

ENCLOSURE A

**Indirect Potable Reuse
and
Direct Potable Reuse**

ENCLOSURE A:
Indirect Potable Reuse and Direct Potable Reuse

The TCEQ is required by the Texas Health and Safety Code (THSC) §341.0315 to protect the public's health, safety and welfare by ensuring that public water systems provide a safe supply of water in adequate quantities. Pursuant to this requirement, the following are DRAFT guidelines and concerns for review of submitted indirect potable reuse (IPR) and direct potable reuse (DPR) projects. These DRAFT guidelines are subject to change as new information becomes available.

- Proposed projects for use of wastewater treatment plant (WWTP) effluents as sources of water for public water systems will be reviewed on a case-by-case basis.
- The TCEQ's rules reference the American Water Works Association's (AWWA) The Drinking Water Dictionary for definitions not contained in Title 30 of the *Texas Administrative Code* (30 TAC) Chapter 290, Subchapters D and F. The 2000 version of The Drinking Water Dictionary does not contain a definition for DPR. The following are guidelines to be used to determine if a submitted project is IPR or DPR until the TCEQ defines these two terms in rule. Please be aware that these guidances are subject to change and may encompass all proposed reuse projects.
 - An IPR project involves the augmentation of a drinking water source (surface or groundwater) with WWTP effluent that has been subject to constructed physical and/or chemical treatment in addition to blending with a natural water source. The treated WWTP effluent must be adequately mixed, diluted, and receive natural biological and/or filtration treatment (environmental buffer/barrier) to reduce harmful, and/or potentially harmful, pathogens and/or chemicals prior to conventional drinking water treatment.
 - A DPR project is when a WWTP effluent receives further constructed physical and/or chemical treatment for the removal of harmful, and/or potentially harmful, pathogens and/or chemicals prior to being distributed for human consumption. The treated WWTP effluent may be mixed with a raw surface or groundwater source at some point during the constructed physical and chemical treatment processes, but this process only achieves dilution and does not provide a measurable or verifiable reduction in harmful, and/or potentially harmful, pathogens and/or chemicals by natural biological and/or filtration treatment processes prior to being distributed for human consumption.
 - A referenced environmental buffer will need to be evaluated to determine if it is actually providing a natural biological and/or filtration treatment barrier for reduction of pathogens and/or chemicals and the log removal achieved.
- Some water professionals believe that sufficient physical and/or chemical treatment barriers can be constructed for the removal/reduction of microbiological and chemical contaminants (both regulated and unregulated chemicals of emerging concern) with sufficient monitoring and automatic DPR plant shutdown to ensure the protection of public health without the need for an environmental buffer.
- Multiple constructed physical and chemical treatment barriers (removal and/or inactivation) will be required for a WWTP's effluent prior to being discharged to a public water system's distribution system for human consumption. One set of minimum removal and inactivation barriers can include those achieved by an existing surface water treatment plant (SWTP) operating in accordance with federal and state requirements. The TCEQ will not include the removal and inactivation achieved in a WWTP. Each set of multiple barriers for a DPR project must include:
 - Two separate and redundant sets of treatment barriers (including removal and/or

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inactivation) in series with a minimum total virus removal and inactivation of 8.0-log. One set of treatment barriers must include a sum of treatment methods (operated in series) to achieve a minimum 4.0-log removal and/or inactivation of viruses. A second set of treatment barriers must also include sufficient treatment methods to achieve a second minimum 4.0-log removal and/or inactivation of viruses.

- Two separate and redundant sets of barriers (including removal and/or inactivation) in series with a minimum total *Giardia* removal and inactivation of 6.0-log. One set of treatment barriers must include a sum of treatment methods operated in series to achieve a minimum 3.0-log removal and/or inactivation of *Giardia*. A second set of treatment barriers must also include sufficient treatment methods to achieve a minimum 3.0-log removal and/or inactivation of *Giardia*.
- Additional treatment may be required based on the results of future virus and *Giardia* monitoring of the WWTP's effluent.
- For *Cryptosporidium* treatment:
 - If a public water system does not have historical *Cryptosporidium* monitoring results for a WWTP's effluent or an insufficient number of sample results to be representative of the effluent, a minimum of two or more removal and inactivation barriers in series will be required that achieve at least 5.5-log total removal and inactivation of *Cryptosporidium* for the WWTP's effluent prior to distribution for human consumption. Based on the sample set size, a reduction in this total 5.5-log removal and inactivation may be considered on a case-by-case basis.
 - If a public water system has at least one year of *Cryptosporidium* monitoring results for a WWTP's effluent, the minimum required *Cryptosporidium* treatment may be based on 30 TAC §290.111(c)(3)(B).
 - Additional treatment may be required based on future *Cryptosporidium* monitoring of the WWTP's effluent.
- The construction of physical removal and chemical treatment barriers for IPR projects will be on a case-by-case basis. Public Water Systems that propose IPR projects will need to coordinate with TCEQ staff outside of the Water Supply Division in order to procure the necessary permits/approvals for aquifer storage and recovery (ASR) and discharges to surface waters of the State.
- Besides the public health risks associated with regulated chemical contaminants, the TCEQ is aware there could be a potential for public health risks from some unregulated contaminants of emerging concern found in wastewater effluent. Some of these unregulated contaminants of emerging concern are under review by the U.S. Environmental Protection Agency (EPA) and other organizations. While aquatic health effects may have been established for some of these chemicals, the human health effects and corresponding concentration levels that have an impact on human health are still under investigation.
- Data indicates that properly designed and operated tertiary WWTPs can remove some of the regulated (primary and secondary drinking water standards) and unregulated chemicals. However, regardless of the chemical quality of a specific WWTP's effluent, other states and countries and engineers are currently recommending/requiring both reverse osmosis (RO) membranes and advanced oxidation processes (AOP) as chemical removal and inactivation barriers at IPR plants. AOP is the use of ultraviolet light with hydrogen peroxide, ozone or another acceptable oxidant as barriers for IPR plants. This is based on what chemicals have

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historically been detected in wastewater or could enter the wastewater collection system from industrial facilities.

