DEPARTMENT OF ENVIRONMENTAL PROTECTION
Bureau of Safe Drinking Water

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TITLE: Guidance for Filter Plant Performance Evaluations

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AUTHORITY: Pennsylvania's Safe Drinking Water Act (35 P.S. § 721.1 *et seq*.) and regulations at 25 Pa. Code Chapter 109

POLICY: This document contains the guidance and procedures developed to guide and support staff implementation of the requirements for the surface water treatment rule under the drinking water management programs.

PURPOSE: The purpose of this document is to establish a rational and reasonable basis for staff decisions in the field, which will promote quality, timely and consistent service to the public and regulated community.

APPLICABILITY: This guidance will apply to public water systems as defined under the Pennsylvania Safe Drinking Water Act.

DISCLAIMER: The policies and procedures outlined in this guidance are intended to supplement existing requirements. Nothing in the policies or procedures shall affect regulatory requirements.

The policies and procedures herein are not an adjudication or a regulation. There is no intent on the part of the Department of Environmental Protection (DEP or the Department) to give the rules in these policies that weight or deference. This document establishes the framework within which DEP will exercise its administrative discretion in the future. DEP reserves the discretion to deviate from this policy statement if circumstances warrant.

PAGE LENGTH: 83 pages

DEFINITIONS: See 25 Pa. Code Chapter 109

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Acronyms

AWWA--American Water Works Association

AwwaRF--American Water Works Association Research Foundation

BOL--Bureau of Laboratories

BWA--Boil Water Advisory

CFE--Combined Filter Effluent

CIP--Clean-In-Place

CL--Control Limit

CT--Chlorine contact Time

DC--Direct Current

DEP or PADEP--Pennsylvania Department of Environmental Protection

DBP--Disinfection Byproduct

EPA or USEPA--United States Environmental Protection Agency

FPPE--Filter Plant Performance Evaluation

GWUDI--Ground Water Under the Direct Influence (of Surface Water)

HAA--Haloacetic Acid

HAA5--Haloacetic Acids (five)

HAA5--(sum of five) Haloacetic Acids

IESWTR--Interim Enhanced Surface Water Treatment Rule

IFE--Individual Filter Effluent

Log--Logarithm

LCL--Lower Control Limit

LRC--Log Removal Credit

LRV--Log Removal Value

LT1ESWTR--Long Term 1 Enhanced Surface Water Treatment Rule

Acronyms (cont.)

LT2ESWTR--Long Term 1 Enhanced Surface Water Treatment Rule

MCF--Membrane Cartridge Filtration

MCL--Maximum Contaminant Level

MF--Microfiltration

MIT--Membrane Integrity Test

mL/min--milliliters per minute

MPA--Microscopic Particulate Analysis

NF--Nanofiltration

NPDES--National Pollutant Discharge Elimination System

NSF--National Sanitation Foundation

NTU--Nephelometric Turbidity Unit

PAC--Powdered Activated Carbon

PDT--Pressure Decay Test

QA--Quality Assurance

QC--Quality Control

RO--Reverse Osmosis

SCADA--Supervisory Control And Data Acquisition system

SDWR--Safe Drinking Water Regulations

SOP--Standard Operating Procedure

STAGE 1 D/DBP--Stage 1 Disinfectants/Disinfection Byproducts Rule

STAGE 2--Stage 2 Disinfectants/Disinfection Byproducts Rule

SWTR--Surface Water Treatment Rule

TDS--Total Dissolved Solids

TMP--Transmembrane Pressure

Acronyms (cont.)

TOC--Total Organic Carbon

TSS--Total Suspended Solids

TTHM--Total Trihalomethanes

UCL--Upper Control Limit

UF—Ultrafiltration

USEPA--United States Environmental Protection Agency

UV--Ultraviolet (Light)

INTRODUCTION

The Filter Plant Performance Evaluation (FPPE) is a method of determining the effectiveness of a water treatment plant in removing pathogens and pathogen-size organic and inorganic particles from the incoming raw water. Of particular concern is the removal of microscopic particles down to the two micron size. This level of filtration reliability is needed to ensure removal of pathogenic protozoan including *Giardia* and *Cryptosporidium*. Both of these pathogens provide a yardstick for a plant's capability of protecting consumers from waterborne diseases, since they are some of the more difficult pathogens to remove and inactivate.

The foundation of the FPPE program is built around optimizing plant performance through operational and equipment changes. Plant performance is measured using optimization goals. At present, these goals are more stringent than the regulatory requirements for surface water treatment plants. Optimized performance goals are important, because studies have shown that plants meeting these optimization goals are less likely to pass microscopic pathogens through their filtration plant and onto their customers. Waterborne disease outbreaks have occurred at surface water systems that were not in violation of regulatory requirements. Therefore, plants meeting these optimization goals are providing a higher level of protection to their customers.

The evaluation process combines an on-site survey of plant operations and general physical conditions, and involves sampling the facility's raw and filtered water for subsequent microscopic evaluation in the laboratory. Each plant is rated as "commendable," "satisfactory," or "needs improvement" based on the plant's ability and operators' skill level to maintain optimal performance on a long-term basis. Oral and written technical assistance for improving the plant's performance are also provided by the FPPE program. Note that this rating is based on plant optimization as measured by the FPPE program. Although FPPEs may discover major treatment problems or identify and record violations of regulations, the rating system is not based on regulatory compliance.

The on-site evaluation is a team effort shared by central office and field operations staff to review the operational processes and physical characteristics of a filter plant. By implementing a team evaluation, the exchange of information and findings pertaining to the facility and its operation can occur among the regional FPPE staff, the district sanitarian, the regional engineer, central office staff, and the facility operator. This team effort ensures understanding of existing problems and violations so that changes necessary to promote sound filter plant operation, maintenance, and performance are clearly understood.

After the team completes the on-site survey, the Bureau of Laboratories performs a procedure called the Microscopic Particulate Analysis (MPA). This procedure is outlined in the department's document called "Interpreting the Microscopic Particulate Analysis" and evaluates the size, type and amount of particulates in these samples to determine if microscopic particles are sufficiently removed by the treatment process. The MPA may help verify acceptable filter plant performance and possibly the effectiveness of treatment to remove pathogenic protozoan, thus providing information to help determine if immediate action is necessary to protect consumers in the water system.

PERFORMANCE RATING SYSTEM

FPPE staff will use the following categories to rate each plant. The ratings are based on the plant's ability and operators' skill level to maintain optimal performance over the long-term. Please note that while FPPEs may discover major treatment problems or identify and record violations of regulations, the rating system is not based on regulatory compliance.

“Commendable”

Department staff have identified only minor operational, equipment, and/or performance problems that affect the plant’s ability to maintain optimized performance. Plant personnel have already taken steps to improve overall filter plant performance and maintain the long-term reliability of the plant.

“Satisfactory”

Department staff have identified operational, equipment, and/or performance problems that may affect the plant’s ability to maintain optimized performance. Plant personnel appear willing and capable of improving overall filter plant performance. However, one or more of the treatment processes showed areas of weakness in operational, equipment, and/or performance that, if corrected, will improve filter plant performance and maintain the long-term reliability of the plant.

“Needs Improvement”

Department staff have identified considerable operational, equipment, and/or performance problems that are affecting the plant’s ability to maintain optimized performance. Limitations are apparent that hinder improvement of overall filter plant performance. Areas of weakness affect the capability and dependability of the plant in providing consumers with an adequate level of protection against waterborne pathogens.

STAFF ADVANCED PREPARATION

Listed below are typical advanced preparation responsibilities for Regional FPPE staff, District Sanitarians, Regional Sanitary Engineers, and Central Office staff.

REGIONAL FPPE STAFF:

- Contact the public water system to arrange the Filter Plant Performance Evaluation and ensure that a certified operator will be available. Briefly explain the procedure and necessary sampling points to the chief operator or superintendent. Emphasize that individual filter taps are preferred over clearwell taps, and that the samples will be collected over a period of hours so that critical stages of the filter run can be sampled. Establish with the operator possible sampling locations and, more importantly, arrange with the operator to include a backwash cycle during the sampling run.

- Coordinate evaluation schedules with the sanitarian, central office and regional engineer 2-3 weeks prior to the scheduled dates to arrange arrival times and discuss the filter plant performance evaluation activities. This will include obtaining information on the available water taps or other possible sites to take the finished water sample for the microscopic evaluation, and to verify that a filter backwash cycle will be included during the sample run.

- Contact the *Giardia* lab to reserve Raw water Method 1623, filtered water MPA, filter media analysis, and any other special sample reservations.

- Review the latest sanitary survey (public water system inventory) and previous FPPE reports to become familiar with the treatment plant and operational practices.

- Review the eMapPA GIS Program to become familiar with the watershed area and to locate possible sources of contamination. At DEP website use search term "eMapPA".

- Verify that all evaluation equipment is calibrated according to manufacturer's recommendations and in good working condition.

- Review the most recent 12 months of raw, settled and finished turbidity data. If a system already submits turbidity data through WebOAS, refer to internal site for information.

- Request plant alarm set points and shut-off set points from the water system. Also, request any additional information such as Annual CT Log Inactivation values and process control data.

DISTRICT SANITARIAN/WATER SUPPLY SPECIALIST:

- Review the facility files to become familiar with the treatment plant, operational practices, system deficiencies, seasonal turbidity trends, and water quality history. Regional FPPE staff should be briefed on violation history at the plant, recent equipment improvements, and general background information.

- Prepare to assist in assessing the treatment processes and water quality characteristics, and remain part of the evaluation team during the entire evaluation process.

REGIONAL ENGINEER/TECHNICAL SERVICE STAFF:

- Review the public water system's permit, including permitted capacity, and provide this information to regional FPPE staff.

- Verify the plant's chlorine dosage rate capability in milligrams per liter (both pre and post-chlorination), including contact time of the treated water and CT values prior to reaching the first customer. This information helps prevent unnecessary boil water advisories or last minute confusion in the event of a breakdown in treatment.

- Prepare to assist the evaluation team during the entire evaluation process.

CENTRAL OFFICE FPPE STAFF:

- Prepare to assist regional FPPE staff with difficult or unusual assignments.

STAFF ON-SITE ACTIVITIES

Listed below are typical on-site activities for staff during the Filter Plant Performance Evaluation:

REGIONAL FPPE STAFF:

- Responsible for taking the lead on the evaluation
- Makes sure that equipment setup is properly completed in a timely manner. Makes sure that the line of questioning with the operator(s) is relevant to the operations of the treatment plant.
- Identify all critical sampling needs.

DISTRICT SANITARIAN/WATER SUPPLY SPECIALIST:

- Document the system deficiencies identified during the FPPE in an inspection report. In situations when operational problems seriously affect the finished water quality, violations and compliance issues must be noted and appropriate actions must be taken. Other less serious operational problems, which do not appear to present a high-risk to the quality of finished water, will be discussed with the operator during the evaluation.
- Assist with equipment set-up.
- Assist with sample collection and shipment.

REGIONAL ENGINEER:

- Verify that the water treatment plant achieves the required “Log inactivation” of *Giardia* cysts.
- Verify that the water treatment plant meets design standards.
- Answer permit related questions.
- Verify status of recent/proposed permit changes.
- Identify and discuss any potential permit modifications.

CENTRAL OFFICE FPPE STAFF:

- Assist regional FPPE staff with the evaluation.
- Observe the evaluation process for quality control and state-wide consistency purposes.
- Introduce new evaluation tools and techniques.

STAFF FOLLOW UP ACTIVITIES

Listed below are typical follow-up activities for staff after the Filter Plant Performance Evaluation occurs:

REGIONAL FPPE STAFF:

- Write the draft FPPE report; send an electronic copy of the draft report to the appropriate central office, regional, and district staff for review and comment; prepare the final report; and make sure that the water supplier receives the final FPPE report. Send an electronic copy of the final FPPE report to appropriate central office, regional, and district staff.

- Ensure that the sanitarian, regional engineer, and any other appropriate department staff have been notified of any violations or compliance issues noted during the FPPE.

- Ensure that the regional engineer has been notified of and given the opportunity to provide input on design and/or permitting issues noted during the FPPE. In addition to requesting engineers to provide a general review of the entire draft FPPE report, direct their attention to any specific areas of the report you would particularly like them to review.

- Review any written responses from the plant and schedule a follow-up meeting with the plant to discuss FPPE comments.

DISTRICT SANITARIAN/WATER SUPPLY SPECIALIST:

- Ensure that violations and compliance issues are properly addressed.

- Review and comment on the draft FPPE report.

- Participate in follow-up meetings with water treatment plant staff.

- Encourage the plant staff to address recommendations listed at the end of the FPPE report.

- Notify regional FPPE staff once the supplier has addressed recommendations.

- Notify regional FPPE staff when plants with a "Needs Improvements" rating are ready for a re-evaluation. Typically, most recommendations should be addressed before scheduling a re-evaluation. Re-evaluations should not be conducted if little or no progress has been made. In addition, before a re-evaluation is scheduled, a minimum of 12 months should pass from the time the supplier has addressed the previous recommendations. The department will consider shorter re-evaluation time periods on a case-by-case basis. Analyzing 12 months of turbidity data is part of the evaluation. Therefore, the supplier should be able to provide annual turbidity trends, which demonstrates improved plant performance.

REGIONAL ENGINEER:

- Work with plant staff to resolve Log Inactivation, design, and/or permitting issues.

- Assist the FPPE staff with Log Inactivation calculations for inclusion in the FPPE report.
- Review and comment on the draft FPPE report.
- Participate in follow-up meetings with plant staff.
- Review written response documents.

CENTRAL OFFICE FPPE STAFF:

- Review and comment on the draft FPPE report.
- Provide comments, which help to assure overall consistency of the program.
- Discuss and attempt to resolve any areas of concern or inconsistency with the FPPE staff.
- For "borderline" plants, help the FPPE staff to determine the most appropriate rating.
- Participate in follow-up meetings with the water supplier, if needed.
- Provide technical assistance where needed.

SOURCE WATER AND WATERSHED REVIEW

The sanitarian should brief FPPE staff on any watershed characteristics or uses that may affect the quality of the water. Additionally, FPPE staff can contact the regional source water protection staff for information on potential or existing sources of contamination of the raw water. The schedule for assessments and summary of finished reports will be posted on the Source Water Protection webpage at www.dep.pa.gov. The full reports will be on file in the regional and district offices.

Discussion with the operator during the evaluation should focus on the characteristics of the raw water, possible points of contamination, and watershed control efforts. Specific areas of concern are animal control methods, algae control, sewage discharges, industrial uses, land uses, seasonal fluctuations in raw water quality (especially turbidity), and organic load variations. Try to identify the worst seasonal raw water quality problems and the corresponding operational changes made to deal with these problems. Describe and document the following:

1. Sources of turbidity and contamination that have been identified and methods for their control.
2. Rapid raw water turbidity fluctuations due to precipitation or snow melt events, their severity, and how the operator accommodates these fluctuations.
3. Seasonal fluctuations in raw water quality.
4. Review annual raw water turbidity data for source water fluctuations. If data is not available, contact treatment plant for source water data.

PLANT OPERATIONS EVALUATION

This is a team participation process of sharing and collecting facility information, and reviewing the overall operations and treatment processes to determine operational procedures and physical characteristics. Filter plant information is gathered and discussed among the district sanitarian, regional engineer, regional FPPE staff, central office staff, and plant operator(s) during the on-site evaluation. However, some information such as annual turbidity data and capacity information can be collected prior to the evaluation so that more time can be spent actually evaluating the operation of the filter plant. **Attachment 1**, "**FORMULA SHEET,**" contains several formulas that are frequently used in the water industry and may come in handy during your evaluation.

For public water systems that utilize Membrane Filtration Technology, refer to the following attachments. **Attachments 8,** "**MEMBRANE EVALUATION PROTOCOL,**" contains membrane specific evaluation guidance. **Attachment 9,** "**MEMBRANE PERMITTING CONDITIONS (EXAMPLE),**" contains an example membrane permit showing detailed special conditions relating to a membrane water plant. **Attachment 10,** "**INTEGRITY TESTING/CONTROL LIMITS GRAPHS (EXAMPLES),**" contains example graphs of membrane plant data. The graphs can be used in an FPPE report to illustrate optimization efforts. **Attachment 11,** "**MEMBRANE TECHNOLOGY TERMS AND DEFINITIONS,**" contains definitions to membrane technology terms and acronyms.

It is crucial that the FPPE be performed under "normal" operating procedures, so that representative data is collected. Therefore, do not request the operator to stray from the "normal" modes of operation to accommodate the FPPE. More specifically, operators should not adjust filter run times, backwash sequences, flow rates, tank levels, or total hours of plant operation solely to accommodate an FPPE. However, an FPPE can be performed under abnormal raw water conditions in order to assess the plant's ability to respond to changing raw water conditions.

Particular attention is given to critical stages of the treatment process, including:

- Intake structure
- chemical pretreatment
- solids removal
- filtration method
- various features of the filter run
- backwash
- waste handling
- other details of plant operation
- facility characteristics
- operational practices

Any operational areas of strength or performance limiting factors that could affect water quality are recorded by regional FPPE staff for later use when completing the Filter Plant Performance Evaluation report. The following examples of activities and questions are usually considered when doing this on-site evaluation:

FACILITY PERMIT: Identify and discuss any permit discrepancies that directly relate to water treatment processes.

- Review permitted source and status.
- Changes in treatment chemicals and treatment process often require a permit amendment.
- If the public water system uses or withdraws from a surface water[1] source (rivers, streams, natural lakes and ponds or other surface waters including springs that eventually form into streams and subsurface intakes designed to capture surface water), then verify that a current valid water allocation permit exists.
- If the water system discharges to the Waters of the Commonwealth, then verify that an National Pollutant Discharge Elimination System (NPDES) permit exists if a permit is required.
- Are permit requirements being met?

CHEMICAL PRETREATMENT AND PROCESS CONTROL: Discuss with the operator and observe chemical pretreatment, focusing on unusual circumstances. Note the following:

- Are all treatment chemicals National Sanitation Foundation (NSF) approved?
- Chemicals used and dosage rates; dosage adjustment frequency; application points and thoroughness of mixing; and overall effectiveness of chemical application.
- Review how chemicals are mixed; inline static mixer, rapid mix, etc.
- Review the operator's methods for making chemical adjustments and procedures for checking and confirming proper dosages.
- Establish what, if any, tests are used (including jar tests, streaming current detectors, zeta potential, filter-ability, etc.) and when and how the results of these tests are used.

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[1] The Water Rights Act of 1939 applies to withdrawals from rivers, streams, natural lakes and ponds or other surface waters. The term other surface waters is subject to interpretation. The first question of interpretation arose upon passage of the act and was addressed by an Attorney General's opinion of August 5, 1940, regarding the inclusion of springs within the definition of surface waters. That opinion stated that springs are "within the terms of the act, where a stream is created by a spring, which stream flows in a natural channel." Conversely, the opinion stated that "where a spring is diffused over the ground and follows no defined course or channel," for example where a spring feeds a bog or marsh and the water then percolates back into the ground, it would not be within the terms of the act. Additionally, it has been the Department's practice that surface water withdrawn from a subsurface intake is considered surface water and the Water Rights Act of 1939 would apply.

- Review historical raw water turbidity data for turbidity fluctuations and ask the operator what treatment adjustments were made to accommodate the raw water changes. Check historical turbidity data to see if settled and finished turbidity spikes occur at the same time as raw water turbidity spikes.

- Does the operator calibrate the chemical feed equipment and how often?

- Does the operator use a dosage chart?

- Does consistent, high-quality source water lead to complacency in the operation and management of the water system?

- Does a certified operator make the process control decisions? Ensure non-certified operators aren't making process control decisions.

- Are current SOP's in place and used by all operators.

PROCESS MONITORING: Identify water quality monitoring points throughout the plant. Parameters such as turbidity, pH, alkalinity, and temperature are especially important, since they affect and/or are affected by pretreatment. These parameters should be monitored, at a minimum, in the raw, settled, and finished water. The FPPE team should use **Attachment 2,** "**WATER QUALITY DATA AND EVALUATION INFORMATION,**" to document all water quality analyses conducted on the day of the evaluation.

