CHAPTER 5

EPA/NSF ETV
EQUIPMENT VERIFICATION TESTING PLAN
PRECOAT FILTRATION FOR THE REMOVAL OF MICROBIOLOGICAL AND PARTICULATE CONTAMINANTS

Prepared by:
NSF International
789 Dixboro Road
Ann Arbor, MI 48105

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1.0 APPLICATION OF THIS VERIFICATION TESTING PLAN

This document is the ETV Testing Plan for evaluation of water treatment equipment utilizing precoat filtration. This Testing Plan is to be used as a guide in the development of the Product-Specific Test Plan for testing precoat filtration equipment, within the structure provided by the document, "EPA/NSF ETV Protocol For Equipment Verification Testing For Physical Removal of Microbiological And Particulate Contaminants: Requirements For All Studies."

In order to participate in the equipment verification process for precoat filtration, the equipment Manufacturer shall employ the procedures and methods described in this test plan and in the referenced ETV Protocol Document as guidelines for the development of the Product-Specific Test Plan. The procedures and methods shall generally follow those Tasks related to Verification Testing that are outlined herein, with changes and modifications made for adaptations to specific precoat filtration equipment. At a minimum, the format of the procedures written for each Task should consist of the following sections:

- Introduction;
- Objectives;
- Work Plan;
- Analytical Schedule;
- Evaluation Criteria.

Each Product-Specific Test Plan shall include Tasks 1 through 6 as described later in this document.

2.0 INTRODUCTION

Water treatment equipment employing precoat filtration is used for a variety of applications, including removal of turbidity from surface waters, removal of *Giardia* and *Cryptosporidium*, and removal of algae from surface waters. Clarification processes generally are not used to pretreat water at precoat filtration plants.

This Equipment Verification Testing Plan is applicable to the testing of water treatment equipment utilizing a precoat filtration process train. Two phases of testing are discussed. The first phase is Initial Operations, which consists of a series of tests that will be used by the Manufacturer to determine the optimum treatment scheme and most appropriate testing schedule at the specific geographical location or locations where testing is carried out. The second phase is Verification Testing, which will evaluate performance of the equipment under different raw water quality conditions. Verification Testing will be done for one or more relatively short time intervals during time periods when the source water or feed water quality is appropriate for testing the full range of water quality conditions that need to be evaluated. Development and execution of well-documented testing covering a wide range of water quality conditions has a better chance of minimizing subsequent on-site testing which states may require before approving use of the equipment at specific locations.

As described in AWWA Manual M30 (AWWA, 1995), "In precoat filtration, unclarified water containing foreign particles is forced, under pressure or by vacuum, through a uniform layer of filtering material (media) that has been deposited (precoated) on a septum. The septum is a permeable support for the media and is sustained by the structure of the filter element. As the water

passes through the filter media and septum, suspended particles about 2 μm and larger are captured and removed." (Unclarified water refers to feed water in the context of this ETV Test Plan.) Types of filter media used in precoat filtration are diatomaceous earth (sometimes referred to as diatomite) and perlite. Of these, diatomaceous earth is used more commonly in treatment of drinking water.

3.0 GENERAL APPROACH

Testing of equipment covered by this Verification Testing Plan will be conducted by an NSF-qualified Testing Organization that is selected by the Manufacturer. Water quality analytical work to be carried out as a part of this Verification Testing Plan will be contracted with a state-certified or third party- or EPA-accredited laboratory.

4.0 OVERVIEW OF TASKS

The following section provides a brief overview of the recommended tasks that may be included in Initial Operations and of the required and optional tasks to be included in the precoat filtration Verification Testing program. Tasks A and B are sequential tasks done before Verification Testing. Tasks 1 through 6 are to be done during Verification Testing and have overlapping time frames.

4.1 Task A: Characterization of Feed Water

The objective of this Initial Operations task is to obtain a chemical, biological and physical characterization of the feed water. A brief description of the watershed that provides the feedwater shall be provided, to aid in interpretation of feedwater characterization.

4.2 Task B: Initial Tests Runs

During Initial Operations, a Manufacturer may want to evaluate equipment operation and determine the treatment conditions that result in effective treatment of the feed water. This is a recommended Initial Operations task.

4.3 Task 1: Verification Testing Runs

Water treatment equipment shall be operated for a 272 hour period, or longer, during one or more testing periods to collect data on equipment performance and water quality for purposes of performance verification.

4.4 Task 2: Feed Water and Finished Water Quality

During each day of Verification Testing, feed water and treated water samples shall be collected, and appropriate sample analysis shall be undertaken.

4.5 Task 3: Operating Conditions and Treatment Equipment Performance

During each day of Verification Testing, operating conditions and performance of the water treatment equipment shall be documented. Operating conditions include precoating, body feed,

filtration rate, and method of cleaning filter septum. Equipment performance includes rate of filter head loss gain and length of filter run.

4.6 Task 4: Microbiological Contaminant Removal

The objective of this task is to evaluate removal of microbiological contaminants or surrogates during Verification Testing by measuring removal of microorganisms naturally present in the feed water or by evaluating removal of bacteria, viruses, or protozoan-sized particles seeded in the feed water, or by undertaking a combination of the above techniques.

4.7 Task 5: Data Management

The objectives of this task are to establish an effective field protocol for data management at the field operations site and for data transmission between the Testing Organization and NSF for data obtained during the Verification Testing and to develop statistical analyses of certain test data.

4.8 Task 6: QA/QC

An important aspect of Verification Testing is the protocol developed for quality assurance and quality control. The objective of this task is to assure accurate measurement of operational and water quality parameters during precoat filtration equipment Verification Testing.

5.0 TESTING PERIODS

The required tasks in the Verification Testing Plan (Tasks 1 through 6) are designed to be carried out over one or more 272 hour periods, not including mobilization, start-up, and Initial Operations.

A minimum of one verification testing period shall be performed. Additional verification testing periods may be necessary to verify the manufacturer's objectives, such as in the treatment of surface water where additional testing during each season may assist in verifying an objective. For systems treating solely groundwater or surface waters of consistent quality due to pre-treatment, one verification testing period may be sufficient. If one verification testing period is selected, the feed water should represent the worst-case concentrations of contaminants which can verify the manufacturer's objectives. For example this may include water having high turbidity or turbidity consisting of sub-micron particulate matter, cold water with high content of dissolved oxygen, or source water in which an algae bloom is occurring. Although one testing period satisfies the minimum requirement of the ETV Program, manufacturers are encouraged to use additional testing periods to cover a wider range of water quality conditions.

Verification testing periods consist of continued evaluation of the treatment system using the pertinent treatment parameters defined in Initial Operations. Performance and reliability of the equipment shall be tested during verification testing periods at a minimum of 272-hour periods. The purposes of the 272-hour test period are to: 1) provide opportunity for treatment of feed water having variable quality; 2) provide a data base on multiple filter runs from precoat and start-up to completion of run and cleaning of filter septa prior to precoating for a new filter run, so data can be subjected to statistical analysis (Data from multiple runs are needed for rate of head loss accumulation, total water production during a filter run, filter aid usage, and filtered water quality.); and 3) provide data demonstrating repeatability and dependability of the treatment process over time.

A schedule describing the duration and initiation of each of the above tasks is provided in Table 1.

6.0 DEFINITIONS

Definitions that apply for precoat filtration processes and that were given in the Surface Water Treatment Rule, as published in the *Federal Register* on June 29, 1989, are:

6.1 Diatomaceous Earth Filtration: A process resulting in substantial particulate removal in which (1) a cake of precoat filter media is deposited on a support membrane (septum), and (2) while the water is filtered by passing through the cake on the septum, additional filter media known as body feed is continuously added to the feed water to maintain the permeability of the filter cake.

6.2 Filtration: A process for removing particulate matter from water by passage through porous media.

7.0 TASK A: CHARACTERIZATION OF FEED WATER

7.1 Introduction

This Initial Operations task is needed to determine if the chemical, biological and physical characteristics of the feed water are appropriate for the water treatment equipment to be tested. Information from this task will be of value in selecting a testing site as well as in identifying times when source water quality may appropriately challenge the filtration equipment.

7.2 Objectives

The objective of this task is to obtain a complete chemical, biological, and physical characterization of the source water or the feed water that will be entering the treatment system being tested. Factors of particular interest include conditions that could affect precoat filtration performance, such as turbidity in runoff events following heavy rainfall or snowfall, and algae blooms.

7.3 Work Plan

This task can be accomplished by using analytical measurements obtained from third party sources (i.e. USGS, USEPA, State Laboratories, Municipal Laboratories). The specific parameters needed to characterize the water will depend on the equipment being tested but information on the following characteristics should be compiled:

- Water Temperature, pH, Turbidity, Iron, and Manganese
- Total Alkalinity and Total Hardness
- Total Coliform, *Bacillus* spores, and Algae

Sufficient information shall be obtained to illustrate the timing and degree of variations expected to occur in these parameters that will be measured during Verification Testing for a typical annual cycle for the water source if all testing is done at a single site. This information will be compiled and shared with NSF so NSF and the Testing Organization can determine the adequacy of the data for use

as the basis to make decisions on the testing schedule. Failure to adequately characterize the feed water (source water) could result in testing at a site later deemed inappropriate, so the initial characterization will be important to the success of the testing program.

A brief description of the watershed that provides the feedwater shall be provided, to aid in interpretation of feedwater characterization. The watershed description should include a statement of the approximate size of the watershed, a description of the topography (i.e. flat, gently rolling, hilly, mountainous) and a description of the kinds of human activities that take place (i.e. mining, manufacturing, cities or towns, farming), or animal activities, with special attention to potential sources of pollution that might influence feed water quality. The nature of the water source, such as stream, river, lake, or man-made reservoir, should be described as well.

