OKLAHOMA
DEPARTMENT OF ENVIRONMENTAL QUALITY

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GUIDANCE

Pilot Study for Membrane Filtration

Oklahoma Department of Environmental Quality

Guidance for Proposed Membrane Filtration System Pilot Study Reports

PURPOSE

The purpose of the pilot study is to determine if the characteristics of the raw water make membrane separation a viable treatment option. Membrane separation is not appropriate for all water sources. Operating parameters for a site-specific, full-scale membrane treatment such as backwash procedures and frequency, chemical clean-in-place (CIP), and amount of irreversible fouling will be established during the pilot study. The pilot study will also be used to demonstrate that the Public Water Supply (PWS) system has the technical capacity to operate and maintain the proposed system, as system operators will be expected to participate in the study and collect much of the required data.

This guidance is intended to facilitate consistent and timely review of pilot study reports submitted for membrane filtration. This guidance will also be used as a guide for DEQ review staff to determine if the scope and nature of the pilot study report and resulting data are adequate and whether proposed membrane system will produce water that meets EPA and DEQ drinking water standards and is acceptable.

BACKGROUND

Systems treating surface water or ground water under the influence of surface water must achieve at least a 3.0-log (99.9%) removal or inactivation of *Giardia lamblia* cysts and 4.0-log (99.99%) removal or inactivation of viruses. Beginning January 1, 2002, these systems must also achieve 2.0-log (99%) removal of *Cryptosporidium parvuum* ocysts, which are resistant to inactivation using chlorine disinfection. This has been generally achieved using conventional treatment (flocculation, coagulation, granular media (sand) filtration, and disinfection). One of the emerging alternative filtration/treatment technologies that is becoming a cost-effective alternative for many surface waters is membrane filtration. Membrane filtration systems can be installed in lieu granular media filters at most water treatment facilities and in some cases, can be used in lieu of complete conventional treatment.

Membrane filtration is the separation of the solids from a pressurized fluid. The pore openings in the membrane material require a significant fluid pressure to drive the liquid through the membrane but the pore sizes do not allow the particles larger than the pore opening to pass. There are four types of membrane classes; Microfiltration (MF), Ultrafiltration (UF), Nanofiltration (NF), and Reverse Osmosis (RO).

Current DEQ regulations require that membrane systems be preceded by conventional treatment, including coagulation, flocculation, and sedimentation. If a pilot study report indicates that this pretreatment is not necessary to produce water that meets drinking water standards, a variance from this requirement may be requested and the membrane system may be installed in lieu of conventional treatment. The pilot study report must be submitted with the Engineering Report prior to submitting site-specific engineering plans and specifications for the membrane filtration system.

Future regulations are being considered that would require a 90-day pilot study for all membrane installations.

Acceptance, by the DEQ, of the pilot study report or the proposed site-specific, full-scale design criteria shall not be construed as approval for construction of a water treatment system. Construction of a water treatment facility may not begin until the DEQ had reviewed and approved the engineering plans and specifications and a construction permit has been issued.

PILOT STUDY

The pilot study must provide all of the information that will be required in the pilot study report and by the engineer to design a site-specific, full-scale membrane filtration system installation. Pilot studies are normally conducted in three stages.

1. The first stage of testing is used to pilot the membrane units under different operating conditions. The stage 1 test period should establish site specific and full-scale operating parameters for each type of membrane tested. In addition, the Sage 1 testing results may indicate site-specific conditions that require modification of a submitted and accepted pilot study protocol. Data must be collected and recorded to establish the operating parameters to be used in Stage 2.
2. After the Stage 1 testing period, a CIP procedure must be conducted. During the Stage 1 testing period, additional CIP procedures may be conducted as dictated by the site-specific feed water quality, testing operating parameters, and manufacturer's recommendations. A physical integrity test of each membrane module must be conducted after each CIP using a Diffusive air flow test or an Air pressure hold test.
3. The Stage 2 period includes testing each membrane module under its optimum set of simulated site-specific, full-scale water treatment plant design conditions determined from the data collected during the Stage 1 testing period. After conducting the required CIP and physical integrity test, each manufacturer's membrane module must be continuously operated under its simulated full-scale plant design conditions for a period of not less than 30 days. If at the end of the 30-day simulated full-scale water treatment plant test, a membrane module has not fouled to a point where it requires a CIP, the engineer and the PWS may choose to continue the Stage 2 testing until the membrane module's filtrate flux reaches unacceptable levels for full-scale water treatment plant operation.
4. Stage 3 will determine the percent loss of original specific flux and if irreversible fouling has occurred. The membrane module must be operated at the same simulated full-scale water treatment plant design conditions for at least 24 hours. The duration of the Stage 3 testing period may be extended if the engineer or the PWS believes that additional time is needed to determine if there is any loss in the original specific flux or if irreversible fouling has occurred.

