TCEQ REGULATORY GUIDANCE
Water Supply Division
RG-640 • July 2023

Seawater Desalination for Public Water Systems

This guide explains how seawater desalination for public drinking water is regulated in Texas, and what is required for a public water system (PWS) to receive approval for a seawater desalination project.

The Texas Health and Safety Code (THSC) requires Texas Commission on Environmental Quality (TCEQ) to ensure that water treated by a seawater desalination facility meets the requirements for public drinking water and rules adopted under THSC Section 341.031

TCEQ must ensure that PWS projects comply with applicable federal and state laws, regulations, rules, guidelines, and design criteria to produce safe drinking water. Before a water source may be used for potable purposes, microbiological and chemical constituents be removed to the maximum extent practicable. Complete removal of all microorganisms and chemicals is impossible, so goals are established to limit human exposure to specific constituents to concentrations that are not harmful to human health.

The maximum allowable concentrations of these constituents are established as drinking water standards by the US Environmental Protection Agency (EPA). The Safe Drinking Water Act (SDWA) requires EPA to establish and enforce standards that PWSs must follow, including maximum contaminant levels (MCLs) for chemicals and log reductions for pathogens and fecal indicator bacteria.

Surface Water Treatment Requirements

Seawater is surface water, and subject to EPA Surface Water Treatment Rules (SWTRs). In addition to pathogens of marine origin, coastal seawater contains an array of pathogens transported from the land surface, which can survive for several days in the marine environment. Seawater intakes are impacted by contaminated stormwater runoff and wastewater treatment plant effluent conveyed by surface waterways. The SWTRs require treatment for bacteria, viruses, and protozoa such as *Cryptosporidium parvum* and *Giardia lamblia*.

Exception Process

TCEQ reviews engineering plans and specifications for all drinking water treatment facilities to ensure that each design meets the minimum design standards in TCEQ's Rules and Regulations for Public Water Systems—Title 30, Texas Administrative Code (30 TAC), Chapter 290, Subchapter D—and will produce water that meets the standards found in the Standards and Reporting Requirements for Public Water Systems in 30 TAC 290, Subchapter F. Because the use of seawater as a source for

PWSs is an uncommon practice, neither TCEQ nor EPA rules define specific design standards for seawater desalination facilities. To be responsive to ongoing research and the latest full-scale plant engineering, TCEQ regulates seawater desalination through the rule exception process.

For treatment technologies without design standards, TCEQ can grant exceptions to requirements in Subchapter D if the PWS can demonstrate that the exception will not compromise public health or result in a degradation of service or water quality. The use of seawater as a source for drinking water is reviewed on a case-by-case basis as an exception. Because seawater contains a much higher concentration of total dissolved solids (approximately 30,000 milligrams per liter (mg/L)) than brackish groundwater (10,000 mg/L or less), seawater desalination is much more challenging. TCEQ therefore requires the PWS to conduct a pilot-scale study, and reviews the results of the study to determine if the proposed treatment scheme will reduce salinity below EPA recommendations (500 mg/L for TDS, 250 mg/l for chloride) and produce water that meets federal and state water quality regulations.

Additional Permitting Considerations

Additional permitting programs within TCEQ may review submittals and set requirements for seawater desalination plants.

Wastewater

Reverse Osmosis (RO) creates concentrated liquid waste (water treatment waste) that must be handled appropriately. If a PWS intends to discharge water treatment wastes into or adjacent to waters in the state, a Texas Pollutant Discharge Elimination System (TPDES) permit from the TCEQ's Water Quality Division will be needed.

Water Rights

The Water Availability Division (WAD) reviews and approves applications for surface water rights permits and processes water supply contracts. Water rights permits include specific types of use, locations where the water may be used, and may also include special conditions related to the use of the water. More information on surface water rights permitting is available on TCEQ's Water Rights website[1].

Community Involvement

Ensuring that the public is aware of the planned seawater desalination project is essential to its success. As with most successful water projects, a PWS that intends to pursue a seawater desalination project should begin discussing the reason for it, the cost, and the type of project with the community from the very beginning. The dialogue should continue throughout the planning, construction, testing, and operation of the plant.

