Guidebook for Commissioning an **ONSITE** WATER TREATMENT SYSTEM in San Francisco

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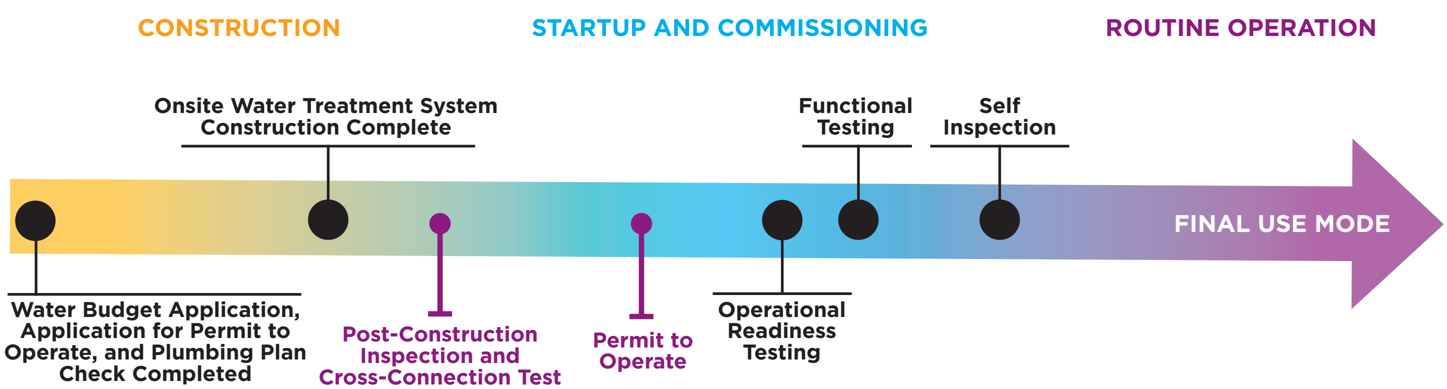
SAN FRANCISCO'S ONSITE WATER TREATMENT PROGRAM

In 2012, San Francisco established the Onsite Water Reuse for Commercial, Multi-Family and Mixed-Use Development Ordinance. Commonly known as the Non-potable Water Ordinance, it added Article 12C to the San Francisco Health Code, allowing for the collection, treatment, and use of alternate water sources for non-potable uses in buildings. In 2013, the Non-potable Water Ordinance was amended to allow for district-scale projects, where two or more parcels can share alternate water sources. In 2015, Article 12C became mandatory and required new development projects of 250,000 square feet or more of gross floor area to install and operate an onsite non-potable water system. In October 2021, Article 12C was amended to further increase potable water savings from new developments and increase opportunities for cost-effective systems. Article 12C now applies to new development projects of 100,000 gross square feet and contains new requirements for different project types. For commercial buildings, the project must meet its toilet and urinal flushing and drain trap priming demands through the collection, treatment, and use of available blackwater and condensate. For residential and mixed-use buildings, the project must meet its toilet and urinal flushing, irrigation, clothes washing, and drain trap priming demands through the collection, treatment, and use of available graywater and condensate. For more information, visit https://sfpuc.gov/construction-contracts/design-guidelines-standards/onsite-water-reuse.

This guidebook provides information to assist Design Engineers, Treatment System Managers, and other stakeholders involved in starting up the operation of an onsite water treatment system. It outlines the overall process for commissioning an onsite system, discusses the key roles of stakeholders, and provides guidance on how to inspect and test each individual treatment process and the overall treatment system. The Appendix includes Inspection Checklists that stakeholders can use to prepare the system for successful operation and to comply with the ordinance requirements.

COMMISSIONING AN ONSITE WATER TREATMENT SYSTEM

Startup and Commissioning refers to the process of preparing the onsite water treatment system for operation and confirming the system can meet regulatory requirements and design specifications during ongoing operation. Projects must complete the Water Budget Application, Application for Permit to Operate, and Plumbing Plan Check steps prior to constructing and commissioning the onsite water treatment system. Refer to the Onsite Water Reuse Program Guidebook or the SFDPH Checklist for more info.



TIP

Communicate early and often among all stakeholders involved with the onsite water treatment system so that quick fixes and re-evaluation of the system can occur efficiently.

Step 1: Obtain Permit-to-Operate Onsite Water Treatment System and Operate in Conditional Startup Mode

The goal of this step is to begin the process of starting up the operation of the onsite water treatment system. Conditional Startup Mode refers to the first 90 days of receiving a permit-to-operate from the San Francisco Department of Public Health-Environmental Health (SFDPH-EH). During this operating mode, the system undergoes startup and commissioning while treated water is diverted to the sewer.