7.4 Analytical Schedule

In many cases, sufficient water quality data may already exist to permit making a determination of the suitability of a source water for use as feed water in a precoat filtration Verification Testing program.

7.5 Evaluation Criteria

Feed water quality will be evaluated in the context of the Manufacturer's statement of performance objectives. The feed water should challenge the capabilities of the equipment but should not be beyond the range of water quality suitable for treatment by the equipment in question.

8.0 TASK B: INITIAL TEST RUNS

8.1 Introduction

During Initial Operations, a Manufacturer may want to evaluate equipment operation and determine the treatment conditions that result in effective treatment of the feed water. This is a recommended Initial Operations task and may occur during each of the periods in which Verification Testing is to be done. Initial test runs are required before the start of the first period of Verification Testing so an NSF field inspection of equipment operations and sampling and field analysis procedures can be carried out during the initial test runs.

8.2 Objectives

The objective of these test runs is to determine the proper approach for treatment of the feedwater during Verification Testing. Treatment requirements may be different for feedwaters from different test sites or for the feedwater from the same site at different times of testing. Therefore, conducting initial test runs is strongly recommended.

8.3 Work Plan

Initial tests for precoat filtration can be conducted using 0.1 m^2 test filters or precoat filtration equipment. Exploratory tests would be used to evaluate the efficacy of different grades of diatomaceous earth or perlite used as precoat or body feed. Exploratory tests also can be used to evaluate appropriate concentrations of body feed diatomaceous earth or perlite concentration, for selection of a body feed concentration that gives filter runs of appropriate duration. If a pressure

filter is used, exploratory tests could be conducted to ascertain the economical upper bound for pressure drop through the filter at termination of the run. (Higher pressure drop across the filter gives longer filter runs and saves on the cost of diatomaceous earth or perlite for precoating and body feed, but if water is pumped through the filter, the higher pressure drop entails greater energy costs for pumping.) The American Water Works Association's Manual M30, "Precoat Filtration," (AWWA, 1995) contains a chapter giving general concepts of precoat filtration and demonstrating the effect of body feed on total diatomaceous earth or perlite usage.

During exploratory tests, filters can be operated until either terminal headloss is reached or effluent turbidity increases above 1.0 NTU or a value set by the Manufacturer, whichever is lower.

8.4 Analytical Schedule

Because these runs are being conducted to define operating conditions for Verification Testing, a strictly defined schedule for sampling and analysis does not need to be followed. Adhering to the schedule for sampling and analysis to be followed during Verification Testing would be wise, however, so the operator can gain familiarity with the time requirements that will be applicable later on in the test program. Also, during the Initial Operations phase, NSF will be conducting an initial on-site inspection of field operations, sampling activities, and on-site sample analysis. The sampling and analysis schedule for Verification Testing shall be followed during the on-site inspection.

8.5 Evaluation Criteria

The Manufacturer should evaluate the data produced during the Initial Operations to determine if the water treatment equipment performed so as to meet or exceed expectations based on the statement of performance objectives. If the performance was not as good as the statement of performance objectives, the Manufacturer may wish to conduct more Initial Operations or to cancel the testing program.

9.0 TASK 1: VERIFICATION TESTING RUNS AND ROUTINE EQUIPMENT OPERATION

9.1 Introduction

Water treatment equipment employing precoat filtration shall be operated for Verification Testing purposes, with the approach to treatment based on the results of the Initial Operations testing.

9.2 Experimental Objectives

The objective of this task is to operate the treatment equipment provided by the Manufacturer and to assess its ability to meet the water quality goals and any other performance characteristics specified by the Manufacturer in the statement of performance objectives.

9.3 Work Plan

9.3.1 Verification Testing Runs

The Verification Testing Runs in this task consist of continued evaluation of the treatment system, using the most successful treatment parameters defined in Initial Operations. To obtain a perspective on the overall performance of the equipment, one or more Verification Testing periods, each lasting for a minimum of 272 hours (this could consist of 9 full days plus 2/3 day at the beginning and 2/3 day at the end of the testing period), are anticipated for evaluating the performance of a treatment system. Verification Testing shall be conducted under conditions likely to provide a suitable range of feed water quality for testing purposes. During each testing period, Tasks 1 through 6 shall be conducted simultaneously.

Testing over a range of feed water quality is recommended because of the differences in water quality that occur on a seasonal basis. For precoat filtration treatment equipment, factors that can influence treatment performance include:

- high turbidity, often occurring in spring, encountered in rivers carrying a high sediment load or in surface waters during periods of high runoff resulting from heavy rains or snowmelt
- algae, which may exhibit blooms on a seasonal basis
- high dissolved oxygen content, which can affect operation of vacuum precoat filters

It is highly unlikely that all of the above problems would occur in a surface water during a single testing period, and this results in the recommendation for multiple testing periods or multiple sites or both to capture critical events that affect water quality.

9.3.2 Routine Equipment Operation

If the water treatment equipment is being used for production of potable water, in the time intervals between verification runs, routine operation for water production is anticipated. In this situation, the operating and water quality data collected and furnished to the SDWA primacy agency shall also be supplied to the NSF-qualified Testing Organization.

9.4 Schedule

During Verification Testing, water treatment equipment shall be operated continuously for a minimum of 272 hours with interruptions in filtration as needed for cleaning and precoating the filter or for other necessary equipment operations. Precoat filtration treatment equipment shall be operated from start-up until turbidity breakthrough or terminal head loss (as defined by the manufacturer) is attained, at which time the spent diatomaceous earth or perlite filter cake shall be removed, the filter cleaned and precoated, and operation shall resume. Filter runs shall not be stopped before turbidity breakthrough or terminal head loss except because of equipment failure or power interruption, because data on complete filter runs are needed to fulfill the objectives of Verification Testing. The duration of each filter run and the number of gallons of water produced per square foot (or cubic meters per square meter) of filter area shall be recorded in the operational results.

During routine equipment operation, the water treatment equipment should be operated in a manner appropriate for the needs of the water system.

9.5 Evaluation Criteria

The goal of this task is to operate the equipment for the 272 hour period, including time for filter cleaning and precoating as well as and other necessary operating activities, during Verification Testing. Data shall be provided to substantiate the operation for 272 hours or more.

10.0 TASK 2: TEST RUNS FOR FEEDWATER AND FINISHED WATER QUALITY

10.1 Introduction

Water quality data shall be collected for the feedwater and filtered water as shown in Table 2, during Verification Testing. At a minimum, the required sampling schedule shown in Table 2 shall be observed by the Testing Organization on behalf of the Manufacturer. Water quality goals and target removal goals for the water treatment equipment shall be recorded in the Product-Specific Test Plan in the statement of objectives.

10.2 Experimental Objectives

A list of the minimum number of water quality parameters to be monitored during equipment verification testing is provided in the Analytical Schedule section below and in Table 2. The actual water quality parameters selected for testing shall be stipulated by the Manufacturer in the Product-Specific Test Plan and shall include all those necessary to permit verification of the statement of performance objectives. The characterization of feed water is intended to provide sufficient information to enable verification report readers to compare the quality of the feed water used in Verification Testing with the quality of source water at a site where the use of the equipment may be proposed.

10.3 Work Plan

The manufacturer will be responsible for establishing the precoat filtration equipment operating parameters, on the basis of the initial test runs. The filter shall be operated continuously until terminal headloss is attained, at which time it shall be cleaned and precoated in preparation for another run.

Many of the water quality parameters described in this task will be measured on-site by the NSF-qualified Testing Organization (refer to Table 3). Analysis of the remaining water quality parameters will be performed by a state-certified or third party- or EPA-accredited analytical laboratory. The methods to be used for measurement of water quality parameters in the field will be described in the Analytical Methods section below and in Table 3. The analytical methods utilized in this study for on-site monitoring of feedwater and filtered water qualities are described in Task 6, Quality Assurance/Quality Control (QA/QC). Where appropriate, the *Standard Methods* reference numbers for water quality parameters are provided for both the field and laboratory analytical procedures. One analytical procedure that is not required but which might prove helpful if excessive clogging of the filters is encountered is the Microscopic Particulate Analysis (MPA) for Filtration Plant Optimization (EPA 910-R-96-001).

10.3.1 Water Quality Sample Collection

Water quality data shall be collected at regular intervals during each period of filtration testing, as noted in this section. Additional sampling and data collection may be performed at the discretion of the Manufacturer. Sample collection frequency and protocol shall be defined by the Manufacturer in the Product-Specific Test Plan.

In the case of water quality samples that will be shipped to the state-certified or third party- or EPA-accredited analytical laboratory for analysis, the samples shall be collected in appropriate containers (containing preservatives as applicable) prepared by the state-certified or third party- or EPA-accredited analytical laboratory. These samples shall be preserved, stored, shipped and analyzed in accordance with appropriate procedures and holding times, as specified by the analytical laboratory.

10.4 Analytical Schedule

During Verification Testing for precoat filtration treatment equipment, the feedwater (raw water) quality and filtered water quality shall be characterized by measurement of the following water quality parameters:

- temperature (daily)
- pH (desired weekly but optional)
- total alkalinity (desired weekly but optional)
- hardness (desired weekly but optional)
- total organic carbon (desired weekly but optional)
- iron (weekly)
- manganese (weekly if above 0.05 mg/L in feed water)
- algae, number and species (weekly if no bloom; daily if bloom occurs)
- UV_{254} absorbance (desired weekly but optional)
- total coliform bacteria (desired every other day but optional)
- turbidity (continuous for filtered water)
- particle counts (see Task 4)
- dissolved oxygen (daily, but only for "vacuum" precoat filters and not for pressure filters)

Turbidity of filtered water shall be measured and recorded using a continuous, flow-through turbidimeter. Turbidity of feed water (before addition of body feed or any other substance) shall be measured continuously using a flow-through turbidimeter or at intervals of not more than four (4) hours if a bench model turbidimeter is used for grab samples. On a daily basis a bench model turbidimeter shall be used to check the continuous turbidimeter readings.

