Innovative Multi-Barrier Drinking Water Disinfection

- Public & Private Water Supplies
- Packaged Systems: Plug and Play Installation
- Designed to Meet and Exceeds Current Drinking Water Standards USA & Canada

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Why? Innovative Alternative Disinfection

- Improvements to Current Disinfection methods over a broader range of microbiological parameters
  - Bacteria
  - Virus
  - Protozoa: Cryptosporidium

- Provide Increased Barrier of Protection
  - Chlorine resistant organisms
  - Emerging pathogens
  - Unknown or Undetected breaches

- User Friendly Designs for Small systems
  - Many managed by part time operators or unmanned

- Improvements to Monitoring and Compliance Issues

- Meet New Federal and Provisional Regulations

![AlwaysFresh](alwaysfresh.png)
Why? : Aging Water Infrastructure increases Need!  USA data

- Leaks in distribution lines can go undetected for years. Leaks allow foreign material into lines as water flow within the pipe creates a venturi effect.
  - Water loss from distribution systems is 1.7 trillion gallons per year or $2.6 billion
  - Drinking water distribution lines - 2.3 million miles of piping

- Water Main Breaks upset home & business everyday
  - 240,000 reported water main breaks per year U.S., poor statistics leave many unreported!

- Waste Water Overflows lead to biological contamination
  - 75,000 Sanitary Sewer reported overflows per year
  - Resulting in 3-10 billion gallons of untreated wastewater
  - Wastewater and drinking water systems rated D- by the American Society of Civil Engineers (2009)

- Funding Gap could reach beyond $500 billion in 20 years to repair systems.

Source: Office of Research & Development, National Risk Management Research Laboratory (EPA)
Why? Amendments to U. S. Safe Drinking Water Act

The U. S. EPA promulgated the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) requiring unfiltered drinking water supplies to be disinfected with a minimum of two disinfectants, including one designed to inactivate Cryptosporidium. More recent regulations from the agency were specifically focused on viruses. The UV guidelines vary from previous rules where a 40 mJ/cm² dose was thought to be effective for total virus inactivation. LT2ESWTR states that a UV dose of 186 mJ/cm² is now required for a four-log (99.99%) reduction of viruses, specifically Adenovirus.

The Ground Water Disinfection Rule (GWR) states that UV light disinfection must be accompanied with additional virus inactivation treatment technology.

Both of regulations were largely aimed at the UV-resistant adenoviruses.
LT2 ESWTR Surface Water or ground water under the direct influence of surface water (GWUDI) Primarily Protozoans - also includes Enteric bacteria and Enteric viruses performance requirements.

If the surface water is contaminated with oocysts, the adjacent ground water may also become contaminated. Because of the potential for contamination, GWUDI is regulated as if it were surface water.
GWR: Ground Water Rules - ground water not under the direct influence of surface water (GWUDI) was modified primarily for enteric bacteria and enteric virus.

Our experience has found that Ground Water has the potential to be impacted to a certain degree from many environmental issues.
Why? Adenovirus

- Adenoviruses are known to survive longer in the environment than other waterborne viruses, likely due to their hearty double-stranded DNA structure. Conventional UV disinfection inactivates viruses by damaging their RNA or DNA; however, the double-stranded DNA characteristic of adenoviruses enables the virus to be repaired once inside a host cell. Thus, adenoviruses have emerged as the most resistant waterborne virus to UV light...

- While there is no cure for adenovirus infection, most illnesses are self-limiting. Infected individuals, however, may shed the virus in their feces and respiratory secretion, exposing others for weeks to months.

- Infections are common globally where immunocompromised individuals, including infants and children, are more susceptible to adenovirus infection and more severe health outcomes.

- Fatality rates may be as high as 60 percent in severely immunocompromised patients.

Source: Water Conditioning & Purification article 2011 Ultraviolet Light-Resistant Viruses
New Rules have Increased UV Dosage Requirements to achieve 4- Log Virus Inactivation, including Adenovirus

Exhibit 5.4 UV Dose Requirements for Virus Inactivation (mJ/cm²)

<table>
<thead>
<tr>
<th>UV Dose</th>
<th>Log Inactivation</th>
</tr>
</thead>
<tbody>
<tr>
<td>58</td>
<td>1.0</td>
</tr>
<tr>
<td>100</td>
<td>2.0</td>
</tr>
<tr>
<td>143</td>
<td>3.0</td>
</tr>
<tr>
<td>186</td>
<td>4.0</td>
</tr>
</tbody>
</table>

- EPA is concerned that fecal-contaminated ground water may contain adenovirus and/or other UV resistant viruses that present a human health risk. The UV dose in exhibit 5.4 are significantly higher than those considered for the proposed GWR.

- The doses are based upon the inactivation of adenoviruses. EPA believes that the UV doses on exhibit 5.4 are sufficient to achieve the designated level of inactivation of all waterborne pathogenic viruses that have been studied.