- Do the operators establish goals for plant performance, or are they more concerned about only meeting the regulations?

- Does management support optimization goals or are they only concerned about meeting the regulations?

- Does the operator use information obtained from these tests to ensure that each major unit process is optimized?

- Does the operator have specific performance targets for each parameter? Are they posted? If there are several operators, do they all have the same performance target? Who sets the target?

- Are good records of the data maintained?

- Is quality control used?

- Have chemical reagents expired?

- Is instrumentation available that is needed to optimize treatment processes?

  Example:

  - pH meter with three point calibration

- Continuous online recording turbidimeters on individual filters

- Jar testing equipment

FLOC CHARACTERISTICS AND SETTLING: Identify the characteristics of floc formation and sedimentation. Whenever possible, determine where the floc blanket occurs. Discuss with the operator what floc characteristics are expected.

- Does sedimentation occur where intended for the type of facility?
- Determine if sludge removal is frequent enough to prevent short-circuiting.
- Where applicable, look for floc carry-over to the filters and check applied turbidity.
- Is the sedimentation effluent (over top the filters) consistently less than 2.0 NTU (<1 NTU if raw is <10 NTU) throughout the year, and no greater than 5.0 NTU, despite raw water turbidity fluctuations?
- Observe filter effluent particle counts and turbidities when the filter is returned to service.
- Is filter-to-waste implemented when the filter is returned to service?
- Pre-filtration processes such as adsorption clarifiers should also meet the same settled turbidity criteria. A clarifier wash should also be observed if possible. Review criteria for clarifier wash if applicable.
- Check for even distribution of air and water wash if applicable.
- The clarifier should be clean at the end of the wash.
- Record applied turbidities when the clarifier is returned to service and take grab samples if necessary.
- Is the filter taken off line during the clarifier wash?

FILTER RUNS: Observe the filters during the filter run.

- Does filter effluent meet optimization goals of 0.1 NTU and <25 counts/mL in the size range of ≥2 microns?
- Is the filter effluent quality in compliance with the Pennsylvania Filtration Rule?
- Determine normal or average filter run time and what criteria the operator uses to determine when to backwash.

- Turbidity, particle counts, head loss, and time should be considered when establishing filter run time.

- Note, frequent start-up and shut down operations can cause turbidity breakthrough.

- Note any start-ups or changes in flow rates on any filters that may result in pathogen breakthrough into the clearwell.

<u>BACKWASH:</u> Observe the backwash cycle**.** Look for thoroughness of cleaning, flow rate, media expansion, dead spots, media "boiling", and filter media loss.

- Does the operator use air scour, surface scour or hand raking during the backwash?

- Are mudballs present, and if so, why?

- Is finished water used for backwashing? Where does backwash water come from?

- Is there sufficient storage for the clean backwash water?

- What is the backwash rate in gpm/ft^2? Is the backwash rate acceptable? Recommended rates are 15-20 gpm/sq ft. Does the operator have control over this rate?

- How are other filters affected during filter backwashes, example - increased flow changes, greater loading?

- Does the operator adjust backwash rates according to seasonal variations in water temperature (increase rate in summer and decrease rate in winter)?

- What is the percent bed expansion during high rate of wash? Is percent expansion within the recommended 20-30 percent range?

- Does the wastewater go to a sewer or a lagoon?

- Does the wastewater lagoon have the capacity to hold two backwashes?

<u>POST BACKWASH PERFORMANCE:</u> Identify how the operator determines when a filter can be put back on line.

- Determine if the system filters-to-waste and for how long.

- If a plant has filter-to-waste capabilities, they should filter-to-waste until filter effluent turbidity falls below 0.10 NTU before filter is returned to service.

- Can the f-t-w period be extended until turbidity is <0.10 NTU?

- If filter-to-waste is not capable, was there a resting period before filter was placed into service?

- What measurements are taken to make this determination?

- How does the operator minimize turbidity breakthrough when placing a filter back into service?

- Is a polymer filter aid applied to reduce on-line turbidity spikes?

- Are valves ramped open as opposed to fully opened?

- What was the filter effluent turbidity when filter was returned to service?

- What was the recovery time for the filter to return to the optimization goal of 0.10 NTU?

- Were there turbidity fluctuations during the filter ripening process?

- Are on-line turbidity spikes less than 0.3 NTU and fewer than 15 minutes in duration if the plant does not have filter-to-waste capability?

- Was the filter given a resting period before placing it back into service?

- Plants should never startup "dirty" filters (filters with runtime) without a filter-to-waste cycle, if capable.

FILTER EVALUATION: Following a backwash, perform a filter evaluation on a filter that is not being used to collect profiling data or MPA samples.

- Evaluation should be conducted on a 'clean' filter. Ensure filter is backwashed prior to evaluation.

- Be aware of FPPE Safety Inspection guidelines when conducting a filter inspection. Refer to **Attachment 7,** "**GUIDELINES FOR PERFORMING FILTER INSPECTIONS,**" for further information.

- A filter evaluation should only be conducted, if the operator is willing and experienced with draining the filter and refilling it slowly from the bottom.

- Drain the water level from the filter cell to expose the media. Time the rate of fall, compare with the total inches of media in the filter, and attempt to estimate when water is drained to the gravel layer of the filter bed.

- Check for mudballs, mud accumulation, mounding, cracking and overall media evenness.

- Use a steel probe to ensure that the media depth to gravel is the same in all locations. Do not use this probe if the plant has filter-cone type underdrains, which may be damaged by the probing.

- Record media specifications, original media depth, and age of media.

- Collect and submit media samples to the lab using the "**MICROSCOPIC PARTICULATE ANALYSIS LAB FORM**" in **Attachment 3**.

- After you receive the results of the media analysis, check to see if the effective size, uniformity coefficient, and percent weight loss are within specifications (see "**FILTER MEDIA CRITERIA**," **Attachment 4**).

- After the filter evaluation, the filter must be filled slowly from the bottom to allow the air to escape and then backwashed again to restratify the media and remove entrapped air.

DISINFECTION: Confirm if the disinfection system is being properly monitored and reliable. Review past chlorine residual data or charts to determine long-term reliability of the disinfection process. If disinfection profiling data is available, it may be evaluated and a log inactivation chart should be included in the FPPE report. See Attachment 5 for an example chart. Any problems should be documented by the sanitarian or regional engineer and discussed with the operator. Do CT levels meet criteria established in the Pennsylvania Filtration Rule and the U.S. Environmental Protection Agency's guidance manual for surface water systems? **Attachment 5** "**CT INSTRUCTIONS**" can be used to calculate CT values at most plants using chlorine as a disinfectant. CT calculations should be reviewed by Regional Engineer. For those who are interested, an electronic Disinfection Profiling/CT Spreadsheet can be obtained from the Bureau of Safe Drinking Water's Technical Assistance Section at 717-787-0122.

DISINFECTION BYPRODUCTS: Review the operator's attempts to reduce disinfection byproduct formation. Because source water characteristics and treatment practices at each plant are different, try to find out "what has worked and what has not."

- Are they having DBP issues?

- Has the operator attempted to determine where any DBP formation is occurring (i.e. in the plant or in the distribution system)? If in the plant, has the operator identified during which treatment process the majority of the formation is occurring?

- Does the operator pre-chlorinate?

- Does the plant have a chlorine analyzer?

- Does the operator have an established flushing program for the distribution system?

- Does the distribution system have dead ends?

- What type of disinfectant(s) does the system use? Does the operator change disinfectant types during the year?

- What are the raw and treated water TOC levels? Any TOC issues?

- Do they have sufficient CTs? Excessive CTs?

- Does the operator vary the chlorine doses during the year as temperatures change to balance CTs for microbial protection and disinfection byproduct formation?

- Does the operator vary the chlorine application points in the plant during the year to balance CTs for microbial protection and disinfection byproduct formation?

<u>WATER STORAGE</u>: Evaluate the clearwell and storage reservoir(s). Determine the maintenance and cleaning schedule for the clearwell and/or storage reservoir.

- Note whether the storage structure is covered and complies with the Pennsylvania Filtration Rule.

- Note the type of baffling in the clearwell and storage reservoir.

- Ask the operator for tracer study results if available.

- How long can the system operate from storage capacity alone if the plant was off line because of an emergency?

- Does the storage tank float on the system?

- What is the established inspection, cleaning and maintenance frequency for the clearwell and storage tanks?

- Has the tank turnover time been determined and minimized for each tank (i.e. is the tank turnover time, in days, as low as possible without adversely impacting system pressure or fire protection needs)?

<u>DATA INTEGRITY:</u> The FPPE staff's ability to effectively evaluate a filter plant is highly dependent on the availability of quality data. A Commendable rating should not be awarded if the integrity of the data is inadequate. (For example: A Commendable rating should not be awarded if the plant's turbidimeters have not been calibrated.) Listed are a few things to check:

- Was the Department's annual data request accommodated prior to the evaluation?

- Determine sampling location of compliance and process control monitoring

    - For CFE monitoring, is location a true combined effluent, (before, at, after clearwell or an average of IFE's)?

- Is there a record of IFE and CFE turbidity?

- Is IFE recorded every 15 minutes, CFE recorded every 4 hours?

- Is turbidity being recorded during times when filter is not in production?

- How is data recording handled during calibration, maintenance or when the process is off line?

- Is data ever deleted or invalidated? Who has this authority? Is there a policy?
- Can data be easily retrieved by the operator?
- Is data trended, reviewed by plant staff and used to make data based decisions?
- How much historical data is available? Turbidity and chlorine residual data should be kept for 3 years.
- Do the operators know the units for the data being recorded? (Example -NTU, gal/day, mg/L, psi/Min)
- Does the data produced by the instrument match the data being recorded? (Example: If the pressure gauge reads 25.55 psi, does the SCADA system display and record 25.55 psi?)
- Is data required by permit special conditions being reviewed and recorded?
- Does the data represent a minimum, maximum, average, and 95th percentile?
- Do data gaps exist? If so, why?
- Was the Department notified (if required) when monitoring instruments or data recording failed?
- Was the Department notified when regulatory values were not met? (high turbidity, low chlorine)
- Are instrument calibration frequencies adequate per regulations/manufacturer recommendation?
- Is instrument cleaning and maintenance adequate?
- Are primary standards used for calibration? Are they expired?
- Are instrument calibration and maintenance records kept? If so, review them.
- Are mandatory EPA methods being followed? EPA method 334.0 must be followed for all on-line chlorine residual analyzers, including CL-17.
- Does the plant have any written procedures (SOPs) for calibration, maintenance, and handling of data?
- Are instrument readings being checked, verified by operators and recorded into plant log sheets?
- What is the interval that the water is analyzed and the data recorded?
- Are spare parts, calibration standards, reagents, and other instrument and recorder consumables readily available?

- When instruments and recorders fail, are they quickly repaired?

COMPLACENCY, RELIABILITY, AND PREPAREDNESS: Assess staff's ability to handle treatment difficulties during normal and unusual events. Is the importance of source water protection, pretreatment, and process control completely understood by plant staff?

- Are there any policies or SOPs that lay out a plan on how to handle unusual events? Example- How would operators respond during a period of very poor source water quality, low finished water storage, and high demand?

- Review historical data to identify periods of poor source water quality, periods of treatment difficulties and interview plant staff to determine how they responded to these situations.

- Determine what they have done to address problematic events or improve their ability to do so.

MAINTENANCE: Discuss the facility maintenance with the operator and briefly review the supplier's O & M plan and records, focusing on critical areas of maintenance that affect plant performance.

- Is preventive maintenance being practiced?

- Is corrective maintenance accomplished in a timely manner?

- Is predictive maintenance used to identify future maintenance needs? (vibrating pumps, infrared analysis, leak detection, etc.)

- Does the plant have adequate workspace and tools to perform maintenance tasks?

- Do plant staff have the expertise to perform maintenance?

- Are critical spare parts stored at the plant?

OTHER IDENTIFIED PROBLEMS: Discuss conditions, which may have a negative effect on the overall system performance (i.e. excessive flow rates, inadequate mixing for flocculation units, poor baffling configurations, leak detection, percent unaccounted water loss, etc.). Attempt to determine general work environment. Determine if operators receive adequate training and administrative support/funding.

FPPE staff should consider action plans developed and past efforts taken by the plant to solve performance problems. Appropriate questions may include the following: Have plant personnel…

- Recognized the issue as a performance problem;

- Investigated causes of the performance problem;

- Developed action plans to address the performance problem;

- Followed best operational practices/preventive maintenance;

- Kept updated maintenance records;
- Made an effort to modify operational practices to solve the performance problem

For more detailed evaluation criteria, refer to American Water Works Association Research Foundation's "Self-Assessment Guide for Surface Water Treatment Plant Optimization" and "Filter Maintenance and Operations Guidance Manual."

SAMPLING FOR THE MICROSCOPIC PARTICULATE ANALYSIS (MPA)

The following MPA samples and measurements should be taken by the regional FPPE staff with the assistance of the sanitarian, engineer, and water system operator. Document the sampling and field measurement information on the "**MICROSCOPIC ANALYSIS LAB FORM**," **Attachment 3**. This form must accompany the MPA samples when sent to the *Giardia* laboratory. After the MPA sample is collected, the MPA filter cartridge must be placed into a whirl-pac bag without touching the filter with your bare hands. This takes great skill and practice. Then place the whirl-pac bag into a zip-loc bag. As with all samples sent to the Bureau of Laboratories, the MPA samples must be iced. Chlorinated samples must be fixed with Sodium Thiosulfate. For additional sampling information, please see the established procedures documented in the Technical Guidance Document, "Guidance for Giardia Sampling & Response" - 394-3130-106. This guidance document can be found on DEP's eLibrary at: www.depgreenport.state.pa.us/elibrary.

RAW WATER:

1. **Method 1623 Sample –**
   - Fill a 10-liter cubitainer with raw water sample collected from a location before any treatment or recycle flow.
   - Pack the 10-liter cubitainer in chest cooler w/ice. Store/ship sample at 32°F to 46°F. Do not allow the sample to freeze.
   - Complete lab submission form and ship to BOL.
   - Note anything unusual in the comments section of the sample submission form.
2. **Field Parameters -** Measure and record the pH level, temperature, and turbidity at the sampling site using approved sample collection and analytical procedures.

FILTERED WATER:

1. **Microscopic Particulate Analysis (MPA) Sample -** Sample the filtered water immediately after filtration, by filtering 500 to 2,000 gallons of water from a filtered water tap. This sample will extend over the period of time needed to include various phases of the filter run. Manual

operation of automated functions may be necessary to include all these phases during a reasonable time period. When possible, the sample should include:

- Effluent quality degradation later in the filter run
- The interval immediately following backwash
- Any period of increased loading on the filter

When the MPA sample is on an individual filter, the MPA sample should be turned off while that filter is being backwashed. If the MPA filter is inadvertently left on during the backwash event, the sample is considered invalid and should be discarded. If an MPA filter cartridge is handled with bare hands, dropped on the floor or otherwise contaminated, it is considered invalid and should be discarded. Do not send invalid MPA samples to the *Giardia* lab, because the analysis is very time-consuming and expensive.

New sample hoses should be used for each sampling event.

When possible, use an individual filter water tap to collect the filtered MPA sample. When this is not available, a finished water tap representing the combined filtered effluent from the system's filters can be used. The finished water sampling is initiated concurrently with the raw water sampling.

2. **Field Parameters -** Measure and record the pH level, temperature, disinfectant and turbidity readings at the sampling site using approved sample collection and analytical procedures. Take disinfectant and turbidity measurements at the time the MPA sample is started and at the time the sample run is completed. Also, compare disinfectant and turbidity measurements with the operator's measurements. In most cases, DEP's portable in-line turbidimeter will record filter effluent turbidity over the entire filter run.

INDIVIDUAL FILTER PROFILE

"A filter profile is a graphical representation of individual filter performance based on continuous turbidity measurements or total particle counts versus time for an entire filter run, from startup to backwash that includes assessment of filter performance while another filter is being backwashed"(EPA Guidance Manual for Compliance with the IESWTR, April 1999). Turbidity or particle count data is plotted on the Y-axis vs. time on the X-axis. A filter profile is a very useful tool used to assess the operation of a filter plant. However, please be aware that the FPPE staff are evaluating the entire plant, not just the filters. A filter profile can point out factors that limit plant performance. A limiting factor could be anything that causes filter effluent turbidity or particle counts to exceed the optimal performance goals. An exceedance of these optimal performance goals could indicate that one or more of the following limiting factors exist:

Limiting Factor	Indications
Excessive filter run times	Turbidity and/or particle counts begin low and then exceed optimization goals prior to being backwashed.

Limiting Factor	Indications
Flow rate exceeds filter capacity	Turbidity and/or particle break-through occurs during high flow conditions, post-backwash turbidity spike exceeds 0.10 NTU for more than 15 minutes.
Changes in flow rates	Turbidity and/or particle break-through occurs during time of flow rate change. Filtration rates often increase on remaining filters, while one filter is being backwashed. Recycling events can also cause flow rates to increase. Seeking valves open and close to maintain desired flow rate.
Filter was not adequately backwashed	Turbidity and/or particle break-through occurs just after a backwash and observation of filter backwash showed that water overflowing into the backwash troughs at the end of the backwash was still dirty and/or evidence of mud balls, post-backwash turbidity spike exceeds 0.10 NTU for more than 15 minutes.
Filter-to-waste too short	Filter was put online while turbidity was above 0.10 NTU
Physical problem with filter or underdrain	Turbidity and/or particle break-through at any time during the filter run, including filter-to-waste, while other filters are performing fine. Turbidity during filter-to-waste should not exceed 0.3 NTU. This could indicate a problem with the filter, especially if other filters are performing fine.
Pretreatment not optimized	Overall filter performance is poor, evidence of sticky media, short filter runs; post-backwash turbidity spike exceeds 0.10 NTU for more than 15 minutes. High headloss or high particle counts are also indicators.

INTERPRETING PROFILES: **Attachment 6**, "**INTERPRETING FILTER PROFILES**," contains example filter profiles and guidance for interpreting them.

PROFILE DATA COLLECTION: The FPPE staff will choose a filter for profiling that is scheduled to be backwashed during the evaluation. When choosing a filter, FPPE staff should keep in mind that they will need sufficient time to setup their equipment (online turbidimeter, particle counter, and MPA cartridge) and collect enough meaningful data prior to the backwash. If sufficient time and equipment is available, multiple filters may be profiled and evaluated. Turbidity and particle count data should be plotted approximately every two minutes to allow proper evaluation of filter performance. Longer intervals (>15 minutes) between data points would allow short periods of poor filter performance to go unnoticed. A shorter interval (<1 minute) creates an enormous amount of data that is very difficult to manage.

It is very important for the FPPE staff to be detail oriented and take thorough notes while collecting data for the filter profile. Periodically check the profile for turbidity and particle count spikes while you are at the plant and especially when:

- other filters are being backwashed
- flow rates change
- chemical feed rates are adjusted
- recycling events occur
- raw or settled turbidities increase
- the filter is at the end of its run time
- the start and stop of filter-to-waste
- the filter is placed into service after a backwash
- any time the filter is placed in or out of service
- the plant starts up automatically

If the cause of a spike is not obvious, record the time that the spike occurred and ask the operators if anything happened during that time period. Do this before you leave the plant, while everything is fresh in the operator's mind. Reference SCADA systems, strip charts, chart recorders, and operator log books in an attempt to gather information concerning the cause of filter profile spikes.

PROFILE LABELS: Individual filter profiles should have labels identifying when the filter backwash begins and ends, and when the filter-to-waste ends. Any spikes that exceed the optimal performance goals should be identified and explained in the text of the FPPE report.

PARTICLE COUNTER: Particle count data is especially useful in a filter profile. Particle counters are typically more sensitive than most turbidimeters used in the drinking water industry. When filter performance begins to degrade, it will most often be noted by an increase in particle counts before it is seen by an increase in turbidity. As a result, with the use of particle counters, filters can be taken off-line to be backwashed when particle counts begin to increase. This reduces the risk of exceeding a turbidity goal and/or passing waterborne pathogens through the filter. In addition, since particle counters measure the size and the number of the particles passing through the filter, FPPE staff are better able to evaluate the filter's ability to remove *Giardia* (6-18 microns) and *Cryptosporidium* (3-6 microns).