The above water quality parameters are listed to provide verification report readers with background data on the quality of the feed water being treated and data on the quality of the filtered water. These data are to be collected to enhance the usefulness of the Verification Testing data to a wide range of verification report readers.

10.5 (Optional Task) Turbidity Spiking

If the anticipated turbidity at the selected site does not challenge the system to the limits of its performance objectives, an optional turbidity augmentation procedure may be implemented after the 272-hour period of verification testing has been completed. A procedure for turbidity spiking was published in *Journal AWWA* in December 1993, pp. 39-46 by Logsdon et al. A spiking procedure based on the published technique is described in the following paragraphs. (In this ETV document, when the word "tank" is used, this term includes a storage tank, an above-ground swimming pool of appropriate size, an earthen basin having a plastic liner, or any other device or means of holding large volumes of water.)

To spike turbidity, use of a local turbidity source is recommended. This could consist of sediments taken from the bottom of a river or lake, or natural soil of the type likely to erode into nearby watercourses and cause turbid waters. For testing done in many locations in the United States where row crop agriculture is practiced, topsoil could be used to prepare a suspension for turbidity spiking, because topsoil is a major contributor to turbid runoff as a result of heavy rains in such locations. Topsoil or sediments would be expected to contain some natural organic matter, and as such would enable the FTO to produce a turbidity suspension typical for much of the turbid runoff found in the United States.

The soil or sediments that will be used to prepare a suspension for turbidity spiking should be screened through a three inch screen to remove rocks, for protection of pumps that will be used to mix soil and water.

After screening, soil or sediment should be added in a batch tank having a capacity in the range of 400 to 1000 gallons. Mixing can be accomplished by using a pump with a flow capacity, expressed in gallons per minute, of about 10 percent of the batch tank volume, expressed in gallons. For a 400 gallon batch tank, a 40 gpm pump theoretically could pump one tank volume in 10 minutes. Use of a trash pump or dewatering pump capable of pumping very muddy water or suspensions of water and mud is recommended. The mixture of water and soil or sediment should be recirculated for about six to eight hours. The action of the pump impeller will help to break up soil particles to smaller sizes that do not settle rapidly.

After the turbidity slurry has been mixed as described above and then settled for one hour to allow small gravel, sand, and grit to settle to the bottom of the batch tank, the slurry can be transferred to a very large tank having the capacity in the range of 10,000 to 15,000 gallons. The diluted suspension should be stirred or recirculated using a gasoline-powered portable pump of the kind used for dewatering at project construction sites, or an electric powered pump of equivalent flow capacity. The objective is to mix the water and slurry with a turnover time of about one hour. This mixing should be done for about six to eight hours, followed by two hours of quiescent settling for removal of the larger particles that would settle of their own accord during treatment. After settling, the turbidity suspension can be blended into feed water to make a more turbid feed water, or depending on the size of the treatment equipment being evaluated, and the length of the filter run, the turbidity suspension in the large tank might be used directly as feed water. If the turbidity suspension was to be used directly, more uniform turbidity could be attained by transferring the suspension to a second large tank that could be continuously stirred.

Depending on the number and duration of filter runs for which highly turbid water will be needed, sequential use of two large tanks may be appropriate. In such a situation, one large tank would be

used for stirring and settling the turbidity slurry, while the second large tank would be used as the source of turbid water for spiking or as the source of feed water.

As an alternative to the use of the 10,000 to 15,000 gallon tanks described above, a second tank in the size range of 400 to 1000 gallons could be used. In this case, the suspension that had been mixed in the first 400 to 1000 gallon tank would be settled for two hours in the original tank, and about 80 percent of the contents would be decanted from the first tank to the second tank, leaving the sediments on the bottom undisturbed. The second tank should be stirred to maintain the turbidity-causing particles in suspension. The suspension that has been transferred to the second tank could be fed as a concentrated suspension and thoroughly mixed into the source water to create the turbid feed water. In this approach to turbidity spiking, an in-line mixer should be used to ensure effective mixing of the turbidity suspension and the source water. Sampling of feed water for turbidity analysis should be done only after the spiked turbidity suspension is thoroughly mixed into the feed water. After the turbidity suspension has been transferred to the second tank where the suspension can be used for spiking, preparation of another batch of turbidity suspension could begin again in the first tank.

The size of the tanks and the amount of soil or sediment slurry originally prepared in the highly concentrated form in the first mixing tank (the 400 to 1000 gallon tank described above) may be influenced by the rate of flow of the package treatment equipment being tested, and by the level of turbidity the FTO is trying to attain. Use of treatment equipment with larger flows, and selection of high turbidity goals may result in the need for bigger tanks and pumps and the use of considerably more soil, silt, or sediment. An estimate of the amount of soil could be made by estimating the mass concentration of suspended solids needed to produce a desired turbidity. In making such an estimate, though, the FTO should consider that a substantial portion of the soil might not be broken up into particles so fine that they do not settle out in the recommended settling times. Therefore, soil usage estimates based on suspended solids would understate actual soil requirements.

The turbid water fed in the treatment testing could be characterized by particle counting, in addition to turbidity measurement. In many cases this would require dilution of the turbid samples. A simpler test would be to simply collect a sample of the water and place it in a 1000 mL graduated cylinder, and then record the location of the interface between turbid water and clearer water over a period of three to five hours as the suspension settles. A turbidity suspension that settled very slowly would be representative of turbid water containing fine particulate matter that would be found in many surface waters after heavy runoff.

10.6 Evaluation Criteria

Evaluation of water quality in this task is related to meeting any water quality objectives indicated by the Manufacturer.

- Turbidity removal equals or exceeds goals specified by the Manufacturer; and
- Water quality and removal goals specified by the Manufacturer.

11.0 TASK 3: DOCUMENTATION OF OPERATING CONDITIONS AND TREATMENT EQUIPMENT PERFORMANCE

11.1 Introduction

During each day of Verification Testing, operating conditions shall be documented. This shall include descriptions of treatment processes used and their operating conditions. In addition, the performance of the water treatment equipment shall be documented, including filtration rate, rate of filter head loss gain, length of filter run and terminal head loss; grade and brand, and amount (kg/m^2) of diatomaceous earth or perlite used for precoat; grade and brand, and concentration (mg/L) of diatomaceous earth or perlite used for body feed. Operating conditions are likely to be evaluated in great detail by state reviewers and are an important aspect related to approval of equipment by states.

11.2 Objectives

The objective of this task is to accurately and fully document the operating conditions that applied during treatment, and the performance of the equipment. This task is intended to result in data that describe the operation of the equipment and data that can be used to develop cost estimates for operation of the equipment.

11.3 Work Plan

A complete description of each process shall be given. Data on the filter shall be provided and shall include the following:

- whether the equipment is a pressure filter or a vacuum filter
- if flat filter elements are used is septum made of stainless steel mesh, synthetic fiber mesh, or other?
- if cylindrical filter elements are used, are they made of porous ceramic, sintered material, flexible woven wire, synthetic mesh, or other?
- description of the method employed for removal of spent diatomaceous earth or perlite at the end of a run and cleaning of filter elements
- description of the precoating technique, and statement of the amount of precoat used (kg/m^2)
- brand and grade of diatomaceous earth or perlite used for precoating and for body feed - if information on particle size distribution and porosity is available from the filter aid manufacturer, this information shall be provided
- any special preparation of the diatomaceous earth or perlite, such as coating with aluminum hydroxide precipitates or polymers - modification of the filtration properties of diatomaceous earth or perlite by coating the filter aids with aluminum hydroxide precipitates or with polymers is not commonly practiced but if done, this shall be completely and carefully documented

The manufacturers of filter aid materials and the manufacturers of precoat filtration equipment are very likely to be different entities. The organization (manufacturer or qualified testing organization) which selects the brands and grades of filter aid materials to be used in testing of precoat filtration equipment shall also obtain descriptive information from the filter aid manufacturer about each filter aid used in the testing program.

In addition, system reliability features including redundancy of components, shall be described. Spatial requirements for the equipment (footprint) shall be stated.

During each day of Verification Testing, treatment equipment operating parameters for precoat filtration shall be monitored and recorded on a routine basis. This shall include rate of flow, filtration rate, and maximum head loss. When pressure filtration equipment is used, the water pressure on both the influent side and the discharge side of the filtration equipment shall be recorded. Data on filter precoating procedures and body feed shall be collected. Electrical energy consumed by the treatment equipment shall be measured, or as an alternative, the aggregate horsepower of all motors supplied with the equipment could be used to develop an estimate of the maximum power consumption during operation. Performance shall be evaluated to develop data on diatomaceous earth or perlite consumed (for both precoating and body feed) and on energy needed for operation of the process train being tested.

A daily log shall be kept which events in the watershed are noted if they could influence source water quality. This includes such things as major storm systems, rainfall, snowmelt, temperature, cloud cover, upstream construction activities that disturb soil, and intermittent operation of hydroelectric generating facilities.

Performance of precoat filtration for removal of turbidity and microorganisms can be strongly influenced by the particle size distribution of the diatomaceous earth or perlite filter aid and by the pore sizes of the filter aid cake through which the water is filtered. Therefore the grade and brand of filter aid material used when turbidity or microorganism data are gathered shall be identified. The types (grade and brand) of filter aid shall not be changed during a filter run, but only after completion of a run, when the filter must be cleaned before precoating. If different grades or brands of filter aid are used during Verification Testing, the water quality data collected in conjunction with the use of each filter aid shall be analyzed and presented separately. Data shall be developed on the volume of spent filter aid slurry produced per 1000 volumes of water filtered (e.g., gallons of slurry per 1000 gallons of water filtered or cubic meters of slurry per 1000 cubic meters of water filtered).