A responsible official of the PWS or their engineer must notify the DEQ that a pilot study will be conducted at least 30 days prior to the start to the study and may request a meeting with DEQ staff prior to starting a pilot study.

   a. A pilot study must be conducted for a period of at least 90 days during a season that represents adverse operating conditions for a full-scale water treatment system.

Any level of pretreatment proposed for a pilot study must be equivalent to that which will be provided at the site-specific, full-scale membrane filtration system installed.

The membrane being tested in the pilot study must contain fibers of the same length and composition as that which will be provided for full-scale membrane filtration system.

The membranes used in the pilot study must be preconditioned in accordance with the manufacturer's recommendations. Preconditioning must be completed prior to beginning the pilot study.

If ozone is to be utilized, residual must be measured and reported.

Bench top particle counters and monitors must be calibrated according to manufacturers specifications prior to startup of a pilot study and again before beginning the full-scale plant testing stage. Bench top particle counters and monitors must be equipped with a sensor capable of reading particles sizes in the 2-15 micron range and reporting the total count with a coincidence error of less than 10%.

The continuous integrity of each manufacturer's tested membrane unit must be monitored during a pilot study. This is to detect if one or more of the fibers have failed. On-line particle counters capable of reading particles sizes in the 2-15 micron range and reporting the total count with a coincidence error of less than

10% or laser turbidimeters are required for pilot and full-scale systems. Readings should be recorded every 15 minutes.

The date, duration, and amount of all rainfall events during the pilot study must be recorded. If conventional pretreatment (coagulation, flocculation, and Sedimentation) is not provided in the pilot study, the study period must include at least one raw water turbidity spike associated with a major rainfall event.

The following data must be collected during the pilot study to create data summary tables and graphs for each membrane module tested in the final pilot study report.

a. During all stages of a pilot study, the following data must be recorded at 15-minute intervals or more frequently. Due to the extensive data collection requirements, it is recommended that data be recorded electronically. However, if charts are used, they must be of sufficient size that each 15-minute reading can be determined.
    a. Feed water turbidity,
    b. Filtrate water turbidity,
    c. Feed water total particle counts in the 2-15 micron range, and
    d. Filtrate water total particle counts in the 2-15 micron range.

b. During the Stage 1 testing period of a pilot study, the following data must be recorded at least once every day and each time an operational parameter is changed. During Stage 2 and 3, the data must be collected at 4-hour intervals or more frequently.
    a. Membrane Rack inlet pressure in pounds per square inch (psi),
    b. Membrane Rack outlet pressure (psi),
    c. Filtrate pressure (psi),
    d. Feed water flow rate in gallons per day (gpd),
    e. Filtrate water flow rate (gpd),
    f. Reject water flow rate (gpd) if applicable, and
    g. Recycle water flow rate (gpd) if applicable.

c. During all stages of the pilot study, the following data must be collected at least once each day and any time raw water quality changes.
    a. Raw water turbidity,
    b. Raw water pH,
    c. Raw water alkalinity,
    d. Raw water temperature,
    e. All oxidant dosage levels at application points,
    f. Feed water pH,
    g. Feed water alkalinity,
    h. Feed water temperature,
    i. Feed water disinfectant residual levels, and
    j. Filtrate water disinfectant residual levels.