[1] www.tceq.texas.gov/permitting/water_rights/wr-permitting/wr_amiregulated.html

Seawater Desalination Approval Process

Based on 30 TAC Subsection 290.39(l), TCEQ can grant exceptions to requirements in Subchapter D if the PWS can demonstrate that the exception will not compromise public health or result in a degradation of service or water quality. The use of seawater as a source for drinking water is reviewed on a case-by-case basis as an exception. The sections below describe the steps for seawater desalination plant approval. These steps must be followed in order and all information requested must be provided for TCEQ to fully understand the project and review it for approval.

Table 1—Steps and Submittals for Seawater Desalination Plant Approval

Step	*Part*	*Submittal*	*Review Timeframe*
1	1	Pilot Study Protocol	100-day
	2	Pilot Study Report	100-day
	3	Engineering Plans and Specifications	60-day
	4	Concentration-Time (CT) Study	100-day
2	5	Site Visit	Varies
	6	Step 2 Package	60-day

Submitting a Pilot-Scale Study Protocol (Step 1)

Part one: An exception for use of seawater as a source must be requested at this stage. Reviewing the exception request will allow TCEQ to verify that the protocol is comprehensive, so that the pilot study can provide an accurate assessment of the treatment train.

An exception for the alternate treatments used in a seawater desalination plant can only be granted based on pilot-scale test data as required by 30 TAC Subsection 290.42(g). A professional engineer licensed in the state of Texas must submit the protocol. Unless explicitly authorized by TCEQ, water created during the pilot-scale study should never enter the drinking water distribution system.

A pilot-scale study is a method of studying different ways of treating water on a small scale, in the field, and using the proposed source water. TCEQ reviews protocols and provides corrections and additions if needed. Review and approval of the protocol ensures all the necessary samples are included since it is extremely difficult, if not impossible, to collect the missing samples after the study has been completed.

Table 2—Contents of Pilot Study Protocol

Content	*Information Required*
General Information	PWS name, ID number, location of the study etc.
A Detailed Plan	Pilot-scale study details.

Content	***Information Required***
Purpose	A narrative explaining what the study will do and why it is being done.
Goals	Goals of each stage and finished water quality
Duration and Schedule	A minimum of 30-days at the maximum flow rate using the cleaning and other operational parameters that will be used at the full-scale seawater desalination plant. An additional 10-days if the treatment will have an intensive cleaning such as clean-in-place process used for low pressure membrane filters to collect data to demonstrate effectiveness of the cleaning. Up to 6 months or more: o to test the equipment to see the effectiveness of treatment when source water quality changes during different seasons. o to test different treatment units to see which one or which combination of treatment units have the best performance. Additional time is used to optimize the flow rate, backwashes, and other operation parameters. o to familiarize and educate operators and the public on the seawater desalination project.

Content	***Information Required***
Treatment Train(s)*	A detailed diagram from the raw source to the finished water including: ◦ Sample collection locations. ◦ Monitoring points. ◦ Chemical injection points. ◦ Any pretreatment or post-treatment. ◦ Flow measuring devices. ◦ Flow control valves. ◦ Pump(s). ◦ Media vessels. ◦ Membrane units. ◦ Waste streams. ◦ Backwash or regeneration sources. ◦ Any other equipment needed to operate the treatment process. The configuration of the treatment trains that will be tested during each stage of the study if the treatment types or sequences will change. The disposal methods for all wastes and permeate. The treatment processes proposed for the full-scale seawater desalination plant.
Treatment Units	For each treatment unit include: ◦ The purpose. ◦ The vendor name. ◦ The make and model number. ◦ The proposed design parameters. ◦ The proposed operating parameters such as feed water quality needs and associated pre-treatment needs, flows, cleaning procedures, monitoring, and stabilization

Content	***Information Required***
Sampling Plan	A summary table listing: ◦ The samples to be collected. ◦ The sampling locations. ◦ The frequency of sample collection. ◦ The analytical method proposed. ◦ Whether the sample will be analyzed in a laboratory or on-site. Samples for the regulated compounds found in 30 TAC Sections 290.104 and 290.105 must be collected at least three times during the study from the study plant's finished water. Collect one full set of samples near the beginning, middle and end of the study's operation. The sampling based on the treatment specific monitoring requirements listed in the Treatment Units section. The regulatory requirements listed in TCEQ rules. Many treatment units have regulatory monitoring requirements that test if the unit is performing adequately. For example, UF/MF membrane units have a combination of turbidity and DIT test requirements as specified in 30 TAC Subsection 290.101(f). The off-site laboratories must be accredited by the State of Texas under the National Environmental Laboratory Accreditation Program (NELAP). On-site and off-site laboratories must use methods approved by EPA[2] to analyze drinking water samples, where available as specified by 30 TAC Section 25.1.