Expectations at optimized surface water treatment plants are for particle counts to remain low in the filter effluent (<25 counts/mL in the $\geq$2 micron size range) regardless of raw water quality. For example, an increase in raw water turbidity should not result in an increase in particle counts in the filter effluent. Although "log removal" can be beneficial for evaluating pilot plants, its weaknesses at existing full-scale plants do not ensure optimization (consistent production of high quality water). For example, a filter plant achieving 2-log removal when the raw water has 10 counts/mL, produces effluent with 0.1 counts/mL. The same plant achieving 2-log removal when the raw water has 10,000 counts/mL, produces effluent with 100 counts/mL. This exceeds the optimization goal of 25 counts/mL and is not a good yardstick for measuring optimization.

The particle counters used during FPPE evaluations have several performance indicating features, which allow the user to perform quality assurance checks.

- **Check instrument flow rates**, measure water flowing from the discharge end (clear tubing) with a graduate cylinder to verify that it is 100 mL/min +5%. If the flow is above the recommended range, the total counts will likely decrease. If the flow is below the recommended range, the total count will likely increase. If the flow needs to be adjusted, adjust the height of the sample drain cup along head pressure tube. Increasing the height of the cup decreases the flow; conversely, decreasing the height of cup increases the flow.

- **Clean sensor with brush**, dip brush in "Liquinox" laboratory grade cleaning reagent if needed (use small amount). Place brush in top of sensor housing and gently work up/down. Sensor can also be cleaned by using a reverse flow direction short burst of compressed air through sensor.

- **Check cell %** on LCD screen on particle counter. Optimal cell condition is 95%. However, a range of 85% to 99% is acceptable. Record the baseline cell condition for each sensor following any manufacturer calibration. If cell condition drops below the baseline, clean sensor using brush and laboratory grade detergent to increase cell percentage. If acceptable range cannot be attained, sensor must be returned to manufacturer for repair and recalibration.

OPTIMIZATION GOALS

Optimization goals are another tool used by the FPPE team to assess the performance at surface water treatment plants. Filter plants should, at all times, strive to meet the goals listed below. However, the FPPE staff should recognize that perfection is not always possible and plants meeting these goals 95% of the time can be considered optimized if no other major operational or equipment problems exist. In addition, FPPE staff should take into consideration past efforts taken and action plans developed by the plant to solve performance problems.

The most recent twelve months of raw, settled, and finished turbidity data should be evaluated using these optimization goals as a yardstick. Pay special attention to performance throughout the plant during periods of high raw water turbidity and during months of cold weather when water is more difficult to treat. When evaluating a system's performance, greater emphasis should be given to annual turbidity data from plants that are challenged with rapidly changing raw water turbidities. However, for plants that are not challenged with rapidly changing raw water conditions, more emphasis should be placed on operator preparedness and complacency.

Process	Optimization Goal
<u>Sedimentation</u> Evaluate the 95% of daily maximum readings for the most recent twelve months. Daily maximum data points should be chosen from 4-hour readings.	• Continuous, stable performance regardless of variations in raw water quality. • Effluent turbidity ≤1 NTU, if annual average of daily maximum raw is <10 NTU (chosen from 4 hour readings) • Effluent turbidity ≤2 NTU, if annual average of daily maximum raw is >10 NTU (chosen from 4 hour readings)
<u>Filtration</u> Evaluate the 95% of daily maximum readings for the most recent twelve months. Daily maximum data points should be chosen from 4-hour readings.	• Continuous, stable performance regardless of variations in raw and settled water quality. • Effluent turbidity ≤0.10 NTU
<u>Filtration Backwash Recovery</u> Evaluate individual filter profiles. Time period should bracket backwash at normal filter run time.	• With filter-to-waste capability: Return to service when turbidity ≤0.10 NTU. A healthy filter should recover to ≤0.10 NTU within 15 minutes following a backwash with no spikes >0.30 NTU during the filter-to-waste period • Without filter-to-waste capability: Maximum turbidity spike of <0.30 NTU and recover to ≤0.10 NTU within 15 minutes

FILTER PLANT PERFORMANCE EVALUATION REPORT

At the conclusion of the evaluation, the district sanitarian, regional engineer, and regional FPPE staff will discuss apparent facility problems and serious conditions. Any violations, especially **<u>imminent threat violations</u>,** and possible approaches to improve the system's performance will be noted by the sanitarian.

At a later date, after all information has been obtained, regional FPPE staff will prepare a final report. This report, along with the laboratory's analysis findings, will be sent to the appropriate district supervisor, regional technical services section chief, regional manager, sanitarian, regional engineer and central office FPPE staff. The following sections should be included in the report:

<u>INTRODUCTION:</u>

- facility background information

<u>PLANT SCHEMATIC:</u>

<u>TREATMENT PROCESS INFORMATION:</u> (This is what we expect to see at the plant)

- Plant Production

- Withdraw Allocations
- Treatment Chemicals
- Mixing
- Flocculation and Sedimentation
- Filtration
- Storage
- Lab and Process Monitoring Equipment
- Alarms
- Operator Certification – current # of certified and uncertified operators

<u>PROCESS OBSERVATIONS:</u> (This is what we found during the evaluation)

- Source
- Treatment Chemicals
- Coagulant Control Strategy
- Mixing
- Coagulation/Flocculation/Sedimentation
- Filtration
- Annual Raw, Settled and Finished Turbidity Data Charts
- Individual Filter Profiles showing turbidity and particle count data
- Recycle/Waste Handling
- Filter Backwash Rule Compliance
- Storage
- Disinfection
- Disinfection Profile if available

- Disinfection Byproducts
- Operation and Maintenance
- Other (leak detection, flushing, dead ends, unaccounted water loss, etc.)

(COMMENTS SECTION:)

- Performance rating
- Areas of operational strength
- Items addressed and not addressed from any past FPPE Report
- Comments section format for 3 or more plant visits? Refer to specified "internal only" website for proper format guidance)
- New Comments

WATER QUALITY DATA AND EVALUATION INFORMATION: (Attach at end of report)

MPA RESULTS: (Attach at end of report)

FILTER MEDIA SIEVE ANALYSIS RESULTS: (Attach at end of report)

ACID SOLUBILITY TEST RESULTS: (If applicable)

MICROSCOPIC PARTICULATE ANALYSIS RESULTS

The filtered MPA samples taken under the observed operating conditions will be evaluated by the Bureau of Laboratories to determine the nature, size, and density of the particulate matter. Samples will also be examined for the presence of *Giardia* and *Cryptosporidium*; and the Bureau of Laboratories will present all results in a report. This will become part of the final Filter Plant Performance Evaluation report. For further details, refer to the document called, "Interpreting the Microscopic Particulate Analysis."

When filtered MPA results show that the filter is not effective in removing sufficient quantities of *Giardia*-sized or *Cryptosporidium*-sized microscopic particulates, the following notifications and responses should occur:

- The Bureau of Laboratories staff will immediately inform regional FPPE staff, via telephone, when their **preliminary** MPA findings show that the filter plant, based on the sample analysis, is not effective in removing sufficient quantities of *Giardia*-sized or *Cryptosporidium*-sized microscopic particulates. This will give regional FPPE staff advanced notice so they may notify appropriate regional, district, and central office staff and prepare for the conference call that will occur when the final MPA results are available. It may be necessary for all involved to share their after hours contact information in case the final results come late in the day.

- The Bureau of Laboratories staff should take digital photos that may be helpful in demonstrating that large particles and organisms are passing through the plant's treatment processes. The photos can be shared with the regional FPPE staff by email. It is helpful to compare the size of the particles and organisms that were found in filter effluent to the *Giardia* and *Cryptosporidium* sized particles that a properly-operated plant should remove. The photos also provide a visual aid when communicating MPA results to water system officials.

- The Bureau of Laboratories staff will immediately inform regional FPPE staff when their **final** MPA results show that the filter plant, based on the sample analysis, is not effective in removing sufficient quantities of *Giardia*-sized or *Cryptosporidium*-sized microscopic particulates. In these cases, BOL staff should contact staff via telephone; e-mail is NOT an adequate notification method. If the Regional FPPE staff person is unavailable, then BOL should contact CO FPPS staff or the appropriate Regional SDW Program Manager.

- The regional FPPE staff will immediately conference with regional, district, and central office staff when the laboratory MPA results show that the filter plant, based on the sample analysis, is not effective in removing sufficient quantities of *Giardia*-sized or *Cryptosporidium*-sized microscopic particulates. Staff will review and discuss the filtered MPA results and onsite FPPE findings to determine if a breakdown in treatment occurred and whether a boil water advisory is needed.

- In situations where both the filtered MPA results and the FPPE findings show that a breakdown in treatment occurred, the appropriate response is to issue a boil water advisory and require Tier 1 public notice. Other situations, where findings are less definitive, should be discussed in detail as a BWA may still be needed.

- If a decision is made to issue a boil water advisory, then during the same conference call, a discussion should take place concerning the steps that are needed for lifting the boil water advisory. The decision to lift a boil water advisory should not hinge solely on the results of follow-up sampling. The primary operational and physical deficiencies that caused the breakdown in treatment in the first place should be corrected before follow-up sampling occurs and before consideration to lift the boil water advisory. An on-site visit to verify reported plant improvements and review applicable performance data should also occur prior to lifting the BWA. The long-term reliability and capability of the plant should be considered when determining follow-up actions. In addition, the distribution system should be flushed to remove any contaminated water and sampling should occur to demonstrate that the water is safe to drink. These steps often become part of the consent order agreement if one is issued.

- Elevated chlorine is often used in conjunction with a boil water advisory as an additional level of protection against viruses, bacteria, and some protozoan. However, elevated chlorine should not be used in lieu of a boil water advisory, because elevated chlorine does not protect against *Cryptosporidium* Oocysts.

- The regional and district regulatory enforcement staff should take the lead with regard to contacting the water supplier, issuing the boil water advisory and requiring the Tier 1 public notice.

- Regional FPPE staff should complete a Boil Water Advisory Summary Sheet after all requirements have been met and the boil water advisory has been lifted.

OTHER DEP PROGRAMS

Based on the needs of the water treatment plant, you may wish to refer a water system to another DEP program. The following programs may be able to provide assistance to the water plant administration, management, or certified operators. Please note that participation in these programs is voluntary. Also remember to include the DEP staff person who is responsible for the water system when referring a system to one of these programs.

THE WATER AND WASTEWATER ASSISTANCE AND OUTREACH PROGRAM: DEP uses peer-based trainers to provide on-site assistance to water and wastewater systems. The program employs the services of the best municipal water and wastewater professional operators in the state. Many of these certified operators are the best specialists in specific treatment areas. For more information, visit DEP website at www.dep.pa.gov.

CAPABILITY ENHANCEMENT PROGRAM: Created in response to requirements in the 1996 Amendments to the Safe Drinking Water Act, this program is designed to ensure the long-term technical, managerial, and financial capability of Pennsylvania's public drinking water systems. In cooperation with the drinking water system, an implementation plan would be developed to identify the type of assistance needed, who the provider would be, and a timeline for implementation. The Capability Enhancement Facilitator assigned to the system would then insure that the plan was completed.

Initially for the systems evaluated under the FPPE Program, the Outreach Program can provide technical assistance as needed to address any immediate operational or process control problems. Personnel in the Technical Services Section can also provide additional managerial and financial assistance to address budgeting and management issues identified in the FPPE. Once this "spot assistance" is provided, if the system would like to take advantage of any of the other assistance tools and providers available through the Capability Enhancement Program, they can contact the appropriate Capability Enhancement Facilitator. Examples of other assistance provided by the Capability Enhancement Program include leak detection, grant preparation, engineering services, and detailed business planning.

THE PARTNERSHIP FOR SAFE WATER PROGRAM: The Partnership for Safe Water is a voluntary, cooperative effort of six US organizations dedicated to safe water. The program represents a partnership between regulators and water utilities. Participants in the Partnership for Safe Water adopt proven operational and administrative practices designed to improve surface water treatment plant performance. For more information, visit the DEP website at www.dep.pa.gov.

REFERENCE DOCUMENTS

AwwaRF. 1997. *Self-Assessment Guide for Surface Water Treatment Plant Optimization*, 1997, AWWA Research Foundation and American Water Works Association.

AwwaRF. 2002. *Filter Maintenance and Operations Guidance Manual*, 2002, AWWA Research Foundation and American Water Works Association.

PADEP. 1992. *Pennsylvania's Action Plan for Cryptosporidium*, Rev. 2008

PADEP. 2000. Pennsylvania Code, Title 25 Environmental Protection, Chapter 109 Safe Drinking Water, Rev. 2010 (DEP's regulations concerning public water systems).

PADEP. 1993. *Filter Plant Performance Evaluation Interpreting The Microscopic Particulate Analysis*, 1993, Rev. 1998 (detailed information on interpreting MPA results).

PADEP. 1993. *Guidance for Giardia Sampling and Response,* January 1993, Rev. 1998 (information on sample collection methods for *Giardia*/MPA).

PADEP. 1993. *Reference Guide for Inspecting Public Water Systems*, October 1993 (detailed inspection items to check at water systems).

PADEP. 1991. *Filter Plant Performance Evaluation Response Strategy*, September 1991, Rev. 1994, 1998 (information on response to surface water treatment plant evaluations).

USEPA. 1999. *Guidance Manual for Compliance with the Interim Enhanced Surface Water Treatment Rule: Turbidity Provisions*, EPA 815-R-99-010, April 1999.

USEPA. 1991. *Guidance Manual for Compliance with the Filtration and Disinfection Requirements for PWSs Using Surface Water Sources*. March 1991, USEPA (information on CT levels, tracer studies, rule-of-thumb fractions).

USEPA. 1991. *Optimizing Water Treatment Plant Performance Using the Composite Correction Program*, February 1991, Rev. 1998, USEPA (comprehensive information on evaluating and correcting problems at filter plants).

ATTACHMENT 1: FORMULA SHEET

Weight Measurement
Cubic ft of water [50 F] x 62.4 = pounds of water (@ 32 F)
Gallons water [50 F] x 8.3453 = pounds of water
Pounds of water x 0.1198 = gallons (gals)
Pounds of water x 0.0166032 = cubic feet (ft^3)
Pounds of water x 0.454 = liters (L)
Pounds of water x 0.454 = kilograms (kg)
Pounds of water x 454 = grams (g)
Pounds of water x 454,000 = milligrams (mg)

Length Measurement
Inches x 0.8333 = feet (ft)
Inches x 2.54 = centimeters (cm)
Feet (ft) x 0.0348 = meters (m)
Meters (m) x 3.28084 = feet (ft)
Feet(ft) x 5280 = miles (mi)

Pressure Measurement
Feet of water x 0.8826 = inches of mercury
Feet of water x 0.4335 = lbs. per square inch (lb/in^2)(psi)
Feet of water x 62.43 = lbs. per square foot (lb/ft^2)
Pounds per square inch (lb/in^2)(psi) x 2.307 = feet of water

Volume Measurement
Cubic feet (ft^3) x 7.48052 = gallons (gal)
Cubic feet (ft^3) x 28.317 = liters (L)
Gallons (gal) x 0.1337 = cubic feet (ft^3)
Gallons (gal) x 3.785 = liters (L)

Area Measurement
Acres x 43,560 = square feet (ft^2)
Square feet (ft^2) x 144 = square inches (in^2)
Square feet (ft^2) x 0.09290 = square meters (m^2)
Square inches (in^2) x 0.00695 = square feet (ft^2)
Square miles (mi^2) x 640 = acres
Square miles (mi^2) x 27,880,000 = square feet (ft^2)
Square miles (mi^2) x 3,098,000 = square yards (yd^2)
Square yards (yd^2) x 9 = square feet (ft^2)

Flow Measurement
Cu ft/ second (ft^3/sec) x 448.831 = gallons per minute (gpm)
Cu ft/second (ft^3/sec) x 0.646317 = million gals per day (mgd)
Gallons/minute (gpm) x .00223 = cubic feet per second (ft^3/sec)
Gallons/minute (gpm) x 1440 = gallons per day (gpd)
Gallons/minute (gpm) x 0.00144 = million gals per day (mgd)
Million gal./day (mgd) x 694.4 = gallons per minute (gpm)
Million gal./day (mgd) x 1.54723 = cubic feet per second (ft^3/sec)

Concentration Measurements
Parts per million (ppm) = milligrams per liter (mg/L)
Percent solution x 10,000 = milligrams per liter (mg/L)
Milligrams/liter (mg/L) x 8.345 = pounds per million gallons (lb/mil gal)
Pounds / million gallons (lbs/mil gal) x 0.1198 = milligrams/liter (mg/L)
Pounds per gallon (lbs/gal) x 119947.15 = milligrams per liter (mg/L)
ml/min x 1440 x .0002642 = gallons per day(gal/day)
gal/day x lbs. of chemical per gallon = lbs/day
lbs/day divided by MGD divided by 8.34 = mg/L

Temperature Equivalents
0.555 (°F – 32) = degrees Celsius (°C)
(1.8 x °C) + 32 = degrees Fahrenheit (°F)
°C + 273.15 = degrees Kelvin (°K)
boiling point = 212°F, 100°C or 373°K
freezing point = 32°F, 0°C or 273°K

Volume Formulas
Sphere volume, ft^3 = (4 x ⑥ x (radius, ft)^3)/ 3
Cylinder volume, ft^3 = ⑥ x (radius, ft)^2 x height, ft
Rectangle volume, ft^3 = length, ft x width, ft x height, ft
Prism volume, ft^3 = area of base, ft^2 x height, ft
Cone volume, ft^3 = ⑥/ 3 x (radius)^2 x height, ft

Area Formulas
Sphere area, ft^2 = ⑥ (diameter, ft)^2
Cylinder area, ft^2 = 2 ⑥ (R)^2 + ((height, ft) x (⑥) x (diameter, ft))
Cone area, ft^2 = ⑥ x (slant height, ft) x (radius, ft)
Circle area, ft^2 = ⑥ (radius, ft)^2
Triangle area, ft^2 = ½ base, ft x height, ft
Rectangle area, ft^2 = length, ft x width, ft

Other formulas

Detention time, (min) = $\frac{\text{(volume, gal)}}{\text{(flow, gpm)}}$ or $\frac{\text{(volume, gal)}}{\text{(flow, mgd)(694.4, gpm/mgd)}}$

Surface overflow rate, (gpm/ft^2) = $\frac{\text{(flow, gpm)}}{\text{(length, ft)(width, ft)}}$

Filtration rate, (gpm/ft^2) = $\frac{\text{(flow, gpm)}}{\text{(surface area, ft}^2\text{)}}$

Dose, (mg/L) = $\frac{\text{(Chemical Feed, lbs/day)}}{\text{(Flow, mgd)(8.34 lbs/gal)}}$

Volume of a water main, (gal/ft) = .0408 x (diameter, inches)^2

Backwash rate 1 gpm/ft^2 = 1.6 inch/minute rise

Particle Counter - 2400P
- Flow rate must be 100 ml/minute
- Cell percentage should be >85%
- Clean sensor with brush and Liquinox after each evaluation

Surface Overflow Rates

Rectangular/Circular/Contact-	>14 ft	0.7 gpm/ft^2
	12 – 14 ft	0.6 gpm/ft^2
	10 – 12 ft	0.5 – 0.6 gpm/ft^2
	<10 ft	0.1-- 0.5 gpm/ft^2
Verticle (>45°) tube settlers	>14 ft	2.0 gpm/ft^2
	12 – 14 ft	1.5 gpm/ft^2
	10 – 12 ft	1.0 – 1.5 gpm/ft^2
	<10 ft	0.2 – 1.0 gpm/ft^2
Horizontal (<45°) tube settlers		2.0 gpm/ft^2
Adsorption clarifier		9.0 gpm/ft^2
Lamella Plates		4.0 gpm/ft^2
SuperPulsator		1.5 gpm/ft^2
With tubes		1.7 gpm/ft^2
Claricone	1.0 gpm/ft^2	

Filtration Rates

Sand media-	2.0 gpm/ft^2
Dual/Mixed media-	4.0 gpm/ft^2
Deep bed-	6.0 gpm/ft^2

Optimization Goals
Filter effluent turbidity $\leq$0.1 NTU
Filter effluent Particle Counts <10 particles/ml (>=3 micron)
Settled turbidity $\leq$2 NTU if raw water turbidity is >10 NTU
Settled turbidity $\leq$1 NTU if raw turbidity is <10 NTU
Filtered turbidity following backwash $\leq$0.3 NTU
Filters recover to $\leq$0.1 NTU within 15 min. after a backwash
Media expansion should be 20-30% on a clean filter

ATTACHMENT 2: WATER QUALITY DATA AND EVALUATION INFORMATION

Plant Name: ____

WATER QUALITY DATA AND EVALUATION INFORMATION

Filter Plant Performance Evaluation Team	Organization/Location	Title

Persons Accompanying Evaluators	Organization	Title

MPA Sample Collection Site Information

On-Site Water Quality Parameters

Date:

Parameter ↓ / *Location* →	*Raw*	*Coagulated*	*Settled*	*Filtered #1*	*Filtered #2*	*Clearwell*
Temp (°C)						
pH						
Turbidity (NTU)						
Alkalinity (mg/L)						
Free Cl_2 (mg/L)						
Iron (mg/L)						
Mn (mg/L)						
TDS (mg/L)						
Low Level Bromide (ug/L)						
Fluoride (mg/L)						

Comments:

ATTACHMENT 3: MICROSCOPIC PARTICULATE ANALYSIS LAB FORM

MICROSCOPIC PARTICULATE ANALYSIS LAB FORM

Request for Microscopic Particulate Analysis
Request for Filter Media Evaluation
Request for Raw Method 1623

Public Water Supply:	**PWSID#:**
Type of Filtration System:	**Collector:**

Raw Water	**Finished Water**	
Sample Number:	**Sample Number:**	
Source/Sample Site:	**Sample Site:**	
	Date Collected:	
Date Collected:	**Start Time:**	**Stop Time:**
Collection Time:	**Gallons (500-2000):**	
Raw Turbidity (ntu):	**Average Turbidity (ntu):**	
pH:	**pH:**	
Temperature:	**Temperature:**	
	Free Cl_2 (mg/L):	
	Fixed: Yes or No	
	Filter Backwashed: Yes or No	

Pretreatment:

Preliminary Operations Rating: Commendable Satisfactory Needs Improvement

Filter Media Information (>200 grams)

Filter Number:	**Media Type:**	**Sample Number:**	**Date:**

System Deficiencies/Comments:

ATTACHMENT 4: FILTER MEDIA CRITERIA

Characteristic	Filter Media Criteria for Sand and Anthracite
Effective size	within 10 percent of original specifications
Uniformity coefficient	<1.7; preferably around 1.3 (< 2.2 for high-density sand)
Acid solubility	<5 percent weight loss
Filter media depth	within 1 to 2 inches of original media depth
Media shape	jagged with no obvious rounding

Please reference AWWA B604 for Granular Activated Carbon (GAC) criteria.