d. The following data must be recorded at least 30 days during the pilot study period and at least once during the Stage 2 (simulated full-scale operation) test period.
    a. Raw water algae counts,
    b. TOC concentrations,
    c. Feed water algae counts,
    d. Feed water total hardness as calcium carbonate,

e. Feed water iron, manganese, and aluminum,
f. Feed water TDS and TSS, and
g. Filtrate true and apparent color.

e. If a disinfectant is applied during the Stage 2 test period, the following must be conducted on the filtrate water at least once during the Stage 2 test period.
   a. Total Trihalomethanes (TTHM)
   b. Trihalomethane (THM) Potential,
   c. Halo acetic Acids (HAA5),
   d. Chlorite if chlorine dioxide is used, and
   e. Bromate if ozone is used.

f. The following data is not required by the DEQ but should be considered to properly design a site-specific, full-scale membrane filtration water treatment system
   a. Silica concentration,
   b. UV_{254} absorbance,
   c. Conductivity,
   d. Barium concentrations,
   e. Strontium concentrations,
   f. Total coliform counts,
   g. *E. Coli* counts, and
   h. Simulated distribution system modeling for TTHM and HAA5 production.

PILOT STUDY REPORT

A pilot study report must be prepared under the direction of a professional engineer, licensed in the State of Oklahoma (engineer). A submitted pilot study report must be accompanied by a cover letter that is signed, sealed and dated by the professional engineer representing the public water supply system (PWS) and having over-site of the pilot study to be conducted.

The DEQ staff member that is reviewing the pilot study report may request a meeting with the responsible official of the PWS or their engineer prior to issuing acceptance of the pilot study report.

The pilot study report contains the results of the pilot study and recommendations for the site-specific, full-scale design of membrane systems. The report must include the following:

1. Summary of the Pilot study results and recommendations,
2. General information about the site where the pilot study was conducted:
   a. The name of the public water system (PWS),
   b. The PWSID Number of the PWS,
   c. The name of the raw water source and the water rights allocated,
   d. A map showing the location of the raw water intake used in the pilot study and the location of the proposed intake (if different that the intake used in the pilot study), and
   e. A schematic of the pilot plant that shows chemical feed points, pretreatment facilities, pilot equipment, flow meters and monitoring points.
3. The pilot study must contain the following information for each membrane that was evaluated:
   a. Membrane manufacturer,
   b. ETV/NSF certifications and verifications,
   c. Type of membrane (Microfiltration, ultrafiltration, reverse osmosis, etc.),

d. Material the membrane is constructed of,
e. Length of membrane fibers,
f. Direction of flow (inside out or outside in),
g. Surface area of the feed water side of the membrane,
h. Nominal and maximum pore size,
i. Oxidant resistance,
j. Temperature operating range,
k. Feed water turbidity operating limit,
l. Method of operation (dead-end or cross flow), and
m. Maximum recommended flux.

4. A pilot study report must include a detailed description of each membrane module's pilot study for each of the membranes piloted. The following information must be included in this description.
   a. A description of the membrane manufacturer's required preconditioning method that occurred prior to the pilot study,
   b. All rainfall events on the watershed,
   c. If conventional pretreatment (coagulation, flocculation, and sedimentation) is not provided in the pilot study, then the pilot study period must include at least one raw water turbidity spike associated with a major rainfall event. The raw water spike or turbidity spike must be representative of the source's of historical raw water turbidity highs,
   d. A description of how the results of the initial Stage 1 testing resulted in the Stage 2 simulated site-specific, full-scale operating conditions piloted foe each membrane tested,
   e. A description of any equipment failures and any resulting time delays or time off line,
   f. A detailed analysis of the pilot study data for each membrane piloted,
   g. A list of the proposed site-specific, full-scale operating parameters for each membrane being considered for the water treatment facility, and
   h. A description of any special tests (intentionally cutting one or more fibers to determine the sensitivity of the on-line monitors or physical integrity tests).

5. Data and results must be presented to establish the following for each phase of the Stage 1 test period:
   a. Backwash duration,
   b. Backwash frequency,
   c. Backwash flow rate,
   d. Raw water flow rate,
   e. Chemical clean-in-place (CIP) frequency,
   f. Range and average filtrate flux,
   g. Specific flux rate (adjusted to 20°C),
   h. Percent element recovery (cross flow) or percent system recovery (dead-end flow),
   i. Expected duration between chemical clean in place (CIP), and
   j. Pretreatment requirements.