[2] www.epa.gov/dwanalyticalmethods/approved-drinking-water-analytical-methods

Content	*Information Required*
Stabilization	The methods to stabilize water are discussed in the EPA Optimal Corrosion Control Treatment Evaluation Technical Recommendations for Primacy Agencies and Public Water Systems[3] in detail. The protocol must include: • Finished water sampling for the corrosion screening water quality parameters of conductivity, TDS, pH, temperature, alkalinity, chloride, sulfate, calcium, and sodium. • If including plans for coupon or pipe loop testing of different stabilization methods for comparison, include: ◦ The different treatments. ◦ The method for running the study. ◦ The dosage of different chemicals injected. ◦ The samples to be the collected in the feed and effluent to compare the different treatments effectiveness.
Calibration and Certification	All flow-measuring devices, turbidimeters, pressure sensors, and other on-line monitoring equipment must be calibrated prior to the study per the manufacturer's recommendations. Calibration assures accurate measurements with reduced uncertainty. All verifications required by TCEQ rules must occur during the study and be documented in the pilot-study report. All treatment chemicals and media used in the study must conform to American National Standards Institute/NSF International (ANSI/NSF) Standard 60 for Drinking Water Treatment Chemicals and ANSI/NSF Standard 61 for Drinking Water System Components and must be certified by an organization accredited by ANSI as specified by several citations in 30 TAC 290, Subchapter D. Documentation demonstrating compliance with these requirements must be included in the pilot-study report.

*If the study will test different types of treatments for the same compound in parallel, samples must be collected from the effluent of each treatment type. For example, if the study will compare nitrate removal using biological denitrification and RO, samples for nitrate must be collected from the effluent from the biological process unit and from the effluent of the RO unit. A single sample collected after the point where the two effluents combine would not allow a PWS to understand which process performs better. Additionally, the impact of any differences in the effluents' water qualities will be obscured if they are blended before entering the next stage of treatment. To avoid this problem, a PWS can test these types of treatment units in different phases of the study.

Treatment Units

Typical design and operating parameters for specific treatment technologies proposed for use at seawater desalination plants are described below.

[3] www.epa.gov/dwreginfo/optimal-corrosion-control-treatment-evaluation-technical-recommendations

Low-Pressure Membrane Units

Drinking water treatment units have manufacturer requirements for feed water quality. Depending on the process, specific compounds need to be limited in the feed water for the treatment to function properly or optimally. For example, in some treatments, parameters such as pH and total solids need to be in a specific range. Monitoring for the compounds or parameters in the feed water is included in the pilot study to determine if the levels are in the correct range. If they are not, the study should include pre-treatment to adjust the feed water quality.

Constituents in the feed water of low-pressure membrane units (ultrafiltration and microfiltration) can cause fouling on the membrane surface and limit flow. Each membrane model can be impacted differently by the different levels and combinations of compounds, so the protocol must be customized to monitor the membrane model specific compounds. The EPA Membrane Filtration Guidance Manual (MFGM)[4] identifies the following feed water constituents and parameters to monitor: turbidity, total organic carbon (TOC), temperature, pH, total suspended solids (TSS), alkalinity, calcium, iron, magnesium, manganese, silica, and sulfate. Depending on the levels detected, pretreatment may be proposed, and different customized backwash and cleaning types and durations can be analyzed and optimized (EPA, 2005).

The protocol must include:

1. Monitoring for the following:
   - Feed flow rate.
   - Feed water temperature.
   - Feed pressure.
   - Filtrate pressure.
   - Hydraulic configuration of the unit.
2. The calculations for flux, transmembrane pressure, temperature-corrected flux at 20˚ C, and temperature corrected specific flux.
3. The information needed to calculate the capacity of the membrane units including recording the total time a unit is not producing water and the amount of filtrate used per unit for each of the following:
   - Backwash.
   - Any maintenance cleanings.
   - Direct integrity testing.
   - Any other event that occurs more frequently than once per 30 days when a membrane unit is not able to produce water.
4. To receive credit for pathogen removal, the PWS can choose membrane units that have already received TCEQ approval of their challenge studies. Alternatively, the PWS can include a challenge study for review in the protocol.
5. The equipment for continuously monitoring each low-pressure membrane unit's effluent turbidity with the readings recorded every 5-minutes.

