structural fire fighting from California and Nonstructural firefighting from California.

Table 23. Biological Standards for Fire Fighting

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Enterococci	Fire Protection	USA TX[1]	4 CFU/100 mL	Geometric mean concentration of samples taken over last 30 days
			9 CFU/100 mL	Maximum concentration in any single “grab” sample
Fecal Coliform or *E. coli*	Fire Protection	USA TX[1]	20 CFU/100 mL	Geometric mean concentration of samples taken over last 30 days
			75 CFU/100 mL	Maximum concentration in any single “grab” sample
	Fire protections systems	USA AZ[2]	23CFU/100 mL	Maximum concentration in any single sample
			No detectable organisms	No detectable organisms in four of the last seven daily reclaimed water samples taken
F-specific bacteriophage MS2 (or poliovirus)	Structural fire fighting	USA CA[3]	See details.	A disinfection process that, when combined with the filtration process, has been demonstrated to inactivate and/or remove 99.999% of the plaque forming units of F-specific bacteriophage MS2, or poliovirus in the water. A virus that is at least as resistant to disinfection as poliovirus may be used for purposes of the demonstration.
Total Coliform	Nonstructural fire fighting	USA CA[3]	23 CFU/100 mL	Mean concentration using last 7 days of sampling results
			240 CFU/100 mL	Highest concentration for any one sample in any 30-day period
	Structural fire fighting	USA CA[3]	2.2 CFU/100 mL	Mean concentration using last 7 days of sampling results
			23 CFU/100 mL	Highest concentration for any one sample in any 30-day period
			240 CFU/100 mL	Maximum concentration for a single sample

Sources:
1. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
2. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards
3. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria

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Table 24. Chemical Standards for Fire Fighting

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
Chlorine Disinfection (CT)	Structural fire fighting	USA CA[1]	≥ 450 mg-min/L	A chlorine disinfection process following filtration that provides a CT (the product of total chlorine residual and modal contact time measured at the same point) value of not less than 450 mg-min/L at all times with a modal contact time of at least 90 min, based on peak dry weather design flow
Total Nitrogen	Fire protections systems	USA AZ[2]	Not required	No details provided.
			10 mg/L	Maximum concentration in any single sample

Sources:
1. CCR. Division 4, Environmental Health. Chapter 3, Water Recycling Criteria
2. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

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Table 25. Physical Standards for Fire Fighting

Measured Parameter	Specified Use in Standard	Source	Standard	Standard Detail
BOD_5 or $CBOD_5$	Fire Protection	USA TX[1]	5 mg/L	Average of samples taken over last 30 days
Turbidity	Fire Protection	USA TX[1]	3 NTU	Average of samples taken over last 30 days
	Fire protections systems	USA AZ[2]	2 NTU	24-hour average of filtered effluent
			5 NTU	Limit filtered effluent does not exceed at any time

Sources:
1. TAC. Title 30, Environmental Quality. Chapter 285, On-Site Sewage Facilities
2. AAC. Title 18. Environmental Quality. Chapter 11. Department of Environmental Quality Water Quality Standards

13 SUMMARY OF STANDARDS—USE CASE #7: SHOWERING

This review did not find any published standards for showering. However, APHC completed a Microbial Risk Assessment (MRA) that evaluated the health risks associated with wastewater reuse for showering in a deployed setting (USAPHC 2014b). The MRA provides risk-based water concentrations (RBWCs) for treated wastewater for unrestricted reuse scenarios (e.g., showering). That document only provides RBWCs for *Escherichia coli*. The MRA provides information that can inform future water detection strategies and water use standards (e.g., TB MED 577, 2010).

14 SUMMARY OF STANDARDS—USE CASE #8: DISH WASHING

The only proposed dish washing standard found during this review is published by Church et al. (2015) in support of an ultrafiltration system developed for field (military) dish washing water reuse. The tentative water reuse standard for dish washing water is based on Federal, state, and military regulations and guidelines for nonpotable water. The water reuse standards for field analysis (simple but accurate) was finalized as follows: turbidity (<1NTU), *Escherichia coli* ($<50\ \mathrm{CFU \cdot mL^{-1}}$), and pH (6–9). A specific form of UV radiation (UV_{254}) was recommended as a surrogate for organic contaminants (e.g., BOD_5), but requires further calibration steps for validation.