<u>Definitions</u>

Effective size: The size opening that will just pass 10 percent (by dry weight) of a representative sample of the filter material; that is, if the size distribution of the particles is such that 10 percent (by dry weight) of a sample is finer than 0.45 mm, the filter material has an effective size of 0.45 mm.

Uniformity coefficient: A ratio calculated as the size opening that will just pass 60 percent (by dry weight) of a representative sample of the filter material divided by the size opening that will just pass 10 percent (by dry weight) of the same sample.

Acid solubility: The acid-solubility test is performed by immersing a know weight of material in 1:1 hydrochloric acid (HCl) (made by combining equal volumes of 1.18 specific gravity HCl and H2O) until the acid-soluble materials are dissolved, then determining the weight loss of the material.

Media Coating Analysis: If the media's Acid Solubility is > 5%, the acid containing the soluble coating is then analyzed for concentrations of Aluminum, Manganese, Iron and Calcium. The purpose of this test is to identify the minerals that make up the media coating.

ATTACHMENT 5: CT INSTRUCTIONS

FOR FILTER PLANT PERFORMANCE EVALUATION PROGRAM

The objective of these instructions is to help DEP field staff and certified operators to do “Log inactivation” calculations (of *Giardia* cysts) at surface water treatment plants that use free chlorine as a disinfectant. These instructions, also walk you through the steps for creating a disinfection profile and a disinfection benchmark.

Disinfection profiling and benchmarking is critical for optimized operation of surface water treatment plants as well as determining compliance with PA Safe Drinking Water Regulations. “Log Inactivation” calculations are the key component of this type of profiling. See attachment C for a further explanation of disinfection profiling and disinfection benchmarking, as well as their application in drinking water treatment.

The following page is entitled ***Basic Instructions for Calculating “Log Inactivations*”**. This page provides a simplified 11-step outline of the process required to calculate log inactivations, also known as “CT calculations”, for surface water treatment plants disinfecting with chlorine. Note that this one page outlines the entire process; therefore, it is possible to successfully calculate log inactivation using only this page. However, due to the complexity of the process, many users may find difficulty in completing one or more of the steps. Therefore, additional instructions have been included to further explain each of the eleven steps. Notes and additional instructions referenced by number for a particular step can be found in the pages following the Basic Instructions page. Following the additional instructions is a one-page example, which summarizes the entire process using data from “XYZ Water Plant.”

Also included is a blank example “Disinfection Profiling Data Sheet” (see attachment ”A”) on which you can enter the log inactivation values of your individual disinfection segments. In addition, we have included a “Disinfection Benchmarking Data Sheet” (see attachment B) on which you can enter your average daily log inactivation for each month of the year. The disinfection benchmark is defined as, the lowest monthly average inactivation level in the disinfection profile. [2]

The following instructions were designed for those who either do not have access to a computer. However, for those who are interested, an electronic Disinfection Profiling Spreadsheet titled “Profile-Calculator” is also available from USEPA. This spreadsheet can be accessed via the Internet at.

Please note that the following instructions only check for *G. lamblia* inactivation with chlorine; they do not include an analysis for viruses or other disinfectants.

Basic Instructions for Calculating
"Log Inactivations":

1) Enter the system's **peak hourly flow rate** ________________________ (*gpm).*

**See "Notes for steps 2,3 & 4" located on the following page under "additional instructions" before performing these steps.*

2) Enter the **effective volume** of the disinfection segment ________________________ (*gal*).

If tracer study data exists, you can skip steps 3 & 4 and enter the T10 value of the tracer study on line 5.

3) Enter the **baffling factor** for the disinfection segment ________________________.

4) Multiply the effective volume on line 2 by the baffling factor on line 3 to get the **corrected volume** and enter the result here ________________________ (gal).

5) Divide the corrected volume on line 4 by the peak hourly flow rate on line 1 to get the **T10 value**. Enter your results here __ (min).

6) Enter the **free chlorine residual** concentration for the disinfection segment ______________________ (*mg/L*). **C**

7) Multiply the T10 value on line 5 by the C value on line 6 to get the **CTactual** value. Enter the results here ___________________________.

8) Enter the **pH** value for the disinfection segment _______________________.

9) **Enter the** temperature **for the disinfection segment __________________________.** ***(°C)***

10) Using the chlorine residual from line 6, the pH from line 8 and the temperature from line 9, determine the **CT1-log *Giardia*** value from the tables located under *Additional Instructions for Step #10*. Enter the value here _______________________________.

11) Divide CT actual from line 7 by CT1-log *Giardia* from line 10 to get the "**log**" **inactivation value**. Enter the results here __________________________.

Enter the log inactivation value, from line 11, to your system's data sheet. A blank example "Disinfection Profiling Data Sheet" is provided – Attachment A.

Repeat steps 1-11 for each disinfection segment. To get total log inactivation, add the log inactivations of all functioning disinfection segments together.

Additional Instructions

Step #1 **(Peak Hourly Flow Rate)**

The peak hourly flow occurs when the greatest volume of water flows through the system during any one hour in a 24 hour period. [2] This value must be in gallons per minute (gpm). To convert gallons per day (gpd) to gpm divide by 1440. To convert million gallons per day (MGD) to gpm multiply by 694.4.

For example: If a plant is producing 700,000 gpd during its peak hour of production the peak flow is 700,000 ÷ 1440 or 486 gpm. You could also say that this same plant produces .7MGD; in this case the peak flow is .7 x 694.4 or 486 gpm. Round any decimals to the nearest whole number.

Notes for Steps 2, 3, & 4

A disinfection segment begins at the point of disinfection application and ends at the disinfection residual sampling point. This sampling point is located just prior to the next disinfection application point. For the last disinfection segment, the sampling point is located at or before the entrance to the distribution system or the first customer.

For disinfection segments containing multiple basins with different baffling factors, multiply the effective volume of each basin by its corresponding baffling factor to get the corrected volume. Add the corrected volumes of each basin together and enter the results on line 4.

Step #2 (Calculating Effective Volume)

The effective volume of the disinfection segment refers to the volume of a basin or pipeline that is available to provide adequate contact time for the disinfectant. Effective volumes are calculated based on worst case operating conditions using the minimum operating depths, in the case of basins. This is especially critical in plants where high service pumps significantly change the operating levels of the clearwell and in plants that use backwash systems supplied from the clearwell [1]. *Choose the formula below which represents the disinfection segment for which you wish to calculate effective volume; then, simply plug in the dimensions and work through the equation. Note that your final answer must be in gallons.*

A. Rectangular Contactor (l x w x d)

1) Enter length _________(ft). **l**
2) Enter width _________(ft). **w**
3) Enter depth of water __________ (ft). **d**
4) Multiply the length on line 1 by the width on line 2 by the depth on line 3 to get the volume in cubic feet ______________(ft^3).
5) Multiply the volume in cubic feet on line 4 by 7.48 gal/ft^3 to get effective volume in gallons ___________ (gal). *Round any decimals to the nearest whole number; enter this value on line two of the Basic Instructions sheet.*

B. Cylindrical Contactor (**π r^2 d**)

1) π = 3.14
2) Enter radius _________ (ft). **r**
3) Multiply line 2 by line 2 to get **r^2**. Enter the results here ________________ (ft^2). **r^2**
4) Enter depth of water ______________ (ft). **d**
5) Multiply 3.14 by **r^2** on line 3 then multiply by the depth on line 4 to get the volume in cubic feet. Enter the results here ________________ (ft^3).
6) Multiply the volume in cubic feet on line 5 by 7.48 gal/ft^3 to get effective volume in gallons ___________ (gal). *Round any decimals to the nearest whole number; enter this value on line two of the Basic Instructions sheet.*

C. Pipeline **(.0408 x d^2)**

1) Enter the pipe diameter here ______________ (inches). **d**
2) Multiply line 1 by line 1 to get **d^2**. Enter the results here ________________ ($in.^2$). **d^2**
3) Multiply the **d^2** on line 2 by .0408 to get gallons per foot. Enter the result here _________ (gal/ft).
4) Multiply the number of feet in your pipeline by line 3 to get the effective volume of your pipeline ________________ (gal.). Note: There are 5,280 ft. in a mile. *Round any decimals to the nearest whole number; enter this value on line two of the Basic Instructions sheet.*

Step #3 (Determining Baffling Factor)

Tracer studies provide the most accurate information about disinfection contact times. If tracer studies are used, make sure that the T_{10} value from your tracer study coincides with your peak hourly flow rate. For those plants where tracer studies have not been conducted, the volume upon which contact time will be determined can be calculated by multiplying the effective volume, calculated on line two, by a factor (the baffling factor). These volumes are based on worst case operating conditions. For example, an unbaffled clearwell may have an effective volume of only 10 percent (factor = 0.1) of actual basin volume because of the potential for short-circuiting; whereas, a transmission line could be based on 100 percent of the line volume because of the plug flow characteristics. A summary of factors to determine corrected volume is presented in the table below. Typically, for unbaffled clearwells a factor of 0.1 has been used because of the fill and draw operational practices (e.g., backwashing, demand changes). A factor of 0.3 has been used when calculating the corrected volume of flocculation and sedimentation basins when rating prechlorination, and a factor of 1.0 has been used for pipeline flow. However, each disinfection system must be assessed on individual basin characteristics, as perceived by the evaluator. Caution is urged when using a factor, from the table below, of greater than 0.1 to project additional disinfection capability for unbaffled basins. [1] *Use your discretion to choose a number from the factor column of the table below and enter this value on line three of the Basic Instructions sheet.*

*Factors for Determining Effective Disinfection Contact Time Based on Disinfection Segment Characteristics:

Baffling Condition	Factor	Baffling Description
UNBAFFLED	0.1	None; agitated basin, high inlet and outlet flow velocities, variable water level
Poor	0.3	Single or multiple unbaffled inlets and outlets, no intra-basin baffles
Average	0.5	Baffled inlet or outlet with some intra-basin baffling
Superior	0.7	Perforated inlet baffle, serpentine or perforated intra-basin baffles, outlet weir or perforated weir
Excellent	0.9	Serpentine baffling throughout basin
Perfect (plug flow)	1.0	Pipeline flow
*Based on hydraulic detention time at minimum operating depth.		

[1]

Step #4 **(Corrected Volume)**

Line two x Line three

For example, if a clearwell holds 90,000 gallons and the baffling factor is 0.1, the corrected volume is 90,000 gal x 0.1 or 9,000 gal. Round any decimals to the nearest whole number.

Step #5 **(T10 value)**

T10 represents the time that 90 percent of the water, including the microorganisms within the water, will be exposed to disinfection within the disinfectant contact chamber. [2]

(Line 4) / (Line 1) = T10 or $\frac{\text{Line 4}}{\text{Line 1}} = \text{T10}$

For example, if a clearwell has a corrected volume of 9000 gal and the peak hourly flow rate is 486 gpm, the T10 value would be 9000 gal /486 gpm or 19 min. Round any decimals to the nearest whole number.

Step #6 **(Free Chlorine Residual Concentration)**

The free chlorine residual concentration is the amount of chlorine in the water that has not reacted/combined with any organic materials or compounds. This is different than total chlorine residual which is the sum of the combined and free chorine residuals. The free chlorine residual must be sampled at the end of each disinfection segment, preferably during the peak hourly flow. Installation of a continuous chlorine analyzer and chart recorder after each disinfection segment may be required by your regional DEP office. *Note that both pH and temperature values will need to be recorded at this same sampling point; these values will be needed for later reference [2]. This number must be in milligrams per liter (mg/L). Note that parts per million (ppm) is equal to mg/L. Always round this value down to the nearest tenth. For example, 1.09 mg/L would be rounded down to 1.0 mg/L and 1.79 mg/L would be rounded down to 1.7 mg/L.*

Step #7 **(CT actual value)**

(line 5) (line 6) = CT actual or Line 5 **X** Line 6 = CT actual

For example, if a clearwell has a T10 value of 1 minutes and a holds a free chlorine residual of 1.3 mg/L, then the CT actual is 19 x 1.3 or 24.7 mg/L-min. Round results so that only one number appears after the decimal.

***Step #8* (pH)**

pH should be measured at the same sampling point as the free chlorine residual. [2] Always round the pH value up to the nearest .5 or .0 - *For example a pH of 7.2 should be recorded as 7.5; and, a pH of 6.7 should be recorded as 7.0.*

***Step #9* (Temperature)**

Temperature should be measured at the same sampling point as the free chlorine residual. Always round the temperature value down to the nearest of the following values: 5°C, 10°C, 15°C, 20°C, or 25°C [1]. For example, a temperature of 13°C would be recorded as 10°C. Any temperature that is less than 5°C should be recorded as <=0.5°C. Note that the temperature must be recorded in °C. To convert Fahrenheit to Celsius, subtract 32 and then multiply by 0.555; or 0.555(°F – 32) = °C. *For example, if your water temperature is 47°F, you would have 0.555(47-32) = 8.3°C, which would be rounded down to 5°C.*

***Step #10* (Determining $CT_{1\text{-log } \textit{Giardia}}$)**

The tables located on the next page are arranged in order of increasing temperature (°C). To use these tables, begin by locating your temperature (from line nine) on the top of one of the tables. On this same table, locate your pH value (from line eight). Make a light pencil mark through the entire column below your pH. Next, locate your chlorine residual concentration (from line six). To be conservative, choose from the chart a chlorine residual that is rounded to the next highest even tenth. For example, if your chlorine residual was 1.2 mg/L, choose 1.2 mg/L from the chart. If your chlorine residual was 1.1 mg/L, choose 1.2 mg/L from the chart. Make a light pencil mark through the entire row located to the right of your chlorine concentration. Finally, follow both pencil lines until the two intersect. This is your $CT_{1\text{-log } \textit{Giardia}}$ value, *enter this value on line ten of the Basic Instructions sheet. Interpolation between values listed on this chart is allowed. Therefore, if you are familiar with the process of interpolation and wish to do so, you may.*

Step #11

Line 7 ÷ Line 10 or $\frac{\text{Line 7}}{\text{Line 10}}$

Round results so that only two numbers appear after the decimal. For example, if the **CTactual** *is 120 and the $CT_{1\text{-log } Giardia}$ is 43, then the log inactivation is 120 ÷ 43 = 2.79 logs*

CT Values for 1-Log Inactivation of *Giardia* Cysts by Free Chlorine

Chlorine Concentration (mg/L)	Temperature <=0.5°C							Temperature =5°C							Temperature = 10°C						
	pH							pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	46	54	65	79	92	110	130	32	39	46	55	66	79	93	24	29	35	42	50	59	70
0.6	47	56	67	80	95	114	136	33	40	48	57	68	81	97	25	30	36	43	51	61	73
0.8	48	57	68	82	98	118	141	34	41	49	58	70	84	100	26	31	37	44	53	63	75
1	49	59	70	84	101	122	146	35	42	50	60	72	87	104	26	31	37	45	54	65	78
1.2	51	60	72	86	104	125	150	36	42	51	61	74	89	107	27	32	38	46	55	67	80
1.4	52	61	74	89	107	129	155	36	43	52	62	76	91	110	27	33	39	47	57	69	82
1.6	52	63	75	91	110	132	159	37	44	53	64	77	94	112	28	33	40	48	58	70	84
1.8	54	64	77	93	113	136	163	38	45	54	65	79	96	115	29	34	41	49	60	72	86
2	55	66	79	95	115	139	167	39	46	55	67	81	98	118	29	35	41	50	61	74	88
2.2	56	67	81	99	118	142	170	39	47	56	68	83	100	120	30	35	42	51	62	75	90
2.4	57	68	82	99	120	145	174	40	48	57	70	84	102	123	30	36	43	52	63	77	92
2.6	58	70	84	101	123	148	178	41	49	58	71	86	104	125	31	37	44	53	65	78	94
2.8	59	71	86	103	125	151	181	41	49	59	72	88	106	127	31	37	45	54	66	80	96
3	60	72	87	105	127	153	184	42	50	61	74	89	108	130	32	38	46	55	67	81	97

Chlorine Concentration (mg/L)	Temperature = 15°C							Temperature = 20°C							Temperature = 25°C						
	pH							pH							pH						
	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0	<=6.0	6.5	7.0	7.5	8.0	8.5	9.0
<=0.4	16	20	23	28	33	39	47	12	15	17	21	25	30	35	8	10	12	14	17	20	23
0.6	17	20	24	29	34	41	49	13	15	18	21	26	31	36	8	10	12	14	17	20	24
0.8	17	20	24	29	35	42	50	13	15	18	22	26	32	38	9	10	12	15	18	21	25
1	18	21	25	30	36	43	52	13	16	19	22	27	33	39	9	10	12	15	18	22	26
1.2	18	21	25	31	37	45	53	13	16	19	23	28	33	40	9	11	13	15	18	22	27
1.4	18	22	26	31	38	46	55	14	16	19	23	28	34	41	9	11	13	16	19	23	27
1.6	19	22	26	32	39	47	56	14	17	20	24	29	35	42	9	11	13	16	19	23	28
1.8	19	23	27	33	40	48	58	14	17	20	25	30	36	43	10	11	14	16	20	24	29
2	19	23	28	33	41	49	59	15	17	21	25	30	37	44	10	12	14	17	20	25	29
2.2	20	23	28	34	41	50	60	15	18	21	26	31	38	45	10	12	14	17	21	25	30
2.4	20	24	29	35	42	51	61	15	18	22	26	32	38	46	10	12	14	17	21	26	31
2.6	20	24	29	36	43	52	63	15	18	22	27	32	39	47	10	12	15	18	22	26	31
2.8	21	25	30	36	44	53	64	16	19	22	27	33	40	48	10	12	15	18	22	27	32
3	21	25	30	37	45	54	65	16	19	23	28	34	41	49	11	13	15	18	22	27	32

"Summary Example for XYZ Water Plant"

1) Enter the system's **peak hourly flow rate <u>1,076</u>** (*gpm).*
(1.55 MGD) (694.4) = 1,076.32 gpm = 1,076 gpm

2) Enter the **effective volume** of the disinfection segment **<u>240,018</u>** (*gal*).
Rectangular clearwell (66.85')(40')(12') = 32,088 cu. ft.
32.088 cu. ft. (7.48 gal/cu. ft.) = 240,018.24 gal = 240,018 gal.

3) Enter the **baffling factor** for the disinfection segment **<u>.5</u>** .
Baffled inlet with some ultra basin baffling

4) Multiply the effective volume on line 2 by the baffling factor on line 3 to get the **corrected volume** for the disinfection segment and enter the result here **<u>120,009</u>** (*gal*).
(240,018 gal) (.5) = 120,009 gal.

5) Divide the corrected volume on line 4 by the peak hourly flow rate on line 1 to get the **T10** value. Enter your result here **<u>112</u>** (*min*).
(120,009 gal)/(1,076 gpm) = 111.5 = 112

6) Enter the **free chlorine residual** concentration for the disinfection segment **<u>1.3</u>** (*mg/L*). **C**
1.31 rounded down to 1.3 mg/L

7) Multiply the T10 value on line 5 by the C value on line 6 to get the **CTactual** value. Enter the results here **<u>145.6</u>** .
(112 min)(1.3 mg/L)= 145.6

8) Enter the **pH** value for the disinfection segment **<u>8.5</u>**.
8.3 rounded up to 8.5

9) **Enter the** temperature **for the disinfection segment** 10 ***(°C*).**
12 °C rounded down to 10 °C

10) Using the chlorine residual from line 6, the pH from line 8 and the temperature from line 9, determine the **$CT_{1\text{-log } \mathit{Giardia}}$** value from the tables located under *Additional Instructions for Step #10*. Enter the value here **<u>69</u>**.
10°C, 8.5 pH, 1.3 mg/L chlorine residual (round to 1.4 to be conservative)

10) Divide CTactual from line 7 by CT1-log $_{\mathit{Giardia}}$ from line 10 to get the **"log" inactivation value**. Enter the results here **<u>2.1</u>**. This is your **"log" inactivation value.**
(145.6)/(69)= 2.1

Attachment A:

"Disinfection Profiling Data Sheet" **Month: _______________**

System Name: ____ **PWSID: ______________**

Date	Total Log Inactivation	Log inactivations for Individual Disinfection Segments											
		#1	#2	#3	#4	#5	#6	#7	#8	#9	#10	#11	#12
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													
21													
22													
23													
24													
25													
26													
27													
28													
29													
30													
31													
Ave-rage	*	*Enter this value in the average daily inactivation column on the Disinfection Benchmarking Data Sheet.											

Attachment B:

"Disinfection Benchmarking Data Sheet" **Year: ________________**

System Name: ____ **PWSID: ______________**

Month	Average Daily Inactivation
January	
February	
March	
April	
May	
June	
July	
August	
September	
October	
November	
December	
Benchmark	

At the end of each month, enter the average daily log inactivation value from the Disinfection Profiling Data Sheet. The disinfection benchmark is the lowest value from the daily log inactivation column. This value should be greater than or equal to 1 log, since DEP requires at least 1 log inactivation through disinfection. If a water system develops a disinfection profile and decides to make a significant change to its disinfection practice, it must contact DEP. Significant changes include: moving the point of disinfection, changing the type of disinfectant, changing the disinfection process, or making any other change designated as significant by DEP. For further explanation refer to attachment C.

Attachment C:

Further Explanation of Disinfection Profiling and Disinfection Benchmarking

EPA defines a disinfection profile as a compilation of daily *Giardia* and/or virus log inactivations over a period of a year or more. Inactivations of pathogens are typically reported in orders of magnitude, on a logarithmic scale. In other words, a 1-log inactivation corresponds to a 90 percent inactivation, a 2-log inactivation corresponds to a 99 percent inactivation, and 3-log inactivation corresponds to a 99.9 percent inactivation.

Disinfection benchmarking is a baseline or benchmark of historical microbial inactivation practices developed from disinfection profiling data. The benchmark is the lowest monthly average inactivation level in the disinfection profile, or the average of the lowest month in each year for multi-year profiles. It is determined from interpretation and analysis of the disinfection profile. This benchmark value identifies the lowest log inactivation that a system has achieved over a period of time. The benchmark sets the target disinfection level for alternative disinfection schemes. If a water system develops a disinfection profile and subsequently decides to make a significant change to its disinfection practice, it must consult with DEP. Significant changes include:

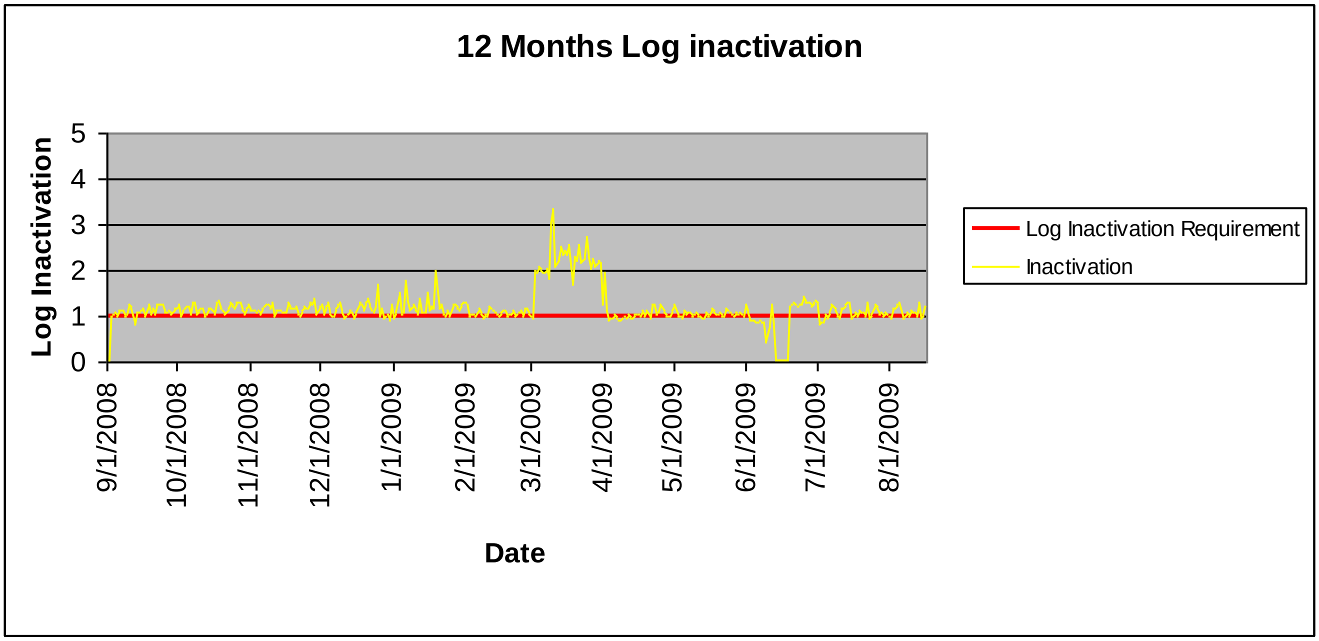
- Moving the point of disinfection
- Changing the type of disinfectant
- Changing the disinfection process
- Making any other change designated as significant by DEP. [3]

For an expanded explanation of profiling and benchmark, you may refer to EPA Guidance Manual, Disinfection Profiling and Benchmarking. The document number is EPA 815-R-99-013. EPA Guidance Manuals can be obtained free of charge from the Internet at https://nepis.epa.gov.

Attachment D:

Log Inactivation Chart

(Example)



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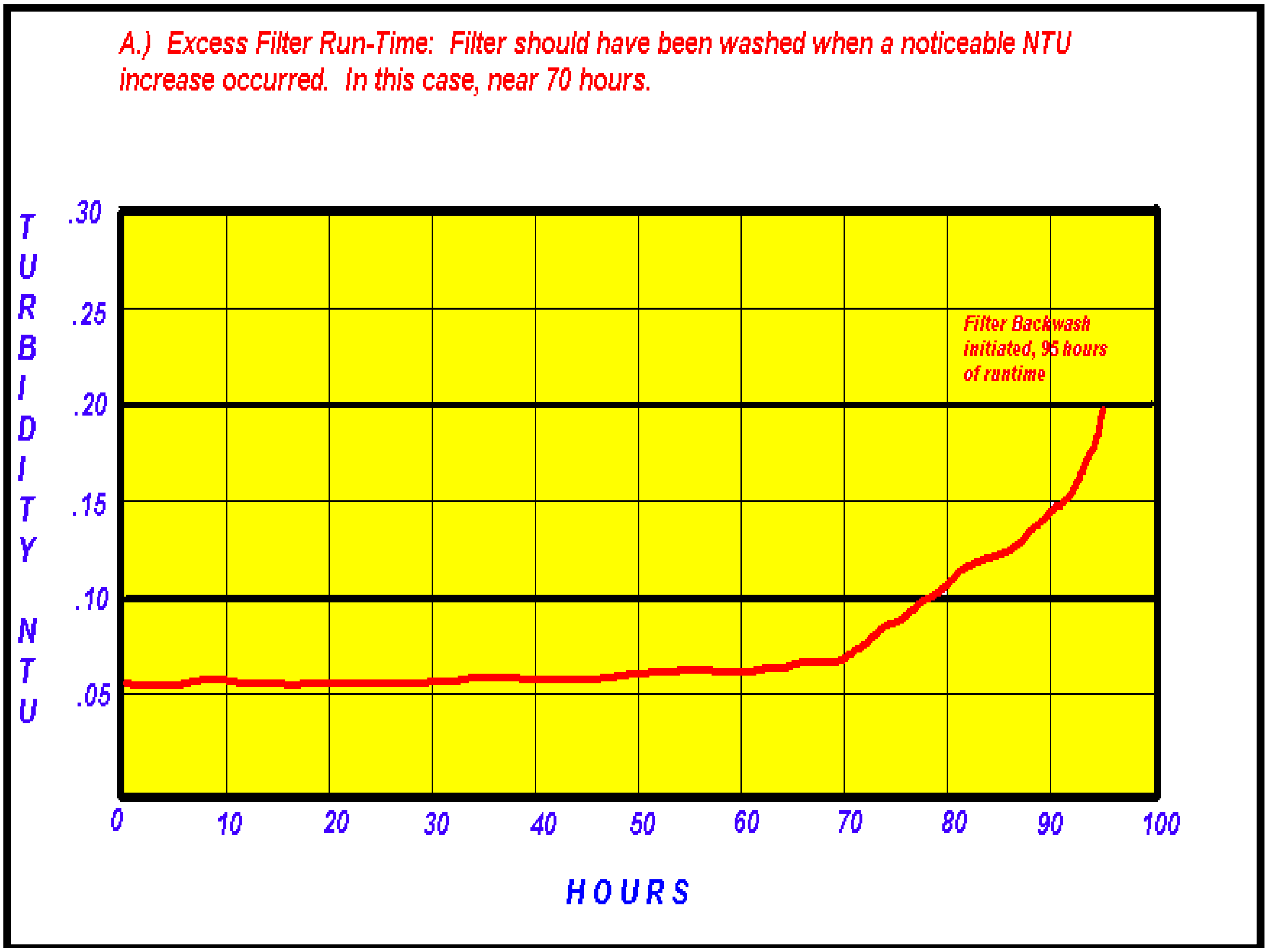
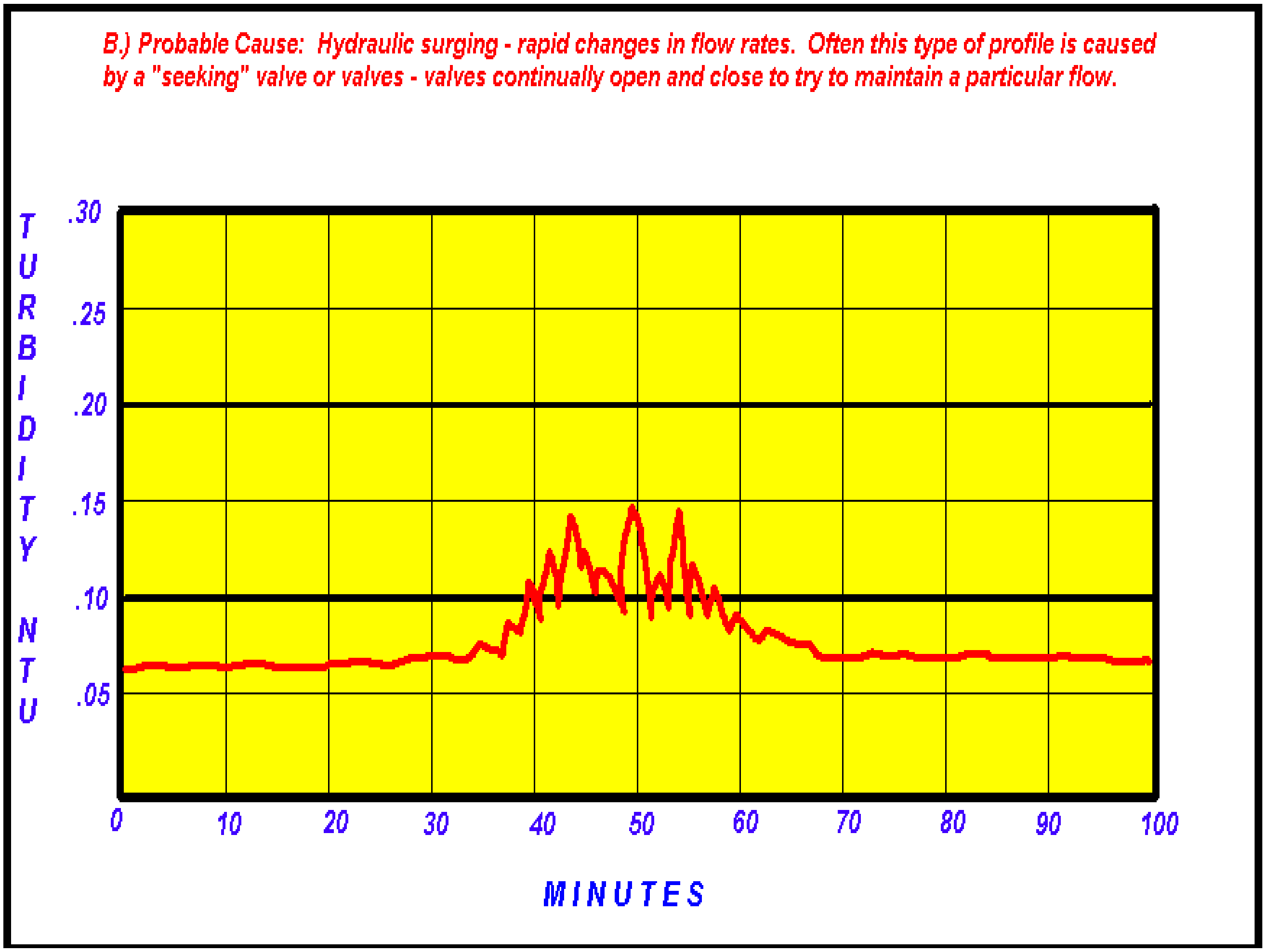
[1] Bob A. Hegg, Larry D. DeMers, Jon H. Bender, Eric M. Bissonette, and Richard J. Lieberman, EPA Handbook: Optimizing Water Treatment Plant Performance Using the Composite Correction Program, M. Lynn Kelly, Process Applications, Inc., Fort Collins, Colorado (1998) pp. 33-35, 135-141.

[2] United States Environmental Protection Agency Guidance Manual, Revised Draft, Disinfection Profiling and Benchmarking, (1998) Section 3, pp. 1-14.

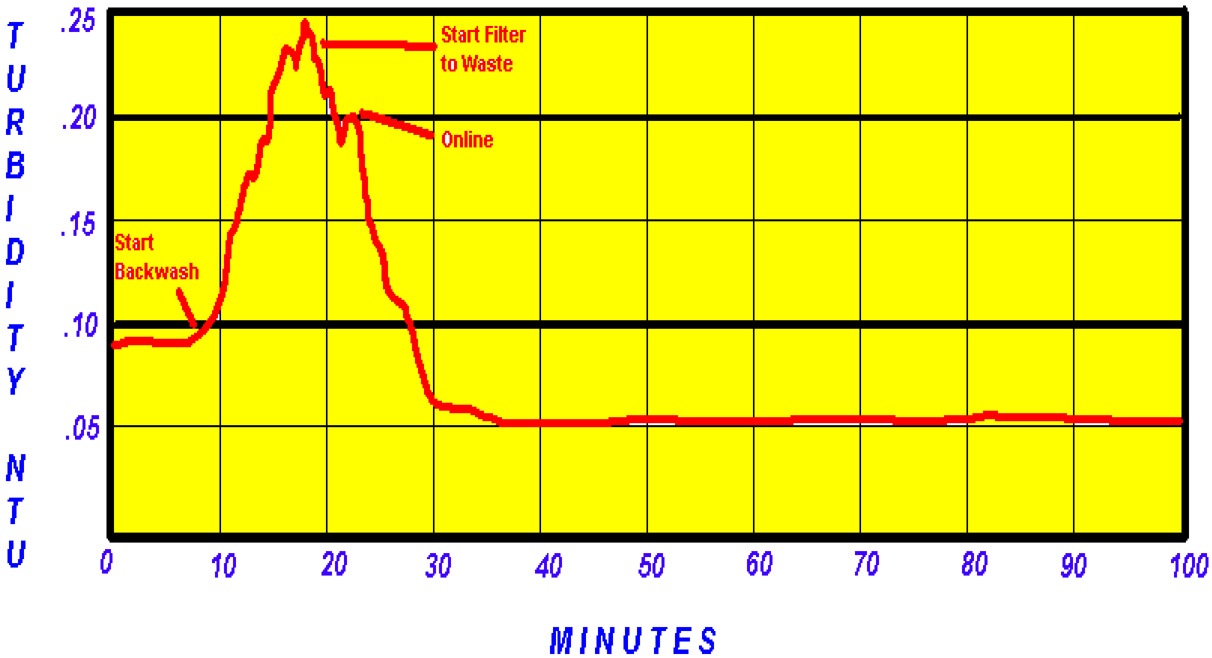
[3] United States Environmental Protection Agency Guidance Manual, Disinfection Profiling and Benchmarking Guidance Manual (1999) Sections 1-3, pp. 1-1 to 3-20.

ATTACHMENT 6: INTERPRETING FILTER PROFILES



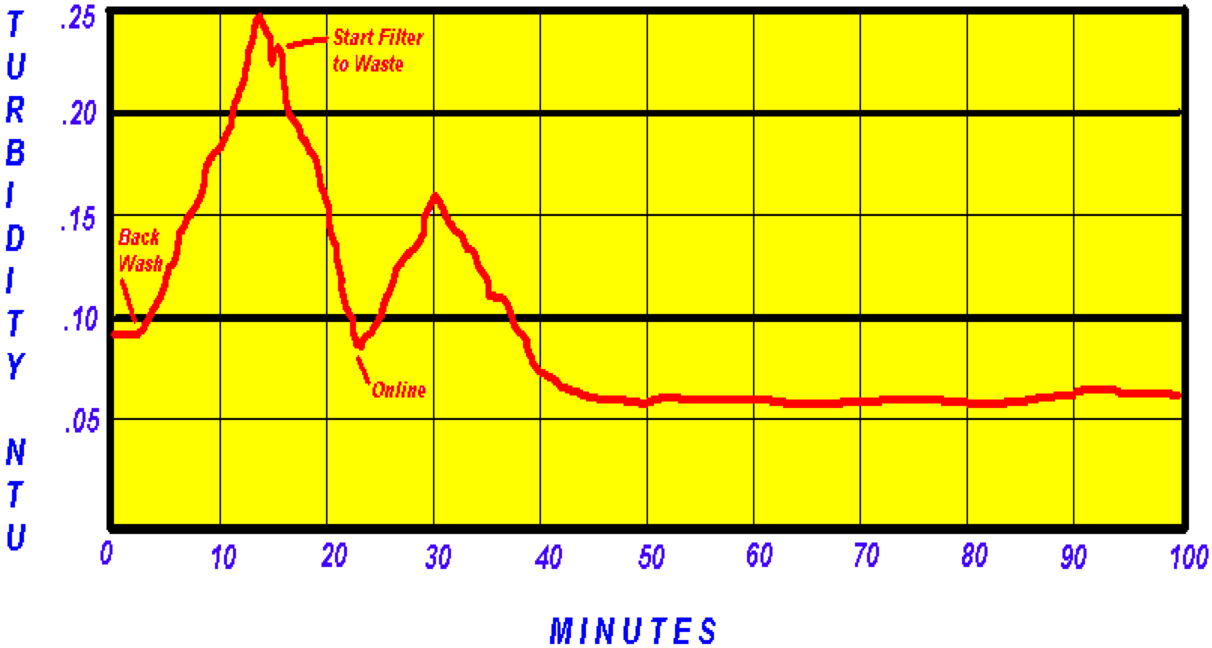

B.) Probable Cause: Hydraulic surging - rapid changes in flow rates. Often this type of profile is caused by a "seeking" valve or valves - valves continually open and close to try to maintain a particular flow.
TURBIDITY NTU
.30
.25
.20
.15
.10
.05
0
10
20
30
40
50
60
70
80
90
100
MINUTES

C.) Filter to Waste time too short: Extend until Turbidity is <.1NTU. The filter-to-waste time for this plant was about 6 minutes; extending the filter-to-waste time for another 6 minutes would have reduced the online turbidity to below .1NTU. It is important to note that many variables affect the amount of time needed for a filter to recover after backwashing. Consequently, it is likely that filter-to-waste times will often need to be adjusted. Therefore, when addressing the filter-to-waste component of a profile, do not tell the plant to extend filter to waste to 12 minutes. Rather, instruct operators to monitor turbidities and extend filter to waste until turbidities fall below the .1 NTU goal. You could include that at the time of this particular evaluation extending filter-to-waste for an additional 6 minutes - total of 12, would have been sufficient.

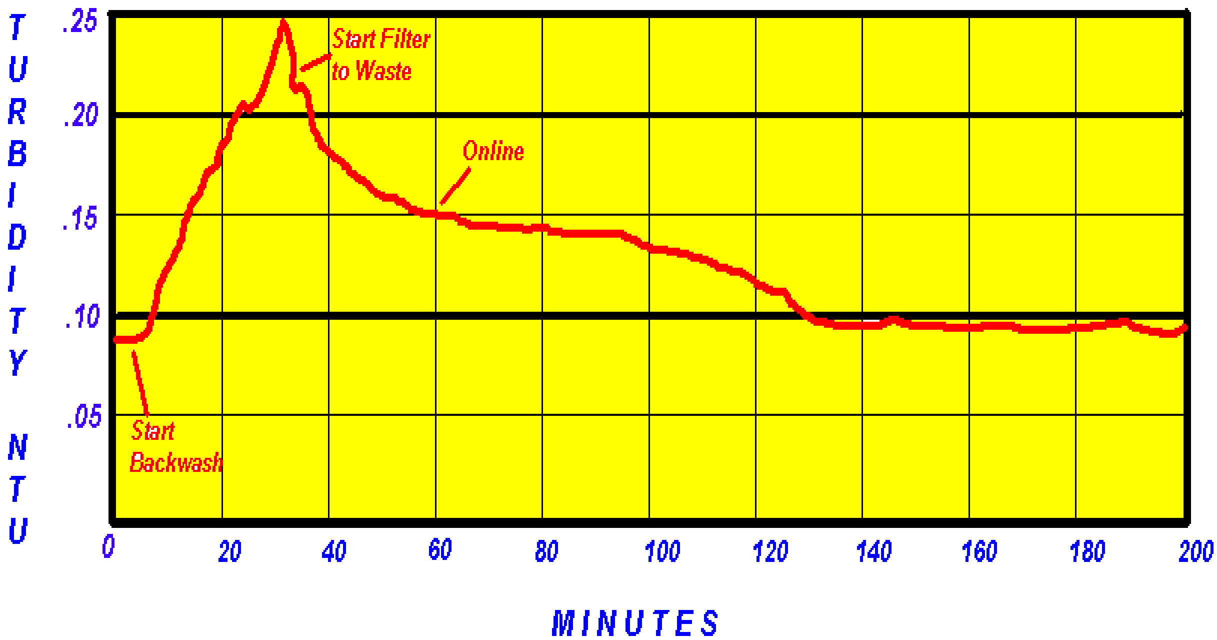


D.) Secondary Spike: Increasing filter to waste probably won't eliminate this spike. Possible solutions may include increasing backwash rates and/or duration of backwash, or allowing filter to "rest" offline for at least 15 minutes before returning to service. Also, a plant may consider adding Alum to their backwash water during the last few minutes of the backwash sequence or adding a filter aid/polymer.

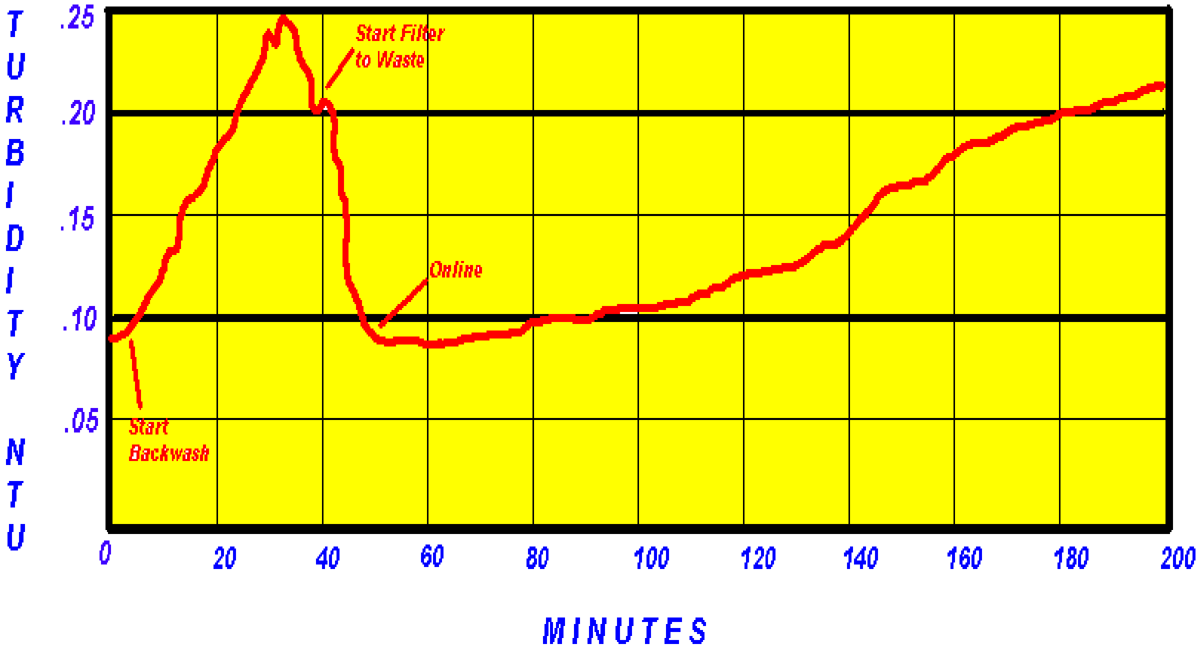
It is important to note that it is often not necessary for a plant to implement all of the above mentioned solutions. Evaluate the duration and severity of the backwash spike; then use some judgement when making recommendations.



E.) Excessive Recovery Time: Something is significantly wrong with this profile. Begin by thoroughly evaluating the backwashing procedures and pretreatment chemical feeds. Look at the performance of upstream unit processes - rapidmix, flocculators, settling. Perform a thorough filter and media inspection. Try to determine where in the treatment process things are going wrong. Often, there are several causes combined; such as lack of rapid mixing + improper chemical dosages + excessive filter run times + inadequate backwash rates. This type of profile is not always caused solely by poor filter performance.

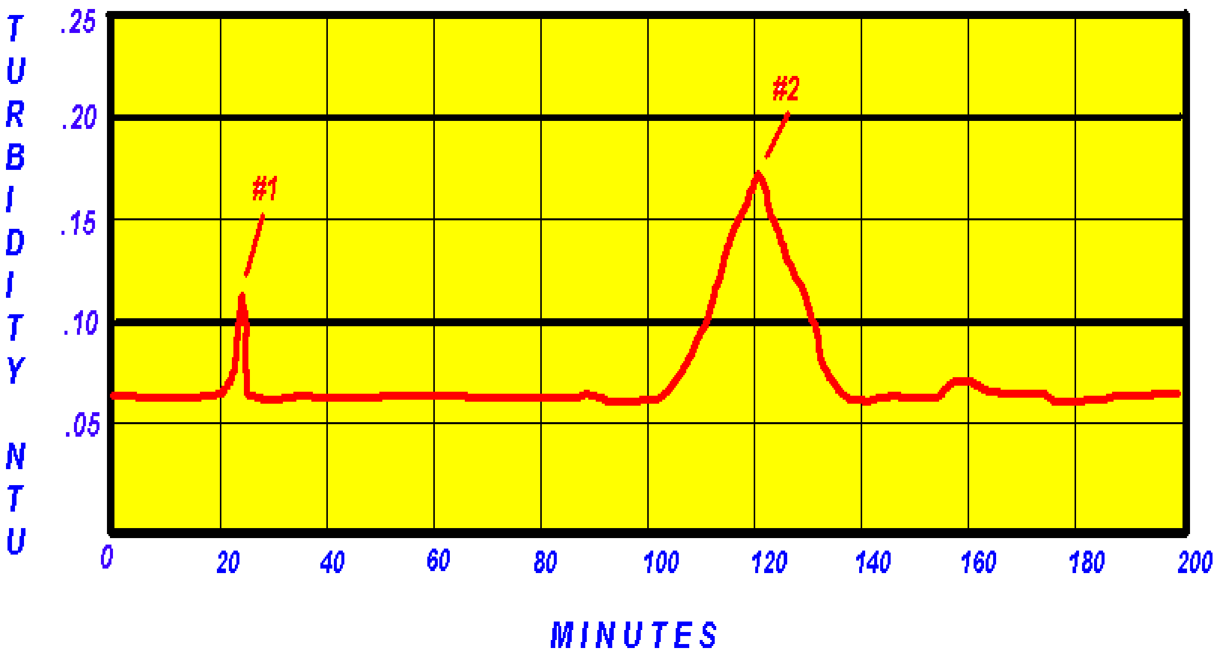


F.) Investigate similar causes as mentioned in Profile "E". However, this profile indicates that the filter appeared to be clean when returned to service, then breakthrough occurred quickly (in Profile "E" the filter never really recovered after backwashing). Sometimes, breakdown of a chemical feed pump may have caused this type of profile.

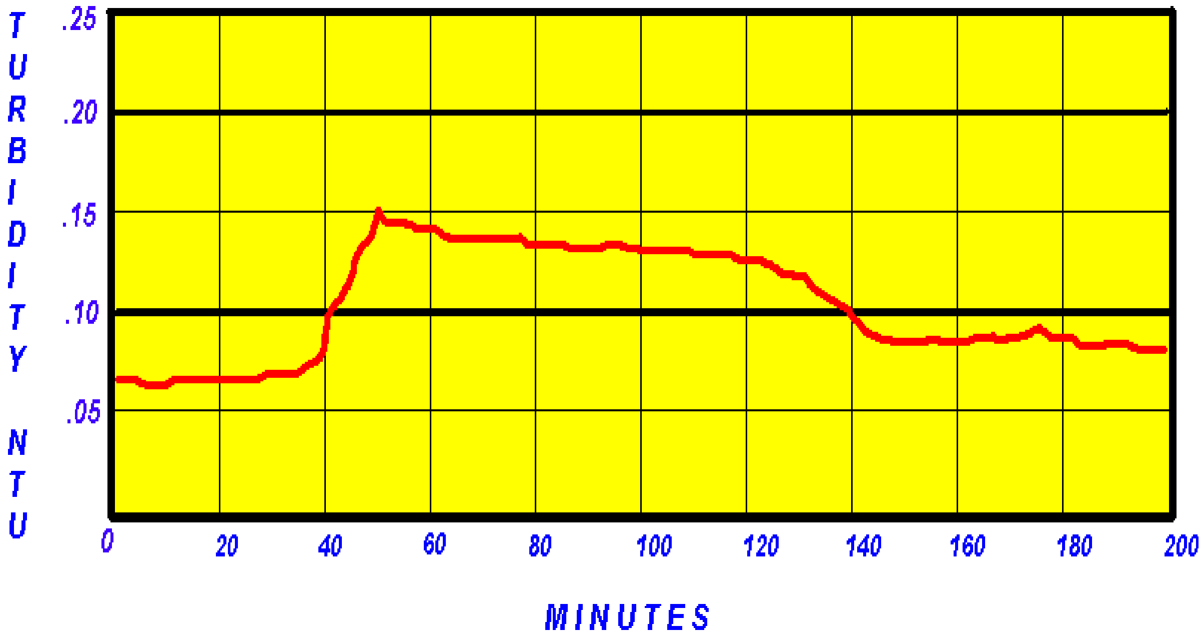


G.) #1. This spike isn't really of major concern. However, you should note the time and attempt to determine the cause. Also, remember that if this same event were to occur when the filter had more run time, the severity and duration of the spike may be greater.

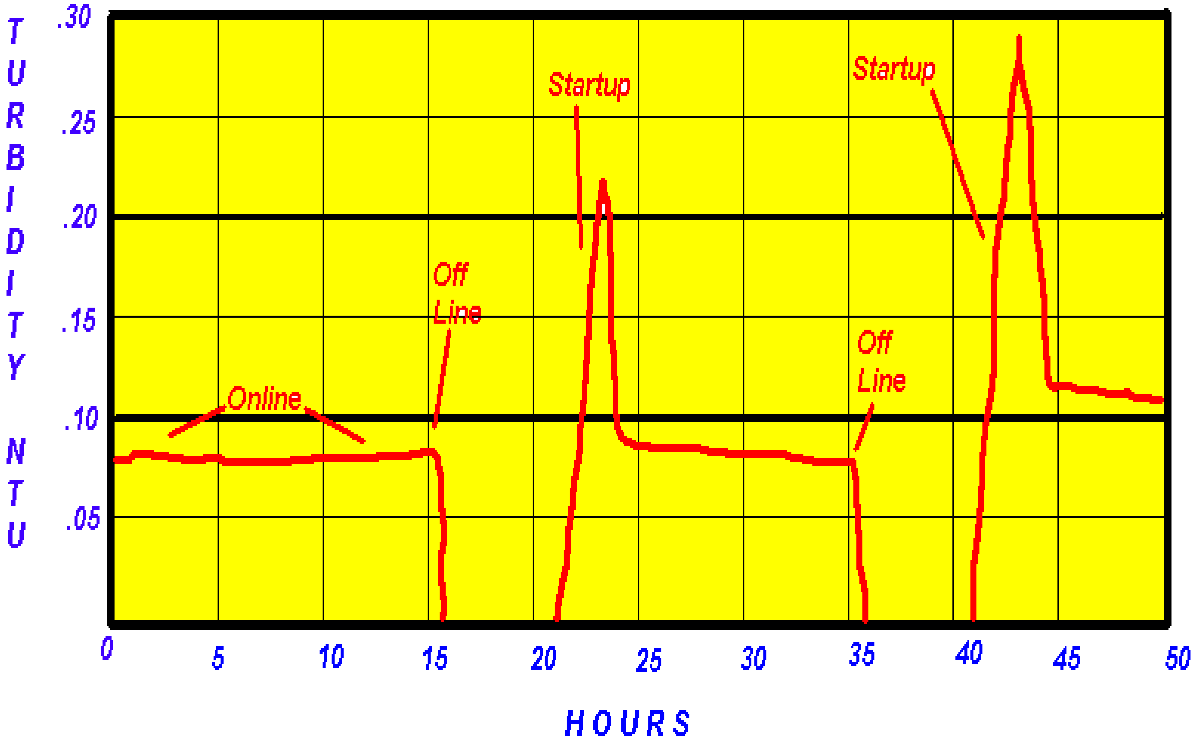
#2. This spike is more significant and a thorough attempt should be made to determine the cause. Possible causes include backwashing another filter of backflushing a clarifier (adsorption). Could also be caused by opening/closing of valves - changing hydraulic flows.



H.) This event is likely caused by increasing the plant flow rate for a period of time. Or, it may be caused by recycling waste water. Note, that sometimes recycling causes this pattern due to increased turbidities; however, sometimes, it may be the increased recycle flow rate itself which hydraulically causes this pattern. Either way, it is a significant problem. When investigating this type of event, pay close attention to the start and stop times of the spikes and try to correlate them with events on SCADA, strip charts, or the operators log books.



I.) This profile is caused by the start/stop operation of a plant. Filter to waste should be implemented whenever a "dirty" filter (filter with runtime) is placed online. Also, operating the plant at a lower flow rate would enable the plant to run longer with fewer shutdowns/startups and better overall process performance.



ATTACHMENT 7: GUIDELINES FOR PERFORMING FILTER INSPECTIONS

PURPOSE:

The following is intended to outline accepted procedures for performing a filter inspection, as conducted by Filter Plant Performance Evaluation (FPPE) field staff working in the FPPE program.

APPLICABILITY:

After obtaining concurrence from their immediate supervisor(s), all FPPE staff should adhere to the following guidelines.

GENERAL:

- Filter inspections are one of many evaluation tools, they provide very valuable information, but it is NOT a requirement to perform a filter inspection during every FPPE.
- Staff should use their discretion in deciding when to perform a filter inspection.
- If, for any reason, the task makes FPPE staff or plant personnel uncomfortable, the task should not be performed and concerns should be discussed with the regional FPPE supervisor.
- Under no circumstances should FPPE staff perform an inspection alone.
- At least one other Department person should be present along with the plant staff person responsible for operating the filter controls.

ENTRY/EXIT:

- Under no circumstances should FPPE staff enter a filter marked as a “confined space”.
- Under no circumstances should FPPE staff enter a pressure or “Permutit filter” - these filter types are considered to be confined spaces.
- Do not “hang and drop” into a filter.
- If the freeboard from where you are standing to where you will step/stand is more than shoulder height (or any distance which makes you uncomfortable) use a ladder or do not enter.
- If a ladder is used to enter, it should remain in place during the entire inspection to allow for a safe exit.
- When using a ladder, it should be placed on a piece of plywood or within a backwash trough for stability.
- Check the stability of the ladder before climbing.

- Request that the additional DEP staff person hold the ladder whenever you are climbing on it - entry and exit of the filter.

- The majority of filter plants should have ladders available for your use - staff are not required to transport a ladder in their DEP vehicle.

<u>SLIP/FALL:</u>

- This is the greatest risk presented within a water plant.

- Always wear proper footwear for filter inspections:

    - Rubber soled boots with good traction (not worn soles) or

    - Felt bottom boots, contact Central Office (CO) if you need ordering information

- Use ladder as described in ENTRY/EXIT section above.

- It is not advisable to stand inside the filter box or in the troughs while a filter is backwashing.

- The 100' retractable bed expansion-measuring reel provided by CO should allow measurement of bed expansions from outside the filter box.

- Contact CO if your measuring reel needs repaired or replaced.

<u>FILTER DRAINED:</u>

- Never attempt to step on the surface of a filter, which contains water.

