# Advanced Water Purification (AWP):

# Technical Advisory Group (TAG) Recommendations

By

AWP: Technical Advisory Group

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Prepared for ADEQ

*Disclaimer: This document is solely a product of the volunteer technical advisory group members and should not be considered an ADEQ decision document. Several of these recommendations are still being discussed and may change.*

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# Table of contents

## Acronyms and Abbreviations

| Term | Means |
|---|---|
| LRV | Log Removal Value |
| LoD | Limit of Detection |
| WRF | Water reclamation facility |
| WPF | Water purification facility |
| SDWA | Safe Drinking Water Act |
| LRV | Log Removal Value |
| TOC | Total Organic Carbon |
| NDMA | N-Nitrosodimethylamine |
| MCL | Maximum contaminant levels |
| HAL | Health advisory level |
| GAC | Granular activated carbon |
| EBCT | Empty bed contact time |
| CCP | Critical control point |
| AWT | Advanced Water Treatment |
| AWTF | Advanced Water Treatment Facility |
| AWTO | Advanced Water Treatment Operator |
| DPR | Direct Potable Reuse |
| EOP | Emergency Operations Plan |
| ERP | Emergency Response Plan |
| TMF | Technical, Managerial and Financial |
| WWTP | Wastewater Treatment Plant |
| DW | Drinking Water |
| WW | Wastewater |
| FAT | Full Advanced Treatment |

# 1. Definitions

i. Barrier: A measure (treatment, operational or management) implemented to control pathogenic organisms or chemical substances. Pathogen log reduction credits are assigned only for treatment processes. Operational barriers (i.e., non-treatment barriers) that are part of ensuring the safety of DPR include source control, wastewater treatment plant optimization, operator certification, and technical, managerial, and financial capacity. (SWRCB 2019; NWRI 2018).

ii. Technical barrier or treatment barrier: A barrier which can be viewed as a physical barrier that can be credited with treatment performance. (Tchobanoglous et al 2015).

iii. Operational barrier: Measures that include operations and monitoring plans, failure and response plans, and operator training and certification (Tchobanoglous et al 2015).

iv. Salinity: Refers to the concentration of Total Dissolved Solids (TDS) in the water. Salinity of drinking water is primarily composed of cations such as sodium, potassium, calcium, and magnesium, and anions such as chloride, sulfate, carbonate and bicarbonate.

v. Mechanism: A physical, biological, or chemical action that reduces (not necessarily eliminate) the concentration of a pathogen or a chemical contaminant (SWRCB 2021).

vi. Redundancy: The use of multiple treatment and operational barriers to attenuate the same type of contaminant, so that if one barrier fails, performs inadequately, or is taken offline for maintenance, the overall system will still perform effectively and risk is reduced (NWRI 2018). Each step is partially or completely redundant of another (WRRF, 2014a). "Additionally, even when true redundancy is not provided, multiple barriers can reduce the consequences of a failure when it does occur"(A. Olivieri et al. 1999; Crittenden et al. 2005) as cited in (National Research Council 2012) (National Research Council 2012). "Redundancy strengthens the reliability of contaminant removal, particularly important for contaminants with acute effects" (National Research Council 2012). Extra treatment above minimal necessary is needed to make safe drinking water. Per (Pecson et al. 2015), "The use of measures beyond minimum requirements to ensure that treatment goals are more reliably met or that performance can be more reliably demonstrated". At least two units must be provided. For designs that include only two units, each unit must be capable of meeting the plant design flowrate. For designs with more than two filter units, the filters must be capable of meeting plant design flowrate with the largest filter removed from service.

vii. Resilience: Per definition contained in Table 3-1 of the Guidance Framework for Direct Potable Reuse in Arizona, a resilience is defined as "ability to adapt successfully or restore performance rapidly in the face of treatment failures and threats" (NWRI AZ 2018).

viii. Robustness: The ability of treatment technology to effectively remove a broad variety of compounds as concentrations of compounds are varied in source water (edited from NWRI 2018). presence of different types of treatment processes acting via different mechanisms such that a yet-unknown pollutant likely will be removed by multiple stages.

ix. Reliability: Per definition contained in Table 3-1 of the Guidance Framework for Direct Potable Reuse in Arizona, a reliability is defined as "ability of a treatment process or treatment train to consistently achieve the desired degree of treatment, based on its inherent redundancy, robustness, and resilience" (NWRI 2018).

x. Treatment train: Per definition contained in Table 3-1 of the Guidance Framework for Direct Potable Reuse in Arizona, a treatment train is defined as “a grouping of treatment technologies or processes to achieve a specific water quality goal” (NWRI AZ 2018).

xi. Chemical peak: Abnormal increase in the level of a chemical that represents a potential human health hazard that is the result of intentional or unintentional illicit discharges of chemicals to the sewershed. Chemical peaks are different from normal facility variation in water quality (CA Technical Memo 2020).

xii. Critical control point (CCP): Per definition in WRRF 13-03 CCP is “point in the treatment process that is specifically designed to reduce, prevent, or eliminate a human health hazard and for which controls exist to ensure the proper performance of that process”(WE&RF, Reuse 13-03 2016). CCP are individual treatment processes that control pathogens and chemical constituents (Tchobanoglous et al 2015).

xiii. Real time monitoring: Online monitoring for treatment performance for each process.

xiv. Pathogen Control Point Critical limits: Pathogen control point is the effluent from each pathogen removal process and critical limit is the monitoring value for each treatment process that indicates if each treatment is effective.

xv. Control system for each treatment that responds appropriately to the online monitoring for information.

xvi. Action level. A limit provided at a critical control point that, when exceeded, triggers a response to prevent a potentially hazardous event. Action limit will trigger a response action. Exceeding an action limit would necessitate taking immediate steps which could include shutting down the production of finished water within a documented time frame until a cause of the event can be identified and eliminated or taking that specific unit offline (if redundant units exist, e.g. multiple filters).

xvii. Alert levels. A limit provided at a critical control point that, when exceeded, alerts an operator that a potential problem may require a response. Exceeding an alert limit would necessitate further action and follow up monitoring, but may involve more investigation rather than just shutting down the production of finished water.

xviii. Indirect potable reuse. The introduction of advanced treated water to an environmental buffer such as a stream, reservoir, or groundwater basin before rediverting and further treating the water, if necessary, to ensure that it is safe for drinking.

xix. Direct potable reuse (DPR): The planned introduction of recycled water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant or public water system’s potable water pipelines or tanks for distribution to customers. This includes the treatment of reclaimed water at an Advanced Wastewater Treatment Facility for direct distribution.

xx. Raw water augmentation: The planned introduction of recycled water into a raw water supply that directly feeds a water treatment plant that supplies potable water to a public water system

xxi. Guidance document - “A non-binding practice recommendation intended to assist and guide actions of regulatory staff, regulated entities, or the public. Guidance documents are used to encourage or educate, and may provide background information or supporting details about a statute, regulation, or policy.” - See Guidelines for Direct Potable Reuse in Colorado.

xxii. Finished water:“Water produced in an Advanced Water Treatment Facility (AWTF), that is also permitted as a DWTF, supplied to the distribution system of a public water system and intended for distribution and human consumption without further treatment, except treatment as necessary to maintain water quality in the distribution system (e.g., booster disinfection, addition of corrosion control chemicals).” (California Water Resource Control Board 2021).

xxiii. Advanced purified water (ATW): Water produced in an AWTF using treated wastewater that is introduced as raw potable water source immediately upstream of a DWTF. APW may or may not meet the requirements of direct introduction into the drinking water distribution system. APW can be from more than one AWTFs (Tchobanoglous et al 2015).

xxiv. Use of existing treatment facilities to obtain disinfection credit leveraging SWTR of the SDWA to meet the required microbial log reduction objective of DPR. See pdf pg. 32 of (Tchobanoglous et al 2015).

xxv. AWTF that is also DWTF: AWTF that produces finished water that meets all federal, state and local regulations where water can be introduced directly into the distribution system.

xxvi. Bypassing the DWTF can only be done with appropriate monitoring and response time procedures. See pdf pg. 33 of (Tchobanoglous et al 2015).

xxvii. Engineered storage buffer (ESB): Per definition contained in Table 3-1 of the Guidance Framework for Direct Potable Reuse in Arizona (NWRI 2018), a barrier is defined as “a storage facility used to provide retention time—before ATW is introduced into the drinking water treatment facility or distribution system—to (1) conduct testing to evaluate water quality; (2) hold the water for a specified time in the event that it does not meet specifications;” (3) complement treatment by providing a barrier for pathogen and chemical control. A storage basin that is designed to provide sufficient time to monitor process performance and respond to acute contaminants (e.g., pathogens, nitrate). Transmission pipes can serve as ESB (Salveson et al. 2016a).

xxviii. Failure response time (FRT): The maximum possible time from when a process failure occurs in the treatment system to when the quality of the final product water is no longer affected by the failure. FRT is calculated as a sum of the sampling interval, sample turnaround time and system reaction time, with overall FRT based on treatment process with the highest individual FRT. It is assumed that process failures are inevitable as well as automated failure responses are built into the treatment system (Tchobanoglous et al 2015; Salveson et al. 2016a).

xxix. Blending: Mixing AWT effluent with another water source that will result in raw water augmentation (prior to DWTP) or treated water augmentation (directly to DS). Blending does not apply to engineered storage buffer (ESB) where storage of only AWT treated water takes place. Per “The use of blending for the averaging of chemical peaks has the distinct advantage that it is non-selective, i.e., it has the potential to reduce concentrations of all chemicals equally. To achieve blending of chemical peaks, an additional water source is required. The blending water source can be DPR water that passes through the advanced water treatment facility (AWTF) before and/or after the chemical peak, raw water during Raw Water Augmentation (RWA) or finished drinking water during Treated Drinking Water Augmentation (TDWA). Blending can occur in an engineered storage tank (Debroux, Plumlee, and Trussell 2021), in an impoundment, or within transmission piping”.

xxx. Log reduction value - A reduction in the concentration of a contaminant or microorganism by a factor of 10. For example, 1 log reduction value (LRV) corresponds to a 90-percent reduction from the original concentration, and 2 LRVs correspond to a 99-percent reduction from the original concentration.

xxxi. Pathogen. A microorganism such as bacteria, virus, or protozoa that can cause human illness.

xxxii. Online monitoring - Locating instruments directly in the process flow or sample line and monitoring water quality in real-time continuously or semi-continuously, with a sample time of 15 minutes or less.

xxxiii. Enhanced Source Control: “Enhancements to a source control program that are enacted specifically for potable reuse and public health protection.” (WRF 2023).

xxxiv. Indicator Compound: “INDICATOR COMPOUND means a chemical compound that has chemical properties that make it removable by some treatment processes but that may be recalcitrant to others. Indicator compounds are indicative of other compounds in that family of compounds and can be used to monitor the efficacy of removal of that group of compounds by a critical control point.” (CDPHE 2023).

xxxv. Interference Hazard: “An interference hazard is defined as a contaminant that can inhibit or disrupt the treatment system’s processes or operations and compromise the safety of water by means other than pass-through. Examples of interference hazard include oxidant and radical scavenging, membrane scaling, biological inhibition, and contaminants with the potential to biodegrade or oxidize into other chemicals that would be more toxic.” (WRF 2023).

xxxvi. Pass-through: “PASS THROUGH means a condition where a constituent of concern enters the waterworks in quantities or concentrations that have a significant potential to have serious adverse effects on public health or to cause a violation either of a treatment technique requirement or of an MCL in finished drinking water.”(CDPHE, 2023).

xxxvii. Source Control Program: “Activities under a Pretreatment Program associated with limiting the discharge of contaminants into a wastewater collection system that can impact wastewater treatment, worker health and safety, or resource recovery.” (WRF 2023).

xxxviii. Treated Wastewater: “Any water source from a wastewater treatment plant that has undergone treated wastewater characterization for either enhanced wastewater treatment or secondary wastewater treatment and originates from a wastewater treatment plant that has liquid stream treatment processes that, at a minimum, are designed and operated to produce oxidized wastewater to achieve a defined source water quality for additional treatment by a supplier utilizing direct potable reuse.” (CDPHE 2023).

# 2. Pathogen Control

Background: Based on available scientific literature and data, characterize the risk posed by human pathogens in wastewater to determine log reduction value (LRV) targets for direct potable reuse.

- Characterize expected human pathogen concentrations in wastewater and treated wastewater.
- Identify tolerable drinking water concentrations.

- Determine the total LRVs needed to achieve the tolerable drinking water concentrations under a range of conditions.

Enteric viruses (specifically norovirus), *Giardia* cysts, and *Cryptosporidium* oocysts have been selected as the reference pathogens.

These pathogens/groups, along with pathogenic bacteria (e.g., *Salmonella*), are the major contributors to gastrointestinal episodes in the U.S. Designing for viruses, *Giardia*, and *Cryptosporidium* is assumed to be protective of bacteria based on historical precedent (Regli et al. 1991; Soller et al. 2017; Amoueyan et al. 2019) and quantitative microbial risk assessments (QMRAs) in the peer-reviewed scientific literature.

- The sub-group discussed which virus should be reflected in the final recommendation. Enterovirus, adenovirus, and norovirus were evaluated and norovirus has been identified as target virus.

Pathogen log reduction value (LRV) targets are determined based on an annual risk of infection of 1 in 10,000 ($10^{-4}$), which was originally proposed by the U.S. EPA for control of *Giardia* in drinking water (Regli et al. 1991) and has also been used in the development of potable reuse regulations in other states.

- The sub-group discussed implementation of a daily risk of infection benchmark of $2.7 \times 10^{-7}$ (annual risk of $10^{-4}$ divided equally over 365 days), similar to what was proposed in California for DPR. However, it was determined that increased costs/burden to the community to implement a DPR program does not necessarily translate to benefits in terms of public health.
- The sub-group discussed compliance targets (e.g., 99$^{th}$, 99.9$^{th}$) that can potentially be used to identify final LRV targets. 97.4$^{th}$ percentile was selected as it coincided with treated effluent option (N = 24 samples).
- Editorial note: Consistent with the U.S. EPA's Long Term 2 Enhanced Surface Water Treatment Rule (LT2) and the raw wastewater monitoring campaign in Pecson et al. (2022), characterization of pathogen concentrations for a given location is often based on approximately 24 samples (N = 24). See (Blom, 1958) - Percentile = (Rank – 0.375) / (N + 0.25).

QMRA scenarios were evaluated using DPRisk (version 1.01; 11.05.2020), a publicly available web-based tool that was developed by the Water Research Foundation (WRF) to facilitate development of regulatory frameworks for potable reuse (Gerrity 2021). In addition, LRVs were also calculated as the difference between raw sewage maximum density from literature and tolerable drinking water density using AZ specific data, dose-response models listed below (See bullet 5) and ingestion volume of 2.5 L/day.

QMRA scenarios were developed using a recently published raw wastewater pathogen concentration dataset that has been demonstrated to be robust, representative of conditions in the U.S., and consistent with historical data in peer-reviewed literature (Pecson et al. 2022).

- The sub-group discussed the appropriateness of using molecular (e.g., qPCR) data, which is important for norovirus in particular because of the lack of a reliable culture-based method to assess viability/infectivity. Norovirus is important to consider because it has been identified as a potential driver of risk in published QMRAs (Soller et al. 2017) and is the most common cause of acute gastroenteritis in the U.S (Scallan et al. 2011).

- The sub-group discussed potential modifications to the reported statistical distributions in Pecson et al. (2022) to account for method limitations. For example, it is estimated that only 10% of potentially infectious viruses are captured by cell culture methods. Also, molecular data can be adjusted using published gene copy to infectious unit (GC:IU) ratios to better reflect potential infectivity (Pecson et al. 2022).

Multiple dose response models were evaluated for the reference pathogens. The following were selected:

- Norovirus: Hypergeometric.
- Giardia: Exponential dose response model.
- Cryptosporidium: Beta-Poisson.

A range of ingestion assumptions were considered when developing the QMRA scenarios.

- Volume: QMRAs typically assume 2 L per day ($90^{th}$ percentile in the U.S.) or 2.5 L per day (US EPA).
- Frequency: Historically, QMRAs have assumed a single ingestion event each day, but more recent QMRA literature has included up to 8 ingestion events per day to evaluate the impacts of off-specification conditions. California assumes 96 ingestion events per day to coincide with online monitoring frequencies. The mean in the U.S. is approximately 4 ingestion events per day.

The sub-group considered the appropriateness of including treatment failure scenarios when selecting target LRVs.

- Strategies for mitigating the risks of treatment failures include specifying tolerance for off-specification treatment or requiring treatment redundancy.
- Sub-group briefly evaluated a range of failure scenarios defined by their magnitude, duration, and frequency. However, no consensus was reached.
- Sub-group considered 4 additional logs to account for treatment failure similar to California for each reference pathogen, but recommended that something other than 4 be considered. This is critical as it will help avoid frequent shutdowns/flow diversions or increased risk to public health.
- Modeled scenarios has off-specification considerations for limited amount of time without exceeding the risk level.

Two options have been identified for demonstrating compliance with pathogen LRV targets:

- **Option 1**: 13 log enteric virus, 10 log *Giardia* cyst, and 10 log *Cryptosporidium* oocyst reduction between raw wastewater and finished drinking water.
    - Justification: Historical precedent, broad applicability without the need for site-specific monitoring (i.e., reduced burden on the facility, not impacted by varying levels of primary/secondary treatment at different facilities).

- **Option 2**: XX log enteric virus, XX log *Giardia* cyst, and XX log *Cryptosporidium* oocyst reduction between treated wastewater (XX is defined by utility) and finished drinking water determined based on site specific monitoring. As treatment within a wastewater treatment plant is quite variable between processes, among treatment plants with the same treatment processes, this option will continue to be refined.

- Justification: potentially more flexible, but at the cost of implementing a long-term sampling campaign at each facility, avoids difficulty in developing a crediting framework for upstream wastewater treatment, potentially more appropriate for separate advanced water treatment (AWT) facilities.
- The interested agency must sample for the reference pathogens for a min. of 2 year period at min. interval of 1 sample per month.
- The interested utility must perform a QMRA to identify target LRVs for the AWT facility that are consistent with the observed pathogen concentrations and are adequately protective of public health (i.e., achieve specified risk benchmarks).
- AWT LRVs must at least be greater than 8/6/5.5 for viruses, *Giardia*, and *Cryptosporidium*, regardless of the results of the site-specific sampling campaign. Minimum LRVs should be determined by site-specific monitoring programs (i.e., replacing non-detect effluent concentrations with study-specific limits of quantification). Thus, a study with larger sample volumes and/or higher recoveries might be able to justify lower LRVs, assuming all concentrations are non-detect. For example, assuming a study with all non-detects had a LoD of 1 oocyst per 100L with 1% recovery, the resultant LRV requirement would be 7.0, but if they could improve the study to 1000L volumes that would decrease the LRV requirement by a factor of 10 to 6.0.
- Recommendations were made to use an external advisory committee when Option 2 is considered.

# 3. Chemical Control & Enhanced Source Control

## 3.1. Chemical control

### 3.1.1. Categories of chemicals to monitor:

To control chemicals in a DPR project, a three tiered monitoring approach should be implemented for addressing a range of chemicals, including both regulated and unregulated chemicals (NWRI 2018). The tiers would be based on the type of monitoring:

- Tier 1 - SDWA and State Requirements: Potable reuse projects must meet all SDWA standards (primary and secondary MCLs) and other requirements, if any, set by the State of Arizona for drinking water. (NWRI 2018).
    - Monitoring location: Finished water at EPDS (Advanced Treated Water (ATW)/ finished water) and treated wastewater. (California Water Resource Control Board 2021; NWRI 2019)
    - Frequency of monitoring will be similar to drinking water.

- Tier 2 - This includes chemicals that are not regulated in SDWA, but could be present in treated wastewater and is a potential health concern as it may pass through AWT. (NWRI 2018). Examples include - 1,4- dioxane, N-nitrosodimethylamine (NDMA).
    - Utility defined and ADEQ approved list of unregulated chemicals. See Section 3: “Method to select Unregulated chemicals (i.e., Tier 2 chemicals)”.
    - Monitoring location: Treated wastewater and finished water. (NWRI 2019)
    - Frequency of monitoring: The department recommends twice per month sampling and at least once per month sampling is required. Refer to the schematic for chemical monitoring prior to initiating DPR. At startup, monitoring must be monthly for one year and then monitoring frequency may be changed to quarterly, or more or less frequently, at the department’s discretion in the approved operating plan. (CDPHE 2023)
    - Finished water monitoring data must be reported in the consumer confidence reports. (group consensus)
    - The utility shall propose an action level for each of the contaminants that are being monitored and must be approved by ADEQ. The utility shall further propose a series of responses that will be implemented if any contaminants exceed the respective action level. This response shall include, at minimum, notifying ADEQ. (Group consensus)

Action limits are limits provided at critical control points that, when exceeded, triggers a response to prevent a potentially hazardous event (NWRI 2019). Action limit will trigger a response action. Exceeding an action limit would necessitate taking immediate steps which could include shutting down the production of finished water within a documented time frame until a cause of the event can be identified and eliminated or taking that specific unit offline (if redundant units exist, e.g. multiple filters). (CDPHE 2023).

Alert limits are limits provided at critical control points to inform operators that they may need to take an action (NWRI 2019). Exceeding an alert limit would necessitate further action and follow up monitoring, but may involve more investigation rather than just shutting down the production of finished water. For example, if the finished water TOC is above the 75th percentile of the median distribution TOC, then it is appropriate to investigate the cause of the alert limit being triggered.Each action and alert limit must have a corresponding action or actions identified to ensure the process is recovered properly and public health is not jeopardized. These detailed response actions must be included in the operations plan (a document that will be submitted at the time of AOC submittal) and be specific to the facility and the type of operation controls that exist at that facility. (CDPHE 2023)

- Tier 3 - Monitor for unregulated chemicals (performance based indicators) that are useful for evaluating the effectiveness of organic chemical removal by the treatment trains. (NWRI 2018).

  These are chemical indicators chosen to monitor treatment performance in the treated wastewater and finished water. Indicator compounds have chemical properties that make them removable by some treatment processes but recalcitrant to others. For example, several artificial sweeteners that are approved for human consumption are useful indicators because of their recalcitrance to biological treatment. (CDPHE 2023).

  - Monitoring Location - Regularly monitored at the critical control points and in finished water. (Group consensus and (NWRI 2019)).
  - Frequency - Similar to Tier 2 chemicals.
  - The utility shall propose an action level for each of the contaminants that are being monitored and must be approved by ADEQ. The utility shall further propose a series of responses that will be implemented if any contaminants exceed the respective action level. This response shall include, at minimum, notifying ADEQ. (Group consensus)
  - Method for selecting Tier 3 chemicals: See Section 4: "Method for selecting performance based indicators".

  These are the chemicals that are detected frequently and at sufficiently high concentrations relative to their detection limits so as to make them useful measures of the removal of health-significant organic chemicals with a variety of structures and physical chemical properties. If the levels in the ATW are above the performance criterion, it may not be necessary to shut down operations; however, the treatment approach should be evaluated in collaboration with regulators to ensure that levels remain below the performance criterion. (NWRI 2018).

  Therefore, the final indicator selection must consider the established steps/criteria as mentioned in Section 4: "Method for selecting performance based indicators" and also use site-specific pilot study data to verify assumptions. By following these criteria, the ability of a treatment plant to remove virtually any chemical can be demonstrated with as few as four indicators (assuming for example minimum three treatment barriers, three for individual chemical contaminants removed by each of the required three chemical treatment barriers and one for the system as a whole). (CDPHE 2023).

**Other States' recommendations:**

California: Monthly sampling is required for primary and secondary MCLs and action levels, priority toxic pollutants, notification levels, specific solvents (acetone, methanol, methyl ethyl ketone, N,N-dimethylacetamide), treatment byproducts and their precursors. The sampling locations are: (California Water Resource Control Board 2021)

i. Municipal wastewater that feeds the DPR project;

ii. Advanced treated water at a location immediately after advanced oxidation; and
iii. Finished water prior to an entry point to the distribution system.

Colorado: Recommends bimonthly sampling for target chemicals and at least once per month sampling is required during the first year of operation. CDPHE may adjust the monitoring frequency to quarterly, or more or less frequently, as justified by the variability of the monthly results. (NWRI 2019).

### 3.1.2. Source water monitoring requirements (period of monitoring, sampling frequency and contaminants to be sampled)

Source water characterization study is a part of the enhanced source control program that includes identification and control of chemicals entering the wastewater collection system. Before the project startup, a source water characterization study should be performed. The study will identify all dischargers within the sewershed of each WRF contributing source water to the DPR project. (NWRI 2019)

Conduct source water characterization studies on the types and quantities of chemicals that can be present in treated wastewater. The results would help determine what chemicals need to be monitored and how much removal is needed. (NWRI 2018)

- Minimum monitoring requirements for regulated chemicals in Drinking water (Primary and Secondary MCLs) should be for at least one-year. It should be sampled monthly. (Colorado DPHE 2023). Sampling should be done prior to submitting a DPR facility permit application to ADEQ (Minimum 12 samples). One full year of monitoring with samples that are approximately a month apart, essentially to capture seasonality. (Group consensus).
- Besides the Regulated chemicals (primary and secondary MCLs), unregulated chemicals should also be included in the monitoring that may impact the specific AWTF treatment systems or have pass-through and be an issue for potable water requirements. (Colorado DPHE 2023)
- Sampling point would be the location at which wastewater will be diverted to the DPR facility (regulated and unregulated chemicals sampling). Justification: Recovery rates using standard methods are higher. ((Colorado DPHE 2023) and Group consensus).

The utility should start sampling monthly for the 1st year. If the results are found consistent then sampling frequency can be reduced to quarterly. In case, there are some chemical spikes or new industries, the sampling frequency can be moved back to monthly again. The state of Colorado recommends that after the initial baseline monitoring is complete, the routine sampling frequency can be reduced, as justified by the variability of the monthly results (NWRI 2019).

Need at least 1 year of sampling data to adequately characterize the source. There will be variability during the year, for example, temperature variation can be captured for the whole year. Minimum number of samples should be 12 and depending on the sampling data or if there is any concerning level of a certain contaminant, the frequency or number of samples can be increased.

A utility must collect these samples evenly throughout the year so as to reflect seasonal variability. Without seasonal data, changes in water quality cannot be scientifically factored into treatment plant design. For example, people drink and flush more water in the summer so the contaminant levels in summer may be less than those in the winter. (Texas Water Development Board 2015).

**Other States' approaches:**

California: Requires 2 years of monthly sampling. Monitoring is required for primary and secondary MCLs, unregulated compounds listed in the Drinking Water Notification Levels (NL) list, priority toxic pollutants, low molecular weight compounds, such as methanol, methyl ethyl ketone, N,N-dimethylacetamide identified as a risk to RO.

Colorado: A minimum of 1-year, monthly sampling is required prior to design. Monitoring is required for both Target chemicals (unregulated chemicals of human health concern) and Indicator chemicals (as selected for each treatment barrier). The department recommends that the supplier propose a list of likely target chemicals for approval prior to the one-year of monitoring. (Colorado DPHE 2023)

Texas: Recommends sampling at least for one year prior to project and during pilot study for specific constituents. Texas Commission on Environmental Quality (TCEQ) requires characterizing wastewater effluent over a period of time that includes seasonal variations. Wastewater effluent should be tested a minimum of four times over the same one year period: one in the summer at the hottest temperature, once in the winter at the lowest temperature, and once in spring and fall at the midpoints. (Texas Water Development Board 2015)

U.S. EPA Long Term 2 (LT2) enhanced surface water treatment rule (ESWTR): Monitoring is required for source water to determine treatment requirements. The monitoring includes an initial two years of monthly sampling for parameters: Turbidity, *E.coli*, and Cryptosporidium (U.S. EPA 2006).

### 3.1.3. Method to select Unregulated chemicals (i.e., Tier 2 chemicals)

Selection of unregulated chemicals will be site-specific. This will ensure that each utility only monitors chemicals that are specific to their sewershed and not unduly burden any utility with an expensive monitoring campaign. The utility should propose this list of unregulated chemicals based on industries and/or commercial establishments within its sewershed. The utility should obtain ADEQ approval prior to the start of any monitoring campaign. Submittal of monitoring data and analysis will be required before the submission of the initial application, i.e., the Approval To Construct (ATC) application. See timeline schematic in Section 5. This approach will ensure that there is an agreed list prior to the commencement of any sampling campaign and avoid any costly rework.

The list should be developed using the following steps which are based partly on the WRF 4960 Report (WRF 2023). The site-specific list should be periodically reevaluated (every 3 years) by following the specific steps for chemical selection (Group consensus).

**Step 1:** List all industrial and/or commercial establishments within the sewershed.

**Step 2:** List the chemicals used or discharged as a part of the processes used by the industrial and commercial facilities (i.e., provide an inventory of chemicals used and stored at the facilities).

**Step 3:** Contributing sources: Identify the industries that pose the greatest risk to potable reuse systems. This should be done by focusing on potential for large chemical spills or discharges both intentional or unintentional and based on the toxicity of the chemical.

Some utilities may have industries in their collection systems that are known challenges, whether inherently because of the type of industry or because of how it is operated or managed. It is recommended that all landfills, centralized waste treatment (CWT) facilities, and metals finishers be included as well as any chemical manufacturers that have complex or challenging discharge. (WRF 2023)

**Step 4:** Identify if any control, communication, or monitoring mechanisms that can be implemented at the industry to alert the WWTP and AWT in the case of a spill.