11.4 Schedule

Table 4 presents the schedule for observing and recording precoat filtration equipment operating and performance data.

11.5 Evaluation Criteria

Where applicable, the data developed from this task will be compared to statements of performance objectives.

If no relevant statement of performance objectives exists, results of operating and performance data will be tabulated for inclusion in the Verification Report.

12.0 TASK 4: MICROBIOLOGICAL CONTAMINANT REMOVAL

12.1 Introduction

Removal of microbiological contaminants is a primary purpose of filtration of surface waters. Consequently, the effectiveness of precoat filtration treatment processes for microbial removal will be evaluated in this task. Assessment of treatment efficacy will be made on the basis of particle counting, removal of one or more microorganisms, removal of polymeric microspheres, or a combination thereof, depending on the manufacturers statement of treatment capability with regard to microorganism removal.

The precoat filtration process removes microorganisms in the size range of *Giardia* and *Cryptosporidium* from water by physically straining out the particles, trapping them in the filter cake which consists of diatomaceous earth or perlite. Walton (1988) presented photographic evidence showing that *Giardia* cysts are strained out and trapped in the fine pores of the filter cake. AWWA Manual M30 (1995) states, "The basic function performed by all water filters is to remove particulate matter from the water. Precoat filters accomplish this by physically straining the solids out of the water." Because the particle removal mechanism is primarily by straining out particles from water on the basis of the sizes of the particles and of the pores in the filter cake, the applicability of surrogate particles depends on their size and shape, rather than on their biological nature. Thus appropriately sized microspheres could be suitable surrogates for protozoan cysts and oocysts. Schuler and Ghosh (1990) evaluated precoat filtration for protozoan cyst and oocyst removal and obtained greater than 99.9% removal of *Cryptosporidium* using diatomaceous earth with no chemical conditioning. In other tests they conditioned diatomaceous earth with alum or polymer before using it as a precoat filter aid or body feed filter aid and attained equal or better results.

Studies of diatomaceous earth filtration have shown that precipitation of aluminum hydroxide coating onto diatomaceous earth used in precoating and body feed can enhance removal of particles too small to be effectively trapped in the diatomaceous earth filter cake pores (Lange et al, 1986). Use of cationic polymer to coat diatomaceous earth has also been demonstrated to have a beneficial effect on removal of microorganisms such as viruses that would be removed less effectively by plain (uncoated) diatomaceous earth (Brown et al, 1974). If removal of bacteria and viruses is an objective of the Verification Testing for precoat filtration, use of alum coating or cationic polymer may be needed in order to attain the most effective results. If filter aid properties are to be modified by use of alum or polymer, the procedures used for such modification shall be clearly described in the Product-Specific Test Plan.

Removal of turbidity by precoat filtration is not synonymous with removal of protozoan organisms because turbidity-causing particles can be much smaller than protozoa, and precoat filters can remove protozoan-sized particles while passing particles in the size range of bacteria, or the micron-sized and sub-micron-sized particles that cause turbidity. Therefore turbidity removal is not a surrogate for protozoan removal in precoat filtration (Logsdon et al., 1981).

Use of electronic particle counting to assess protozoan removal would be appropriate only for feed waters containing large numbers of particles in the size range of *Cryptosporidium.* For *Cryptosporidium* oocyst removal, assessment of particle removal in the size range of 3 to 7 μm would be appropriate. If sufficient concentrations of appropriately sized particles are not present in the feed water, use of electronic particle counting may not be capable of demonstrating adequately high log removals.

Research has shown (Lange et al., 1986) that total coliform removal varies with the grade (particle size) of diatomaceous earth used. Therefore, microbiological results must be related to the grade and brand of diatomaceous earth or perlite used in the Verification Testing.

Microbiological challenge testing for removal of bacteria is needed only if the Manufacturer's statement of performance objectives indicates that bacteria can be removed by the precoat filtration equipment. Microbiological challenge testing for removal of viruses is needed only if the Manufacturer's statement of performance objectives indicates that viruses can be removed by the precoat filtration equipment. Challenge tests conducted with bacteria or viruses may not be relevant for protozoan oocyst or cyst removal or indicative of the results to be expected for protozoan oocysts or cysts in precoat filtration equipment testing.

12.2 Experimental Objectives

The objective of this task is to evaluate removal of particles and microbiological contaminants during Verification Testing by measuring removal of microorganisms naturally present in the feed water; by measuring the removal of microorganisms seeded into the feed water; by assessing removal of polystyrene fluorescent microspheres; by electronic particle counting; or with a combination of these techniques. Seeded microorganisms may be bacteria or coliphage. Both *Giardia* and *Cryptosporidium* are pathogens of public health concern. *Cryptosporidium* is the smaller organism, so testing with a surrogate for *Cryptosporidium* would indicate the results that would be expected for *Giardia* removal, which would be removed as well as or better than *Cryptosporidium*. *Cryptosporidium* oocyst removal of up to 6-log has been reported (Ongerth and Hutton, 1997), with results being somewhat dependent on the grade (permeability) of the diatomaceous earth used.

12.3 Work Plan

The portions of Task 4 (required portions consisting of electronic particle counting and microsphere challenge testing, plus optional portions, if any) shall be carried out during the Verification Testing runs being conducted in Task 1. A minimum of three test runs shall be conducted during each period of Verification Testing to provide verifiable microorganism or surrogate particle removal data that can be analyzed statistically.

12.3.1 Electronic Particle Counting

Use of electronic particle counting is a required portion of Task 4, both for providing general information on particle removal and specific information on removal of particles such as *Cryptosporidium*. When an electronic particle counter is used for a general evaluation of particle removal, particle counts in feed water before any seeding and before any addition of body feed diatomaceous earth or perlite) and particle counts in filtered water shall be measured.

For evaluation of *Cryptosporidium* oocyst removal, particles in the size range of 3 to 7 μm shall be counted. If particles are not present in sufficient densities (concentrations) to permit calculation of log removals of protozoan-sized particles consistent with the Manufacturer's statement of performance capability, then particle counting for log removal should be done during microsphere challenge events.

12.3.2 Microspheres

For microspheres intended to serve as surrogates for *Cryptosporidium* oocysts in Verification Testing, the nominal diameter shall be 3 to 5 μm, based on commercially available sizes. This mix of sizes can be attained by purchasing 3 μm and 5 μm microspheres and seeding a 50/50 (by volume) blend of the two suspensions. If blended on an equal volume basis this mixture would have a higher proportion of the smaller microspheres. Microspheres have been used as surrogates for *Giardia* cysts in precoat filtration research. This was considered feasible because the particle removal mechanism for cyst-sized particles was straining (Logsdon et al., 1981).

Evaluation of microsphere removal shall be conducted by determining the density (concentration) of microspheres in the precoat filtration equipment feed water and in the filtered water. Counting of microspheres in water may be done using electronic particle counting, if the microspheres can be detected in both the feed water and the filtered water. If the density of microspheres in filtered water is too low to be reliably measured by electronic particle counting, then a microscopic enumeration technique shall be used. In either case, microspheres must be seeded into the feed water, mixed adequately, and sampled before any body feed filter aid is added to the feed water. Use of a static or in-line mixer that results in head loss of about 0.3 to 0.5 feet of water is recommended.

If electronic particle counting is not feasible, enumeration of microspheres in feed water and filtered water by optical microscopy shall be required. For testing involving microscopic enumeration of microspheres, fluorescent microspheres shall be used, and an optical microscope equipped with ultraviolet illumination shall be used to enumerate the microspheres. For microspheres intended to serve as surrogates for *Cryptosporidium* oocysts, the nominal diameter shall be 3 μm to 5 μm.

During filtration tests in which polymeric microspheres are seeded into the feed water, the microspheres shall be suspended in a solution of 0.01% Tween 20. The microsphere suspension shall be gently stirred during the time when microspheres are being injected into the feed water. Before each run with seeded microspheres, the holding vessel shall be washed with hot water and laboratory glassware detergent and thoroughly rinsed with tap water or filtered water. The number of microspheres used shall be sufficient to permit calculation of log removals that exceed the removal capability as set forth in the Manufacturer's statement of performance objectives. Recovery of microspheres in filtered water provides data for use in calculating definite removal percentages, in contrast to the practice of reporting removals that exceed a specified value based on the detection limit, which would have to be done when no microspheres are detected in filtered water.

Two techniques for analysis of water samples containing fluorescent microspheres may be used. One is the method used by Abbaszadegan *et al.* (1997) for enumeration of *Giardia* cysts and *Cryptosporidium* oocysts, and the other is the method of Li *et al*. (1997) which they used for enumeration of microspheres.

If the techniques for microsphere sampling and enumeration are based on the research work of Li *et al.* (1997) which was carried out at the U.S. EPA's research laboratory in Cincinnati, the procedures below shall be followed.

Samples of feed water seeded with microspheres and filtered water shall be filtered through 1 μm pore size, 293 mm diameter polycarbonate membranes. A stainless steel filter manifold shall be used to support the polycarbonate membrane. Volume of water filtered, and the times of initiation and completion of filtration shall be noted. The filter shall be removed from the manifold, placed in a storage container, and refrigerated until shipment to the EPA-accredited analytical laboratory. At the analytical laboratory the microspheres shall be removed from the filter with a laboratory squeegee and by washing with about 200 mL of 0.01% Tween 20. The liquid and particulate matter removed from the membrane shall be concentrated to a volume of between 1 and 10 mL by means of centrifugation for 10 minutes at 1200 x gravity. The volume of the concentrated suspension shall be recorded. Microspheres shall be enumerated using a hemacytometer under a UV microscope at 400 magnification. A minimum of three hemacytometer counts shall be performed for each sample. The volume of suspension examined in the hemacytometer shall be recorded and used to determine the fraction of the original water sample which was ultimately examined under the microscope. *Standard Methods* states that hemacytometer chambers come with detailed manufacturer's instructions concerning calculations and proper usage.

