Field Operations Document Environmental Technology Verification

of the
Kinetico CPS100CPT
Coagulation and Filtration System
for the Physical Removal
of Giardia and Cryptosporidium
from Drinking Water

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FORWARD

The following Field Operations Document (FOD) was prepared for the Environmental Technology Verification of the Kinetico Macrolite® CPS100CPT Prefiltration by Coagulation and Pressure Filtration System. It was prepared by the Field Testing Organization (FTO) in accordance with the Protocols and Test Plan established by NSF and EPA for the removal of microorganism contaminants.

The ETV program is a cooperative program of the NSF and EPA developed to evaluate in a structured and comprehensive manner new and innovative water treatment technologies. The program was designed with the needs of small systems in mind, although the technologies may be applicable to larger public water supplies as well.

The purpose of this document is to coordinate the understanding of the FTO, the manufacturer of the technology, NSF and EPA with respect to the objectives and methodologies of the testing. It is intended to serve as an on-site working document, and is subject to some modification as testing proceeds. While it is a public document and is not intended to be proprietary, it is written for the benefit of principal parties and for the convenience of the reviewers of the final verification and performance report, and not for the general public. Accordingly, while some background is offered, it is not intended to be a tutorial on the technology. It is expected that future reviewers of the performance report will have at their disposal copies of this document, however, to offer them a background to the testing procedures.

This FOD is based on the Protocols and Test Plans published as Chapters 1 and 3 of the EPA/NSF ETV *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* dated April 20, 1998 (updated May 14, 1999), and conforms to those documents.

The Kinetico Coagulation System is a Direct Filtration System consisting of coagulant chemical injection into the raw water, a mixing chamber and a backwashable pressure filter system. The filter system consists of two identical 10 inch diameter filter tanks piped for alternating service, thereby providing continuous flows of 5 gpm. The media, called Macrolite®, consists of synthetic ceramic spheres, and is more fully described within the body of the document.

The technology in this FOD is well established; however, the use of a synthetic ceramic media as a filter media is relatively new, so some adaptation to the common filtration technology is required. Macrolite® has properties that the manufacturer feels ideally suited to filtration—especially for smaller particulate matter. Moreover, the coagulation and filter system has control and monitoring functions that are exclusive to the design. These functions are also being verified in this study.

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1.0 INTRODUCTION

1.1 EXECUTIVE SUMMARY

The following is the Field Operations Document (FOD) for the Environmental Technology Verification (ETV) third party field testing of the Kinetico, Inc. (KI) coagulation and backwashable Macrolite® Pressure Filtration System. The KI filter system will be challenged with *Giardia lamblia* cysts and *Cryptosporidium parvum* oocysts seeded into a blend of untreated water from the Mississippi River, and finished water from the University of Minnesota St. Anthony Falls Hydraulic Laboratory.

This FOD was prepared by an NSF approved Field Testing Organization (FTO), Cartwright, Olsen and Associates, LLC, (COA) and is based on the Protocols and Test Plans published as Chapters 1 and 3 of the EPA/NSF ETV *Protocol for Equipment Verification Testing for Physical Removal of Microbiological and Particulate Contaminants* , April 20, 1998.

The purpose of the testing is to verify the performance expectations of the manufacturer through a carefully designed study involving rigorous QA/QC controls. The manufacturer expects 2+ log removal of particles 5 µm or larger (the size of *G. lamblia*) at flow rates of 5 gpm (10 gpm per square foot) and 1.5 log removal of particles 3-6 µm in size, which includes *C. parvum.* This is the benchmark against which the system will be tested. This test will employ viable microorganisms and thus, the ETV claim is for a 1.5 log removal of *C. parvum,* and a 2 log removal of *G. lamblia.*

The following are the maximum and minimum influent conditions as limitations to the system.

Inlet flow rate—maximum	5 gpm
Inlet flow rate—minimum	0 gpm
Maximum static pressure	100 psi
Minimum inlet dynamic pressure	35 psi
Maximum temperature	100 F
Minimum temperature	35 F
Maximum inlet turbidity	8 NTU

Testing is performed in the field and consists of two phases:

I) An initial operations phase and
II) A testing and verification phase

The initial operations phase consists of two tasks:

A) An evaluation of the source water characteristics for establishing the suitability of the site for the performance study

B) Initial test runs to determine the readiness of the equipment for the second phase

The testing and verification phase consists of six tasks designed to measure the equipment performance against the manufacturer's claims. The six tasks are:

1) Verification testing runs and routine equipment operation
2) Test runs for feed and finished water
3) Documentation of operating conditions and treatment equipment performance
4) Documentation of microbiological contaminant removal
5) Data management
6) Data quality assurance/quality control

Inorganic water analyses will be conducted by Spectrum Labs, Inc., of New Brighton Minnesota, and Microbiological Laboratory work will be performed by BioVir Laboratories, Inc. of Banicia, California.

These tasks and the testing procedures are more fully described in this document below. Following the testing and verification phase, the data will be reviewed, summarized and a full verification report generated by the FTO for submission to the NSF/EPA. EPA will publish the final report for distribution to interested State and Municipal water treatment regulators and engineers.

1.2 ACRONYMS, ABBREVIATIONS, FORMULA AND SYMBOLS

APHA
American Public Health Association.

ASTM
American Society for Testing and Materials.

AWWA
American Water Works Association.

COA
Cartwright, Olsen and Associates, LLC

DI
Deionized (demineralized) water.

EPA
US Environmental Protection Agency.

ESWTR
Enhanced Surface Water Treatment Rule

ETV
Environmental Technology Verification.

FOD
Field Operations Document.

FTO
Field Testing Organization.

ICR
Information Collection Rule.

KI
Kinetico Incorporated.

MPA
Microscopic Particulate Analysis.

NIST
National Institute of Standards and Technology.

NSF
NSF International, Formerly National Sanitation Foundation.

(Oo)cyst
Will be used to refer to both cysts and oocysts when used together.

PFW
Particle Free Water.

PLC
Programmable Logic Computer.

SM
Standard Methods for the Examination of Water and Wastewater.

SWTR
Surface Water Treatment Rule.

TOC
Total Organic Carbon.

TSS
Total Suspended Solids.

Ten State's Standards
Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Water Works*.

USEPA
United States Environmental Protection Agency.

WEF
Water Environment Federation.

2.0 EQUIPMENT VERIFICATION TESTING RESPONSIBILITIES

2.1 VERIFICATION TESTING ORGANIZATION AND PARTICIPANTS

The Field Testing Organization, Cartwright, Olsen and Associates, LLC (COA), is responsible for all elements in the testing sequence, including collection of samples, calibration and verification of instruments, data collection and analysis, and test data management.

Kinetico Incorporated (KI) will be responsible for the installation and maintenance of the equipment and will provide logistical and technical support during set up and the initial operations period. The FTO will supervise any and all repair and maintenance procedures during the test period for documentation into the final report.

Responsibilities Specific to COA:

- COA will act as coordinator of all communications during the test period and will coordinate all activities.
- COA will ensure that the selected site meets the requirements of the test.
- All data relevant to the data collection, verification studies and analyses will be managed and controlled by COA.
- COA personnel will operate the equipment during the testing period. The equipment will be under the supervision of COA as the Field Testing Organization.
- COA will interpret the data and write the final report for submission to EPA/NSF.

Following is a list of the persons, firms and associates of COA as members of the Field Testing Organization.

Cartwright, Olsen & Associates, LLC
19406 East Bethel Blvd.
Cedar, Minnesota 55011
(612) 434-1300
Fax (612) 434-8450
e-mail: p.olsen@ix.netcom.com

– Peter S. Cartwright, P.E., Principal Investigator, QA/QC.
– Philip C. Olsen, Managing Partner.
– Debra E. Huffman, Ph.D., Principal Investigator (Microbiology).
– Lawrence Henke, Associate, Documentation, Field Technician.
– Russell G. Olsen, Field Engineer, Technician.
– Julie A. Tank, Jr. Engineer, University of Minnesota.
– Scott Morgan, M.S., P.E. Research Fellow, University of Minnesota
– Richard L. Voight, P.E. Research Fellow, University of Minnesota

The laboratory selected for microbiological analysis is:

BioVir Laboratories, Inc.
685 Stone Road
Benicia, CA 94510
(707) 747-5906 or (800) 442-7342
Fax (707) 747-1751

– John L. Riggs, Ph.D., President
– Robert C. Cooper, Ph.D., Vice President, Research

Staff that will be affiliated with this project:

– Richard E. Danielson, Ph.D., Quality Assurance Officer, Principal Analyst/Supervisor
– Koichi Nakamura, Principal Analyst/Supervisor
– Mark D. Wallin, Principal Analyst/Supervisor
– Steven J. Mullaney, Analyst
– Mary P. Philbrook, Analyst
– Dennis Catanyag, Technician
– Christine Willits, Technician

A Quality Assurance Program Plan, sample data sheet/chain of custody form, the EPA ICR Approval notification, and the State of California Environmental Laboratory Certification are attached as Appendix F.

Additional, off-site analytical work will be performed by:

Spectrum Labs Inc.
301 West County Road E2
St. Paul, MN 55112
(651) 633-0101
Fax (651) 633-1402

– Duane Nowlin, PhD, President
– Tom Halverson, Laboratory Manager
– Wayne Mattsfield, Microbiologist

The Spectrum Labs, Inc. Quality Assurance Plan/Manual, along with appropriate chain of custody and other recording and lab forms are included as Appendix E.

The Manufacturer of the Equipment is:

Kinetico Incorporated
10845 Kinsman Road
Newbury, Ohio 44065
(440) 564-9111 or (800) 432-1166
Fax (440) 564-9541

– Bill Prior, President
– Glen Latimer, Operations Manager

KI staff associated with the ETV Project include:

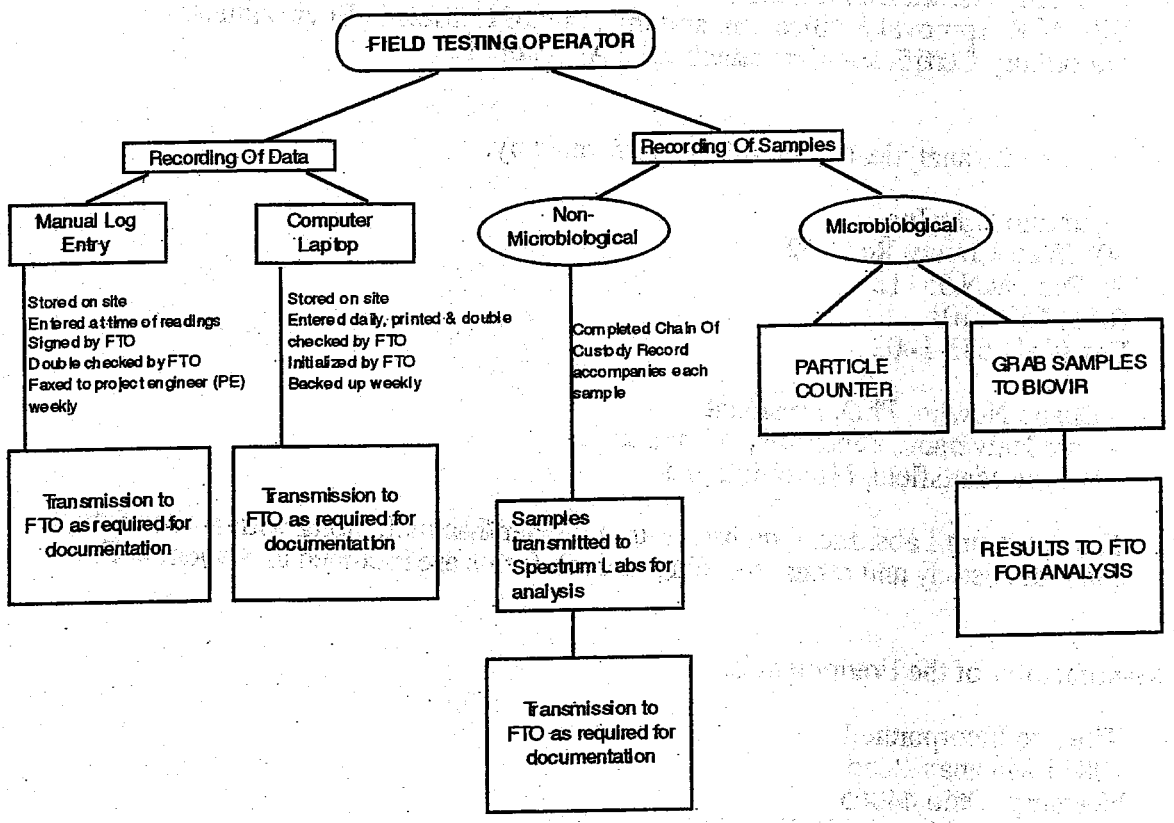
– Skip Wolfe, Project Manager, Engineer
– Chip Fatheringham, Engineering Technician
– Jeremy Litz, Electrical Engineer
– Wilfreid Schott, Engineer
– Dan Combs, Accountant
– Vicky Zbozein, Administrator
– Holly Nickita, Secretary

2.2 ORGANIZATION

An organizational chart illustrating communication is shown in Figure 2-1.