[4]www.tceq.texas.gov/goto/epa-membrane-guidance

6. To show that the membrane units do not contain breaches, include the performance of a daily DIT, and the calculations used to determine the DIT parameters for the study unit(s).
7. The collection of the following information for each DIT performed:
    - The date and time all DITs are initiated.
    - The starting and ending pressure.
    - The duration of the test.
    - Corrective actions performed due to the DIT results.

High-Pressure Membrane Units

Similar to low-pressure membrane units, constituents in the feed water of high-pressure membrane units—reverse osmosis (RO) and nanofiltration (NF)—can cause fouling. Due to the smaller pores of RO and NF modules, the same feed levels can cause more fouling in high-pressure units than in low-pressure membrane units. Additionally, many RO and NF membrane modules can be harmed by chlorine, so the feed may need to be dechlorinated. The MFGM provides the following as feed water constituents and parameters to monitor: turbidity, TOC, temperature, pH, silt density index (SDI), total dissolved solids (TDS), alkalinity, aluminum, ammonia, barium, calcium, iron, magnesium, manganese, potassium, sodium, strontium, chloride, fluoride, nitrate, silica, and sulfate. Depending on the levels detected, pretreatment (e.g., antifoulant addition) may be needed.

The protocol must include:

1. Monitoring for the following:
    - Feed flow rate.
    - Feed water temperature.
    - Permeate flow rate.
    - Concentrate flow rate.
    - System pressures.
    - Hydraulic configuration of the unit.
2. The calculations for flux, net driving pressure, and temperature-corrected flux at 25˚ C.
3. Effluent monitoring for TDS.
4. Effluent monitoring for the constituents of concern that the unit is proposed to remove.
5. Concentrate monitoring to assist with concentrate disposal.

Ion Exchange Units

Ion exchange[5] (IX) processes are reversible chemical reactions for removing dissolved ions from solution and replacing them with other similarly charged ions typically in a pressure vessel filled with a specific IX resin. Contaminants such as hardness, nitrate, fluoride, sulfate, arsenic, and others can all be removed by IX, which is typically used for targeted removal of specific compounds. When the capacity of the resin is

[5] www.tdb.epa.gov/tdb/treatmentprocess?treatmentProcessId=263654386

exhausted, it is necessary to regenerate and return the resin to its initial condition. Competition for ion exchange sites on a resin can greatly impact a system's efficiency in removing the target compounds, and at worst case can cause a slug of the target compound to release into the effluent. The choice of resin used must consider the feed water quality to avoid competition or release issues.

Relative affinities of common ions listed from highest to lowest include:

- Silver (Ag^{+}) > cesium (Cs^{+}) > potassium (K^{+})> sodium (Na^{+}) > lithium (Li^{+});
- Barium (Ba^{+2}) > strontium (Sr^{+2}) > calcium (Ca^{+2}) > magnesium (Mg^{+2}); and
- Iodine (I^{-}) > nitrate ($NO_3{}^{-}$) > cyanide (CN^{-}) > hydrogen sulfate ($HSO_4{}^{-}$) > nitrite ($NO_2{}^{-}$) > chlorine (Cl^{-}) > bicarbonate ($HCO_3{}^{-}$).

Scaling of minerals, chemical precipitants, and surface clogging all lead to resin fouling. Pretreatment measures such as filtration of suspended solids, or addition of chemicals to reduce scaling, may be needed.

The protocol must include:

1. The contaminant to be removed by the IX process.
2. The monitoring upstream and downstream of the unit to document effectiveness of the treatment.
3. Monitoring of the feed flow rate for competing ions.
4. Dimensions of the unit.
5. The empty bed contact time.
6. The recording of information about each backwash or regeneration including:
    - The time or flow between cleanings.
    - The length of each backwash or regeneration.
    - The backwash or regeneration procedure
    - Any other information about the backwash.