Standard Methods contains the precaution that a disadvantage of hemacytometers is that the sample must have a very high density of objects being counted in order to yield statistically reliable data. Some exploratory tests may be needed to identify appropriate volumes of treated water to filter through the polycarbonate membrane or appropriate densities (concentrations) of microspheres in the seeded feed water, so that reliable statistics can be attained in filtered water analysis. The total number of microspheres counted in the hemacytometer should be between 30 and 300 to obtain good statistical results without counting overwhelming numbers of microspheres.

If the entire flow stream produced by the precoat filtration equipment can not be filtered through the 293 mm membrane filter for sampling, a measured portion of the total filtered water flow can be sampled as it is produced, or the entire flow of filtered water from a seeding test can be stored in clean vessel and later filtered through the 293 mm membrane filter at a rate of flow suitable for the membrane filter. If an instantaneous slug dose of microspheres is applied and the entire volume of filtered water is saved in a storage vessel for subsequent membrane filtration as the sampling procedure, at least 20 times the volume of the precoat filtration pressure vessel or open filtration tank shall be filtered through the precoat filtration equipment and saved for sampling and analysis. (If this volume is impractically large, then seeding of microspheres on a continuous basis is the only acceptable seeding technique.)

12.3.3 Challenge Tests with Microorganisms

Microbiological testing, if done, shall be performed by seeding one or more of the kinds of organisms listed in Table 5 into the feed water or by testing for ambient organisms in the feed water, and by analyzing for the organisms in question in the feed water and in the filtered water. If challenge testing is done with seeded bacteria or coliphage, the manufacturer may find it helpful to evaluate the use of filter aids conditioned with metal coagulant or polymer.

The bacteria listed in Table 5 are considered representative of the sizes of bacteria that would be encountered in natural waters.

MS2 bacterial virus was identified for use as the model virus for the optional virus challenge studies. MS2 virus is the virus of choice for challenge studies because it is similar in size (0.025 μm), shape (icosahedron) and nucleic acid (RNA) to polio virus and hepatitis. This bacterial virus is the suggested organism to use in the SWTR Guidance Manual when conducting studies of microbial removal (USEPA, 1989).

If sufficient numbers of bacteria are naturally present in the feed water so that 3-log removal can be calculated without seeding bacteria, treatment equipment shall be operated as usual in Verification Testing runs, and sampling shall be done as stipulated in the Analytical Schedule if data on bacteria removal by precoat filtration are obtained during Verification Testing.

If testing is done with seeded organisms, an initial control test lasting 2 to 3 hours shall be made in which the organisms are seeded but the filter is operated with no precoat and no body feed filter aid. This test shall be done to evaluate organism losses through the filter equipment. When microorganisms are seeded, they shall be injected into the feed water at the same location that is used for seeding microspheres into the feed water.

For testing with seeded microorganisms, the microorganisms shall be used in densities sufficient to permit calculation of at least 3-log removal, and seeding of microorganisms shall begin at start-up of the treatment equipment. The organism feed suspension will be prepared by diluting the organisms to be seeded into dilution water that is distilled or deionized and disinfectant free. The feed reservoir for the organism suspension shall be made of biologically inert material (i.e., not toxic to the organisms in the suspension) and cleaned with hot water and laboratory glassware detergent followed by thorough rinsing before each test run in which microorganisms are seeded. The reservoir will be mixed continuously but gently, as with a magnetic stirring bar, throughout the experiment and kept packed in ice in a cooler. The seed suspension will be fed into the feedwater using an adjustable rate chemical feed pump. Mixing of this suspension with the feedwater will be accomplished using an in-line static mixer as described previously. Sample collection for seeded organisms should be made at the same location that is used for collection of microsphere samples.

If virus (coliphage) challenges are undertaken, water samples of at least 100 mL volume will be collected. Virus samples shall be shipped to an EPA-accredited laboratory for analysis.

12.4 Analytical Schedule

Analysis of feed water samples by electronic particle counters may be done on a batch or a continuous basis. If batch measurements are made, they shall be made for at least 8 hours each working day during Verification Testing with samples collected and analyzed at least once each hour. Filtered water analysis shall be done using flow-through particle counters, equipped with recording capability so data can be collected on a 24-hour-per-day basis during Verification Testing.

When microspheres are seeded for a period of hours on a continuous basis, microsphere samples shall be collected from the plant influent (feed water after seeding) and the filter effluent. Samples shall not be collected until the treatment plant has been in operation for a total of 3 theoretical detention times as measured through the filter vessel. For microsphere sampling purposes, the time of operation when three filtration vessel detention times have elapsed shall be considered time zero. Microsphere samples shall be collected at time zero and at 0.5 and 1 hours past time zero. Microsphere samples shall also be collected during the time period that is estimated to occur between

85% and 95% of the total run length, based on prior filter run performance. Seeding of microspheres, if not done continuously from the beginning of the run to the end of the run, shall be done during the first 1.5 hours of operation and shall again be started 1 hour before the time that is estimated to represent 85% of the total run length. The time of sampling shall be recorded so turbidity measurements can be determined at the time of sampling. Volumes of feed water and filtered water to be filtered should be large enough that 30 to 300 microspheres are detected in each seeded feed water sample. Ideally for statistical purposes 30 to 300 microspheres should be detected in each filtered water sample also. If the filtration process is highly efficient for removal of the microspheres, detection of such large numbers in samples of filtered water would not be possible. In such a case, detection of at least 5 microspheres is desirable. If removal is extremely high, detecting 5 or more microspheres in filtered water may not be possible but probably would be indicative of very high log removals of microspheres.

When microspheres are seeded on a slug dose basis, the number of microspheres in the concentrated suspension shall be based on an analysis of the concentrated suspension before it was dosed. The entire production of filtered water shall be collected for sampling, from the instant of dosing until a volume of filtered water equal to 20 volumes of the filter vessel has been collected. For example, if the filter vessel volume is 100 liters, a 2000-liter sample of filtered water shall be collected and then filtered through a membrane filter as described above in the procedure of Li *et al.*
If microbiological challenge testing is undertaken, microbiological samples shall be collected from feed water and filtered water on the same schedule stipulated for microsphere samples.

The Testing Organization shall then submit collected water samples to an EPA-accredited analytical laboratory for microbial testing.

12.5 Evaluation Criteria

Performance evaluation shall be conducted in a number of ways, depending on the types of data collected during testing.

Performance of precoat filtration equipment shall be evaluated in the context of the Manufacturer's statement of performance objectives. Turbidity results will be analyzed to determine the percentage of turbidity data in the range of 0.50 NTU or lower, the percentage between 0.51 NTU and 1.0 NTU, and the percentage that exceeded 1.0 NTU. The time intervals used for determining filtered water turbidity values shall be the same for all data analyzed, and because continuous turbidimeters are to be used to collect turbidity data, the intervals shall be between 15 and 60 minutes.

Electronic particle count data shall be evaluated by calculating the change in total particle count from feed water to filtered water, expressing the change as log reduction. The aggregate of particle counting data obtained during each verification testing period shall be analyzed to determine the median log removal and 95th percentile log removal during that verification testing period. Because of possible complications in conducting electronic particle counts on feed water, 1 to 4 hour time intervals shall be used for analysis of particle counting data for log reduction of particles.

Data on the density of microspheres in feed water and filtered water shall be analyzed to determine the median log removal and 95th percentile log removal during that verification testing period.

Data on the density of microorganisms in feed water and filtered water shall be analyzed to determine the median log removal and 95th percentile log removal during that verification testing period.

Particle counting data taken throughout the filter runs shall be used to determine whether particle removal performance improves, remains about the same, or declines throughout the course of a precoat filtration filter run, as the filter cake thickness increases and head loss increases.

13.0 TASK 5: DATA MANAGEMENT

13.1 Introduction

The data management system used in the verification testing program shall involve the use of computer spreadsheet software or manual recording methods, or both, for recording operational parameters for the precoat filtration equipment on a daily basis.

13.2 Experimental Objectives

One objective of this task is to establish a viable structure for the recording and transmission of field testing data such that the Testing Organization provides sufficient and reliable operational data for verification purposes. A second objective is to develop a statistical analysis of the data, as described in "EPA/NSF ETV Protocol For Equipment Verification Testing For Physical Removal of Microbiological And Particulate Contaminants: Requirements For All Studies."

13.3 Work Plan

13.3.1 Data Management

The following protocol has been developed for data handling and data verification by the Testing Organization. Where possible, a Supervisory Control and Data Acquisition (SCADA) system should be used for automatic entry of testing data into computer databases. Specific parcels of the computer databases for operational and water quality parameters should then be downloaded by manual importation into Excel (or similar spreadsheet software) as a comma delimited file. These specific database parcels will be identified based upon discrete time spans and monitoring parameters. In spreadsheet form, the data will be manipulated into a convenient framework to allow analysis of equipment operation. Backup of the computer databases to diskette should be performed on a monthly basis at a minimum.

In the case when a SCADA system is not available, field testing operators will record data and calculations by hand in laboratory notebooks. (Daily measurements will be recorded on specially-prepared data log sheets as appropriate.) The laboratory notebook will provide carbon copies of each page. The original notebooks will be stored on-site; the carbon copy sheets will be forwarded to the project engineer of the Testing Organization at least once per week. This protocol will not only ease referencing the original data, but offer protection of the original record of results. Operating logs shall include a description of the precoat filtration equipment (description of test runs, names of visitors, description of any problems or issues, etc.); such descriptions shall be provided in addition to experimental calculations and other items.

