Appendix G

Technical Considerations for Filtration and Disinfection Processes

G.1 Ultraviolet (UV) Light Disinfection

The use of UV disinfection systems for water treatment is becoming more common in Nova Scotia. UV dose delivery depends on a number of factors including reactor design (hydrodynamics), flow rate, UV transmittance of water, UV intensity, lamp output, lamp placement, aging, fouling and microbe inactivation kinetics. A safety factor is added to establish a design dose and is established through UV validation.

UV validation testing is usually conducted by the UV manufacturer or a third party to pre-validate their reactors to determine the operating conditions under which a UV reactor would deliver the validated dose. The validation testing is conducted for the full-scale testing of the reactor that will actually be used in field and inactivation of a test micro-organism with dose-response characteristics quantified through bioassay tests. The operating conditions include flow rate, UV intensity, UV lampstatus, an account for UV absorbance of the water, lamp fouling, aging inlet and outlet piping configuration of the UV reactor and measurement of uncertainty of on-line sensors, etc.

The purpose of this appendix is to specify minimum requirements when UV is used for primary disinfection. UV systems should be designed taking into account:

- Redundancy and reliability;
- Minimum dose and performance requirements;
- UV transmittance (UVT); and
- Scaling and fouling.

G.1.1 Redundancy and Reliability

a. A minimum of two UV treatment units are required in parallel to provide redundancy regardless of the design of the system.

b. Where two units are provided, each unit shall be capable of meeting the maximum day demand flow. Where more than two units are provided, the maximum day demand flow shall be met with the largest unit out of service.

c. The UV dose must be equal to or greater than 40 mJ/cm^2, or Department accepted alternate dose.

d. UV intensity and flow through the reactors, shall be monitored a minimum of once every five minutes to ensure the UV dose is greater than or equal to 40 mJ/cm^2 or Department accepted alternate dose.

e. Provisions shall be in place to prevent the distribution of water if UV dosedrops below 40 mJ/cm^2, or Department accepted alternate dose.

f. Each UV unit shall be equipped with an alarm notification and shutdown in the event of:

- High temperature in the reactor, lamp, ballast or transformer;
- High flow rates that causes the dose to fall below design specifications;
- Low UV dose;
- Low UV intensity;
- Low UVT that causes dose to fall below design specifications;
- UV has shutdown; or
- Any other emergency situation.

Note: NSF 55, Class A units are acceptable for small systems with flow less than 25 lgpm (30 USgpm).

g. In the case of a power outage or power quality problems, which cause one or more of the UV units to become inoperable, contingencies shall be in place that prevent inadequately disinfected water from being distributed, including during the lamp warm-up time.

h. The UV disinfection unit shall be equipped with UV sensors reading calibrated UV intensity. The UV sensors shall be calibrated on a monthly basis. Off-line reference sensors used for calibration shall be of equal quality to the on-line sensors and shall be calibrated annually.

i. UVT analyzers shall be calibrated weekly.

j. UV equipment replacement components shall be equal to or better than components used during validation.

k. The UV lamp shall be monitored in a manner that ensures bulb replacement is accomplished prior to the maximum lamp life expectancy.

l. In the case of UV bulb breakage during operation, provisions shall be in place to contain the broken lamp, and contingencies shall be in place that prevent inadequately disinfected water from being distributed.

G.1.2 Minimum Dose and Performance Requirements

a. UV systems shall be certified to provide a minimum dose of 40 mJ/cm^2 or a Department-accepted alternate dose at all points within the reactor at all times when water is passing through the treatment process. Acceptable certification includes:
    - US EPA UVDGM;
    - German guideline DVGW W294;
    - Austrian standard ONORM M 5873; and
    - NSF Standard 55 Class A (for small systems with flow less than 25 Igpm (30 USgpm))

b. The Approval Holder shall provide to the Department an independent third-party validation that demonstrates the manufacturer's system will meet the 40 mJ/cm^2 or Department accepted alternate dose. The UV dose shall be sufficient to ensure log inactivation requirements.

c. If the UV dose is inadequate to achieve the required virus reduction, UV shall be followed by another disinfectant such as chlorine with the appropriate CT to achieve log inactivation requirements for viruses.