Step 2: Operational Readiness Testing

The goal of this step is to conduct the initial checks and verifications needed prior to introducing water into the system, including:

- Perform electrical testing to verify proper installation such as:
  - Power checks
  - Signal wiring termination checks
  - Signal loop checks
  - Control panel input/output checks
- Perform mechanical testing to verify proper installation such as:
  - Pump and valve checks
  - Hydrostatic and pressure leak testing
- Perform plumbing checks such as:
  - Backflow prevention device checks
  - Cross-connection test

TIP

Qualified personnel such as the DESIGN ENGINEER & TREATMENT SYSTEM MANAGER should participate in Functional Testing to ensure the protection of equipment and adherence to manufacturer warranties (see Benchmarks for System Readiness on page 9 for information on roles of involved parties).

Step 3: Functional Testing

The goal of this step is to confirm that the treatment processes function as designed. Alternate water sources captured for reuse onsite (e.g., blackwater or graywater) are introduced to the onsite water system, but treated water is not used in the building yet and is discharged to the sewer. Once the first treatment process is confirmed to be meeting design requirements, effluent from that process is introduced to the second treatment process. This pattern continues until all treatment processes are brought online and demonstrate proper functioning. System performance and effluent water quality is confirmed through online analyzers, hand-held analytical instruments, and laboratory analysis. The overall system controls are also tested during this stage (e.g., diversions, critical alarm shutdown, etc). Upon completion, the onsite water treatment system should be operational, treating source water, and meeting the design specifications and regulatory requirements. Actions include:

- Perform wet testing of treatment processes
- Conduct initial instrument calibration
- Verify that each treatment process responds appropriately to controls and alarms
- Test interfaces between treatment processes and systemwide communication (e.g., downstream process response to failures upstream)
- Perform sequence testing of treatment processes (e.g., backwash cycle on a membrane filtration process) and the overall treatment system (e.g., treatment processes are able to shut down in correct sequence)
- Operate treatment processes in various modes: local manual mode (controlled manually at treatment process level), remote manual mode (controlled manually via SCADA[1]), and remote automatic mode (controlled automatically via SCADA)
- Verify operation of chemical skids

TIP

The duration and complexity of Functional Testing can vary significantly depending on the treatment process. For example, a biological process (such as MBR) may require multiple weeks or months to establish a stable population of microorganisms needed to meet treatment standards.

1 SCADA = supervisory control and data acquisition, i.e., the computer system that controls and logs data from each unit process and the overall treatment system.

Step 4: Self Inspection

The goal of this step is to test the monitoring and control points that have a direct impact on public health protection. Performing an inspection is beneficial because it can provide greater confidence that the system is functioning properly. An inspection can also help Treatment System Managers identify and fix issues that could threaten public health. Setpoints, alarm limits, and shutdown/diversion triggers are tested to demonstrate that the system can respond appropriately and prevent off-specification water from being distributed to end users. Refer to pages 12-24 for information on how to perform the Inspection. Actions include:

- Verify that log reduction targets are met
- Verify compliance with water quality standards – BOD, TSS, turbidity, pH, and total coliform
- Confirm all alarms and diversions work as described in the Engineering Report

Step 5: Operate Onsite Water Treatment System in Final Use Mode

The goal of this step is to successfully operate the onsite water treatment system and use the treated water for the building's approved non-potable uses. To maintain a valid permit-to-operate from SFDPH-EH, ongoing monitoring and reporting are required for all onsite water treatment systems to ensure systems are properly working and continuously protecting public health. Submission of routine Data and Monitoring Reports (DMRs) and Annual Reports are required.

KEY ROLES OF STAKEHOLDERS

The following stakeholders play a key role in Startup and Commissioning:

Design Engineer: verifies that system performance meets design criteria and treatment requirements. If questions or system changes are identified during the Self Inspection, the Design Engineer assists with design modifications and documents changes in the Engineering Report and O&M Manual.

System Programmer or Integrator: facilitates field verification testing during the Self Inspection (e.g., modifies input signals or setpoints to demonstrate system controls) and is available to troubleshoot communication and instrumentation/controls issues. Programmer/Integrator makes modifications to the control system to correct issues identified during the Self Inspection.

Contractor: addresses a variety of technical issues related to the physical facility such as leaks, loose parts, plumbing issues, and mechanical and electrical component adjustments (e.g., fuse replacement or pump issues).

Treatment System Manager: conducts the Self Inspection and facilitates communication between the stakeholders. The Treatment System Manager conducting the Self Inspection should also be responsible for operating the system during the Conditional Startup Mode and Final Use Mode. If a separate entity is responsible for operating the system during startup, proper training of the long-term Treatment System Manager should be conducted prior to the Self Inspection.

TIP

Depending on how the onsite water treatment system project is implemented, there may be overlap between the Contractor, Programmer/Integrator, and Treatment System Manager.