**Step 5:** Develop a list of chemicals, i.e., a subset from Step 2 based on the contributing sources, that may interfere with impact specific AWTF treatment processes (i.e, potential for pass through) or and affect potable water quality. This is an exercise in paper. Also develop a list of chemicals with pass-through potential using…..[in the paper is the ICSS…]

An interference hazard is defined as a contaminant that can inhibit or disrupt the treatment system's processes or operations and compromise the safety of water by means other than pass-through. Examples of interference hazard include oxidant and radical scavenging, membrane scaling, biological inhibition, and contaminants with the potential to biodegrade or oxidize into other chemicals that would be more toxic. (WRF 2023)

Along with the list of pass-through chemicals, a utility should identify and propose a list of potentially interfering chemicals based on the contributing sources and propose a mitigation plan which should be submitted to ADEQ for approval.

**Step 6:** Once the chemical lists (from Step 5) is developed, perform treated wastewater characterization (i.e., WWTP effluent sampling) to identify chemicals that must be treated, monitored, and controlled through the Enhanced Source Water Control Program or other means. This is actual sampling of chemicals that were identified in Step 5.

**Step 7**: Perform risk analysis of each contaminant using site specific sampling data.

Use the sampling data (concentration of contaminants) and the industrial contaminant screening score (ICSS) obtained from literature review (see WRF 4960 Report for more details) to calculate the Industrial Contaminant Risk Quotient (ICRQ), which is the risk for each contaminant.

ICRQ = ICSS × Average concentration (mg/L) × Exposure factors

The ICSS accounts for toxicity and removal for each contaminant across the advanced treatment trains. ICSS provides a metric that prioritizes the contaminants based on pass-through potential and toxicity. ICSS was calculated by dividing the estimated fraction of the contaminant remaining after advanced treatment (1 – R_overall) by the lower of two toxicity metrics: oral chronic reference dose (RfD) (milligrams per kilogram per day [mg/kg/day]) or risk-specific dose (RSD) (mg/kg/day). The details are provided in WRF 4960 Report.

ICSS provides a metric that prioritizes the contaminants based on pass-through potential and toxicity. It is recommended that ICSS values be updated with site-specific removal values, as available. The ICSS calculation is shown in the following equation: (WRF 2023)

$$ICSS = (1 - R\_overall)/min\{RfD, RSD\}$$

RfDs are calculated by dividing the No Observed Adverse Effect Level (NOAEL) by safety factors for interspecies differences, intraspecies sensitivity, and other uncertainty factors. RfDs generally pertain to non-cancer toxicity endpoints. RSD based on a one-in-ten-thousand risk (10-4 risk) was calculated from oral cancer slope factor (CSF) as: (WRF 2023)

$$RSD = [\![10]\!]^\wedge(-4)/CSF$$

RfDs and CSFs can be obtained from the Risk Assessment Information System database or the EPA list of health advisories. The integrated Risk Information System (IRIS) database also includes guidelines on how to evaluate human health hazards for new chemicals and new health risk data. (WRF 2023)

- Document risk of each contaminant and develop mitigation plans for any contaminant with **ICRQ > 0.5,** which will trigger **<u>ongoing</u>** source water monitoring for the contaminant.
  (WRF 2023) stated that **“**Contaminants with an ICRQ greater than 0.2 should be tracked in the Industrial ESCP, as recommended in (Drewes et al. 2018)**”.**
- Any contaminant with ICRQ>0.5 shall be monitored monthly. The department may allow upon request a system to reduce the sampling frequency to quarterly if all analytical results from four consecutive monthly samples are reliably and consistently ICRQ < 0.5. The system must return to monthly monitoring for any contaminant with ICRQ > 0.5. (This language is based on the surface water/groundwater nitrate monitoring requirements found in 40 CFR 141.23.d.2 and 40 CFR 141.23.d.3).
- An ICRQ greater than 1.0 suggests that the contaminant could be in the AWTP effluent (i.e, finished water) at concentrations above the recommended health levels. This will trigger discussion on additional treatment steps or ways to reduce the source loading (i.e., part of enhanced source control), such that the ICRQ is consistently below 1.0. (WRF 2023).

**Step 8:** Determine the loading rates (load-based contributions of contaminants) at which the industrial and commercial facilities are going to be discharging.

- WRF 4960 report (WRF 2023) recommends identifying the industrial dischargers that are significant contributors of the contaminant and recommends working with each industry that has a greater than 5 percent contribution on a load basis.
- Establish site specific or local limits, if needed.
- Consider isolating or eliminating specific dischargers.

**Step 9:** Design the AWT treatment train by considering chemical contaminants that are expected at the AWT facility. Such considerations must include loading rates and the associated risk.

**Step 10:** Continue tracking new industries/commercial establishments into the sewershed and communication with industries about any changes in operation that could have resulted in higher discharge concentrations.

**Comparison of method B along with procedure for the Selection of Unregulated Chemicals (Tier-2)**

**Step 1:** List all categories of dischargers within the sewershed along with identification of industrial and commercial dischargers.

**Step 2:** List all chemicals used by the identified dischargers along with all chemicals that are discharged by each discharger (i.e., provide an inventory of chemicals used and stored at the facilities).

**Step 3:** Identify the industries that pose the greatest risk to potable reuse systems. This should be done by focusing on potential for large chemical spills or discharges both intentional or unintentional and based on the toxicity of the chemical and the mass loading of the chemicals into the water coming to the DPR plant.

Some utilities may have industries in their collection systems that are known challenges, whether inherently because of the type of industry or because of how it is operated or managed. It is recommended that all landfills, centralized waste treatment (CWT) facilities, and metals finishers be included as well as any chemical manufacturers that have complex or challenging discharge. (WRF, 2023)

**Step 4:** Identify any control, communication, or monitoring mechanisms that can be implemented at the industry to alert the WWTP and AWT in the case of a spill.

**Step 5:** Develop a list of chemicals, i.e., a subset from Step 2 based on the contributing sources, that may interfere with specific AWTF treatment processes and pass through or affect potable water quality. This is an exercise in paper.

Along with the list of pass-through chemicals, a utility should identify and propose a list of potentially interfering chemicals based on the contributing sources and propose a mitigation plan which should be submitted to ADEQ for approval.

**Step 6:** Once the chemical lists (from Step 5) is developed, perform treated wastewater characterization (i.e., WWTP effluent sampling) to identify chemicals that must be treated, monitored, and controlled through the Enhanced Source Water Control Program or other means. This is initial monitoring of chemicals that were identified in Step 5.

To address potential disparities resulting from variation in time of day/week in samples, composite sampling should be done. The state of Colorado also recommends composite sampling. One year of sampling will be required at a minimum of once per month. The department recommends suppliers perform 24-hour composite sampling for certain parameters a minimum of 26 times spread about evenly throughout the year. Sample times are expected to target days that would provide the most information about the quality of the sources (CDPHE, 2023).

**Step 7:** Use the sampling data (concentration of contaminants, mg/L) to calculate **the Risk in "Method A (current method)"** or **the safe volume of consumed water (L/day) in "Method B (new proposed method)"** as following:

Notes for the New Proposed Method:

- If concentrations from individual dischargers are known those can be used in the example spreadsheet following steps (a) to step (h) in this document.
- If the concentrations in the treated wastewater is known, those can be directly used as the expected concentration at the DPR plant in step (d) and continue following steps (e) to step (h).

<table>
<tr><th>Step</th><th>Method A (Current method)</th><th>Method B (New Proposed Method)</th></tr>
<tr><td colspan="3">For both the current method and the new proposed method, the above steps (Step 1-Step 6) are the same. The only difference between the two methods is the calculation of the threshold value in step 7 based on which unregulated chemicals will be selected. The WRF 4960 approach (current methods) utilizes an arbitrary factor of 0.2. The EPA documents based approach (new proposed method) could be utilized for the initial screening with or without concentrations from individual dischargers.</td></tr>
<tr><td>7</td><td>Perform risk analysis of each contaminant using site specific sampling data.<br><br>The calculation is based on the WRF 4960 Report. (WRF, 2023)<br><br>Use the sampling data (concentration of contaminants in the treated wastewater effluent; location where water will be diverted to AWTF) and the industrial contaminant screening score (ICSS) to calculate the Industrial Contaminant Risk Quotient (ICRQ), which is the risk for each contaminant.</td><td>Calculate the Total Contaminant Load (lb/day) and the safe volume of water consumed (L/day) for each contaminant.<br><br>The calculation is based on the EPA method.<br><br>ADD = Cmedium x IngR x EF x ED / BW x AT<br><br>Where:<br>ADD = Average daily potential dose (mg/kg-day)<br>$C_{medium}$ = Concentration of contaminant in medium (e.g., mg/L, mg/g)<br>IngR = Ingestion rate (e.g., L/day, g/day)<br>EF = Exposure frequency (days/year)<br>ED = Exposure duration (years)<br>BW = Body weight (kg)<br>AT = Averaging time (days)<br><br>https://www.epa.gov/expobox/exposure-assessment-tools-routes-ingestion</td></tr>
</table>

| | | |
|---|---|---|
| | **ICRQ = ICSS x Average conc. (mg/L) x Exposure factor**<br><br>$ICSS = \frac{(1-R_{overall})}{min\{RfD, RSD\}}$<br><br>$RSD = \frac{10^{-4}}{CSF}$<br>RfDs and CSFs can be obtained from the EPA Drinking Water Health Advisories (HAs), US EPA IRIS database, US EPA Provisional Peer-Reviewed Toxicity Values (PPRTVs) Assessments.<br><br>**Assumptions:**<br><br>○ The removal of the contaminant across each of the selected advanced treatment processes can be evaluated based on available literature. If the site-specific removal values (% Removal) is available based on pilot testing or other testing for each treatment process, the utility should update the ICSS.<br><br>○ There is not a lot of scientific literature for the 0.2 value.<br>○ Exposure factor: Typical EPA lifetime Health Advisory (HA) assumptions: an average adult weighs 70 kg, consumes 2 L/day, 20% of a person's intake of this chemical comes from water. | ● (a) Calculate Mass Loading of contaminant for each discharger:<br><br>Mass loading of contaminant (lb/day) = Flow (MGD) x Average Concentration (mg/L) x 8.34 (for unit conversion)<br><br>● (b) Calculate Total contaminant load (lb/day):<br>$Total\ Load\left(\frac{lb}{day}\right) = \sum Mass\ loading\left(\frac{lb}{day}\right) for\ all\ discharger$<br><br>● (c ) Calculate Total Influent Flow (MGD) coming to the DPR plant from all dischargers.<br><br>$Total\ Influent\ Flow\ (MGD) = \sum Flow\ (MGD) from\ all\ disch$<br><br>● (d) Calculate Expected concentration at DPR influent (mg/L):<br><br>$\text{Expected concentration (mg/L)} = \frac{Total\ Contaminant\ Load\ (lb/day)}{\left(max\begin{cases}DPR\ Plant\ Capacity\ (MGD)\\ Total\ Influent\ Flow\ (MGD)\end{cases}\right) \times 8.34}$<br><br>● (e) Obtain the Reference dose (RfD, mg/kg-day) or Cancer Slope Factor (CSF) from EPA IRIS Database.<br><br>● (f) Determine Risk Specific dose, RSD (mg/kg-day):<br>$RSD = \frac{10^{-4}}{CSF}$<br><br>● (g) Calculate Safe Exposure level at 10% of life span (70 years) for an average person of body weight of 70 kg.<br><br>Safe Exposure level (mg) = min {RfD or RSD} x BW (kg) x 70 years x 365 days/year x 0.10<br><br>● (h) Calculate safe volume of water consumed (L/day):<br><br>$Water\ consumed\ (\frac{L}{day}) = \frac{Safe\ Exposure\ level\ (mg)}{Expected\ concentration\ (\frac{mg}{L}) \times (70 \times 365) days \times 0.10}$<br><br>**Assumptions:**<br><br>○ For exposure calculation, **10% of average life** expectancy (**70 years**) was assumed. (US EPA, 2002)<br>○ For calculating the safe amount of water consumed to avoid health consequences, **the consumption of 2 L/day was adjusted with a safety factor of 10.** |

| | | |
|---|---|---|
| 8 | Document risk of each contaminant and develop mitigation plans for any contaminant with **ICRQ > 0.2,** which will trigger **ongoing** source water monitoring for the contaminant.<br><br>An ICRQ greater than 1.0 suggests that the contaminant could be in the AWTP effluent (i.e, finished water) at concentrations above the recommended health levels. This will trigger discussion on additional treatment steps or ways to reduce the source loading (i.e., part of enhanced source control), such that the ICRQ is consistently below 1.0. (WRF, 2023). | If the **safe volume of water consumed > 20 L/day** the contaminant is **NOT** expected to pose any health consequences, otherwise these should be included in the monitoring program. |

### 3.1.4. Method for selecting Performance Based Indicators (PBI), i.e., Tier 3 chemicals

Indicator chemical selection should be site-specific. The initial candidate list should also take into account expected chemical discharges from local industries/commercial facilities. The indicators should target specific treatment processes used at the specific DPR facility. (CDPHE 2023). A utility should submit a list of indicator compounds to ADEQ for approval.

**Procedure used by the State of Colorado to consider:**

- The State of Colorado established specific criteria/steps for indicator compound selection, i.e, Tier 3 chemical selection. ADEQ approval of the Tier 3 chemicals can be accomplished using site-specific pilot study data submitted by the utility to determine the appropriate number and types of indicator chemicals. Colorado recommends that the DPR train should be designed, built, and operated to remove at least 75% of each indicator compound as measured from the treated wastewater to the finished water (CDPHE 2023).

- The Colorado DPR policy (CDPHE 2023) and the AWWA study report: "A performance-based indicator chemical framework for potable reuse" (Thompson and Dickenson 2020) recommended the following criteria for the selection of indicator compounds.
- All criteria cannot be met. It may be challenging to meet all the criteria in the following Table with indicator compounds that are prevalent in treated wastewater at relevant concentrations. While the criteria below represent the ideal, site-specific pilot study data will be used case by case by the utility and the department to select the appropriate number and types of indicator compounds. (CDPHE 2023)

Table: Proposed criteria for selection of Tier-3 chemicals (Performance based indicators), (CDPHE 2023)

| Criterion | Description |
|---|---|
| Concentration | The PBI should have a median concentration at least five times greater than its MRL (method reporting limit). Otherwise a high percentage of removal cannot be demonstrated. The median concentration divided by the MRL is referred to as detection ratio (DR). |
| Prevalence | The PBI should have a detection frequency (DF) over 80% in the site-specific treated wastewater. Otherwise, its absence may be random or seasonal and may not reflect treatment efficacy. For example, sunscreen UV blockers or allergy medications follow a seasonal occurrence pattern in treated wastewater (Petrie, Barden, and Kasprzyk-Hordern 2015). (CDPHE 2023) |
| Measurability | Sufficiently precise and sensitive analytical methods for the compound are necessary to meet the above two criteria.<br>Analytical methods should be well established in the scientific literature. While some methods may be approved by the EPA, the department can allow other methods that are well-established but not yet EPA approved. |
| Specificity | The indicator compound should be removable by the process(es) it is intended to monitor.<br>It should be sufficiently recalcitrant to any upstream processes—or at such high concentration in the treated wastewater—that it meets the concentration and prevalence criteria at the influent of the targeted treatment process.<br>Optionally, the indicator compound should be recalcitrant to downstream processes as well, however that may not always be the |

| | |
|---|---|
| | case. If all indicators meet this sub-criterion, then all indicators could be monitored at just two sampling locations (WPF influent and final effluent).<br>This criterion is based on convenience and operational efficiency, however in practice the department expects that some indicator compounds will be monitoring within the process as well. |
| Sensitivity | The indicator has good removal by the targeted process, such that 75% removal is feasible only when the process is functioning as designed.(CDPHE 2023).<br>● For example, ozone doses in reuse systems are typically around CT10 = 4-11 mg*min/L to balance chemical and pathogen removal against bromate formation (Dickenson, et al. 2009). Some compounds such as hydrocodone are so sensitive to oxidation that they are more than 90 percent removed even when the operationally defined ozone exposure is 0 mg*min/L  (Dickenson et al. 2009). Hydrocodone would be a poor indicator for ozonation, since it can be removed below its MRL even if an ozone generator is malfunctioning and dosing less ozone than intended.<br>● On the other hand, ozonation removes chemicals such as chloroform and tris(2-chloroethyl) phosphate by less than 25 percent under typical conditions (Dickenson et al. 2009). Removing more than 75 percent of these compounds with ozone would be cost prohibitive or physically impossible, and would likely cause the bromate concentration to exceed regulation.<br>● Moderately oxidizable compounds such as DEET or iopromide would serve as better ozonation indicators because they are more than 75 percent removed under typical conditions but mostly pass through at lower ozone exposure (Dickenson et al. 2009). |
| Diversity | The other criteria apply to each PBI individually, but this criteria applies to PBIs as a set.<br>There should be at least one indicator that specifically monitors each chemical treatment barrier.<br>Furthermore, there should be at least one indicator that is partially removed by each treatment barrier, but only removed to a target of at least 75% if all treatment barriers are functioning as intended- a system indicator to monitor the system as a whole. |

**Step 1:** During early planning stages, begin monitoring a list of TOrCs in the treated wastewater at least monthly for at least one year. The initial candidate list should take into account expected chemical discharges from local industries/commercial facilities. Focus on compounds highlighted as potential indicators used in previous reuse studies and reports (Thompson and Dickenson 2020).

**Step 2:** Based on this monitoring and historical data if available, determine which TOrCs meet the Criteria 1-3 at the site: Concentration (detection ratio), Prevalence, and Measurability.

**Step 3:** Conduct a desktop study to categorize each compounds as "negligible" (<25%), "partial" (25%-75%), "good" (75%-99%), or "excellent" (>99%) removal by each chemical barrier based on scientific literature.

To determine which compounds meet criteria 3 through 5, chemicals can be organized into groups based on their expected removal by each treatment process as mentioned in Step 3. Preliminary screening and organization of proposed indicators can be conducted using chemical properties that correlate with removal (for example, molecular weight, logD), bench scale experiments under controlled, standardized conditions (for example, Rapid Small Scale Column Test), or published pilot-scale data. (CDPHE 2023)

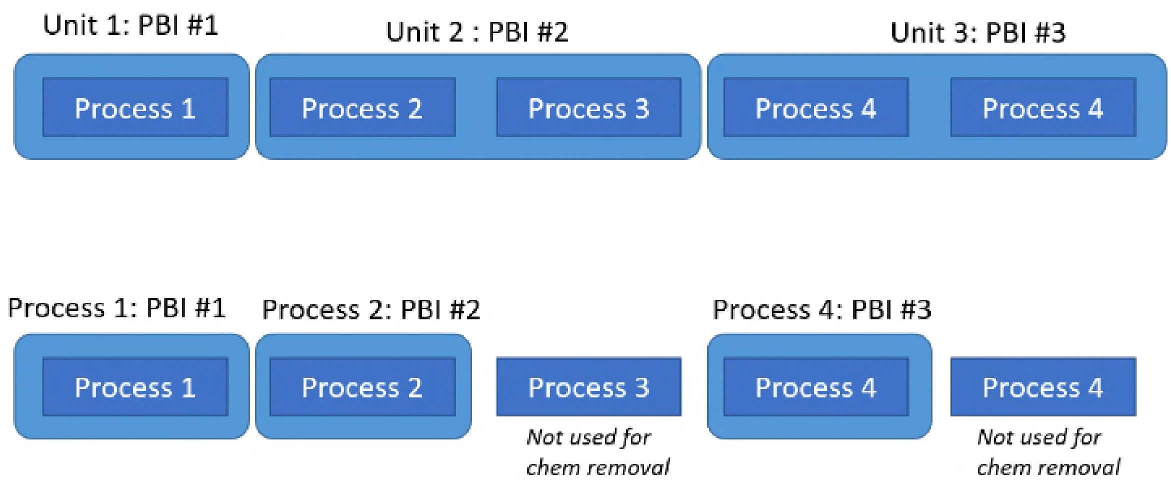
**Step 4:** Based on the categorization, select a subset of the proposed indicators that meet Criteria 4-6: Specificity, Sensitivity, and Diversity.

**Step 5:** Perform pilot testing to measure the subset of the proposed indicator compounds at the influent and effluent of each barrier at least monthly for a period commensurate with the replacement frequency, such as any adsorbents or membranes. Use this site-specific pilot scale data to verify and further narrow which compounds meet criteria 1-6.

The final indicator selection must consider the above and also use site-specific pilot study data to verify assumptions.

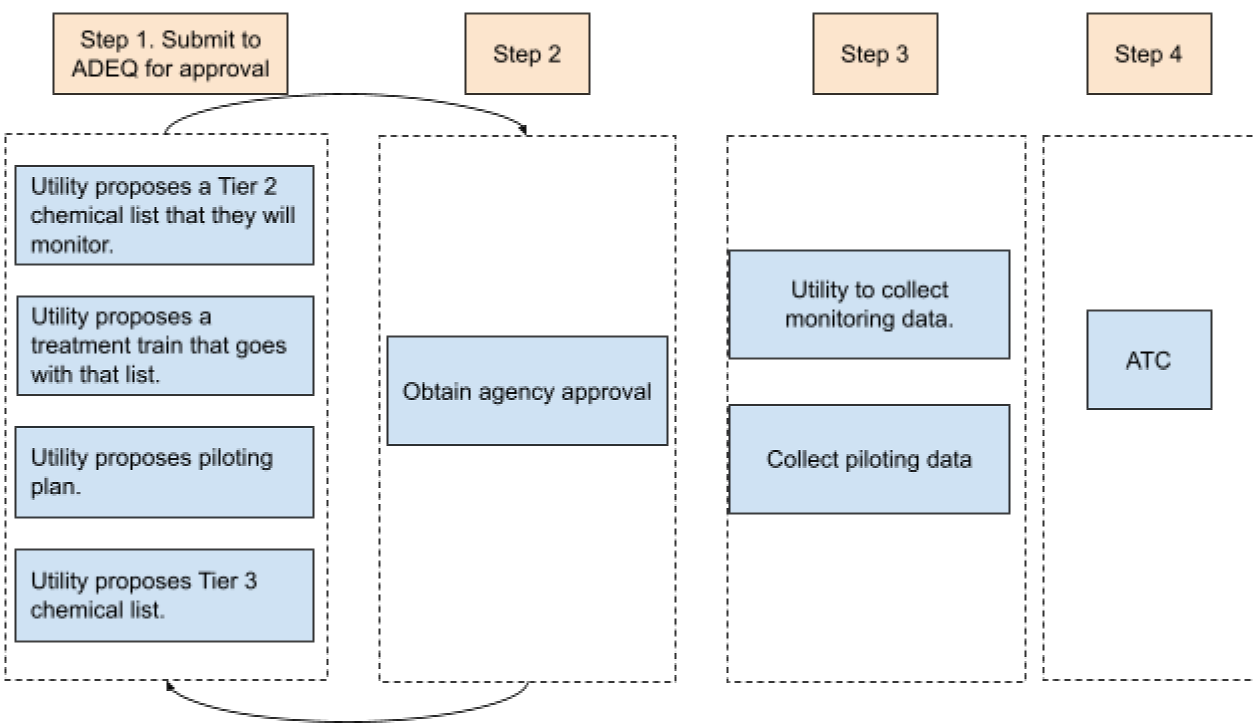
**Step 6:** if multiple compounds meet all criteria 1-6 for one of the treatment processes, select the indicator with the highest DR (median concentration divided by MRL), that meets criteria 1 by the widest margin.

**Step 7:** During full scale start-up and operation, continually monitor whether the indicator is verifying process performance and whether it continues to meet the selection criteria. PBis should be periodically reevaluated and substituted as needed if influent concentrations decline or better suited PBIs are discovered.




Both systems have three "parts" that are subject to performance-based indicators

### 3.1.5. Schematic for chemical monitoring



## 3.2. Enhanced Source Control

### 3.2.1. Goals of Enhanced Source Control Program:

- Understand the sources of chemical constituents entering the collection system (NWRI, 2018)
- Minimize 'pass-through' and 'interference' – minimize the discharge of potentially harmful or difficult-to-treat chemical constituents to the collection system. (NWRI 2018)
- Improve wastewater effluent quality and advanced wastewater performance.

Prior to the establishment of an Enhanced Source Control Program (ESCP) there should be an initial review and planning stage several years prior to startup (recommended 4 years) (WRF 2023).

Recommended Steps for Initial Review and Planning (WRF 2023):

- Review of existing National Pretreatment Program (NPP) authority
- Identify partner agencies, begin inter-agency discussions, and consider stakeholder engagement and public outreach plans
- Review existing industrial pretreatment program
- Identify Technical, Managerial, and Financial (TMF) Capacity
- Identify contaminants to monitor and begin WWTP sampling program
    - Regulated drinking water contaminants
    - Industrial contaminants with special concern for potable reuse
    - Contaminants knows to be a challenge for the utility
    - Pass-through hazards, interference hazards, and the highest ICSS contaminants for the selected AWT train.
- Review of Existing NPP Authority
    - AZ Surface Water Program - AZPDES Program
    - Determine the level of communication required to the State, industries, and the public when ESCP is established.
- Identify partner agencies, begin inter-agency discussions, and consider stakeholder engagement and public outreach plans
    - Safety of the DPR program depends on a well operated AWTF, a well operated WWTF, and a robust ESCP.
    - Dischargers (industrial, businesses, and residences) are all stakeholders.
    - Identify collections system components (sewer lines, manholes, lift stations, force mains) and flows (helps to identify where larger flows are coming from)
- Review existing industrial pretreatment program including:
    - Inventory of permitted industries (quantity, type)
    - Sampling and inspection processes between differing facilities
    - Flow data and prior violation for each industry including Notice of Violations for discharges of hazardous waste

- Prohibited discharge contaminants and applicable categorical limits
    - Local limits applied to different industries
- Identify Technical, Managerial, and Financial Capacity
    - Identify expertise (technical, managerial) is required for the implementation of an ESCP program. Identify financial resources required to establish and implement an ESCP program (plan, permit, operate, investigate, sample, enforce).
- Identify contaminants to monitor (see Chemical Control steps).

### 3.2.2. Critical Components of Enhanced Source Control Program (ESCP)

The DPR program should include the following 6 core components (NWRI 2020); (Colorado DPHE 2023); (WRF 2023); (WateReuse 2015); (U.S. EPA 2017); (Texas Water Development Board April, 2015a); (Florida Potable Reuse Commission 2020).

I. Regulatory authority
II. Monitoring and assessment of commercial and industrial dischargers to the wastewater collection system within the service area
III. Investigation of chemical and other constituent sources
IV. Chemical Inventory Program
V. Public Outreach
VI. Response Plan for deviations

#### 3.2.2.1. Regulatory/Legal Authority

Ensure sufficient legal authority is established to develop and implement enhanced source control measures that include:

A. Ability to establish regulations such as statutes, ordinances, codes, rules, and enforcement
B. Ability to establish robust interagency collaboration that includes enforcement procedures and response plans
C. Ability to establish binding agreements (including annexation), Interconnection agreements between plants, contracts, leases, homeowner agreements, covenants, permits
D. Ability to establish discharge permits (including permitting industries in annexed areas) and requirements with enforcement capabilities
E. Alternative Control Programs
    - Control mechanisms (BMPs…) for certain classes of industries or commercial businesses.

The suppliers should be prepared to demonstrate the following to the State:

Demonstration by suppliers that they have funding, resources, and staff to establish and implement legal authority.

Actions currently taking place in Arizona:

- Interconnection agreements between plants crossing county boundaries
  - Sewage collection lines crossing county lines and district boundaries:
    - Need response and authority associated with collection system lines and plant
    - Need Responsibility associated with collection system monitoring
  - Acceptance of septage waste
    - Need manifest or reporting requirements
    - Ned oversight for collected or disposed septage
    - Need contracts with WWTPs to allocate capacity and increase knowledge of collected waste
    - Need collection system monitoring to avoid illegal dumping
    - Need disposal stations upstream of WWTP to avoid slugs at plant

#### 3.2.2.2. Monitoring and Assessment

A. Local Limits

Facilities should develop local limits for contaminants that present challenges to their treatment process. Actions that should take place include:

1. Authority to develop local limits for Chemicals of Concerns (COCs)
2. Evaluation of service area to identify industrial risks
3. Inspection and Sampling conducted the plant
   a) Based on determination of sampling requirements (parameters and frequency)
   b) Self monitoring by dischargers; district monitor annually
      (1) Self-monitoring should include minimum sampling requirements (i.e. pH, COD, TSS)
4. Slug Control Plan
   a) Identify challenges due to influent slugs (i.e. illegal discharges into manholes or illegal discharge by an industry)
   b) Response to slugs at the plant
5. Enhanced Monitoring and Early Warning Systems
   a) Traditional Monitoring focuses on compliance and identifying illegal discharges.
   b) Enhanced Monitoring Systems
      (1) Online sensors and software in real time (increased maintenance and cost but may reduce staffing need)
      (2) Used not for real-time decision making but for an alert to deploy traditional monitoring.
      (3) Can monitor flow, pH, conductivity, temperature, hydrogen sulfide, and VOCs.
      (4) Collection systems establish requirements for calibrating and modifying sensors.