Source: Nov.2008 Ground Water Rule Corrective Actions Manual 5.2.1, exhibit 5.4

- These rules have been implemented, and/or being implemented Internationally
Why? 186KmJ/cm² Dose for UV

Table 1.4
UV Dose Requirements- millijoules per centimeter squared (mJ/cm²)

<table>
<thead>
<tr>
<th>Targeted Pathogen</th>
<th>40 mJ/cm²</th>
<th>1.0</th>
<th>1.5</th>
<th>2.0</th>
<th>2.5</th>
<th>3.0</th>
<th>3.5</th>
<th>4.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cryptosporidium</td>
<td>1.6</td>
<td>2.5</td>
<td>3.9</td>
<td>5.8</td>
<td>8.5</td>
<td>12.0</td>
<td>15.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Giardia</td>
<td>1.5</td>
<td>2.1</td>
<td>3.0</td>
<td>5.2</td>
<td>7.7</td>
<td>11.0</td>
<td>15.0</td>
<td>22.0</td>
</tr>
<tr>
<td>Virus</td>
<td>39.0</td>
<td>58.0</td>
<td>79.0</td>
<td>100.0</td>
<td>121.0</td>
<td>143.0</td>
<td>163.0</td>
<td>186.0</td>
</tr>
</tbody>
</table>

Source: EPA UV Disinfection Guidance Manual for the Final LT2ESWTR

Table 5.2
UV Sensitivity of Challenge Microorganisms

<table>
<thead>
<tr>
<th>Microorganism</th>
<th>1-log</th>
<th>2-log</th>
<th>3-log</th>
<th>4-log</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bacillus subtilis</td>
<td>28.0</td>
<td>39.0</td>
<td>50.0</td>
<td>62.0</td>
<td>Summers et al. 1998</td>
</tr>
<tr>
<td>MS2 phage</td>
<td>16.0</td>
<td>34.0</td>
<td>52.0</td>
<td>71.0</td>
<td>Wilson et al. 1992</td>
</tr>
<tr>
<td>E.Coli</td>
<td>3.0</td>
<td>4.8</td>
<td>6.7</td>
<td>8.4</td>
<td>Chang et al. 1985</td>
</tr>
<tr>
<td>T7</td>
<td>3.6</td>
<td>7.5</td>
<td>11.8</td>
<td>16.6</td>
<td>Mackey et al. 2006</td>
</tr>
<tr>
<td>T1</td>
<td>≈5.0</td>
<td>≈10.0</td>
<td>≈15.0</td>
<td>≈20.0</td>
<td>Wright 2006</td>
</tr>
</tbody>
</table>

Source: EPA UV Disinfection Guidance Manual for the Final LT2ESWTR
Typical UV Dosage Credits as a result of new & existing regulations being awarded Ultraviolet systems

- **40 mJ/cm² Ultraviolet Systems Log Credit**
  - Virus including Adenovirus 0.5 Log Reduction Credit
  - Bacteria 3-4 Log Reduction Credit
  - Cysts 3-4 Log Reduction Credit

- **186 mJ/cm² Ultraviolet Systems Log Credit**
  - Adenovirus 4 Log Reduction Credit
  - Bacteria 4 Log Reduction Credit
  - Cysts 4 Log Reduction Credit

Applicable to US and Canada
Why? Chemical Disinfectants – Including chlorines do not guarantee protection from all bacteria, protozoa's or viruses!

“Disinfectants are often the final stage in a multi barrier drinking water treatment system aimed at preventing exposures to waterborne microbial pathogens. Microbes, however, differ greatly in their sensitivity to disinfectants. Specific protozoa, viruses and bacteria are known to be highly resistant to chemical agents and pose a unique challenge to the water treatment industry. “

Source: Water Conditioning and Purification Article April 2002: Volume 44, Number 4 Microbial Resistance to Disinfectants by Kelly A. Reynolds, MSPH, Ph.D.

About the author
Dr. Kelly A. Reynolds is a research scientist at the University of Arizona with a focus on development of rapid methods for detecting human pathogenic viruses in drinking water. She holds a master of science degree in public health (MSPH) from the University of South Florida and doctorate in microbiology from the University of Arizona. Reynolds also has been a member of the WC&P Technical Review Committee since 1997.
Why? Chemical Disinfectants – Including chlorines do not guarantee protection from all bacteria, protozoa's or viruses!

“The power to resist
Other bacteria resistant to disinfectants include *Mycobacterium avium, Legionella, and Staphylococcus aureus*. Environmental isolates of *M. avium*, an opportunistic pathogen commonly found in water and soil, are known to be highly resistant to disinfectants including chlorine, monochloramine, chlorine dioxide and ozone. *M. avium* strains are up to 2,300 times more resistant to chlorine than *E. coli*, an indicator of drinking water quality. Levels of chemical disinfectant used in drinking water treatment are unlikely to be effective against many Mycobacteria species.”

Source: Water Conditioning and Purification Article April 2002: Volume 44, Number 4 Microbial Resistance to Disinfectants by Kelly A. Reynolds, MSPH, Ph.D.

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Why? Chemical Disinfectants – Including chlorines do not guarantee protection from all bacteria, protozoa's or viruses!

Conclusion
The increased emergence of antibiotic resistant bacteria suggests the need for heavier reliance on disinfection practices to prevent initial infection. Biocidal agents used in water treatment have been essential for virtually eliminating once rampant diseases like cholera, typhoid and dysentery. In developing countries where disinfectants aren’t used in water treatment, these diseases are still responsible for significant numbers of fatalities and illnesses.

The ideal disinfectant hasn’t yet been developed. The variable nature of microbial populations and their ecological habitat alter the efficacy and predictability of the disinfection process. The innate resistance of the microbe and the intrinsic power of the disinfectant must be in balance, keeping in mind the presence of organic matter, turbidity, excessive numbers of organisms, exposure times or dilution use concentrations, pH, temperature, and water hardness may affect treatment. Even well operated water treatment plants cannot ensure drinking water will be completely free of harmful microbes such as Cryptosporidium.

Source: Water Conditioning and Purification Article April 2002: Volume 44, Number 4 Microbial Resistance to Disinfectants by Kelly A. Reynolds, MSPH, Ph.D.