KEY ROLES OF STAKEHOLDERS (continued)

Treatment System Manager Qualifications:

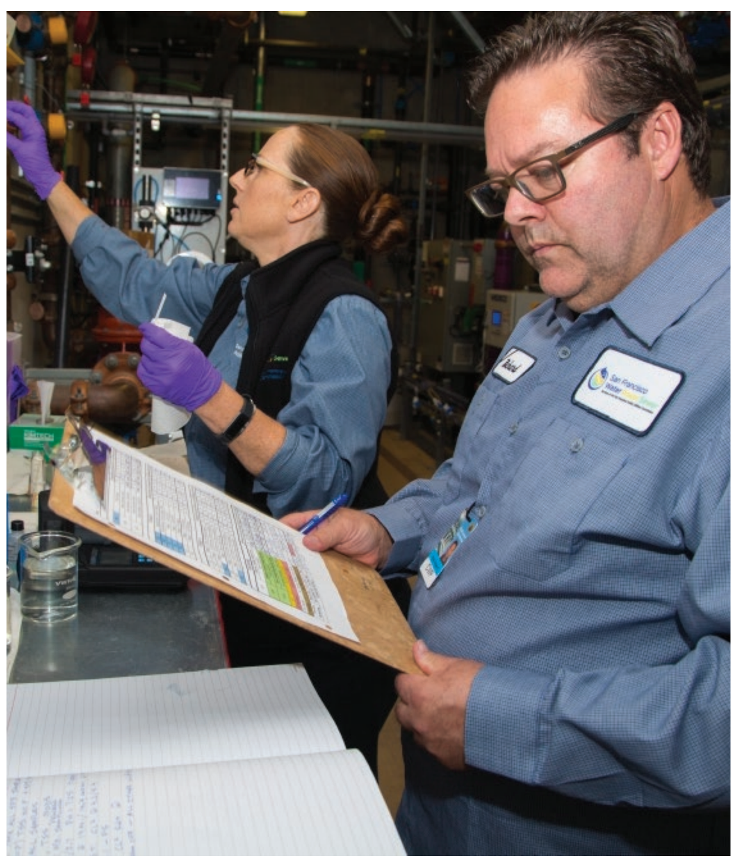
- Sign affidavit acknowledging sufficient knowledge, skills, abilities, and training
- Graywater Systems:
  - Grade 2 Water Treatment Plant or Distribution System Operator
  - Grade II Wastewater Treatment Plant Operator, or
  - Comparable education and/or experience
- Blackwater Systems:
  - Grade II Wastewater Treatment Plant Operator, or
  - Comparable education and/or experience

BENCHMARKS FOR SYSTEM READINESS

Determining system readiness involves verifying that each treatment process and the treatment system as a whole are functioning together as designed. The goal for the overall system is to be able to meet all water quality standards for at least one week. The following checklists should be used during Functional Testing prior to performing the Self Inspection. This section includes checklists for common treatment processes, but it is not comprehensive. For alternative treatment processes, it's recommended to consider the relevant benchmarks based on the examples provided.

General Benchmarks Applicable to All Treatment Processes

- ☐ All treatment processes in the treatment train have been stably operating together for at least one week
- ☐ Each treatment process meets its design criteria for performance and effluent water quality. At a minimum, verify the system is meeting design targets similar to those specified in Tables 1 through 6 in Performing the Self Inspection section.
- ☐ All alarms are automatically logged and accessible for future reference and reporting
- ☐ All information displayed on any local human machine interfaces (HMIs) matches what is recorded via SCADA and displayed on the system-wide HMI
- ☐ Chemical dosing pumps are functional and maintaining target setpoints
- ☐ The instrumentation used to control process operations has been calibrated and/or verified
- ☐ All calculated parameters have been verified to be accurate in SCADA
- ☐ All automatic responses to alarms have been tested and verified to be working as designed (e.g., automatic diversion of product water when a critical setpoint is violated)



Membrane Bioreactor (MBR)

- ☐ System has been operated for a period equal to at least three times the design solids retention time (3 x SRT) after seeding the system with microbial populations
- ☐ Design mixed liquor suspended solids (MLSS) is achieved and stable for at least one week
- ☐ Ensure that treatment process sequences have been tested and are functioning such as the production cycle, rest period/backwash sequence, maintenance clean sequence, and recovery clean sequence
- ☐ Perform a bubble test on the membranes to confirm that they are intact and functioning as designed

Membrane Filtration (MF)

- ☐ Daily pressure decay tests (PDTs) have been conducted for at least one week and meet minimum design requirements
- ☐ The backwash sequence has been tested and verified to function properly
- ☐ At least one chemical clean (e.g., enhanced flux maintenance or maintenance clean) has been conducted and verified to function properly
- ☐ One CIP sequence has been conducted and verified to function properly