FIGURE 2-1

ORGANIZATIONAL CHART



2.3 VERIFICATION TESTING SITE

The site selected for challenge testing of the Kinetico CPS100CPT Coagulation and Filtration System is the University of Minnesota, St. Anthony Falls Hydraulic Laboratory located at the University of Minnesota campus, Minneapolis, MN (Appendix I) . The St. Anthony Falls Hydraulics Laboratory is not a water treatment plant, therefore no historical data is available. The Minneapolis Water Treatment Plant however, is located on the Mississippi River in close proximity to the Hydraulic Laboratory, thus the historical data is from the Minneapolis Water Treatment Plant.

This site was selected because of the ability to blend treated and raw water to meet special water quality matrix requirements and because of the proximity to FTO offices for test period staffing. The test site makes available a wide range of water quality matrices, and thereby offers a wide variety of challenge opportunities. The equipment will be connected to the appropriate water supplies through Watts Reduced Pressure Zone backflow prevention valves.

The University of Minnesota St. Anthony Falls Hydraulic Laboratory takes water directly from the Mississippi River. Typical water quality of Mississippi River water at the intake location is summarized in Table 2–1.

The effluent from the pilot plant will be directed to sanitary sewer. The Metropolitan Environmental Authority, which encompasses the Twin Cities Metro Area, maintains a primary sewage treatment plant that discharges to the Mississippi River downstream of the Hydraulic Laboratory. The addition of this volume of water and particulate matter from this test is minuscule with respect to the 235,000,000 gallons processed daily. Metropolitan Environmental Industrial Waste Authorities have given written approval to disposal of the effluent (letter attached as Appendix J).

River water at the University of Minnesota St. Anthony Falls Hydraulics Laboratory will be fully compiled as a function of Task A in initial operations and described in the final report. Water Quality Data for 1997 are included as Appendix B, and are briefly summarized below.

2.4 WATER QUALITY

2.4.1 Summary of Raw Water Quality Parameters

Typical water quality of the Mississippi River Water is represented by the data from 1997, which is summarized in Table 2-1. Printouts of water quality parameters are attached as Appendix B.

TABLE 2-1
MISSISSIPPI RIVER
RAW WATER QUALITY PARAMETERS

PARAMETER	AVERAGE	MAXIMUM	MINIMUM
Temperature (C)	12.00	26.00	1.00
Turbidity (NTU)	8.60	27.00	2.20
Order Threshold	37.00	80.00	3.00
Color	42.00	81.00	23.00
pH	8.31	8.70	7.84
Total Hardness (ppm)	201.00	265.00	142.00
Alkalinity (ppm)	172.00	226.50	127.50
HCO3 (ppm)	162.00	219.00	113.00
Calcium Hardness (ppm)	135.00	170.00	92.00
Fluoride (ppm)	0.18	0.28	0.10
TOC (ppm)	9.10	12.00	7.25

2.4.2 Treated Water Data From The University of Minnesota St. Anthony Falls Hydraulics Laboratory

Summary of the effluent water at the University of Minnesota St. Anthony Falls Hydraulics Laboratory is summarized in Table 2-2. Additional parameters will be collected during Task A and included as a part of the final report.

TABLE 2-2
SUMMARY OF UNIVERSITY OF MINNESOTA ST. ANTHONY FALLS HYDRAULICS LABORATORY TREATED WATER
(ALL IN PPM)

PARAMETER	AVERAGE	MAXIMUM	MINIMUM
Silica	7.10	9.30	3.80
Aluminum	0.07	0.12	<0.01
Calcium	23.80	28.80	18.80
Magnesium	4.30	5.40	2.20
Sulfate	22.00	25.30	18.70
Chloride	20.70	25.00	17.00
Iron	<0.02	0.02	<0.01
Manganese	<0.01	<0.01	<0.01
Fluoride	1.04	1.30	0.14
Total Alkalinity	39.00	53.00	22.00
Total Hardness	76.00	102.00	61.00
Total Residue	145.00	169.00	106.00
pH	8.49	9.27	7.74
Chlorine/-amine	4.00	4.40	3.60
Phosphate	0.49	0.56	0.21
Nitrate-Nitrogen	0.10	0.16	0.02

FIGURE 2-2
FLOW SCHEMATIC OF EXISTING WATER TREATMENT FACILITY AND INCORPORATION OF PILOT INSTALLATION

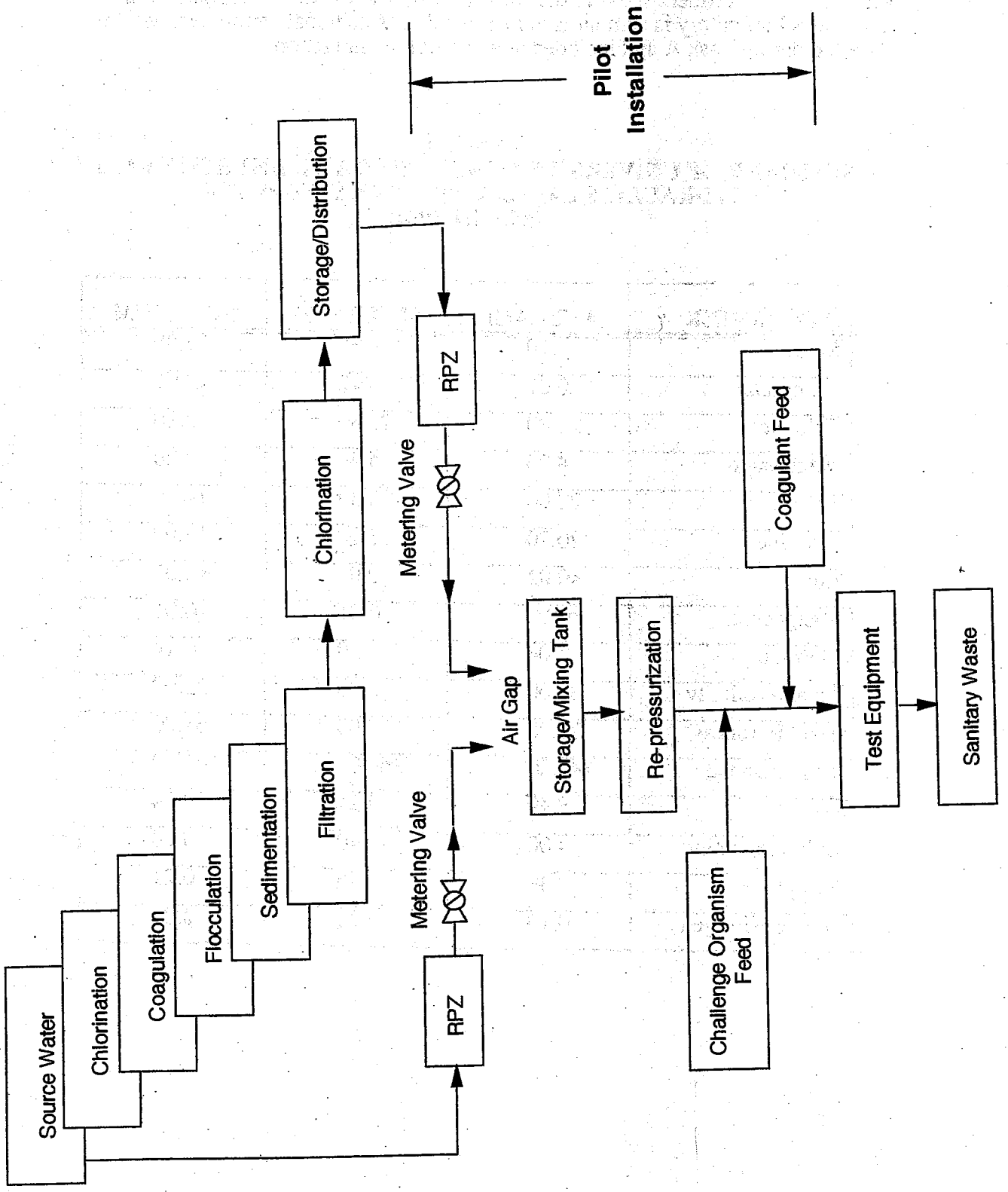
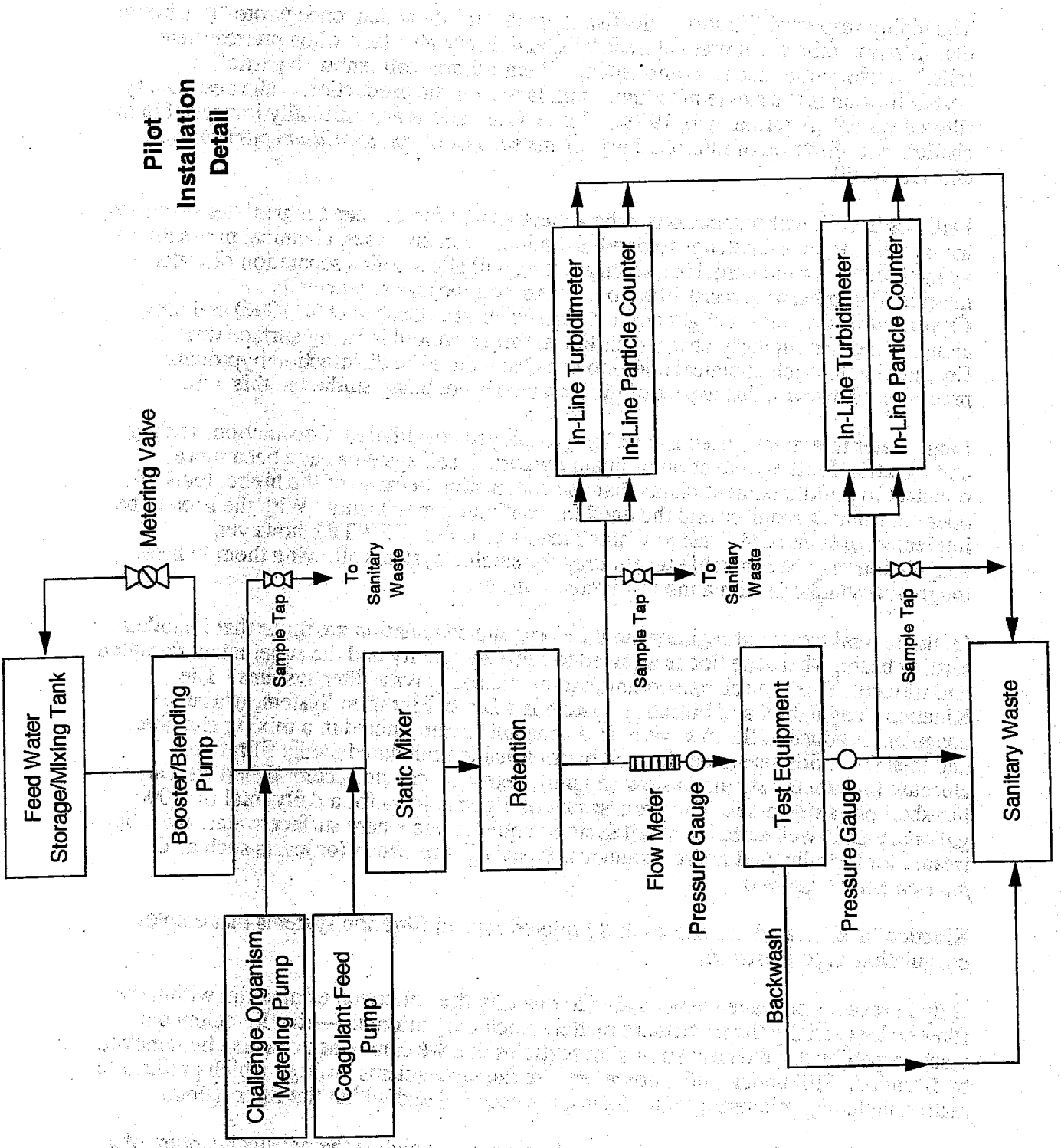


FIGURE 2-3
SCHEMATIC OF PILOT INSTALLATION FOR VERIFICATION PERIOD



3.0 EQUIPMENT CAPABILITIES AND DESCRIPTION

3.1 EQUIPMENT CAPABILITIES

The highly respected filtration scientist, Appiah Amirthqarajah, once wrote "It is ironic that filtration fails when pretreatment fails, and theory also fails when pretreatment fails." At the same time he commented, "Chemical pretreatment with particle destabilization is the single most important factor for the production of the best quality filtered water" (Amirtharajah, 1988). These observations are especially important in the challenge to filtration of microbial organisms such as *Cryptosporidium parvum* and *Giardia lamblia*.