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Direct Expects: “In general the highest priority guidelines are those dealing with microbiological contaminants, such as bacteria, protozoa and viruses. Any measures taken to reduce concentrations of chemical contaminants should not compromise the effectiveness of disinfection.”

www.healthcanada.gc.ca/waterquality

Guidelines for microbiological parameters
Currently available detection methods do not allow for the routine analysis of all microorganisms that could be present in inadequately treated drinking water. Instead, microbiological quality is determined by testing drinking water for Escherichia coli, a bacterium that is always present in the intestines of humans and other animals and whose presence in drinking water would indicate faecal contamination of the water.

Note: Research has shown that Negative E-Coli or Total coliforms tests does not guarantee that protozoan or virus are not presence in disinfected water (using chlorines as disinfectant) under typical dosage and residual chlorine levels.
Viruses – 4 LRV

Although enteric viruses can be responsible for severe and, in some cases, fatal illnesses, it is not possible to establish maximum acceptable concentrations MAC’s) for enteric viruses in drinking water at this time. Treatment technologies and watershed or wellhead protection measures known to reduce the risk of waterborne outbreaks should be implemented and maintained if source water is subject to faecal contamination or if enteric viruses have been responsible for past waterborne outbreaks. Where treatment is required, treatment technologies should achieve at least a 4-log reduction and/or inactivation of viruses.
 Protozoan Cysts – 3LRV

Although *Giardia* and *Cryptosporidium* can be responsible for severe and, in some cases, fatal gastrointestinal illness, it is not possible to establish MAC’s for these protozoa in drinking water at this time. Routine methods available for the detection of cysts and oocysts suffer from low recovery rates and do not provide any information on their viability or human infectivity.

Nevertheless, until better monitoring data and information on the viability and infectivity of cysts and oocysts present in drinking water are available, measures should be implemented to reduce the risk of illness as much as possible. Treatment technologies in place should achieve at least a **3-log reduction** in and/or inactivation of cysts and oocysts, unless source water quality requires a greater log reduction and/or inactivation.
Guidelines for Canadian Drinking Water Quality December 2010

Treatment - 2 Multi-Barrier Approach*

“Waterworks systems that use a ground water source at risk of containing pathogens”


• “As no one type of treatment systems is effective in treating all hazards, a Multi-Barrier approach is usually required to adequately address all risks, which typically includes two or more forms of treatment.”

Source - Drinking Water Treatment Objectives (Microbiological) for Surface Water Supplies in British Columbia
Turbidity - 1 NTU

“Waterworks systems that use a surface water source or a groundwater source under the direct influence of surface water should filter the source water to meet the following health-based turbidity limits, as defined for specific treatment technologies. Where possible, filtration systems should be designed and operated to reduce turbidity levels as low as possible, with a treated water turbidity target of less than 1 NTU at all times.”
**Escherichia coli – 0**

The maximum acceptable concentration (MAC) of *Escherichia coli* in public, semi-public, and private drinking water systems is none detectable per 100 mL.

Testing for *E. coli* should be carried out in all drinking water systems. The number, frequency, and location of samples for *E. coli* testing will vary according to the type and size of the system and jurisdictional requirement.
Bacteriological guidelines

Total coliforms – 0

The MAC of total coliforms in water leaving a treatment plant in a public system and throughout semi-public and private supply systems is none detectable per 100 mL.

Testing for total coliforms should be carried out in all drinking water systems. The number, frequency, and location of samples for total coliform testing will vary according to the type and size of the system and jurisdictional requirements.
Ultraviolet (UV) light disinfection systems
May be used to reduce viruses in water, but the effectiveness of UV varies significantly among different types of viruses. Double-stranded DNA viruses, such as adenoviruses, are more resistant to UV radiation than single-stranded RNA viruses, such as HAV (Meng and Gerba, 1996; cited in Health Canada, 2010). Because of their high level of resistance to UV treatment and because adenoviruses cause illness in children and immunocompromised adults, adenoviruses have been used by the U.S. EPA as the indicator pathogen for establishing UV light inactivation requirements for enteric viruses in the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR) (U.S. EPA, 2006b).

Accordingly, the LT2ESWTR requires a UV dose of 186 mJ/cm2 to achieve a 4-log credit for viral removal (U.S. EPA, 2006b).
Example of Alternative Treatment Schematic and Conventional Treatment Process

Multi Barrier example w/ UV This configuration would allow removal of particles and microbial pathogens as well as inactivation of Cryptosporidium, Giardia, and viruses. In this case, the bag or cartridge filter would serve as the primary filter and thus, be subject to SWTR, IESWTR, LT1, LT2 requirements, while the UV system would be subject to the LT2 requirements. LT2 requires high dose UV 186mJ
Drinking Water Primary Disinfection Treatment Options – typical use

- **Conventional Drinking Water Disinfection Treatment Techniques**
  - **Chlorine/Chloramines** as the primary & residual disinfection have faced challenges due to *disinfection by-product formations* that cause non compliance issues exceeding the TTHM’s MCL. Additionally some water supplies have also been in non compliance for cryptosporidium and other protozoans.
  - Some Enteric Bacteria and Enteric Viruses have high chemical disinfectant resistance!

- **Alternative Treatment**
  - The EPA rules allow States to approve and set compliance monitoring parameters for any alternative treatment.
    - UV light or UV light in combination with another treatment technology, which will ensure that systems continuously meet the 4-log virus treatment requirements, including Adenovirus.
Now Available!