### 3.2.2.3. Investigation of chemical and other constituent sources

A. Inventory of industrial and commercial businesses
B. Joint response plans between WWT-AWTF
    1. Key responsibilities for each
    2. Inspections
    3. Routine Site Investigations
    4. Sampling
    5. Waste Hauler Program
        (a) Disposal permit requirements for each licensed vehicle
        (b) Manifest requirement
            (i) Volume and type of waste
            (ii) Sanitation district to check for pH, COD, TSS, and heavy metals
            (iii) Samples to be kept for a period of time
        (c) RV disposal waste
        (d) Commercial septage

### 3.2.2.4. Chemical Inventory Program

A. Create and maintain list of all dischargers in the area and include:
    1. Used/stored chemicals
    2. Control measures in place to mitigate and/or detect spills
    3. Rank volume of chemical that could
        (a) Spill into collection system
        (b) Toxicity of chemical
        (c) Control measures in place
B. Develop and maintain database of chemicals stored
    1. Leverage TRI / Tier II Program?
C. Inventory of volumes used annually
D. Communications with LEPC, fire departments

### 3.2.2.5. Outreach - Outreach plan with associated terminology

A. Domestic Sources
    1. Proper disposal of pharmaceuticals
    2. Proper disposal of household hazardous waste by domestic source
    3. Household hazardous waste collection program establishment by city or community
B. Commercial Sources
    1. Proper disposal of expired chemicals
    2. Floor drain education
C. Source Control Practices
    1. Hazardous Waste Training (small generators)

        2. Industrial Sources
    D. Pollution Prevention
        1. Participation in AZ P2 Program
        2. Participation in AZ Environmental Stewardship Program
        3. Establish plant recognition awards
    E. Education Program
        1. Programs for elementary – high school grades
        2. Programs for college level courses

#### 3.2.2.6. Response Plan

A. Plant Upsets
   - Set up staff dedicated to address upsets (24/7)
     a) Ability to mobilize staff and perform confirmation sampling and troubleshooting
   - Equipment includes proper field kits with calibration procedures and training
   - Data management system for entering/reporting collected data
   - Plan to identify dischargers within collection system affected
   - Enforcement
     a) Notice of Violations (NOV)
        (1) Details violation
        (2) Details actions to correct violations
        (3) Provides a response timeframe
     b) Review of facility response
     c) Adjustment of permit (if necessary)
     d) Escalation of enforcement action based on
        (1) Type, severity, number and duration of violation
        (2) Impact on district
        (3) Discharger compliance history
        (4) Good faith effort
     e) Follow up inspection and/or sampling by district
     f) Higher stage NOV
        (1) Mandatory compliance schedules

### 3.2.3. Steps to develop an ESCP

WRF Project No. 4960 (2023) recommends 13 steps for the implementation of an ESCP. Recommended Steps for the implementation of an ESCP program.

<u>Planning Stage</u>

1. Review the National Pretreatment Program and DPR program authority and begin discussions with the State.
2. Identify partner agencies and begin discussions and consider stakeholder engagement
3. Begin planning and development of outreach program implementation

    a. Develop and begin any research studies
    b. Engage influencers early
4. Review existing industrial pretreatment program for all partner agencies involved
5. Identify Technical, Managerial and Financial (TMF) Capacity for all partner agencies involved
6. Identify contaminants to monitor and sample (must include annexed facilities)

<u>Risk Assessment and Analysis</u>

7. Identify Industrial Risks
8. Perform Risk Analysis using the ISCSS framework and measured contaminant concentrations
9. Evaluate, document, and mitigate system risk

<u>Contaminant Monitoring and Tracking</u>

10. Perform industry sampling to identify source of contaminants
11. Develop sampling and monitoring plan
12. Finalize industrial ESCP for permitting and implementation
13. Implement ESCP advisory team
14. Implement ESCP

**INITIAL REVIEW AND PLANNING**

1. Review existing National Pretreatment Program authority
2. Identify partner agencies, begin interagency discussions, and consider stakeholder engagement and public outreach plans
3. Review existing industrial pretreatment program
4. Identify Technical, Managerial, and Financial (TMF) Capacity
5. Identify contaminants to monitor and begin WWTP sampling program

- Regulated drinking water contaminants
- Industrial contaminants with special concern for potable reuse
- Contaminants known to be a challenge for the utility
- Pass-through hazards, interference hazards, and the highest ICSS contaminants for the selected AWT train

Feasibility Study Phase (>4 years before project)

**RISK ASSESSMENT AND ANALYSIS**

6. Identify industrial risks
    - Create a chemical inventory for all industries and list existing control measures
    - Perform site-specific sampling at industries that are known to be a challenge
7. Perform risk analysis using the ICSS framework and measured contaminant concentrations
8. Evaluate, document, and mitigate system risk

Facility Planning Phase (>3 years before project)

**Contaminant Monitoring and Tracking**

9. Perform industry sampling to identify sources of contaminants
   - Calculate load-based contributions of contaminants by discharger
   - Establish site-specific and local limits, as needed
   - Consider isolating or eliminating specific industrial dischargers
   - Draft pollutant tracking strategy
10. Develop robust sampling and monitoring plan
11. Finalize Industrial ESCP for permitting and implementation
   - Revisit TMF Goals based on identified risks and additional sampling and monitoring requirements

Preliminary Design Phase (>2 years before project)

**Industrial ESCP Implementation**

12. Implement an Industrial ESCP Advisory Team
13. Implement Industrial ESCP
   - Annual evaluation, audit, and continuous improvement plan
   - Monitoring, responses, and corrective action plans for contaminants of concern
   - Stakeholder management, communication protocols, and enhanced public education outreach
   - Documentation and reporting
   - Communication and recognition plans for industries

Permitting or Design Phase (~1 year before project)

# 4. Treatment requirements/recommendations

## 4.1 Multiple-barrier treatment approach

**Objective:**

For any drinking water, including DPR, the goal of water quality regulation is to limit human exposure to concentrations of chemicals and pathogens that may be harmful to human health. Drinking water standards under the SDWA are established using "maximum contaminant levels" (MCLs) or treatment techniques. The treatment technique for pathogens requires inactivation or removal resulting in specific log removal value (LRV) reductions for enteric virus, Giardia, and Cryptosporidium. [edited from NWRI 2018, page 19]

For DPR, beyond the existing regulatory requirements to meet LRVs and MCLs, unregulated chemicals and potential peaks of regulated and unregulated chemicals also must be characterized and properly controlled [NWRI, 2018, page 19, verbatim].

Multi-barrier treatment is needed to achieve these pathogen and chemical removal goals.

**Requirement:**

Multiple barrier treatment is a requirement for all DPR projects.

**Defined in Rule:**

Minimum criteria is established in rule such as number or diverse type of barriers.

**Total number of treatment barriers:**

Depends on treatment technology type(s) used, demonstrated performance, and how the treatment train(s) is put together for implementation.

### 4.1.1 Minimum treatment barriers requirements:

### A. Pathogen removal

Pathogen control will require a minimum one filtration (physical separation) and one disinfection (chemical or physical destruction) process per each target organism (i.e., virus, Giardia, Cryptosporidium) to achieve specific LRV targets to be established based on demonstrated performance.

- This requirement is similar to (1) existing SWTR filtration and disinfection requirements, and (2) need for additional DPR treatment reliability (inherent redundancy, robustness, and resilience) established in published DPR guidance documents. In addition, as described in (National Research Council 2012), "it is uncertain whether LT2ESWTR regulatory framework is sufficient when source waters contain a high proportion of wastewater". Furthermore, as documented in (U.S. EPA 2017) a process that can achieve a 5-log reduction of both viruses and protozoa is required to replace the environmental buffer's treatment value. "While an additional level of treatment can offset the treatment effectiveness of an environmental buffer, it does not address the loss in response time from a process upset."
    - The provisions of the SWTR require that filtration must be included in the treatment train unless certain criteria are met ("CFR, Title 40, Chapter I, Subchapter D, Part 141," n.d.). Filtration processes shall achieve minimum 2-log removal of Giardia, 1-log removal of viruses and 2-log removal of Cryptosporidium (US EPA 1991, 199; "Long Term 2 Enhanced SWTR (LT2) – 40 CFR Part 141, Subpart W," n.d.) (LT2ESWTR). Filtration requirement for viruses is based on its non-selectivity towards viruses' types that cannot be achieved with disinfection techniques (adenoviruses and reoviruses are very resistant to UV light while reovirus is also more resistant to chlorine than the other enteric viruses) (ask Chuck for ref). Examples for filtration processes that can physically separate viruses include conventional, direct, slow sand and diatomic earth filtration, alternative high pressure membrane filtration and membrane bioreactor (MBR).
- Each pathogen barrier must be a barrier to at least one of the required pathogens (i.e., virus, Giardia, Cryptosporidium), but is not required to be a barrier to all three. Rule.
- Each pathogen treatment barrier must provide a minimum of 0.5 log removal, and no treatment barrier can be awarded more than 6 LRVs. Rule.
- Each treatment process used to meet the LRV requirements shall have the microorganism log reduction validated by a study. Study must characterize the performance. Rule.
- Log removal credit is available only for treatment barriers with accurate performance monitoring.
    - Log reduction credits achieved by any process are the minimum of the potential credit based on the actual process efficiency and the credit that can be confirmed based on the method sensitivity (WE&RF 12-06, DPR Framework 2015). (WE&RF, Reuse 12-06 2016; WateReuse 2015)
- In case of raw water augmentation, an existing drinking water treatment plant (DWTP) can be considered part of the treatment train. Processes of the DWTP shall be validated in the same

manner as other individual treatment processes and efficiency monitored according to CCP requirements.

- Establishing LRV credits for each treatment process is primarily based on current drinking water guidelines, such as the EPA Membrane Filtration Guidance Manual (EPA 2005), EPA Alternative Disinfectants and Oxidants Guidance Manual (J. USEPA 1999) and EPA UV Disinfection Guidance Manual (A. USEPA 2006). Alternatively, where pathogen reduction guidance has not been provided by EPA (for example, for RO and MBR), other sources can be considered. Other sources include: 1) crediting systems developed in other states (e.g., CA); 2) validation protocols by independent third-party agencies and have gone through an acceptable peer review process (definition needed for independent third party) such as those established for membrane bioreactors (Australian WaterSecure Innovations); and 3) utilities' demonstration of log reduction levels for unit processes through pilot testing (criteria under development, i.e. min. number of samples, type of samples/parameters among others, test conditions).
- Log reduction credits can be achieved with technical non-treatment barriers such as blending, but other listed requirements must be first met before availing this credit.
    - As with treatment barriers, blending log removal credit is available only for accurate (definition needed for accurate) performance (definition needed?) (blending) monitoring.
    - In accordance with the log removal definition, the 10 times dilution is equal to 1 log credit.
    - Log removal credit is available only for blending between AWTP effluent and finished drinking water.
- The LRV for each reference pathogen is calculated taking the differences of organism densities between the influent (feed) and effluent streams of an individual process in logarithmic scale. A treatment train LRV is the sum of the individual process LRVs for the train for each pathogen.

**Explanation of 4 different barriers**

The intention is that there should be 4 different barriers in place, each able to achieve more than 1 LRV. This criteria should be met for each reference pathogen (e.g. Cryptosporidium, Giardia and Viruses).

The intention of the above is to regulate multiple barriers to ensure resilient treatment – which is good practice. However, there isn't really good science to date that specifies how many barriers are truly enough. This will come down to site specific pathogen loads and control/operational effectiveness.

The quantitative approach and necessity to achieve 1 log cryptosporidium does mean practically that DDW is willing to trade an increased risk of disinfection by products from excessive ozone dosages required to achieve 1 log cryptosporidium removal.

The required number of barriers is not scientifically based. It has looked at the previous IPR regulations (requiring 3 barriers but not necessarily stipulating for each pathogen), assumed a higher risk from DPR and added a 4th required barrier.

Developing prescriptive policy based on one go by or existing project without making allowances to include future innovations or proof from site specific demonstration will negatively impact treatment economics. The CA alternative clause for DPR has limited any discussion of alternatives to chemical control, not pathogen control – where the biggest efficiencies could reasonably be proposed (and the currently excessive level of risk control challenged).

There could be other ways to achieve the same resilience with multiple barriers, without creating other sources of risk (e.g. the DBP risk above). This could include:

Acknowledging the additional margin of safety from barriers that are know to work, but are difficult to credit via online monitoring. Such as the size exclusion capacity of BAC, downstream of ozone.

Providing a means to demonstrate resilience through quantitative microbial risk assessment simulating realistic failures and durations of failures to test for the likelihood of exceeding acceptable risk levels on a train that does not necessarily have the prescribed number of barriers.

## B. Chemical removal

The treatment train shall consist of at least three separate treatment processes, using diverse treatment mechanisms including advanced oxidation and physical separation as mandatory.

- One of the chemical removal barriers must be an advanced oxidation process (AOP).
    - AOP is an oxidation process that produces hydroxyl radicals acting as reactive electrophiles that readily react with most electron rich organic compounds and in a fast and non-selective way to destroy organic contaminants in water such as pesticides and herbicides, fuels, solvents, drugs, and other potential endocrine disruptors (Crittenden et al. 2005).
    - This requirement is primarily based on AOP mechanism's ability to degrade a wide range of trace organic chemicals present in WWTP effluent that do not normally occur in traditional uncontaminated water sources. (Hokanson et al 2016; CDPHE 2023; California 2020; SWRCB 2019; California Addendum 2021). Additionally, as defined in (US EPA 2017), "At present, the rules promulgated under the CWA and SDWA do not sufficiently address the public health concerns associated with reclaimed water for potable reuse". Additional reasons for mandating AOP over other processes include: (1) the organic contaminants can be destroyed completely and avoid creation of byproducts (converted to carbon dioxide, water and mineral acids); (2) contaminants that are not absorbable or volatile can usually be destroyed, and (3) contaminants that are oxidizable are not accumulated in another phase that requires additional treatment (Crittenden et al. 2005).
    - Examples of AOP include but are not limited to: H2O2/UV, HOCl/UV, and H2O2/O3. The application of ozone to effluent organic matter (EfOM) has also been demonstrated to create an AOP, even without the presence of another oxidant, such as H2O2 (Wert, Rosario-Ortiz, and Snyder 2009; Audenaert et al. 2013). This application of ozone` to EfOM could be designated "O3/EfOM based AOP" to distinguish it from the application of ozone to conventional source (surface) waters, where an AOP does not necessarily occur.
    - Approval and crediting of AOP processes require demonstration of treatment performance. AOP shall demonstrate no less than 0.5-log reduction of 1,4-dioxane. This is usually achieved by spiking of 1,4-dioxane to AOP feed water under the proposed oxidation process's normal full-scale operating conditions and establishing correlation with another indicator compound normally present in the water, that meets indicator criteria specified in the Table x Provided in chemical control), and that will be used for process performance validation after pilot study.

- The 0.5-log reduction of 1,4-dioxane is a performance benchmark for all AOP processes. This specific target is based on the current DPR research that demonstrated quality and quantity of DPR specific trace organics removal when 0.5-log reduction of 1,4-dioxane performance is achieved (Hokans et al 2016, CA Technical Memo 2020-see graph in Supporting Information).
- If proposed AOP does not meet 0.5-log removal of 1,4 dioxane, an alternative solution must be provided. Alternative solutions include blending and UV/AOP. For example, if O3/EfOM is designed as AOP, the 0.5-log 1,4-D is not a suitable surrogate knowing that it cannot demonstrate such removal, the treatment train shall include a UV/AOP at tail end which should be sized for a minimum 0.5-log 1-4, dioxane removal.
- In addition to performance demonstration, all AOP designs shall address major challenges of AOP processes such as scavenging of hydroxyl radicals by carbonates, bicarbonates, nitrites, nitrate, bromides and NOM, pH and UV light absorption.

Alternate approach (**still being discussed**)

A few facts about Ozone AOP on wastewater effluent

We need to recognize that ozone alone with EfOM creates OH* - no need for peroxide. There is plenty of literature to that effect. Quick google search finds one of the first / most comprehensive papers: https://www.sciencedirect.com/science/article/abs/pii/S0043135408005988, but there have been plenty since. This paper also shows the substantial CECs reduction you get through Ozone/EfOM based AOP.
A common benchmark for dosing ozone for effluent / potable reuse application is to benchmark the dose off the incoming TOC. This "ozone:TOC" approach is useful because there is actual a linear dose-response to virus inactivation, and it also relates nicely to the transition between a "subresidual dose" where you still get plenty of AOP, CECs destruction, and virus inactivation, but don't yet form substantial quantities of bromate. (The paper above walks through this as well.) The typical transition from subresidual dose to measurable residual is at O3:TOC between 0.8 and 1.0 (~ish).
Unlike UVAOP (with peroxide) , when you dose ozone, you have to balance disinfection and OH* formation versus creation of DBPs, such as bromate. This is why a 0.5-log 1,4-dioxane standard is inappropriate for ozone – it may well be protective from a "are we creating enough OH*" perspective, but it causes other harm by creating substantial risk from bromate. See Tackaert et al paper – their O3:TOC ranged from 1.2 to 1.4, which could cause significant bromate formation issues and did not even achieve 0.5-log 1,4-D removal. There are similar issues with this at HRSD as well.

alternative definition/benchmark for "what is enough AOP" for ozone.
Establish a "standard" ozone dose target at O3:TOC = 1.0 (controlled for nitrite).
This level is consistent with robust CECs removal (and virus disinfection), but typically will not result in a significant ozone residual and thus limiting bromate formation.
Require ozone system design capacity up to a higher value (O3:TOC = 1.2? Plus typical design safety factors?)
Providing this capacity will provide the ability to provide additional ozone dose if unexpectedly higher TOC or nitrite are encountered at a later date, in order to be able to maintain 1.0 O3:TOC.

Allow potential dose reduction to O3:TOC < 1.0 for cases where bromate formation has been seen to be an issue in pilot testing.
Maybe establish a O3:TOC= 0.8 minimum level? We still get very good AOP/CECs destruction at this level, but it does start to fall off below this level.
This can be justified by showing through sampling that you can still achieve 0.5-log removal of Group 3 chemicals (see Gerrity et al, 2012) at the proposed lower ozone dose.

Establish an appropriate dose monitoring approach:
If you are targeting a true sub-residual dose, use a % removal of UVA through ozone/BAC as the online surrogate that confirms proper operation of the ozone system based on correlations established during pilot testing.
A practical alternative may be to operate where you can just barely measure an ozone residual. This makes sure that you are achieving the most AOP practically possible without risking bromate issues.

- Strategy for chemical peaks mitigation must be provided for all DPR projects.
    - Targeted chemical peaks are chemicals that when discharged (illicitly or not) into sewer collection systems have potential to pass through common treatment units if present in high enough concentrations (SWRCB 2019).
    - This requirement is specific for DPR projects due to a lack of environmental buffer that results in loss of treatment, attenuation and extended response time for potential chemical peaks (Olivieri et al. 2020, Advances in Chemical Pollution, Environmental Management and Protection, Volume 5, Chapter 2) (A. W. Olivieri et al. 2020).
    - Chemical peaks were recorded in 2013 in Orange County Water District's Ground Water Replenishment System (GWRS) where acetone increased TOC in feed water to over 20 mg/L, and during 2007 and 2008 in West Basin Municipal Water District's Ed C. Little Water Recycling Plant where up to 350 ug/L of formaldehyde was measured.
    - For attenuating potential chemical peaks, additional treatment barriers, flow equalization and/or blending shall be provided.
    - Enhanced source control program and online monitoring cannot substitute for additional treatment barriers, and/or blending, instead, they should complement and increase robustness of the overall peaks mitigation strategy. Justification is provided in paragraphs below.
    - The main objective with chemical control in DPR is to identify treatment processes that are effective at controlling a wide variety of chemicals, identify chemical indicators and treatment surrogates to validate treatment technologies to ensure effective treatment to reduce concentrations of chemicals below the level of health concern. When coupled with the regulatory requirements for industrial and commercial enhanced source control it could help to reduce the discharge of toxic (or otherwise of public health concern) chemicals into the sewer collection systems and other requirements that evaluate and reduce the risk of treatment failure. Additional tool in improving treatment resilience is incorporation of extensive online monitoring at multiple steps of WWTP and AWTP. However, when evaluating risk reduction with this operational barrier, sensitivity

limitations driven by few orders of magnitude concentration level differences between bulk and trace organics, cannot be neglected. This is particularly important for recognizing VOC peaks in non-RO treatment trains where MCLs are in ug/L concentration range and high (mg/L vs. ug/L) TOC concentrations are allowed in AWTP effluent.

- Even a bedroom community
  - While drastic chemical peaks that were observed at GWRS may not occur frequently and they may not be representative of chemical peaks at other potable reuse facilities, we still need to address chemical peaks which can occur anytime even with enhanced source control. In addition, there are some compounds such as methanol that are poisonous and highly toxic at very low concentrations. Introduction of those compounds into the AWTP is a concern. For example, methanol is a frequently used chemical in wastewater treatment facilities to enhance biological nitrogen removal and could be present at high concentrations in AWTP influent because enhanced source control is not a factor here and TOC is not sufficiently sensitive to provide useful information regarding the presence nor concentration of the specific chemical. Therefore, the approach suggested using enhanced source control, monitoring and periodic sampling may not adequately address issues like this. Flow equalization, dilution and/or additional treatment barriers such as air stripping (for some volatile organic compounds only) provide a reasonable protection against chemical peaks that could occur at WWTP effluent and AWTP feed. Additionally, "Overall, utilities implementing DPR should pursue a balanced approach to control chemical peaks that includes an appropriate combination of two or more of the following: source control, enhanced monitoring, additional treatment barriers, and/or blending" (Debroux, Plumlee, and Trussell 2021).
  - In line with Proposed Framework of Regulating Direct Potable Reuse in CA, minimum design criteria for attenuating potential chemical peaks is 1.0 log removal (10x dilution) of treatment train specific chemical surrogate with high potential to pass through all AWTP unit processes (CA Addendum 2021).
  - At the moment, some research is available for attenuation of chemical peaks in RO trains where this is addressed by ozone/BAC as an additional pretreatment barrier and/or blending (California Addendum version 8-17-2021). In addition,
    - Blending ratio sets up minimum requirements for percentage of the WW contribution that must be treated by additional treatment units. The 10% blending alone satisfies 1 log removal and does not require additional treatment barriers for chemical peaks. For blending in higher concentration, formula from California Addendum version 8-17-2021 apply.
    - Demonstration testing is required and performance of ozone and BAC must be evaluated separately. Minimum design criteria is 1.0 log removal of carbamazepine and sulfamethoxazole for ozone performance indicators, and acetone and formaldehyde for BAC performance indicators.
  - An alternative that meets treatment requirements defined in this section may be used if it is demonstrated that the proposed alternative provides an equivalent or better level of performance with respect to the efficacy and reliability of the removal of contaminants of concern and ensures the same level of protection to public health.

  - For non-RO trains, the goal for chemical peaks management is the same as for RO that requires a minimum 90% (10x dilution) chemical reduction achieved by blending and/or additional treatment barriers.
  - Examples for carbon-based trains include but are not limited to surrogates such as formaldehyde and acetone, and additional treatment barriers such as air stripping (for VOCs) and GAC with extended contact time.

- Treatment processes may serve as both chemical and pathogen barriers, depending on the type of technology employed (for example, ozone).
- Log removal credits and chemical control mechanism can be achieved/counted between a point where the raw water is not subject to recontamination (raw water entering the WWTP) and a point downstream before or at the first customer (finished drinking water prior to entering the public distribution system).
  - Location of barrier outside AWT treatment train does not qualify for reduced level of performance monitoring (CCP assignment together with corresponding requirements apply).

### 4.1.2 Performance monitoring of treatment barriers:

- Operational monitoring parameters are used to measure the performance of the treatment process unit, and based on specific performance criteria, can be correlated to the reduction performance of the target pathogen, chemicals and contaminants.
- An effective treatment performance program is essential for a fail-safe DPR project where response urgency substantially increases due to loss of environmental buffer benefits. Operational monitoring parameters are collected at CCPs (SWRCB 2019).
- Each barrier claimed for pathogen or chemical removal is a CCP regardless of the number and location installed. Credit will not be given for a process that does not have a CCP and corresponding surrogate correlated with removal (SWRCB 2019).
- DPR criteria heavily rely on continuous online and periodic monitoring of treatment plant performance indicators and appropriate surrogates to determine whether the treated water is safe to drink.
- Monitoring requirements at CCP include: (1) continuous online, and (2) periodic monitoring.
- Continuous monitoring of operational parameters provides assurance that the system is operated under intended operating conditions, and can indicate when treatment efficacy is reduced to an unacceptable level.
  - Continuous monitoring of key parameters has a frequency of no less than once every 15 minutes (40 CFR 141.719(b)(4)(ii)).
- Requirement for selection of indicator monitoring is provided under chemical control and frequency of monitoring is specified in xx.
- CCP specifies conditions for failure detection, alarm and response, and triggers for corrective action. The out of specification water production is the ultimate risk and requires specific mitigation action. At least one surrogate or operational parameter (e.g. turbidity, UV transmittance, etc.) shall be capable of being monitored continuously, recorded, and have associated alarms that indicate when the process is not operating as designed. For example, if

out-of-specification water is produced), CCPs will shut down the plant or divert water to a redundant system or to waste.

- The WE&RF 13-03 recommendations shall be followed to:
  - identify and validate CCPs,
  - determine the monitoring requirements around those CCPs,
  - establish needed response procedures (i.e., what to do when systems begin to fail),
  - assess and document water quality risks in potable reuse systems.
- Some of available options for online and chemical indicator monitoring at specific treatment units are provided in Tables 1 and 2.

**Table notes:**

**In MBR**, no single mechanism is responsible for elimination of pathogens but a combination of size exclusion, predation, adsorption and biodegradation. Because some MBR membrane systems are not equipped for DIT, this method needs to be validated to be considered as an online monitoring technique. Based on literature findings where it is explained that LRVs achieved by membrane filtration alone are typically two to five times higher than those achieved by activated sludge (Van den Akker et al. 2014), an approach for focusing on monitoring membrane integrity over bioreactor performance was implemented. WaterVal 2017 protocol recommends that online turbidity monitoring (surrogates continuous indirect integrity testing) with a suitable system design and controls be systematically implemented on MBRs and that critical limits be established to detect catastrophic breaches of integrity. MBR crediting specified in the Table 1 is based on Tier 1 approach Validation Protocol, WaterVal 2017. These values can only be applied to submerged MBR systems that have specific nominal pore sizes and are operated in accordance with design specifications covered by operational monitoring and listed in the protocol or as part of validation tests. Higher credits are possible with challenge testing (e.g.; WaterVal Tier 2/3 approaches) in accordance with this protocol. This paragraph will be updated with protocol presented in WRF 4997 (this protocol supersedes WaterVal and gives 1 and 2.5 credit for virus and protozoa) .

**BAC and GAC** alone have 0/0/0 (no credit for pathogens). Credit is possible if they are designed as direct filtration with chemical coagulation/flocculation provided prior to BAC and GAC.

**Ozone**: According to EPA, an ozone residual must be measured to obtain a CT and score corresponding log reduction credit. The ozone demand can be estimated on a mass basis as a sum of TOC and nitrite, where nitrite is usually much lower and dosing is made in excess to total demand to provide residual for CT (WRRF 11-02).

**NF:** Due to limited capacity for salt removal, NF membranes are not able to provide a significant amount of LRV based on conductivity removal (WE&RF, Reuse 12-06 2016). Because NF retention of viruses is not well understood, maximum 1 LRV for pathogens can be granted when online TOC and daily sulfate grab performance monitoring, similar to RO, is performed.

**UF**: Pore size distribution in UF membranes are not uniform and they do not have capability to retain small viruses (e.g.; MS-2, Norovirus) especially when membranes are clean. CA does not guarantee any virus credit for tertiary UF filtration systems.

**Daily integrity test:** This test is standard procedure to validate LRVs per EPA Membrane Guidance Manual. In a DPR setting MF/UF systems may need to be designed with N-1 or likely N-2 arrangement to treat target production flow while doing backwashes and daily integrity testing. Each membrane train must run DIT in every 24-hours even though turbidity in filtrate (permeate) is conforming to limits.

**UV/AOP**: UV doses vary depending on the water quality. Values of >500-700 mJ/cm2 can be required to achieve minimum 0.5-log 1,4 Dioxane removal and validate performance of UVAOP systems. Continuous validation of target 1,4 Dioxane removals automatically warrants 6-log LRV credits for all 3 target pathogens.

**Table 3: Example treatment barriers available for chemical control and associated example indicators and surrogates**

| Technology | Mechanism | Types of chemicals removed | Chemical Indicators | Process monitoring Surrogates |
|---|---|---|---|---|
| RO | High pressure membrane filtration by size exclusion, charge separation and diffusion. | Molecular weight cut off (MWCO) < 200 Da. Used to remove residual salts and colloidal and dissolved solids, and charged trace organics (including pharmaceuticals and personal care products). | Strontium, sulfate (Report 243) | TOC, EC |
| NF | High pressure membrane filtration by size exclusion, charge separation and diffusion. | MWCO 0.2-10 kDa. Used to remove residual fine particles and polyvalent cations, in place of RO when only softening or partial demineralization is needed. | Sulfate, calcium | TOC |
| UF | Low pressure membrane filtration by mechanical sieving. | MWCO 1-500 kDa. Used to remove residual particles, often in place of MF. | No chemical credit | |
| MF | Low pressure membrane filtration by mechanical sieving. | MWCO >100 kDa. Used to remove residual particles. | No chemical credit | |
| GAC | Adsorption, Physical Removal | Removes dissolved hydrophobic uncharged organics, DBPs, some chemicals known to pass through RO. Require disinfectant residual or pathogen removal downstream due to potential for biogrowth. | Meprobamate or PFHpA (AWWA 2020), sucralose (WRF 15-04 2020) | UVA, TOC |
| UV (requires >300 mJ/cm2) | Photolysis (light-induced oxidation or reduction processes | Removes nitrosamines, iodinated and nitro compounds, several oxidants and disinfectants. | Iohexol (AWWA 2020) | Intensity sensors, lamp status, UV transmittance, flow rate |
| AOP (UV/H2O2, UV/HOCl, and O3/H2O2) | Oxidation | Used to destroy or alter chemical constituents that are not oxidized completely by conventional biological treatment processes or removed by filtration, trace organics, NDMA, 1,4 dioxane. | 1,4 dioxane or another surrogate correlated with it. | UV intensity, lamp status, UV transmittance, flow rate, oxidant dosage/concentration. |
| Ozone/EfOM AOP | Oxidation | Used to destroy or alter chemical constituents that are not oxidized completely by conventional biological treatment processes or removed by filtration, trace organics, NDMA, 1,4 dioxane. | "Group 3" chemicals (Gerrity et al. 2012): DEET, ibuprofen, pCBA, phenytoin, primidone | UVA |
| BAC | Biological, Physical Removal, Adsorption (with not fully exhausted activated carbon). | Biodegrades organics made bioavailable by upstream O3. Removes oxidation byproducts, such as NDMA, effective for chemical peaks. Ozonation and biofiltration are often considered a single water purification unit since the performance depends on their tandem operation. | Acetone and formaldehyde | TOC |
| Enhanced coagulation, electrocoagulation | Coagulation | Contributes to overall TOC and DBP precursor removal, useful pretreatment to increase particle size before filtration, reduce membrane fouling, lower the required ozone dosage, removes certain heavy metals and radionuclides. | No chemical credit | |

### 4.1.3. Implementation of the multiple barrier treatment process

The goals of the multiple barrier treatment process are to eliminate acute risk through pathogen control, and reduce chronic risk achieved through chemical control. To address this goal, a number of different treatment processes are grouped together in the treatment train to remove pathogens and particulate, colloidal, and dissolved chemical constituents found in the effluent from WWTPs. Pathogen control, including meeting required log removal values, can be accomplished in RO and non-RO treatment trains through the use of filtration and disinfection treatment technologies. Lack of TDS removal and a higher level of TOC in the effluent are the principal differences between the RO-based and non-RO based treatment trains (WateReuse 2015).