Particles in colloidal suspensions, where electrostatic forces keep the particles dispersed, have proven to be a challenge to depth filtration. In many cases, chemical pretreatment, by agglomerating the particles into larger floc, will allow solids separation of water matrices that otherwise resist filtration. Protozoan (oo)cysts, especially *Cryptosporidium,* have a slight anionic surface charge (Cushen et al. 1996) and thus, along with other similarly charged particles, form a colloid in many surface waters. Coagulation through chemical addition can also reduce the disinfection byproduct precursors; however, that aspect of performance is not being studied in this test.

Large water treatment systems have long employed coagulation, flocculation, settling and filtration for the production of quality water. Small systems have been more reluctant to build treatment plants that use coagulation because of the higher level of operator training required and the need for continuing monitoring. With the soon to be implemented Enhanced Surface Water Treatment Rules (ESWTR), however, coagulation may be a suitable technology for smaller systems allowing them to meet tough new standards with a modest increase in costs.

Of the several treatment regimens that incorporate coagulation are those that include a settling basin, where the floc is allowed to settle by gravity and the supernatant decanted and filtered. This is a scheme common to municipal gravity filter systems. The Kinetico Coagulation and Filtration system is a Direct Filtration System, where the coagulant is added to the raw water in a constant stream, mixed in a mixing chamber, and then the solids separated through backwashable granulated media filtration. Because the process stream is slow (5 gpm), detention can be accomplished with an off-the-shelf pressure vessel. The process rate of 5 gpm allows for a daily total of 7,000 gallons; thus is well suited to small system requirements where surface waters must be treated for turbidity and microorganisms, especially protozoan (oo)cysts such as *C. parvum* and *G. lamblia.*

Kinetico Incorporated has successfully piloted several filtration systems that employ coagulation as pretreatment.

Only in recent time have we been able to quantify the collection of material within the filter bed, especially the particulate matter—including microbes—that lie below our visual capabilities. We now know that particles that we cannot see can also be removed by filtration. Still under study, however, are the mechanisms through which particulate matter, including microscopic life forms, are accumulated within the filter media.

It has been assumed that along with simple straining, which is the physical capture of a small mass too large to move through the pores between the media granules, small

particles are captured through other attachment mechanisms. Most of those mechanisms involve a surface charge attraction of the particle to granulated media and as a result many experiments have been performed to both better understand the process and to seek methods to improve it. Some particles are also assumed to be collected by impact on the surface of the filter media granules; while the actual mechanisms are not clearly understood, straining is certainly among them.

The most common filtration system used in municipal treatment is the gravity filter, which uses the weight or head of the water to force it through the filter at very low flow rates. Normal gravity filters, often called "rapid" sand filters, have a normal flow rate of 3 gpm per square foot of surface, or less. Other filters, such as slow sand filters, have even slower service flow rates.

Also included among rapid sand filters are pressure filters, where the water is forced through a media bed by high head pressures, and where the media is contained in a pressure vessel. They have long been used for iron and manganese removal, but have not been as readily accepted for surface water treatment where microbial matter is of concern (Ten State's Standards, 1992). The advantage—especially to small systems—of rapid sand pressure filters are many. They are relatively passive treatment systems, involve minimal operator attention, are low in cost and long lived. Of concern, however, is whether pressure filters can capture and contain particles that are small, and more importantly, particles that may pose a threat to public health, such as the protozoan oocyst *Cryptosporidium parvum.*

C. parvum oocysts are small, from 3 to 5 microns (μm) in diameter, relatively round in shape, and somewhat pliable. They have a slight anionic charge which serves to keep them separated from each other; that is, they behave as colloids in water suspensions. The primary issue then here is whether the Kinetico pressure filter CPS100CPT can act as a suitable barrier for these particles, preventing their passage into drinking water.

The operation of this equipment is more technically sophisticated than a filter alone, and requires more extensive training in the proper dosing of coagulating chemistry, therefore, the states and municipal health authorities may have requirements for operation beyond those of a filter. Kinetico, Inc. (KI) requires no special licensing, and will offer operator training upon equipment installation and start-up.

3.2 EQUIPMENT DESCRIPTION

This environmental technology verification (ETV) test is designed to challenge the Kinetico, Inc. CPS100CPT filter system to capture and contain 5 μm particles at flow rates of 5 gpm (9-10 gpm/ft^2). Prior field and pilot testing has demonstrated that pressure filters containing Macrolite® can achieve a 1-2 log removal of *C. parvum.* Kinetico, Inc. expects that the filter system will achieve 1.5 log removal of *C. parvum* oocysts at a flow rate of 5 gpm (9-10 gpm/ft^2) filter bed surface area.

The Kinetico CPS100CPT System will produce the following effluent characteristics:

TABLE 3-1
KINETICO CPS100CPT SYSTEM EFFLUENT CHARACTERISTICS

Inlet flow rate—maximum	5 gpm
Inlet flow rate—minimum	0 gpm
Expected pressure drop	15/30 psi
Minimum outlet pressure	10 psi
High pH	pH 8
Low pH	pH 3
Maximum temperature	100° F
Minimum temperature	35° F
Normal outlet turbidity	0.10 NTU
Maximum allowable outlet turbidity	0.50 NTU

The following are the maximum and minimum influent conditions.

TABLE 3-2
MAXIMUM AND MINIMUM INFLUENT CONDITIONS

Inlet flow rate—maximum	5 gpm
Inlet flow rate—minimum	0 gpm
Maximum static pressure	100 psi
Minimum inlet dynamic pressure	35 psi
High pH	pH 8
Low pH	pH 3
Maximum temperature	100° F
Minimum temperature	35° F
Maximum inlet turbidity	8 NTU

The filter media is Macrolite®, stable, ceramic substance synthesized into small, slightly elongated spheres. The mesh size for this test will be 70 mesh (US Standard Sieve). For mesh size 70, the individual grains have a diameter of 0.008 inches (210 microns).

The equipment tested will be two identical filters vessels operating alternately. Each filter vessel is 10 inches in diameter and 60 inches high, constructed of fiberglass, and pressure rated to 100 psi.

The water flow will be controlled with air activated George Fischer valves mounted on face piping constructed of Schedule 80 PVC. The valves also have handles for manual activation. At the inlet of the filter manifold will be a Ross motionless mixer with an injection probe for inoculation of challenge(oo)cysts.

The system, along with controls and a backwash pump is mounted on an epoxy coated, welded steel frame.

An illustration of the filter is attached as Figure 3-1.

The KI CPS100CPT is an automated, 100% redundant system with electronic monitoring and electronic controls for placing a filter vessel on line, backwash and rinse (filter to waste) cycles. The automation is performed by a programmable industrial computer with a touch screen monitor and interface control. Turbidimeters, flow meters and particle counting serve a monitoring and control function, although in the instance of the ETV test, monitoring will be subjected to more rigorous QA/QC.

The KI CPS100CPT Filter System is designed to backwash under any of the following conditions:

Effluent Turbidity	0.5 or greater (adjustable)
Differential pressure	20 psid or greater
Run Time	24 hours
By Manual Initiation	

The KI CPS100CPT is designed to backwash until a minimum turbidity of 5 NTU is reached. Built in are several controls to allow repeated backwash if the initial sequence is insufficient. In addition, controls to signal an alarm in the event of backwash failure are incorporated into the system.

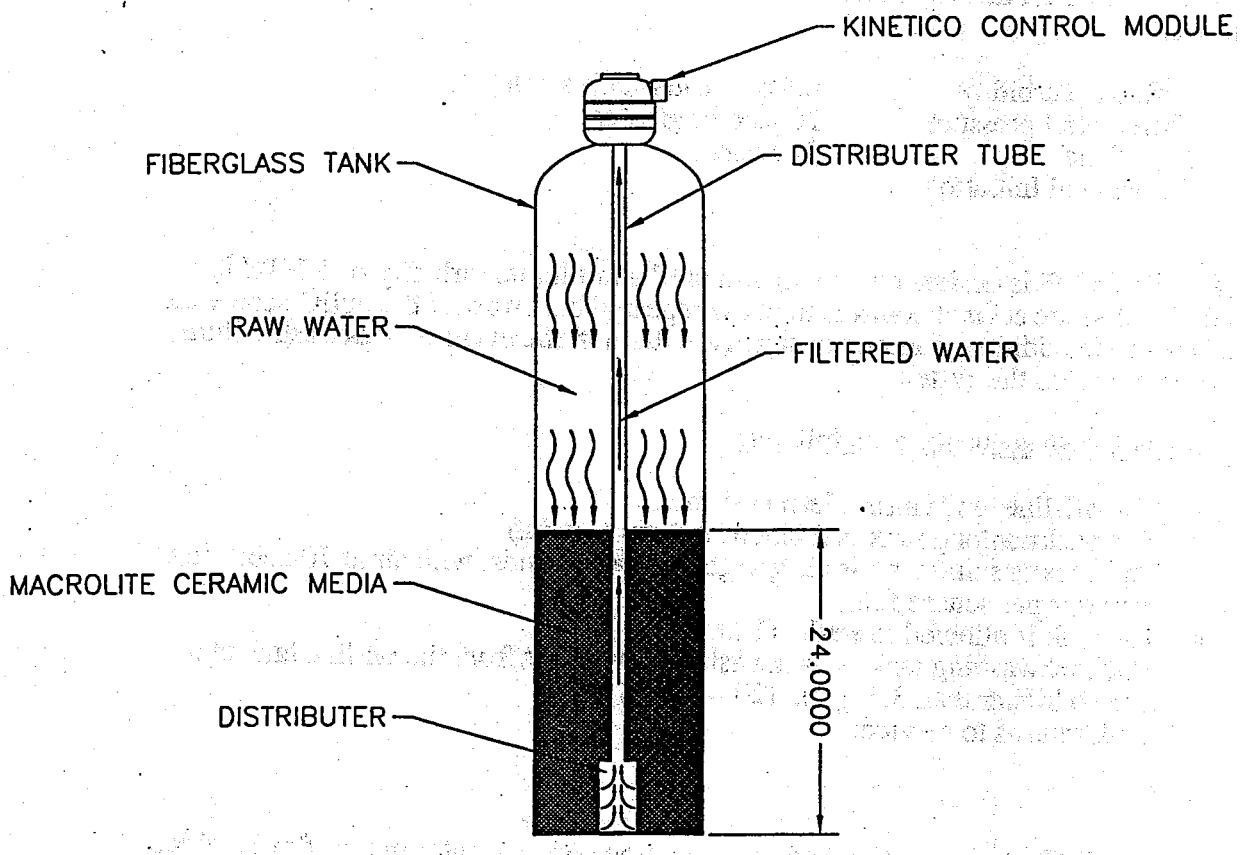
<u>The usual backwash sequence is as follows:</u>

1. The off-line tank rinses clean (3-5 min.)
2. The backwashing tank is drained slightly. (1 min.)
3. The backwashing tank is air sparged for 30 seconds, with air at 70 cubic feet per hour per square foot;
4. The tank is allowed to settle. (1 min.)
5. The backwashing tank is backwashed with water from the on-line tank at a rate no higher than 3.5 gpm. (20 min.)
6. Tank returns to service.