15 CONCLUSIONS

The U.S. military and allied contingency operations are occurring in remote locations with limited water supplies. Gray water reuse is increasingly considered a viable water conservation strategy for such missions. Gray water reuse could increase mission sustainability and significantly reduce the resources, logistics and attack vulnerabilities posed by convoy transport of water supplies. Development of health-based (nonpotable) exposure guidelines for common biological (e.g., bacteria, viruses) and chemical (e.g., insect repellents, detergents, solvents, grease/oil byproducts) components of gray water would provide a logical and human-health basis for water reuse strategies resulting in improved Army water security for contingency operations. The existence of such exposure guidelines would also greatly assist in the characterization of source water quality under consideration for specific nonpotable use-case application.

It is timely to update joint-capability documents to incorporate current military health-risk analysis expertise and to enhance mission sustainability. Of particular need are estimates of operational impact characterizing personnel health or mission risks potentially associated with nonpotable gray water reuse. This report summarizes current guidelines and published standards associated with treated wastewater reuse activities that are to be considered until and unless U.S. military guidelines for treated wastewater and reuse are established. This review represents an initial appraisal of: (1) potentially applicable guidelines drawn from existing water reuse guidelines in use by the states and territories of the United States, as well as selected overseas host jurisdictions and (2) the need to proceed to develop and establish wastewater reuse guidelines for military contingency operations.

This report identifies the need for health-based water reuse guidelines to support gray water reuse at forward deployed operations; it has outlined relevant use cases and exposure routes that can provide structural functionality within a health risk assessment framework for guideline development. This assessment is intended to enhance future risk analyses and exposure guideline development regarding military water reuse; as such, the authors consider that the present assessment is not yet sufficiently mature to support “picking a standard” for any particular application. Prior to such selection, the authors recommend the completion of a quantitative risk assessment for specific use cases of interest, which would involve use-case scenario validation, determination of exposure factors, and determination of the approach for characterizing risk. It seems reasonable that acceptable risk levels could be developed for each use case and, therefore, be use-case specific. The ability to focus on a particular use case versus general “reuse” may serve to facilitate implementation of using treated wastewater in contingency operations. It is also acknowledged that it is appropriate to apply the developed framework and use-case approach to evaluate black and other wastewaters at some time in the future.

16 RECOMMENDATIONS

It is recommended to continue the collaborative work between APHC, the U.S. Army Tank Automotive Research Development and Engineering Center, and the DOD Tri-Service field water community through the Joint Environmental Surveillance Working Group in order to build upon the findings of this assessment to fulfill the following next steps:

1. Define and reach consensus on the proposed use cases and relevant exposure parameters to support targeted guideline development.

2. Define and reach consensus on acceptable risk for the selected use cases.

3. Establish (derive) health-based gray water reuse exposure guidelines for target chemical, biological, and physical components of gray water.

4. Develop health-risk based monitoring protocols and techniques, in close collaboration with water quality characterization technology development, to ensure adequate monitoring of water quality for intended (fit-for-purpose) water use.

5. Begin a communication campaign as early as possible [now] to learn about current perceptions, and educate users about water reuse applications and benefits.

APPENDIX A

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APPENDIX B

Typical Uses of Different Classes/Qualities of Water in the Field and Associated Caveats

Table B-1. Typical Uses of Different Classes/Qualities of Water in the Field and Associated Caveats (DA, 2010)

Water Class/Quality	Acceptable Activities
Class I – Potable **a. ROWPU Treated Water** **b. Bottled Water** **c. Packaged Field Water** **d. Approved Municipal Water** **e. Approved Ground Water**	a. Drinking water b. Brushing teeth c. Showers and personal sanitation[1] d. Dining facility operations e. Ice production for food preservation and cooling f. Medical treatment g. Potable water hose and pipeline testing and flushing
Class II[2] **a. Disinfected[3] Filtered[4] Fresh Water** **b. Disinfected[3] Fresh Water** **c. Treated Shower and Laundry Water[5]**	a. Decontamination of personnel[1] b. Heat casualty body cooling[1] c. Well development d. Graves registration personnel sanitation e. Retrograde cargo washing
Class III – Not Potable **a. Untreated Fresh Water**	a. Vehicle coolant b. Aircraft washing c. Pest control d. Field laundry e. Concrete construction f. Well drilling
Class IV[6] – Not Potable **a. Brackish Water** **b. Seawater**	a. Vehicle washing b. Electrical grounding c. Fire fighting d. Chemical, biological, radiological, and nuclear decontamination of materiel e. Dust control[7]

[Source: TB MED 577, Sanitary Control and Surveillance of Field Water Supplies, Table 2-12]

Notes continued on next page:

Notes for TB MED 577, Table 2-12:

[1] Permission to use other than potable water for these activities requires a risk assessment by PM assets and approval by the commander.