## Supporting Information

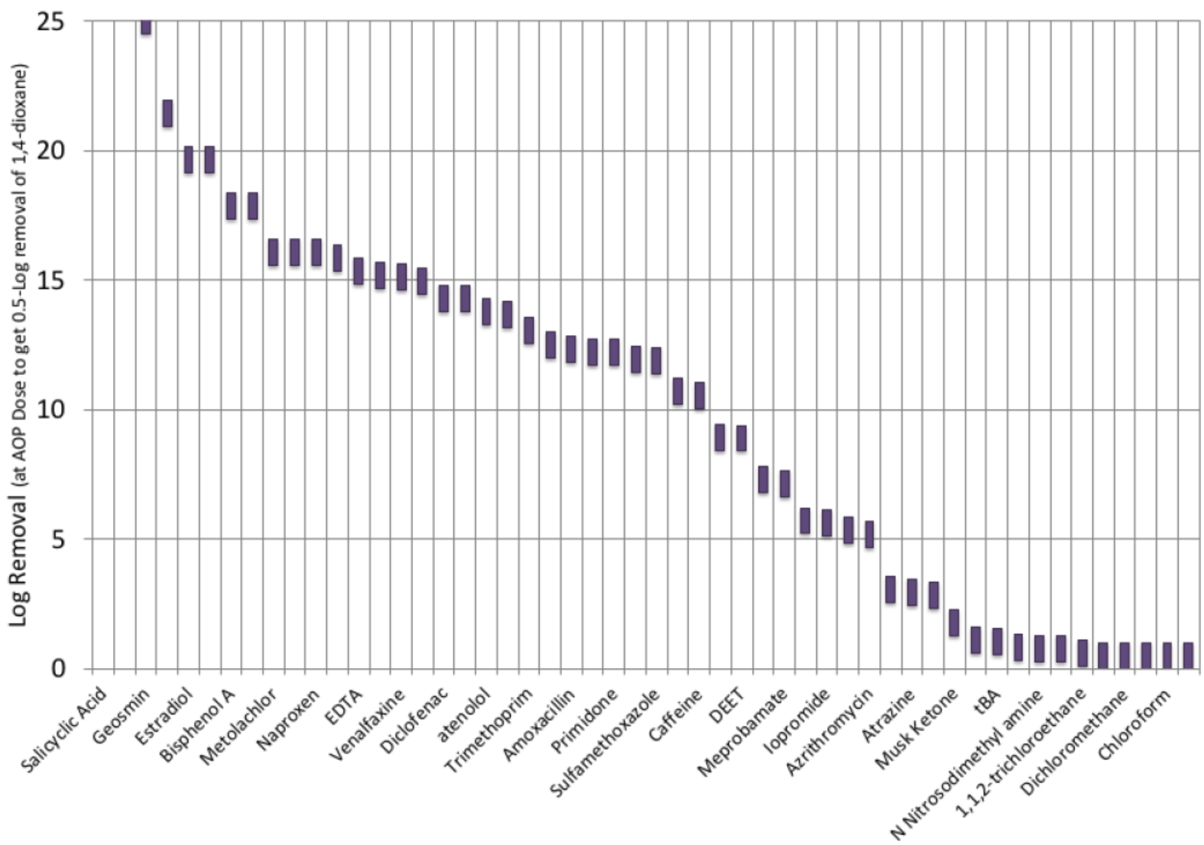



***Figure 10. Removal of trace organics at the AOP dose needed to achieve 0.5-log removal of 1,4-Dioxane (adapted from Hokanson et. al 2016)***

## 4.2 Organics control (TOC) - Treatment

**Definitions:**

Recalcitrant total organic carbon (rTOC): Concentration of TOC resistant to the common chemical and biological water treatment processes. The rTOC is originally present in natural water sources as natural organic matter and further transferred to finish drinking water that ultimately becomes treated wastewater. TOC concentration of treated wastewater is higher than rTOC, this addition is from anthropogenic sources and does not represent a recalcitrant portion of TOC.

**Background:**

To reduce formation of known and unknown disinfection byproducts (DBP) which may have adverse health effects, the Disinfectants and Disinfection Byproducts Rule mandates reduction of precursors through treatment technique requirements based on achieving specific TOC percentage reduction in regards to source water's TOC and alkalinity values (40 CFR, Part 141.130, n.d.). As a result of different source water parameters and consequently different TOC reduction requirements, a wide range of TOC levels in drinking water has been recorded across the US. According to the 2017 Water Utility Disinfection Survey Report that analyzed disinfection practices in water systems throughout the US, TOC data were collected for 275 systems of which 65% had <2 mg/L TOC, 26% were in 2-4 mg/L TOC range and about 8% showed TOC concentrations > 4 mg/L (AWWA 2017). In Arizona, most of the population is served by water blend supplied from 3 surface sources (Colorado River, Verde River, Salt River) and wells. The contribution of sources varies during the year and in 2021 TOC in drinking water in Phoenix ranged from 2.7 to 4.2 mg/L with an average of 3.3 mg/L (City of Phoenix 2021).

While the drinking water keeps moving through domestic and industrial cycles, its TOC is increasing because organics are added into municipal wastewater collections systems and through industrial discharges. Effluent organic matter (EfOM) of WWTP consists of microbes and microbial byproducts, cellulose fibers, antibiotic resistant bacteria, antibiotic resistant genes, dissolved non or slowly degradable natural organic matter, and trace organic compounds (Michael-Kordatou et al, 2015). Some of these organics are removed by conventional WWTPs, however, removal efficiency depends upon influent concentration, characterization of the organic matter, and the level of treatment. In order to meet minimum requirements established by SDWA and DBP rule, and provide public health protection against emerging constituents, the advanced water treatment at potable reuse plants must be designed to remove the residual organics added through water cycling and not removed by the WWTP.
In line with increasing interest in addressing trace organic compounds in reclaimed water for potable reuse, EPA reduced the minimum recommended TOC level for IPR from 3 mg/L to 2 mg/L (EPA/600/R-12/618 2012).

For DPR applications, existing regulatory frameworks for TOC include the California approach of TOC less than 0.5 mg/L (CA Addendum 8/2021) and the Colorado approach (CO Policy 10/2022) which is adapted from WRF Reuse 15-04/4771 (15-04). Both approaches exhibit limitations which complicate development of a regulatory framework for Arizona. The California approach is a value that can only be achieved through the use of specific treatment technology; namely reverse osmosis. This is problematic for inland potable reuse applications as the costs for disposal of the high salinity waste stream associated with the RO process, called concentrate or brine, significantly increases the overall cost of purified water. 15-04 acknowledges this challenge and provides a framework by which purified water TOC limits are based upon existing drinking water TOC levels, which are presumed safe through compliance with current SDWA regulations. One of the observations made in 15-04 is that by reducing effluent TOC though advanced treatment to at least the same numeric TOC value as the drinking water corresponded to a very high degree of CEC removal and reduced DBP formation potential. The research supporting 15-04 was conducted on water systems that are wholly or partially supplied by surface water sources; groundwater-based systems were not included.

Drewes and Fox (2001) surveyed several water systems that use only groundwater with TOC levels in the range of 0.3 to 1.0 mg/L. It is quite likely that the TOC in these waters is the result of biological growth in the soil, well casing, or distribution system. In the activated sludge systems included in this study that were treating wastewater derived from groundwaters, the gain in TOC was typically between 3 and 5 mg/L. The researchers also reported that approximately half of the effluent TOC was slowly biodegradable through soil aquifer treatment of 30 days. If the 15-04 framework is applied to groundwater with low TOC, then it is probable that either nanofiltration or RO, either full or partial, will be required.

Class A+ effluent is highly treated and can be reasonably expected to have TOC values well below 10 mg/L (See also WRF 4832). Data from the Mesa NWWRP published by Drewes and Fox, 2001 demonstrates this (TOC ranged from 3.3 to 7.0 mg/L). Data collected by McCandless and Mackey (2018) from ultrafiltered effluent at the Scottsdale Water Campus showed TOC levels from 2.2 to 2.8 mg/L with one sample at 5.7 mg/L. The aggregate concentrations of CECs in the same Scottsdale Water Campus samples ranged from 21 to 30 parts per billion.

Several studies have shown that carbon based advanced treatment (CBAT) is highly effective at removing CECs, transforming organics to reduce DBP formation potential, and achieving 40% to 70% reduction of TOC. It is reasonable to expect that microbial products make up a significant fraction of the TOC in CBAT effluents and CECs should be a negligible fraction. If the remaining microbial products and NOM following CBAT treatment do not pose a significant health risk, then it stands to reason that the purified water from CBAT treating Class A+ water is as safe for human consumption as drinking water from other sources. This treatment approach and fate of various categories of organics should be confirmed through pilot testing.

**Requirement:** TOC management is a requirement for any DPR project.

**Goal:**

For controlling organics in AWT effluent, Arizona adapted the framework developed in the WRF 15-04 project that similarly to existing DBP Rule set up goals for organics removal by incorporating (1) quality differences in source, (2) relative target for bulk organics (non-constant TOC limit for all sources), and (3) proactive control of non-regulated trace organics. The main outlines adapted from WRF 15-04 are:

Potable reuse train shall reduce undesirable anthropogenic organic chemicals introduced through the domestic and industrial water cycle and produce a treated water that has organic characteristics similar to that of the original drinking water.

By returning the water's bulk organics back to approximately that of the original drinking water, anthropogenic effluent-derived organics that have adverse health impacts are removed.

TOC of the local drinking water is a relative benchmark goal for achieving quality and safety of the potable reuse water generated by AWTP starting from WWTP effluent originating from the local drinking water.

By achieving a 1:1 ratio of TOC between finished drinking water and potable reuse water, MCLs and CECs organics are well controlled.

TOC measurement serves as a bulk organics surrogate.

**Approach:**

In Arizona, the application of WRF 15-04 project is extended to encompass:

- All types of treatment trains. While recognizing differences in treatment technique capabilities to reduce TOC and requirement of RO not to exceed 0.5 mg/L TOC in order to achieve pathogen credit, TOC goal does not set up different requirements based on treatment trains.
- All types of natural water sources with potential for adjustments of TOC goal based on dominant (>50%) groundwater contribution in drinking water.
    - For special cases where groundwater with typically low (<0.5 mg/L) TOC concentration has a dominant contribution to drinking water supply, and targeted TOC based on original drinking water may not be achievable by non-RO treatment train, establishing specific action and alert limits with proven safety is allowed through pilot testing.
- Raw and treated water augmentation where the potable reuse water fraction is not far too low or high in regards to that provided to the water treatment plant from natural sources. For <5% potable reuse fraction in augmented water, dilution and downstream WTP benefits must be analyzed. For >95% potable reuse fraction in augmented water, comparison of the potable reuse water to that of the natural source(s), prior to blending, is required.

**Monitoring:**

As proposed by WRF 15-04, to ensure that reliable removal of organics is achieved through AWTP, two monitoring categories are required: 1) online monitoring, and 2) quarterly monitoring.

- Online monitoring to provide real-time information on the bulk organic quality of purified water, potential WWTP and AWTP failures, and chemical peaks that may occur in the sewershed.
    - Two options are available for real-time online organics monitoring: A) online TOC analyzers, or B) online UV254 analyzer in conjunction with daily TOC samples. Use of UV254 is limited due to its ability to only measure compounds that absorb light at a single wavelength and do not detect a variety of anthropogenic organics present in WWTP effluent. On-line TOC monitoring overcomes this limitation by detecting discharges of all organic contaminants.
- Quarterly monitoring is performed regularly or when TOC alert limit is exceeded. Quarterly sampling is conducted for regulated (DBPs, VOCs and SOCs) and selected unregulated organic compounds (CECs) to periodically check on the adequacy of the AWT process in removing organic chemicals or disinfection byproducts that may have formed during AWT.
    - Even though the U.S. EPA SDWA requires monitoring of 53 regulated organic chemicals on a semiannual basis, quarterly organic sampling is required for organics control with DPR because of the increased potential for contamination through the wastewater collection system.
- Monitoring location has to be approved by ADEQ.

Table 1: Monitoring Plan for Purified Water

| Chemical | Limit | Tier | Reference | Monitoring Frequency |
|---|---|---|---|---|
| TOC | Alert and action limit (site specific) | 2 | WRF 15-04 | Online |
| SDWA (DBPs, VOCs, SOCs) | EPA MCL | 1 | EPA SDWA | Quarterly |
| NDMA | HAL | 2 | EPA | |
| 1,4 dioxane | HAL | 2 | EPA | |
| CECs identified by initial monitoring | HAL | 2 | EPA | |
| PFAS | EPA proposed MCL | 1 | EPA | |
| CECs treatment indicators | TT (Removal %) | 3 | WRF 15-04 | Monthly for year after what can be reduced to quarterly |

*define HAL (has to be in line with Chemical Control doc)

**Compliance:**

As proposed by WRF 15-04, alert and action limits based on TOC concentration are designed to trigger additional monitoring and/or treatment modifications or to stop production of potable reuse water.

- Alert level is calculated as drinking water's historical median TOC value based on minimum 52 measurements collected over one year long weekly TOC sampling period.
    - Location and time of drinking water (recalcitrant) TOC monitoring must be approved by ADEQ and median, 75$^{th}$ percentile and 95$^{th}$ percentile must be calculated.
    - DPR water with a 30-day running average TOC concentration higher than alert value, suggests the potential for higher organic contamination compared to the local drinking water, and triggers more in-depth analytical analysis of specific organic constituents to determine the safety of the water.
    - During in depth analysis, if concentrations of MCLs and CECs are: (1) below their limits, the facility may continue operations; (2) above their limits, two additional confirmation sampling events three days apart are required to determine if this initial test was an anomaly or if the treatment train should undergo a operational modification (e.g., media regeneration).
    - Exceedance of the alert limit requires development of an action plan and reporting to the State within 72 hours.
- Action level is calculated based on historical data (same data used for alert limit calculation), as the 95th percentile value times 1.5. The purpose of the 1.5 multiplier is to prevent unnecessary DPR plant shutdowns that could result from variations in the concentration of NOM in the source water that do not necessarily have adverse health impact.
    - Exceedance of the action limit indicates occurrence of chemically unsafe water that could be the result of WWTP or AWTP treatment failure or chemical peaks.
    - Set of actions for exceedance of the action limit - within 72 hours of becoming aware:

- a) either stop producing finished water and investigate, identify, and correct issue, or
- b) correct the issue with confirmation that treated water TOC is acceptable, identify the issue.

## 4.3 Engineered storage buffer and Blending

### 4.3.1 Engineered storage buffer

**Background:** Existence of environmental buffer is a major difference between IPR and DPR water reuse. Due to lack of environmental buffer and corresponding absence of environmental dilution, blending, and contaminant removal through sieving, adsorption and absorption, and biodegradation (aquifers), photolysis (surface waters), n, DPR has inherent risks that differ from treatment of traditional source waters and IPR (U.S. EPA 2017; WE&RF, Reuse 12-06 2016). In addition to that, DPR is a more closely coupled system, in which loss of retention time that occurs as a result of absence of an environmental buffer results in less time to monitor and respond to water quality concerns (WE&RF, Reuse 12-06 2016). When balanced with monitoring, response time, and treatment, ESB can provide capacity to manage fluctuations in water supply and demand, and more importantly act in lieu of environmental buffer and mitigate the inevitable process failures (U.S. EPA 2017; WE&RF, Reuse 12-06 2016).

**Requirement:** The use of an ESB is optional and recommended.

**Purpose:** To replace the value of the environmental buffer by providing: (1) process control for water quality assurance, (2) managerial control for demand, (3) operational barrier for pathogen control and chemical peaks attenuation.

- Consistent with requirements specified in Colorado Direct Potable Reuse Policy (CDPHE 2023), every DPR project must address ESB element. Project design must include rationale for:
    - Adding ESB: justification for volume selection is needed.
    - Not adding ESB: justification for alternative approach.
        - The challenge with alternative options such as allowing additional levels of treatment to stand in for process monitoring is that it does not address the loss in response time from a process failure and if improperly monitored, redundant treatment processes may be unnoticed and not provide safe operations. Consequently, a detailed failure analysis of all the treatment and monitoring processes is required for approval (U.S. EPA 2017; WE&RF, Reuse 12-06 2016).
- Response time is one of the most significant factors in DPR system design and benefits of the reservoir are directly related to the retention time that it provides. Because each unit process has an applicable monitoring procedure and corresponding response time, ESB retention time relates to time needed to detect and respond to a failure that dictates the potential of unit processes to score treatment credit (U.S. EPA 2017; WE&RF, Reuse 12-06 2016; California 2020).

- The ESB shall be sized to hold water for the time period no shorter than failure response time (FRT), ensuring that ATW effluent does not get distributed unless in full compliance with operational and regulatory parameters.
  - Use of advanced monitoring techniques is usually a controlling factor for FRT (US EPA 2017).
  - Configurations that can be used for the design of ESB include but are not limited to: plug flow pipelines, baffled tanks and tanks (WateReuse 2015).
  - The treatment credits evaluation and granting is contingent upon FRT for specific unit process and storage time provided by the ESB (WateReuse 2015; WE&RF, Reuse 12-06 2016).
- The ability of an ESB to provide protection against pathogens is based on CT value and corresponding credit achieved by prolonged retention time and specific concentration of disinfectant (US EPA 2017) (EPA Compendium 2017).
- The ability of an ESB to provide protection against chemical contaminants is based on the concentration of contaminants in the AWTF effluent. These specific conditions are outlined in the literature (California 2020):
  - In an ESB reservoir setting, chemical peaks can be attenuated if that pulse mixes with the existing on-spec water that makes up the remaining volume of the reservoir consequently reducing or eliminating the need for additional treatment barriers for the control of peak contaminants. In contrast, an ESB does not provide benefits in terms of reducing the concentrations of chemicals that are consistently present near health thresholds in the AWTF effluents.
    - An ESB with 10 days of retention time provides a 10-fold dilution of a one-day chemical peak assuming it was perfectly-mixed. Such ESB provides sufficient control of a chemical peak.
    - With reduction of retention time with smaller ESB, peak reduction benefits reduce and additional treatment barriers are needed to supplement ESB.

### 4.3.2 Blending

**Requirement:** Location and ratio of blending are not prescribed.

**Purpose:** Depending on the location and ratio, blending with another source water may offer benefits for meeting treatment goals for pathogens and chemicals. Impact of blending ratios in regards to benefits are outlined as follows (California 2020; US EPA 2017; California Water Resource Control Board 2021):

- High blending ratios (10-fold or higher dilution), provide protection from:
  - Pathogens: 1 log removal credit for pathogens can be given based on 10:1 dilution ratio of AWT effluent and finished drinking water in line with log reduction formula provided in Pathogen Control document.
  - Chemicals consistently existing around MCL and chemical peaks: Blending ratios of minimum 10:1 would solve concentration issues for chemicals around MCL and eliminate the need for additional treatment processes for chemical peaks.
- Lower blending ratios (<10-fold dilution) provide protection from:

- Pathogens: Credit based on blending ratio cannot be scored. For blending upstream DWTP, credit can be scored from DWTP if appropriately verified.
- Chemicals: only chemicals that are consistently present at or near health-thresholds can benefit from lower blending ratios (even 1:1). This is significant because this cannot be addressed by ESB. Common compounds that would benefit from even moderate levels of blending include nitrate, boron, and the DBPs.
- Treated AWT effluent stabilization. Some examples include TDS adjustment and remineralization.

**Implications**: Existing drinking water infrastructure may be impacted when introducing highly purified recycled water and such impact shall be evaluated (WateReuse 2015; California 2020; US EPA 2017; Texas Water Development Board 2015).

- Impact primarily depends on location of blending, purified recycled and drinking water quality (treatment train used), and ratio of blending.
- Every project must analyze potential blending impact based on site specific bench and/or pilot scale tests.
    - For blending prior DWTP, treatability, DBPs, reformation and corrosion tests are needed.
    - For blending after DWTP, DBPs, reformation and corrosion tests are needed.
- Treatability of existing DWTFs or the distribution system may be impacted positively or negatively.
    - RO effluent has a potential adverse impact on existing coagulation processes through reduction of alkalinity and turbidity. Carbon based train effluent is the opposite and could increase the organic content of the blended water, which could affect the DWTF treatment process. Regardless of treatment train, the potential increase in temperature of the blended water is expected and as such could affect treatment kinetics, odor production, and aesthetic acceptance.
- Because of different precursors being introduced and depending upon efficiency of treatment process and TOC, disinfectant residuals may be less stable and DBPs (e.g., TTHM and HAA5) may form in greater or lesser concentrations and different compositions.
- Reformations are challenges associated with age of AWT effluent and usually occur during traveling through a transmission pipeline.
    - Reformation of NDMA: NDMA is highly photosensitive and as such is well-removed through photolysis (high dose UV disinfection or UV/AOP). Removal of NDMA at AWT, however, does not necessarily mean that NDMA will not be present in drinking water. There are three components that lead to NDMA reformation: (1) the presence of NDMA precursors (stay even after UV/AOP), (2) the presence of dichloramine (as a result of monochloramines added to prevent membrane biofouling), and (3) elevated pH (usually as a part of water stabilization) (McCurry et al. 2017)). If a disinfectant was applied or maintained through the transmission pipeline to control biofilm growth, this could impact NDMA reformation, and the downstream treatment processes would need to be designed to account for any increase in NDMA concentrations that may occur in the pipeline.
    - Reformation of antibiotic-resistant bacteria (ARB) and antibiotic-resistant genes (ARGs). While chlorination within the pipeline may be sufficient to control ARB and ARGs, there

is a potential for ARB to regrow and ARG transfer to proceed in the presence of chlorine (Hong et al. 2018).

- Corrosion: A new water source and/or treatment changes (such as AWT effluent) requires review and approval under the R18 4 111. Control of Lead and Copper – 40 CFR Part 141, no less than six months prior to implementing a source water and/or treatment change.
    - When estimating water quality as a result of blending of AWT effluent and traditional water source, mass balance calculations may be used only as an partial analysis for chemical stability and corresponding corrosion potential because the complexity of the corrosion phenomenon requires that each water blend should be examined individually (Tang et al. 2006). While the corrosion impact of RO effluent is widely studied, the impact TDS may have on corrosion, with carbon-based train effluent, is not well understood. Carbon-based treatment trains are known to increase TDS which may result in higher alkalinity and therefore improve the water's buffering capacities (WateReuse 2015). However, TDS changes have the potential to increase chloride anions which may lead to lead and copper leaching. As well as, an increase of sulfate anions which may promote dissolution of iron sediments and depending on its content, heavy metals such as arsenic and radionuclides can be released. The nature of various metallic carbonate species influence the development and characteristics of protective coatings on the interior of the distribution system piping. Therefore, a thorough understanding and evaluation on the factors that influence the presence of carbonate and bicarbonate species in water, called the carbonate balance, is necessary in developing effective corrosion control tests (get ref from Chelsey).
- Corrosion assessment shall cover: ESB, transmission line, DWTP, distribution system and service connections (lines and premise plumbing).
    - Corrosivity impact is particularly acute for the ESB, because the benefit of blending with higher-alkalinity water usually occurs after this water element. Typical mitigation measures include compatible tank material or coating in combination with chemical stabilization of water (WRF 4536 2018).
- For corrosion assessment requirements, including category classification and corrosion evaluation steps, Safe Drinking Water Program Corrosion Control Treatment Matrix (Adapted from Colorado Water Quality Division and Edited by Arizona Department of Environmental Quality) shall be followed (will be on ADEQ web soon).
    - DPR projects are classified at Category 3 – Probable impact to corrosivity where the source/treatment project has a probable impact on corrosivity and additional evaluation is required during the design phase. The mitigation plan is required if corrosivity is expected to be adversely impacted.
- The corrosion evaluation study design must be submitted for review and approval prior to beginning the evaluation. Corrosivity evaluation shall follow ADEQ guidelines referenced in 'Safe Drinking Water Program Corrosion Control Treatment Matrix' which includes:

2. Analysis of materials Inventory (what materials are present in DLs and SLs, age of service area)
    a. Considerations for age of home, community, and disadvantaged determination (ie. EJ40) should be incorporated into the material inventory analysis.
3. Baseline monitoring (what to monitor, where (EPDS, DS, SC), minimum 1 year)

    a. Must include considerations and evaluations for seasonality, source, and treatment changes

4. Desktop analysis together with corrosivity tests where testing protocol shall follow EPA 2016 Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems.
    - The anticipated changes to water chemistry as a result of the project (e.g. pH, alkalinity, dissolved inorganic carbon (DIC), chloride to sulfate mass ratio, etc.) must be summarized and the anticipated effect on corrosivity must be described.
    - Anticipated corrosivity effects must be evaluated through corrosivity tests. This paragraph will be updated with information about suitable tests and protocols (immersion or coupon testing vs closed loop test with real pipe samples, immersion okay for Pb and Cu but not for Fe due to importance of sediment composition, protocol for harvesting pipes).
    - If the corrosivity evaluation indicates that corrosivity is expected to be adversely impacted, design must also include a mitigation plan to describe how corrosion will be controlled (US EPA 1992).
    - The State may require the system to conduct additional water quality parameter monitoring in accordance with §141.87(b) to assist the State in reviewing the system's recommendation.

- In summary, corrosivity tests or evaluations should be accomplished by:
    - Developing an understanding of factors affecting internal corrosion
    - Determine the extent and magnitude of corrosion
    - Assess corrosion control alternatives
    - Select a corrosion control strategy
    - Implement a corrosion control program
    - Monitor the effectiveness of the corrosion control program
    - Optimize the control program if necessary

- Monitoring:
    - Continued operation and compliance monitoring follow R18 4 111. Control of Lead and Copper – 40 CFR Part 141 (what is monitored, how often, how is reported, what if violated).
    - Additional monitoring. The State may require any such system to conduct additional monitoring or to take other action the State deems appropriate to ensure that such systems maintain minimal levels of corrosion in the distribution system (40 CFR, Part 141.81).

## 4.4 Salinity management

The secondary MCLs contained within SDWA, while non-enforceable, have Total Dissolved Solids (TDS) concentration at 500 mg/L (US EPA 2023). The 1958 WHO International Standards for drinking water documents the presence of more than 1500 mg/L TDS in drinking-water would markedly impair the potability of the water and become objectionable to consumers. Salinity is progressively accumulating in the soil and water supplies in Southwest due to: intensive irrigation, urban growth, low rainfall and high mineral content of geologic features. TDS in AZ sources waters are generally higher. Traditional water sources such as surface water from CAP and SRP are in the range 450-800 mg/L of TDS and 500-980 mg/L of TDS, respectively; while 46% of groundwater is over 500 mg/L TDS. Conventional drinking water treatment techniques do not remove TDS and consequently most PWSs in Central/Southern Arizona routinely deliver water in excess of the secondary standard. Some PWSs deliver water with TDS levels above 1000 mg/L.

Treated wastewater discharges in Arizona do not have a specific TDS limit. Municipal, industrial and wastewater operations typically add between 200 and 400 mg/L TDS to the drinking water supply. For example, TDS added each cycle for a City within Maricopa County that is mainly a bedroom community is 400 approx. mg/L based on 10 years of TDS data estimated as the difference between the median of drinking water and treated wastewater (See Figure 1).

A highly purified recycled water generated from an Carbon Based Advanced Treatment (CBAT) train will inevitably increase TDS in finished water. The extent of accumulation depends on source water TDS concentration, water consumption per capita, nature of industrial discharges, type and amount of wastewater chemicals used at WWTP and AWPF, and blending ratio, which will vary with spatial location and impact of natural and anthropogenic factors. The 500 mg/L secondary MCL serves as a guideline to assist public water systems in managing their drinking water for aesthetic (taste and color) and technical (corrosivity and scaling) reasons, which both can have significant economic implications. CASS model for AZ estimated that a TDS increase of 100 mg/L in 3 SW sources will result in a $30 million/yr increase in salinity related costs (USBR 2006).

There are two schools of thought about salinity management within the TAG, one group believes salinity must be managed within the rule and others believe we do not require management of salinity.

Considerations regarding salinity management include:

1. Depending on the project, water may be recycled through a closed loop system, meaning salts will continue to accumulate (NWRI, 2018).
2. Changes in TDS may affect corrosion.
3. Changes in TDS may affect other MCLs such as disinfection by products and other inorganic chemicals (e.g., lead and copper) that are regulated within SDWA.
4. Changes in TDS may have a negative economic impact on the customer. Higher TDS can shorten the life of household appliances such as hot water heaters. Several studies document the role of increased TDS including Metropolitan Water District study and Central Arizona Salinity Study (CASS Study, 2006).
5. Central Arizona Project (CAP) canal has a limit for TDS downstream of Parker Dam.
6. Higher TDS translates to higher levels of sodium which has health implications (blood pressure). Without setting MCL requirements, the US EPA in 2003 recommended that sodium concentration in drinking water should be in the range 30-60 mg/L, while this value should not exceed 20 mg/L for people on a restricted sodium diet. Health implications related to corrosivity are discussed in the blending section and managed by LCR in accordance with SDWA.
7. Increases in chlorides may affect irrigation. For this reason, the City of Scottsdale added technology (Reverse Osmosis) to remove salts.