The KI CPS100CPT assumes a finished water storage tank and intermittent flows, which are common to small system requirements. Several of the control functions are initiated by sensors in the storage tank. One such is the return to on-line filtration, initiated when a storage tank reaches a pre-established low level. When that occurs, the next filter vessel on active standby is placed into a filter to waste position. The verification study will not employ a storage tank so these functions will be challenged artificially.

FIGURE 3-1
ILLUSTRATION OF KINETICO KI CPS100CPT FILTER

MODEL 100
TANK DRAWING



MODEL 100 10 X 54 FIBERGLASS TANK

3.2.1 Design Specifications and Limitations

The Kinetico CPS100CPT is designed for small system applications. The tanks can be made of fiberglass or of steel. Fiberglass tanks will be used for this ETV test. The piping is Schedule 80 PVC.

The following are the maximum and minimum influent conditions.

TABLE 3-3
MAXIMUM AND MINIMUM INFLUENT CONDITIONS

Inlet flow rate—maximum	5 gpm
Inlet flow rate—minimum	0 gpm
Maximum static pressure	100 psi
Minimum inlet dynamic pressure	35 psi
Maximum temperature	100° F
Minimum temperature	35° F
Maximum inlet turbidity	8 NTU

The Macrolite® media employed has a US sieve size of 70. That is equivalent to 0.008 inches (0.2 mm or 210 microns) average diameter for each sphere. The pore size for three such spheres that are touching will leave a void that is 15.47% of the diameter of the spheres, or 32.5 microns, considerably larger than the size of *C. parvum* oocysts. Thus, straining alone is not likely the sole mechanism of removal.

Surface attachment mechanisms, none of which are entirely understood, probably play a role in containment. Some of the surface mechanisms have been related to pH and to ionic strengths as well as to surface charges. The performance claim however, is not for removal of particulate matter only, but for protozoan (oo)cysts; thus it is of importance to this study to employ viable (oo)cysts in the trials.

Macrolite® media has a surface charge that varies with pH. At pH 2.3 and pH 8 it has no charge. Between those points, the charge is positive, with a maximum positive charge at pH 3-4; outside that range (<pH2.3 and > pH8) the charge is negative.

Moreover, the surface of the spherical granules is rough, suggesting that some particles may become trapped on the surface through adhesion as well as through surface charge attraction. The pore area and volume are described below.

Macrolite® —a synthetic filter medium—is not covered under AWWA standards for filter media (B100-89). Standard B100-89 is a purchase guide for filter media and is not intended as a design standard; however, many of the testing parameters will be of interest to public health administrators, especially those physical characteristics which may impact on the longevity of the material. Thus, hardness, specific gravity, acid solubility, uniformity coefficients, particle sieve size distributions (within manufacturing

lots and from lot to lot) and other similar physical data have been furnished by the manufacturer and are noted below. The physical characteristics of Macrolite® will be further discussed in the final verification report presented to NSF.

Macrolite® of the 70/80 mesh size has a bulk density of 0.96 grams/cc. The specific gravity (as measured by ASTM D2840) is 2.23 g/cc. The collapse strength for the media of this size has not been measured; however, for a larger sphere (30/50 mesh) the collapse strength (as measured by ASTM D 3102) is a nominal 7000 psi for 10% and nominal 8000 psi for 20% collapse. A magnified view of Macrolite® is provided in Figure 3-2.

The uniformity of the Macrolite® 70/80 mesh media was analyzed in accordance with AWWA Standard B100-96 by Bowser-Morner, Inc. in December, 1997. The results of this analysis are summarized below:

TABLE 3-4
UNIFORMITY OF THE MACROLITE® 70/80 MESH MEDIA

Sieve Size, USA Std.	Nominal, mm	Effective, mm	Percent passing
#45	0.355	0.360	100.0
#50	0.300	0.307	99.9
#60	0.250	0.249	79.8
#70	0.212	0.212	28.9
#80	0.180	0.180	7.2
#100	0.150	0.150	0.4

Effective Size: 0.19 mm
Uniformity Coefficient: 1.2

In addition, a Kinetico Inc. internal laboratory analysis of 70 mesh media employing a mercury/penetrometer Micromeritics Autopore II 9220 instrument produced the following results:

TABLE 3-5
INTERNAL LABORATORY ANALYSIS OF 70 MESH MEDIA

Total intrusion volume	0.2098 mL/g
Total pore area	0.18 sq-m/g
Median pore diameter volume	53.7990 µm
Median pore diameter area	52.5351 µm
Median pore diameter 4V/A	46.5685 µm

A Material Safety Data Sheet is included as a part of Appendix A. Macrolite® media meets the requirements of NSF Standard 61 and is NSF listed.

3.2.2 Statement Of Performance.

The Kinetico CPS100CPT System will produce the following effluent characteristics

TABLE 3-6
KINETICO CPS100CPT SYSTEM EFFLUENT CHARACTERISTICS

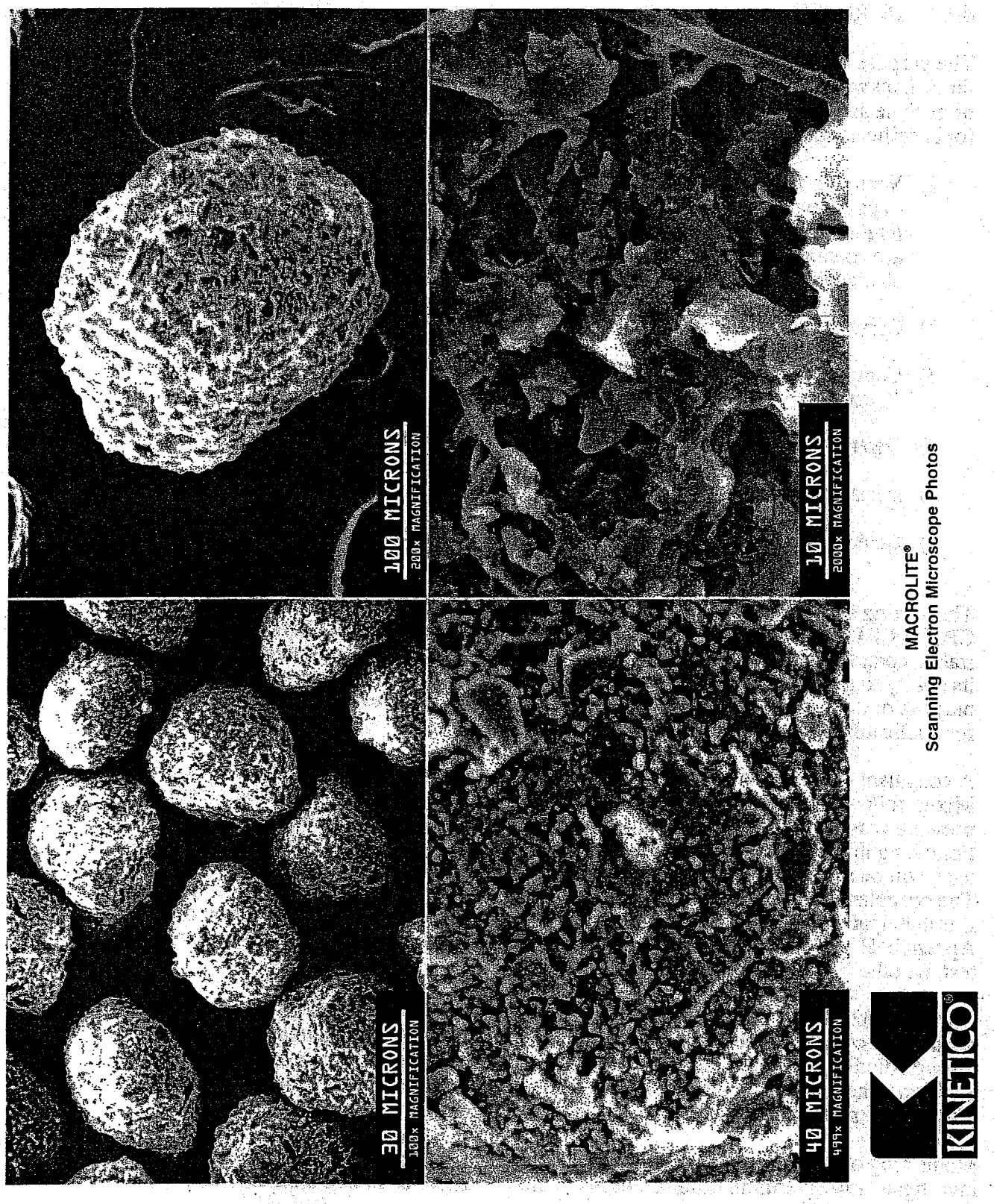
Inlet flow rate—maximum	5 gpm
Inlet flow rate—minimum	0 gpm
Expected pressure drop	15/30 psi
Minimum outlet pressure	10 psi
High pH	pH 8
Low pH	pH 3
Maximum temperature	100° F
Minimum temperature	35° F
Normal outlet turbidity	0.10 NTU
Maximum allowable outlet turbidity	0.50 NTU

The Kinetico CPS100CPT Pressure Filtration System is expected to produce a 95% (1.5 log) removal of particles of 3 µm and a 2 log removal of particles of 5 µm or larger of 5 gpm (10 gpm/ft^2), and with a maximum pressure differential of less than 15 psi. Since the Kinetico system will be challenged with live organisms, the ETV claim is a 1.5 log removal of *C. parvum*, and a 2 log removal of *G. lamblia*.

3.2.3 Installation Requirements

• Room temperature range	50-120° F
• Voltage/frequency/amperage	120,220,480 v/60 Hz/ 30 amps
• Ceiling height	8 feet
• Phone service for instrumentation	2 lines

FIGURE 3-2
MAGNIFICATION OF MACROLITE ® MEDIA



4.0 EXPERIMENTAL DESIGN

4.1 PURPOSE

The purpose of this test is to verify the performance of the Kinetico coagulation and direct backwashable depth filtration system in a formal and comprehensive manner to offer State and Local public health professionals an opportunity to evaluate the system for specific applications. Accordingly, the test will:

1) Verify performance claims of the manufacturer of the Kinetico filter with respect to particle reduction in the size range of *C. parvum*, (3-6 microns). Since *G. lamblia* cysts are larger (5-15 microns) it is assumed that if the smaller oocysts are contained, the larger cysts will be contained at least the same level; however, challenging with *G. lamblia* cysts will confirm removal percentage;

2) Correlate particle reduction to SWTR requirements (minimum 2 log reduction);

3) Compare the performance with the performance recommendations for the "Partnership for Safe Water";

4) Determine the effects of variations in water quality on performance;

5) Measure the operational costs for the system;

6) Determine reliability and underscore other operational parameters.

This testing and verification period is designed to challenge the Kinetico, Inc. CPS100CPT Coagulation and Pressure Filtration System, which employs Macrolite®, a stable, ceramic media—fully described above—as a backwashable granulated bed and its ability to remove live *G. lamblia* cysts and *C. parvum* oocysts from water. The purpose of the test is to offer state public health regulators an evaluation of the system for applicability to specific small system needs.

A coagulant chemical will be added to the water stream through a Ross Motionless Mixer, followed by a mixing chamber consisting of a 13 inch by 54 inch fiberglass pressure vessel. The mixing vessel will also offer 6.2 minutes of detention time. Following mixing and detention the water will be directed to the filters. The coagulant used will be selected from among seven formulations available from Aquamark, Inc. The coagulant will be selected on the basis of jar testing performed as a part of Task B. It is anticipated that one of the filter coagulation chemicals included as a portion of Appendix H will be used, although if none of these are found acceptable during jar testing, other formulations are available.

During the challenge period, viable cysts and oocysts will be injected into the water stream, the coagulant added, the water passed through the mixing chamber, passed through the filters, and the filter effluent studied to determine the level of capture. In addition, other conditions such as start/stop, backwash, filter ripening and (oo)cyst removal from the bed will also be evaluated.

Monitoring of turbidity and particle counts of both influent and effluent water will allow investigators to determine filtration performance. Particle counts in the range of 3 to 15

microns will be studied to offer evaluators a comprehensive overview of performance under varying water conditions.