Conducting the Pilot-Scale Study

After TCEQ has reviewed and approved the protocol, the PWS should proceed with the pilot-scale study. TCEQ staff are available to assist with any questions that might arise during the study. Following the study, the results should be compiled, analyzed, and packaged into a pilot-study report.

Submitting the Pilot-Scale Study Report

Part two: When TCEQ reviews a seawater desalination pilot-study report, if all the information is present, TCEQ can grant all the project's necessary exceptions. If all the decisions about which treatment units will be used or the order of the treatment units have not been made, additional submittals can be provided until all the needed exceptions have been granted.

Table 3—Contents of Pilot Study Report

Content	***Information Required***
Summary	A summary of the study including all the information, documents, and sample results proposed in the protocol.

Content	*Information Required*
Treatment Methods and Units	○ A discussion of each treatment included in the study. ○ The performance of each treatment unit. ○ The treatment train chosen for the full-scale facility and the basis for how it was chosen.
Electronic Data	The raw data in Microsoft Excel format on a data storage device or via electronic transfer.
Data Analysis	An analysis of the data in the form of tables and graphs.

Submitting Seawater Desalination Plant Plans and Specifications

Part three: TCEQ's review of plans and specifications is based on the requirements in the Rules and Regulations for Public Water Systems in 30 TAC 290, Subchapter D and the conditions included in the granted exceptions as specified in 30 TAC Subsection 290.39(d). Plans, specifications, and related documents must be prepared under the direction of a licensed professional engineer. All engineering documents must have engineering seals, signatures, and dates affixed in accordance with the rules of the Texas Board of Professional Engineers. Upon completion of the review of plans and specifications for the seawater desalination plant, TCEQ will approve the PWS to construct the plant.

Constructing a Seawater Desalination Plant

After TCEQ has reviewed and approved the plans and specifications, the PWS can construct the seawater desalination plant. TCEQ staff are available to assist with any questions that might arise during construction. During the construction the PWS can begin compiling the information needed for the CT study, the DIT parameters—if UF or MF membranes are used—and the verification study protocol.

Submitting CT Study and DIT Parameters

Part four: The performance of a water treatment plant's disinfection process is evaluated in a CT study based on analyses of the concentration (C) of a disinfectant and the theoretical contact time (T) of a disinfectant used in each stage of treatment. The purposes of the CT study are to: identify the number of disinfection zones at the seawater desalination plant; determine the effective contact time for each disinfection zone; calculate crucial CT parameters to track the plant's daily disinfection performance; and determine the plant's total disinfection ability. When the seawater desalination plant is approximately 90 percent complete or at least 6 months from startup, whichever comes first, the PWS can submit a CT study. You can find the electronic template to assist the PWS at the webpage Concentration-Time Study for Water Treatment Plants[6]. TCEQ reviews and approves CT studies after construction is substantially complete because the CT is based on contact time. Contact time is

[6] www.tceq.texas.gov/drinkingwater/swmor/swmor/

calculated from the accurate measurements of treatment units and length of pipes, which may change from the submitted plans during construction.

If the PWS is proposing microfiltration or ultrafiltration membrane units for pathogen treatment, DIT parameters must also be submitted for review and approved before the units can be used to produce drinking water, as specified in 30 TAC Subsection 290.111(f). We recommend submitting the DIT parameters as soon as the membrane units and associated systems have been installed,

Requesting a Site Visit from TOP (Step 2)

Part five: All new low-pressure membrane filtration facilities that will receive pathogen removal credit must undergo an evaluation prior to sending water from the facilities to distribution. The purpose of the evaluation is to ensure that the low-pressure membrane facilities have been designed and constructed and will be operated in accordance with TCEQ rules and numerous, site-specific approval letters issued by Water Supply Division to the PWS. Members of the Texas Optimization Program (TOP) team in Water Supply Division conduct these onsite evaluations. The evaluations typically take six to eight hours to complete.