The database for the project will be set up in the form of custom-designed spreadsheets. The spreadsheets will be capable of storing and manipulating each monitored water quality and operational parameter from each task, each sampling location, and each sampling time. All data from the laboratory notebooks and data log sheets will be entered into the appropriate spreadsheet. Data entry will be conducted on-site by the designated field testing operators. All recorded calculations will also be checked at this time. Following data entry, the spreadsheet will be printed out and the print-out will be checked against the handwritten data sheet. Any corrections will be noted on the hard-copies and corrected on the screen, and then a corrected version of the spreadsheet will be printed out. Each step of the verification process will be initialed by the field testing operator or engineer performing the entry or verification step.

Each experiment (e.g. each filtration test run) will be assigned a run number which will then be tied to the data from that experiment through each step of data entry and analysis. As samples are collected and sent to state-certified or third party- or EPA-accredited analytical laboratories, the data will be tracked by use of the same system of run numbers. Data from the outside laboratories will be received and reviewed by the field testing operator. These data will be entered into the data spreadsheets, corrected, and verified in the same manner as the field data.

If different grades or brands of filter aid are used during Verification Testing, the water quality data collected in conjunction with the use of each filter aid shall be analyzed and presented separately. Complete data shall also be provided on the use of metal coagulant or cationic polymer to condition the filter aid before its usage in water filtration, if this has been done in any tests.

13.3.2 Statistical Analysis

Water quality data developed from grab samples collected during filter runs according to the Analytical Schedule in Task 4 of this Test Plan shall be analyzed for statistical uncertainty. The Testing Organization shall calculate 95% confidence intervals for grab sample data obtained during Verification Testing as described in "EPA/NSF ETV Protocol For Equipment Verification Testing For Physical Removal of Microbiological And Particulate Contaminants: Requirements For All Studies." Statistical analysis could be carried out for a large variety of testing conditions. Two conditions that are specifically required to be analyzed statistically are:

- All grab sample data for each Verification Testing run; and
- All grab sample data for every Verification Testing run operated at the same filtration rate and having the same quantity and grade of precoat filter aid and the same concentration and grade of precoat body feed.

The statistics developed will be helpful in demonstrating the degree of reliability with which water treatment equipment can attain quality goals. Information on the differences in water quality for filter runs having different grades or quantities of filter aid or different concentrations of body feed or different amounts of precoat filter aid would be useful in evaluating appropriate operating procedures for filter runs.

14.0 TASK 6: QA/QC

14.1 Introduction

Quality assurance and quality control of the operation of the precoat filtration equipment and the measured water quality parameters shall be maintained during the Verification Testing program.

14.2 Experimental Objectives

The objective of this task is to maintain strict QA/QC methods and procedures. When specific items of equipment or instruments are used, the objective is to maintain the operation of the equipment or instructions within the ranges specified by the Manufacturer or *Standard Methods*. Maintenance of strict QA/QC procedures is important, in that if a question arises when analyzing or interpreting data collected for a given experiment, it will be possible to verify exact conditions at the time of testing.

14.3 Work Plan

Equipment flow rates and associated signals should be documented and recorded on a routine basis. A routine daily walk-through during testing will be established to verify that each piece of equipment or instrumentation is operating properly. Particular care will be taken to confirm that filter aid is being fed at the defined flow rate into a flow stream that is operating at the expected flow rate. In-line monitoring equipment such as flow meters, etc. will be checked to verify that the readout matches with the actual measurement (i.e. flow rate) and that the signal being recorded is correct. The items listed are in addition to any specified checks outlined in the analytical methods.

14.4 Daily QA/QC Verifications:

- Body feed flow rates (verified volumetrically over a specific time period)
- In-line turbidimeter flow rates (verified volumetrically over a specific time period)
- In-line turbidimeter readings checked against a properly calibrated bench model
- Batch and in-line particle counter flow rates (checked volumetrically over a specific time period).

14.5 QA/QC Verifications Performed Every Two Weeks:

- In-line flow meters/rotameters (clean equipment to remove any debris or biological buildup and verify flow volumetrically to avoid erroneous readings).

14.6 QA/QC Verifications For Each Testing Period:

- In-line turbidimeters (clean out reservoirs and recalibrate)
- Differential pressure transmitters (verify gauge readings and electrical signal using a pressure meter)
- Tubing (verify good condition of all tubing and connections, replace if necessary)
- Particle counters (perform microsphere calibration verification)
- If challenge tests are going to be conducted with bacteria or coliphage, a control test shall be done at the beginning of the test period to evaluate the recovery of the test organism or organisms used, when low-turbidity water is passed through the treatment equipment at its intended rate of flow but no precoat filter aid and no body feed filter aid are to be used.

14.7 On-Site Analytical Methods

The analytical methods utilized in this study for on-site monitoring of raw water and filtered water quality are described in the section below. In-line equipment is recommended for its ease of operation and because it limits the introduction of error and the variability of analytical results generated by inconsistent sampling techniques. In-line equipment is recommended for measurement of turbidity and for particle counting for feed water and is required for measurement of turbidity and for particle counting for filtered water.

14.7.1 pH

Analysis for pH shall be performed according to *Standard Methods* 4500-H^+ or EPA Method 150.1/150.2. A three-point calibration of the pH meter used in this study shall be performed once per day when the instrument is in use. Certified pH buffers in the expected range shall be used. The pH probe shall be stored in the appropriate solution defined in the instrument manual. Transport of carbon dioxide across the air-water interface can confound pH measurement in poorly buffered waters. If this is a problem, measurement of pH in a confined vessel is recommended to minimize the effects of carbon dioxide loss to the atmosphere.

14.7.2 Temperature

Readings for temperature shall be conducted in accordance with *Standard Methods* 2550. Raw water temperatures shall be obtained at least once daily. The thermometer shall have a scale marked for every 0.1°C, as a minimum, and should be calibrated weekly against a precision thermometer certified by the National Institute of Standards and Technology (NIST). (A thermometer having a range of -1°C to +51°C, subdivided in 0.1° increments, would be appropriate for this work.)

14.7.3 Dissolved Oxygen

Analysis for dissolved oxygen shall be performed according to *Standard Method* 4500-O using an iodometric method or the membrane electrode method. The techniques described for sample collection must be followed very carefully to avoid causing changes in dissolved oxygen during the sampling event. Sampling for dissolved oxygen does not need to be coordinated with sampling for other water quality parameters, so dissolved oxygen samples should be taken at times when immediate analysis is going to be possible. This will eliminate problems that may be associated with holding samples for a period of time before the determination is made.

14.7.4 Turbidity Analysis

Turbidity analyses shall be performed according to *Standard Methods* 2130 or EPA Method 180.1 with either a bench-top or in-line turbidimeter. In-line turbidimeters shall be used for measurement of turbidity in the filtrate waters, and either an in-line or bench-top turbidimeter may be used for measurement of the feedwater.

During each verification testing period, the bench-top and in-line turbidimeters will be left on continuously. Once each turbidity measurement is complete, the unit will be switched back

to its lowest setting. All glassware used for turbidity measurements will be cleaned and handled using lint-free tissues to prevent scratching. Sample vials will be stored inverted to prevent deposits from forming on the bottom surface of the cell.

The Field Testing Organization shall be required to document any problems experienced with the monitoring turbidity instruments, and shall also be required to document any subsequent modifications or enhancements made to monitoring instruments.

14.7.4.1 Bench-top Turbidimeters. Grab samples shall be analyzed using a bench-top turbidimeter. Readings from this instrument will serve as reference measurements throughout the study. The bench-top turbidimeter shall be calibrated within the expected range of sample measurements at the beginning of equipment operation and on a weekly basis using primary turbidity standards of 0.1, 0.5, and 3.0 NTU. Secondary turbidity standards shall be obtained and checked against the primary standards. Secondary standards shall be used on a daily basis to verify calibration of the turbidimeter and to recalibrate when more than one turbidity range is used.

The method for collecting grab samples will consist of running a slow, steady stream from the sample tap, triple-rinsing a dedicated sample beaker in this stream, allowing the sample to flow down the side of the beaker to minimize bubble entrainment, double-rinsing the sample vial with the sample, carefully pouring from the beaker down the side of the sample vial, wiping the sample vial clean, inserting the sample vial into the turbidimeter, and recording the measured turbidity.

For the case of cold water samples that cause the vial to fog preventing accurate readings, allow the vial to warm up by submersing partially into a warm water bath for approximately 30 seconds.

14.7.4.2 In-line Turbidimeters. In-line turbidimeters are required for filtered water monitoring during verification testing and must be calibrated and maintained as specified in the manufacturer's operation and maintenance manual. It will be necessary to verify the in-line readings using a bench-top turbidimeter at least daily; although the mechanism of analysis is not identical between the two instruments the readings should be comparable. Should these readings suggest inaccurate readings then all in-line turbidimeters should be recalibrated. In addition to calibration, periodic cleaning of the lens should be conducted, using lint-free paper, to prevent any particle or microbiological build-up that could produce inaccurate readings. Periodic verification of the sample flow rate should also be performed using a volumetric measurement. Instrument bulbs should be replaced on an as-needed basis. It should also be verified that the LED readout matches the data recorded on the data acquisition system, if the latter is employed.

14.7.5 Particle Counting

In-line particle counters shall be employed for measurement of particle concentrations in filtrate waters. However, either a bench-top or an in-line particle counter may be used to measure particle concentrations in the feedwater, concentrate (where applicable) and pretreated waters (where applicable). Laser light scattering or light blocking instruments are recommended for particle counting during verification testing. However, other types of counters such as Coulter counters or Elzone counters may be considered for use if they can

be configured to provide continuous, in-line monitoring for the filtrate product water stream. The following discussion of operation and maintenance applies primarily for use of laser light blocking instruments.

The following particle size ranges (as recommended by the AWWARF Task Force) shall be monitored by both in-line and bench-top analytical instruments during the verification testing:

- 2-3 μm
- 3-5 μm
- 5-7 μm
- 7-10 μm
- 10-15 μm
- > 15 μm

The Field Testing Organization shall be required to document any problems experienced with the monitoring particle counting instruments, and shall also be required to document any subsequent modifications or enhancements made to monitoring instruments.