Important to the overall evaluation of performance is a characterization of the raw water quality matrix. Water quality considerations are intended to challenge the coagulation and filtration process in typical applications, not necessarily applications of extreme conditions which would not likely be encountered. The ability of the coagulant and the filters to react to modest changes in water quality are important, however.

All testing will be performed in accordance with the procedures and protocols established in *Standard Methods*. All on-site testing instruments will be calibrated and/or standardized daily by FTO staff.

The analyses of water quality data from grab samples will be analyzed for 95% confidence interval by the FTO. The confidence formula is that noted in Chapter 1 of the EPA/NSF ETV Protocol and repeated in section 4.5 below.

4.2 EQUIPMENT CHARACTERISTICS

The equipment is designed to be used in water as a final barrier to the cysts and oocysts *G. lamblia* and *C. parvum* respectively.

The performance of the Kinetico, Inc. CPS100CPT Coagulation and Pressure Filtration system will be challenged by seeding viable *G. lamblia* cysts and *C. parvum* oocysts at a known concentration, passing them through the filter system at the design flow rate, and then measuring the effluent concentration of those particles. Coagulant chemicals will be added following the (oo)cyst inoculation to simulate real world conditions.

The primary counting process will be with an electronic optical particle counter, a Met One Particle Counter with PCC Display and PCX counting sensors, and will be confirmed by grab sample filtration through Gelman track etched filter cartridges.

Small systems are particularly vulnerable to changes in process flow, and assurance that particles will not detach or be driven through the media during these episodes is of considerable concern to small system operators and purveyors.

4.2.1 Qualitative Factors

Under test also are operational aspects of the Kinetico CPS100CPT System (for example, the measurement of head loss) as well as other factors that might impact performance. Hands-on operation of the system by FTO staff will be instrumental in determining the skill level required to maintain and service the filter system.

The KI CPS100CPT Filter System can be controlled either automatically, or through a manual over-ride. During initial operations, certain functions will be manually controlled. During the operational phase of the verification period, the automatic controller will be employed to verify performance of that aspect of the system.

4.2.2 Quantitative Factors

Among the relevant factors in the verification process are costs associated with the system. Especially important is the dosing requirement of the coagulant chemical. The operating conditions will be recorded to allow reasonable prediction of performance under other, similar conditions. The specific parameters to be measured are discussed below, but their impact on filter run length will be addressed and noted for inclusion in the final report. Also to be noted and reported are any occasional, anomalous conditions that might require operator response such as unexpected turbidity breakthrough, chemical dosing alterations, changes in disinfection levels, high levels of algal growth, excessive turbidity spikes or frequent filter clogging.

4.3 WATER QUALITY CONSIDERATIONS

The Kinetico, Inc. CPS100CPT Coagulation and Pressure Filtration System is designed for application to small systems where the source might be surface water or well water under the influence of surface water. Along with the challenge microbial contaminants *C. parvum* and *G. lamblia,* the filter system will remove other particulate matter and the filter load of those materials—along with their possible origin—will be studied. Coagulants are often used in waters colored by organic acids or excessive turbidities along with microorganisms that otherwise resist filtration. Specifically, the water quality characteristics to be recorded and analyzed are:

- Turbidity and Particle concentrations (especially in the range of 3-15 microns).
- Temperature (the daily range is important to chemical performance
- pH (also of significance in chemical pretreatment)
- Total Alkalinity
- Total Hardness
- Total Organic Carbon
- UV Absorption
- True Color
- Total Coliform
- Algae
- Iron
- Manganese
- Free and Total Chlorine

4.3.1 Source Water Quality

The Mississippi River source water historical data are attached as Appendix B. Finished and raw water will be blended as necessary to provide turbidity levels and other water conditions appropriate to the study.

4.3.2 Treated Water Quality

The Kinetico, Inc. CPS100CPT Coagulation and Pressure Filtration System is designed to remove particles at the 3-5 micron size range which include *C. parvum*. It is expected that in actual field conditions, disinfection procedures will be employed in addition to filtration to achieve EPA log removal/inactivation specifications under the SWTR or the ESWTR to include virus and bacterial disinfection. It is assumed that with a 1.5 log reduction in *C. parvum* concentration, equal or greater log removal of *G. lamblia* will

result. Disinfection residual levels will be recorded to allow correlations with other removal factors.

The presence of aluminum, iron, manganese, silica or clay particulate matter will naturally impact on filter performance and may shorten filter runs. Moreover, high levels of bacteria such as heterotrophic or iron bacteria may produce biofouling effects which would need to be addressed. Disinfection will therefore be assured by introducing a chlorine residual of 0.5 mg/L through a chemical feed pump upstream of the filtration systems. The chemical feed pump for this ETV test is a ProMinet Gamma G14B.

Chlorine will be fed into the water stream before the injection point to limit biological growth on the filter media. In addition, because of the blending of finished and raw water for the study, some chlorine residual may be present. Note that during the seedings, the addition of chlorine will be suspended, and sodium thiosulfate will be added to destroy any possible residual.

Although the filters are not impacted by the viability of the organisms, and it is their capture, not their inactivation that is being determined, chlorine may influence the filtration characteristics by altering the surface charge conditions of the microorganisms or by changing the characteristics of the coagulant.

4.4 DATA RECORDING

The chemical parameters and operator read operating data will be maintained in a bound log book and transferred to computer spread sheets. The control system for the CPS100CPT includes automatic data recording access and automatic systems will be employed where possible. Other readings will be manually logged.

In addition to the items noted in the data sheets (contained in Appendices D), any variations in the treatment plant regimen will be noted. Among the changes possible are changes in chemical coagulant aids, changes in disinfection levels to respond to varying biological contamination and unusual source water episodes, such as weather related incidents (ice outs, storms), unusual river traffic or contaminant spills. The source water will be a blend of finished and raw water.

4.5 RECORDING STATISTICAL UNCERTAINTY

Statistical 95% confidence calculations shall be performed for water quality data. Each of the water quality parameters will be analyzed, and confidence intervals determined by taking three discrete samples for each of the parameters at one operating set during the testing period. Sampling requirements are noted below in the work plan below.

$$confidence\ interval = \overline{X} \pm t_{n-1,\,1-\frac{\alpha}{2}} (S / \sqrt{n})$$

S = standard deviation
n = number of measurements in data set
t = distribution value with n-1 degrees of freedom
α = the significance level defined for 95% confidence as: 1- 0.95 = 0.05.

$$95\%\ confidence\ interval = \overline{X} \pm t_{n-1,0.975} (S / \sqrt{n})$$

4.6 VERIFICATION TESTING SCHEDULE

The verification testing will be conducted over a single season. Initial operations are expected to be longer in the initial period than in subsequent periods. Following initial operations the verification period will continue until the tasks are completed according to the work plan, but for at least 320 hours. Once begun, the Testing and Verification phase will not be stopped and restarted.

Turbidity variations from run to run, and in this instance from filter to filter, will be evaluated at 30 minute intervals during the run (beginning at 1.0 hours into the run). If the average for the filter run deviates less than 15% (should the average turbidity be >0.11 NTU, or by less than 0.02 NTU (if the average is < 0.10 NTU)), the test shall be considered consistent, however, testing shall continue for 320 hours.

An anticipated Timeline is shown in Appendix C.

5.0 FIELD OPERATIONS PROCEDURES

This section of the FOD describes the testing procedures to be performed for the verification of the Kinetico, Inc. CPS100CPT Coagulation and Pressure Filtration System. Each of the following tasks will be performed four times using the same skid mounted equipment.

5.1 TASK A: CHARACTERIZATION OF FEED WATER

5.1.1 Objective

The objective of this task is to determine the suitability of the feed water to the application of the technology.

5.1.2 Data

Data from past years from local and regional sources will be compiled and analyzed with respect to the biological, physical and chemical characteristics of the water. Parameters to be studied at each site include (but are not limited to) the following:

- Turbidity,
- Temperature and temperature variations within a season,
- pH,
- Total Coliform,
- Total Alkalinity,
- Hardness,
- True Color,
- UV_{254} Absorbance,
- Aluminum,
- Algae, (number and species)
- Total Suspended Solids (TSS),
- Iron and manganese
- Total Organic Carbon (TOC)
- Total Coliform,
- *E. coli*
- *Cryptosporidium*
- *Giardia*
- Microbial Particulate Analysis (MPA)

Data from other sources will be subjected to QA/QC evaluation as to method, sampling technique and confidence calculations.

Factors that could influence water chemistry, such as weather, recreational or commercial boat traffic, in and out-flows, and lake bottom composition will be included where appropriate. Also included will be a discussion of the human impact upon the source; for example, whether the source is used as a source for other activities, or whether it accepts waste water of any description.

5.2 TASK B: INITIAL TEST RUNS

5.2.1 Objective

The objective of this task is to establish operational data including coagulant, filter run times and backwashing schedules, and to qualify the equipment for performance with the selected source water.

5.2.2 Data Required

An important element of this task is the performance of jar testing to select a suitable coagulant chemical and its proper dosage. Once jar testing is complete, initial test runs will be performed to both terminal headloss and to turbidity breakthrough.

Initial test runs will be performed to both terminal headloss and to turbidity breakthrough. Flow rate variations and the character of finished water will also be studied to determine optimum operational conditions. Backwashing will be initiated manually, when either a terminal headloss is reached or when turbidity breakthrough occurs. Filters will be backwashed until the waste stream runs clear, as determined by a turbidity of 5 NTU or less. Filters will be run to waste for a minimum of two bed volumes of the filter and the time to clear noted in the logbook. Terminal headloss will be considered to be when the filter experiences a 12 psi pressure drop. Turbidity breakthrough is considered reached when the turbidity in the effluent water is 0.5 NTU.

Upon return to service, the filter ripening period will be monitored and timed. These data will be used to determine the benchmarks for backwash, rinse and run cycles during the testing and verification period.

The coagulant chemistry will be chosen from among seven formulations from the Aquamark, Inc. company. Specification and data sheets, along with MSDS Sheets for the several coagulants to be studied are attached as Appendix H.

Also during initial operations, tracer tests using sodium chloride will be used to time the residence period of the filter and the side stream through the testing ports. This is done by injecting salt water into the influent stream through the metering pump injection probe ahead of the static mixer. The flow can be timed by using a stopwatch and a TDS meter. The use of salt water over tracer dye in this application is preferable because it can be conveniently measured at small increments thereby demonstrating both initial and final concentrations; it dissolves readily and hence is not itself impeded by the filter; and after it is rinsed clean it leaves no residual on the filter media.

Data from these tests will be used to establish test runs using polystyrene microspheres for seeding and recovery studies. These studies will be used to calibrate side stream flows, capture and recovery parameters for the challenge tests using *G. lamblia* cysts and *C. parvum* oocysts.

5.3 TASK 1: VERIFICATION TESTING RUNS AND ROUTINE EQUIPMENT OPERATION

5.3.1 Objective

The objective of this task is to operate the equipment for the prescribed period of 320 hours, to monitor and register run lengths, backwash frequencies and ripening periods, and to evaluate equipment control features.

5.3.2 Initial Operations

The verification test period will be defined in initial operations. The equipment is to be operated continuously during this period, under varying conditions. A single season period is required, however, varying water quality parameters and other conditions may impact of performance, and these shall be recorded.

Factors that may effect the treatment performance, and that shall be recorded and measured where appropriate:

- High turbidity due to ice out or snow melt, rainfall, excessive traffic or construction activities up river;
- Algal blooms, possibly seasonal;
- Diurnal pH changes;
- Elevated natural organic matter from runoff;
- Changes in feed (blended) water disinfection.

5.3.3 Schedule

The schedule requires the equipment to be run continuously for 320 hours. The KI CPS100CPT has control functions that allow for differing conditions to initiate backwash. The control functions that allow backwash initiation due to headloss will be verified, as well as the controls that initiate backwash on turbidity breakthrough.

The verification period includes a minimum of two backwashes followed by filtration to terminal headloss cycles. Data will be collected during the entire period.

Table 5-1 below summarizes the operational objectives of this ETV challenge.