- Only step onto the filter media <u>after</u> it is adequately drained.

- A filter is considered adequately drained when the water level has fallen below the support gravel layer.

- There are several ways to assure that the filter is adequately drained - it is suggested that you use at least two of the following methods before stepping onto the filter surface:

    - The operator draining the filter can normally provide you with an indication, based on flow, of when the filter is drained.

    - Use stainless steel probing rod to determine the depth of water below the surface of the media. If FPPE staff do not know how to perform this test, advise CO FPP section staff and they will provide training.

    - Often, a plant design will allow FPPE staff to hear when the water has stopped exiting the filter to waste drain. If the operator verifies that this drain valve is still open, then the filter should be adequately drained.

- 2’ X 2’ plywood squares can be placed on the media surface to make a walkway – this is not required, but is suggested especially if the filter surface contains a thin layer of mud.

LOCK OUT/TAG OUT:

- Lock out/tag out procedures should be followed to reduce the risk of filter refill during the inspection.

- FPPE staff should use the custom lock out tags provided by CO.

- A wet-erase marker should be used to record the “Filter #” and “Date”, and “Time” on the lock out tag.

- Lock out tags are re-usable; staff should alert CO if their supply of lock out tags are running low.

- For plants with SCADA controls that allow remote operation of the filter, operators should place the local filter control on manual to prevent remote access. If this cannot be accomplished, it is important to make sure tags are also placed on the SCADA controls to prevent an operator from remotely opening valving to refill the filter.

- The operator that drained the filter should remain on-site during the inspection.

- Request that the operator on-site informs all other plant operators that the filter is drained for inspection and must not be refilled until the inspection is completed.

ATMOSPHERE:

- Industry experts have indicated that performing filter inspections, on freshly drained conventional anthracite or sand filters used for particulate removal at surface water filtration plants, does not present a significant risk for poor atmosphere.

- Therefore, always perform inspections on a newly drained filter...you should observe the filter draining while on-site.

- Never enter a filter that has been off line long enough for the media to completely dry.

- Filter media, especially GAC, may release adsorbed treatment chemicals (“off-gas”) if it is allowed to dry.

SAFETY TRAININGS:

All FPPE field staff should attend the Department’s Confined Space and all other applicable safety trainings on an annual basis. These trainings should take place at the regional level and coordinated via regional FPPE supervisor. A portion of FPPE meetings will be dedicated to safety training and discussing safety issues.

CONTACTS:

Regional FPPE staff encountering safety concerns, while in the field, should contact their immediate supervisor(s). Questions regarding the above information or suggestions on how to further improve the safety of filter inspections should be directed to Central Office FPPE Section at 717-772-4018.

ATTACHMENT 8: MEMBRANE EVALUATION PROTOCOL

MEMBRANE OPERATIONS EVALUATION

This is a team participation process of sharing and collecting facility information, and reviewing the overall operations and treatment processes to determine operational procedures and physical characteristics. Membrane treatment plant information is gathered and discussed among the district sanitarian, regional engineer, regional FPPE staff, central office staff, and plant operator(s) during the on-site evaluation. However, some information such as annual turbidity data, capacity information, and membrane specific trending data including, but not limited to, Flux rates, Transmembrane Pressure (TMP), Pressure Decay Test (PDT) trends, and Log Removal Value (LRV) calculations can be collected prior to the evaluation so that more time can be spent actually evaluating the operation of the membrane plant. **Attachment 1**, "**FORMULA SHEET,**" can also be used for reasons mentioned earlier.

It is crucial that the FPPE be performed under "normal" operating procedures, so that representative data is collected. Therefore, do not request the operator to stray from the "normal" modes of operation to accommodate the FPPE. More specifically, operators should not adjust membrane flow cycles, backflow sequences, flow rates, tank levels, or total hours of plant operation solely to accommodate an FPPE. However, an FPPE can be performed under abnormal raw water conditions in order to assess the plants ability to respond to changing raw water conditions. It may be beneficial to visit the water plant on a day a Clean In Place (CIP) is on the plant's maintenance schedule. This could be completed during the FPPE or at a follow-up visit to the plant. CIP's are a crucial part of periodic operator maintenance on membrane units.

Particular attention is given to critical stages of the treatment process if applicable, including:

- chemical pretreatment (If Applicable)
- type of membrane technology - (Vacuum (Submersed) or Pressure Driven (Encased); Flow - inside out or outside in and type/direction of flow through modules/hydraulic configuration
- various plant specific features of the membrane plant - Number of membrane process trains/skids, cassettes/racks, modules and manufactures of major components, PLC (Programmable Logic Controller) Functionality, Overall plant data management (SCADA)
- Integrity Testing: Examples – Pressure Decay Tests/Membrane Integrity Tests
- membrane production cycle
- Daily Maintenance Cleaning - Flux Maintenance (FM) - daily backflow or Reverse flush cycle
- Enhanced Maintenance Cleaning - Enhanced Flux Maintenance (EFM), Clean in Place (CIP)
- facility characteristics
- operational practices

Any operational areas of strength or performance limiting factors that could affect water quality are recorded by regional FPPE staff for later use when completing the Filter Plant Performance Evaluation report. The following examples of activities and questions are usually considered when doing this on-site evaluation:

PREPARATION: Follow guidance previously discussed in the FPPE Protocol. Preparation specific to membrane filtration may include:

- Advanced scheduling may be needed for the first evaluation of new membrane plants
- Request most recent annual data well in advance to give the supplier time to retrieve data and to give you time to graph and evaluate the data.
- Review the "Special Conditions" section of the permit to know what data to ask for and what criteria to use to evaluate the data. (For older permits, needed information may not be the in special conditions permit, but may be found in permit related data)
- A pre-visit may be needed for new membrane plants. You may need to request an additional sample tap to connect your equipment. You may also need to plan additional time for equipment setup to deal with problems with air or pump cycling. A pre-visit is also a good time to retrieve the data that you requested or to clarify what data you need.

DATA GATHERING: Identify the kinds of data, duration, and interval that you will request from the water supplier. Later, data will be evaluated for comparison to permitting control limits, regulatory requirements and/or optimal performance goals. Please see Attachment 10 for some example graphs. You may ask for the following kinds of data:

- Daily maximum Raw, Settled, and Filtered turbidity data during the past year.
- Daily particle count data for the past year.
- Daily Disinfection log inactivation values for past year
- Results of Pressure Decay Tests (PDT) during the past year. This is often expressed in units of psi/min.
- The starting pressure used for initiating Pressure Decay Tests (PDT) during the past year.
- Daily Log Removal Value (LRV) for the past year
- Daily maximum Transmembrane Pressure (TMP) for past year
- Dates of membrane Enhanced Maintenance Cleaning - Enhanced Flux Maintenance (EFM), Clean in Place (CIP)
- Daily maximum flux rate for past year
- Effluent pH following cleanings during past year

FACILITY PERMIT: Identify and discuss any permit discrepancies that directly relate to water treatment processes. Since many operational set points for membrane plants are proprietary and may differ from plant to plant, it is very important to pay special attention to the "Special Condition" section of the operations permit. Operational data that you will request from the water supplier and criteria that you will use to evaluate performance is often outlined in the "Special Conditions." Please see Attachment 9 for an example "Special Conditions" for one type of membrane filter plant. Please note that special conditions may differ from plant to plant.

- Review "Special Conditions"; Are they being met?
- Are there any Special Innovative Permit conditions? Are they being met?
- Changes in treatment chemicals, treatment processes and membrane operation often require a permit amendment.
- If the water system withdraws from a lake, river, or stream, then verify that a Water Allocation Permit exists.
- If the water system discharges to a lake, river, or stream, then verify that a National Pollutant Discharge Elimination System (NPDES) permit exists.
- Do control limits specified by the permit conditions match the control limits that are programmed into the PLC and/or SCADA?
- Have any alarms or automated shut down features of the membrane filtration plant been disabled?

SOURCE WATER, PRETREATMENT, and PROCESS MONITORING: Follow guidance previously discussed in the FPPE Protocol. Identify any Source, Pretreatment, and Process Monitoring performance limitations that may be unique to membrane filtration such as:

- For a plant utilizing conventional sedimentation and/or clarification processes, follow floc characteristics and settling protocol on Page 10 in this FPPE Guidance Document.
- What other physical pretreatment is being utilized at the plant?
- If strainers are used, what micron size are the strainers?
- How often are the strainers flushed, washed, and/or cleaned?
- If more than one, is each strainer used on regular basis?

DIRECT AND INDIRECT INTEGRITY TESTING: Identify specifics of any direct or indirect integrity testing on membrane treatment units such a pressure decay testing (PDT), Log Removal Value (LRV) calculations, turbidity monitoring, particle counting, or other established control limits.

- What types of testing are performed?

- How often are these tests being performed?
- Are test results recorded, maintained, trended on site through the membranes PLC and/or plants SCADA?
- Are there special permit conditions for any integrity testing conducted at the plant?
  - Are these conditions being met? If so, how is DEP notified whether they are in or out of compliance?
- What practices are completed if any of these integrity tests fail during normal operations?
- Are there any alarms in place to notify operators during a failed test?
- What direct integrity testing is being conducted?
  - What is the maximum direct integrity pressure?
  - Are LRV calculations determined during testing? How are they calculated?
  - Are there any plant specific forms/logs maintained regarding these tests?
  - Is the test reaching the required minimum starting pressure?
  - Is the starting pressure recorded?
  - How long is the test?
  - What triggers a failure?
- Identify control limit values on Pressure Decay Tests.
- Are Pressure Decay Tests (PDT) performed following all non-routine shutdowns?
- Are there any written procures for operators to follow in the event of a failed Pressure Decay Test (PDT)?
- Identify any alarm set points for TMP (Transmembrane Pressure).
- Observe at least 1 pressure decay test.
- What indirect integrity testing is being conducted? (Turbidity, Particle Counting)
  - Are there any specific performance goals for these tests?

PRODUCTION CYCLE: Observe the membranes during production cycles.

- How are the membrane units operated regarding flow direction? Ex. Inside/Out, Outside/In?
- Are there air pulsing or agitation cycles during production cycle?
    - If so, is the air cyclical or constant? Why?
- What is the design Flux rate for the membranes? Is this flux rate maintained? Does the plant trend this data?
- Does membrane filtrate meet optimization goals of <0.10 NTU and <25 counts/mL in the size range of ≥2 microns?
- Is the filtrate quality in compliance with the Pennsylvania Filtration Rule?
- Determine normal or average production cycle length and what criteria the operator used to determine this.
- Note: any excessive changes in flow rates on membrane units may result in damage to membrane fibers.

DAILY MAINTENANCE CLEAN (FLUX MAINTENANCE): This type of cleaning is used to remove floc and other loose particles from the membrane surface. Observe the backflow/reverse flush/daily maintenance clean cycle.

- How often are the daily maintenance cleaning cycles performed?
- Does the membrane filter unit have a backpulse cleaning cycle?
    - If so, how long is the backpulse?
    - What triggers a backpulse?
    - How often does a backpulse occur?
- Is there a Deconcentration cycle? (Submersed type membrane units only)
    - If so, what triggers a deconcentration cycle?
    - At what recovery % does the deconcentration cycle take place?
    - Does the recovery % change at all?
    - How often does a deconcentration cycle take place?
    - How much water is wasted?

    - Where does the wastewater go?

- How long does a cycle take? Were turbidity, particle counts, membrane fouling, and time considered when the cleaning cycle was established during the pilot study? Is that information available?

- Are chemicals used in any of the maintenance cleaning processes?

    - If so, are they monitored?

    - Are they heated?

    - NSF approved?

- Is finished water used for the backflow? Where does backflow water come from?

- Is there sufficient storage for the clean backflow wastewater? Does it go to a sewer, lagoon, or somewhere else?

- Can the backflush rate be determined? If so, what is it in gpm/ft^2 and does this rate change at all? Does the operator have control over this rate?

- How are other membrane treatment units affected during maintenance cleans, example - increased flow changes, greater loading?

- Are the maintenance cycles adjusted at all based on seasonal variation in water quality?

- Does the plant have the capacity to conduct two maintenance cleans one after the other?

- Does the plant recycle any wastewater? If so, what percentage?

<u>CLEAN IN PLACE/ENHANCED FLUX MAINTENANCE:</u> This type of major chemical cleaning is used to remove organic and inorganic fouling. Identify specifics about all additional membrane unit cleaning/maintenance procedures with respect to Clean In Place (CIP) and Enhanced Flux Maintenance (EFM).

- What type of fouling is occurring on the membrane units? Organic or Inorganic?

- Is the appropriate chemical used to remove fouling?

- Does fouling change seasonally?

- Are the membranes oxidant resistant?

- Does the plant practice a CIP (Clean in Place) procedure?

- If a CIP is performed, what triggers it?
    - At what frequency? Is it based on time, high TMP or both?
    - How long is the unit offline?
    - Are there plant SOP's specific to the CIP procedure available to the operators at the plant?
    - Observe the process if possible.
    - What chemicals are used in the cleaning process? Are they NSF approved?
    - Are the cleaning solutions heated? Are they designed to be heated?
    - How does the operator monitor dosage rate of any chemicals used in the cleaning processes?
    - How many rinses are performed after a CIP?
    - How does the operator check pH or any other water quality parameters of filtrate rinse water before sending it to production?
    - Where does the soak and rinse wastewater go?
    - Are completed CIP procedures recorded or maintained on the plant's log?
- Any other routine membrane maintenance conducted that hasn't already been mentioned?

POST CLEANING PERFORMANCE: Identify what happens once major cleaning is complete.

- Observe membrane unit filtrate particle counts and turbidities when membrane unit filtrate is returned to production.
- Does the plant have filter-to-waste capabilities? If so, is filter-to-waste implemented when the membrane unit is returned to service after a cleaning? If so, for how long? Why?
- Can the f-t-w period be extended if needed until filtrate turbidity is $\leq$0.10 NTU or other water quality goals are not met?
- Is pH monitored during a maintenance clean and is the pH control limit met before filtrate goes to production?
- If used, is chlorine residual checked prior to returning to production? What is chlorine goal?
- Are valves ramped open as opposed to quickly opened?
- What was the recovery time for the membrane unit to return to optimization goal of 0.10 NTU?

MAINTENANCE: Most membrane plants employ automation that contains many components such as valves, relays, instrumentation, gauges, wiring, PLCs and SCADA systems. If any one component breaks down, the automated feature does not work. It is important that the membrane facility have a rigorous maintenance program. Here are a few things to check:

- Do they have an up-to-date O&M Plan?
- Are spare parts and components kept on hand?
- Are repairs made in a timely manner?
- Does the plant have redundancy for plant process?
- Is there a service and maintenance contract established?
- Do they have vendor support?
- What is the expected life of the membranes?
- How will the operator know when a membrane needs to be repaired/pinned?
- Have operators repaired/pinned any membrane fibers?
- For encased cartridge membrane treatment units, how many fibers can be pinned before the cartridge needs to be replaced?
- Have they had any valve/O-ring problems?

FILTER PLANT PERFORMANCE EVALUATION REPORT (Membrane specific)

At the conclusion of the evaluation, the district sanitarian, regional engineer, and regional FPPE staff will discuss apparent facility problems and serious conditions. Any violations, especially **imminent threat violations,** and possible approaches to improve the system's performance will be noted by the sanitarian.

At a later date, after all information has been obtained, regional FPPE staff will prepare a final report. This report, along with the laboratory's analysis findings, will be sent to the appropriate district supervisor, regional technical services section chief, operations chief, regional manager, sanitarian, regional engineer and central office FPPE staff. The following sections should be included in the report:

INTRODUCTION:

- facility background information

PLANT SCHEMATIC:

TREATMENT PROCESS INFORMATION: (This is what we expect to see at the plant)

- Plant Production
- Withdraw Allocations
- Treatment Chemicals
- Mixing
- Flocculation and Sedimentation
- Membrane Technology/Design Operational Set Points and Control Limits
- Storage
- Lab and Process Monitoring Equipment
- Alarms
- Operator Certification – current # of certified and uncertified operators

PROCESS OBSERVATIONS: (This is what we found during the evaluation)

- Source
- Treatment Chemicals
- Coagulant Control Strategy
- Mixing
- Coagulation/Flocculation/Sedimentation
- Membrane Technology Used
- Annual Raw, Settled and Finished Turbidity Data Charts
- Types of Decay/Integrity testing done on Membrane units
- Trending Graphs – Transmembrane Pressure (TMP), Pressure Decay Testing (PDT), Pressure at PDT initiation, Log Removal Value (LRV), turbidity, pH, Log Inactivation, particle counts, and/or Flux Rates
- Individual Effluent Profiles showing turbidity and particle count data

- Recycle/Waste Handling
- Daily Maintenance Cleaning - Backflow/Reverse Flush Cleaning (Flux Maintenance) Procedure
- Enhance Maintenance Cleaning – EFM (Enhanced Flux Maintenance) and/or CIP (Clean in Place) procedures
- Additional Membrane Cleaning/maintenance Procedures
- Storage
- Disinfection
- Disinfection Byproducts
- Operation and Maintenance
- Other (leak detection, flushing, dead ends, unaccounted water loss, etc.)

COMMENTS SECTION:

- Performance rating
- Areas of operational strength
- Items addressed and not addressed from any past FPPE Report
- New Comments

WATER QUALITY DATA AND EVALUATION INFORMATION: (Attach at end of report)

MPA RESULTS: (Attach at end of report)

ATTACHMENT 9: MEMBRANE PERMITTING CONDITIONS

(EXAMPLE)

This permit is issued subject to all Department of Environmental Protection Rules and Regulations now in force and the following Special Conditions:

1. The capacity of this membrane filtration plant is limited to a maximum of 1,005 gallons per minute (gpm) per membrane train based on a maximum flux rate of 38.0 gallons per square foot per day (gfd). With prior written approval from the Department, the capacity of the membrane filtration plant may be increased to 1,148 gpm per train through installation of sixteen (16) additional XXXX XXXX modules per train.

2. The XXXXX membrane filtration plant shall be limited to a maximum withdrawal of 4.5 million gallons per day (mgd) from XXXXX Creek as stated in Water Allocation Permit No. WA 22-XXXX issued August 30, 2005. This condition may be modified if and when a new Water Allocation Permit is issued for XXXX Creek.

3. Operators shall conduct indirect integrity testing via continuous on-line turbidity monitoring of the permeate. The permeate from each individual membrane train shall be monitored using a laser turbidimeter. Such monitoring shall include measurement and recording of the permeate turbidity at least once every fifteen (15) minutes that the system is operated. All test results shall be recorded and maintained on site.

4. Operators shall conduct direct integrity testing via off-line pressure hold testing of the system at least once per day, or fraction thereof, when the system is operated. The system <u>shall not</u> be returned to service until system integrity has been confirmed by a successful direct integrity test within the established control limits as per Special Condition No. 6 below. All test results, including testing date, starting pressure, ending pressure, test duration, filtrate flow, Transmembrane Pressure (TMP), Air-Liquid Conversion Ratio (ALCR), Log Removal Value (LRV) and membrane integrity (pass/fail) shall be recorded and maintained on site.

   The test results shall be summarized in a monthly report and submitted to the Department by the 10th day of the following month. Submit the monthly report to the Department's Safe Drinking Water Program at:

   Department of Environmental Protection
   Safe Drinking Water Program
   Example Address
   Example City, PA 00000-0000

5. Operators shall also conduct pressure hold testing of the system before placing it back into service after any non-routine shutdown. The system <u>shall not</u> be returned to service until system integrity has been confirmed by a successful direct integrity test within the established control limits as per Special Condition No. 6 below. For purposes of this condition, a routine shutdown includes normal cycling of the membrane equipment caused by rising and falling water levels within the clearwell, which, is referred to as STANDBY mode. A non-routine shutdown is any shutdown that is not routine and includes those caused by exceedance of any control limit

specified in Special Condition No. 6 below, periods of inactivity caused by maintenance, repair, chemical cleaning or extended (greater than 24 hours) non-use.