Reverse Osmosis (RO)

- ☐ Ensure that treatment process sequences have been tested and are functioning such as the production mode, feed and permeate flush sequence, and recovery clean sequence
- ☐ Verify that salt passage meets vendor specifications

Ultraviolet Light (UV) Disinfection

- ☐ Verify UVT (UV transmittance) of feedwater meets design specifications for the selected UV reactor
- ☐ Verify that the UV intensity meets design specifications for the selected UV reactor for the full range of potential operating scenarios. Optimize wiper/manual cleaning frequency to maintain stable UV intensity
- ☐ Verify that all UV lamps are operational

Free Chlorine Disinfection

- ☐ Verify instrumentation used to confirm disinfection CT is functioning and reading within design specifications, including the flow meter, turbidimeter, free chlorine residual meter, pH probe, and temperature probe
- ☐ Confirm target CT is automatically maintained continuously for at least one week

Ozone Disinfection

- ☐ Verify instrumentation used to confirm CT is functioning and reading within design specifications, including the flow meter, turbidimeter, dissolved ozone meters, and temperature probe
- ☐ Confirm target CT is automatically maintained continuously for at least one week
- ☐ Confirm that the applied ozone dose meets or exceeds the design target

TIP

To minimize disruptions to the treatment system, monitoring equipment, and flow meters, consider including a backup power source in the building.

PERFORMING THE SELF INSPECTION

The purpose of the Self Inspection is to test the monitoring and control points that have a direct impact on public health protection. A successful Inspection should verify that all treatment processes and system-wide controls operate as designed.

In general, the Inspection should test the following:

- Target setpoints
- Alarm thresholds
- Response delay timers
- Automatic responses
- Treatment System Manager responses
- Logging of alarms

TIP

Post construction, Contractors and Treatment System Managers should ensure storage cisterns and tanks are clean and free of dirt and debris prior to introducing water into the system.

Simulating and Testing Treatment Process Failures

As part of the Inspection, it's important to verify the onsite water system will respond correctly to water quality excursions and treatment process failures. The system does not need to enter an actual failure mode for this verification; rather, signals can be manipulated to simulate a scenario in which a public health threshold has been exceeded resulting in a system response such as a diversion.

To simulate a failure condition, one option is to manipulate source signals (i.e., the outputs from an instrument) or control signals (i.e., inputs into the programmable logic controller (PLC) or HMI) to simulate a failure. To do this, the programmer or integrator could force an output signal from a given control point monitor outside of its range, such as forcing an RO conductivity meter to show an unacceptable amount of reduction through the process. This action should trigger an alarm and a given system response, e.g., diversion of the off-spec water to sewer.

It's also possible to simulate failures by adjusting alarm setpoints. For example, the setpoint for minimum free chlorine residual could be adjusted to a value above the current reading to simulate a failure to meet the threshold. This setpoint adjustment should then cause the system to respond to the forced "failure" and provide an opportunity to confirm the appropriateness of the response.

TIP

When considering options for how to manipulate the system, narrowly targeting the outcome of interest is recommended to avoid large-scale disruptions or unintended consequences from the temporary changes being made.

Individual Treatment Process Testing Approaches

Each treatment process should have the ability to initiate an immediate and automatic response that stops the distribution of off-specification water to the building. The following sections describe how to inspect and test the functioning of setpoints, alarms, delay timers, and automatic responses for common treatment processes used for onsite water reuse. For each treatment process, a checklist is also included in the Appendix.

The alarm levels and responses shown in the following tables are examples of acceptable actions. Other responses that prevent off-specification water from being used may also be acceptable. Treatment System Managers should reference the manufacturer's design and operation parameters for each treatment process.

Membrane Bioreactor (MBR)

An MBR offers excellent biological treatment through the control of biological oxygen demand (BOD), total suspended solids (TSS), turbidity, and ammonia. MBRs also have the added benefit of receiving credit for pathogen reduction. If the MBR system is operated according to the specifications for the Tier 1 operating envelope as defined by the Australian Water Recycling Center of Excellence (AWRCE) MBR WaterVal validation protocol, the system can achieve 1.5/2/4 log reduction of virus, protozoa, and bacteria, respectively. Table 1 provides the typical parameters that are monitored for an MBR process operating in the Tier 1 envelope to receive credit for pathogen reduction.