Innovative Technology for Drinking Water Disinfection with High LRV for Bacteria, Protozoa & Virus

Skid Mounted Packaged Multi-Barrier Disinfection Systems using CAF™ Charged Adsorptive Filtration Technology & HDUV-186K™ High Dose 186mJ/cm² Ultraviolet Technology with on site and remote monitoring for quick and simple compliance monitoring.

Designed for Primary Disinfection for Public and Private Water Supplies.

Standard Flow rates 10-480 gpm with larger custom designs available.
Product Development Process

*Waterline Technology & Aqua Treatment Service, Inc.*, through long term supply agreements and a collaborative efforts have produced:

Industry’s First Fully Engineered Packaged Multi Barrier Disinfection Systems which have been 3rd Party Independently tested and evaluated by the U. S. EPA’s Testing and Evaluation Laboratory in Cincinnati, OH. Using live test organisms

- MS2 10⁹/100mL
- Adenovirus 5x10⁵/100mL
- Cryptosporidium oocysts 5x10⁵/100mL

These Multi Barrier Disinfection Package Systems meet and exceed the U.S. EPA’s Ground Water Rules (GWR) and Long Term 2 Enhanced Surface Water Treatment Rules (LT2ESWTR) and most international regulations as well.

Work is under way to gain acceptance world wide for public water supply for these multi-barrier disinfection systems!
Series CAF™/HDUV-186K™
Multi Barrier Disinfection System
Skid Mounted with Fail Safe Monitoring

*Waterline’s & ATS’s Multi-Barrier Disinfection Systems consists of four basic components that are completely engineered and marketed as a packaged system for public and private water supplies.*

**Stage 1:** The CAF™ Charged Adsorptive Filtration Pleated Cartridge Technology

**Stage 2:** The HDUV-186K™ High Dose Ultraviolet (186mJ/cm²)

**Remote Logic Controller (RLC):** Intelligent Microprocessor that continually monitors the entire system.

**Packaged Skid System:** Fully integrated and factory plumbed, pressure tested, wired and tested for quick and easy installation.
Innovation vs 3rd Party Industry Standards

- USEPA Guidelines - Industry Standards & Protocols
  - LT2ESWTR & GWR include Guidelines for Ultraviolet, Membranes and Cartridge Filtration Systems but not for CAF™ Charged Adsorptive Filtration Technology
  - No current ANSI/NSF or International Industry Standards exist for these new Innovative technologies
    - CAF™ Charged Adsorptive Filtration
    - HDUV-186K™ high dosage ultraviolet
    - Need for alternative multi barrier disinfection technology now!
      - Standard development could take up to 7 years
Therefore the process began to find and work with an accredited Independent 3rd Party Organization to develop a Test Plan /Scope of Work for the basis in which to verify the 4 Log Reduction performance of these CAF/HDUV-186K disinfection systems.

- **A stand-alone HDUV device** at 186,000uws/cm² (186mJ) High Dose UV
  - New and End of Life.

- **A stand-alone CAF™ Charged Adsorptive Filtration device**
  - New Life, Mid-Life and End of Life.

- **A Multi-Barrier CAF™ & HDUV device** To verify the 4 Log Reduction performance
  - New Life, Mid-Life and End of Life.

- To meet and exceed both LT2SWTR and GWR 4 Log Reduction requirements
  - **Multi-Barrier Approach**.

- To **Develop test protocol** with all EPA Testing Guidelines incorporated in final test plan to develop an industry acceptable protocol for testing this new innovative technology.
Accredited Certification Agencies

- There are at least 5 agencies that are accredited by the American National Standards Institute (ANSI) to perform testing and certification to the NSF/ANSI standards for drinking water treatment units, drinking water system components and drinking water additives and also accredited by Canada by Standards Council of Canada:
  - Water Quality Association (WQA) – GOLD SEAL PROGRAM
  - NSF International (NSF)
  - Underwriter Laboratories (UL)
  - Canadian Standards Association
  - International Association of Plumbing Mechanical Officials (IAPMO)

- None of these agencies currently provide testing of these innovative products
  - Lack of AN APPROVED TEST PROTOCOL METHOD for HDUV-186 mJ/cm² systems or CAF™ charged adsorptive filtration in which to:
    - PROVIDE INDEPENDENT 3RD PARTY TESTING & EVALUATION
    - GAIN MARKET ACCEPTANCE FOR PUBLIC WATER SUPPLIES TO MEET THE NEW EPA REGULATIONS to comply with 4 Log Reduction of ADENOVIRUS.
How does a manufacturer meet new regulations where there are no written test protocols for Innovative technology?

*We have 3 Choices*

1. CONTACT ALL APPROVAL AGENCIES TO SEE IF THEY CAN TEST Innovative Technology FOR 4 Log Reduction of Bacteria, Cysts and ADENOVIRUS ✓

-OR-

2. Wait years until testing protocol is developed to validate systems to meet these new regulations N/A

-or Why Not-

3. Work with an approved agency (Independent 3rd party) to establish testing protocol and validation protocol for innovative technology meeting a 4 Log Reduction of Bacteria, Cysts, and Viruses including Adenovirus! ✓ ✓ ✓
USEPA Definition of Independent 3rd Party Validation Test

USEPA UV Guideline Manual for LT2 ESWTR provides the following definition for validation testing & data analysis:

“An independent 3rd party provides oversight to ensure that validation testing and data analysis are conducted in a technically sound matter and without bias. A person independent of the UV reactor and Filtration manufacturer should oversee validation testing.

The testing and validation will follow the documented protocol and review the report for accurate data and results.

The result of the testing will provide a highly credible verification report bearing the name of Test and Evaluation (T&E) Facility which will constitute as the independent 3rd Party organization and industry recognized laboratory.”