8. As the hardness in water goes up, customers may install water softeners, which worsens the problem. This is one of the reasons why the City of Scottsdale offered incentives to buy out water softeners and paid their rate payers.
9. All other intermountain states that surround Arizona have enforceable limits for TDS.
10. As documented within the NWRI 2018 report, “Managing salinity is a long-term sustainability issue. As water is recycled in a community, chemical constituents will increase in concentration unless some form of salinity control is employed.”
11. Increases in TDS may have negative impacts on water infrastructure.

Consideration A: Regulated Salinity Management
DPR project design shall include:

1. A salinity analysis projection at the point of entry to the distribution system. The mass balance calculations must be based on specific blending ratios, salinity of influent water and cycling contributions. Minimum 1-year monitoring data must be used to account for seasonality influence and oscillations from steady state conditions.
2. A salinity reduction plan must be submitted if analysis shows that the overall TDS is over specified limits or steady state cannot be reached.
3. A public outreach effort demonstrating that the appearance and taste of DPR water are acceptable.

Examples of salinity reduction (guidance purposes only):

1. Non-treatment: Salinity can be partially managed through source control by characterizing dischargers to the collection system and requiring both homeowners and industrial users to remove TDS in their respective discharges. If not managed at the source, blending with another low TDS water source can also be implemented.
2. Treatment: Most common options include RO, NF or electrodialysis reversal (EDR). Evaporative and distillation processes can also remove salts, but are not usually employed due to higher capital costs.

Salinity targets:

1. If TDS is less than 500 mg/L, there is no regulatory requirement to control salinity.
2. If TDS is 500<TDS<1500 mg/L, then TDS should be reduced to a level not more than 100 mg/L greater than the local drinking water.
    a. This assumes that 20% DPR water (consumptive use plus treatment process loss), will raise TDS by 100 mg/L. Calculation is based on CAP as a source water with average concentration of 620 mg/L TDS (monitoring data 1997-2022), and +400 mg/L addition of TDS with every cycle of wastewater. See Figure 3.
3. TDS should not exceed 1500 mg/L.
4. Utilities may choose tailored TDS limits if they meet State limits (1-3).

Monitoring:

1. TDS monitoring is required and defined in the rule.

2. Online analyzers shall be used. Conductivity analyzers as a good continuous measurement, coupled with periodic laboratory analysis to confirm the correlation between conductivity and TDS.
3. Mean TDS values of compliance and non-compliance locations should be monthly reported.
    a. As part of the preliminary engineering and planning studies, applicants should monitor salinity of treated wastewater effluent (AWTF influent) and at the local finished drinking water (EPDS). Twelve months of data provides insight into seasonal changes due to changing water use patterns and changing water sources.
    b. Compliance: TDS monitoring of final water entering the distribution system (EPDS).
    c. Non-compliance: TDS monitoring of WWTP effluent and AWT effluent.

Proposed requirement to report exceedances:
Report to ADEQ within 3 days, provide a response plan within 30 days, implement within 90 days.

TAG Recommendation:
Regulation of Total Dissolved Solids (TDS) by the State of Arizona (State), beyond the SDWA, is not recommended. Our recommendation is that the AWT, just like any other water treatment plant or treated source water, meet the SDWA and secondary drinking water regulations.

The above recommendation is based on the fact that the EPA under the SDWA has determined that TDS does not present a risk to human health, but, rather an aesthetic (taste) and/or technical (hardness/scaling) effect (US EPA, 2023). Regulating TDS by establishing a de facto maximum contaminate level (MCL) for a non-health based chemical, such as TDS, creates regulatory challenges for the State to show beneficial economic and health outcomes. Additionally, it creates unnecessarily burdensome technical and economic impact to the utility and their ratepayers. For these reasons, decisions regarding TDS and salinity management, beyond the SDWA, should remain with the utility and their ratepayers and should not be regulated by the State.

## 4.5 Piloting

**Other State Analysis:**

**Colorado:**

- Pilot plant must be constructed and operated for a minimum of 3 months for each proposed DPR treatment train.
- Piloting can occur during the year of wastewater characterization but it is appropriate to do after sampling based on wastewater characterization.
- Piloting of each pathogen and chemical critical control point needs to be performed to generate empirical data in order to demonstrate that the barrier can reliably and consistently comply with the DPR rule.
- No pilot scaling requirements defined.

**California:**

- No specific requirements are defined for piloting

- The Validation Study protocol needs to be developed and the treatment process needs to be validated.

**Texas:**

- DPR treatment and testing requirements are being determined by the TCEQ on a case-by-case basis.
- Pilot or bench scale testing is required and should be tailored to the project specific requirements that are unique to each DPR project.

Texas Water Development Board **DIRECT POTABLE REUSE RESOURCE DOCUMENT**

**Table 7-2: Example advanced water treatment testing plans**

| Treatment Scheme No. | AWT Process | Example Test Plan | Feed Source | Typical Testing Considerations[1] |
|---|---|---|---|---|
| 1 | Secondary/Tertiary | ---[2] | --- | --- |
| | Ozone | Pilot-Scale | Secondary/Tertiary | R,D,T |
| | MF/UF | Pilot-Scale | Ozone | R,D,T,P,O |
| | RO | Pilot-Scale | MF/UF | R,D,T,P,O |
| | UV/AOP | Bench-Scale | RO | D,T,P |
| | Stabilization | Bench-Scale | RO | D |
| 2 | Secondary/Tertiary | --- | --- | --- |
| | MF/UF | Pilot-Scale | Secondary/Tertiary | R,D,T,P,O |
| | RO | Pilot-Scale | MF/UF | R,D,T,P,O |
| | UV/AOP | Bench-Scale | RO | D,T,P |
| | Stabilization | Bench-Scale | RO | D |
| | WTP | --- | --- | --- |
| 3 | MBR | Pilot-Scale | --- | R,D,T,P,O |
| | RO | Pilot-Scale | MBR | R,D,T,P,O |
| | UV/AOP | Bench-Scale | RO | D,T,P |
| | Stabilization | Bench-Scale | RO | D |

**Recommendation for Piloting:**

- Piloting period - at least 1 year at the flow rate which can be scalable to the full treatment train.
- Pilot plan need to demonstrate the pathogen and chemical removal targets and operation of the critical control points.

# 5. Wastewater Treatment

**Goal:**

- Per NWRI AZ, 2018 (NWRI 2018), "the goal of wastewater treatment is to remove or inactivate physical, chemical, and microbial constituents from raw wastewater so that the treated effluent can be an appropriate source for advanced treatment".

**Background and Current Rules:**

- The Arizona Administrative Code (A.A.C.) requires that all the new wastewater treatment facilities meet the treatment performance criteria requirements provided under R18-9-B204 which requires the facility to meet 10 mg/l of Total Nitrogen in the treated wastewater through a Best Available Demonstrated Control Technology.
- Similarly, Class A+ and B+ standards under A.A.C. R18-11, Article 3, requires the Total Nitrogen of 10 mg/l in the reclaimed water.
- Currently, in Arizona almost 80% of the wastewater treatment plants meet the requirements for Total Nitrogen per the Rule.

## 5.1 Nitrogen Management

### 5.1.1 Benefits of complete nitrification and denitrification:

- 

### 5.1.2 Nitrogen Removal Requirements:

- The wastewater treatment plant (WWTP) acts as the first critical control point for the DPR project (CDPHE 2023).
- For DPR applications, control of nitrate should either be accomplished in the WWTP to supply Class A+ or Class B+ for advanced water treatment, or properly engineered multiple barrier AWTP processes proposed (ADEQ 2018).
- For DPR, the control of pathogens and chemicals in the wastewater is an important factor for water quality. As a result, Class A+ and Class B+ should be used for DPR applications unless full-stream RO is used for advanced water treatment (NWRI 2018).
- Following approach can be adapted for DPR application:

    1) Standard approach per the current AZ rules:

        a) The nitrate removal is achieved using the biological treatment processes at the WWTP to meet the limit of 10 mg/l and alert limit of 8 mg/l and provide Class A+ or Class B+ water as a source for AWT.

b) The operational barrier needs to be provided using the continuous online analyzer/monitoring for nitrates to demonstrate the source water quality for the Advanced Water Treatment (AWT).

c) Any off-spec water needs to be diverted prior to entering the AWT train.

2) Alternative approach:

a) If the WWTP is not designed to denitrify (assumed all plants will nitrify) and the nitrate removal is not achieved at the WWTP, t. The nitrate removal must be demonstrated with the AWT train. Under that scenario, full-stream RO/ or other appropriate treatment technologies shall be provided in the AWT train to appropriately nitrate removal and meet the limit of 10 mg/l for nitrate and Total Nitrogen and limit of <1.0 mg/l for nitrite.

b) The operational barriers need to be proposed using the online analyzers for the source water to AWT and for finished water.

c) The utility may need to provide engineered storage as a barrier prior to discharge to EPDS (such as accounting for FRTs).

d) The utility needs to demonstrate how to handle the off-spec water from AWT e.g. divert back to the head of the plant, divert it to lined impoundment etc.

e) The utility needs to propose plans to discharge the effluent from WWTP in case AWT is offline.

## 5.2 Disinfection Requirements at WWTP:

- The disinfection of the treated wastewater is not mandatory because it will be a source water for AWT.
- Disinfection is required if the treated wastewater is sent for non-DPR uses and not to AWT as a source water.

## 5.3 Flow Equalization:

The TAG recommended not to have a requirement for flow equalization.

## 5.4 Monitoring Requirements:

### 5.4.1 Class A+ & B+ Monitoring:

- Daily monitoring requirements will be removed for fecal coliform in Class A+ and Class B+ reclaimed water that will serve as source water to the AWT. APP requirements will still apply if and when the plant needs to discharge.
    - Class A+ and Class B+ have daily fecal coliform monitoring requirements. Since this treated wastewater will be a source water to AWT, it will be further treated. This additional burden does not translate to increased safety.

- The treated wastewater quality for Class A+ and Class B+ will continue to include the other secondary treatment performance requirements such as BOD, TSS, turbidity, total nitrogen, and disinfection (Refer Item #5.2).

## 5.5 Instrumentation

Still being discussed

## 5.6 Bench, pilot and full scale demonstration testing and analysis

a. Sampling - Monthing sampling spanning 2 years is required for all treatment trains. Should RO be reduced to 1 and non- RO to two years?

b. Raw water and treated water sampling -

   i. Pathogens - protozoa and virus.

   ii. SDWA Regulated and SDWA unregulated chemicals.

## 6. Operations

**Goal:**

A Direct Potable Reuse (DPR) system involves the use of a number treatment and monitoring processes. The goal is to have an appropriate operation and maintenance (O&M) plan, knowledgeable and skilled operators and adequate technical, managerial and financial capacity to ensure that the DPR system meets all public health objectives and operates consistently and reliably, (NWRI 2018).

**Requirement:**

- "A DPR system must be based on 'Four R's": Redundancy, Reliability, Robustness and Resilience (Pecson et al. 2015). For DPR system, when considering holistically, these four Rs can be expanded to six Rs: Redundancy, Reliability, Robustness, Resilience, Response and Reporting as a means of incorporating not only the technology needs but also the operations team integral to the proper functioning of the processes to achieve the goals" (Walker et al., 2018).

- Operation and Maintenance Plan is required for a DPR system which includes initial start up plan, shutdown plan, Emergency Operations Plan (EOP), Emergency Response Plan (ERP), and operations plan. DPR systems are required to have well trained and highly skilled operators for operation of the Advanced Water Treatment Facilities.

### 6.1 Operation and Maintenance Plan:

a. Emergency Operations Plan (EOP) and Emergency Response Plan (ERP):

I. The requirements for EOP and ERP would be similar to the Drinking water systems. ADEQ has a template for EOP for the current drinking water plants. Amend existing plans to include the requirements and items that address AWT operations. The templates will be updated to include the following items for AWT (likely more):
   - Critical control point failures.
   - Diversion of source water (treated wastewater effluent) at the entry point of AWT, such as when to divert the off-spec water and where to divert (e.g. back to headworks or sewer line, or discharge under APP).
   - AWT needs a constant source of water (cannot dry out). Address the scenario when off-spec source water is diverted and there is no water going to AWT.

b. Vulnerability Assessment:

I. The Federal requirements of vulnerability assessment for DW systems will be followed for the AWT.

c. Operations Plan Requirements:

I. Operations plan should include at least operations of all AWT components, process descriptions, schematics, controls, alarms, equipment, SOPs, unit process guidelines, operator requirements & training, maintenance and monitoring requirements and regulatory compliance.

II. The staffing requirement will be included in guidance to avoid under-staffing.

III. O&M plan needs to be reviewed and updated at least annually (look into risks, contaminants, etc.).

IV. Maintenance needs to be done as per manufacturer's recommendation and needs to be reviewed as part of inspections.

V. The DPR Operations Management Plan will include Risk Management, Critical Control Points and Operations Management information for the facility

d. Initial Startup Plan:

I. Once AWT is constructed, we need to do the initial startup plan. Initial start up plan will consist of testing each component of the treatment train as well as the complete treatment train. Group recommended to check the well water treatment start up requirements. ADEQ should dictate the startup period (was recommended by utility).

II. Disposal of water during initial startup: Recommendation was to a sanitary sewer, discharge to the recharge basin, Type 1.04 like permit (water is from the same aquifer), or new rule for AWT water discharge, stormwater drain, retention basin) stormwater drain, retention basin.

e. Shutdown Plan: It should be the same as required for the Drinking Water Systems.

## 6.2 Operator Certification Requirements AWT

- Per NWRI AZ, 2018, "Advanced Water Treatment Facilities (AWTFs) are complex systems that must be operated and maintained by well-trained, highly skilled operations staff. These operators must be able to effectively respond to any issues or challenges that arise at the AWTF, as well as receive ongoing training and certification as new processes and techniques become available. Highly trained and certified operators are critical to the safe, successful functioning of DPR systems".
- "DPR projects are unique in that they will require operations staff with expertise in wastewater treatment, drinking water treatment, and water quality, as well as advanced treatment. With advanced treatment processes for potable reuse, the degree of expertise required is the same regardless of the size of the facility" (WateReuse 2015).
- A key element of success of any water treatment system relies on its operators and the ability of those operators to evaluate and respond to any issues that may arise. Since the source water is from the wastewater treatment plant, operations must have robust and reliable operational plans, systems, and processes to ensure safety and reliability – essential elements for the advancement of public acceptance of direct potable reuse (DPR). Relative to existing water and wastewater treatment systems, operations teams are under much greater scrutiny for performance, and must therefore have adequate training and certification processes in place to provide a framework for developing and evaluating the necessary skills for successful operation and management of water recycling systems (Walker et al 2017).

- As mentioned in Walker et al., 2018, considering six 'Rs' for DPR system, Response and Reporting is critical. Per (Pecson et al. 2015) Pecson, Trussell, Pisarenko, et al., 2015, the two strategies for achieving reliability are failure prevention through redundancy and robustness and failure response through resilience. For the DPR system, AWT operator certification needs to be based on specific knowledge, skills and experience to respond to any failure.

**Why Separate Categories of Certification?**

- The Advanced Water Treatment Operator (AWTO) must understand a broad range of water purification and monitoring systems. The focus of both Drinking water and wastewater operator certification is more on the conventional wastewater and drinking water treatment trains, and as such, there is a gap in the specific process and operating requirements for the advanced treatment processes used for potable water reuse. Processes such as membranes, ozone, biological activated carbon or biofiltration, and advanced oxidation are not adequately covered by existing training programs (Walker et al 2017).

- The AWT train is different from conventional water treatment operations in a number of important ways as listed below per CUWA, 2016.
    - DPR requires multiple barriers using a different technologies and AWT train is more complex than conventional water and wastewater treatment processes
    - Both raw wastewater quality into the WWTP and secondary or tertiary effluent source water quality to the AWT process can vary significantly, which can impact the daily operation of the AWT and potentially the finished water quality.
    - Since the source water is treated wastewater effluent, it is critical that all treatment components of AWT are operated and maintained as intended.

**Comparison of AWTO certification with DW certification:**

- The current DW certification is administered by Water Professionals Internations (WPI)/ Associated Boards of Certification (ABC). The Need-to-Know Criteria provides an understanding of the content that will be covered in ABC's Standardized Water Treatment Operator exam. A methodical and comprehensive international investigation was conducted to determine the most significant job tasks performed by water treatment operators. The content covered on the exam represents the job tasks identified through this research as essential operator competencies (ABC Website).

- Comparative analysis was performed for the 'Need to know Criteria' from ABC for DW operator exam with the content domains of operator requirements of the AWWA -CA-NV Section. Some of the advanced water treatment technologies are covered to some extent for example, reverse osmosis and membrane filtration. Following shows the content/topics which are completely missing from the DW operator certification requirements and not currently covered at all.

| AWTO requirements missing from DW 'Need to Know Criteria' |
|---|
| Source Water:<br>● Wastewater<br>● Raw Wastewater and Industrial Source Control<br><br>Advanced Treatment Processes:<br>● Nanofiltration<br>● Advanced Oxidation<br>● Biological Activated Carbon<br><br>Controls and Monitoring<br>● Critical Control Points |

The following content is adapted from 'Development of an Operation and Maintenance Plan and Training and Certification for Direct Potable Reuse (DPR) Systems by Walker et al., 2017. The details comparison table is attached in the Appendix. Under this report, the gap analysis is performed among the Drinking Water and Wastewater Certification Curriculum of California with the requirements for Advanced Water Treatment Operator content. The DW operator certification curriculum for California is comparable to the AZ DW operator.

| **Topic Area** | **Additional Requirements for DPR** |
|---|---|
| Source Water/Water Quality (Groundwater/Surface Water/Raw Water Storage) | Additional information for sewershed management and source control. Understanding of industrial waste contributions and other source contaminants that may risk treatment processes.<br>The source water for DPR treatment processes is municipal wastewater. For drinking water operators, a basic knowledge of wastewater processes are required. In addition,<br>● Understanding source water risks from wastewater sources.<br>● Ability to develop and manage a water quality risk register.<br>● Understanding process changes and impacts from wastewater treatment processes.<br>● Understand important key process monitoring parameters at inlet of an advanced treatment plant. |
| Treatment Processes - Filtration | Conventional filtration appears well covered,however granular activated carbon and biologically carbon will require significantly more coverage. Membrane filtration (MF/UF) will require substantial coverage. |
| Treatment Processes - Disinfection | Will require additional detail for chloramine dosing, which is used for membrane disinfection. Additional content required includes:<br>● Knowledge of chloramine control. Protection of RO membranes from chlorine.<br>Ozone also requires additional information including: |

| Topic Area | Additional Requirements for DPR |
|---|---|
| | ● Basic understanding of ozone chemistry.<br>● Knowledge of UV absorbance analyzer calibration.<br>● Ozone residual analyzer management<br>● Ozone dose-control strategies |
| Treatment Processes - Demineralization (RO, NF and Ion Exchange<br>Treatment | Reverse osmosis is a core technology for the RO based treatment train. Content for this process is required, including:<br>● Operation and maintenance of membranes<br>● Measurements of process performance and membrane integrity<br>● Monitoring and measurement of chemical rejection and log reduction of pathogens |
| Wastewater Treatment Technologies | Valuable knowledge for DPR treatment to understand impacts upstream of advanced treatment. It is also important to understand the difference between monthly compliance goals/environmental impacts versus continuous water quality goals for DPR and drinking water quality goals.<br>Also need an understanding of enhanced source control. |
| Operations & Maintenance (O&M) | Specific knowledge of treatment process maintenance requirements including items such as membrane management, UV lamps, ozone generation and lime/$CO_2$ systems for stabilization.<br>The understanding of detailed instrument verification and calibration for multiple analyzers is an important addition for DPR. |
| Regulations | Additional knowledge of future DPR regulatory requirements must be included. In addition, any specific reporting and communication protocols for regulators must be included.<br>An important aspect will be the comparison and contrast with water and wastewater regulations. A specific example will be how water quality treatment requirements will likely be a single maximum target, rather than monthly averages |
| Communication | Effective communication is critical for the success of DPR. Operators must understand the importance of timely communication within their operating facility to assist in rapid and effective operational responses to issues. They must also<br>understand the importance of clear communication across operational interfaces, and to external stakeholders including regulators and the public |
| Management of analyzers and instruments. | There is a high reliance on analyzers and instruments for successful IPR and DPR plant operation. Specific curriculum material that covers the importance of regular instrument |

| Topic Area | Additional Requirements for DPR |
|---|---|
| | verification, calibration and key maintenance requirements for important instruments is required. |
| Operational Interfaces | Knowledge of requirements at operator interfaces between wastewater treatment and advanced treatment, and advanced treatment and drinking water treatment is required. For some utilities, the full suite of treatment may be operated by a single entity. For others, there will be different organizations operating these entities. An understanding of process and treatment at these interfaces is required. |
| Critical Control Point and the HACCP Process | An understanding of the critical control point approach, including specific critical control points for DPR processes, water quality risk management and operational responses. |

***Source: 1.)*** *Walker, et. al., 2017 - Development of an Operation and Maintenance Plan and Training and Certification for Direct Potable Reuse (DPR) Systems. Project Number Reuse-13-13.* ***2)*** *'Need to Know Criteria' for DW and WW operator certification from* Association of Boards of Certification

**Path forward for AWTO certification:**

As discussed in the previous sections, there are essential components which are missing from the current operator certification curriculum. Per Walker et al., 2017, an AWTO operator certification must provide:

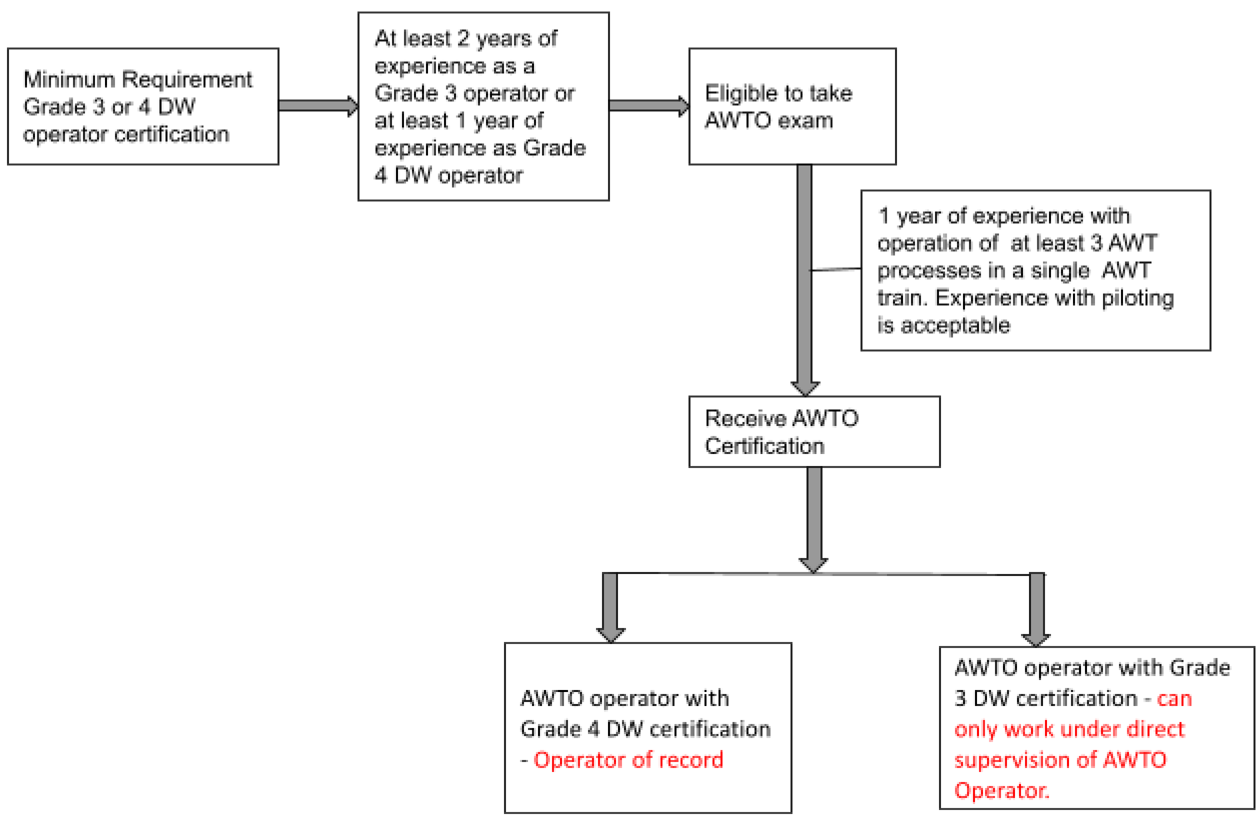
- Adequate coverage of DPR technologies.
- Understanding of source water risks and risk management.
- Incorporation of the critical control point methodology.
- Specific DPR regulatory requirements.
- Management of operational responses.

The Technical Advisory Committee (TAG) for DPR recommended having a separate category of certification for AWT and recommended having two categories of AWTO certification - Grade 3 & 4. It was also recommended to keep the highest level of certification to Grade 4 for AWTO. Based on the recommendations, following are the options for AWTO certification:

- **Option 1: Separate Category for AWTO Certification With One AWTO Grade:**
    - Create one grade for AWTO certification.
    - Eligibility for test: Grade 3 or 4 DW operators will be eligible to take the AWTO certification exam.
    - Eligibility for certification:
        - Grade 3 DW operator will need to have at least 2 year of experience in operation of drinking water facility as a Grade 3 DW operator and at least 1 year of

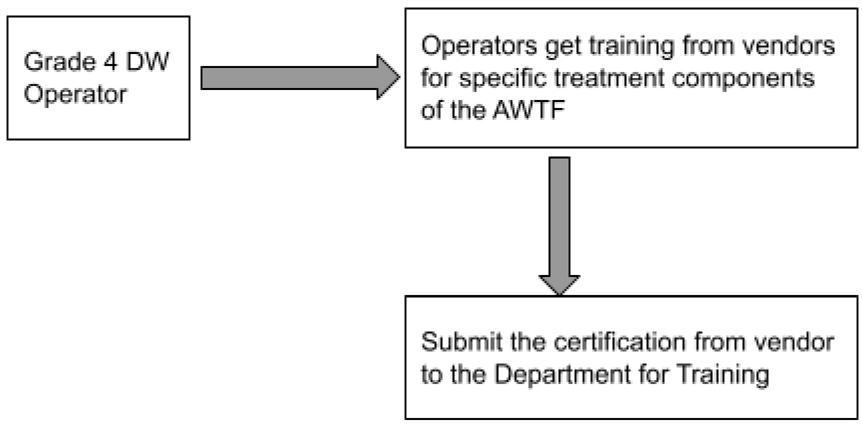
experience in the operation of at least 3 AWT processes (e.g. Ozone-BAC, MF, UF, RO, UV-AOP) in a single AWT train to obtain AWTO certification.

- Grade 4 DW operator will need to have at least 1 year of experience in operation of drinking water facility as a Grade 4 DW operator and at least 1 year of experience in the operation of at least 3 AWT processes (e.g. Ozone-BAC, MF, UF, RO, UV-AOP) in a single AWT train to obtain AWTO certification.The experience in operation of a pilot treatment train will be acceptable.
- AWTO with Grade 4 DW operator certification is required to operate AWTF as in direct responsible charge.
- AWTO with Grade 3 DW operator certification can be a shift operator under the supervision of AWTO with Grade 4 DW certification.
- Transition period - There will be a transition period initially till the operator certification program gets developed.




- **Option 2: Training Certification for AWTO Processes:**
  - Another option is to have a training certificate for AWTO processes. The facility will require a Grade 4 WW operator for the wastewater treatment plant from where the DPR source is generated. The AWT facility will require a Grade 4 DW operator for AWT trains.

- ○ Grade 4 DW operators with a minimum of 30 months of qualifying experience and training from vendors for the specific treatment train components are eligible to operate the AWT facility. The training certificate needs to be presented to the Department.
- ○ The following are the disadvantages with this option:
  - ■ Training offered by vendors is not standardized. Different vendors will have different styles of training so it will be challenging to standardize it.
  - ■ There will not be any assessment for the DPR treatment processes and rules.
  - ■ The DW operator will not have understanding of WWTP processes or source control.




## 6.3 Technical, Managerial and Financial (TMF) Capacity for DPR Facility

**Purpose:** This document contains the background information for the TMF capacity and proposed requirements for the TMF capacity for DPR facility.

**Current Requirement for TMF for DW system:**

- The 1996 SDWA requires states to incorporate TMF capacity into public water system operations. Arizona has an existing capacity development program for public drinking water systems, per requirements in the 1996 SDWA, to assess the TMF capacities of water systems. Capacity Development is defined as a process for water systems to acquire and maintain adequate TMF capacity to provide healthy drinking water consistently, reliably and cost-effectively.
- Per current Rule, New community and nontransient, noncommunity public water systems must provide an Elementary Business Plan, including supporting documentation for the capacity development evaluation.

**Technical Capacity |** The physical and technical capability of the system, including but not limited to, source water adequacy, infrastructure sufficiency and technical knowledge of certified operators.

**Managerial Capacity |** The administrative and organizational structure of the system, including but not limited to, ownership accountability, staffing, corporate structure and communication.

**Financial Capacity |** The financial resources to maintain the system now and in the future, including but not limited to, revenue sufficiency, credit worthiness and fiscal controls.