Table 1: Membrane Bioreactor Example Control Point Monitors

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
Instantaneous Filtrate Turbidity	On-line Turbidimeter(s)	0.17 NTU (H) 0.2 NTU (HH)	Effluent is automatically diverted to sanitary sewer on HH Alarm	**H:** Confirm turbidity with hand-held instrument **HH:** Confirm turbidity with hand-held instrument and troubleshoot as needed Take the impacted skid offline and initiate a bubble test and repair as needed
Bioreactor pH	pH Probe	6 (L) 8 (H)	–	Confirm pH with hand-held instrument and troubleshoot as needed Check upstream pH adjustment equipment and controls
Bioreactor Dissolved Oxygen	Dissolved Oxygen probe	1 mg/L (L) 7 mg/L (H)	–	Confirm dissolved oxygen with hand-held instrument and troubleshoot as needed Check oxygen gas flow, blowers, etc.
Bioreactor Temperature	Temperature Probe	16˚C (L) 30˚C (H)	–	Confirm temperature with hand-held instrument and troubleshoot as needed
Solids Retention Time	Calculation	11 days (L)	–	Verify solids concentration and wasting rate and adjust as needed
Hydraulic Retention Time	Calculation	6 hours (L)	–	Verify flow rate and adjust as needed
MLSS	TSS Probe	3,000 mg/L (L)	–	Confirm TSS with hand-held instrument, inspect mixers, and check wasting rate. Troubleshoot and make operational changes as needed
Transmembrane Pressure	Feed and Filtrate Pressure Gages	0.44 psi* (L)	–	Verify pressure gages and flow rate and troubleshoot as needed
Membrane Flux	Calculation	18.1 gfd (H)	–	Verify filtrate flow and troubleshoot as needed

H = high, H = high high, LL = low low

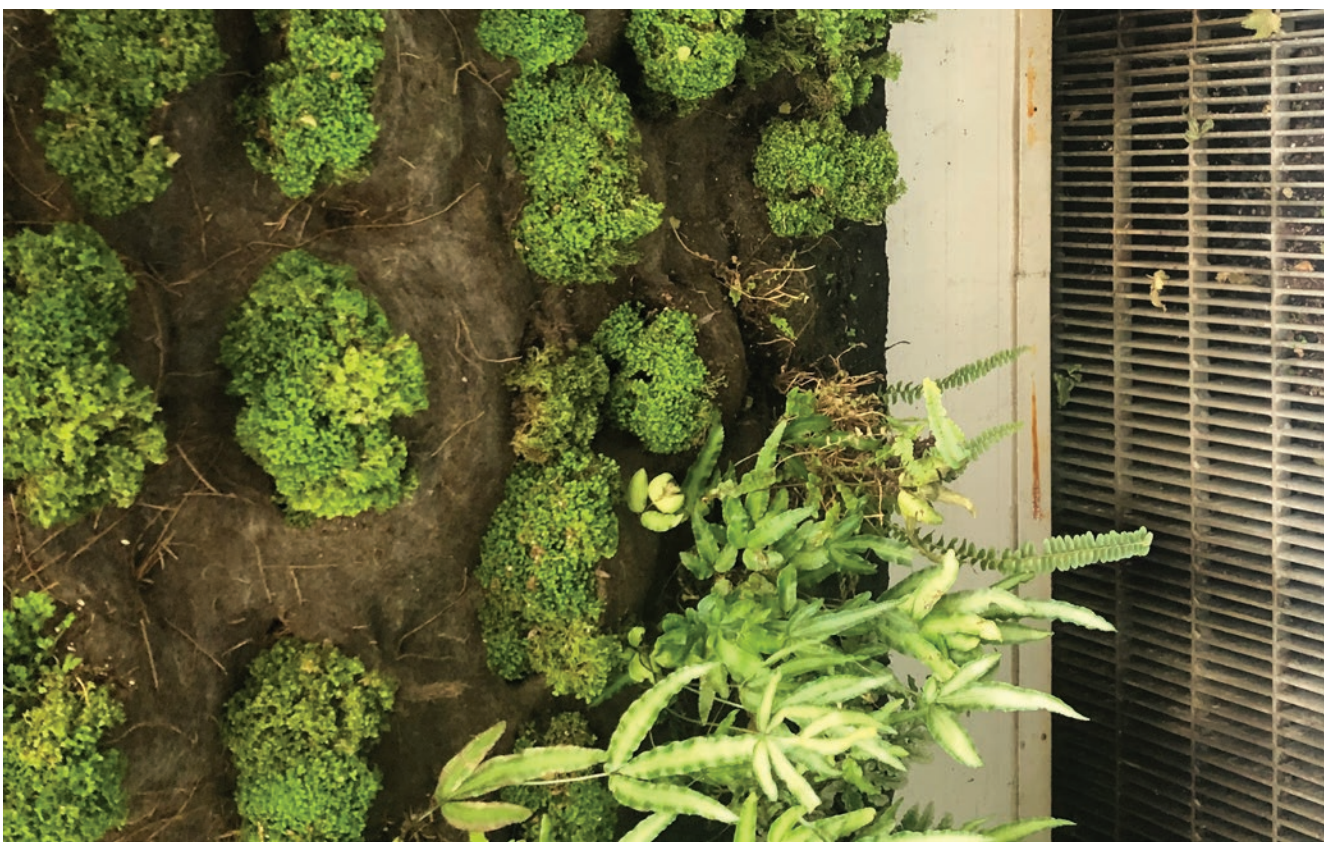
* The absolute value measured as a positive change in pressure across the membrane

MBR Inspection Checklist:

- ☐ Filtrate turbidity alarm levels trigger an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer on a high high alarm).