TABLE 5-1
FILTRATION PERFORMANCE CAPABILITY OBJECTIVES

CHARACTERISTIC	DEFINITION	CRITERIA
Initial turbidity	Filtrate turbidity at 15 minutes into run	0.5 NTU or less
Length of ripening period	Time to reach 0.2 NTU	0.5 hours or less
Length of further ripening period	Time to reach 0.1 NTU	1.0 hour or less
Operating turbidity	Turbidity from matured filter	0.10 NTU or less
All turbidity	All data to be taken at equal intervals	0.5 NTU or less in 95% of all samples, or in all data from continuous turbidimeters
Time to reach turbidity breakthrough	Time to reach 5 feet headloss (manufacturer claims 8.6 feet headloss before breakthrough	8 hours minimum
Water production	Volume of water during a filter run	5,000 gallons per sq. ft. (2,750 gallons)

During the seedings, 10 liter samples for microbiological evaluation (identification and enumeration) will be taken on a side stream and filtered through a Gelman capsule filter for enumeration. The 10 liter grab samples filtered through a Gelman capsule filter will be evaluated in accordance with the procedures indicated in EPA Method 1622, (draft of 1999). The enumeration when compared with the particle counts for the same period, will account for indigenous microbes as well as those seeded.

5.3.4 Verification Period

The verification period consists of a 320 hour period, with a minimum of two backwash sequences per filter, followed by at least two filtration to terminal headloss cycles. Data will be collected during the entire period.

5.4 TASK 2: FEED AND FINISHED WATER QUALITY CHARACTERIZATION

5.4.1 Objective

The objective of this test is to evaluate the water quality matrices of the influent water and effluent water and to identify the composition of the removed particulate material, with the relationships to the terminal headloss and/or turbidity breakthrough point. Certain feedwater parameters will be noted and finished water will be examined relative to the level of removal attained.

5.4.2 Initial Test Runs

Based on the initial test runs, the terminal headloss and turbidity breakthrough point will be established, and the performance of the filter will be evaluated relative to the water quality parameters.

5.4.3 Testing Schedule For Quality Parameters

The testing schedule for water quality parameters is as follows:

The testing schedule for water quality parameters is indicated in Table 5-2. Samples of both feedwater and filtered water will be analyzed.

TABLE 5-2

TESTING SCHEDULE FOR QUALITY PARAMETERS

PARAMETER	FREQUENCY	WHERE TESTED	METHOD	STD. REF.
Temperature	daily	on-site	instrument	2550B
pH	once per 8 hours	on-site	instrument	4500H+
Total Alkalinity	daily	lab		2320B
Total Hardness	weekly	lab		2340C
Total Organic Carbon	weekly	lab		5310 C
UV Absorbance(254)	weekly (with TOC)	lab		5910
Turbidity	daily	on-site	instrument	2130B(2)
Continuous Turbidity	15,30,60 minutes for calculations plus spike****	on-site	instrument	2130B and instrument manufacturer
True color	weekly	lab	instrument	Hach SM2120
Total Coliform	semi-weekly	lab		9221 or 9222
E.coli	semi-weekly	lab		9223 (Colilert)
Algae (identify number and species)	weekly***	lab		10200F
Aluminum	weekly	lab		3113B
Iron	weekly*	lab		3113B
Manganese	weekly**	lab		3113B
Particle Count	continuous	on-site		per instrument manufacturer, ASTM 658

Notes:
* More often once found in raw water;
** Weekly if above 0.05 mg/L in raw water;
*** Daily if algae bloom occurs;
**** Turbidity readings at 30 minute intervals following a filter run will be averages for filter consistency as noted in section 4.6.

All testing will be performed in accordance with the procedures and protocols established in *Standard Methods*. All on-site testing instrumentation or procedures will be calibrated and/or standardized daily by FTO staff.

Turbidity and particle counters will be both continuous and on line. The on line turbidity meter will be checked daily against a bench turbidimeter which is checked against turbidity standards.

The turbidity instruments for this study are Great Lakes, Model 95T/8220 (bench) and Great Lakes Model 95T/SS4 (on-line). The particle counter is a MetOne PCX. Operations and maintenance manuals for these instruments are included in the KI equipment O&M Manual.

5.4.4 Evaluation Criteria

The package plant will be evaluated with respect to manufacturer's claims of performance, with the requirements of the SWTR as a basis.

5.4.4.1 Turbidity

Turbidity will be analyzed to determine the percentages in the following ranges:

<0.10 NTU
>0.10 - 0.20 NTU
>0.20 - 0.35 NTU
>0.35 - 0.55 NTU
>0.55 NTU
>1.0 NTU

In addition, any occurrences where the filter produced water of > 0.5 NTU following fours after being placed on line. These events shall be recorded separately for each filter, identified as A and B.

5.4.4.2 Particle Count Data

Particle counts will be evaluated by recording the change between influent and effluent particle counts in the ranges 3-5 μm, 5-10 μm, 10-15 μm and 15+ μm and will be reported as log removals in those ranges.

5.5 TASK 3: DOCUMENTATION OF OPERATING CONDITIONS AND TREATMENT EQUIPMENT PERFORMANCE.

5.5.1 Objective

The objective of this task is to denote the conditions surrounding the performance of the filter system, including the physical instrument measurement of pressure losses at and prior to turbidity breakthrough. Included in the performance parameters will be flow rates (and any variations), pressures of influent and effluent streams, length of filter runs, and backwash lengths.

The flowmeter for the equipment is a Data Industrial Corp. Series 2100. Its accuracy will be verified by bucket and stopwatch technique.

The two filter vessels are intended to be operated on an alternating basis at 5 gpm, for a throughput flowrate of 9.1 gpm/ft^2 bed area. When one filter reaches the end of the run, as determined by one of the conditions noted above, the stand-by vessel is brought on line and the first backwashed and placed into a standby mode. This process is automatically controlled by electrically activated, motorized ball valves, with no discernible loss of flow, which are controlled automatically by the on-board programmable computer.

While the primary objective is the verification of particle capture in the 3-5 μm range, additional data regarding the expected expenses related to the technology will be

compiled so that regulators can make a reasoned evaluation of filter performance relative to costs.

A part of the operational information will include pumps and other motor driven components associated with the plant and their power consumption which will be related to the filter performance, specifically to gallons produced per service period and consumed during backwash cycles. Operating data to be included are itemized in the following table:

TABLE 5-3
OPERATING DATA

OPERATING DATA	ACTION
Coagulant Used	Name of chemical, supplier, strength, dilution from stock solution.
Chemical Feed Volume and Dose Rate	Check rate and record every two hours, refill as required and note volume consumed and time.
Feedwater and Filter Flow	Check and record 2X/day and adjust when flows are off by +/- 10%. Record rates before and after adjustment in log book.
Filter Headloss	Record at beginning of run and every two hours, also record at end of run or when breakthrough occurs.
Air Sparging	Record date, time and duration.
Backwashing	Record date, time, feed and filtered water meter reading and calculate filter finished water volume. Note terminal headloss prior to filter backwash. Describe reason for backwash; note backwash rate and volume for each backwash.
Electric Power	Read meter once daily at same time.
Hours of Operation	Record daily at beginning of first shift.
Filtered Water Production	Calculate total volume per filter run and total for each day per filter.
Watershed Events	Record weather, snow melt, construction, excessive traffic or other events that could impact on source water quality daily at end of shift.

A utility power meter, reading in kilowatt-hours will be attached to the power connection for the pilot plant.

5.6 TASK 4: MICROBIOLOGICAL CONTAMINANT REMOVAL TESTING

The object of this Task is to measure the ability of the filter to remove seeded microorganisms. This portion of the study is of central importance, as it is the ability of the filters to remove the target microorganisms *C. parvum* and *G. lamblia* that is the primary claim of the manufacturer, and of greatest interest to the public water community.

The ability of the KI CPS100CPT, with Macrolite® media, to remove the oocysts from water has been demonstrated in prior studies, and the mechanism is *not* under examination here (that is beyond the scope of this ETV study). Here, only the ability to remove particles in the range of 3-6 microns and 6-15 microns, to detach them from the media during backwash, and to prevent re-entry into the process stream, will be challenged and verified.

5.6.1 Preparation of Microbial Doses

The (oo)cyst will be purchased from commercial (academic) sources. *Giardia* cysts will be less than four weeks old, and *Cryptosporidium* oocysts will be less than eight weeks old. The (oo)cysts will be stored in water without preservatives. At a field lab near the site they will be divided into the required number of doses, and into the required concentration of 10^8 (oo)cysts for injection into the water stream.

The doses are prepared by removing an aliquot of the enumerated (oo)cyst suspension and diluting with deionized water to a volume containing the target number of oocysts. These doses are again enumerated with a hemocytometer and analyzed with the Fisher Chi-Squared index. If the variance exceeds chance, the suspension is re-sampled and recounted until an acceptable variance for a minimum of five replicate counts is obtained. The hemocytometer counts are then used to calculate the mean number of oocysts per 10 L dose.

The inoculation point is through an injection probe at the intake of the static mixer. An inert carboy containing a diluted preparation of suspension and stirred by a magnetic stir bar is connected by tubing to an injection probe that reaches into the axis of the static mixer. Each challenge test will inject 10^8 (oo)cysts concentrated into 600 milliliters of deionized, particle free water containing 0.01% Tween 20. There will be no detergents, wetting agents or other chemicals added to the suspension. The injection will take place evenly over a period of one hour plus three theoretical detention times, such that slightly more than 360 gallons (1360 liters) of water will be inoculated. This will be followed by two volumes of particle free sanitized water to void the excess (oo)cysts through the injection stream.

A seeded suspension containing 10^8 (oo)cysts is capable of indicating 3 log reduction as follows: The seeding will introduce 10^8 (oo)cysts concentrated into 600 mL of water for a density of 1.66×10^6 (oo)cysts/mL into the process stream. The process stream will dilute this concentration evenly into 1360 liters for a concentration of approximately 75 (oo)cysts/mL. Detection of effluent (oo)cysts by particle counter and by EPA Method 1622 enumeration at levels less than 5/mL will indicate 2+ log reduction. Since a 10 liter grab sample is taken through a Gelman capsule filter for Method 1622 evaluation, 10,000 milliliters will be evaluated, potentially capable of a 3+ log reduction evaluation if expected Gelman capsule recovery rates are realized.

During the seedings, 10 liter samples for microbiological evaluation (identification and enumeration) will be taken on a side stream and filtered through a Gelman filter for enumeration. The 10 liter grab samples filtered through a Gelman capsule filter will be evaluated in accordance with the procedures indicated in EPA Method 1622, (draft of 1999). This enumeration, when compared with the particle counts for the same period, will account for indigenous microbes as well as those seeded.

5.6.2 Analytical Schedule

There will be three challenges employing a mixed cocktail of *Giardia* cysts and *Cryptosporidium* oocysts added to the raw water prior to the addition of the coagulant chemical and the mixing chamber.

During the seeding, 10 liter samples for microbiological evaluation (identification and enumeration) will be taken on a side stream and filtered through a Gelman capsule filter for enumeration.

Filter influent (following pretreatment chambers) and effluent grab samples will be taken as follows:

1) At time zero (after three detention volumes following initiation of seeding)
2) At 1.0 hours
3) At 3.0 hours
4) At 6 hours past time zero
5) At every 6 hours following until the end of the run
6) Plus one sample at the 90% of terminal headloss point

Simultaneous with the seeding, on line particle counters located at the raw water intake, at the filter inlet following the static mixer, and at the effluent of the filter, will record the particle analyses in the ranges 3-5 µm, 5-10 µm, and 10-15 µm. If the particle counter, during initial operations testing, is incapable of the high level of counts, (due to indigenous particulate matter in that range) grab samples will be evaluated through dilution procedures.

Four 1 liter grab samples for microbes other than the seeded microbes will be collected at the same time. In addition, turbidity grab samples will be collected and evaluated with the bench turbidimeter.

In the event of a turbidity breakthrough during the challenge period, an additional sample of (oo)cysts will be collected.

This sequence will be repeated twice, for a total of three successive runs of the same filter; the second and third runs will follow those of the second, non-seeded filter. Since both filters are identical, only one filter of the two will be employed for the seeding studies.

5.6.3 Data Evaluation

The performance will be evaluated with respect to the manufacturer's expected performance for inclusion in to the final report to NSF. The data from electronic particle counters shall be analyzed to determine the median log removal as well as the 95th percentile removal for the verification period.