6. Exceedance of any of the following operational control limits shall cause the programmable logic controller (PLC) to initiate immediate shutdown of the affected membrane train:
For indirect integrity testing via continuous on-line turbidity monitoring:

A. The permeate turbidity exceeds 0.15 NTU and stays above 0.15 NTU for any 15-minute period based on continuous turbidity monitoring. In the event that a turbidity reading falls below the 0.15 NTU threshold during any 15-minute period, the timer resets.

For direct integrity testing:

B. The minimum direct integrity test pressure (P_{Test}) is less than 9.1 psi at any time during the test.

C. The log removal value (LRV) is less than 3.0. The LRV shall be determined through direct integrity testing in accordance with Special Condition Nos. 4, 5 and 7 to verify membrane integrity with a resolution of no more than 3 microns (μm) for *Cryptosporidium* removal credit as required by the Long Term 2 Enhanced Surface Water Treatment Rule.

The filtration system shall not be returned to service until operators have investigated the control limit exceedance resulting in shutdown and taken follow-up corrective action to resolve the problem.

The permittee may petition the Department, in writing and stating just cause after commencement of operation, to change any of the operational control limits specified above. However, control limits may not be changed until the Department approves the request in writing.

7. The permittee shall utilize the attached “Summary of LRV Calculations” dated April 6, 2009, including Appendices A and B, as the basis for operational control and determination of LRV. Any changes to the control logic or underlying assumptions must first be approved, in writing, by the Department.

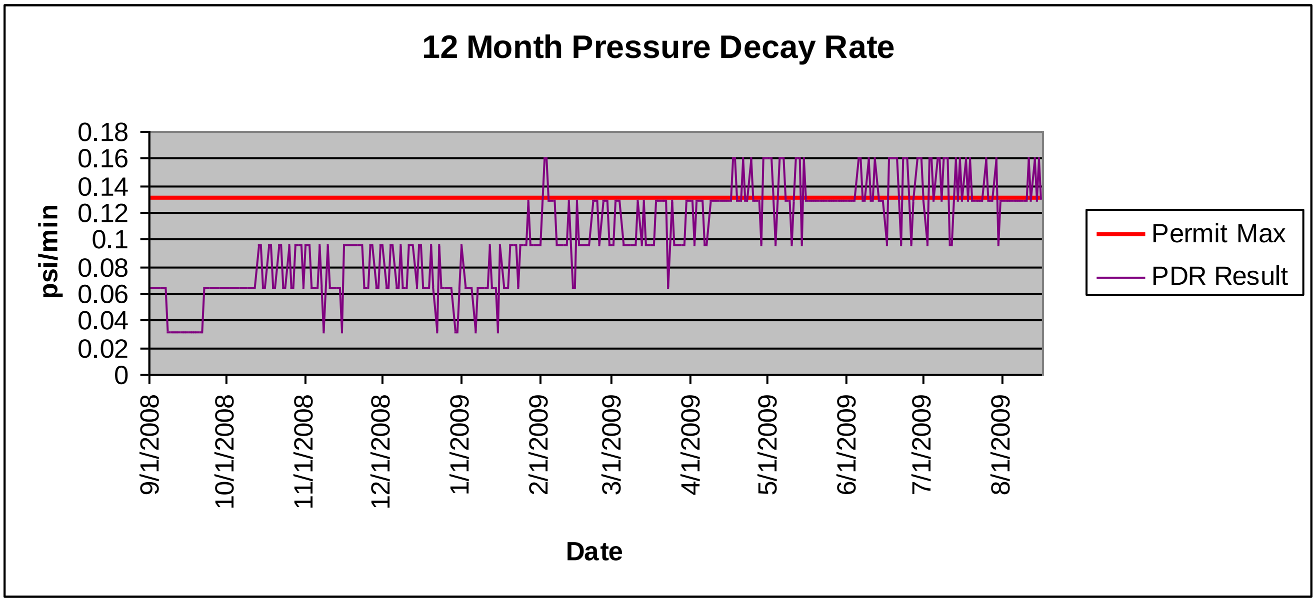
8. Operators shall measure and record the pH of the water within the membrane system after each chemical cleaning is completed to make certain that all cleansers have been adequately flushed. The membranes may not be returned to service until the permeate pH is within one (1) pH unit of the raw water.

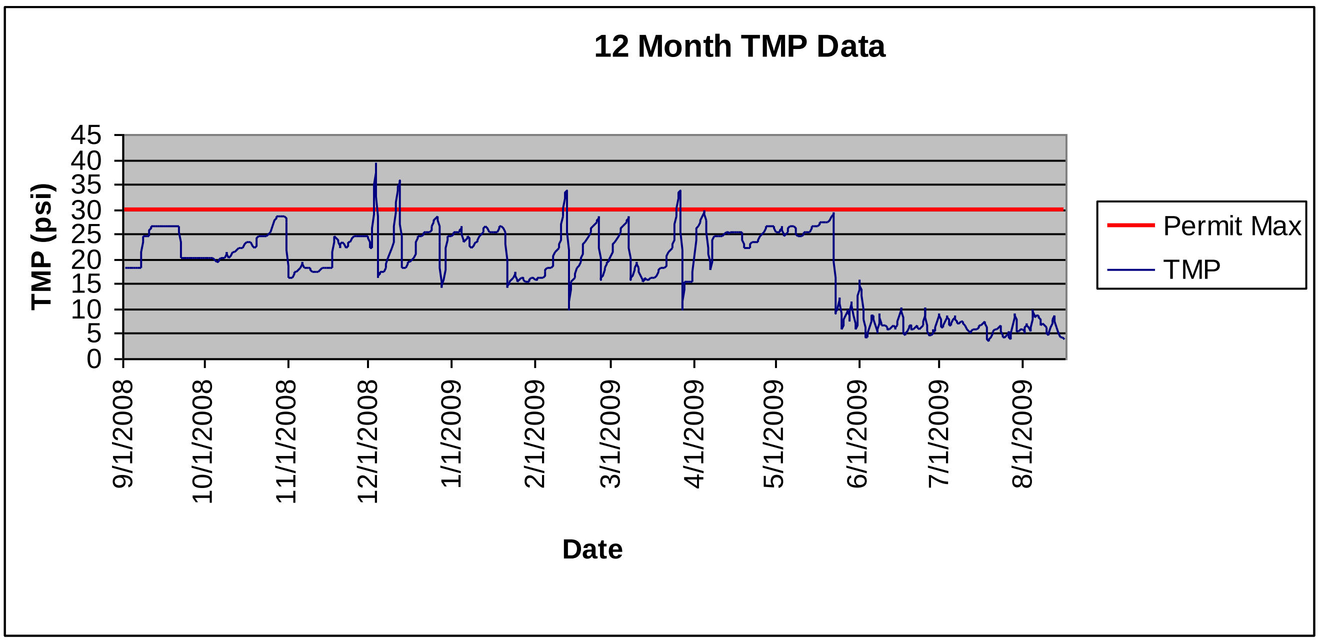
9. The permittee shall create and maintain a set of chlorine contact time (CT) tables for operator’s use. This set of tables shall identify the minimum Entry Point chlorine residual needed to achieve 1-log and 3-log post-filtration *Giardia* inactivation. Those tables shall assume a maximum T_{10}/T of 0.6 in the clearwell and a maximum flow rate. The tables shall also consider the various possible water levels in the clearwell. The tables shall be provided for the range of pH and temperatures that can reasonably be seen in the finished water.

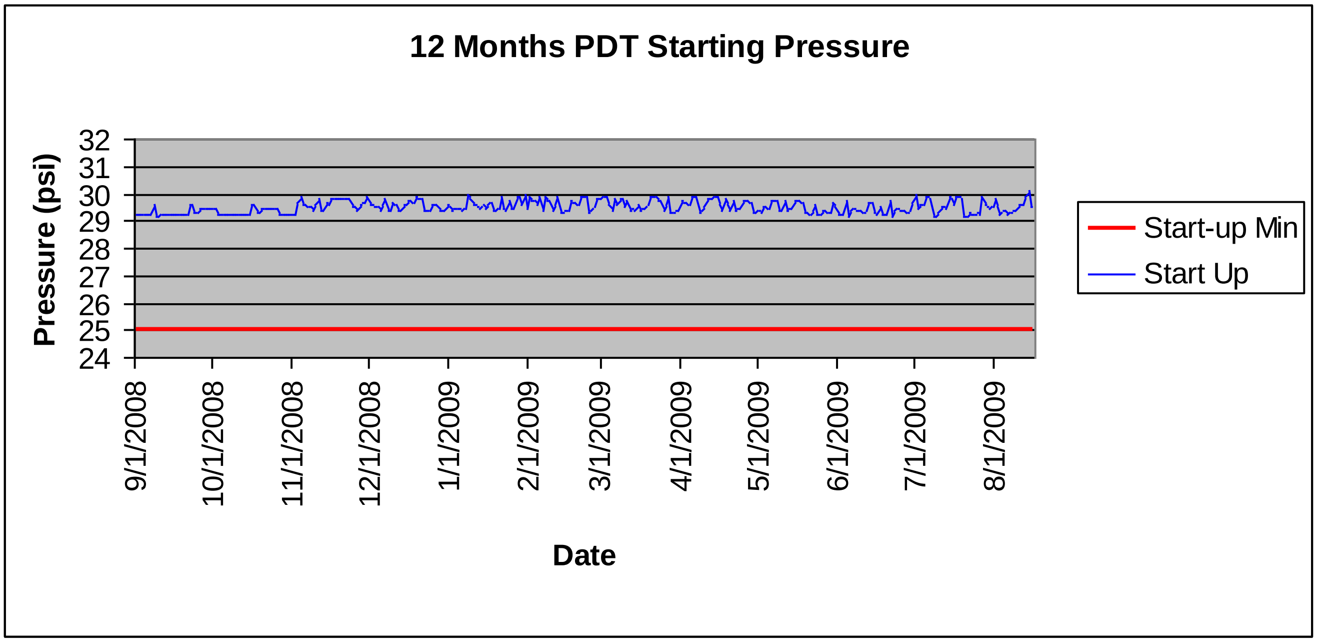
10. All laser turbidimeters shall be calibrated on a quarterly basis.

ATTACHMENT 10: INTEGRITY TESTING/CONTROL LIMIT GRAPHS

(EXAMPLES)







12 Months PDT Starting Pressure
Pressure (psi)
32
31
30
29
28
27
26
25
24
9/1/2008
10/1/2008
11/1/2008
12/1/2008
1/1/2009
2/1/2009
3/1/2009
4/1/2009
5/1/2009
6/1/2009
7/1/2009
8/1/2009
Date
Start-up Min
Start Up

ATTACHMENT 11: MEMBRANE TECHNOLOGY TERMS AND DEFINITIONS

Cartridge – a term commonly used to describe a disposable filter element; included under the term "module" for the purposes of the LT2ESWTR

Challenge Particulate – the target organism or acceptable surrogate used to determine the log removal value (LRV) during a challenge test

Challenge Test – a study conducted to determine the removal efficiency (i.e., log removal value (LRV)) of a membrane material for a particular organism, particulate, or surrogate

Clean-In Place (CIP) – the periodic application of a chemical solution or (series of solutions) to a membrane unit for the intended purpose of removing accumulated foulants and thus restoring permeability and resistance to baseline levels; commonly used term for in-situ chemical cleaning

Control Limit (CL) – a response from an integrity test, which, if exceeded, indicates a potential problem with the membrane filtration system and triggers a response; synonymous with "upper control limit" (UCL) as used in the Membrane Filtration Guidance Manual to distinguish from additional voluntary or State-mandated "lower control limits" (LCLs)

Crossflow – 1) the application of water at high velocity tangential to the surface of a membrane to maintain contaminants in suspension; also, 2) suspension mode hydraulic configuration that is typically associated with spiral-wound nanofiltration (NF) and reverse osmosis (RO) systems and a few hollow-fiber microfiltration (MF) and ultrafiltration (UF) systems

Diagnostic Test – precise direct integrity tests that are specifically used to isolate any integrity breaches that may be initially detected via other means, such as coarser direct integrity tests that simply indicate the presence or absence of a breach within a membrane unit

Differential Pressure – pressure drop across a membrane module or unit from the feed inlet to concentrate outlet (as distinguished from transmembrane pressure (TMP), which represents the pressure drop across the membrane barrier)

Direct Integrity Test – a physical test applied to a membrane unit in order to identify and/or isolate integrity breaches

Element – a term commonly used to describe an encased spiral-wound membrane module; included under the term "module" for the purposes of the LT2ESWTR

Filtrate – the water produced from a filtration process; typically used to describe the water produced by porous membranes such those used in membrane cartridge filtration (MCF), microfiltration (MF), and ultrafiltration (UF) processes.

Flux – the throughput of a pressure-driven membrane filtration system expressed as flow per unit of membrane area (e.g., gallons per square foot per day (gfd) or liters per hour per square meter (Lmh))

Foulant – any substance that causes fouling

Fouling – the gradual accumulation of contaminants on a membrane surface or within a porous membrane structure that inhibits the passage of water, thus decreasing productivity Heterogeneous – composed of a combination of different materials (e.g., composite and some asymmetric membranes)

Hollow-Fiber Module – a configuration in which hollow-fiber membranes are bundled longitudinally and either encased in a pressure vessel or submerged in a basin; typically associated with microfiltration (MF) and ultrafiltration (UF) membrane processes

Indirect integrity monitoring – monitoring some aspect of filtrate water quality that is indicative of the removal of particulate matter. In the context of indirect integrity monitoring, continuous is defined as a frequency of no less than once every 15 minutes (40 CFR 141.719(b)(4)(ii)).

Integrity breach – one or more leaks in a membrane filtration system that could result in the contamination of the filtrate with unfiltered feed water

Irreversible Fouling – any membrane fouling that is permanent and cannot be removed by either backwashing (if applicable) or chemical cleaning

Log Removal Value (LRV) – filtration removal efficiency for a target organism, particulate, or surrogate expressed as log10 (i.e., log10 (feed concentration) – log10 (filtrate concentration))

Lower Control Limit (LCL) – a control limit (CL) that is not mandated by the LT2ESWTR but which is instead voluntarily implemented or which may be required by the State at its discretion Lumen – the center or bore of a hollow-fiber membrane

Membrane Filtration – a pressure- or vacuum-driven separation process in which particulate matter larger than 1 mm is rejected by an engineered barrier, primarily through a size-exclusion mechanism and which has a measurable removal efficiency of a target organism that can be verified through the application of a direct integrity test.

Membrane Cartridge Filtration (MCF) – any cartridge filtration devices that meet the definition of membrane filtration

Membrane Softening – semi-permeable membrane treatment process designed to selectively remove hardness (i.e., calcium, magnesium, and certain other multivalent cations) but allow significant passage of monovalent ions; typically used to describe the application of nanofiltration (NF) for hardness removal

Membrane Unit – a group of membrane modules that share common valving which allows the unit to be isolated from the rest of the system for the purpose of integrity testing or other maintenance

Microfiltration (MF) – a pressure-driven membrane filtration process that typically employs hollow-fiber membranes with a pore size range of approximately 0.1 - 0.2 mm (nominally mm)

Module – the smallest component of a membrane unit in which a specific membrane surface area is housed in a device with a filtrate outlet structure; used in the Membrane Filtration Guidance Manual to refer to all types of membrane configurations, including terms such as “element” or “cartridge” that are commonly used in the membrane treatment industry

Nanofiltration (NF) – a pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water; typically applied for membrane softening or the removal of dissolved organic contaminants

Osmosis – the passage of a solvent (e.g., water) through a semi-permeable membrane from a solution of lower concentration to a solution of higher concentration so as to equalize the concentrations on either side of the membrane

Osmotic Pressure – the amount of pressure that must be applied to stop the natural process of Osmosis

Particle Counter – an instrument used to count the number of discrete particles in a solution and classify them according to size

Permeability – the ability of a membrane barrier to allow the passage or diffusion of a substance (i.e., a gas, a liquid, or solute)

Permeate – the water that passes through a nanofiltration (NF) or reverse osmosis (RO) membrane; synonymous with the term filtrate, which is used in the context of the LT2ESWTR

Plugging – the physical blockage of the feed side flow passages of a membrane or membrane module (e.g., a blockage in the lumen of an hollow-fiber module operated in inside-out mode or in the spacer of a spiral-wound module)

Pore Size – the size of the openings in a porous membrane expressed either as nominal (average) or the absolute (maximum), typically in terms of microns

Porosity – for a membrane material, the ratio of the volume of voids to the total volume

Post-Treatment – any treatment applied to the filtrate of a membrane process in order to meet given water quality objectives

Pretreatment – any treatment applied to the feed water to a membrane process to achieve desired water quality objectives and/or protect the membranes from damage or fouling

Productivity – the amount of filtered water that can be produced from a membrane module, filtration unit, or system over a period of time, accounting for the use of filtrate in backwash and chemical cleaning operations, as well as otherwise productive time that a unit or system is offline for routine maintenance processes such as backwashing, chemical cleaning, integrity testing, or repair

Quality Control Release Value (QCRV) – a minimum quality standard of a non-destructive performance test (NDPT) established by the manufacturer for membrane module production that ensures that the module will attain the targeted log removal value (LRV) demonstrated during challenge testing in compliance with the LT2ESWTR

Rack – in a nanofiltration (NF) or reverse osmosis (RO) spiral-wound membrane filtration system, a group of pressure vessels that share common valving and which can be isolated as a group for testing, cleaning, or repair; synonymous with the terms train and skid.

Recovery – the volumetric percent of feed water that is converted to filtrate in the treatment process over the course of an uninterrupted (i.e., by chemical cleaning or a solids removal process such as backwashing) operating cycle (excluding losses that occur due to the use of filtrate in backwashing or cleaning operations)

Rejection – the prevention of feed water constituents from passing through a semi-permeable membrane; typically used in association with dissolved solids rather than particulate matter

Resistance – the measurement of the degree to which the flow of water is impeded by a membrane material or fouling

Resolution – the size of the smallest integrity breach that contributes to a response from a direct integrity test; also applicable to some indirect integrity monitoring methods

Reverse Osmosis (RO) – 1) the reverse of the natural osmosis process – i.e., the passage of a solvent (e.g., water) through a semi-permeable membrane from a solution of higher concentration to a solution of lower concentration against the concentration gradient, achieved by applying pressure greater than the osmotic pressure to the more concentrated solution; also, 2) the pressure-driven membrane separation process that employs the principles of reverse osmosis to remove dissolved contaminants from water

Scaling – the precipitation or crystallization of salts on a surface (e.g., on the feed side of a membrane)

Semi-Permeable – the property of a membrane barrier that allows it to selectively pass certain molecules in a solution while restricting the passage of others

Sensitivity – the maximum log removal value (LRV) that can be reliably verified by a direct integrity test; also applicable to some continuous indirect integrity monitoring methods

Skid – in a nanofiltration (NF) or reverse osmosis (RO) spiral-wound membrane filtration system, a group of pressure vessels that share common valving and which can be isolated as a group for testing, cleaning, or repair.

Softening – the removal of hardness (i.e., divalent metal ions, primarily calcium and magnesium) from water

Spacer – the material that separates the semi-permeable membrane layers and creates flow passages in a spiral-wound module; also called feed water spacer or brine spacer

Specific Flux – membrane flux normalized for pressure and temperature

Stage – a group of membrane units operating in parallel

Surrogate – a challenge particulate that is a substitute for the target microorganism of interest and which is removed to an equivalent or lesser extent by a membrane filtration device

Telescoping – the physical deformation of a spiral-wound membrane module due to high differential pressure in which the membrane, support, and spacer layers are displaced axially (i.e., in the direction of the feed flow) from the center, causing membrane fracture and element failure

Train – in a nanofiltration (NF) or reverse osmosis (RO) spiral-wound membrane filtration system, a group of pressure vessels that share common valving and which can be isolated as a group for testing, cleaning, or repair; synonymous with the terms rack and skid; included under the term “unit” for the purposes of the LT2ESWTR

Transmembrane Pressure (TMP) – the difference in pressure from the feed (or feed concentrate average, if applicable) to the filtrate across a membrane barrier

MEMBRANE REFERENCE DOCUMENT

USEPA. 2005. *Membrane Filtration Guidance Manual*, EPA 815-R-06-009, Nov 2005.