6. A pilot study report must include a list of the analytical methods and equipment to be used during the pilot study. All flow measuring devices, rate-of-flow controllers, and laboratory equipment must be calibrated as specified by the manufacturer prior to beginning data collection. A description of the calibration methods and frequency must be included for verification of data.

7. A list of analytical procedures conducted at off-site laboratories must be included.

8. A pilot study report must provide the following clean-in-place CIP data for each membrane module that will be considered for the site-specific, full-scale membrane system.
    a. Documentation that all CIP chemicals used meet American National Sanitation Institute/National Sanitation Foundation (ANSI/NSF) Standard 60,
    b. CIP flow rate,
    c. CIP duration (time offline),
    d. Quality of filtrate water used,
    e. pH of the CIP solution,
    f. CIP procedure,
    g. Disposal method of CIP water, and
    h. The expected CIP intervals for the full-scale water treatment system.
9. The pilot study must contain the following graphs for each membrane module being considered for site-specific, full-scale installation. Each of the graphs must show the time the data was collected on the x-axis and the results of the measurements on the y-axis. The scale of each axis, Stage 1, Stage 2, Stage 3 test periods, all rainfall events, and all CIP events must be clearly identified.
    a. A plot showing the turbidity levels of the raw feed, and filtrate water on the same graph,
    b. A plot showing total particle counts in the 2-15 micron range for each 15-minute period of the feed and filtrate waters on the same graph,
    c. A plot showing filtrate specific flux rates (adjusted to 20°C) and Transmembrane pressure (TMP) on the same graph,
    d. A plot showing filtrate specific flux rates and percent recovery (i.e. percent system recovery for membrane modules operated in dead-end flow and percent element recovery for membrane modules operated in cross flow) on the same graph, and
    e. A plot showing the percent loss of original specific flux rate and feed water turbidity levels on the same graph.
10. A pilot report must contain each of the following data summary tables. Each of the tables must contain the number of data points collected, the range of the data values (i.e. the maximum and minimum values), the average value, and the 95^{th} percentile if more than 10 data points are collected.
    a. A "Log Removal Table" summarizing the feed water and filtrate water data and the level of removal achieved for each of the following parameters.
        i. Turbidity,
        ii. Particle counts, and
        iii. *E. Coli* (if data is collected).
    b. A "Membrane Performance Table" summarizing the following operating conditions and each membrane module's performance during Stages 2 and 3 simulated full-scale membrane treatment system tested.
        i. Feed water flow rate,
        ii. Filtrate water flow rate,
        iii. Recycle water flow rate (if applicable),
        iv. Reject water flow rate (if applicable),
        v. Filtrate flux,
        vi. Transmembrane Pressure (TMP),
        vii. Feed water temperature,
        viii. Specific flux (adjusted to 20°C),

ix. Percent recovery of specific flux after CIP,
x. Loss recovery of original specific flux due to irreversible fouling,
xi. Backwash frequency,
xii. Backwash duration, and
xiii. Backwash flow rate.

c. A "Water Quality Table" summarizing the results of the following water quality analyses.
i. Raw water hardness as calcium carbonate,
ii. Raw water total alkalinity,
iii. Raw water Iron, manganese, and aluminum,
iv. Raw water TDS and TSS,
v. Raw water conductivity,
vi. Raw water pH,
vii. Raw water algae count,
viii. Raw water TOC
ix. Feed water pH,
x. Feed water algae count,
xi. Filtrate water pH,
xii. Filtrate water TOC,
xiii. Percentage of TOC reduction, and
xiv. Filtrate water true and apparent color.

11. If a disinfectant is was applied during the study, the pilot study report must include a Disinfection Data Table" that includes the number of data points collected, the range of the values, and the average value for each of the following parameters.
a. Disinfectant and application point,
b. Disinfectant dose,
c. Filtrate disinfectant residual concentration,
d. Total Trihalomethanes (TTHM),
e. Halo acetic acids (HAA5),
f. Chlorite (if chlorine dioxide is used), and
g. Bromate (if ozone is used).