Particle count data will be analyzed at one hour intervals, except during challenge periods where additional particle count data will be correlated to grab sample data times as closely as possible. The particle counter will be continuous, and will record the particle analyses in the ranges of 3-5 μm, 5-10 μm, and 10-15 μm. The data will be presented as time series data to display trends of particle count over time.

Microbial densities between feed and filtered water will be analyzed for median log removal and 95th percentile log removal for each of the operating points noted above: startup following backwash, following restart after midpoint interruption, and at 85-95% of terminal head loss.

5.6.4 Evaluation Criteria

All particle counting and turbidity data taken during the challenge period will be correlated with the microbial samples. Microbial results will be compared with the log removals for coagulation and filtration processes in he SWTR, and with respect to KI expected values.

5.7 TASK 5: DATA MANAGEMENT

5.7.1 Objective

The objective of this task is to tabulate the collection of data for completeness and accuracy, and to permit ready retrieval for analysis and reporting. In addition, the use of computer spread sheets will allow manipulation of the data for arrangement into forms, useful for evaluation. A second objective is the statistical analysis of the data as described in the Protocol.

COA as the FTO for the project will be responsible for the maintenance of the logbooks and field notebooks. Data will be collected in bound logbooks and on charts from the instrumentation panels and individual testing instruments. There will be a single field logbook containing all on-site operating data which will remain on site and will contain instrument readings, on-site analyses and any comments concerning the test run with respect to either the nature of the feedwater or the operation of the equipment. The particle counter produces a printed copy of the particle count and that tape will be attached to and become a part of the field log book.

Data will be entered into a computer spreadsheet program (Excel) on a daily basis from the logbook and from any analytical reports. A back-up copy of the log book and computer data will be maintained off site. The database for the project will be set up in the form of a custom-designed spreadsheets. All data from the laboratory notebooks and the data logbook will be entered into the appropriate spreadsheet. Data entry will be conducted on-site by COA operators. All recorded calculations will 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 initialized by the COA operator or engineer performing the entry or verification step.

Each page of the logbook will be sequentially numbered and identified as Kinetico ETV Test. Each completed page will be signed by the on-duty FTO staff. Errors will be crossed with a single line and initialed. Deviations from the FOD whether by error or by

a change in the conditions of either the test equipment or the water conditions will be noted in the logbook. The logbook will include a carbon copy of each page. The original logbook will be stored on-site, the carbon copy sheets will be forwarded to the project engineer of COA at least once per week. This will not only ease referencing the original data, but offer protection of the original record of results.

Also entered into the logbook will be any photographs of the station, test equipment or the installation. The existence of video tapes or other documentation will be entered. Photographs must be noted as to direction, time, subject and identity of the photographer.

Included in the logbook will be copies of chain of custody, field sheets and laboratory notes. Original chain of custody forms will travel with the samples. Examples of the spreadsheet format, chain of custody and laboratory worksheets are included as Appendix D.

While the use of laptop computers and electronic data recording is encouraged, any use will be documented in the logbook. Laptop computers will be employed in the spreadsheet analysis and the contents of the data spreadsheets will be noted in the logbook.

Computer data can be transferred either electronically or by physical transfer of data discs.

Each challenge test run will numbered for coordination with the on-site data from that run along with the laboratory testing data. The operating conditions for each test run will be entered into the logbooks and onto the spreadsheet. The spreadsheet will consolidate the information from Tasks 2, 3, 4, and the results from any and all off-site laboratory analyses.

Analysis of all water quality data, including that from each of the seeding studies from Task 4 shall be analyzed separately for 95% confidence in accordance with the confidence formula noted in Chapter 1 of the EPA/NSF ETV Protocol:

$$\textit{confidence interval} = \overline{X} \pm t_{n-1,\,1-\frac{\alpha}{2}} \left(S / \sqrt{n}\right)$$

S = standard deviation
n = number of measurements in data set
t = distribution value with n-1 degrees of freedom
α = the significance level defined for 95% confidence as: 1- 0.95 = 0.05.

$$\textit{95\% confidence interval} = \overline{X} \pm t_{n-1,0.975} \left(S / \sqrt{n}\right)$$

5.7.2 Work Plan

5.7.2.1 Data Handling

The filtration instrumentation is controlled by an industrial, programmable computer (IC693 9460) readily attachable to data recording devices; manual logbooks will be used to record data not connected to automatic records such as flow rates, pressure and differential gauge readings and power consumption. All data will be maintained by the FTO and the data entered into the spreadsheet database. The data acquisition system for this evaluation study is a Telogers R-3000. The O&M manuals for the PLC and Data system are attached as a portion of this FOD.

5.7.3 Statistical Analysis

The water quality data grab samples shall be analyzed for statistical uncertainty. The FTO will calculate 95% confidence intervals for all data ad described in the protocol

Data on coagulation chemical changes during filter runs, or low rate variations, would require statistical analysis. Two specific conditions requiring statistical analysis are:

1. Runs involving microbiological sampling, grab sample test data following filter ripening and prior to turbidity breakthrough, separate for each run to show variations in performance during optimum operations conditions.

2. Runs involving microbiological sampling, all grab sample test data collected from beginning to end of filter run to show the variability of performance through each filter run.

Such statistical analysis may be presented as graphs to assist regulators and plant designers evaluate applicability of the system to specific requirements. Data on the grab samples should be correlated to any pressure losses and the time of the filter run (whether just prior to or following backwash, for example).

5.8 TASK 6: QA/QC

The objective of this task is to control the methods and instrumentation procedures such that the data are not subject to corruption. Adherence to analytical methods as published in *Standard Methods* will be assured. Moreover, instrumentation and standard reagents will be referenced to the National Institute of Standards and Technology (NIST). Instruments used to gather data will be standardized and calibrated in accordance with the schedules noted below.

5.8.1 QA/QC Verifications

QA/QC verifications to be performed at the beginning of each testing period include instrumentation checks, cleaning and maintenance of the turbidimeters, pressure gauges, tubing and other components. Flow meters will be calibrated with "bucket and stopwatch". Turbidimeters will be tested for volumetric accuracy and standardized. The particle counters will be verified using calibrated microspheres in the 2, 5 and 15 µm levels.

In addition, daily verification of turbidimeters and particle counters will be performed.

Daily QA/QC Verifications will include:

In-line turbidimeter flow rates verified (bucket and stopwatch);
In-line turbidimeter readings standardized against a calibrated bench turbidimeter;
Batch and in-line particle counting flow rates verified (bucket and stopwatch);
Chemical feed pump flow rates (verified volumetrically over a specific period of time).

Bi-weekly QA/QC Verifications will include:

In-line flow meters cleaned and verified (bucket and stopwatch).

QA/QC Verifications at the beginning of each testing period will include:

Cleaning and re-calibration of in-line turbidimeters;
Verification of particle counter calibration with gradated microspheres;
Check differential pressure transmitter signal and pressure gauge readings with pressure meter;
Inspection of particle counter and turbidimeter tubing for unimpeded flow and integrity.

5.8.2 Specific Instrumentation Methods

Specific Instrumentation methods for on site QA/QC accuracy are as follows:

5.8.2.1 pH

Analysis will be by *SM* 4500-H^+. A two point calibration with NIST traceable pH buffers will be performed daily. Between tests the pH probe will be kept wet in KCl solution. For on-site determination of pH, field procedures will be used to limit absorbance of carbon dioxide to avoid skewing results by poorly buffered water.

5.8.2.2 Temperature

Temperatures will be measured in accordance with *SM* 2550 two times daily at times selected to bracket the extremes of water temperature at the site. The thermometer will be in 0.1° C increments, and will be calibrated weekly against an NIST precision thermometer.

5.8.2.3 Turbidity

Although turbidity is not an effective measure of filter performance with respect to the removal of *C. parvum*, it is an important measure of overall filter performance. Moreover, turbidity has been recorded in many prior pilot tests, hence the inclusion of turbidity data, along with particle counts, is an important addition to the data collection. Since the data are only as valuable as the confidence in them allowed by proper testing, *Standard Methods* 2130 protocol will be employed.

The turbidimeters will remain on during the duration of the testing period. On line and bench top turbidimeters will be used, and the bench top turbidimeter will be the calibration standard for the test. The benchtop turbidimeter will be calibrated at the start of testing and then weekly, during the testing period, against standards of 0.1, 0.5 and 3.0 NTU. Manufacturers procedures for maintenance will be followed and the schedules

for maintenance and cleaning noted in the log book. All glassware will be dedicated and cleaned with lint free tissues to prevent scouring or deposits on the cells.

A copy of *SM* 2130 is attached to this FOD as part of Appendix G "Testing and Calibration Procedures" for on-site convenience.

5.8.2.4 Particle Counting

Particle counting is a rapid and efficient means of determining with some accuracy the size distribution and enumeration of particles in a sample. While it conveys more information than turbidity, it cannot alone identify the source or nature of any specific particulate matter. Particle counters are generally calibrated against NIST standards by the manufacturer. Calibration shall be verified on-site with calibrated, mono-sized polymer microspheres. The procedure for monosphere verification is that as follows, and as described in the Test Plan.

1) Establish an initial analysis of particle concentration in the dilution water.

2) To that dilution water add a sample of each size of the monospheres (2, 10, and 15 μm) to achieve a close approximation to 50,000 particles in 25 mL, swirl each suspension in turn.

3) Quickly run the particle counter through the testing ranges to determine that the peak concentration lies at the size of the added monospheres.

4) Prepare a suspension that combines all three of the particle sizes in a concentration of 1000 particles of each of the three sizes (3000 total) in 1 mL, swirl the suspension.

5) Quickly run the particle counter range to determine that the particle counter peaks at each of the three particle sizes, and in approximately the proper enumeration.

Maintenance of the particle counters is important. Manufacturer recommended maintenance shall be followed and noted in the log book.

Procedures for particle counting will be those as noted in *Standard Methods* 2560 (and subsections appropriate to the equipment in use).

5.8.2.5 Particle Free Water (PFW)

Particle free water (PFW) is a necessary component of the testing procedure and shall be prepared fresh and as often as storage limitations will allow. Fresh water is necessary to limit biological growth that could affect the particle counts. The water for this study will be commercially available distilled and/or deionized (DI) water that has been additionally filtered through a .22 m cartridge filter. Field conditions make the production of PFW in accordance with *Standard Methods* difficult. Commercially prepared DI water, filtered on site through a .22 m filter will be suitable for particle counting and other reagent preparation in this application.

Glassware associated with the particle counters will be dedicated and cleaned with laboratory glassware detergent, then triple rinsed with PFW.

5.8.2.6 Pressure Gauges

While absolute pressure is less important than relative pressure and pressure differentials, differential pressure gauges, or matched gauges with calibration, and accurate to 1 psi shall be used to measure pressure losses across the vessels. The pressure gauges for this study are Orange Research Differential Pressure Instruments. The operating and installation instructions are included as a portion of Appendix X.

5.8.3 Procedures for Chemical and Biological Samples Shipped For Off-Site Analysis

Procedures for Chemical and Biological Samples Shipped for Off-Site Analysis.

5.8.3.1 Organic Parameters, Total Organic Carbon and UV Absorbance

Samples for these analysis shall be collected in glass bottles supplied by Spectrum Labs (a State Qualified Laboratory) and will be delivered by courier (the travel time is approximately twenty minutes). Samples will be preserved, held and shipped in accordance with *Standard Methods* 5010B and *SM* 1060.

5.8.3.2 Microbial Samples: Coliform and Algae

Samples will be collected in glass bottles supplied by Spectrum Labs and kept at 4 C in the proper shipping cooler. Coliform samples may be preserved with sodium thiosulfate if chlorine is present. Algae samples will be preserved with Lugol's solution.

5.8.3.3 Inorganic Samples

Inorganic Samples will be collected, preserved and shipped in accordance with *Standard Methods* 3010B and C and 1060 and EPA §136.3, 40 CFR Ch.1. Proper bottles and preservatives where required (Iron and Manganese for example) will be used. Although the travel time is brief, samples will be shipped in coolers at 4° C.

5.8.3.4 True Color

True color shall be measured in accordance with SM 2120 with a spectrophotometer at 455 nm. The sample shall be collected in glass vials and maintained at a temperature of 4° C during shipment to Spectrum Labs. The sample will be warmed to room temperature before analysis.