Source: USEPA UV Guideline Manual for LT2 ESWTR
International Definition of Independent 3rd Party
ISO 17000-2004

Conformity Assessment – Vocabulary and General Principles. Section 2.4 provides the requested definition as follow:

“third-party conformity assessment activity that is performed by a person or body that is independent of the person or organization that provides the object, and of user interests in that object.

NOTE 1 Criteria for the independence of conformity assessment bodies and accreditation bodies are provided in the International Standards and Guides applicable to their activities (see Bibliography).”
(Source: ISO 17000 – 2004)

This information was provided by Standards Council of Canada, Denis LaPorte, Information Officer.
Performance Testing vs Component Material Safety Verification

- Raw Materials require conversion into a finished product design which is modified during the manufacturing process.

- For example: Conversion into a pleated cartridge or spiral design needs to be integrally sealed and verified with production standards not typically used for aesthetic filtration systems.

- Only Engineered Systems can then be validated for performance.

- Using raw material test data which is manufactured into a cartridge, membrane or other components which are then inserted into an off the shelf filter or chamber housing cannot make performance claims.

- NSF/ANSI Std 61 is for components only – Health Effects
  Health Effects are for material safety only not performance

Performance Testing & Evaluation by an Accredited Independent 3rd Party is critical for any product making a health claim.
Selection of a 3rd Party Industry Testing & Evaluation Facility

Accredited Independent 3rd Party Test Facility: 
The USEPA Test & Evaluation Facility, Cincinnati, Ohio.

Preformed by: 
Shaw Environmental & Infrastructure, Cincinnati, Ohio

With analysis and results of Adenovirus by: 
The USEPA National Exposure Research Laboratory (NERL) 
Cincinnati, Ohio

These facilities meet the requirements as an Independent 3rd Party testing and evaluation agent as defined by US and International guidelines.
Testing & Evaluation

- Waterline Technology, Aqua Treatment Service, EPA & Shaw Environmental jointly developed Scope of Work, Health & Safety Plan, Quality Assurance Project Plan to meet the LT2ESWTR & GWR requirements.

  - This provided the framework for Independent 3rd Party biodosimetry based full scale testing for the challenge viruses and organisms to undergo a validation procedure that apply to this design using the established protocols from the US EPA’s Ultraviolet Disinfection Guidelines.

  - The scope of work uses live organisms

    - Adenovirus samples were analyzed using the Tissue Culture method in conjunction with EPA’s National Exposure Research Laboratory in Cincinnati, OH.

    - This is the first live Adenovirus testing in the industry for full scale Multi-Barrier Filtration/UV-186K approach

- Microbiological Challenge Tests

  - MS2 bacteriophage 10⁹/100mL
  - Live Adenovirus 5x10⁵/100mL
  - Live Cryptosporidium oocysts 5x10⁵/100mL
Packaged Multi-Barrier Equipment Specifications
- 20 gpm @60psi – clear, fresh water
- Stage 1 Treatment - CAF™ Charged Adsorptive Filtration
- Stage 2 Treatment - HDUV-186K™ high dosage ultraviolet
- Microprocessor – Remote Logic Controller (RLC)

The Scope of Work (SOW) Log Reduction Value (LRV) test results of this production unit will be used to scale the test results for flow rates from 1-480 gpm based upon
- F² of CAF™ Charged Adsorptive Filtration’s surface area
- 186 mJ/cm² UV dose flow rate calculations
Testing conducted with Live Organisms

**Adenovirus-2**
Stock prepared in conjunction with EPA’s National Exposure Research Laboratory in Cincinnati, Ohio.

**MS2 bacteriophage**
Bio Vir Laboratory (California)
E.coli host culture for MS2 bacteriophage will be prepared at EPA’s T&E Facility in Cincinnati, Ohio.
The original freeze-dried culture will be obtained from ATCC.

**Cryptosporidium oocysts**
Sterling Parasitology Laboratory at University of Arizona.
Photos: epa.gov
Microbiological contaminants, such as Adenovirus-2, MS2 bacteriophage and Cryptosporidium oocysts will be injected into the influent stream of the system using a peristaltic pump.

The target influent Adenovirus-2 will be $10^5/100\text{mL}$ for demonstrating 4-log removal.

The target influent concentration of MS2 bacteriophage is $10^9/100\text{mL}$ for achieving up to a 9 LRV removal.

The higher challenge concentration of MS2 bacteriophage may be used to determine the equivalence of Adenovirus-2 removal.

According to NSF protocol the target concentration of Cryptosporidium oocysts will be $5 \times 10^4 /\text{L}$. 
Collimated Beam Tests

- A collimated beam test is completed on the challenge microbial contaminants test runs- Adenovirus-2, MS2 bacteriophage and Cryptosporidium oocysts to provide the Log Removal Value (LRV) from direct exposure to ultraviolet light.

- Determine the UV dose in units of uws/cm² (mJ/cm²) for Log Removal Value (LRV) with a UV dose response curve.

- Collimated Beam Test Log Reduction and UV Dose results are compared to the UV System test Log Reduction results to verify the *ACTUAL* UV System Dose at rated flow.
Figure 5.1. Overview of Recommended Validation Protocol

Step 1. Experimental Testing Using a Challenge Microorganism

1a: Bench Scale Testing
- Measure the log inactivation for different UV doses to develop a UV dose-response curve:
  - UV dose (mJ/cm²)
  - Log inactivation

1b: Full-Scale Reactor Testing
- Measure UV intensity with a UV sensor.
- Measure influent flow rate, UVT, and microorganism concentration.
- Measure effluent microorganism concentration, compare to influent to calculate the log inactivation.

