Efficacy of AquaStar *Plus!*™ UV-C Water Treatment System
(or AquaStar ™)
product of Meridian Design, Inc.

Meridian Design, Inc. July 29, 2005.
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The basis for this document is the Meridian Design, Inc. submission to the EPA. We requested that they review our "claims" and other substantiating references on the viability and efficacy of the AquaStar Plus!™ UV-C Water Treatment System and UV-C treatment in general. This document incorporates the EPA's input and is based upon industry research and testing performed at the request of Meridian Design, Inc.

Source Information on UV-C Efficacy
We have found that few people, especially outside of the water quality industry, are aware of much of the body of recent research demonstrating that UV-C is excellent at reducing pathogens. In fact it is superior in many ways to other methods of water treatment; for instance, it is now accepted as being highly effective at treating Cryptosporidium and Giardia. Confirmation of this fact is in recent EPA papers. [2, 3, 4, 6]

We have included footnotes throughout so that our statements about UV-C can be verified. Most of them are in reference to the EPA's literature, and much of that is summarized in a single EPA document. That is, the "Ultraviolet Disinfection Guidance Manual " dated June 2003 "Draft". It can be found on the EPA website at:

http://www.epa.gov/safewater/lt2/guides.html
>>Ultraviolet Disinfection Guidance Manual
http://www.epa.gov/safewater/lt2/pdfs/guide_lt2_uvguidance_draft.pdf

This EPA Guidance Manual is intended "...to provide technical information on the application of ultraviolet light for the disinfection of drinking water by public water systems." This document is one of the most recent collections of research and explanation on the subject of using UV-C for water treatment and is highly enlightened on the subject. The Guidance Manual is intended as advice to municipalities so in many ways it is not directly relevant to a portable system, but much work was put into this document by the EPA to collect and summarize what is known about UV-C, how it works, and how well it works. In this discussion we will use this EPA document as support for our arguments since, owing to its source, it should be an acceptable independent reference. However all of the statements in that document are, rightly, based on a large body of research that can be referred to independent of the EPA manual.

AquaStar efficacy

Before we go too far, the following pictures and test results table might save a few words. It is really quite straight forward; we drive a big UV-C Germicidal Lamp in a little 1 liter bottle. Normally a lamp of this type would have water flowing past it, but we irradiate 1 liter of water for over a minute. That is why the UV-C dosage is so high and that is why AquaStar works so well. If conditions call for even higher dosages, more cycles can be run.

Transmittance	*Water Qual./ ° C*	*mJ/cm²*	*Mixing*
UVT = 96%	Clean / 25C	67	Mag Mix
UVT = 78%	Clean / 25C	42	"Multi Shake"
UVT = 86%	Clean / 4C	23	"Multi Shake"

Results based on MS-2 biodosimetry[15]. Each test dosage is one cycle. A cycle runs about 80 seconds. The challenge waters used were de-chlorinated tap water ("Clean Water"). The units were either shaken by hand ("Multi Shake") during the cycle, or were stirred with a laboratory stirring unit ("Mag Mix"). Results were reported in mJ/cm^2(note: 1).

Efficacy of UV-C

Up until the last few years, UV-C was thought not to treat effectively for Cryptosporidium and Giardia [2, 3]. These spores' hard outer surface were thought to be too impenetrable for light, much as it is difficult even for chemicals to penetrate and treat them. More recent live animal studies [6] demonstrated that, though the pathogens may still be alive, the spores' reproductive process had been so damaged that infection was prevented at much lower dosages of UV-C ($<10 mJ/cm^2$) than had been previously thought necessary. These recent studies have lead to UV-C's acceptance into water treatment by municipalities, research and certification laboratories and even industries where disinfection efficacy is critical and has now entered into the EPA guidelines[4].

Other past concerns with UV-C included photo-reactivation. It has been demonstrated and accepted that photo-reactivation is diminished significantly as higher dosages are given[9, 10, 14]. The EPA cites specific dosages high enough to prevent significant reactivation, photo or otherwise[10, 19, 20]. