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Removal of Contaminants with Reverse Osmosis Using the TCEQ's New Modelling and Challenge Testing Approach

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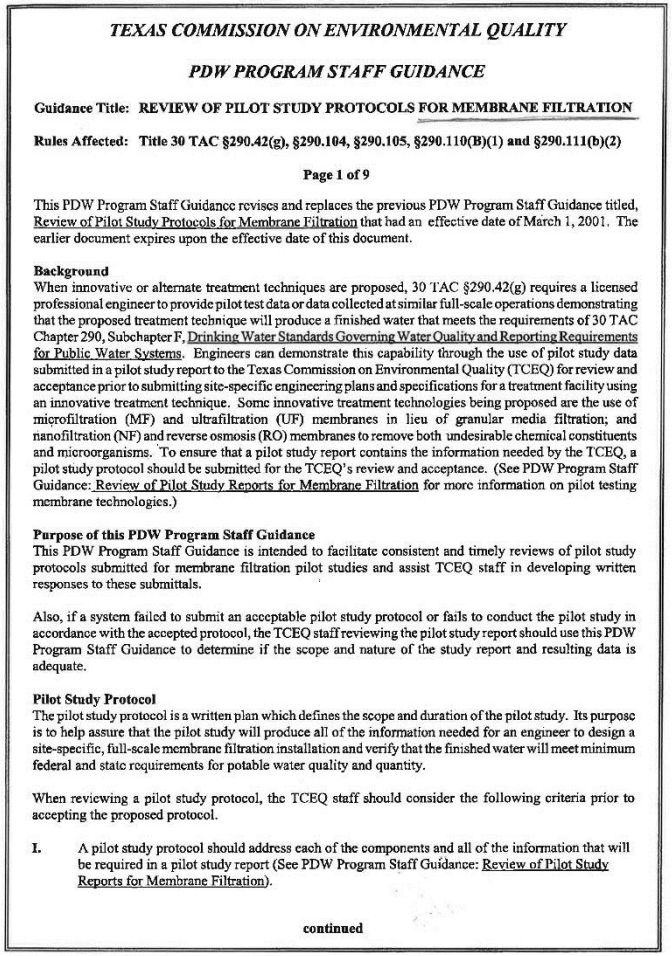
Presentation Topics

- Previous TCEQ Requirements for Piloting
- TCEQ's New Guidelines for RO Membranes
- Targeting Contaminants
- Case Studies
  - City of Ballinger
  - City of Roscoe
  - City of Granbury
- Downsides to New Approach
- Lessons Learned with RO

Previous TCEQ Requirements - Piloting

- The first step involves the development of a pilot protocol
- This pilot protocol, or testing plan of action, is submitted to the TCEQ for review and subsequent approval
- Review can take anywhere from 30 to 90 days, typically



TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

PDW PROGRAM STAFF GUIDANCE

Guidance Title: REVIEW OF PILOT STUDY PROTOCOLS FOR MEMBRANE FILTRATION

Rules Affected: Title 30 TAC §290.42(g), §290.104, §290.105, §290.110(B)(1) and §290.111(b)(2)

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This PDW Program Staff Guidance revises and replaces the previous PDW Program Staff Guidance titled, Review of Pilot Study Protocols for Membrane Filtration that had an effective date of March 1, 2001. The earlier document expires upon the effective date of this document.

Background

When innovative or alternate treatment techniques are proposed, 30 TAC §290.42(g) requires a licensed professional engineer to provide pilot test data or data collected at similar full-scale operations demonstrating that the proposed treatment technique will produce a finished water that meets the requirements of 30 TAC Chapter 290, Subchapter F, Drinking Water Standards Governing Water Quality and Reporting Requirements for Public Water Systems. Engineers can demonstrate this capability through the use of pilot study data submitted in a pilot study report to the Texas Commission on Environmental Quality (TCEQ) for review and acceptance prior to submitting site-specific engineering plans and specifications for a treatment facility using an innovative treatment technique. Some innovative treatment technologies being proposed are the use of microfiltration (MF) and ultrafiltration (UF) membranes in lieu of granular media filtration; and nanofiltration (NF) and reverse osmosis (RO) membranes to remove both undesirable chemical constituents and microorganisms. To ensure that a pilot study report contains the information needed by the TCEQ, a pilot study protocol should be submitted for the TCEQ's review and acceptance. (See PDW Program Staff Guidance: Review of Pilot Study Reports for Membrane Filtration for more information on pilot testing membrane technologies.)

Purpose of this PDW Program Staff Guidance

This PDW Program Staff Guidance is intended to facilitate consistent and timely reviews of pilot study protocols submitted for membrane filtration pilot studies and assist TCEQ staff in developing written responses to these submittals.

Also, if a system failed to submit an acceptable pilot study protocol or fails to conduct the pilot study in accordance with the accepted protocol, the TCEQ staff reviewing the pilot study report should use this PDW Program Staff Guidance to determine if the scope and nature of the study report and resulting data is adequate.

Pilot Study Protocol

The pilot study protocol is a written plan which defines the scope and duration of the pilot study. Its purpose is to help assure that the pilot study will produce all of the information needed for an engineer to design a site-specific, full-scale membrane filtration installation and verify that the finished water will meet minimum federal and state requirements for potable water quality and quantity.

When reviewing a pilot study protocol, the TCEQ staff should consider the following criteria prior to accepting the proposed protocol.

I. A pilot study protocol should address each of the components and all of the information that will be required in a pilot study report (See PDW Program Staff Guidance: Review of Pilot Study Reports for Membrane Filtration).

continued

Piloting

- Once the protocol is approved, construction would begin on the pilot rigs and ancillary equipment
- Typically, the TCEQ likes to see the following:
  - Demonstrational test period to work out “bugs”; usually 30-60 days
  - 30-45 day run in which all testing parameters are held constant
  - Perform Clean-In-Place (CIP)
  - 10-15 day run after CIP to demonstrate recovery
- If any major changes in the operational strategy are desired, the TCEQ would request that these changes all have separate runs (such as pretreatment, coagulant, etc.)

Pilot Testing - Operations

- Data collection and routine operations are typically performed by on-site operators
- Water samples are collected and analyzed or sent to a third party lab
- Typically, an operator would expect to spend 2-3 hours per day with the pilot unit(s)

Pilot Report

- Once pilot operations were complete, a report is written to document the study.
- The TCEQ reviews and approves/amends the report. This sets the design parameters for the full-scale plant.
- Once a response letter is generated (typically 90-110 days), Engineers can proceed with approved design parameters.

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Protecting Texas by Reducing and Preventing Pollution

Piloting - Costs

- Pilot Equipment Rental
- Engineering time for protocol, operational coordination, and pilot report
- Power, chemicals, miscellaneous consumables
- Related appurtenances (piping/valves/etc.)
- Vendor time and expenses
- Lab Testing

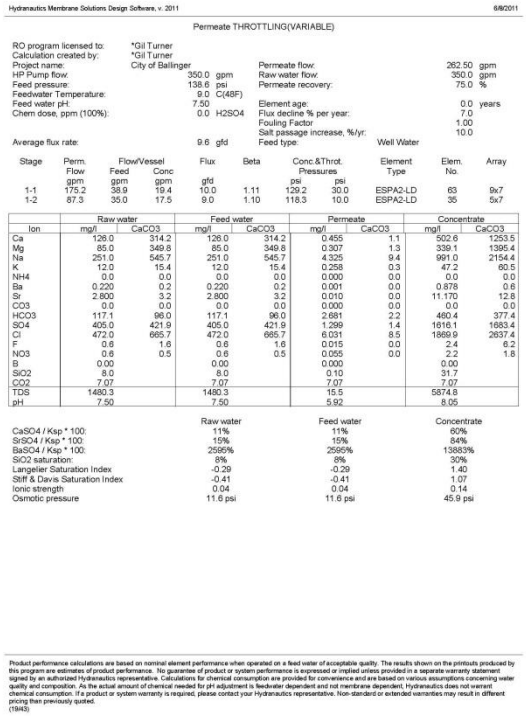
Depending on how many vendors are piloting and the duration of the pilot, costs can range anywhere from $60,000 up to $600,000 or even higher

New TCEQ Guidelines

- Due to the ongoing drought, several years ago, the TCEQ recognized the need to update how membrane design, specifically Reverse Osmosis membrane design, is regulated.
- The TCEQ issued a new Staff Guidance Document entitled *Review of Reverse Osmosis Membrane Filtration for the Treatment of Secondary Contaminants for Groundwater Sources.*

New TCEQ Guidelines – Computer Modeling

- The new guideline document allows the use of computer modeling in lieu of a pilot study.
- Several vendors have software to model how a RO membrane system will perform with a specified feed water quality
- These models have been proven to be very accurate
- Examples:
  - GE: Winflows©
  - Dow: ROSA©



Hydranautics Membrane Solutions Design Software, v. 2011 6/8/2011

Permeate THROTTLING(VARIABLE)

RO program licensed to: *Gil Turner
Calculation created by: *Gil Turner
Project name: City of Ballinger
HP Pump flow: 350.0 gpm
Feed pressure: 138.6 psi
Feedwater Temperature: 9.0 C(48F)
Feed water pH: 7.50
Chem dose, ppm (100%): 0.0 H2SO4
Average flux rate: 9.6 gfd

Permeate flow: 262.50 gpm
Raw water flow: 350.0 gpm
Permeate recovery: 75.0 %
Element age: 0.0 years
Flux decline % per year: 7.0
Fouling Factor 1.00
Salt passage increase, %/yr: 10.0
Feed type: Well Water

Stage	Perm. Flow gpm	Flow/Vessel Feed gpm	Flow/Vessel Conc gpm	Flux gfd	Beta	Conc.&Throt. Pressures psi	psi	Element Type	Elem. No.	Array
1-1	175.2	38.9	19.4	10.0	1.11	129.2	30.0	ESPA2-LD	63	9x7
1-2	87.3	35.0	17.5	9.0	1.10	118.3	10.0	ESPA2-LD	35	5x7

	Raw water		Feed water		Permeate		Concentrate	
Ion	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3	mg/l	CaCO3
Ca	126.0	314.2	126.0	314.2	0.455	1.1	502.6	1253.5
Mg	85.0	349.8	85.0	349.8	0.307	1.3	339.1	1395.4
Na	251.0	545.7	251.0	545.7	4.325	9.4	991.0	2154.4
K	12.0	15.4	12.0	15.4	0.258	0.3	47.2	60.5
NH4	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
Ba	0.220	0.2	0.220	0.2	0.001	0.0	0.878	0.6
Sr	2.800	3.2	2.800	3.2	0.010	0.0	11.170	12.8
CO3	0.0	0.0	0.0	0.0	0.000	0.0	0.0	0.0
HCO3	117.1	96.0	117.1	96.0	2.681	2.2	480.4	377.4
SO4	405.0	421.9	405.0	421.9	1.299	1.4	1616.1	1683.4
Cl	472.0	665.7	472.0	665.7	6.031	8.5	1869.9	2637.4
F	0.6	1.6	0.6	1.6	0.015	0.0	2.4	6.2
NO3	0.6	0.5	0.6	0.5	0.055	0.0	2.2	1.8
B	0.00		0.00		0.000		0.00	
SiO2	8.0		8.0		0.10		31.7	
CO2	7.07		7.07		7.07		7.07	
TDS	1480.3		1480.3		15.5		5874.8	
pH	7.50		7.50		5.92		8.05	

	Raw water	Feed water	Concentrate
CaSO4 / Ksp * 100:	11%	11%	60%
SrSO4 / Ksp * 100:	15%	15%	84%
BaSO4 / Ksp * 100:	2595%	2595%	13883%
SiO2 saturation:	8%	8%	30%
Langelier Saturation Index	-0.29	-0.29	1.40
Stiff & Davis Saturation Index	-0.41	-0.41	1.07
Ionic strength	0.04	0.04	0.14
Osmotic pressure	11.6 psi	11.6 psi	45.9 psi

Product performance calculations are based on nominal element performance when operated on a feed water of acceptable quality. The results shown on the printouts produced by this program are estimates of product performance. No guarantee of product or system performance is expressed or implied unless provided in a separate warranty statement signed by an authorized Hydranautics representative. Calculations for chemical consumption are provided for convenience and are based on various assumptions concerning water quality and composition. As the actual amount of chemical needed for pH adjustment is feedwater dependent and not membrane dependent, Hydranautics does not warrant chemical consumption. If a product or system warranty is required, please contact your Hydranautics representative. Non-standard or extended warranties may result in different pricing than previously quoted.
(1843)

What is modeling?

- Takes a set of input parameters and water quality parameters and predicts how a RO system will perform
- Usually, RO systems are modeled at different stages of age (0, 3, 5 years)

New TCEQ Guidelines – Design Report

- In addition to the modeling results, the Design Report submitted to the TCEQ must include the following:
  - General information about the project and water system
  - Project summary describing the purpose of the project
  - Raw water quality data
  - Finished water quality goals
  - Process flow rates
  - Design criteria for the proposed project including a process flow diagram and a description of each process
  - Detailed information on the RO system and related systems (CIP, blending, and reject waste)
  - Operational strategy

How is this different from before?