6.0 QUALITY ASSURANCE PROJECT PLAN

6.1 OBJECTIVE

The purpose of this section is to assure that the data are reliable. The primary responsibility for recording and monitoring the data lies with the FTO, although other individuals, especially those in off-site analytical laboratories, have responsibilities for supplying the data in accessible and reliable formats.

The inorganic laboratory for this project is Spectrum Labs, Inc. A copy of the Spectrum Labs, Inc. QA/QC manual is attached to this FOD as Appendix E.

The microbiological portions of this study will be performed by BioVir Laboratories, Inc. A copy of their QA/QC manual is attached as Appendix F.

6.2 REPRESENTATIVENESS

Water quality parameter samples will be taken as indicated in Table 5-2. Insofar as possible, samples will be taken at the same time of day. Off-site samples will be delivered to the laboratory for analysis. Included in Appendix E are samples of chain of custody forms, sampling protocols, sample volumes required for the different analyses, and holding times. The holding times are those indicated in EPA 40 CFR, Ch. 1, § 136.3 and *Standard Methods* 1060.

The samples will be transported from the test site to the laboratory via courier; the travel time is approximately 20 minutes.

On-site samples will also be taken utilizing *SM* 1060 sampling techniques.

Operating data such as flow rate, volume measurements and pressure gauges will be recorded and the time noted; they too will be recorded at the same time of day whenever appropriate. Operational parameters shall be recorded and graphed to indicate changes. A +/- 10 percent change in an operating parameter shall be noted.

6.3 COMPLETENESS

Data collection will be considered complete if 85% of the collected data are acceptable. For the operations period and the measurement of operational parameters such as flow rate and power consumption, data will be acceptable within ±5% of control values. Instrument failure will be rectified by back-up instrument systems, or through redundant measurement. For example, flow rates can be measured by stopwatch; continuous turbidity failure can be corrected by more frequent bench-top measurements. Particle counting data during the operations period can be verified and backed up by bench top counters as well. Filter measuring data such as particle counts and turbidities will be deemed complete if 85% of the data are acceptable.

Outliners and anomalous data will be evaluated for cause and if more than 15% of data are not accepted, the corrective action is as follows: if instrumental errors are introduced, back-up systems can be employed; if the errors or anomalous data have other causes such as an abrupt and unforeseeable change in raw water quality, the feed water

can be adjusted; if the errors are beyond adjustment, such as a catastrophic failure of the equipment, that portion of the test may need to be aborted.

Frequent (daily) review of collected data in spread sheet form should quickly identify instrument anomalies.

The microbial seedings are crucial to the performance verification and loss of any single test result will nullify that testing sequence and require repetition.

The completeness goal for this project is 85 percent. These data will be reported, at a minimum, in the verification report.

6.4 ACCURACY

For water quality parameters, the accuracy refers to the difference between the sample result and the true or reference value. Care in sampling, calibration and standardization of instrumentation and consistency in analytical technique will ensure accuracy. Also noted in Appendices E and F are accuracy goals for the off-site laboratories.

For operating parameters such as flow rates and pressures, high levels of accuracy can be ensured by redundant testing with different methods, for example, by confirming flow meters with bucket and stopwatch measurements. Pressure gauges will be verified either by reference to NIST standard gauges, or by changing gauge positions within a process flow.

Performance Evaluation (PE) sample tests will be conducted for on-site water quality parameters specifically, turbidity and pH measurements. These will be conducted by unknown samples supplied by off-site laboratory personnel, tested by on-site FTO staff, and then verified by the off-site lab.

Accuracy can be measured by spiking a known value to a solute, or by using a standard sample. The spiked (or standard) sample is analyzed and the following equations are used:

For a spiked sample: $$\%R = 100\left[\frac{A - B}{S}\right]$$

For a standard: $$\%R = 100 \times \frac{\text{Observed}}{\text{True}}$$

Where:

%R	=	Recovery percent
A	=	Result of spiked sample
B	=	Result of un-spiked sample
S	=	Spike value

6.5 PRECISION

Precision is a measure of the degree of consistency from test to test and can be assured by replication. In the case of on-site testing for water quality, precision will be ensured by triplicate tests and averaging; for single reading parameters such as pressure and flow rate, precision will be ensured by redundant readings from operator to operator.

Travel blanks are not required for this testing.

Matrix and method blanks will be used for turbidity measurements, pH standardization, and for calibration of the particle counter both with respect to enumeration and size distribution.

Samples to be analyzed in duplicate and triplicate include only those on-site parameters consequential to the testing which include bench-top turbidity, pH and bench-top particle counts associated with the calibration of the equipment.

Laboratory precision is assured by spiked samples an explanation of those procedures is included in Appendix E.

The equation employed for precision is:

$$RPD = \frac{D_1 - D_2}{(D_1 + D_2)/2} \times 100$$

RPD	=	Relative percent difference.
D1	=	First sample value
D2	=	Second sample value

6.6 REPORTS

During the verification testing period, periodic reports will be prepared to detail progress, problems and corrective actions. The reports will address problems encountered either with the testing procedures or with the equipment, and will include the corrective action taken. The reports will be distributed to all concerned parties, specifically to the project manager at EPA, the project manager at NSF, the manufacturer's representatives and the staff of the FTO. Brief reports shall follow the initial operations, and at thirty day intervals, or more often if warranted. Reports will be in brief memo form and written. If instrumentation is the subject of a corrective action, the manufacturer of the instrument in question will also be copied in the report.

QA reports will also be forwarded to NSF by the FTO.

6.7 CORRECTIVE ACTION

Contingencies are by their nature unpredictable; however, the FTO will document contingency plans for foreseeable problems to include analytical instrument backup, delays due to weather, equipment malfunction, or to problems associated with the site during the initial operations period and before formal verification begins. These plans will be maintained on site so that on-site operators can quickly respond to problems.

7.0 DATA MANAGEMENT, ANALYSIS AND REPORTING

7.1 DATA MANAGEMENT AND ANALYSIS

Data from daily written logs relating to the operation of the equipment will be tabulated in electronic spreadsheets. In addition, data from laboratory analysis, along with relevant QA/QC data will be entered from hard copy into electronic spreadsheet form. These data will be correlated with data from the challenge testing of microorganisms and the removal values as determined by particle counter, turbidimeter and other on-line apparatus. In this manner, graphic displays of the data showing relationships between meaningful parameters can be analyzed and conveniently displayed for the final verification report.

Raw data will be furnished in appendices, along with discussion of any anomalies in the testing procedure, raw water source, or operating conditions that may impact the performance of the equipment.

Photographs, drawings, visitors logs, and field notebooks will be permanent and incorporated into the final report.

In summary, data to be compiled include:

- Laboratory Results on Water Quality Parameters
- On-site Water Testing Results
- Challenge In/Out Enumerations and Reports (from Instruments and Laboratories)
- Operations Logs of Flow meters, Pressure Readings, Chemical Consumption, Power Use, Total Water Volumes,
- Photographs, Visitor Logs, Time Lines and Schedules.

7.2 PERFORMANCE REPORT DRAFT

A final report will be prepared by the FTO following the testing period for submission to NSF and EPA. Included in the report will be a consolidation of the data, achieved results as determined by the data presented, a record of all aspects of the testing period and a discussion of all factors concerning the operation and maintenance of the equipment. The basic outline for the report will be:

- Introduction
- Executive Summary
- Description and Identification of the Product Tested
- Procedures and Methods Used in Testing
- Results and Discussion
- References
- Glossary
- Appendices (containing logs, prior report copies, relevant correspondence, and raw data forms)
- FOD
- QA/QC Results and Verifications of Instrument Calibrations

8.0 SAFETY MEASURES

The testing site is the University of Minnesota, St. Anthonly Falls Hydraulic Laboratory. The site safety plan documentation will be forwarded to COA, and be reviewed for applicability to this testing plan.

Manufacturers' safety procedures for handling pressure vessels and for the use of on-site hazardous chemicals will be addressed.

For protection against accidental infection by (oo)cysts, strict environmental laboratory procedures will be followed. Protective clothing such as lab coats and gloves will be used, and the Gelman capsules removed will be double wrapped. Handling of all (oo)cysts and (oo)cyst containing materials will be done by laboratory personnel trained in biological safety.

Reduced Pressure Zone (RPZ) backflow prevention devices of appropriate pipe size will be plumbed between both the raw and finished water supplies to ensure (oo)cysts are not inadvertently introduced into the treatment plant water streams.

Safety considerations associated with a portable, skid mounted filtration system with the accompanying weight and stability issues must be addressed; however, these are incident to the test proper, and not to the use of the equipment.

9.0 OPERATIONS AND MAINTENANCE

During the testing and verification period, the FTO will evaluate the manufacturer supplied O&M manual to evaluate the instructions and procedures for their applicability to small system operators.

Maintenance issues will include (but not be limited to) the following components of the system:

- Valves
- Meters
- Pumps
- Motors
- Backwashing apparatus
- Pressure vessel opening mechanism
- Measuring and analytical instrumentation, such as turbidimeters and pressure gauges.

In addition, cleaning and parts replacement shall be addressed to prevent premature aging and rusting of vessels.

The FTO will also evaluate the manufacturer provided operating procedures. Among the issues to be addressed are:

- Chemical feed calibration, set points for frequency and stroke
- Chemical dilution and mixing
- Filtration rate control through flow controls or valves
- Determination of head loss schedules
- Filter run limits determination
- Backwashing rates and start mechanisms
- Control of backwash rate and duration
- Determination of backwash frequency
- Determination of backwash length
- Return of filter to service, including filter to waste period
- Can filter run be stopped without initiating backwash?
- Inlet and outlet pressure readings
- Head loss indication or calculations
- Raw water turbidity
- Filtrate turbidity
- Rate of flow control
- Procedures for turbidity breakthrough
- Turbidity levels and turbidity meter calibration procedures

Troubleshooting guides shall include contingency plans for:

- loss of chemical feed
- loss of flow
- uncontrolled flow rates
- loss of meter or gauge readings
- leaking vessels

- high turbidity
- no turbidity reading
- too rapid filter head loss
- excessive headloss following backwash
- stuck, broken (won't seal) or leaky valves.

Questions included in the Test Plan addressing operation and maintenance of the package plant —apart from the ETV test set-up itself—will be reviewed by the FTO for inclusion into the verification report. Among the issues are:

- pressure measurement at the vessel,
- rate of flow measurement device, (if volume meter or flow meter),
- on line turbidity measurement and any fail-safe controls and signals,
- ease of media replacement,
- procedure for seal and entrained air release,
- ease of operation relative to other components of the treatment system (additional prefiltration, chemical feed, check valves, etc.),
- efficiency and performance of other treatment equipment.

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11.0 GLOSSARY

Backwashable Depth Filter
A bag filter, cartridge filter, or granulated media filter intended to filter uncoagulated or coagulated water and designed to be backwashed when either turbidity breakthrough occurs or terminal headloss is reached.

Coagulant
Although technically the coagulant is the product of a chemical reaction that is formed when chemicals are added to water containing colloidal suspensions, the term is often used to refer to the chemicals that are added. These include aluminum and ferric salts, along with organic polymers.

Coagulant aid
Activated silica when used to coagulate suspensions.

Coagulation
The destabilization of colloidal and suspended materials in water using coagulant chemicals, thus allowing the particles to agglomerate into floc.

Colloid
In water treatment the term refers to irreversible colloids such as clays, metal salts and microbes which coagulate into larger agglomerates in water, thus allowing filtration.

Conventional filtration treatment
A treatment train involving coagulation, flocculation, sedimentation, and filtration.

Direct filtration
A process involving coagulation through chemical coagulant addition and filtration, but excluding the sedimentation step.

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

Flocculation
The employment of stirring through hydraulic or mechanical means to agglomerate smaller floc into larger particles for more ready separation.

Granular Media Filter
A deep bed filter containing granular media used to filter water that has not been coagulated. These filters rely on straining particles out of the water, or by attachment of the particles to the media.

Sedimentation
Separation of solids prior to filtration by gravity settling or through other hydraulic means.

Ten State's Standards
A compilation of accepted civil engineering water treatment plant design standards, published as "Great Lakes-Upper Mississippi River Board of State Public Health and Environmental Managers, *Recommended Standards for Water Works*".