d. UV shall always be followed by a secondary disinfectant such as chlorine to maintain a residual in the water distribution system.

e. The quality of the raw water entering the UV system shall meet the manufacturer's requirements or pre-treatment shall be installed to ensure the quality of the raw water entering the UV system meets the manufacturer's requirements.

f. If the UV manufacturer has not specified water quality requirements, the following are recommended:
    - Turbidity: <1.0 NTU;
    - Hardness: <120 mg/L;
    - Iron: <0.3 mg/L;
    - Manganese: <0.05 mg/L;
    - Hydrogen sulfide: not detectable;
    - Total suspended solids: <10 mg/L;
    - pH: 6.5-9.5;
    - Total coliforms: <1000/100mL; and
    - UVT: >75%

G.1.3 UV Transmittance (UVT)

a. UVT is an important water quality parameter for determining the efficacy of the UV unit. UVT is a measure of the UV light at 254 nm that transmits through the water column in the UV chamber. UVT is described by the following equation.

$$UVT = 100 \times 10^{-A254}$$

b. Knowledge of the UV254 absorbance/transmittance of the water to be treated is critical when designing for good performance of UV systems.

c. Design of UV systems should ideally be based on the worst-case water transmittance of at least 12 months of UVT data for each facility (e.g. using the 5th percentile of monthly, bimonthly or weekly samples) (Bolton and Cotton, 2008).

d. UV units should be installed with UV sensors so that %UVT is calculated at a minimum daily. Alarms should be installed and configured in such a manner that alarms sound when UVT is below the manufacturer's specifications.

G.1.4 Scaling and Fouling

a. Scaling and fouling of the quartz sleeve can have a significant influence on disinfection efficacy. Over time, water quality parameters can form or deposit on the sleeve and interfere with the UV light penetrating the water column. Scaling and fouling results from the presence of metals, hardness, alkalinity, and particulate suspended in the water column.

b. Scaling and fouling can be controlled if proper maintenance of the UV unit has been performed. Frequency of cleaning will vary depending on the water quality characteristics. Maintenance of the quartz sleeve shall be performed based on the manufacturer's recommendations.

c. UV units shall have on-line mechanical sleeve cleaning devices or provision for physical-chemical cleaning.

G.2 On-site Generation of Sodium Hypochlorite

G.2.1 Salt Quality

The salt supplied shall be tested and certified as meeting the specifications of NSF 60. The salt shall contain no organic binders, flow control agents or resin cleaning material.

G.2.2 Equipment Quality

The electrolyzer and generator shall be certified as meeting the specifications of NSF 61 for use in drinking water systems.

G.2.3 Redundancy

A minimum of two electrolyzers are required to provide redundancy. Where two units are provided, each shall be capable of meeting the maximum day demand flow. Where more than two disinfection units are provided, the maximum day flow shall be met with the largest unit out of service.

G.2.4 Other Requirements

Appropriate precautions shall be in place to handle hydrogen gas.

G.3 Membrane Treatment Technology Requirements

The use of membranes for water treatment is becoming more common, especially in Nova Scotia. The purpose of this appendix is to state the requirements that membrane water treatment plants shall be required to meet in Nova Scotia with regard to:

- The number of membrane treatment units (e.g., trains, skids, racks, stages, etc.)
- Challenge Testing
- Direct Integrity Testing
- Continuous Indirect Integrity Testing
- Turbidity
- Filter-to-waste

G.3.1 Number of Membrane Treatment Units

Case studies of existing membrane plants have shown that having additional capacity has been extremely beneficial to deal with unexpected fouling rates and the corresponding decrease in flux to compensate for the higher fouling rates (AWWARF, 2004). The EPA *Membrane Filtration Guidance Manual*, as amended from time to time states that standard operational unit processes such as backwashing, chemical cleaning, and integrity testing may be problematic if it becomes necessary to conduct these processes more frequently than was planned. The effect can be more pronounced for smaller systems with fewer membrane treatment units. As well, filter redundancy is an industry-wide practice that helps ensure that a safe and a consistent quality and quantity of water is provided.