Source: UV Disinfection Guidance Manual
For the Final LT2EWSTR Nov.2006
Figure 5.1. Overview of Recommended Validation Protocol

Step 2. Determine the Reduction Equivalent Dose (RED)

Input the log inactivation from Step 1b into the dose-response curve from Step 1a to estimate RED.

- UV dose (mJ/cm²)
- Log inactivation (from step 1b)
- Dose-response curve (from step 1a)

Step 3. Adjust for Uncertainty to Calculate the Validated Dose

Validated Dose = RED / VF

Where VF = Validation Factor that accounts for biases and experimental uncertainty.

Source: UV Disinfection Guidance Manual
For the Final LT2EWSTR Nov.2006
Phase 1 Preliminary Test Results

- MS2 bacteriophage testing completed with final report to be published in early 2012
  - Final report to include all 3 organisms
  - Phase 1 report with its high challenge level of MS2 can be used as a surrogate today for:
    - Adenovirus
    - Cryptosporidium
- Phase 1 results showed that the Multi-Barrier System meet and exceeds the 4 -LRV requirements for the LT2ESWTR & GWR established by the EPA Guidance Manuals.
  - Beginning of Life 9.0 LRV (99.9999999%)
  - 50% Life 8.2 LRV (99.9999992%)
  - End of Life 5.8 LRV (99.9998%)
Upcoming Industry Conference Papers
June 2012 Abstracts submitted

EVALUATION OF AN ULTRAVIOLET LIGHT DISINFECTION SYSTEM FOR REMOVAL ENTERIC VIRUS IN DRINKING WATER

EVALUATION OF A CHARGED ADSORPTIVE FILTER (CAF) SYSTEM FOR REMOVAL OF ENTERIC VIRUS IN DRINKING WATER

EVALUATION OF A GREEN AND SUSTAINABLE MULTI-BARRIER WATER TREATMENT SYSTEM FOR REMOVAL OF ENTERIC VIRUS IN DRINKING WATER

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1&6 U.S. EPA National Risk Management Research Laboratory, Cincinnati, Ohio
2&3 Shaw Environmental & Infrastructure, Inc., Cincinnati, Ohio
Shaw Environmental & Infrastructure, Inc., Cincinnati, Ohio
4 Waterline Technology, Mansfield, Ohio
5 Aqua Treatment Service, Mechanicsburg, Pennsylvania
Multi Barrier Innovative Technology
The inside Story

CAF™ Charged Adsorptive Filtration Technology
HDUV-186K™ high dosage ultraviolet Technology
Remote Logic Controller
Packaged skid system
CAF™ Charged Adsorptive Filtration pleated cartridge
Technology and System Design

Stage 1

- Waterline Technology, partnered with industry leaders in advanced water filtration raw materials and production processes to produce its new CAF™ Charged Adsorptive Filtration design into a pleated cartridge with various filter vessels and integral sealing systems to insure all water is filtered!
  - Point of Use (POU) Designs - Exclusive quick change cartridge
  - Point of Entry (POE) Designs - Exclusive 304 Stainless Steel filter vessels

- These designs are utilized for two separate market applications
  - Final barrier of purification protection for POU & POE
  - Stage 1 Treatment for Packaged Multi Barrier Disinfection Systems & Advanced Oxidation Systems
HDUV-186K™ High Dose Ultraviolet System

Stage 2

- Aqua Treatment Service, Inc. (ATS), Mechanicsburg, PA designed and manufactured the Industries 1st Innovative HDUV-186K™ High Dose Ultraviolet & Monitoring System
  - 4 Log (99.99%) reduction of Virus Including Adenovirus to meet the requirements of the new EPA Drinking Water Regulations.
  - **Stage 2 Treatment** for Packaged Multi Barrier Disinfection Systems
  - **Stage 3 Treatment** for Packaged Advanced Oxidation / VOC Reduction Systems.
Remote Logic Controller (RLC)

Stage 3

- Aqua Treatment Service, Inc. (ATS), Mechanicsburg, PA designed and manufactured the Innovative Intelligent Microprocessor that continually monitors the entire system
  - Fail Safe Design
  - Communication on site and with multiple remote options
  - Solid State
Engineered Skid System

- Aqua Treatment Service, Inc. (ATS), Mechanicsburg, PA designs and manufactures the Skid system
  - Factory Integrated Plumbed & Wired
  - Factory Tested
  - Many sizes fit small spaces – 36” door opening
- Plug and Play Design
  - Quick and simple installation
  - Small footprint
CAF™ Charged Adsorptive Filtration pleated cartridge Technology

Design Features
CAF™ Charged Adsorptive Filtration
Nano alumina fibers on glass fiber

- Nano fibers are the mineral pseudoboehmite AlO(OH)
- Zeta potential >50 millivolts at pH 7.2
- One gram of Nano fibers have a surface area of >500 m²
- Square meter of pleated filter media has >42,000 square meters of surface area

R.Ristau, IMS, UCONN
Nano Fibers Adsorption characteristics

- Nano fibers are 2 nm in diameter and approximately 250 nm in length
- Have an electrokinetic charge potential resulting from the exposed Al+++ ion on the surface of the fibers
- CAF™ Media has unique properties that may make it a universal foundation material for applications in many fields
Mechanical filtration

• Three, 0.65 micron micro glass fibers coated with Nano alumina forming a pore approximately 3 x 2 microns

Photo courtesy of R. Ristau, IMS, Univ. of Conn
Electro positive charge field

- Charge field extends up to 1 micron from Nano-fibers in water and other polar solutions

Photo courtesy of R. Ristau, IMS, Univ. of Conn
Provides mechanical and adsorptive filtration

- The charge field creates a nearly total capture cross section of the entire pore volume.
- There are approximately 400 such layers in the .8 mm thick CAF™ pleated filter media.