- RO membranes alone have not been considered a sufficient barrier to all chemical contaminants because while they are very effective at removing salts and larger molecular weight chemicals, RO membrane removal efficiencies for smaller molecular weight chemicals can be quite low. The AOP is used to breakdown these smaller molecular weight chemicals so that they may no longer pose a potential or actual human health treat. This combined treatment process also can provide a second chemical treatment barrier for some chemicals against upsets in a WWTP's treatment processes.
- Information from individuals involved in design, operation and approval of IPR plants indicate that high salt rejection rate (99.5%, or greater) RO membranes must be specified. RO membranes with lower salt rejections are also less effective at removing chemicals that pose a potential or actual human health threat.
- Membrane filtration systems for public water systems installed after April 1, 2012 and used for a microbiological barrier must have undergone challenge testing, a TCEQ review of the challenge test report, and the TCEQ issuance of a challenge test Log Removal Value (LRV_{C-test}).
- Compliance with disinfection-by-product (DBP) requirements has become more difficult and WWTP effluent is known to contain elevated levels of DBP precursors. The potential for noncompliance with these regulated chemicals needs to be evaluated for each WWTP.

ENCLOSURE B:

**Chemical
and
Microbiological Data**

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Background Related to Monitoring Wastewater Effluent Intended for use as Drinking Water

As water resources are diminished by drought, Texas communities may seek approval to reuse (reclaim) wastewater to produce drinking water. Wastewater is subject to contamination from microbes and chemicals; many of these contaminants have been identified, but some are not yet regulated.

List of Chemicals to Sample in Wastewater Effluent proposed as Drinking Water Source

The Texas rules require that any entity proposing to use a new source of water must identify the quality of that source water. Wastewater effluent is by definition fecally impacted, and is subject to the presence of chemicals of human origin. Therefore, it is critical that the quality of wastewater effluent be characterized before use as a drinking water source.

Texas adopts specific rules under 30 TAC 210 for reclaimed water quality. However, the 30 TAC 210 standards do not address all of the chemical and microbial constituents of concern in drinking water. Drinking water rules are based on removal of constituents at levels found in ambient water, which is of higher quality than wastewater effluent.

The list presented here is for planning purposes only and is subject to change. A public water system may wish to sample additional constituents that are not listed here. Additionally, when a public water system (PWS) requests that they be granted permission to use wastewater effluent as a drinking water source, the TCEQ may require additional, site-specific testing.

Frequency

Although a single 'snapshot' view of water quality may be considered sufficient by a PWS's design engineer, that snapshot must be viewed as a non-statistically representative sample.

Seasonal variation

The TCEQ recommends that wastewater intended for use as a drinking water source be characterized over a period of time that includes seasonal variation. Without seasonal data, changes in quality cannot be scientifically factored into treatment plant design. Indoor use of drinking water increases in the summer, suggesting that the contaminant levels in summer may be less than those in the winter. PWSs often use different initial sources of raw water on a seasonal basis, so that the baseline water quality characteristics can change seasonally. A system may use surface water as their initial source, but also use well water during the high-demand summer periods.

Locations

The wastewater effluent that is intended as a new source of drinking water should be characterized. It is recommended that any water streams intended for blending with the wastewater be characterized as well. Likewise, any raw water used for treatment as

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surface water should be sampled. Treated water should be analyzed in accordance with the site-specific requirements applied by the TCEQ.

Sampling at various stages in the process allows a PWS to demonstrate the source of any pathogens or chemical contaminants. A map showing the sampling locations, and a list describing the sample location(s) should be provided to the TCEQ when the sampling regime is proposed.

Lists of Recommended Analyses

The constituents of concern in wastewater effluent can be broadly grouped as microbes or chemicals and other constituents such as hardness and pH. Although the lists of recommended analytes are not exhaustive, they provide a starting place for planning. The EPA's Unregulated Contaminant Monitoring Regulation 3 (UCMR3) will apply to systems that serve 100,000 or more people. Constituents identified for monitoring under UCMR3 are included in the recommended monitoring for wastewater effluent.