From the TCEQ's Website:

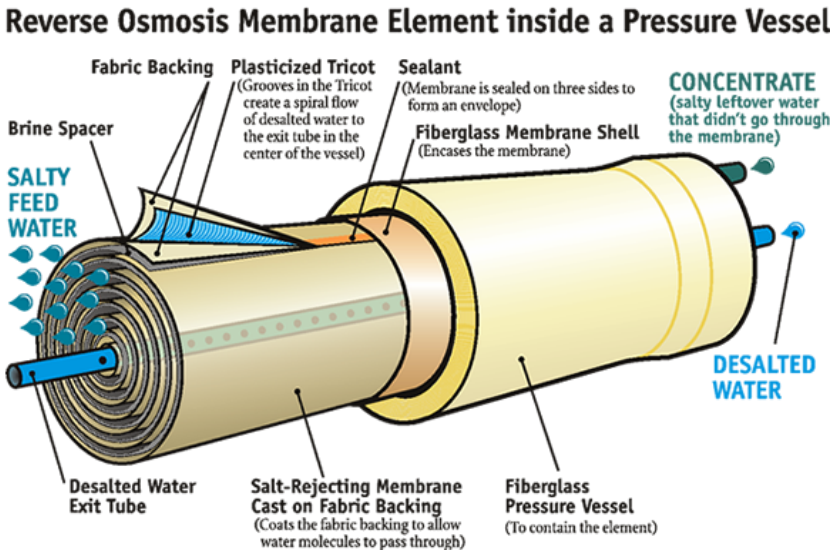
- "Previously, for the TCEQ to approve alternative treatments, such as RO, a licensed professional engineer was required to provide pilot test data, or data collected at similar full-scale operations, to demonstrate that the proposed treatment will produce water that meets the requirement of Title 30 TAC Chapter 290, Subchapter F: Drinking Water Standards Governing Water Quality and Reporting Requirement for Public Water Systems. With the release of the new staff guidance document, the public water system, through their licensed professional engineer, can receive approval from the TCEQ based on a streamlined approach:
  - The staff guidance **allows the use of computer modeling in lieu of on-site pilot studies** for RO filtration treatment for secondary contaminants from a groundwater source. The computer model results will provide the capacity and water quality information necessary for TCEQ to approve an exception. Computer modeling data will provide the design basis for approving the exception to use RO treatment for brackish groundwater. The TCEQ will still allow the submittal of pilot data to support the exception request if the engineer determines that pilot testing better addresses the needs of the water system.
  - To further assist drought stricken communities, the TCEQ will offer **concurrent reviews of plans, specifications and exception requests**. The Professional Engineer should submit both the exception request (with the computer modeling data) and the plans and specifications at the same time for review using the plan review submittal form."

New TCEQ Guidelines

- As with all Exception Requests, the TCEQ looks at these on a case-by-case basis; meaning no two requests are the same and no two requests receive the same requirements back from the TCEQ.
- A specific request might not fit into these guidelines exactly, but that does not mean that the TCEQ will not work with that entity to find a solution.

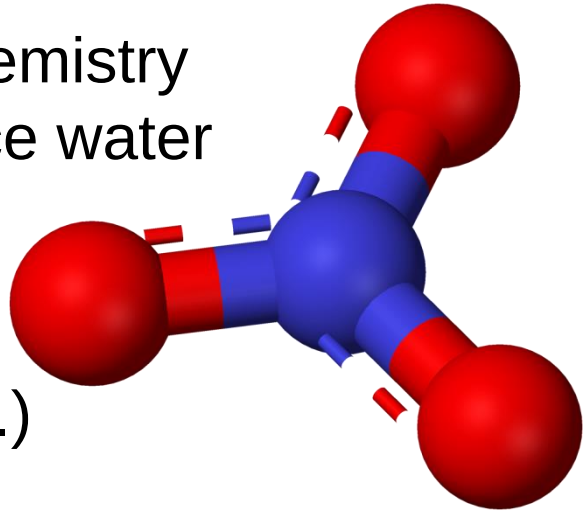
Contaminants

- Reverse Osmosis systems allow operators to target specific contaminants
- High molecular weight compounds are easily rejected by RO systems
- Large valence shell ions are also rejected well



Nitrate

- Nitrate is a naturally occurring polyatomic ion that is commonly used in fertilizers
- Because it can be harmful to humans (especially infants), it has a Maximum Contaminant Level (MCL) of 10 mg/L
- There are no changes in feed water chemistry required to remove Nitrate from a source water
- Many source waters will experience added benefits with RO used to target Nitrates (hardness, alkalinity, etc.)