[2] For some surface and ground water sources, class II a and II b waters may meet short- and/or long-term potability standards, and may be used for drinking water, with PM and command approval. Such use would require a 2 mg/L FAC residual after a 30-min contact time prior to distribution.

[3] For nonpotable water, disinfected means having at least a 1 mg/L FAC residual after a 30-min contact time and at the time of use.

[4] Fresh water that has been filtered through multimedia filters, microfilters, or ultrafilters, and possibly RO concentrate water from fresh water treatment operations, depending on its quality, may be disinfected and used in lieu of or in preference to disinfected fresh water, with PM and command approval.

[5] Applies to Force Provider operations only, and has specific treatment and operational monitoring requirements specified in a 2004 Office of The Surgeon General memorandum and USACHPPM Information Paper (IP) 31-027.

[6] Brackish and seawater are minimally acceptable and may lead to significant corrosion if used; therefore, fresh water should be used if possible. ROWPU brine from seawater desalination operations may not be used.

[7] Use of nondisinfected water or any kind of wastewater, treated or not, for dust suppression requires the approval of the area medical authority, and is dependent on the quality of the water and on the potential it poses for human contact with pathogenic microorganisms.

GLOSSARY

Acronyms/Abbreviations

AAC
Arizona Administrative Code

AEPI
Army Environmental Policy Institute

ANSI
American National Standards Institute

AOAC
Association of Official Analytical Chemists, International

APHA
American Public Health Association

APHC
U.S. Army Public Health Center

AR
Army Regulation

ATP
Army Techniques Publications

AWWA
American Water Works Asssociation

AZ
Arizona, USA

BOD
Biochemical oxygen demand

BOD_5
5-day biochemical oxygen demand

C
Celsius

CA
California, USA

CBOD
Carbonaceous biochemical oxygen demand

$CBOD_5$
5-day carbonaceous biochemical oxygen demand

CCR
California Code of Regulations

CDPH
California Department of Public Health

cm^3
cubic centimeter

CERL
Construction Engineering Research Laboratory

CFR
Code of the Federal Regulations

CFU
colony-forming unit

CONUS
Continental United States

CT
concentration-time; an indicator of disinfection efficacy, the product of the FAC chlorine residual concentration in mg/L and the contact time in minutes (TB MED 577).

CWA
Clean Water Act

DA
Department of the Army

DALY
disability-adjusted life year

DPD
N, N-diethyl-p-phenylenediamine

EC
Electrical conductivity

EMA
Environmental Management Act

EPA EFH
U.S. Environmental Protection Agency Exposure Factors Handbook

EU
European Union

FAC
free available chlorine

FIV
Fecal Indicator Viruses

FOB
Forward Operating Base

GM
geometric mean

MCL
maximum contaminant level

µS/cm
micro-Siemens per centimeter

mg/L
milligrams per liter

mg/min/L
milligrams per minute per liter

mL
milliliters

MPN
most probable number

MRA
Microbial Risk Assessment

NAS
National Academy of Sciences

NSF
National Sanitation Foundation

NSW
New South Wales, Australia

NSRDEC
Natick Soldier Research Development and Engineering Center

NTU
nephelometric turbidity unit

NWRI
National Water Research Institute

OCONUS
outside Continental United States

PFU
Plaque-forming unit

Pp
Preventive medicine

PNNL
Pacific Northwest National Laboratory

PPE
personal protective equipment

QLD
Queensland, Australia

RBWC
risk-based water concentrations

SA
South Australia, Australia

SDWA
Safe Drinking Water Act

SMCL
secondary maximum contaminant levels

SS
suspended solids

TARDEC
U.S. Army Tank Automotive Research Development and Engineering Center

TAS
Tasmania, Australia

TDS
total dissolved solids

TKN
Total Kjeldahl Nitrogen

TSS
total suspended solids

TX
Texas, USA

VIC
Victoria, Australia

USACE
U.S. Army Corps of Engineers

USACHPPM
U.S. Army Center for Health Promotion and Preventive Medicine

USAPHC
U.S. Army Public Health Command

USEPA
U.S. Environmental Protection Agency; also EPA

USGS
U.S. Geological Survey

UV
ultraviolet (light)

UV_{254}
ultraviolet (light) (254 nanometer wavelength)

WEF
Water Environment Foundation

WHO
World Health Organization

Terms

Advanced Treatment
Advanced wastewater treatment processes provide reduction of nutrients, trace organics, and total dissolved solids. In addition, they provide a redundant barrier to pathogens that may have survived previous stages of treatment.