**Why TMF Capacity Assessment for DPR (Reference #1 and #2)**: Since wastewater is used as the source water, DPR facilities should require a higher level of accountability. TMF assessment for DPR can be used to determine the capacity of a utility to:

- Build, operate, manage, and sustain a DPR system for the long-term.
- Plan, achieve, and maintain regulatory compliance.
- Provide effective public health and environmental protection.
- Make efficient use of public funds and sustainable public investments.

**Current Drinking Water Rule Requirements for TMF:**

- R18-4-602 - New public water systems are required to submit Elementary Business Plan - https://apps.azsos.gov/public_services/Title_18/18-04.pdf

- ADEQ has a template for 'Capacity Development Application For A New Public Water System' - https://static.azdeq.gov/forms/capacitydevelopmentapp.pdf

**Comparison of TMF Capacity requirements under Arizona Administrative Code for DW systems and for DPR facilities per NWRI Guidance:**

| **Technical Capacity** | |
|---|---|
| **Elementary Business Plan Checklist per Arizona Administrative Code** | **Guidance from Direct Potable Reuse in Arizona by NWRI and Recycled Water Work Group (Reference #1 & #2)** |
| ☐ Source adequacy<br>☐ Source meets DW quality standard and technology<br>☐ Infrastructure - Design criteria met<br>☐ Treatment Technology<br>☐ Certified Operator requirements | ☐ Feasibility of consolidation.<br>☐ Existing water sources (sufficient sources, source control, etc.).<br>☐ Water system treatment capacity.<br>☐ Monitoring.<br>☐ Number of trained certified operators. |

| | |
|---|---|
| ☐ Projection of technical and engineering need for period covering day-1 to final build-out or for a 5-year time period<br>☐ System design specification & proposed uses<br>☐ Components used in the design & Construction based on specs<br>☐ Operation & Maintenance plan including repair & replacement protocols<br>☐ Emergency operation plan | ☐ Operations and maintenance (O&M) plan.<br>☐ Treatment, storage, and distribution facilities.<br>☐ Compliance records, violations of federal and state compliance standards, and plans to correct these violations. |

**Proposed requirements of Technical Capacity for DPR Facility:**

1. **Technical Capacity:**
   - Existing water sources (sufficient sources, source control, etc.), source adequacy
   - DPR water system treatment capacity
   - Treatment Technology and infrastructure design meet design criteria for DPR
   - Technical and engineering needs, manufacturer specifications showing component life span
   - Treatment, storage and distribution facilities information
   - Certified operator requirements
   - Monitoring requirements
   - Emergency operations plan and Operation and maintenance plan including manufacturer's specification, repair and replacement protocols,
   - Compliance records, violations of federal and state compliance standards, and plans to correct these violations.
   - Feasibility of consolidation - Discussion on if there is a possibility to consolidate with other facility/system

| **Managerial Capacity** | |
|---|---|
| **Elementary Business Plan Checklist per Arizona Administrative Code** | **Guidance from Direct Potable Reuse in Arizona by NWRI and Recycled Water Work Group** |

| Managerial Capacity | |
|---|---|
| ☐ Ownership Type info<br>☐ Management info with organizational chart, job description and responsibilities<br>☐ Proper grade Operator<br>☐ Capital improvement plan up to the proposed full system build-out or for a 5-year projection<br>☐ Intent to create CWS or NTNCWS<br>☐ Ownership transfer<br>☐ Policies to ensure all TMF info to transfer to new owner | ☐ Ownership<br>☐ Management<br>☐ Water rights<br>☐ Operations (including training and technical competency, and the O&M plan)<br>☐ Organization<br>☐ Master planning (including an inventory of equipment and infrastructure)<br>☐ Emergency response planning<br>☐ System policies<br>☐ Customer service |

**Proposed requirements of Managerial Capacity for DPR Facility:**

2. **Managerial Capacity:**

- Ownership information
- Management and organization info with organizational chart, job description and responsibilities
- Reclaimed water rights to the DPR source through a contract (Recommendation during AZ WateReuse Symposium)
    - In a scenario, where the WWTP is owned by a different entity than the DPR facility and WWTP provides reclaimed water to a DPR facility. There has to be a contractual agreement between both parties for sale price of the reclaimed water, quality of the reclaimed water, compliance and reporting requirements if quality does not meet etc.
- Manage APP or AZPDES permit to use as back-up options (Recommendation during AZ WateReuse Symposium)
- Proper grade of certified operators
- Operations (including training for staff, technical competency, technical knowledge & implementation, and O&M plan)
- Master planning (including an inventory of equipment and infrastructure), tool for a strategic asset management plan and a computerized maintenance management system
- Emergency response planning
- Create system policies
- Provide customer service and communication/outreach
- Implement a continuous improvement program for the DPR project based on best practices (Reference: #3)
- Institute a quality assurance process to demonstrate that data and information gathered to make compliance determinations and operations and management decisions are based on best practices (Reference: #3)

| **<u>Financial Capacity</u>** | |
|---|---|
| **Elementary Business Plan Checklist per Arizona Administrative Code** | **Guidance from Direct Potable Reuse in Arizona by NWRI and Recycled Water Work Group** |
| ☐ 5-year Financial Capacity Plan<br>☐ ACC registration for private entity, rate approval from ACC - Review for DPR facility<br>☐ Financial Capacity information*<br>☐ Financial Capacity Viability Testing* | ☐ Capital costs<br>☐ Lifecycle costs<br>☐ Budgeting (and budget control)<br>☐ User fees<br>☐ Financial audits/bond rating<br>☐ Rate studies<br>☐ Financial planning and management<br>☐ Capital improvement plan |

***https://static.azdeq.gov/forms/capacitydevelopmentapp.pdf**

**<u>Proposed requirements of Financial Capacity for DPR Facility:</u>**

3. **<u>Financial Capacity:</u>**
   - 5-year financial projection (Template available for DW system - https://static.azdeq.gov/forms/capacitydevelopmentapp.pdf)
   - Financial Viability Test - (Template available for DW system - https://static.azdeq.gov/forms/capacitydevelopmentapp.pdf)
   - Capital Cost
   - Lifecycle cost - 20-year life cycle cost of equipment
   - Budgeting (and budget control) - funding sources shall be identified for the necessary costs associated with annual operations and maintenance, energy cost, personnel cost, capital replacement, and an annual capital budget (Reference: #3)
   - User fees
   - Financial audits/bond rating
   - Rate studies or assessment of impact fees needs to be in place for DPR facilities (As a guidance but not to require in Rule - Recommendation during AZ WateReuse Symposium)
   - Financial planning and management
   - Capital improvement plan and replacement cost

## 6.4 Small Facility Consideration:

- Per SDWA, small public water systems (PWSs) are broadly characterized as systems serving 10,000 or fewer customers.
- Small water systems interested in implementing DPR will present unique challenges; however, small systems will need to comply with all DPR regulations and all criteria should be similar to all sizes of the systems. (NWRI 2018)
- There will not be any flow/population threshold for the small system for DPR purposes and all rules and regulations of DPR will be applicable to small DPR systems.

## 6.5 Utility Collaboration:

- DPR projects often involve multiple water and wastewater utilities. Because of the collaboration required for DPR, inter-jurisdictional issues are important and must be addressed. It should be required to develop Memorandums of Understanding (MOUs) or an inter-governmental agreement that define roles and responsibilities and describe how different agencies will work together (e.g., joint committees) (NWRI 2018)

- **<u>Other State Analysis for Utility Collaboration:</u>**

  a. **California - § 64669.25 Joint Plan**

     (a) A DiPRRA shall submit a Joint Plan that describes the wastewater management agency(ies), wastewater collection agency(ies), public water system(s), and other partner agency(ies) involved in the DPR project, the roles and responsibilities of the partner agency(ies) involved in the project, the legal authority of each to fulfill its role, and the overall organizational structure involved in implementing the Joint Plan. At a minimum, the Joint Plan shall include the following:

       (1) Procedures to ensure that the DiPRRA will have current knowledge of the status of treatment for the entire DPR project;

       (2) A description of corrective actions to be taken if water delivered from a treatment facility fails to meet the treatment or water quality requirements of this Article;

       (3) The procedures to implement source control requirements pursuant to section 64669.40, including provisions to conduct source control investigations;

       (4) The procedures a DiPRRA will implement for notifying partner agency(ies) and the State Board of:

         (A) Operational changes that may adversely affect the quality of water delivered by the treatment facility;

(B) Treatment failure incidents and the corresponding corrective actions taken;

(5) The procedures for notifying customers pursuant to sections 64669.20, 64669.60, and 64669.125, and the procedures for receiving customer complaints pursuant to section 64669.95;

(6) A plan to optimize corrosion control to reduce lead and copper levels in the distribution system; and

(7) The steps the DiPRRA and partner agency(ies) will take to provide an alternative source of domestic water supply or drinking water in the event that the DPR project is unable to supply water.

(b) A DiPRRA shall submit an updated Joint Plan when there is a change in the organizational or legal structure of the DPR project management.

(c) A DiPRRA shall submit to the State Board with the permit application copies of all agreements, such as Joint Powers Authority or bilateral agreements, that were entered into to facilitate the operation of a DPR project.

b. **Colorado:** Requires interagency agreements between the supplier and the wastewater entity to implement an enhanced source control.

- **Recommendation for Utility Collaboration:**
  a. The DPR facility will be required to develop Memorandums of Understanding (MOUs) or an inter-governmental agreement that define roles and responsibilities and describe how different agencies will work together (e.g., joint committees)
  b. Agreement should include at minimum:
     - Roles and responsibilities for all involved (e.g. utilities/facilities/Utilities' departments) - Agreement needs to include roles and responsibilities for each utility involved including utility departments if same utility but WW and DW departments. For e.g. WWTP's role is to treat wastewater and in case of treatment upset at WWTP, how do they notify other utility/department, what is their responsibility. This needs to be defined under agreement and should be agreed upon by both entities.
     - Legal authority - There legal authority should be defined for each utility/department to fulfill the role and organizational structure involved in implementing the collaboration plan (DPR Framework, CA).
     - Contingency action requirements - The agreement should describe the procedures regarding the contingency e.g. if any failure happens at the WWTP how it will be handled

and notified to downstream AWT, how it will be notified to the Department, which entity will be responsible etc.

- Enforcement action - The agreement should describe enforcement actions e.g. if WWTP is consistently providing off spec water to DPR utility, then DPR utility can take enforcement action against WWTP or impose the penalties.
- Notifications for treatment failure, incident reporting, any operational changes - There should be an agreement on who will be responsible for notifying the Department and also internal notification regarding any failure, incident reporting.

c. The agreement needs to be submitted to the Department for approval prior to operation of the DPR facility.

d. Any changes to the agreement need to be reviewed and approved by the Department.

# 7. Public Outreach

## 7.1 Recommendations Follow:

ADEQ's Direct Potable Reuse Program should address public communication and outreach in three different ways:

1. Facility required outreach/communication
2. State outreach and communication efforts
3. State produced resources, including program guidance and a communication toolkit

The Outreach Subgroup was heavily influenced by the NWRI report (NWRI, 2018), which states, in part:

"Public confidence, acceptance, and support is necessary for the successful implementation of potable reuse projects and will be essential for DPR. Notably, public acceptance is equally as important as technical merit (TWDB, 2015; Macpherson and Slovic, 2011). The public needs to trust that the use of recycled water as a source of municipal water supply is protective of public health. For example, one concern could be the health risks associated with chemical constituents, such as CECs, in the water supply. Proponents of DPR (i.e., utilities and communities) should develop and launch public outreach programs within their service areas to address public concerns, build public confidence, and garner public acceptance of potable reuse.

…..

It is not the role of the State of Arizona to perform outreach for individual DPR projects or to provide guidance to utilities on DPR outreach strategies; however, the State should be aware of how it can impact the public's perception of potable reuse and develop a strategy for communicating about DPR in general.

For example: The State of Arizona should consider adopting a general outreach program on DPR, especially during the initial years of DPR rule adoption and implementation of the first few DPR projects in Arizona. Guidance on a statewide approach for potable reuse communications and outreach is available (Milan, 2015)." NWRI p. 94

## 7.2 The state's or a project proponent's outreach/communication plan should:

- Be a written plan with a detailed set of strategies to communicate information about the project or program to stakeholders.
- Have a clearly defined purpose and goal with consistent, accurate, and understandable messaging.
- Use consistent terminology.
- Be comprehensive and promote transparency, connection, accessibility, and inclusivity.
- Be tailored to meet the needs of the community, whether that community is statewide or local.
- Include culturally relevant materials, conduct outreach in multiple languages, and consider access to technology and literacy.

- Materials should be available in alternative formats including for non-English speakers, deaf and hard of hearing individuals and those with visual limitation.
- Be implemented early with audiences who represent a broad array of the constituents impacted by DPR.
- Build on past lessons learned from other potable reuse projects (i.e. East County Advanced Water Purification, Pure Water San Diego).
- Use various communications strategies, such as social media marketing, digital materials, media outreach, collateral materials and advertising as well as guidance from other demonstrations in the country to:
  - Inform
    - provide information to the community via printed materials, website, etc.
  - Consult
    - obtain community input ie focus groups, surveys
  - Involve
    - work directly with the community through the process ie workshops, community forums
  - Collaborate
    - create partnerships with groups within the community (stakeholders, influencers) to be involved on an ongoing basis ie resident advisory committees
  - Empower
    - provide a place for people to ask questions and be heard via accessible means such as a phone number or inbox
- Consider competing issues. Water availability and reliability is only one pressing issue of many that face the state and communities.
- Consider multiple demographics, accessibility, and environmental justice.
- Consider giving special attention to groups less likely to accept DPR.
- Include metrics to determine progress/success of the above plan elements.
- Should be reviewed often and updated as needed.

## 7.3 Facility Outreach/Communication Plan

- Required by rule for each facility producing or supplying direct potable reuse (purified water).
- Facility shall submit a proposed outreach/communication plan for approval with a permit application for each proposed direct potable reuse (purified water) facility project.
- A communication plan is a written plan with a detailed set of strategies to communicate information about the project to stakeholders. The plan must be comprehensive and promote transparency, connection, accessibility and inclusivity.
- Facility (or its liaisons) may have already initiated and completed aspects of the project's communication/outreach plan at the time of application. In such cases, the facility may submit documentation of implementation of the outreach/communication plan to date with the permit application.
- ***Requirements*** **for Facility** Outreach/Communication include:
  - A robust communication plan to adequately notify and accurately inform potentially interested community stakeholders of a facility's project plan to produce DPR finished

water, as well as of long-term key aspects of the project, including operation, costs, water quality, and safety (NWRI, 2018).

  i. Interested stakeholders include water customers and consumers, government officials, and property owners.
  ii. Proven techniques and tools to listen to and communicate with the community and address concerns.
  iii. Communication plans shall be tailored to meet the needs of the community via various communication means, such as social media marketing, digital materials, media outreach, demonstration facilities, advertising, and public meetings or workshops.
  iv. Communication plans shall be scaled commensurate to the expected number and scope of consumers of direct potable reuse (purified reuse water).

  - Establish a Project-specific Independent Advisory Panel to provide an on-going periodic scientific peer review of the potable reuse project at least once annually during the first five years of operation of the facility, and then every two years thereafter. The panel may provide findings and recommendations related to water quality monitoring, treatment process efficiency and compliance with regulations, which the facility shall in good faith attempt to obtain from the panel. The facility shall remit panel findings to the regulatory body with each renewal application with a summary of responses to each finding, including any actions taken in response. The facility shall also make such findings and responses readily accessible on their website within…..[timeframe? for how long?];
  - Applicable SDWA notification requirements; and
  - Other notification and outreach/communication requirements as prescribed by the program, such as:
    i. Salinity in the source water (or potential source water) exceeding some level defined by the facility, that may interfere with treatment, or where pass-through levels may negatively impact distribution or the environment, as determined as a part of the approved facility's salinity evaluation and response plan, then the outreach/communication plan can must also be designed address salinity issues and include information such as:
      1. Potential source water is mentioned in the case that there are multiple contracts or seasonal source water scenarios at the site
      2. Source water may also accumulate salts if, for example, a facility does not blend and it is a part of a closed loop water system reliant on DPR,
      3. An outreach/communication plan would address salinity by informing the public about the deleterious effects of salt accumulation and what they can do about it, such as limiting use of water softeners.
      4. See examples of previous communications from Tucson Water: https://www.tucsonaz.gov/files/water/docs/1005empnews-eng.pdf
    ii. Required communications as a part of the approved contingency plan

- A facility shall maintain a written record demonstrating/documenting good faith substantial compliance with its approved communication plan.
- **ADEQ may not issue an operating permit to a facility unless** the outreach/communication plan has been submitted and approved.

- ADEQ shall approve a proposed communication plan <u>unless</u> the Department determines that the plan will not adequately and accurately notify the service area customers.
- ***Recommendations*** **to Facilities** for the Required Outreach/Communication Plan (*To Be Documented in Guidance*)
    - It is recommended that a communication plan be initiated and partly implemented prior to the application stage, and continue throughout design, construction, startup phases, and in some manner throughout the lifetime of the facility.
    - It is recommended that a communication plan be used to communicate :
        i. Early, which can be as early as the planning process and specific to the project.
        ii. To various different audiences in the community, including those that can build awareness in others (such as opinion leaders, educators, and other influential community members, and maybe even communicate in partnership or through such members of the community)
        iii. In a manner to build awareness, trust, and confidence with a non-technical audience.
        iv. Using consistent messaging and proven techniques and tools to communicate with the community, engage the media, and respond to tough questions and misinformation
        v. Utilizing messaging developed by ADEQ or creating localized messages consistent with the state's program and overarching messaging, for example:
            1. What direct potable reuse (purified water)is
            2. The need for the DPR project in the community
            3. Expected changes in costs to the community due to the DPR project (cost - benefit analysis)
            4. Expected changes in taste, if significant
            5. Key aspects of the project, including operation, project costs, water quality, and safety
    - Have a rapid response plan to communicate internally and externally in order to respond to sudden misinformation or unexpected events.
    - Materials should be available in alternative formats including for non-English speakers, deaf and hard of hearing individuals and those with visual limitation.
    - Regarding a potential demonstration Facility or Demonstration Pilot
        i. The inclusion of a demonstration facility is recommended as part of an overall public outreach and communication plan.
        ii. Coupling such a program with the construction of the facility, the operation of a demonstration facility would be ideal in order to provide community stakeholders with a tangible representation of the project.
        iii. Additionally, pilot demonstration facilities support operator training, water treatment validation, and monitoring opportunities in addition to public outreach.
        iv. It is recommended that the Project-specific Independent Advisory Panel review any or all technical or scientific aspects of the public outreach and education program including the pilot demonstration facility to support the Project Team.

## 7.4 State Produced Resources for Facilities

- The state should draft guidance for facilities in order to provide:
    - Permitting information. Help facilitate the permitting and operating process and to provide a holistic and visual understanding of how a project interacts within various water quality programs.
    - Technical information. Technical examples and current literature for a facility to understand what the state considers to be sound engineering when designing a system and planning for monitoring and operation.
    - Communication plan resources. Tools and materials (i.e., a communication toolkit) for the use by communities planning to propose a DPR project.
        - This should include useful outreach resources to provide facilities with a draft communication roadmap, and draft messaging, communication strategies, and example tools and materials that may be adjusted to fit the community served by a proposed project.
        - State should keep a repository of information, tools, outreach materials developed by the State.
        - State should keep a repository of tools and outreach materials developed by Arizona specific communities.
        - The state should not perform outreach for specific DPR facilities (except for permit hearings on the permit itself), and should only provide suggested strategies for developing an outreach/communication plan to raise awareness of DPR and foster acceptance.
- State guidance should be reviewed and updated every five years with stakeholders (possibly in partnership with a stakeholder panel).

## 7.5 State Conducted Outreach/Communication Plan:

The state's outreach/communication plan goal should be to create public acceptance of direct potable reuse. Acceptance is built through awareness, trust, and confidence. It is also important to raise awareness of the water situation in Arizona to demonstrate why direct potable reuse is a viable and sustainable option.

The state should:

- Identify and engage key audiences and stakeholders to develop target outreach lists.
- Conduct research on public perception of the water situation in the state and the viability of direct potable reuse as a possible solution. This should be completed by June 30, 2023.
- Begin messaging and communication once target audiences have been identified and the research on public perception has been completed and analyzed.
- Engage statewide associations involved with water supply management and quality.
- Partner and co-sponsor events or other educational opportunities to educate the public and increase support for potable reuse.
- Use the framework document itself as a tool in its messaging to stakeholders as to what program's goal is and how it will operate, including how stakeholders will interact with drinking

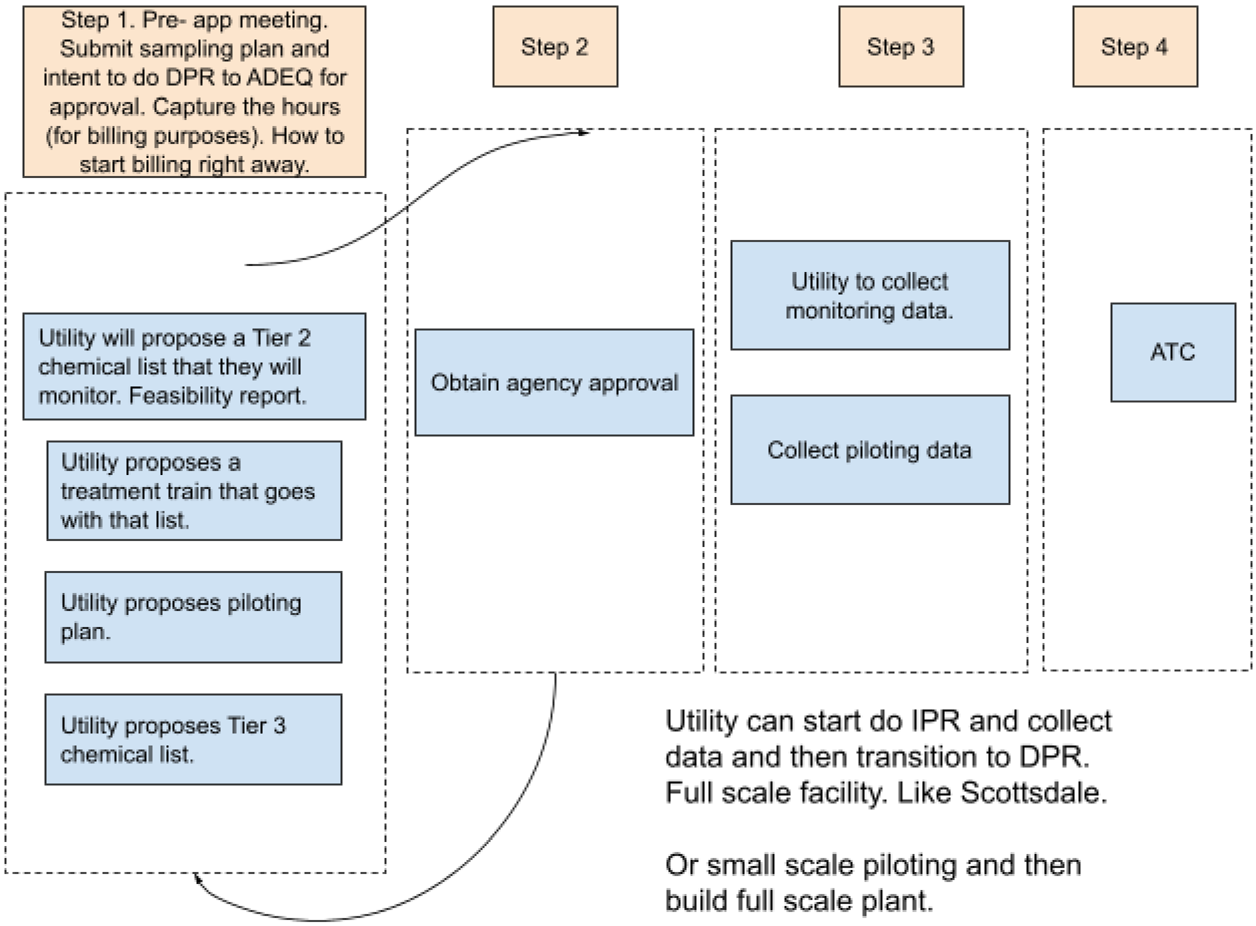
water staff and DPR permitting staff. The audience for this is wide and varied, including utilities, media, legal and compliance advisors, and the general public.

- Develop tools and resources that can be used as templates or guidance by facilities.
- Develop consistent terminology.

In its messaging, the state should:

- Clearly convey what DPR is and why it's beneficial.
- Clearly colloquially convey what the DPR program is, and how it interacts with other water quality programs.
- Clearly articulate water problems in the State such as diminishing water levels and reduction of aquifer recharge and highlight a solution through DPR.
- Explain the water cycle and value of potable reuse in a non-technical structure
- Assist the public in viewing direct potable reuse as "key to a sustainable planet"
- Develop consistent terminology
    - Use uniform terminology and potentially develop specific terminology on a local level
    - The State can take the lead on setting appropriate terminology that can be used when discussing potable reuse to the public.
    - Avoid using technical terms not understood by the public.

## 8. Permitting process




**DPR Process Steps:**

STEP 1: DPR Meeting with ADEQ:

- Introduction meeting to get familiar with the process: Utility will reach out to ADEQ for pre-application (DPR Meeting?) and express interest to do DPR. This is beneficial particularly if utility/consultants are not familiar with the rules/framework/guidance.
- Discuss the procedure for sampling, enhance source control, design of treatment train, and piloting at high level.
- Discuss the public outreach plan

STEP 2: Submit proposed DPR plan to ADEQ which shall include:

- Sampling/monitoring plan based on local conditions and based on 'Chemical Control Guidance'.
- Enhance source control plan based on 'Chemical Control Guidance'
- Proposes Tier 2 and Tier 3 chemicals.

- Proposes the treatment train based on the list of chemicals.
- Propose piloting plan including piloting scale, and duration of piloting operation
- Propose the public outreach plan

STEP 3: ADEQ reviews the DPR plan
- ADEQ receives the DPR plan and review the plan
- ADEQ approves the DPR plan and notify the applicant in writing.

STEP 4: Utility implements the DPR plan approved by ADEQ
- Utility starts sampling for the approved chemicals under DPR plan for the frequency approved by ADEQ
- Utility may commence operating pilot trains as approved under the DPR plan. - Is ATC required for pilot trains?
- Utility starts collecting data from source water sampling and pilot train operation sampling.

STEP 5: Utility submit a DPR application for ATC
- Utility submit DPR application for ATC approval. This application needs to include all DPR components and demonstrate BADCT for treatment, pathogen removal, chemical control, and enhance source control.
- The application needs to include demonstration for TMF capacity, operations plan and draft utility collaboration document.

STEP 6: ADEQ issues ATC Permit for DPR facility
- ADEQ reviews ATC application and issues the ATC permit for DPR facility.

STEP 7: Utility submits AOC application
- Utility constructs the DPR facility per the approved ATC permit
- Utility submits AOC application along with final operation and maintenance plan, final agreements for utility collaboration, financial requirements.

STEP 8: ADEQ issues AOC permit for DPR facility
- ADEQ reviews the AOC application.
- ADEQ does the validation inspection for the DPR facility.
- ADEQ issues the AOC permit to operate the DPR facility.

Fees - The fees would be similar to the APP. The DPR project would be a multi-year process so the billing will start from a pre-application meeting in Step 1 Determine/discuss the billing for these steps.

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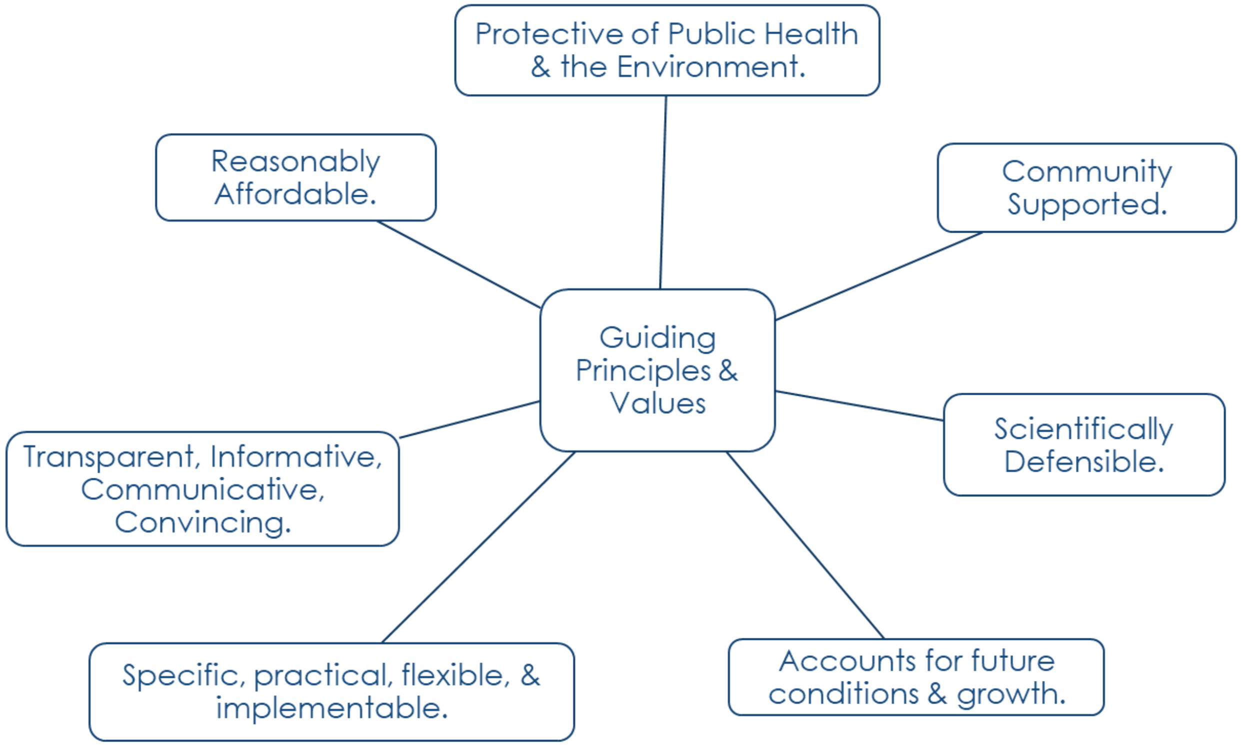
# Appendix

## Appendix #1
## Guiding Principles and values



# Appendix #2
# Pathogen control survey summary

**Question 1:** Should we include two log reduction value (LRV) frameworks for utilities, (1) a raw sewage option that requires no further pathogen monitoring and (2) a treated effluent approach requiring a site-specific study?