List of Microorganisms Recommended for Sampling in Wastewater Effluent Proposed for use as a Drinking Water Source

MICROBIALS	Method¹	Regulated?
Viruses²		
*Endovirus	1615	UCMR3 ³
*Norovirus		
Rotavirus	1	No ²
Poliovirus	1	No ²
Echoviruses	1	No ²
Coxsackieviruses group A and B	1	No ²
Adenovirus	1	No ²
Hepatitis A	1	No ²
Protozoans		
* <i>Cryptosporidium</i>	1623	Yes
* <i>Giardia</i>		
<i>Naegleria fowleri</i>	5	No
<i>Cyclospora</i>	5	No
Microsporidia (fungus)	5	No
Bacteria		
*Total coliform (indicator)	1604 ⁴	Yes ³
* <i>Escherichia coli</i> (<i>E. coli</i>) (indicator)	1604 ⁴	Yes ³
Enterococci	1600, 1106	No
Salmonella (and / or Shigella, Campylobacter, Pseudomonas ⁵)	1200	No
Aeromonas	1605	No
Heterotrophic plate count (indicator)	9215	No

* Highly recommended for sampling

1 Method listed is an EPA method unless otherwise noted. List of methods is not exhaustive, but is included for reference only.

2 Viruses are regulated as a group through treatment technique requirements of the EPA's Surface Water Treatment Rules and Ground Water Rule

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- 3 Regulations cover distribution levels and removal requirements.
- 4 Several approved methods exist. A PWS should propose one of these approved methods for analysis.
- 5 Methods are in development. A PWS should propose the method they plan to use.

List of Chemicals and Other Constituents Recommended for Sampling in Wastewater Effluent Proposed for use as a Drinking Water Source

CHEMICALS	Method ¹	Regulated
Disinfection byproducts		
*Trihalomethanes	524	Yes ²
*Haloacetic acids (also report bromochloroacetic acid (BCAA))	552	Yes ² (BCAA is not regulated)
*Nitroso-dimethylamine (NDMA)	521	UCMR3 ³
*Nitroso-pyrrolidine (NPYR)		
Any other DBPs expected to occur on a site-specific basis, for example chlorite, if chlorine dioxide is used.		
Organic chemicals		
*SOC (Regulated (and tentatively identified unregulated) synthetic organic chemicals): Alachlor, atrazine, benzo(a)pyrene, di(ethylhexyl)-adipate, di(ethylhexyl)-phthalate, endrin, heptachlor, heptachlor epoxide, hexachlorobenzene (HCB), Hexachlorocyclopentadiene, lindane, methoxychlor, pentachlorophenol (PCP), simazine.	525.2	Yes
*SOC (Regulated (and tentatively identified unregulated) synthetic organic chemicals): 2, 4, 5-TP (Silvex), 2,4-D, Dalapon, Dinoseb, pentachlorophenol, picloram	515.4	Yes
* SOC Chlordane, toxaphene (and unregulated aroclor species)	531.1	Yes
*EDP/DBCP (ethylene dibromide & 1,2-dichloro-3-propane)	504.1	Yes
*carbofuran, oxamyl (Vydate)	531.1	Yes
*Glyphosate	547	Yes
*2,3,7,8-TCDD (Dioxin)	1613	Yes
Diquat	549.2	Yes
Endothall	548.1	Yes
*VOC (Regulated (and tentatively identified unregulated) volatile organic chemicals): 1,1,1,2-Tetrachloroethane, 1,1,2,2-Tetrachloroethane, 1,1-Dichloroethylene, 1,2-dichloroethane, 1,2-dichloropropane, 1,2,4-trichlorobenzene, benzene, carbon tetrachloride, cis-1,2-dichloroethylene, dichloromethane, ethylbenzene, monochlorobenzene, o-dichlorobenzene, para-dichlorobenzene, styrene, tetrachloroethylene, toluene, trans-1,2-dichloroethylene, trichloroethylene, vinyl chloride, xylenes	524.2	Yes
* Pharmaceutical indicators: 17- α -ethynylestradiol (ethinyl estradiol), 16- α -hydroxyestradiol (estriol), equilin, estrone, testosterone, 4-androstene-3,17-dione	537	UCMR3
* Chemicals of human origin: Perfluorooctanesulfonic sulfonate (PFOS), perfluorooctanoic acid (PFOA) perfluorononanoic acid (PFNA) perfluorohexanesulfonic	537	UCMR3

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CHEMICALS	Method ¹	Regulated
acid (PFHxS) perfluoroheptanoic acid (PFHpA) perfluorobutanesulfonic acid (PFBS)		
*Sucralose	4	No
1,4 dioxane	522	No
Caffeine	1694	No
N,N-Diethyl-meta-toluamide (DEET)	633	No
Gemfibrozil	1694	No
Iopromide	1694	No
Inorganic chemicals		
*Nitrate/nitrate, as nitrogen	300.0	Yes
*Other regulated minerals: fluoride, chloride, sulfate, total dissolved solids (TDS)		
*Regulated primary metals: Antimony, arsenic, barium, beryllium, cadmium, chromium, mercury, selenium, thallium	200.5	Yes
*Regulated secondary metals: Aluminum, copper, iron, manganese, silver, zinc		
Asbestos (if asbestos/cement pipe is used in drinking water distribution, wastewater collection, or associated piping)	100.2	Yes
Cyanide	335.4	Yes
Sodium	200.7	Yes ²
Perchlorate	314	UCMR2
Other water quality parameters		
*pH		
*Temperature		
Bicarbonate and carbonate alkalinity		
Total hardness		
Total suspended solids		
Total chlorine, free chlorine, monochloramine		
Ammonia		

* Highly recommended for sampling.

1 Method listed is an EPA method unless otherwise noted. List of methods is not exhaustive, but is included for reference only.