Biochemical Oxygen Demand (BOD, BOD_5)
“The amount of oxygen per unit volume of water required to bacterially or chemically oxidize (stabilize) the oxidizable matter in water. Biochemical oxygen demand measurements are usually conducted over specific time intervals (5, 10, 20, 30 days). The term BOD generally refers to standard 5-day BOD test.” (USEPA 1995).

Black Water
Source-separated wastewater from latrines and kitchens containing one or more of the following: urine, feces, toilet paper, food waste, and flush water (USAPHC 2014a)

Chlorine Residual
The chlorine present in the water after the chlorine demand has been met (USAPHC (Provisional) 2008).

Carbonaceous Biochemical Oxygen Demand (CBOD,CBOD$_5$)

(1) The carbonaceous (nonnitrogenous) stage of the bioassay for biochemical oxygen demand representing that portion of the oxygen demand involved in the conversion of organic carbon to carbon dioxide. The results are reported as CBOD or as CBOD$_5$ when a nitrification inhibitor is used; standard oxidation (or incubation) test period for CBOD is 5 days (Delzer and McKenzie in USGS 2003).

(2) CBOD$_5$ stands for carbonaceous biochemical oxygen demand. It is a method defined test measured by the depletion of dissolved oxygen by biological organisms in a body of water in which the contribution from nitrogenous bacteria has been suppressed. CBOD is a method defined parameter widely used as an indication of the pollutant removal from wastewater of organic matter (USACE 2014).

CFU (colony-forming Unit)
A measure of bacterial population density (single cells or cell clusters) resulting from a protocol involving membrane filtration of water samples, plating of the membrane onto suitable media, incubation, and counting of the resulting colonies (from Forster and Pinedo 2015). CFU/100 mL is a standard unit of comparison, and is calculated as follows:

$$\text{CFU/100 mL} = \frac{\text{number of colonies on membrane x 100}}{\text{volume (mL) of undiluted sample filtered}}$$

CT
Concentration ($C_{mg/L}$)·Time ($T_{minutes}$). The product of these two variables represents the disinfectant effectiveness. CT tables are provided by USEPA and others for various microbial hazards and water conditions. Though concentration should be measured after the demand has been realized, CT may not fully account for the interference of other water constituents (USAPHC 2014a). Units often in mg/min/L.

Coliform Bacteria
“Any fermentative, Gram-negative, rod-shaped anaerobic bacteria, typically found in the intestinal tracts of humans and other animals.” (Academic Press, 1992)

Coliphage
Viruses that infect and replicate in coliform bacteria; coliphages are used as indicators of fecal contamination in water (Bushon in USGS 2003)

Contingency Operations
Activities carried out in austere environments or under austere conditions; synonymous with deployed operations (USAPHC 2014a).

Direct Potable Reuse
The introduction of highly treated reclaimed water directly into the potable water supply distribution system (USAPHC 2014a).

Disinfection
The inactivation of pathogenic organisms (USAPHC (Provisional) 2008).

Data Utility
The usefulness of data (or data set) to answer a particular question (Thran and Tannenbaum 2008).

Disability-Adjusted Life Year
A metric used by the WHO as a means of quantifying the burden of disease from both mortality and morbidity; calculated as the sum of Years of Life Lost [YLL] due to premature mortality in the population and the Years Lost due to Disability [YLD] for people living with the health condition or its consequences. One DALY can be thought of as one lost year of "healthy" life. The sum of these DALYs across the population, or the burden of disease, can be thought of as a measurement of the gap between current health status and an ideal health situation where the entire population lives to an advanced age, free of disease and disability. Available at: http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/. Accessed 14 April 2016.

Effluent
Liquid that flows out of a process (USAPHC (Provisional) 2008).

Electrical Conductivity (EC)
A measure of a substance's ability to transmit an electrical current. Units are typically expressed in millimhos/meter (USEPA Office of Land and Emergency Management). Available at: http://www.epa.gov/swerust1/pubs/sam.htm. Accessed 18 April 2016.

Escherichia coli
A species of coliform bacteria. Some serotoypes (a specific kind of *E. coli*) of *E.coli* are pathogenic (able to cause disease) (USAPHC 2014b).

F-specific Coliphages
Coliphages that attach only to hairlike projections (called F pili) of coliform bacteria that carry an extrachromosomal genetic element called the F plasmid; F pili are produced only by bacteria grown at higher temperatures. F-specific coliphages presumably come from warm-blooded animals or sewage (Bushon in USGS 2003).

Fecal coliforms
Indicator bacteria which occur naturally in the intestines and feces of warm blooded animals (USAPHC (Provisional) 2008); subset of coliforms that are associated with the fecal material from warm-blooded animals. The representative species of fecal coliforms is *Escherichia coli* (USAPHC 2014b).