Photo courtesy of R. Ristau, IMS, Univ. of Conn
CAF™ redefines filtration media

Retention

Flow Rate

Capacity
CAF™ Charged Adsorptive Filtration cartridges have lowest Pressure Requirements
CAF™ Raw Material Testing/Certification

Raw material for Waterline’s CAF™ Charged Adsorptive Filtration pleated cartridges is manufactured and patented by Ahlstrom’s, at their ISO Certified Specialty Paper Plant in Mt Holly, Pennsylvania.

They conduct extensive flat sheet testing of their media as standard quality control production process.

Ahlstrom production expertise is critical to our product design to meet the industry challenges for these products.

Raw material is NSF/ANSI Std 61 Certified
CAF™ Raw Material Testing/Certification

Raw Material trade name Disruptor® is tested and validated by:
- USP Class VI certified for endotoxins contamination
- Test validated for endotoxins reduction
- Test validated for pathogen reduction - virus, bacteria and cysts
- NSF/ANSI Standard 42/61 certified for water contact and material safety

- Raw Material testing cannot be used for validation of finished units.
  - NSF/ANSI Standard 42/61 are for components only
Dirt Holding

Influent:
- 200 mg/l of A2 Test Dust throughout test
- Flow rate 5 gpm (18.9 L/m)

Flow through:
- 186,354 mg of A2 test dust
- 246 US gallons/932 Liters

5 F² Surface Area
Product Testing/Certification CAF™ Charges Adsorptive Filtration

Filtration Efficiency
0.6 – 8 micron
>99%
Terminal efficiency = 35psid

[Graph showing WL410#1 efficiency data over diameter]
CAF™ Charged Adsorptive Filtration
Point of Entry Filter Vessel Designs

- **Single Cartridge Filter Housing – 10, 20, 40 gpm**
  - Small foot print -13” diameter floor space:
    - Bottom outlet
    - Top inlet

- **Multiple Cartridge Filter Housing - 60-240 gpm**
  - Up to 480 gpm dual parallel designs

- Pressure relief valve
- Pressure Differential gauge (0-35 PSID)
- Adjustable tank height
- Material of Construction 304 Stainless
- Swing Bolt on top cover w/o-Ring Seal
- Bolt down base ready
CAF™ Charged Adsorptive Filtration
Point of Entry Cartridge Designs

Cartridge features

- Pleated Media surrounds a Stainless Steel filter core
  - Outside / Inside filtration pattern
  - Low flux rate
- Integral Sealing system
  - Exclusive Double O-Ring Sealing system
  - Welded side seam and end caps
- User Friendly quick and sanitary cartridge change
- <7 psid pressure differential of new cartridge
- 35 psid end of life
- Inlet deflector shield with built in handle (4.5” od only)
- Available in 4 sizes for Point of Entry Markets
  - 2.5” x 30” = 10 gpm
  - 4.5” x 12” = 10 gpm
  - 4.5” x 24” = 20 gpm
  - 4.5” x 40” = 40 gpm
CAF™ Charged Adsorptive Filtration
Point of Entry Operating Specifications

- Min/Max working pressure: 10 psi (.7bar) / 150 psi (10.4 bar)
- Temperature 35-200º F (2-93º C)
- Service Flow rate per cartridge
  - 2.5 x 30” length 10 gpm
  - 4.5 x 12” length 10 gpm
  - 4.5 x 24” length 20 gpm
  - 4.5 x 40” length 40 gpm
- <7 psi initial pressure drop
- pH range 5-9
- Fresh or brackish water

All raw Materials are certified to NSF/ANSI Standard 42, and/or 61 for potable water contact, material safety and structural integrity
HDUV-186K™ High Dose Ultraviolet System
Stage 2 Disinfection
Design Features
How do UV Systems Work?

UV affects the cell replication process by promoting the dimerization reaction of pyrimidine nucleotides. Inhibition of replication results in inactivation and death of cells.

Source-Nov.2008 Ground Water Rule Corrective Actions Manual 5.2.2
How do UV Systems Work?

The most effective spectral region corresponding to maximum absorption by nucleic acids is around 254nm (USEPA, 2006b).
**HDUV-186K™** high dosage ultraviolet system

**Design Features**

- **Multi-Barrier CAF™- HDUV-186K™ System**
- **Stage 2 Treatment**
  - UV adds to Total Log Reduction
  - Does not form regulated disinfection byproducts (DBPs).