Use of particle counting to characterize feedwater and filtered water quality is required as one surrogate method for evaluation of microbiological contaminant removal.

14.7.5.1 Bench-top Particle Counters. All particle counting shall be performed on-site. The particle sensor selected must be capable of measuring particles as small as 2 μm. There should be less than a ten percent coincidence error for any one measurement.

Calibration. Calibration of the particle counter is generally performed by the instrument manufacturer. The calibration data will be provided by the manufacturer for entry into the software calibration program. Once the data has been entered it should be verified using calibrated commercially-available particle standards or methods. This calibration should be verified at the beginning of each Verification Testing period.

Maintenance. The need for routine cleaning of the sensor cell is typically indicated by: 1) illumination of the sensor's "cell" or "laser" lamps, 2) an increase in sampling time from measurement to measurement, or 3) an increase in particle counts from measurement to measurement. During the ETV testing, the sensor's "cell" and "laser" lamps and the sampling time will be checked periodically. The number of particles in the "particle-free water" will also be monitored daily.

Particle-Free Water System. "Particle-free water" (PFW) will be used for final glassware rinsing, dilution water, and blank water. This water will consist of de-ionized (DI) water that has passed through a 0.22-μm cartridge filtration system. This water is expected to contain fewer than 10 total particles per mL, as quantified by the on-site particle counter.

Glassware Preparation. All glassware used for particle counting samples shall consist of beakers designed specifically for the instrument being used. Glassware will be cleaned after every use by hand washing using hot water and laboratory glassware detergent solution followed by a triple PFW rinse. Sample beakers will then be stored inverted. Dedicated beakers will be used at all times for unfiltered water (feed water before addition of body feed), diluted unfiltered water, filtered water, and PFW. When several samples are collected

from various equipment sampling points during one day, the appropriate beakers will be hand-washed as described above, and then rinsed three times with sample prior to collection. Other materials in contact with the samples, including volumetric pipettes, volumetric flasks, and other glassware used for dilution, will also be triple-rinsed with both PFW and sample between each measurement.

Sample Collection. Beakers should be rinsed with the sample at least three times prior to sample collection for particle counting. Sample taps should be opened slowly prior to sampling. Sudden changes in the velocity of flow through the sampling taps should be avoided immediately prior to sample collection to avoid scouring of particles from interior surfaces. A slow, steady flow rate from the sample tap will be established and maintained for at least one minute prior to sample collection. The sample will be collected by allowing the sample water to flow down the side of the flask or beaker; thereby minimizing entrainment of air bubbles.

Dilution. The number of particles in the raw waters is likely to exceed the coincidence limit of the sensor. If so, these samples will be diluted prior to analysis. In all cases, PFW will be used as dilution water. When necessary, dilutions will be performed as follows:

- Dilution water will be dispensed directly into a 500-mL volumetric flask;
- A volumetric pipette (i.e. 10-mL for a 50:1 dilution) will be used to collect an aliquot of the sample to be diluted (stock);
- The appropriate volume of the stock will be slowly added to the volumetric flask containing the dilution water;
- The volumetric flask will be slowly filled to the full-volume etch with dilution water;
- The volumetric flask will be inverted gently and then its contents will be poured slowly into the appropriate 500-mL flask for analysis.

During each of the above steps, care will be taken to avoid entrainment of air bubbles; thus, samples and dilution water will flow slowly down the side of containers to which they are added. Excessive flow rates through pipette tips, which can cause particle break-up, will be avoided by use of wide-mouth pipettes. Sample water will be drawn into and out of pipettes slowly to further minimize particle break-up.

$$Sample\ Particle\ Concentration = \frac{\{MP - (1 - X) \times PF\}}{X}$$

Actual particle counts in a size range for diluted samples will be calculated based on the following formula:

where MP is the measured particle concentration (particles per mL) in the diluted sample, PF is the measured particle concentration (particles per mL) in the particle-free water, and X represents the dilution factor. For a 25:1 dilution, the dilution factor would be 1/25, or 0.04. The expression for the dilution factor is provided by the following equation:

$$Dilution\ Factor = X = \frac{Volume\ Sample}{Addition\ of\ Volume\ Sample + Volume\ Dilution\ Water}$$

Particle Counting Sample Analysis. To collect samples for particle counting, at least 200 mL of each water sample to be counted (diluted or not) should be collected in the appropriate beaker. The beaker will be placed into the pressure cell and counting will take place in the "auto" mode of the instrument. Four counts will be made of each sample. The first count will serve to rinse the instrument with the sample; data from this count are discarded. Data from the subsequent three counts will be averaged, and the average value will be reported as the count for that sample.

14.7.5.2 In-line Particle Counters. Any in-line particle sensors selected for use must have capabilities for measurement of particles as small as 2 μm and have a coincidence error of less than ten percent. The particle counter manufacturer shall provide data and methods that the in-line particle sensors meet these criteria or an independent third party shall verify the in-line particle sensor meets the above criteria. The particle counter manufacturer shall provide the methods for demonstration of coincidence error.

The sensors of the in-line units must also be provided with a recent (two months before the start of testing) manufacturer calibration. The calibration shall be verified by measurement of the individual and cocktail suspensions of the monospheres as described for the batch counter; however, in this case the samples must be fed in-line to the counters.
No dilution of the filtered water samples will be conducted. The data acquired from the counters will be electronically transferred to the data acquisition system. If it is known that a particular sensor will not be used for a period of several days or more, refer to the manufacturer recommendations for an appropriate storage protocol.

14.8 Chemical and Biological Samples Shipped Off-Site for Analyses

14.8.1 Organic Parameters: Total Organic Carbon and UV_{254} Absorbance

Samples for analysis of TOC and UV_{254} absorbance shall be collected in glass bottles supplied by the state-certified or third party- or EPA-accredited laboratory and shipped at 4^{o}C to the analytical laboratory. These samples shall be preserved, held, and shipped in accordance with *Standard Method* 5010B. Storage time before analysis shall be minimized, according to *Standard Methods*.

14.8.2 Microbial Parameters: Viruses, Bacteria, and Algae

Samples for analysis of Total Coliforms (TC) and Heterotrophic Plate Counts (HPC) shall be collected in bottles supplied by the state-certified or third party- or EPA-accredited laboratory and shipped with an internal cooler temperature of approximately 4°C to the analytical laboratory. Samples shall be processed for analysis by a state-certified or third party- or EPA-accredited analytical laboratory within the time specified for the relevant analytical method. The laboratory shall keep the samples at approximately 4^{o}C until initiation of analysis. TC densities will be reported as most probable number per 100 mL (MPN/100 mL) or as total coliform densities per 100 mL. HPC densities will be reported as colony forming units per milliliter (cfu/mL).

Algae samples shall be preserved with Lugol's solution after collection, stored and shipped in a cooler at a temperature of approximately 4^{o}C, and held at that temperature range until counted.

14.8.3 Inorganic Samples

Inorganic chemical samples, including alkalinity, hardness, iron, and manganese, shall be collected, preserved, shipped, and held in accordance with *Standard Method* 3010B, paying particular attention to the sources of contamination as outlined in *Standard Methods* 3010C. The samples shall be refrigerated at approximately 4°C immediately upon collection, shipped in a cooler, and maintained at a temperature of approximately 4°C during shipment. Samples shall be processed for analysis by a state-certified or third party- or EPA-accredited laboratory within 24 hours of collection. The laboratory shall keep the samples at approximately 4°C until initiation of analysis.

14.8.4 Microspheres

The membrane filters used for obtaining microsphere samples shall be refrigerated at approximately 4°C immediately upon collection. Such samples shall be shipped in a cooler and maintained at a temperature of approximately 4°C during shipment and in the analytical laboratory, until they are analyzed. This is done to minimize microbiological growth on the membranes.

Recovery of microspheres from suspensions held in glassware shall be evaluated by preparing a suspension of microspheres in which the number of microspheres used to make the suspension is estimated, based on either the weight of dry microspheres or the volume of microspheres in liquid suspension as provided by the supplier. After the suspension is prepared and mixed until it is homogeneous, five aliquots shall be taken and counted in the hemacytometer. After the microsphere density (concentration) has been calculated, aliquots of the suspension shall be diluted and filtered through polycarbonate membrane filters having 1 μm pore size. The elution and concentration steps described in Task 4 shall be followed, and the microspheres shall be counted in a hemacytometer. This shall be done five times, so that statistics can be developed on the recovery of microspheres in the sampling procedure.

As a check on possible interference from fluorescing organisms in the feed water, during each Verification Testing run in which fluorescent microspheres are used, a sample of feed water with no seeded microspheres shall be filtered through a polycarbonate membrane, and the particulate matter on the membrane shall be concentrated using the procedures for microsphere analysis, and the concentrate shall be examined in a hemacytometer by microscope, with UV illumination. If no objects of the size and shape of the microspheres are seen to fluoresce, displaying the same color as the microspheres, then fluorescent objects of the proper color seen in samples with seeded microspheres can be considered to be microspheres.

Microspheres may adhere to surfaces of tanks, vessels, and glassware. All glassware, holding tanks, and membrane filter manifolds must be cleaned between seeding events or sampling events.

15.0 OPERATION AND MAINTENANCE

The Field Testing Organization shall obtain the Manufacturer-supplied O&M manual to evaluate the instructions and procedures for their applicability during the verification testing period. The following are recommendations for criteria for O&M Manuals for equipment employing precoat filtration.