- ☐ An exceedance of the alarm levels for the following constituents triggers an alarm:

  - ○ Bioreactor pH
  - ○ Bioreactor dissolved oxygen
  - ○ Bioreactor temperature
  - ○ Solids retention time
  - ○ Hydraulic retention time
  - ○ Mixed Liquour Suspended Solids (MLSS)
  - ○ Transmembrane pressure
  - ○ Membrane flux



Membrane Filtration (MF)

MF systems provide a robust barrier for removal of particulates and pathogens from the water. Benefits also include pathogen reduction credit as well as pretreatment for downstream processes. Table 2 provides the typical monitoring associated with an MF process. To achieve 4-log protozoa credit, the onsite water treatment system must provide continuous turbidity monitoring and daily pressure decay tests (PDT) must be performed per the EPA's Membrane Filtration Guidance Manual.

Table 2: Membrane Filtration Example Control Point Monitors

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
Instantaneous Filtrate Turbidity	On-line turbidimeter(s)	0.4 NTU (H) 0.5 NTU (HH)	Unit shuts down on HH Alarm	**H:** Confirm turbidity with hand-held instrument Review last PDT result **HH:** Initiate PDT for unit Repair unit if PDT fails and return to queue only after passing PDT is demonstrated
Filtrate Turbidity Running 24-h 95th Percentile	On-line turbidimeter(s)	0.17 NTU (H) 0.2 NTU (HH)	Unit shuts down on HH Alarm	**H:** Confirm turbidity with hand-held instrument Review last PDT result **HH:** Initiate PDT for unit Repair unit if PDT fails and return to queue only after passing PDT is demonstrated
Calculated LRV	Daily PDT result	< 4 log (LL)	Unit shuts down on LL Alarm	**LL:** Repeat PDT Investigate and correct system to meet minimum PDT requirements

H = high, H = high high, LL = low low

MF Inspection Checklist:

- ☐ An exceedance of the instantaneous filtrate turbidity high alarm level triggers an alarm.
- ☐ An exceedance of the instantaneous filtrate turbidity high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., unit shutdown).
- ☐ An exceedance of the 95th percentile filtrate turbidity high alarm level triggers an alarm.
- ☐ An exceedance of the 95th percentile filtrate turbidity high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., unit shutdown).
- ☐ The calculated LRV low low alarm level is triggered by an off-specification PDT result and the system initiates the proper response (e.g., unit shutdown).

Reverse Osmosis (RO)

RO provides significant reduction of dissolved constituents and essentially complete removal of particulates. Table 3 provides the typical monitoring associated with an RO process and example alarm setpoints and responses. To achieve up to 2-log virus, protozoa, and bacteria credit, the onsite water treatment system must monitor RO influent and RO permeate electrical conductivity (EC) or total organic carbon (TOC). The calculated removal between either EC or TOC in the influent and permeate is then used to calculate the LRV for the process in real time.

Table 3: Reverse Osmosis Example Control Point Monitors

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
Calculated LRV (from EC)	Influent EC on-line analyzer Permeate EC on-line analyzer	1.5 (L) 1.0 (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	**L:** Check train permeate conductivity reading with handheld probe **LL:** Perform RO profiling to identify the problematic vessel(s) and take RO system out of service if necessary
Calculated LRV (from TOC)	Influent TOC on-line analyzer Permeate TOC on-line analyzer	1.5 (L) 1.0 (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	**L:** Check train permeate TOC reading **LL:** Perform RO profiling to identify the problematic vessel(s) and take RO system out of service if necessary

L = low, LL = low low

RO Inspection Checklist:

- ☐ The calculated LRV low alarm level is triggered by an off-specification removal EC/TOC result.

- ☐ The calculated LRV low low alarm level is triggered by an off-specification removal EC/TOC result and the system initiates the proper response.

UV Disinfection

UV disinfection is a common method for achieving pathogen log reduction credit in onsite water treatment system projects because the process is relatively easy to control and provides up to 6-log virus, protozoa, and bacteria disinfection credit when using a validated UV reactor (e.g., NSF/ANSI 55 Class A validation). Table 4 provides the typical monitoring associated with a UV disinfection process controlled using the UV intensity setpoint method.

Table 4: UV Disinfection Example Control Point Monitors.