Source: UV Disinfection Guidance Manual For the Final LT2EWSTR Nov.2006
HDUV-186K™ high dosage ultraviolet system

Design Features

186K System: Provides a minimum UV dose of 186,000uws/cm² (186mJ) at rated flows and water quality transmission throughout the UV chamber at the End of Lamp Life (EOL) to achieve a 4 Log Reduction/Inactivation of Bacteria, Virus and Cysts

- Vertical UV Chamber Design:
  - 304 S.S. or 316L S.S.
  - L – Flow Hydraulic Profile
  - Vented UV Lamp Cover
  - Internal Inlet Water Flow Diverter
  - Internal Multi-Level Flow Balance Assembly
  - Internal Multi-Level UV Lamp Quartz Sleeve Stabilizer
  - Removable UV Lamp/Quartz Sleeve Service Rack Assembly

- Features:
  - 254NM Discrete, Calibrated and Documented NIST Traceable Sensor
  - Energy Saver- Pacing
  - High Temperature Auto-Shutdown protection and Auto-restart
  - S.S. Adjustable Mounting Stand Assembly
HDUV-186K™ high dosage ultraviolet system

Design Features

- **Low Pressure High Output Amalgam Lamps**
  - Increased UV output at 254 nm wavelength
  - High lamp efficiency only 20% loss UV of at EOL
  - Spectral distribution same as low pressure lamps
  - Increased operating temperature range
  - Short warm-up time
  - Reduced equipment footprint

- **Certified Validated Output @ 100 hours**

- **12,000-Hour Lamp Life**

- **Quartz Sleeve**
  - Pure Fused Quartz
  - 99% UV wavelength Transmission
  - Fire Polished Ends
HDUV-186K™ high dosage ultraviolet system

Sensor Probe

- UV Sensor accuracy is critical monitor of UV Dosage
- UV Sensor Must respond to
  - 245NM UV Wavelength
  - UV Lamp (s) Output
  - Lamp (s) Aging
  - Flow rate changes
  - System Quartz Sleeve Fouling Factors
  - One UV Sensor required per 10 LPHO Lamps
  - Water UVT Changes
  - Sensor Positioning is critical
  - Validated to NIST Traceable Standards

UV Light energy transmits in all directions & the UV Sensor measures individual lamp output to register the Total UV System Dose throughout UV Chamber
Total System Monitoring capabilities is a growing requirement for Federal, State and Private Sectors

- Real Time Monitoring Provides
  - Verification of the System Status and on-line Operation
  - Alarm Conditions
  - Maintenance Requirements

- Monitoring Assistance
  - Compliance Officials
  - Water treatment Professionals
  - Certified Water System Operators
HDUV-186K™ high dosage ultraviolet system

Microprocessor Controller

- Remote Logic Controller (RLC)
  - Operator Touch Pad
  - LCD Display is integral to the NEMA 4 type 304 SS enclosure
  - Continually Self Monitors the Multi Barrier Stage 1 Cartridge System & Stage 2 UV Disinfection System
    - Operation
    - Performance
    - Maintenance requirements
- Contains: Ballast, solid state circuitry and UV Monitor
- Quick connection of system monitoring devices
HDUV-186K™ high dosage ultraviolet system

Microprocessor Controller

**System Monitor & Display Features:**

- UV Sensor Probe
- UV System Ultraviolet Intensity total output
- Display UV intensity at 0-100% levels
- Ultraviolet Low Level Alarm
- Water Temperature inside the UV Chamber at the UV Sensor Probe
- Overheat Safety Control
- Ballast Operation
- UV Lamp Watts
- Ultraviolet Lamp Type
- Hours on UV Lamps
- Elapsed Total Hours of System Operation
- Alarm Silence function
- Detect and register incoming line voltage
System Monitor & Display Features continued:

- Power On/Off Status
- Flow Meter GPM
- Flow Meter total Gallons
- Auxiliary Contacts to operate adjoining system
  - Post Chlorination if required
- Pressure differential for Stage 1
- Pressure Differential Alarm
- Auxiliary Contacts for Alarms
- Solenoid valve operation
- Fail-Safe System Control
- Remote PLC Monitoring connections
- Provide Technician Module with Operation Alarm History
Markets: Drinking Water Purification & Multi Barrier Disinfection

Final Barrier of protection for Home or Business
- Drinking water treatment plant upsets in disinfection process
  - Mechanic, Human, Natural disasters
- Disinfection system failure protection prior to “Boil Orders”
  - Water main breaks or undetected leaks & cross connections
- Undetected biological impact to source water
  - Hostile Acts, runoff, illegal dumping

Commercial Industrial Process
- Food, Beverage, pharmaceutical (ingredient water protection)
- Medical and Dental
- Rainwater Harvest (component of total treatment process)
- Pre/Post Treatment for other water treatment devices

Primary Disinfection Alternative Technology
- Private water supplies
  - Wells and surface waters not protected with continuous disinfection
- Public water supplies
  - Alternative treatment options to meet USEPA & International Drinking Water Regulations
Market Applications short list

- Home/Office/Business/Commercial/Industrial Markets
  - Public and Private Water
  - Health Care – ice, drinking, showers, bathing
  - Food Service – ice, drinking, fountain beverage, coffee
  - Office – ice, drinking, coffee
  - Food process manufacturing – ingredient water protection
  - Beverage industry – ingredient water protection
  - Grocery stores – misting stations, ice, drinking
  - Transportation – drinking water, ice, onboard water storage
  - Recreational – RV’s, boats onboard water storage
  - Hospital – Patient bathing, low flow showers, drinking, ice etc
  - Hospitality – ice, drinking, coffee
  - Industrial processes - Microbiological controls
Packaged Multi-Barrier Disinfection Systems CAF™-HDUV-186K™

Summary

- **Fully Engineered Multi-Barrier Skid Mounted Systems** meet and exceed the States and Federal regulated Site locations to Meet the 4 Log Reduction Requirements for Bacteria, Virus and Cysts, Including Adenovirus.

- **Distributor Responsibility:**
  - Make your local State Regulators aware of new Technology that will meet the 4 Log Reduction Requirements
  - Insure all personal are trained

- **Manufacturers Responsibility:**
  - Provide the Water Treatment Professional with the Documentation required by the approving agency to gain acceptance
  - Product Support:
    - Operations and Service Training