Both options = 7 | Treated Effluent = 2 | Raw Sewage = 1

**<u>Support for "Both":</u>**

1. Raw sewage is most intuitive choice, but treated effluent gives facilities an opportunity to indirectly receive credit for upstream treatment processes.
2. Desire to allow utilities to adapt to their unique situation and/or constraints.
3. Allowing both options will increase utility adoption of DPR.
4. Both options facilitate adoption when there are different owner/operators of the WWTP and advanced treatment facility.
5. Both options are preferred but treated effluent option must include an independent advisory panel (IAP) that ultimately signs off on the utility-specific approach.

Support for "One or the Other":

1. Allowing two options may be difficult to manage/permit à raw sewage preferred to eliminate need for site-specific monitoring.
2. The treated effluent approach for distinct entities could be a concern if an upstream treatment upset potentially impacts the 'treated effluent' concentration arriving at the advanced treatment facility. That upset might not be reflected in the historical monitoring data that were used to determine the LRVs needed at the advanced treatment facility. This would not be an issue for the raw wastewater approach.

**Question 2:** For determining viral LRV requirements, which type of concentration data (i.e., methods) should be considered?

Culture + molecular data = 7 | Culture data only = 3

**<u>Support for "Culture + Molecular"</u>**

1. High infection/illness burden for norovirus justifies its inclusion (molecular).
2. In the absence of additional data, use of molecular data is preferred because it is more conservative.

Support for "Culture"

Literature: "[t]he uncoupling between high-number genome copies of adenoviruses detected by real-time PCR and the absence of infectivity detected by tissue culture suggests that genome-based detection methods are inadequate for direct assessment of human health risk."

Editorial note:

Assuming the 10x correction is applied to enterovirus, use of both culture (10x enterovirus) and molecular data (norovirus) results in the same LRV target. So this might not be a critical issue.

**Question 3:** If molecular (e.g., qPCR) data are considered, should an adjustment be made for infectivity?

Yes, reduce molecular data by factor of 200 = 4 | No = 3 | Need more information = 2 | Yes, reduce molecular data by some other factor = 1

**<u>Support for "reduce by 200"</u>**

1. Molecular data are known to overestimate infectivity, thus molecular data must be appropriately translated. Data seems to suggest 200 is a good option.

Support for No

1. Uncertain how to reliably apply a correction factor

Editorial note:

Assuming the 10x correction is applied to enterovirus, use of both culture (10x enterovirus) and molecular data (norovirus with no GC:IU adjustment) results in the same LRV target. Thus, if we applied a GC:IU adjustment, 10x enterovirus would still drive risk and result in the same LRV target. So this might not be a critical issue (assuming molecular data are not being considered for enterovirus or adenovirus).

**Question 4:** Should enterovirus culture data be adjusted to reflect known method inefficiencies?

Yes = 8 | No = 1 | Need more information = 1

**<u>Support for adjust by 10%:</u>**

1. Underestimate of cell culture viruses should be accounted for, similar to the overestimate of molecular data.
2. Generally agree but question of whether 10% efficiency is a consistent value.

Support for "No" (and related comments):

1. Question of whether this correction factor might be double-counting since it might already be reflected in the dose response function. Editorial note: dose response functions are based on specific targets while these inefficiencies are presumably linked to the complex mixtures present in environmental waters.

**Question 5:** For the raw sewage approach (no site-specific monitoring), which concentration data should be considered?

**<u>Support for 13/10/10:</u>**

97.4$^{th}$ percentile simulated concentrations from the Pecson/DPR-2 distribution. This seeks equivalency with the treated effluent approach (corresponds to the maximum value from a 24-sample dataset), but is not as conservative as choosing the maximum simulated values. Assuming a 1:1 GC:IU ratio would result in a **13/10/10**.

97.4$^{th}$ Percentile DPR-2 = 4 | Maximum Simulated DPR-2 = 3 | Maximum AZ = 2 | Need more information = 1

Support for "97.4$^{th}$ percentile": **<u>13/10/10</u>**

1. There should be consistency between raw wastewater and treated effluent approaches.
2. There is sufficient conservatism **if we include treatment redundancy** for failures.
3. Achieves LRV targets that mostly align with historical targets in CA and DPR in Colorado.

Support for "Maximum simulated":

1. More robust.
2. Potentially eliminates the need for treatment redundancy aimed at addressing undetected failures; resulting LRVs can still be achieved by both RO and non-RO treatment trains.

Support for "Need more Info":

1. Prefers modified version.

**Question 6:** For the treated effluent approach (with site-specific monitoring), how should minimum LRVs be addressed?

**<u>Support for minimum LRVs similar to TX with requirements for following a sampling protocol:</u>**

Minimum LRVs should be determined by site-specific monitoring programs (i.e., replacing non-detect effluent concentrations with study-specific limits of quantification). Thus, a study with larger sample volumes and/or higher recoveries might be able to justify lower LRVs, assuming all concentrations are non-detect. For example, assuming a study with all non-detects had a LoD of 1 oocyst per 100L with 1%

recovery, the resultant LRV requirement would be 7.0, but if they could improve the study to 1000L volumes that would decrease the LRV requirement by a factor of 10 to 6.0.

Minimum LRVs determined by LoQ = 7 | Minimum LRVs specified but with AZ-specific values = 2 |Minimum LRVs specified and consistent with Texas = 1

Support for "LoQ approach"

1. Should be determined by monitoring methods but there should also be a floor.
2. Consistent with original NWRI panel approach.
3. LoQ option is preferred but must include an independent advisory panel (IAP) that ultimately signs off on the utility-specific approach. The IAP may also help avoid the need to establish a 'floor'.

Support for "Texas approach":

1. All options acceptable, but should have a floor consistent with the EPA's SWTR (4/3/2). Selected Texas approach to achieve some consistency between states.

**Question 7:** Should treatment redundancy be included to compensate for undetected unit process failures?

**Support for treatment redundancy of other than 4 logs.**

Yes, but something other than 4 logs = 4 | No treatment redundancy = 3 | Yes, treatment redundancy of 4 logs = 2 | Need more information = 1

Support for "Yes but not 4 logs"

1. Redundancy is needed in the absence of an environmental buffer.
2. The 96 ingestion events per day is not justified based on documented exposure/ingestion data. Therefore, something other than 4 logs should be targeted.
3. Parallel (i.e., N+1) redundancy should be required to ensure backup options are available to utilities. Series (i.e., treatment) redundancy should be required if the community is entirely dependent on the DPR system. If the DPR system can be taken offline without impacting the ability to provide water to the community, then treatment redundancy may not be necessary.

Support for "Yes 4 logs:

1. Will help avoid frequent shutdowns/flow diversions.

Support for "No"

1. There is sufficient conservatism elsewhere in the framework. Additional conservatism will make it difficult to broadly implement DPR in AZ.

2. Risk from advanced treatment trains for potable reuse is documented to be less than conventional drinking water system. Requiring added conservatism unnecessarily increases costs (i.e., requires over designed facilities) without achieving a measurable increase in public health protection.
3. Note that LRV crediting will presumably require surrogate monitoring at critical control points, which should identify detectable off-spec/failure conditions. Coupled with conservative crediting of unit treatment processes, it is hard to justify something that is not included in conventional drinking water systems.

**Question 8:** Please share any additional thoughts, potential barriers you may observe, or knowledge barriers you would like more information on.

1. 3.Need additional monitoring and assessment of new technologies.
2. Not clear whether enterovirus or norovirus approach is more protective.
3. Proposed frameworks are overly conservative.

# Appendix #3
# Example Log Reduction Credit (LRC)

Table A - 1. LRC for select treatment processes (credited log reduction may vary depending on the operating conditions and validated monitoring approach). For examples see (Salveson et al. 2016b). **This Table is being included for illustration and discussion purposes only.** All AWTFs will be permitted only for a period of 5 years. If a AWTF receives credit based on specific literature and if new information emerges when the permittee comes for new approval, it will be re evaluated based on the most recent literature.

| Treatment | Virus | Cryptosporidium | Giardia | References | Surrogates for online monitoring (CCP monitor) |
|---|---|---|---|---|---|
| **Filtration** | | | | | |
| MBR | 1 | 2.5 | 2.5 | WRF 4997 | Indirect Integrity: Turbidity |
| Slow sand | 2 | >2 | 2 | 40 CFR Part 141 | Indirect Integrity: Turbidity |
| Conventional filtration (including BAC with coagulation-fl occulation) | 2 | >2 | 2.5 | 40 CFR Part 141 | Indirect Integrity: Turbidity |
| Diatomaceous earth filtration | 1 | >2 | 2 | 40 CFR Part 141 | Indirect Integrity: Turbidity |
| Direct filtration | 1 | >2 | 2 | 40 CFR Part 141 | Indirect Integrity: Turbidity |
| Cartridge Filtration (With Pretreatment) | 0 | 2 | 2 | 40 CFR Part 141 | Indirect Integrity: Turbidity, differential pressure |
| Low pressure membranes MF/UF | 0 | 4 | 4 | 40 CFR Part 141, U.S. EPA. 2005. Membrane Filtration Guidance Manual. Dependent on challenge and integrity tests. | Direct Integrity: Pressure Decay Test, daily. Indirect Integrity: Turbidity |
| High pressure membranes RO | 1.5-3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC based monitoring Tier 3: EC based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1) | 1.5-3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC based monitoring Tier 3: EC based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1) | 1.5-3.0 Tier 1: Strontium or sulfate-based monitoring Tier 2: TOC based monitoring Tier 3: EC based monitoring (1.5 with Tier 3 and Up to 3 with Tier 1) | 40 CFR Part 141, U.S. EPA. 2005. Membrane Filtration Guidance Manual Dependent on challenge and integrity tests. | Online indirect Integrity: EC, TOC. Daily grab sample: Strontium or sulfate. If the highest credit is not pursued only EC and/or TOC may be used |
| High pressure membranes NF | 1 | 1 | 1 | 40 CFR Part 141, U.S. EPA. 2005. Membrane Filtration Guidance Manual Dependent on challenge and integrity tests. | Online indirect Integrity: TOC. Daily grab sample: sulfate. In contrast to RO, TOC monitoring is not sufficient for any credit and sulfate grab samples are mandatory. |
| **Disinfection** | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| Chlorine | Up to 6 | 0 | Up to 6<br>Not practical | Extrapolation equations from 40 CFR Part 141, EPA 1999 SWTR Guidance Manual and Alternative Disinfectants and Oxidants | CT, Online Cl2, flow rate, temperature, pH |
| Monochloramine | Up to 4 | 0 | Up to 3<br>Not practical, requires CT value of >1,100 mg-min/L at 20oC | 40 CFR Part 141, EPA 1999 SWTR Guidance Manual and Alternative Disinfectants and Oxidants | CT, Disinfectant feed rate, flow rate, temperature, pH |
| Chlorine dioxide | Up to 4 | Up to 3 | Up to 3 | 40 CFR Part 141, EPA 1999 SWTR Guidance Manual and Alternative Disinfectants and Oxidants | CT, Disinfectant feed rate, flow rate, temperature, pH |
| Ozone | Up to 6 | Up to 1<br>highest resistance | Up to 6<br>higher doses than for virus | Extrapolation equations from 40 CFR Part 141, EPA 1999 SWTR Guidance Manual and Alternative Disinfectants and Oxidants | CT, Online O3, flow rate, temperature |
| UV | 4 (186 mJ/cm2)<br>6 (276 mJ/cm2) | 4 (22 mJ/cm2)<br>6 (84 mJ/cm2) | 4 (22 mJ/cm2)<br>6 (84 mJ/cm2) | 40 CFR Part 141, USEPA 2020 "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems" | UV intensity, lamp status, UV transmittance, flow rate |
| UV/AOP | 6 | 6 | 6 | USEPA 2020 "Innovative Approaches for Validation of Ultraviolet Disinfection Reactors for Drinking Water Systems | UV intensity, lamp status, UV transmittance, flow rate, oxidant dosage/concentration. |

Table A- 2. Examples of treatment trains designed under established/validated conditions crediting for pathogen and chemical control. **This Table is being included for illustration and discussion purposes only.**

| **Unit** | **Pathogens** | | | **Chemicals** | | |
|---|---|---|---|---|---|---|
| | **Virus** | **Cryptosporidium** | **Giardia** | **Known-bulk** | **CECs-trace** | **Peaks** |
| **Train #1: MBR > O3 > BAC > MF > RO > UV/AOP** | | | | | | |
| MBR | 1 | 2.5 | 2.5 | yes | yes | yes |
| O3 - BAC (CT = 0.9 mg•min/L, 15C) | 6 | 0 | 3 | yes | yes | yes |
| MF or UF | 0 | 4 | 4 | | | |
| RO | 1.5-3 | 1.5-3 | 1.5-3 | yes | yes | |
| UV/AOP | 6 | 6 | 6 | yes | yes | |
| Free Chlorine (CT of ~9 mgxmin/L at 15oC and pH 6-9) | 6 | 0 | 1 | | | |
| Total | 20.5-22 | 14-15.5 | 18-19.5 | YES | YES | YES |
| **Train #2: MBR > O3 > Coagulation/BAC > GAC > UF > UV** | | | | | | |
| MBR | 1 | 2.5 | 2.5 | yes | yes | yes |
| O3 /EfOM AOP (CT = 3.9 mg•min/L, 15C) | 6 | 1 | 6 | yes | yes | yes |
| Coag/BAC | 1 | 2.5 | 2 | | | |
| GAC | 0 | 0 | 0 | yes | yes | yes |
| UF | 0 | 4 | 4 | | | |
| UV (276 mJ/cm2) | 6 | 6 | 6 | yes | yes | |

| | | | | | | |
|---|---|---|---|---|---|---|
| Free Chlorine (CT of ~9 mgxmin/L at 15oC and pH 6-9) | 6 | 0 | 1 | | | |
| Total | 20 | 16 | 21.5 | YES | YES | YES |
| **Train #3: MBR > O3 > Cartridge Filter > RO > UV/AOP** | | | | | | |
| MBR | 1 | 2.5 | 2.5 | yes | yes | yes |
| O3 – BAC (Ozone CT of 3.9 mgxmin/Lat 15oC) | 6 | 1 | 6 | yes | yes | yes |
| Cartridge Filtration | 0 | 2 | 2 | | | |
| RO | 1.5-3.0 | 1.5-3.0 | 1.5-3.0 | yes | yes | |
| UV/AOP | 6 | 6 | 6 | yes | yes | |
| Free Chlorine (CT of ~9 mgxmin/L at 15oC and pH 6-9) | 6 | 0 | 1 | | | |
| Total | 20.5-22 | 13-14.5 | 19-20.5 | YES | YES | YES |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| *Comment: (a) To meet credit requirements for protozoa, an extended ESB or alternations of treatment trains are needed to allow pressure integrity test performance monitoring for MF and 4 log credits. If a shortened ESB is needed or desired, or if no multiple trains can be provided, then another form of treatment would be required to increase protozoa credit.*<br>*(b) MBR LRV credits only apply for projects using raw wastewater approach. No LRV credits are awarded to MBRs for projects using the effluent characterization method, as only credits downstream of the MBR unit process can be applied.*<br>*(c) Accepting treatment barriers for chemical peaks will depend on meeting performance criteria specified in this document.* | | | | | | |

# Appendix #4

## Water and Wastewater Operations Certification Curriculum – Gap Analysis

***Source:*** *Walker, et. al., 2017 - Development of an Operation and Maintenance Plan and Training and Certification for Direct Potable Reuse (DPR) Systems. Project Number Reuse-13-13*

**Table 6.14. Water and Wastewater Operations Certification Curriculum – Gap Analysis**

| Topic Area | Existing Curriculum Helpful for DPR | | Additional Requirements for DPR |
|---|---|---|---|
| | Drinking Water Operations | Wastewater Operations | |
| Source Water/Water Quality (Groundwater/Surface Water/Raw Water Storage) | Provides basic knowledge of water quality assessment and characteristics, including a knowledge of microbial contamination. This will provide a solid base for operators moving to a future DPR certification. Some of the important items include:<br>• Water quality characteristics.<br>• Source water assessment<br>• Ability to recognize abnormal conditions.<br>• Microbial contamination.<br>• Interpretation of water quality reports<br>• Flow and flow measurement.<br>• Calculation of chemical dose.<br>• Measuring pH | Relatively small amount of information on sewer shed and source control. | Additional information for sewershed management and source control. Understanding of industrial waste contributions and other source contaminants that may risk treatment processes.<br><br>The source water for DPR treatment processes is municipal wastewater. For drinking water operators, a basic knowledge of wastewater processes. In addition,<br>• Understanding source water risks from wastewater source.<br>• Ability to develop and manage a water quality risk register.<br>• Understanding process changes and impacts from wastewater treatment processes.<br>• Understand important key process monitoring parameters at inlet of advanced treatment plant. |
| Treatment Processes | | | |
| Coagulation/Flocculation/Sedimentation | Provides a thorough coverage of these processes. This knowledge is likely adequate for DPR operators where this technology is employed (non RO based treatment train) | Some knowledge of clarification processes for primary sedimentation and secondary clarification. | No additional curriculum required for DPR. |
| Filtration | Provides a thorough coverage of conventional media filtration, with a limited coverage of granular activated carbon. | Minimal information. | Conventional filtration appears well covered, however granular activated carbon and biologically carbon will require significantly more coverage.<br><br>Membrane filtration (MF/UF) will require substantial coverage. |
| Disinfection | Provides a thorough knowledge of chlorination practices including analysis of free and total chlorine, calculation of CT, calculation of chemical dose and a knowledge of breakpoint chemistry.<br>Includes some material for ozone, UV disinfection and chloramines. | Provides some knowledge of calculating chlorine demand, operation and maintenance procedures for disinfection, calculating disinfection usage. | Will require additional detail for chloramine dosing, which is used for membrane disinfection. Additional content required includes:<br>• Knowledge of chloramine control.<br>• Protection of RO membranes from chlorine.<br>Ozone also requires additional information including:<br>• Basic understanding of ozone chemistry.<br>• Basic ozone generation management.<br>• Knowledge of UV absorbance analyzer calibration.<br>• Ozone residual analyzer management<br>• Ozone dose-control strategies |
| Demineralization (RO, NF and Ion Exchange Treatment) | This contains some water quality analysis content, knowledge of electrical conductivity and total dissolved solids analysis.<br>There is subject matter relating to ion exchange but none for reverse osmosis. | Not included | Reverse osmosis is a core technology for the RO based treatment train. Content for this process is required, including:<br>• Operation and maintenance of membranes<br>• Measurements of process performance and membrane integrity<br>• Monitoring and measurement of chemical rejection and log reduction of pathogens |
| Corrosion Control | Useful basic knowledge of corrosion, including health effects from lead and copper. | Not included | Will provide useful basis for additional chemical stabilization process required for the RO based treatment train. |
| Iron and Manganese Removal | Thorough knowledge of iron and manganese removal. | Not included | Not specific to DPR treatment processes, however will provide some useful knowledge for RO system membrane scaling and fouling. |
| Fluoridation | General knowledge of fluoridation processes. | Not included | Not specific to DPR treatment, unless fluoridation is required in a DPR system that operates directly to distribution. |
| Softening | Knowledge of water hardness chemistry, hardness removal and softening processes. | Not included | Not directly related to DPR, but some value to RO treatment processes. May also be important for non-RO membrane-based treatment |
| Wastewater Treatment Technologies | Not included | Material that is focused on the main wastewater treatment processes including:<br>• Preliminary treatment (screening, grit removal)<br>• Primary treatment processes.<br>• Anaerobic sludge digestion<br>• Stabilization ponds | Valuable knowledge for DPR treatment to understand impacts upstream of advanced treatment. It is also important to understand the difference between monthly compliance goals/environmental impacts versus continuous water quality goals for DPR and drinking water quality goals. |

| Topic Area | Existing Curriculum Helpful for DPR | | Additional Requirements for DPR |
|---|---|---|---|
| | **Drinking Water Operations** | **Wastewater Operations** | |
| | | • Secondary processes including trickling filters and activated sludge<br>• Sludge handling and solids thickening<br>• Tertiary treatment<br>• Overall process control. | |
| Best Available Technology | Knowledge of waterborne pathogens, best available technologies for removal, adverse health effects from regulated contaminants and knowledge of emerging contaminants. | Not included | Specific knowledge of technologies / BATs used in drinking water treatment (and DPR) is required. |
| Operations & Maintenance (O&M) | Requires knowledge of key process plant mechanical components including:<br>• Chemical feeder.<br>• Pumps and motors<br>• Blowers and compressors<br>• Water Meters<br>• Instruments and analyzers<br>• SCADA components and on line analyzers<br>• Calibration of some key instruments. | Thorough review of some maintenance requirements including:<br>• Electrical equipment<br>• Motors<br>• Pumps<br>• Valves | Specific knowledge of treatment process maintenance requirements including items such as membrane management, UV lamps, ozone generation and lime/$CO_2$ systems for stabilization.<br>The understanding of detailed instrument verification and calibration for multiple analyzers is an important addition for DPR. |
| Laboratory | Thorough requirements for laboratory analysis, chains of custody, sampling and analysis requirements as well as detail on a number of specific, common water quality analyses. | Thorough review of sampling and analysis requirements for wastewater treatment applications. | Some additional knowledge for management of numerous water quality analysis parameters, including knowledge of sampling and sample management for complex contaminants. |
| Safety | General knowledge of safety, safe working practices, lock out-tag out procedures and some first aid. | General knowledge of safety, including importance of hygiene, lock out tag out, safe work practices and specific safety requirements for wastewater technologies. | Suitable for DPR, with a focus on safety requirements included for technologies specific to DPR. |
| Administration | Covers a broad range of administrative requirements including organization, monitoring and reporting requirements, reviewing and transcribing data, review of overall plant performance, review of reports, evaluating facility performance. | Covers a broad range of administrative requirements including staffing, financial management, capital planning, and data management. | Additional requirements include:<br>• Critical control point methodology<br>• Critical control point response procedures and communication protocols<br>• Critical control point incident investigation and follow up action methodology |
| Regulations | Knowledge of key regulatory requirements including disinfection requirements, knowledge of MCLs, consumer confidence reports, Surface Water Treatment Rule, development of operations plans, disinfection requirements and other regulatory aspects. | Some regulatory content including classification of wastewater treatment plants and operator certification regulations, and requirements for reclamation and reuse (although not focused on IPR/DPR). | Additional knowledge of future DPR regulatory requirements must be included.<br>In addition, any specific reporting and communication protocols for regulators must be included.<br>An important aspect will be the comparison and contrast with water and wastewater regulations. A specific example will be how water quality treatment requirements will likely be a single maximum target, rather than monthly averages or means as is common in wastewater treatment. |
| Math | Specific calculations for major water treatment operations including:<br>• Flow rate calculation<br>• Volume calculation<br>• Chemical dosing rates.<br>• Detention times<br>• Backwash rates<br>• Production rates<br>• CT calculations | Specific calculations for wastewater treatment operations including:<br>• Removal efficiencies<br>• Overflow rates<br>• Hydraulic loading<br>• Solids loading<br>• Chemical dosing<br>• Evaluation of specific processes. | Additional calculations will be required for specific unit processes not covered in the existing curricula but required for DPR. |
| Communication | | | Effective communication is critical for the success of DPR. Operators must understand the importance of timely communication within their operating facility to assist in rapid and effective operational responses to issues. They must also understand the importance of clear communication across operational interfaces, and to external stakeholders including regulators and the public. |
| Management of analyzers and instruments. | | | There is a high reliance on analyzers and instruments for successful IPR and DPR plant operation. Specific curriculum material that covers the importance of regular instrument verification, calibration and key maintenance requirements for important instruments is required. |
| SCADA, reporting and alarm management | | | Covering important SCADA management and reporting with a focus in particular on alarm management and operator response. |
| Operational Interfaces | General knowledge of water treatment processes. | General knowledge of wastewater treatment processes. | Knowledge of requirements at operator interfaces between wastewater treatment and advanced treatment, and advanced treatment and drinking water treatment is required. For some utilities, the full suite of treatment may be operated by a single entity. For others, there will be different organizations operating these entities. An understanding of process and treatment at these interfaces is required. |
| Critical Control Point and the HACCP Process | | | An understanding of the critical control point approach, including specific critical control points for DPR processes, water quality risk management and operational responses. |

## Appendix #5
## Flow Adequacy

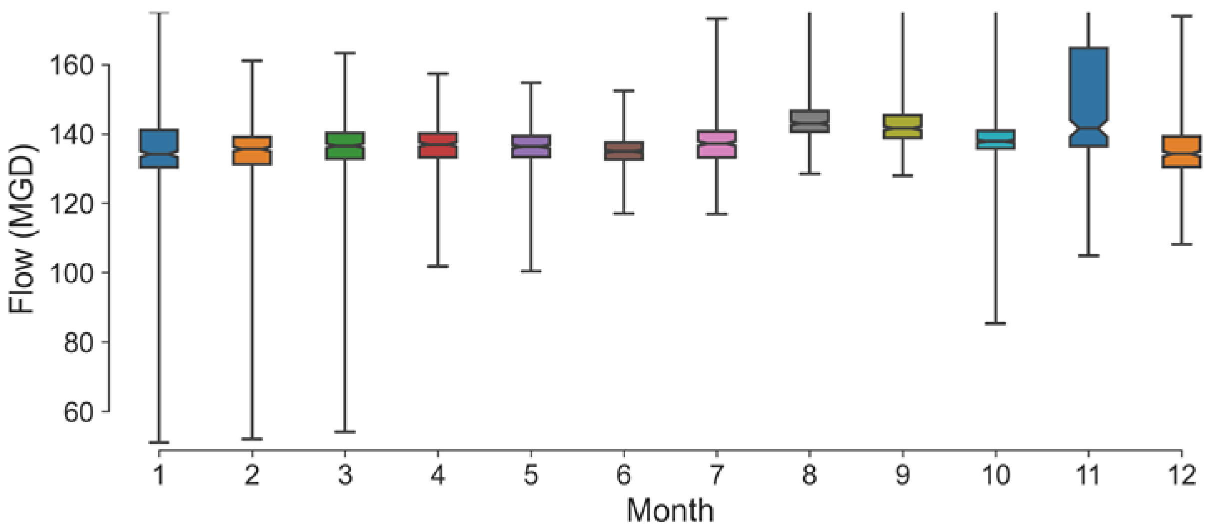



Figure 1.

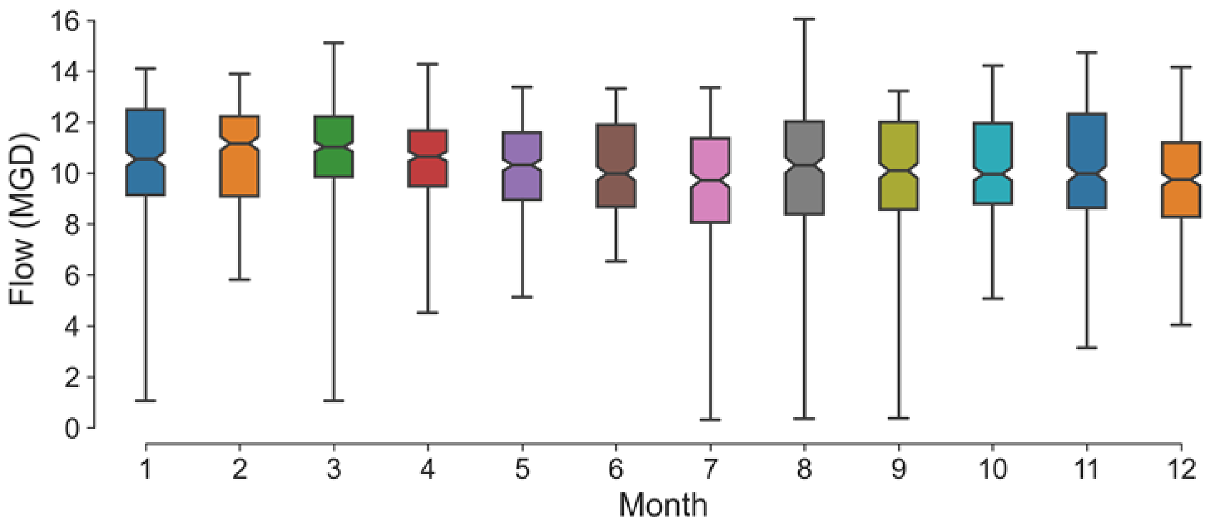



Figure 2.