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
UV Reactor Flow Rate	Online flow meter	90% of Max Design Flow (H) Max Design Flow (HH)	Effluent is automatically diverted to sanitary sewer on HH alarm	Check upstream and downstream production flows Inspect flow control valves and flow isolation valves
UV Reactor Intensity	UV intensity probe	Minimum Design Intensity (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	Verify the result of the UV intensity probe Determine the turbidity of the UV influent and compare it to the reactor's Validation Report Verify the UV reactor is providing 100% power

H = high, H = high high, LL = low low

UV Disinfection Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The UV intensity low low level alarm is triggered and the system initiates the proper response (e.g., automatic diversion to the sanitary sewer).

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Free Chlorine Disinfection

Free chlorine disinfection is another common method of achieving virus log inactivation credit in onsite water treatment systems. Because a chlorine residual of 0.5 mg/L is required for secondary disinfection, free chlorine can offer the benefit of both pathogen control and effective distribution system management. Up to 5-log of virus inactivation credit can be achieved depending on the design CT (product of free chlorine concentration "C" and contact time "T"), and both free chlorine residual and flow rate must be measured continuously. Additionally, the system's contact time must be determined as a function of flow rate based on the contactor design and associated baffling factor. Table 5 provides the typical monitoring associated with a free chlorine disinfection process.

Table 5: Free Chlorine Disinfection Example Control Point Monitors

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
Free Chlorine Contactor Flow Rate	Online flow meter	90% of Max Design Flow (H) Max Design Flow (HH)	Effluent is automatically diverted to sanitary sewer on HH alarm	Check upstream and downstream production flows Inspect flow control valves and flow isolation valves
Free Chlorine Residual (contactor effluent)	Free chlorine analyzer	120% of Min Design Residual (L) Min Design Residual (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	**L:** Verify the result of the chlorine analyzer Check the calibration of the chlorine analyzer Verify concentration of bulk sodium hypochlorite solution Manually increase sodium hypochlorite dose and/or check that control logic is dosing proper amount based on residual and flow rate inputs **LL:** Verify the result of the chlorine analyzer Check the calibration of the chlorine analyzer Verify concentration of bulk sodium hypochlorite solution Increase sodium hypochlorite dose
Calculated Free Chlorine CT	Free chlorine analyzer Flow rate Baffling factor	Design CT (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	Review system alarms to determine whether an excursion of the flow rate or residual triggered the alarm Troubleshoot accordingly following above actions

H = high, H = high high, L= low, LL = low low

Free Chlorine Disinfection Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The free chlorine residual is measured below the low alarm level, triggering an alarm.
- ☐ The free chlorine residual is measured below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).
- ☐ The calculated free chlorine CT is determined to be below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).

Ozone Disinfection

Ozone disinfection is less common for onsite water treatment system projects due to the relative complexity compared to UV or free chlorine disinfection. However, according to the SFDPH-EH Rules and Regulations, 4/3/4[2] log reduction credit of virus, protozoa, and bacteria, respectively, can be achieved. Additionally, ozone has the added benefit of effectively removing color. The control of ozone is similar to other disinfection processes in that flow rate, disinfectant residual, and CT are monitored continuously to verify the system is meeting the targets as designed. Example alarm levels and responses are shown in Table 6.

Table 6: Ozone Disinfection Example Control Point Monitors

Parameter	Related Instrumentation	Alarm Level	Automatic Response	Treatment System Manager Response
Ozone Contactor Flow Rate	Online flow meter	90% of Max Design Flow (H) Max Design Flow (HH)	Effluent is automatically diverted to sanitary sewer on HH alarm	Check upstream and downstream production flows Inspect flow control valves and flow isolation valves
Ozone Residual (contactor effluent)	Ozone analyzer	120% of Min Design Residual (L) Min Design Residual (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	**L:** Verify the result of the ozone analyzer Check the calibration of the ozone analyzer Manually increase ozone dose and/or check that control logic is dosing proper amount based on residual and flow rate inputs **LL:** Verify the result of the ozone analyzer Check the calibration of the ozone analyzer Increase the ozone dose
Calculated Ozone CT	Ozone analyzer Flow rate Baffling factor	Design CT (LL)	Effluent is automatically diverted to sanitary sewer on LL alarm	Review system alarms to determine whether an excursion of the flow rate or residual triggered the alarm Troubleshoot accordingly following above actions

H = high, H = high high, L= low, LL = low low

2 Bacteria credit can be obtained for ozone according to the Tier 1 framework of the AWRCE Ozone WaterVal Validation protocol, which includes CT tables for water with turbidity < 0.15 NTU (WaterSecure 2017c).

Ozone Disinfection Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The ozone residual is measured below the low alarm level, triggering an alarm.
- ☐ The ozone residual is measured below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).
- ☐ The calculated ozone CT is determined to be below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).