G.3.2 Membrane Treatment Units Used for Pathogen Reduction Credits

a. A minimum of two membrane treatment units are required in parallel to provide redundancy regardless of the design capacity of the system.

b. Where only two units are provided, each shall be capable of meeting the maximum daily design flow at the approved flux rate.

c. Where more than two membrane treatment units are provided, the maximum daily design flow shall be met with the largest unit out of service at the approved flux rate.

d. Design parameters established by manufacturer shall not be exceeded.

G.3.3 Integrated Membrane Systems

An integrated membrane system is one that incorporates microfiltration/ ultrafiltration (MF/UF) for pathogen reduction credits followed by nanofiltration/reverse osmosis (NF/RO) for the reduction of organics to reduce the formation of disinfection by-products.

Membrane treatment units used for pathogen reduction credits shall meet the requirements outlined G.3.2. In addition, the Approval Holder shall provide documentation that there will be no operational scenarios where the NF/RO system for organics reduction will be operated without pre-treatment by the MF/UF system for pathogen reduction unless stipulated in the Approval to Operate.

Membrane treatment units used for the reduction of organics shall meet the following requirements:

a. 0 to 1,000 m^3/d - one or two membrane treatment units may be provided.

   Where only one membrane treatment unit is provided, the following requirements shall apply:

   - a shelf spare shall be provided for the following equipment: pressure pump, pressure meter, transducer, pressure switches, conductivity meter, fuses and any other unique electrical device.
   - the unit shall be sized to meet 100% of the maximum daily design flow at the approved flux rate.

   Where two membrane treatment units are provided:

   - each unit may be sized to meet a minimum of 50% of the maximum daily design flow at the approved flux rate.

b. 1,001 to 2,000 m^3/d - a minimum of two membrane treatment units shall be provided. Each unit may be sized to meet a minimum of 50% of the maximum daily design flow at the approved flux rate.

c. Greater than 2,000 m^3/d - a minimum of two membrane treatment units shall be provided. Where only two units are provided, each shall be capable of meeting the maximum daily design flow at the approved flux rate. Where more than two membrane treatment units are provided, the maximum daily design flow shall be met with the largest unit out of service at the approved flux rate.

Regardless of the capacity of the membrane units, the design parameters set by the manufacturer shall not be exceeded.

G.3.4 Challenge Testing

The objective of challenge testing is to demonstrate pathogen removal efficiency. It is intended to be a one-time, product-specific test to establish the maximum log reduction credit that the product is eligible to receive. Challenge testing involves seeding the feed water with an acceptable challenge particulate and measuring the log reduction in the concentration of the challenge particulate between the feed and filtrate. Testing shall be conducted on a full-scale membrane module or small-scale module that is identical in material and similar in construction as that used at the treatment facility.

The actual removal efficiency of a membrane shall be verified by third party challenge testing. This is a one-time product specific test and is not site-specific. Acceptable challenge testing shall follow that provided in the EPA *Membrane Filtration Guidance Manual*, as amended from time to time, or an acceptable equivalent. This documentation shall be provided to the Department upon request.

G.3.5 Direct Integrity Testing

The purpose of direct integrity testing is to verify the removal efficiency of a membrane filtration system on an ongoing basis during operation. This will verify that the membrane has no integrity breaches of a magnitude that would compromise the ability of the membrane to achieve the pathogen reduction required. Direct integrity testing is a physical test applied directly to the pathogen barrier associated with a membrane treatment unit (e.g. an individual train, skid, rack, stage, etc.) in order to identify and isolate integrity breaches.

Direct integrity testing is commonly accomplished using pressure-based tests or marker-based tests. As new types of direct integrity tests are developed in the future, they may be used provided the basic requirements for test resolution, sensitivity, and frequency can be satisfied.

G.3.6 Membrane Treatment Units Used for Pathogen Reduction Credits

The integrity of the membrane system and the actual removal efficiency of the membrane shall be demonstrated by direct integrity testing of the membrane under normal operating conditions. Direct integrity testing shall follow that outlined in the EPA *Membrane Filtration Guidance Manual*, as amended from time to time, or an acceptable equivalent.

Direct integrity testing shall be responsive to an integrity breach in the order of three micrometres or less.

Direct integrity testing shall be conducted on each membrane treatment unit at a frequency of no less than once each day that the unit is in operation. Less frequent testing may be approved if supported by demonstrated process reliability, the use of multiple barriers effective for cysts (*Giardia*), oocysts (*Cryptosporidium*) or viruses or reliable process safeguards.