2 Regulated in distribution systems.

3 Regulatory monitoring requirements, not health-based standards.

4 Acceptable methods exist but have not yet been approved by the EPA.

It is generally understood that the cost of analysis may be a concern to a PWS. A system should consider this cost in planning. Based on industry experience, the cost of sampling prior to design is offset by the ability to design treatment based on actual levels of contaminants. If the raw wastewater is not fully characterized, regulators may require additional safety factors which may result in additional treatment needs with their associated additional costs.

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It is acceptable if a system wishes to propose a shorter list of analytes for consideration during the source approval request process; but it is highly recommended that the 'starred' analytes in the list above be included in analyses. The intent of the sampling is to establish what viral, bacterial, protozoan, and chemical contaminants are present in order to protect public health; an acceptable sampling regime will ensure that characterization is accomplished.

In general, analyses should be performed at NELAC-accredited laboratories using EPA-approved methods. Where those labs or methods are unavailable, a PWS should identify a capable lab and request permission for its use. Methods listed in these tables are recommendations; other approved EPA-methods exist, and may be proposed for use.

The analytes of greatest concern are those with documented, immediate negative health effects ("acute" health effects), such as pathogens and nitrate/nitrite. It may be acceptable for a system to perform sampling for constituents that have long-term health effects, like regulated organics, less frequently than sampling for pathogens or nitrate/nitrite.

Depending on the treatment method selected by the PWS, it may be necessary for a PWS to perform additional sampling to characterize the impact on treatment. For example, selenium interferes with adsorption under some conditions; if adsorption is used for treatment, additional selenium sampling may be required.

Results

Results should be tabulated in a clear, easy-to-read manner for submittal; analytical detail such as the quality assurance documentation should also be submitted. The summary tables should be organized with sample sites in order of extent of treatment; for sampling over a period of time, analyses should be presented in the order that the samples were collected. The summary tables should contain the units of measurement.

Notes Related to Sampling for Chemicals of Emerging Concern

Simultaneously, the drinking water industry and EPA are becoming concerned about contaminants of emerging concern (CEC). Many of the CEC are of human origin, especially pharmaceuticals and personal care products.

Public concern regarding these CECs is very high, and the EPA is researching their presence through the Contaminant Candidate List and Unregulated Contaminant Monitoring Regulation (UCMR) process. As of 2012, the EPA has not determined or set health-based maximum contaminant levels (MCLs) for these potentially harmful microbes and chemicals. Additional research into ambient levels of CEC chemicals is ongoing. Therefore, levels identified in wastewater intended for use as drinking water will be compared to levels present in ambient water in order to determine the relative risk of wastewater effluent as contrasted with ambient (river or lake) waters. If the EPA sets MCLs, further characterization may be necessary (see References).

Analytical methods do not yet exist for some of these CEC chemicals. The best current (May 4, 2012) methods for CEC chemicals are captured in the EPA's Unregulated Contaminant Monitoring Regulations (UCMRs), 1 through 3.

Although the UCMR contaminants are not required by EPA to be sampled in all direct and indirect reuse sources, the list provides a well-researched source of information for chemicals that EPA is most likely to regulate in the future, and that are most likely to have negative health effects.

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Additionally, as interest in chemicals of emerging concern grows, researchers have identified chemicals that can indicate the presence of anthropogenic contamination, but that are not harmful to human health.

Pharmaceutical indicators

The UCMR3 list includes estrogenic hormones used in pharmaceuticals. It is recommended that reuse sources be evaluated for these chemicals using analytical method 537.

Personal care product indicator

The UCMR3 list includes 1,4 dioxane, which is used in personal care products such as soaps and makeup. It is recommended that reuse sources be evaluated for 1,4 dioxane using method EPA 522.

Chemicals of human origin

New research has identified sucralose as an excellent, conservative, easy-to-measure indicator that water contains chemicals of human origin. Sucralose is not biologically degraded, so it passes through wastewater biological treatment plants unchanged. Sucralose should be quantified in reuse sources.

Additionally, EPA identified six perfluorinated compounds that may indicate contamination from human industrial activities. These compounds (perfluorooctanesulfonic sulfonate (PFOS), perfluorooctanoic acid (PFOA), perfluorononanoic acid (PFNA), perfluorohexanesulfonic acid (PFHxS), perfluoroheptanoic acid (PFHpA), and perfluorobutanesulfonic acid (PFBS)) should be quantified using method EPA 537 (1.1).

Disinfection byproducts of emerging concern

Wastewater sources are frequently chlorinated during the wastewater treatment process. Regulated disinfection byproducts (trihalomethanes and haloacetic acids) are known to frequently occur at levels of concern in wastewater. Additionally, the EPA has identified the presence of other potentially carcinogenic disinfection byproducts called nitrosamines. It is recommended that the two most-frequently occurring nitrosamines (nitroso-dimethylamine (NDMA) and Nitroso-pyrrolidine (NPYR)) be quantified using method EPA 521.