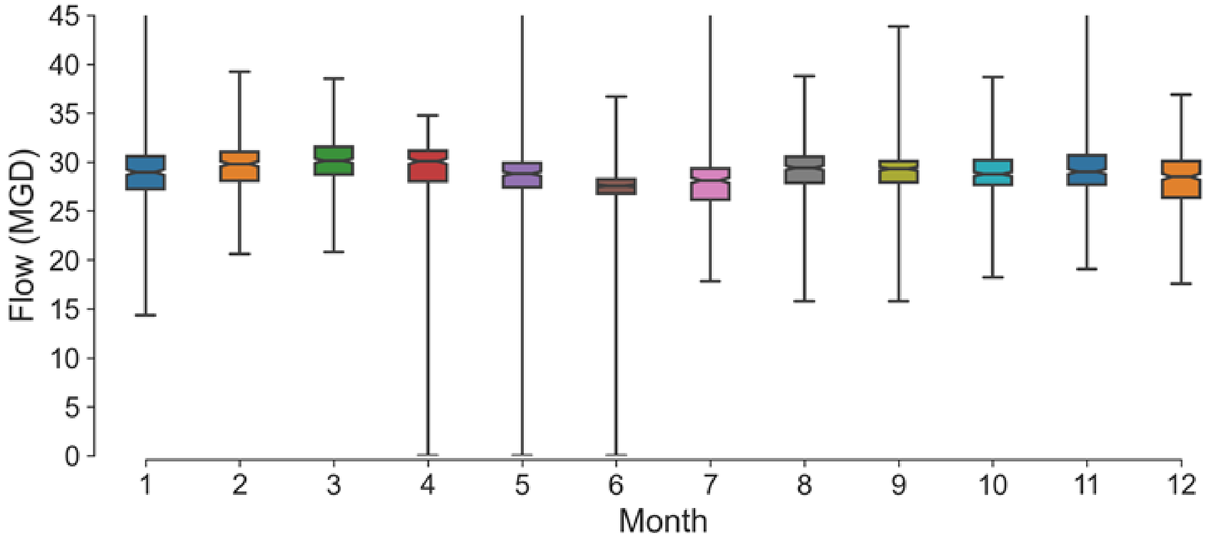



Figure 3.

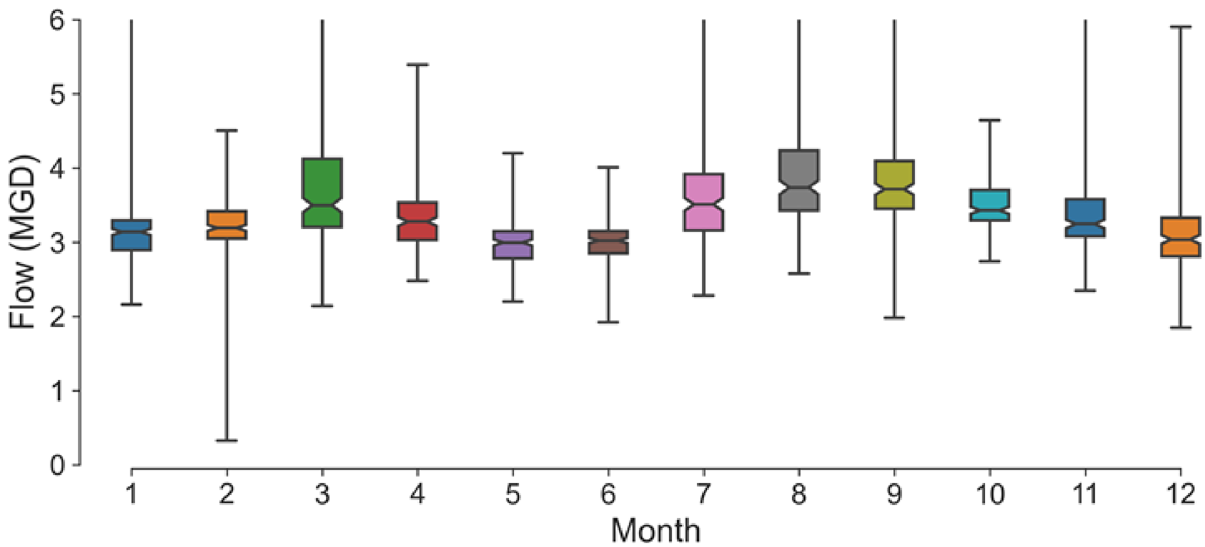



Figure 4.

## Appendix #6

## TOC analysis using data from AZ

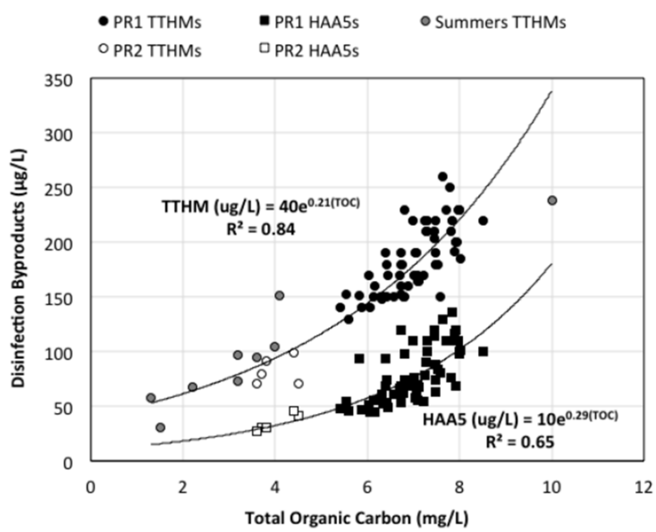
Current approach based on WRF 15-04

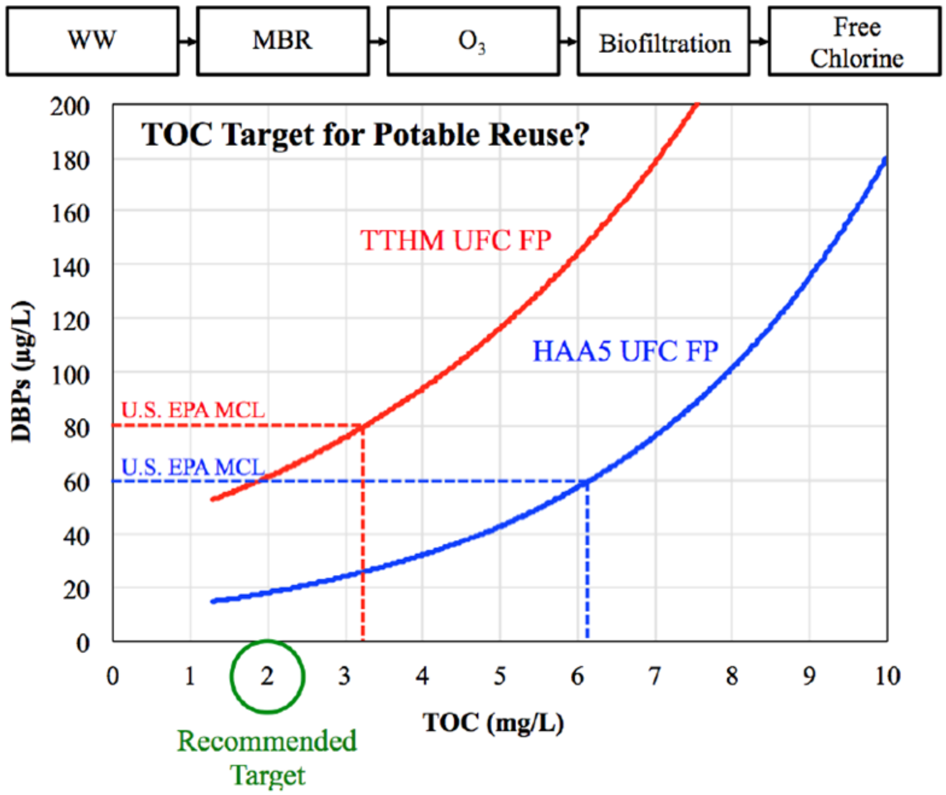
1. Potable reuse produces a treated water that has organic characteristics similar to that of the original drinking water.
2. Return to initial TOC assumes that anthropogenic effluent-derived organics that have adverse health impacts are removed.
3. TOC measurement serves as a bulk organics surrogate.
4. By achieving a 1:1 ratio of TOC between finished drinking water and potable reuse water, MCLs and CECs organics are well controlled.

| TOC | Canal #1 | | Canal #2 | |
|---|---|---|---|---|
| | Raw | Finished | Raw | Finished |
| **Median** | 1.83 | **1.46** | 4.2 | **3.1 - ALERT (triggered monitoring)** |
| **Min** | 0.33 | 0.36 | 2.42 | 1.7 |
| **Max** | 4.84 | 4.57 | 5.89 | 4 |
| **1.5x95th percentile** | | **3.88** | | **5.4 - ACTION (media change)** |

TOC - DBP correlations

**Figure 5.** Exponential correlations between DBP formation and effluent TOC concentration. The TTHM correlation includes data from the current study (PR1 and PR2) and from Summers et al. (1996). The HAA5 correlation includes data only from the current study (PR1 and PR2).






"On average, the specific DBP formation potentials (i.e., standardized to TOC concentration) were 26 µg-TTHMs/mg-C and 12 µg-HAA5s/mg-C (Table 1), which are consistent with previous studies reporting specific formation potentials chlorinated wastewater effluents (Sirivedhin and Gray, 2005; Krasner et al., 2009b; 422 Liu and Li, 2010). Summers et al. (1996) also observed similar results for chlorinated surface waters, with averages of 29 µg-TTHMs/mg-C and 19 µg-HAA6s/mg-C. Therefore, effluent TOC concentration may be a more reliable and practical indicator of TTHM and HAA5 formation potential.

## Potential issues with current approach:

### Alert level

1. Keep running avg. after DPR implementation.
2. Seasonal variations.
3. Triggered sampling cannot cover all unknown DBPs.

### Action level

1. Not tested.
2. Too high (>> 3 ppm).
3. Operating between ALERT and ACTION levels.

4. How often to test?
5. Safety vs. economic impact.

## Appendix #7
## Nitrogen analysis using data from AZ treated effluent

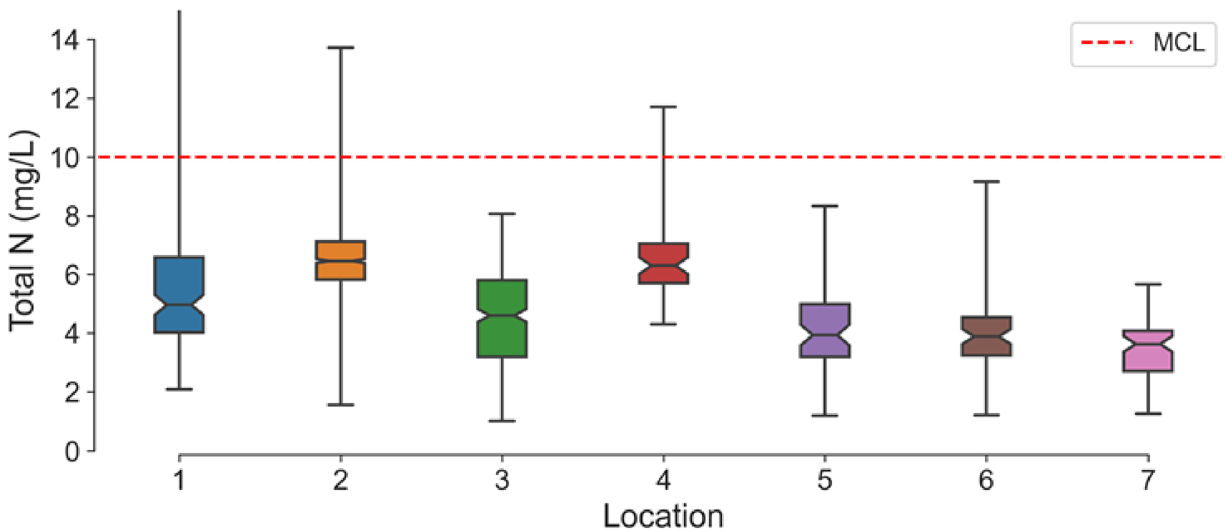



Figure 1. Treated wastewater grab samples at different WWTPs

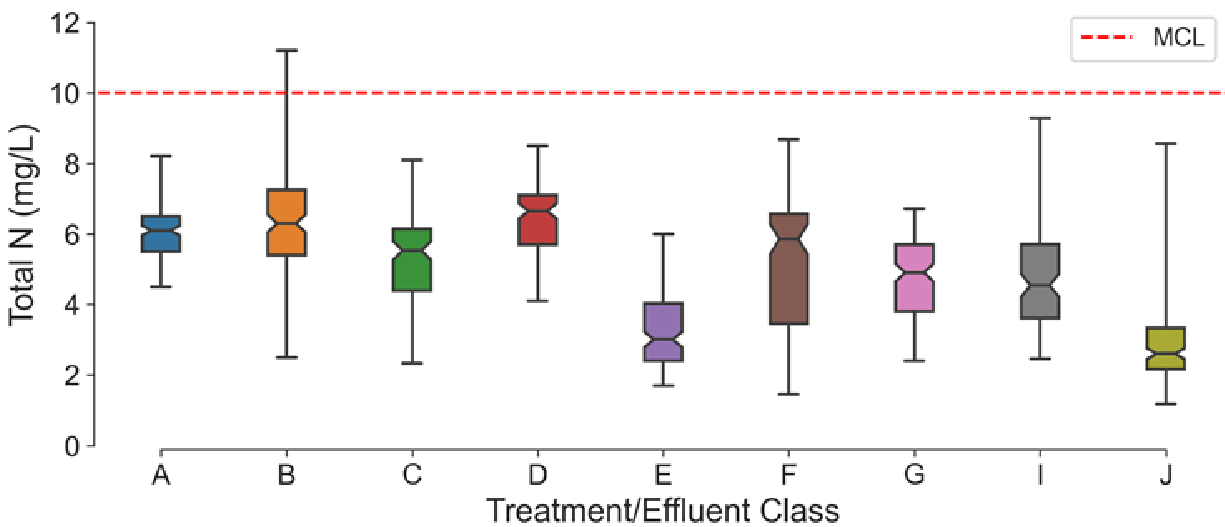



Figure 2. Geometric mean - Implications for DPR at different WWTPs. Each letter represents a unique combination of treatment and effluent class.

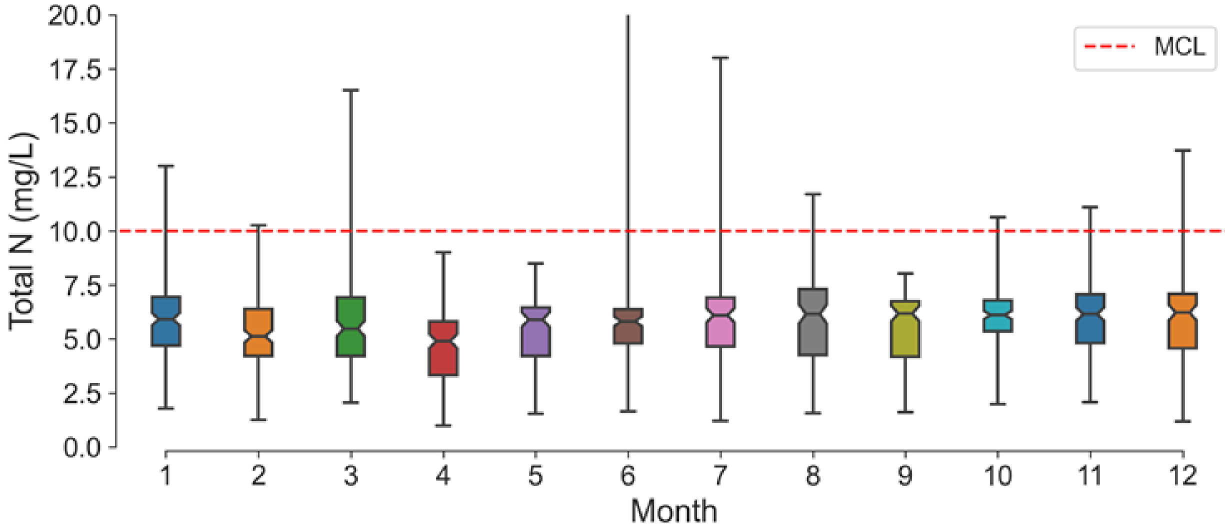



Figure 3. Grab sample – temporal variability.

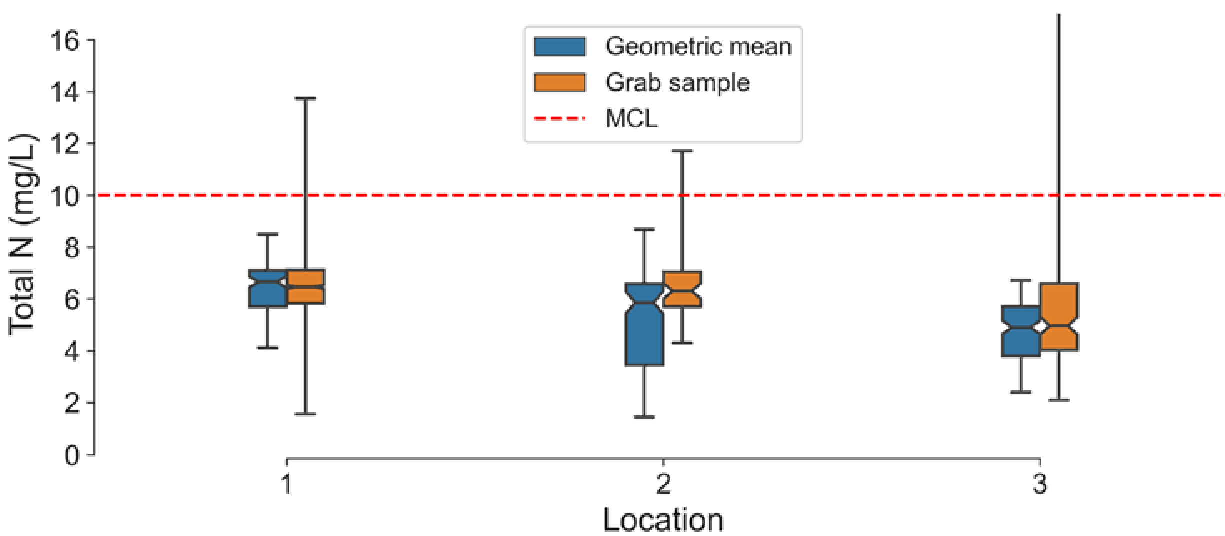



Figure 4. Class A+: Impact of applying geometric mean

## Appendix #8
## Salinity analysis using data from AZ treated effluent

TDS in Surface water sources

CAP: 450 - 800, avg. 650 mg/L TDS

SRP (Salt River Project)

Salt River: 500 - 980 mg/L TDS

Verde River: 270 mg/L TDS

TDS in Groundwater (46% with >500 mg/L TDS) sources

Reclaimed water (source + 400 mg/L)

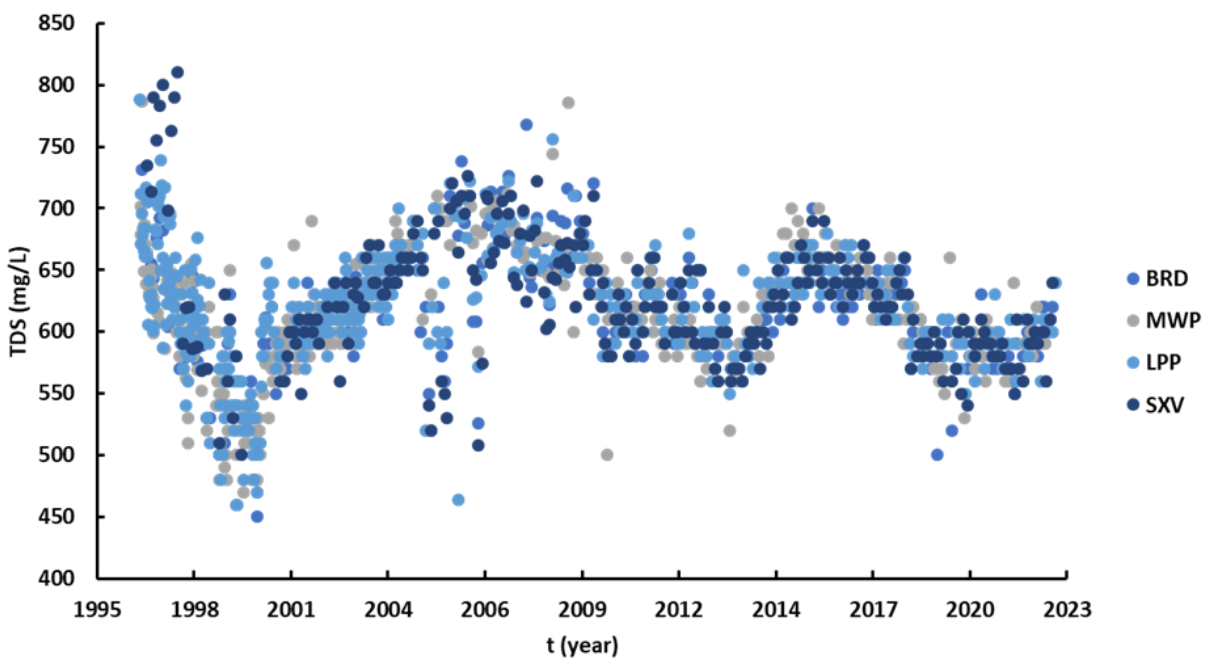



Figure 1. Traditional source (CAP canal). Variability of TDS in CAP canal at 4 locations along the canal.

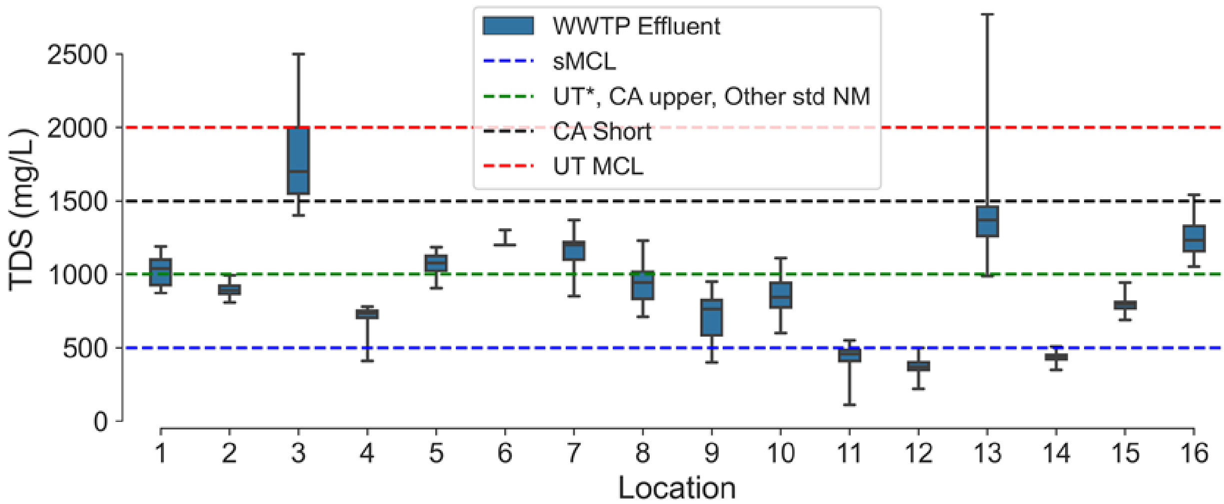



Figure 2. DPR source (WWTP effluent)

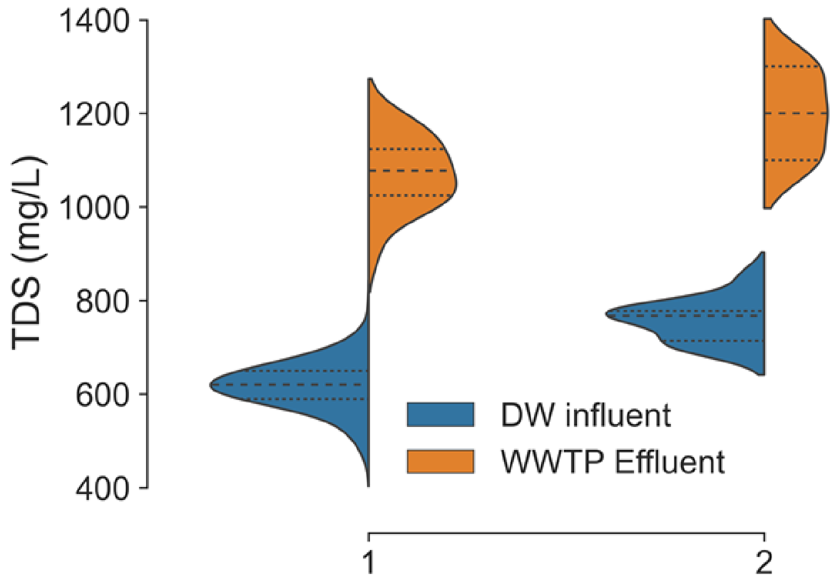



Figure 3.

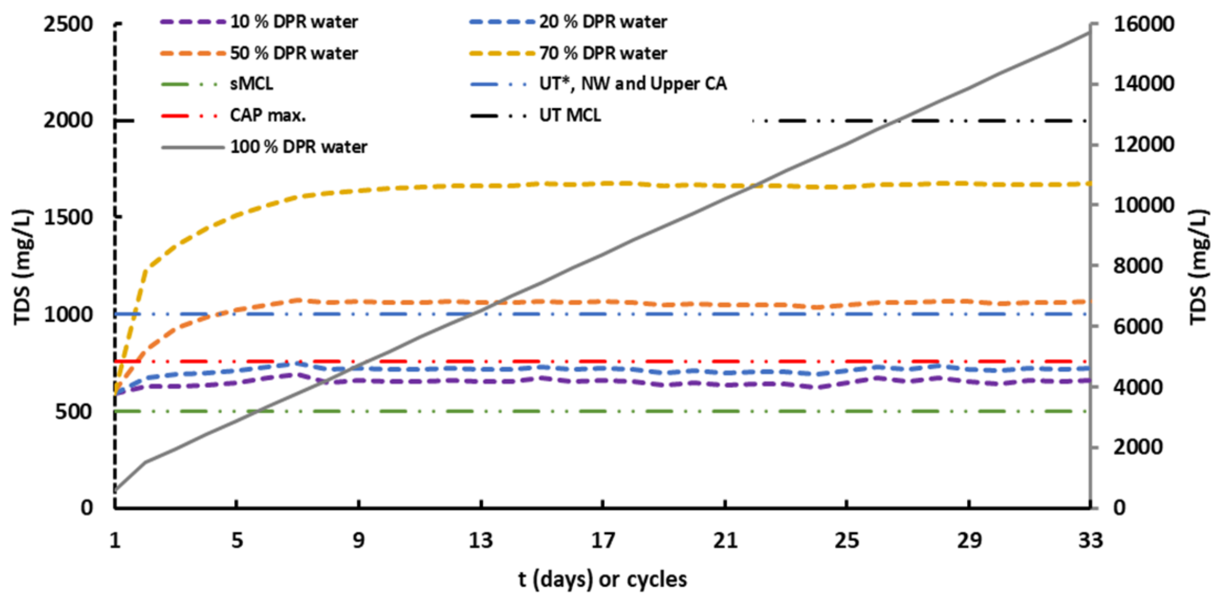



Figure 4. TDS Variability Based on Blend Ratios

## Appendix # 9

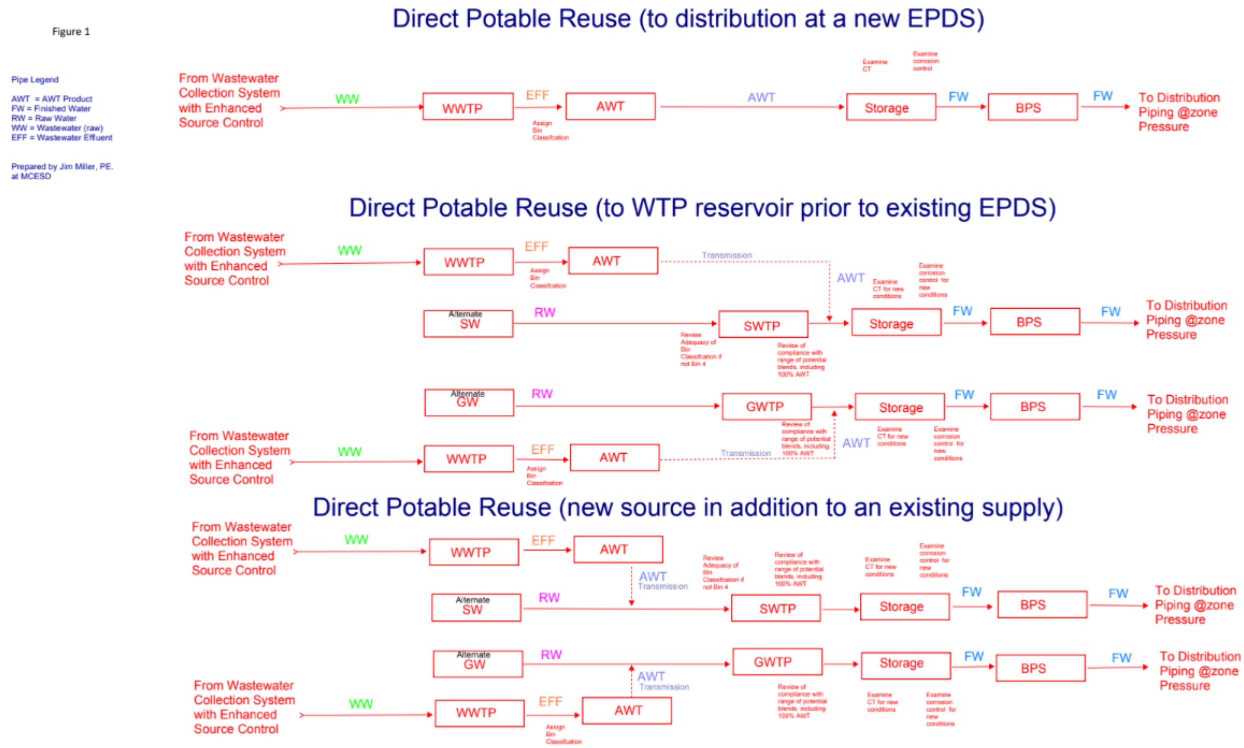



Figure 1. Schematic for DPR configurations