G.3.7 Continuous Indirect Integrity Testing

The objective of continuous indirect integrity monitoring is to monitor a membrane filtrate system for significant integrity problems between direct integrity test applications. Indirect methods do not assess the integrity of the membrane barrier directly, but instead utilize water quality parameters as a surrogate to infer information about membrane integrity based on the levels of the monitored parameters relative to the known baseline in a fully integral system. Although indirect integrity monitoring is generally not as sensitive for detecting integrity breaches as the various direct methods, the indirect methods do have the advantage of being able to be applied to continuously monitor membrane filtrate quality during production, thus providing some means of assessing integrity between direct integrity test applications.

In addition to continuous turbidity monitoring, other methods of indirect testing include particle counting, particle monitoring, conductivity monitoring (for NF/RO systems), or others as deemed acceptable by the Department.

G.3.8 Membrane Treatment Units Used for Pathogen Reduction Credits

All membranes shall have continuous indirect integrity testing. Indirect integrity testing shall follow that outlined in the EPA *Membrane Filtration Guidance Manual*, as amended from time to time, or an acceptable equivalent.

Continuous indirect integrity testing shall be conducted at a minimum frequency of once every 5 minutes.

G.3.9 Integrated Membrane Systems

Membrane treatment units used for pathogen reduction credits - shall meet the requirements outlined in G.3.2 above.

Membrane treatment units used for the reduction of organics – the Approval Holder shall have a means of verifying the rejection rate and rectifying any performance issues.

G.3.10 Turbidity

The treated water turbidity levels from individual membrane units shall be based on continuous measurements of turbidity, using an on-line turbidimeter, with results recorded at a minimum frequency of once every five minutes.

If turbidity exceeds 0.1 NTU for more than 15 minutes, direct integrity testing shall be immediately conducted on the membrane treatment unit. If the unit passes direct integrity testing, it may continue to be used for water treatment; if not, the unit shall be taken out of service.

G.3.11 Filter-to-waste

A “filter-to-waste” feature shall be provided for:

- Initial start-up and commissioning of the membrane system;
- Those systems that have to be tested on-line during production in the event of a membrane integrity breach; and
- Emergency diversion of water.

The filter-to-waste feature for membranes is to provide operational flexibility and therefore shall not have any filter ripening conditions associated with it in an Approval to Operate.

G.4 Management of Waste Streams

Waste streams that are generated from backwash and cleaning cycles shall be managed properly. The use of membrane technology produces the following waste streams:

- Filter backwash wastewater;
- Filter backwash solids;
- Clean-in-place chemical waste;
- Chemically enhanced backwash (CEB) wastewater and solids.

The Approval Holder should provide an estimate of the waste stream composition and concentrations. It should be noted that membrane treatment processes may concentrate naturally-occurring compounds such as metals, solids and radionuclides in the waste streams.

G.4.1 Filter Backwash Water

The Approval Holder shall manage filter backwash water in accordance with Part V, Section 2.

G.4.2 Filter Backwash Solids

The Approval Holder shall manage filter backwash solids in accordance with Part V, Section 1.

G.4.3 Clean-in-place (CIP) Chemical Waste

Membranes require periodic chemical cleaning, which involves re-circulating cleaning chemicals and scouring the membrane surface, to reduce fouling. CIP chemical wastes shall be disposed in a manner that is acceptable to the Department. Neutralization of

cleaning solutions shall be provided including dechlorination such that the chlorine residual concentration shall not exceed 0.02 mg/l and adjustment of pH such that the pH is within a range of 6.5 to 9.0 (unless background values are outside this range in which case pH shall be within 0.2 of background). The CIP chemical waste stream may be neutralized in the process tank where CIP has taken place or transferred to a holding tank until neutralization has occurred.

G.4.4 Chemically Enhanced Backwash (CEB) Wastewater and Solids

Membranes may require periodic enhanced backwash, which involves injecting chlorine, caustic, or acid during a filter backwash cycle to improve, and lengthen cycles before CIP is required. CEB wastewater shall meet the requirements outlined in G.4.1 and G.4.3. CEB solids shall meet the requirements outlined in G.4.2.