References

_____, "Guidelines for Water Reuse," (EPA/625/R-04/108); U.S. Environmental Protection Agency, Municipal Support Division, Office of Wastewater Management, Office of Water; September 2004; available at: <http://www.epa.gov/nrmrl/wswrd/dw/smallsystems/pubs/625r04108.pdf>

_____, "Revisions to the Unregulated Contaminant Monitoring Regulation (UCMR 3) for Public Water Systems," (77 FR 26072); U.S. Environmental Protection Agency; May 5 2012

ENCLOSURE C:

***Cryptosporidium* Monitoring**

ENCLOSURE C: **Cryptosporidium Monitoring**

Please provide *Cryptosporidium* results from the City's raw water source monitoring for Lake Kickapoo and Lake Arrowhead in a comparison table. Additionally, please provide the following data so that the TCEQ may complete our review of the City's proposed reuse of wastewater for human consumption:

- All of the analytical results for *Cryptosporidium* that the City has for Lake Kickapoo and Lake Arrowhead raw water sources analyzed since October 1, 2006, in a comparison table with all of the *Cryptosporidium* results for the River Road Wastewater Treatment Plant (RRWWTP) effluent.
- All turbidity and *E. coli* (as required in conjunction with *Cryptosporidium* sampling) monitoring results for Lake Kickapoo and Lake Arrowhead raw water sources and any turbidity and *E. coli* results for the RRWWTP's effluent analyzed since October 1, 2006, in a comparison table.
- Include all analytical results for *Giardia* and viruses the City has results for during the same time frame for the Lake Kickapoo and Lake Arrowhead raw water sources and RRWWTP's effluent data.
- Include copies of the laboratory's analytical sheets and Quality Assurance and Quality Control (QA/QC) for all of the above results.

Your letter stated that the preliminary data indicates that the RRWWTP effluent would have a Bin 2 Classification. Individual sample results for the three months consisted of three non-detects, one Bin 1 Classification, three Bin 2 Classifications and one Bin 3 Classification. Please see the following TCEQ responses:

- Using a 0-value for the three non-detect results; the three-month, eight-sample set had an average of 0.296 oocysts/liter.
- The average of the submitted *Cryptosporidium* monitoring sample set falls within the Bin 2 Classification in 30 TAC §290.111(c)(3)(B) and would require a 4.0-log removal and/or inactivation of *Cryptosporidium*.
- The three months of samples do not represent the possible variances that can occur in the RRWWTP's effluent quality over a year.
- Without the additional *Cryptosporidium* data and at least one year of *Cryptosporidium* monitoring results for the RRWWTP's effluent, the TCEQ staff cannot determine the Bin Classification of the RRWWTP's effluent. **At this time, the TCEQ must assume a worst-case condition to protect public health and require a total of 5.5-log removal/inactivation of *Cryptosporidium***, in accordance with 30 TAC §290.111(c)(4) Please note that less treatment may be required based on review of additional source water monitoring results in the future.

ENCLOSURE D:

**Requested Membrane Specific
Sensitivity and Resolution
Pilot Study Data**

ENCLOSURE D:
Requested Membrane Specific Sensitivity and Resolution Pilot Study Data

The pilot study reports submitted with your May 7, 2012 letter did not include the detailed information and calculations requested in the TCEQ's December 1, 2009 letter for each HF membrane vendor's test pressure (P_{test}) values and for all equations used in reporting each direct integrity test's log removal value (LRV_{DIT}) during the pilot studies. Each system granted an exception to use HF membrane for the removal of *Giardia* and *Cryptosporidium* must submit this information for TCEQ review and approval with their pilot study reports. The TCEQ will only accept the equations and methods set forth in the EPA Membrane Filtration Guidance Manual – EPA 815-R-06-009, November 2005 (EPA MFGM), unless prior TCEQ approval has been received for an equation or value as noted in Enclosure 5: TCEQ Approved Membrane Specific Values.

1. Please provide detailed calculations and supporting documentation showing how Siemens', Pall's and GE Zenon's reported minimum test pressures (P_{test}) meet the required direct integrity test (DIT) **resolution** to detect a 3.0 micron defect or larger. The P_{test} calculation must include the back pressure (BP_{max}) on the system during the test. Use EPA Equation 4.1 to support each calculation.

Equation 4.1 (for a 3.0 micron defect): $P_{test} = (0.193 \times \kappa \times \sigma \times \cos \theta) + BP_{max}$

- a. Since the surface tension (σ) changes with temperature, submit the P_{test} for each direct integrity test (DIT) using either a σ value that corresponds to the actual water temperature at the time of the DIT or a worse case σ value of 74.9 dynes/cm.
 - b. Use a pore shape factor (κ) value of "1.0" unless the TCEQ has approved another value.
 - c. Use a liquid contact angle (θ) value of "0" unless the TCEQ has approved another value.
 - d. Based on a minimum stack height of 81 inches for three GE Zenon modules, a minimum BP_{max} value should be greater than 2.9 pounds per square inches (psi) based on the actual water head to the bottom of the submerged membrane stack during a DIT.
 - e. Based on a fiber length 47 inches for the Siemens modules, the minimum BP_{max} value should be greater than 1.7 psi based on the actual water head to the bottom of the submerged membrane modules during a DIT.
 - f. Based on a fiber length of approximately 6.5 feet for the Pall membrane module, the minimum BP_{max} value would be 2.8 psi based on the actual water head to the bottom of the membrane module during a DIT.
2. Using EPA Equation B.7 provide the minimum defect that could be detected for each P_{test} value used during the pilot study. Include the κ , σ and θ values used.

Equation B.7: $d_{feet} = (0.58 \times \kappa \times \sigma \times \cos \theta) \div P_{test}$

3. Provide the necessary data and detailed calculations using EPA MFGM's Sections 4.3.1.1 and 4.3.1.2 (specifically, Equations 4.3 or 4.9) to verify that the **sensitivity** of all of the DITs conducted during the pilot study were adequate to verify the proposed *Cryptosporidium* log removal credit (**LRC**) for each membrane piloted. Using EPA equations only, include the calculated log removal value for each DIT (LRV_{DIT}) conducted during the pilot study.