An abbreviated list of topics and issues that are evaluated follows:

1. Direct Integrity Tests (DITs)
    - Confirmation that the conditions of the DIT parameters approval letter have been met.
    - Each membrane unit (skid, train, etc.) passes a DIT.
2. Mode of Operation
    - Confirmation that each membrane unit is operated in deposition/dead-end mode or in crossflow/suspension/recycling mode in accordance with the approval letters.
3. Surface Water Monthly Operating Report (SWMOR)
    - The customized SWMOR form for the plant, a Microsoft Excel workbook, is reviewed to confirm it meets the conditions of the approval letters.
4. General Plant Compliance
    - Confirmation that coagulant is used, and pretreatment units are in place if required for pathogen removal credits granted in the approval letters.
    - Staff ensure the plant matches assumptions in the Concentration-Time (CT) Study approval letter.
5. Turbidity Data
    - Staff confirm that 5-minute record of Individual Filter Effluent (IFE) turbidity data is used for reporting in the SWMOR and to trigger plant alarms and shutdowns.
    - Confirmation that the turbidity alarm and shutdown settings have been programmed correctly.
        - Online turbidimeter spans meet regulatory requirements.
    - Staff ensure the plant's membrane control systems and SCADA interpret the signals from turbidimeters correctly.

TCEQ has created an evaluation checklist that covers each of the issues listed above plus many more. A companion document to the checklist is also available that describes in detail what TCEQ is looking for with respect to each checklist item. These documents can be downloaded at Low-Pressure Membrane Treatment Plant Checklist.[7]

Submitting for Approval to Use the Seawater Desalination Plant

Part six: When construction is complete and the seawater desalination plant is ready to send water to distribution, the PWS must request final approval to place the plant in service by submitting facility completion data. Review of this data will verify that all facilities were constructed substantially in accordance with the plans and specifications on file at TCEQ, that the water's corrosivity parameters are suitable for entry into the distribution system, and that the plant's facilities and processes will produce water that meets all primary and secondary quality standards. Key components of the completion data submittal include:

Table 4—Contents of Final Approval Submittal

Content	***Information Required***
Physical and Chemical Analysis	A complete physical and chemical analysis of the raw water and finished water showing finished water compliance with all MCLs and SCLs
Engineering Report	An engineering report on the final corrosion control treatment
Performance and Operation Verification	○ Verification of the initial baseline performance of the plant, along with the plant capacity ○ Verification that the plant will be staffed by suitably licensed operators with appropriate training

As with the TOP site visit, TCEQ has created evaluation checklists that indicate what data must be submitted to receive approval for use. Submitters should follow the *Membrane Use Checklist—Step 2*[8] and the *Surface Water Plant Checklist—Step 2*[9] found at the Forms and Checklists for Submitting Plans or Specifications for Public Water Systems.[10] All plans, specifications, and related documents must be prepared under the direction of a licensed professional engineer. All engineering documents must have engineering seals, signatures, and dates affixed in accordance with the rules of the Texas Board of Professional Engineers. Additional information can be found online at Submit Public Water System Plans for Review.[11]

[7] www.tceq.texas.gov/drinkingwater/technical_guidance/staff_guidance/treatment/lpmtp_checklist
[8] www.tceq.texas.gov/downloads/drinking-water/plan-technical-review/forms/checklist-membrane-use-step2.pdf
[9] www.tceq.texas.gov/downloads/drinking-water/plan-technical-review/forms/checklist-surface-water-plant-step2.pdf
[10] www.tceq.texas.gov/drinkingwater/udpubs.html
[11] www.tceq.texas.gov/drinkingwater/planrev.html

Additional Source Water Sampling

The Long Term 2 Enhanced Surface Water Treatment Rule (LT2) requires source water sampling. Once the intake is put into service, the PWS is required to collect *Cryptosporidium*, *E. coli,* and turbidity samples once a month for two years to determine if additional treatment or sampling is required. If the PWS serves less than 10,000 people, the PWS can choose to collect *E. coli* samples every other week for one year. PWSs that choose to collect *E. coli* samples will need to collect *Cryptosporidium* samples if the *E. coli* levels are elevated. Until a Bin classification has been determined after the completion of LT2 testing, PWSs are required to meet Bin 1 treatment levels to comply with the LT2 sampling requirement.[12]

Conclusion

Whether the water source is seawater, rainwater, or any other form of surface water, drinking water produced by a PWS must be of a quality that is suitable for human consumption. The unique challenges of using desalinated seawater as a source require careful study and planning by the water provider, in conjunction with careful oversight and regulation by TCEQ. The process outlined above will allow effective collaboration between the PWS and TCEQ to provide safe drinking water to the public.

[12] www.tceq.texas.gov/drinkingwater/trot/lt2schedule4.html