Arsenic

- Can cause skin damage and circulatory problems
- MCL is 0.01 mg/L
- Arsenic 5 or Arsenate is typically rejected at a rate of approximately 80%
- Arsenic 3 or Arsenite is not rejected very well – likely 25% or less

TDS/Sulfates/Chlorides

- These are all Secondary Standards as set by the United States Environmental Protection Agency
- MCLs are:
  - TDS: 500 mg/L
  - Sulfates: 250 mg/L
  - Chlorides: 250 mg/L
- RO systems are most commonly known for their salt rejection

TDS/Sulfates/Chlorides

- Desalination is typically associated with RO systems
- A properly designed RO system will reject these contaminants at a rate of 99% or better
- Note: this is with new elements

THM Precursors

- RO systems typically remove organics pretty well
- TOC is usually reduced by 60-70%
- Bromide is usually reduced by 80-90%
- This can be very beneficial to many systems in the region that struggle with high TTHMs

Case Study: City of Ballinger

- Population of approximately 3,800
- Located 55 miles South of Abilene and 35 miles Northeast of San Angelo
- Treat a blended surface water from O.H. Ivie and Lake Ballinger (two very different sources)

Case Study: City of Ballinger

- A 350 gpm (permeate) RO system was added as a polishing step to help reduce TDS/sulfates/chlorides and to also help the operators by reducing THM precursors
- The system is fed from the combined filter effluent line and is returned to the line just prior to disinfection before the clearwell
- A pressure filter was added to further reduce SDI prior to the system
- The system works well and has helped the City achieve better finished water quality even with dwindling water supplies

Case Study: City of Ballinger

Case Study: City of Roscoe

- Population of approximately 1,300 people
- Served by several wells located throughout the City
- These wells are high in Nitrates; the average is around 15 mg/L
- The MCL for Nitrates is 10 mg/L

Case Study: City of Roscoe

- A 350 gpm system was designed to reduce the Nitrate levels in the City's drinking water down to 5 mg/L or less
- The system is a blended system that produces 250 gpm of permeate with 100 gpm of bypass to meet the City's daily potable demands
- The system was modeled and a challenge testing approach was approved by the TCEQ in which no piloting was required
- The system is currently in the testing phase (full-scale with all water being sent to the distribution system) and the system is producing finished water with 4-5 mg/L of Nitrates

Case Study: City of Granbury

- The City of Granbury has a population of approximately 8,500
- Located southwest of Fort Worth right on Lake Granbury
- The City operates 20 or so wells along with a 0.5 MGD surface water plant to provide drinking water to its citizens
- The conventional plant is in severe disrepair and requires complete replacement

Case Study: City of Granbury

- A new MF/RO plant was designed to replace the existing plant
- A pilot study was performed because microfiltration was being implemented
- A RO system was piloted as well, but the pilot skid that was provided could not be configured to match the flux of the proposed plant
- The pilot was run at a lower flux and after the pilot report was approved, the TCEQ granted a higher flux rate to match the proposed full-scale plant
- Modeling data, along with the original pilot report, was submitted with the higher flux exception request

Downsides to Not Performing a Pilot

- Obviously, the system is not test “driven” prior to full-scale implementation
- Issues that might get overlooked during design can be resolved during the pilot stages
- Operators do not get a trial period before the system is put on line

Treatment plant's grand opening
February 27, 2013

Dutch Wilkinson (left), the owner of Plantation Inn, and Mickey Parson (in black hat), Granbury Place 6 City Council member, discuss aspects of the city's new water treatment plant with engineer Jordan Hibbs (right front) of Enprotec/Hibbs & Todd, Inc., Friday during the event at 1402 E. Pearl St. The three-phase project will replace the existing 40-year-old water treatment plant.

Lessons Learned and Other Tips

- A good quality feed source is critical:
  - SDI < 3
- Trending your system is very important for the long-term life of the membranes
- Implement a sinking fund to plan for membrane replacement
- Be patient with your system; it can take months and even a year to work bugs out
- Pay close attention to bio-fouling and scaling on your membranes; work with vendors/engineers to identify the causes

Summary

- The TCEQ's new guidelines allow Owners to bypass the conventional piloting step for groundwater (non-GUI) systems
- There are many advantages, some more primary and some secondary to using RO to target specific contaminants
- When a pilot study is not performed, Engineers should pay careful attention to feed water quality, seasonal variations, and other ancillary factors before implementing a new RO design

Any Questions?

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