Equation 4.3: $LRV_{DIT} = \log [(Q_p) \div (VCF \times Q_{breach})]$

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Requested Membrane Specific Sensitivity and Resolution Pilot Study Data

Equation 4.9: $LRV_{DIT} = \log [(Q_p \times ALCR \times P_{atm}) \div (\Delta P_{test} \times V_{sys} \times VCF)]$

Where:

- a. V_{sys} is the volume of pressurized air in each HF membrane unit during each DIT;
 - b. VCF is the applicable TCEQ approved volumetric concentration factor for the site design and operation;
 - c. BP_{max} is the backpressure on each HF membrane unit during a DIT;
 - d. $ALCR$ is the air-liquid conversion ratio;
 - e. Q_{air} is the flow of air through a critical breach during a pressure based DIT;
 - f. Q_{breach} is the flow of water through a critical breach at the designed and approved maximum filtration rate;
 - g. Q_p is the piloted filtrate flow rate;
 - h. P_{test} is the DIT test pressure for each HF membrane unit; and,
 - i. ΔP_{test} is the smallest rate of pressure decay that can be reliably measured and associated with a known breach during the DIT.
4. For the $ALCR$ values use one of the methods and equations in Appendix C of the EPA MFGM only. Provide each membrane vendor's specific values used in the EPA equation used.

Equation C.1: $ALCR = (Q_{air} \div Q_{breach})$

Equations C.4 and C.9:

$$ALCR = 170 \times Y \times \sqrt{\{[(P_{test} - BP) \times (P_{test} - P_{atm})] \div [460 + T] \times TMP\}}$$

Equation C.14: $ALCR = (527 \times \Delta P_{eff} \times \mu_w) \div [TMP \times \mu_{air} \times (460 + T)]$

Equation C.15:

$$ALCR = [527 \times \Delta P_{eff} \times (175 - 2.71 \times T + 0.0137 \times T^2)] \div [TMP \times (460 + T)]$$

Where:

- a. Q_{air} is the flow of air through a critical breach during a pressure based DIT;
- b. Q_{breach} is the flow of water through a critical breach at the designed and approved maximum filtration rate;
- c. Y is the net expansion factor for compressible flow through a pipe to a larger area;
- d. T is the historical **high** temperature over the last five years for the RRWWTP's effluent;
- e. TMP is the membrane vendor's maximum allowable operating transmembrane pressure;
- f. $\Delta P_{eff} = (P_{test} - BP) \times \{[(P_{test} + P_{atm}) + (BP + P_{atm})] \div [2 \times (BP + P_{atm})]\}$;
- g. P_{test} is the minimum test pressure for the resolution of a 3.0 micron defect;
- h. P_{atm} is the actual atmospheric pressure for the elevation at this site;
- i. EPA Equation C.15 is to be used only if the water temperatures are between 32 and 86 °F, otherwise use EPA Equation C.14;

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Requested Membrane Specific Sensitivity and Resolution Pilot Study Data

- j. The viscosity values for water (μ_{water}) and air (μ_{air}) are to be taken from CRC Handbook of tables for Applied Engineering Science, 2nd Edition. Our research has indicated that viscosity values at specified temperatures vary according to different scientific and engineering references. Since the EPA did not provide a reference, the TCEQ selected this source for consistency.
5. Using EPA Equation 4.17 and worse-case conditions, provide a single upper control limit (**UCL**) for each of the three piloted HF membranes at their requested log removal credit (**LRC**) and **Q_p** values.
- Equation C.17:
$$\text{UCL} = (\text{Q}_p \times \text{ALCR} \times \text{P}_{\text{atm}}) \div (10^{\text{LRC}} \times \text{V}_{\text{sys}} \times \text{VCF})$$
- Where:
- Q_p** is the filtrated flow rate based on a TCEQ filtrate flux rate adjusted to 20 °C; and
 - V_{sys}** is the volume of pressurized air in each HF membrane unit during each DIT.
6. It is noted that both Siemens and GE Zenon used **VCF** values of 1.0. Even if the submerged system is operated in deposition-mode, a submerged system that utilizes periodic backwash procedures potentially can re-suspend particles and increase the concentration of suspended material on the feed-side of the membrane. Consider the unique hydraulics of each of these submerged tank installations and the changes in the **VCF** between the backwash procedures and then validate the **VCF** for each submerged tank configuration.
7. Siemens reported **LRV_{max}** for the S10V UF membrane greater than 9.0. Please explain how these values were calculated.
8. Siemens' equation No. 4 in Appendix B of the submittal does not match the corresponding EPA Equation in Chapter 4 of the EPA MFGM. Please correct this in your revised Report.

ENCLOSURE E:

TCEQ Approved Membrane Specific Values

ENCLOSURE E: TCEQ Approved Membrane Specific Values

The TCEQ has approved the following membrane specific equations and values in lieu of those contained in the EPA MFGM. If TCEQ has not approved an alternative value, the worse case values must be used.