Force Provider
A modular base camp, capable of supporting 550 Soldiers with showers, kitchens, laundry, latrines, recreational services, and climate-controlled billeting (USAPHC (Provisional) 2008).

Gray water/Greywater
Wastewater from nonhuman waste sources such as showers, laundry, and handwash devices (USAPHC 2014b); untreated household wastewater that does not come into contact with toilet waste (USAPHC (Provisional) 2008).

Health Endpoint
An observable or measurable biological event used as an index to determine when a deviation in the normal function of the host has occurred (USEPA 2007b.)

Most Probable Number
A measure of the amount of microorganisms in a sample, based on serial dilutions (USAPHC 2014a).

Net-Zero Initiative
A holistic strategy founded upon long-standing sustainable practices and incorporates emerging best practices to manage energy, water, and waste at Army installations. Available at: http://www.asaie.army.mil/Public/ES/netzero/docs/FY13%20Army%20Net%20Zero%20and%20Energy%20Program%20Summary.pdf

Pathogenic Microorganism
Any disease-producing microorganism (USAPHC (Provisional) 2008).

Potable Water
Water that is safe for drinking (USAPHC (Provisional) 2008).

Personal protective equipment
Protective equipment individually worn by occupational populations, emergency responders and/or decontamination personnel to reduce/eliminate exposure to hazardous materials or conditions. Depending on need and conditions, PPE can include respirators, protective clothing, skin protection, eye protection and hearing protection. Available at http://www.cdc.gov/niosh/topics/emres/ppe.html. Accessed 13 April 2016.

Plaque-forming Unit
The organism (most commonly a virus) that is detected by plaque assays, in which a coliphage (or some other bacteriophage) is introduced into agar containing bacterial host cells and allowed to incubate for a set duration, after which the phage lyse the bacterial "lawn" and generate zones of clearing on the agar plate. These cleared zones are known as plaques. Each plaque represents the presence of a "plaque – forming unit," and is interpreted as representing a single phage particle in the original sample. This method is often used for the isolation and enumeration of phage particles in environmental samples (Panec and Katz 2006).

Primary Treatment
Primary treatment is a sedimentation process. This type of process removes SSs and some organic matter from the wastewater. It can also help remove chemicals and microbes that adhere to the solids (USAPHC 2014a).

Reclaimed Water
Wastewater effluent that has been adequately and reliably treated so that it is suitable for beneficial use (USAPHC (Provisional) 2008).

Recycle Water
Using water again in the process that generated it (USAPHC 2014a).

Reuse Water
Using water again for a different purpose (USAPHC 2014a.)

Secondary Treatment
Secondary treatment removes biodegradable organic matter and additional suspended solid matter using biological and chemical processes (USAPHC 2014a).

Settleable Solids
Particles of matter heavy enough to settle out of water under quiescent conditions (USAPHC (Provisional) 2008).

Somatic Coliphages
Coliphages that infect coliform bacteria by attaching to the outer cell membrane or cell wall. They are widely distributed in both fecal-contaminated and uncontaminated waters.

Suspended Solids
Small particles of matter that contribute to turbidity and resist separation by gravity (USAPHC (Provisional) 2008); organic and inorganic particles (sediment) suspended in and carried by a fluid (water). The suspension is governed by the upward components of turbulence, currents, or colloidal suspension (USEPA 1995).

Tertiary Treatment
Tertiary treatment employs another level of filtration to remove SSs and the microbial and chemical contaminants which may be entrained or adhered to the solids (USAPHC 2014a).

Total Coliforms
A term used to describe the amount of coliform bacteria in a water sample. Coliform bacteria are a large class of bacteria that can be found in the environment, soil, and water. Total coliforms are used as an indicator of water quality (USAPHC 2014b).

Total Suspended Solids (TSS)
A water quality measurement referring to dry weight of particles trapped by a filter (USACE 2014).

Turbidity
The cloudiness of water caused by the presence of fine suspended matter (USAPHC (Provisional) 2008). Cloudiness or haziness of a fluid caused by individual particles. For water quality it is measured by using a calibrated nephelometer and expressed in NTU. Particles in the water will scatter when a light beam is focused on them, and the nephelometer is set up with a detector to the side of the light beam (USACE 2014).

Use Case
A use case serves to tell the story of a flow of events and places functional requirements into context. A use case can serve as a bridge between stakeholders of a system and a development team working to provide information. There can be multiple exposure possibilities inside a use case (this document).

Water Reuse
The use of treated wastewater for beneficial application (USAPHC (Provisional) 2008).