15.1 Maintenance

The manufacturer should provide readily understood information on the recommended or required maintenance schedule for each piece of operating equipment such as:

- pumps
- valves
- filter aid feeders
- mixers
- motors
- quick-opening pressure filter vessels
- instruments, such as turbidimeters
- water meters, if provided

The manufacturer should provide readily understood information on the recommended or required maintenance for non-mechanical or non-electrical equipment such as:

- tanks and basins
- piping used to convey filter aid slurries
- filter vessels

15.2 Operation

The manufacturer should provide readily understood recommendations for procedures related to proper operation of the equipment. Among the operating aspects that should be discussed are:

- Filter aid feeders:
- calibration check
- settings and adjustments -- how they should be made
- make-up of body feed slurry (for wet feed systems)

Mixers:

- purpose
- appropriate mixing intensity for maintaining filter aid slurry in suspension

Body feed system:

- importance of maintaining proper body feed at all times

Filtration:

- control of filtration rate
- observation and measurement of head loss during filter run
- filtered water recirculation through filter vessel during times of low demand

Filter precoating:

- Preparation of filter aid precoat slurry
- Recycle of slurry through filter
- Completion of precoating

Filter cleaning:

- end of filter run
- technique for removal of spent filter aid from filter septa or leaves (sluicing, flow reversal, or draining, drying, and vibrating most commonly used)
- conclusion of filter washing
- provision for visual inspection of clean septum provided?
- manual cleaning of septa on periodic (e.g. yearly) basis

Monitoring and observing operation:

- filter vessel inlet pressure
- filter vessel outlet pressure
- raw water turbidity
- filtered water turbidity
- rate of flow
- what to do if turbidity breakthrough occurs

Filter aid selection and handling:

- information on safety aspects of handling of dry filter media
- techniques for determining proper filter aid grade and dosage

Strongly recommend that Manufacturer include a copy of AWWA Manual M30, "Precoat Filtration" with each precoat filtration system, as an AWWA committee of experts has prepared an excellent manual that would be very helpful to plant operators.

The manufacturer should provide a troubleshooting guide; a simple check-list of what to do for a variety of problems including:

- loss of raw water (feed water) flow to plant during a filter run
- poor raw water quality (raw water quality falls outside the performance range of the equipment)
- can't control rate of flow of water through equipment
- no body feed
- mixer will not operate
- filter can't be cleaned
- precoat recycle pump failure
- excessively high head loss through filter septa after spent filter aid cake removed and septa cleaned
- precoat filter aid cake not building up on filter septa during precoating
- uneven build-up of filter aid precoat cake on septa, indicated by lumpy precoat or bare spots on septa, after precoating completed
- no reading on turbidimeter
- automatic operation (if provided) not functioning
- filtered water turbidity too high
- filter head loss builds up excessively rapidly
- no head loss readings

- valve stuck or won't operate
- piping to convey filter aid becomes clogged
- no electric power

It is also recommended that the Manufacturer add a toll free number to the O&M manual for technical assistance on operation and maintenance of the equipment.

The following are recommendations regarding operability aspects of equipment employing precoat filtration. These aspects of plant operation should be included if possible in reviews of historical data, and should be included to the extent practical in reports of equipment testing when the testing is done under the ETV Program.

During Verification Testing and during compilation of historical equipment operating data, attention shall be given to equipment operability aspects. Among the factors that should be considered are:

- fluctuation of body feed rate from desired value -- the time interval at which re-setting is needed (i.e., how long can feed pumps hold on a set value for the feed rate?)
- can feed water flow rate be held constant even though head loss builds up during filter run?
- ease with which body feed rate can be checked
- can filter cleaning be done automatically?
- if automatic cleaning is provided, could it be initiated by:
- reaching a set value for head loss?
- reaching a set value for filtered water turbidity?
- does remote notification to operator occur when cleaning happens?
- can operator observe filter septa after cleaning?
- how can plant operator check on condition filter cake after precoating?
- can both influent pressure and effluent pressure be measured at filter vessel?
- is rate of flow of raw water measured?
- is filter aid body feed paced with raw water flow?
- is recirculation of filtered water provided for times of low flow?
- can volume of water used for cleaning filter be measured?

Both the reviews of historical data and the reports on Verification Testing should address the above questions in the written reports. The issues of operability should be dealt with in the portion of the reports that are written in response to Task 3: Documentation of Operating Conditions and Treatment Equipment Performance, in the Precoat Filtration Test Plan.

16.0 REFERENCES

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Walton, H.G. 1988. "Diatomite Filtration: Why It Removes *Giardia* From Water," In: *Advances in Giardia Research*, P.M. Wallis and B.R. Hammond, Editors, University of Calgary Press, Calgary, Alberta. p. 113-116.

Table 1. Generic Schedule for Verification Testing		
Test Period	Initial Operations, Estimated Time	Verification Testing, Minimum Required Time
#1, required	1 - 6 weeks	272 hours
#2, optional	1 - 3 weeks	272 hours
#3, optional	1 - 3 weeks	272 hours
#4, optional	1 - 3 weeks	272 hours

Table 2. Water Quality Sampling and Measurement Schedule	
Sample or Measure For:	Minimum Frequency
Temperature	Daily
pH	Weekly - desired but optional
Total alkalinity	Weekly - desired but optional
Hardness	Weekly - desired but optional
Dissolved oxygen	Daily (for vacuum filters only)
Total organic carbon	Weekly - desired but optional
Turbidity, feed water	Intervals of 4 hours or less
Continuous turbidity monitoring, filtered water (and feedwater, if used)	Use data at 1/4, 1/2, or 1 hour intervals for calculation of long-term performance. Also note maximum turbidity observed each day.
Iron	Weekly
Manganese	Weekly if present in concentration of 0.05 mg/L or greater
Algae, number and species	Weekly if no algae bloom; Daily if algae bloom occurs.
Microscopic particulate analysis	As needed for diagnosis of short filter runs
Total coliform	Every other day for feed water and filtered water characterization - desired but optional.
UV_{254} absorbance	Weekly when sample for TOC taken - desired but optional.
Particle Counting	See Task 4.

Table 3. Analytical Methods			
Parameter	Facility	*Standard Methods*[1] number or Other Method Reference	EPA Method[2]
Temperature	On-Site	2550 B	
pH	On-Site	4500-H^+ B	150.1 / 150.2
Total alkalinity	Lab	2320 B	
Total Hardness	Lab	2340 C	
Total organic carbon	Lab	5310 C	
Turbidity	On-Site	2130 B / Method 2	180.1
Particle counts (electronic)	On-Site	Manufacturer	
Dissolved Oxygen	On-Site	4500-O	
Iron	Lab	3111 D / 3113 B / 3120 B	200.7 / 200.8 / 200.9
Manganese	Lab	3111 D / 3113 B / 3120 B	200.7 / 200.8 / 200.9
Algae, number and species	Lab	10200 and 10900	
Microscopic particulate analysis	Lab		EPA 910-R-96-001
UV_{254} absorbance	Lab	5910 B	
Total coliform	Lab	9221 / 9222 / 9223	
E. Coli	Lab	9221 / 9222 / 9223 (Colilert)	
Bacillus spores	Lab	Rice et al. 1996	
MS2 virus	Lab		EPA ICR Method for Coliphage Assay, 1996
Microsphere counts	Lab	Li *et al.*, 1997	

Notes:
1) *Standard Methods* Source: 20th Edition of Standard Methods for the Examination of Water and Wastewater, 1999, American Water Works Association.
2) EPA Methods Source: EPA Office of Ground Water and Drinking Water. EPA Methods are available from the National Technical Information Service (NTIS).

Table 4. Equipment Description and Operating Data	
Operating Data	Action
Feedwater Flow and Filter Flow	Check and record each two hours, adjust when >10% above or below goal. Record both before and after adjustment. (If filter operates on a declining rate principle, note flow through filter every two hours but do not adjust flow rate.)
Filtration Rate	Calculate based on flow rate data and run times.
Filter Precoating	Record quantity of filter media (diatomaceous earth or perlite) used to coat filter, for each precoating. (Volume of slurry used and concentration of filter media in slurry). Record grade and brand.
Body Feed	Record body feed slurry concentration when body feed slurry prepared and record flow rate for body feed at least once each eight hours. Record grade and brand.
Filter Head Loss (filter inlet pressure and filter outlet pressure)	Record initial clean bed total head loss at start of filter run and record total head loss each two hours.
Filter Run Length	Calculate based on starting time and ending time for each filter run.
Filtered Water Production	Calculate gallons of water produced per square foot of filter area (or m^3/m^2), for each filter run.
Filter Aid Usage	Using data for precoating and body feed and for water production, calculate total pounds or kilograms of filter aid used in each run and total filter aid usage expressed as mg/L.
Filter Cleaning	Record time and duration of each filter cleaning. Record water volume used to clean filter.
Electric Power	Record meter reading once per day
Hours operated per day	Record in log book at end of day or at beginning of first shift on the following work day.
Log of events in watershed	Record occurrence of storms, construction activity, snowmelt, or other activities that could influence source water quality in log book at end of day or at beginning of first shift on the following work day.
Provide complete description of precoat filtration plant as required in Task 3.	
All parameters will be checked only during times when the equipment is staffed.	

Table 5. Precoat Filtration Challenge Tests Using Microorganisms and Surrogates	
Microorganism	Surrogate
Giardia cysts	use *Cryptosporidium* surrogate because *Cryptosporidium* is a somewhat smaller protozoan organism
Cryptosporidium oocysts	3 to 5 μm microspheres
Bacteria	*E. coli*
	Total coliform bacteria
	Bacillus bacteria
Human Enteroviruses	MS2 coliphage
Sampling Schedule for Microorganisms and Surrogates	
Microspheres and Microorganisms	Take samples at time zero (as defined in Task 4), at 0.5 hr and at 1.0 hr past time zero, and at a time when head loss is estimated to be between 85% and 95% of terminal head loss.
Particle counting	Filtered water analyzed by flow-through particle counter. Feed water analyzed at least once per hour if using batch samples, or use flow-through particle counter.