- Pall Microza® UNA-620A HF MF membrane
 - A temperature correction factor (TCF) equation of:
$$\text{TCF}_{20} = [(0.0004483 \times T^2 - 0.03946 \times T + 1.593) \div 0.9826]$$

Where:
 TCF_{20} is multiplied times the filtrate flux rate at T
T is the ambient water temperature.
 - A volumetric concentration factor (VCF) value of 1.0.
 - A liquid contact angle (θ) value of 0.0.
 - A pore shape value of (κ) value of 1.0.
- GE Zenon ZeeWeed® 1000 HF UF membrane with a CPX-0.80 fiber
 - Temperature adjustment of flux using EPA Equation 2.10:
$$J_{20} = J_T \times [1.784 - (0.0575 \times T) + (0.0011 \times T^2) - (10^{-5} T^3)]$$
 - The last document for GE Zenon ZeeWeed® 1000 V4. The fiber type was not specified, but based on the reported 550 sf of area; it is assumed this had the CPX-0.95 fiber. A VCF value of 1.1 was reported for this fiber in a test unit. We are not aware that we have received full-scale study data for the 1000 with the CPX-0.80 fiber. This data needs to be provided for us to complete our evaluation of the pilot study report.
 - A θ value of 50.3-degrees.
 - A κ value of 1.0.
- Siemens Memcor® HF UF 4S10V membrane
 - Temperature adjustment of flux using EPA Equation 2.10:
$$J_{20} = J_T \times [1.784 - (0.0575 \times T) + (0.0011 \times T^2) - (10^{-5} T^3)]$$
 - The TCEQ found the Siemens' VCF value study conducted at the Robert W. Sokoll Membrane SWTP, Texas to be incomplete for verifying a VCF value of 1.0. The TCEQ will require the results of another VCF study that includes additional monitoring locations, sample sites at different depths, within a full-scale submerged membrane tank. A plan and profile diagram showing the sample locations and influent piping/channel will be necessary. In addition, the TCEQ recommends that a more sensitive turbidity meter be used.
 - A θ value of 0.0-degrees.
 - A κ value of 1.0.

ENCLOSURE F:

Review of 2009 Pilot Study Reports

ENCLOSURE F: Review of 2009 Pilot Study Reports

Base on our review, the pilot study included the following operating parameters. Please review and provide any necessary corrections with the revised Report.

- The treated effluent from the RRWWTP as a feed water source.
- 5 – 8 mg/L doses of ferric sulfate as a coagulant with 5.8 minutes of mixing time.
- A Siemens Memcor® XS 4S10V test unit with:
 - Flow measuring device;
 - 500-micron pre-strainer;
 - Membrane tank;
 - Four vacuum Memcor® HF UF S10V membrane modules;
 - One meter fiber lengths with 300 square feet (sf) feed-side area per module for a total of 1200 sf;
 - Outside-in flow path;
 - A maximum transmembrane pressure (TMP) of 14.7 pounds per square-inch (psi);
 - A nominal pore size of 0.04 microns with a maximum pore size of 0.1 microns;
 - A pH operating range of 2 -10;
 - A temperature operating range of 110 °F;
 - Chlorine tolerance of 1000 milligrams per liter (mg/L);
 - A Q_{breach} value of $3.51E-11$ cubic feet per second (cfs);
 - A Stage 2 average flux rate of 31 gallons per square-foot per day (gfd) at an average temperature of 19.9 °C for a **flux rate of 30.88 gfd temperature adjusted to 20 °C** using the EPA MFGM temperature correction factor (TCF);
 - A backwash frequency of 22 minutes for a duration of 3.0 minutes using 0.25 minutes of aeration followed by reverse filtrate flow using 15.85 gallons of filtrate;
 - A maintenance clean once a day using a 300 parts per million (ppm) chlorine solution with a backwash procedure for 3.0 minutes, recirculation for 10.0 minutes at 3.0 gallons per minute (gpm) per module, a 20-minute soak and a final 3.0 minute backwash procedure for a total of 13.21 gallons of filtrate per 300 sf module;
 - A maintenance clean once every 72 hours using 0.1% hydrochloric acid solution with a 3.0-minute backwash, recirculation for 10.0 minutes at 3.0 gpm per 300 sf module, two 1.0-minute aeration and 9.0-minute soak cycles for 20 minutes and a final 3.0 minute backwash for a total of 13.21 gallons of filtrate per 300 sf module;
 - A chemical clean-in-place (CIP) procedure approximately once every 30 days with a 2% citric acid solution preheated to 38 °C recirculated for 30.0 minutes at 3.0 gpm per 300 sf module followed by nine (90 minutes) 1.0-minute aeration and 9.0-minute soak cycles, a 500 to 1000 ppm free chlorine solution preheated to 20 °C recirculated for 30.0 minutes at 3.0 gpm per 300 sf module followed by 90.0 minutes of soaking for a total of 26.42 gallons of filtrate used per 300 sf module; and,
 - Vacuum pump.
- A Pall Microza® UNA-620A HF MF test unit with:
 - A 500-micron pre-strainer;
 - Flow indicating device;
 - Feed tank;
 - A 538 sf of feed-side area per pressure membrane module six inches in diameter and 6.56 feet long fibers;
 - A nominal pore size of 0.1 micron with a maximum pore size of 0.2 microns;
 - Outside-in flow path;
 - Dead-end filtration mode;