APPENDIX: INSPECTION CHECKLISTS

MEMBRANE BIOREACTOR (MBR)

System Readiness Checklist (Perform Prior to Inspection):

- ☐ System has been operated for a period equal to at least three times the design solids retention time (3 x SRT) after seeding the system with microbial populations
- ☐ Design mixed liquor suspended solids (MLSS) is achieved and stable for at least one week
- ☐ Ensure that treatment process sequences have been tested and are functioning such as the production cycle, rest period/backwash sequence, maintenance clean sequence, and recovery clean sequence
- ☐ Perform a bubble test on the membranes to confirm that they are intact and functioning as designed

Inspection Checklist:

- ☐ Filtrate turbidity alarm levels trigger an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer on a high high alarm).
- ☐ An exceedance of the alarm levels for the following constituents triggers an alarm:
  - Bioreactor pH
  - Bioreactor dissolved oxygen
  - Bioreactor temperature
  - Solids retention time
  - Hydraulic retention time
  - MLSS
  - Transmembrane pressure
  - Membrane flux

MEMBRANE FILTRATION (MF)

System Readiness Checklist (Perform Prior to Inspection):

- ☐ Daily pressure decay tests (PDTs) have been conducted for at least one week and meet minimum design requirements
- ☐ The backwash sequence has been tested and verified to function properly
- ☐ At least one chemical clean (e.g., enhanced flux maintenance or maintenance clean) has been conducted and verified to function properly
- ☐ One CIP sequence has been conducted and verified to function properly

Inspection Checklist:

- ☐ An exceedance of the instantaneous filtrate turbidity high alarm level triggers an alarm.
- ☐ An exceedance of the instantaneous filtrate turbidity high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., unit shutdown).
- ☐ An exceedance of the 95th percentile filtrate turbidity high alarm level triggers an alarm.
- ☐ An exceedance of the 95th percentile filtrate turbidity high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., unit shutdown).
- ☐ The calculated LRV low low alarm level is triggered by an off-specification PDT result and the system initiates the proper response (e.g., unit shutdown).

REVERSE OSMOSIS (RO)

System Readiness Checklist (Perform Prior to Inspection):

- ☐ Ensure that treatment process sequences have been tested and are functioning such as the production mode, feed and permeate flush sequence, and recovery clean sequence
- ☐ Verify that salt passage meets vendor specifications

Inspection Checklist:

- ☐ The calculated LRV low alarm level is triggered by an off-specification removal EC/TOC result.
- ☐ The calculated LRV low low alarm level is triggered by an off-specification removal EC/TOC result and the system initiates the proper response (e.g., automatic diversion to the sanitary sewer).

ULTRAVIOLET LIGHT (UV) DISINFECTION

System Readiness Checklist (Perform Prior to Inspection):

- ☐ Verify UVT of feedwater meets design specifications for the selected UV reactor
- ☐ Verify that the UV intensity meets design specifications for the selected UV reactor for the full range of potential operating scenarios. Optimize wiper/manual cleaning frequency to maintain stable UV intensity
- ☐ Verify that all UV lamps are operational

Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The UV intensity low low level alarm is triggered and the system initiates the proper response (e.g., automatic diversion to the sanitary sewer).

FREE CHLORINE DISINFECTION

System Readiness Checklist (Perform Prior to Inspection):

- ☐ Verify instrumentation used to confirm disinfection CT is functioning and reading within design specifications, including the flow meter, turbidimeter, free chlorine residual meter, pH probe, and temperature probe
- ☐ Confirm target CT is automatically maintained continuously for at least one week

Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The free chlorine residual is measured below the low alarm level, triggering an alarm.
- ☐ The free chlorine residual is measured below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).
- ☐ The calculated free chlorine CT is determined to be below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).

OZONE DISINFECTION

System Readiness Checklist (Perform Prior to Inspection):

- ☐ Verify instrumentation used to confirm CT is functioning and reading within design specifications, including the flow meter, turbidimeter, dissolved ozone meters, and temperature probe
- ☐ Confirm target CT is automatically maintained continuously for at least one week
- ☐ Comfirm that the applied ozone dose meets or exceeds the design target

Inspection Checklist:

- ☐ An exceedance of the flow rate high alarm level triggers an alarm.
- ☐ An exceedance of the flow rate high high alarm level triggers an alarm and the system initiates the proper automatic response (e.g., automatic diversion to the sanitary sewer).
- ☐ The ozone residual is measured below the low alarm level, triggering an alarm.
- ☐ The ozone residual is measured below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).
- ☐ The calculated ozone CT is determined to be below the low low level alarm, triggering the system to initiate the proper response (e.g., automatic diversion to the sanitary sewer).

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