ENCLOSURE F: Review of 2009 Pilot Study Reports

- A pH operating range of 1 to 10;
- A oxidant tolerance of zero for ozone, 0.2 mg/L for chlorine dioxide, 5,000 parts per million (ppm) for free chlorine and 50 mg/L for potassium permanganate;
- A temperature operating range of 0 °C to 40 °C;
- A maximum allowable TMP of 43.5 psi;
- A Q_{breach} value of 0.00825 gallons per minute (gpm);
- A Stage 2 average flux rate of 72 gfd at an average temperature of 66.2 °F (19.0 °C) for a **filtrate flux rate of 72.24 gfd temperature adjusted to 68 °F (20.0 °C)** using Pall's TCEQ approved TCF equation;
- A simultaneous air scour and reverse flush (SASRF) frequency every 16.5 minutes for a 1.0 minute duration with a filtrate flow rate of 8.0 gpm per module and an air flow of 3.0 SCFM at 30 psi;
- Each SASRF is followed by a forward flush (FF) procedure for a duration of 0.5 minute using a flow rate of 17.0 gpm of feed water;
- An enhanced filtration maintenance (EFM) once a day for duration of 30.0 minutes using a 400 mg/L sodium hypochlorite solution with 12.0 gallon are filtrate; and,
- A chemical CIP frequency of 30 days for a duration of 4.0 hours using 160 gallon of filtrate using two preheated solutions, a 1% caustic/sodium hypochlorite at a pH of 12.6 and a 2% citric acid at a pH of 2.4.
- A GE Zenon ZeeWeed® 1000 CPX-0.80 HF UF membrane test unit with:
 - A membrane tank;
 - Three 600 sf submerged modules 27.2 inches by 27.0 inches by 4.2 inches with 21.38-inch long fibers in a single stack with 1800 sf total area;
 - Outside in flow path;
 - A nominal pore size of 0.02 microns and a maximum pore size of 0.1 microns;
 - Temperature operating range of 1 °C to 40 °C;
 - Oxidant resistance of 1,000 ppm free chlorine at less than 30 °C and 500 ppm between 30 and 40 °C;
 - A maximum allowable TMP of ± 13.0 psi;
 - A Q_{breach} value of $6.6E-4$ gpm;
 - A Stage 2 average filtrate flux rate of 33 gfd at an average temperature of 19 °C for a **filtrate flux 33.6 gfd temperature adjusted to 20.0 °C** using the EPA TCF;
 - A backpulse frequency of 27 minutes for a 0.25 minute duration;
 - A maintenance clean once each day using either a 100 mg/L sodium hypochlorite or 2 g/L citric acid solution at a pH of 2.1 initiated with a backpulse/tank drain, fill tank with the maintenance clean solution, soak for 15 minutes and backpulse/tank flush prior to returning to service for 15 minutes;
 - A CIP procedure every 30 days using sequential soaking solutions of 500 mg/L sodium hypochlorite and a 2 grams per liter (g/L) citric acid with a pH of 2.1 initiated with a backpulse and tank drain, fill tank with the CIP solution, soak for 4.0 hours, repeat with second solution and backpulse/tank drain prior to returning to service for 5 to 6 hour durations for each solution;
 - A vacuum pump.
- Individual membrane test unit feed and filtrate turbidity, pH and temperature monitoring and associated pressure indicating equipment.

ENCLOSURE G:

**Comparison of GE Zenon 1000
CPX-o.80 and CPX-o.95 Fibers**

ENCLOSURE G:
Comparison of GE Zenon 1000 CPX-0.80 and CPX-0.95 Fibers

- On November 4, 2009, the TCEQ received a letter from Mr. Chris Lipski, P.E., Senior Drinking Water Process Engineer with GE Zenon, providing comparison data for the CPX-0.80 and CPX-0.95 fibers. This data included test results for 45 days of operational data for two side-by-side test units. One test unit contained three 500-square-foot (sf) 1000 modules with CPX-0.80 fibers and the other test unit contained three 450-sf 1000 modules with CPX-0.95 fibers.

The TCEQ has accepted that these two GE Zenon fibers in the side-by-side comparison can operate at the same flux rate with similar backpulse and chemical cleaning procedures.

- The TCEQ has also received test results comparing liquid contact angles (θ) for the CPX-0.80 and CPA-0.95 fibers from MWH consulting engineers. The test results show very similar results for cleaned fibers of these models. The testing was conducted by Augustine Scientific with results presented for:
 - Three new, three clean, and three fouled CPX-0.95 fibers; and
 - Three clean and three fouled CPX-0.80 fibers.

The TCEQ has accepted the following θ values:

- 53.1-degrees for the CPX-0.80; and
- 50.3-degrees for the CPX-0.95.

ENCLOSURE H:

**Separation Distances Between Reuse Piping
From Wastewater Piping
And
From Potable Water Piping**

ENCLOSURE H:
**Separation Distances between Reuse Piping from
Wastewater Piping and from Potable Water Piping**

Since 30 TAC §290.44 does not contain applicable rules for reclaimed wastewater treatment plant (WWTP) effluent or proposed potable reuse piping, the separation distances contained in 30 TAC Chapter 210 must be met between:

- All WWTP's piping and raw sewage collection piping AND indirect potable reuse (IPR) and direct potable reuse (DPR) plants' internal and effluent piping; and
- All IPR and DPR plant's internal piping (until the water in the piping has received adequate treatment to be classified as potable water by the TCEQ) AND a public water system's potable water piping;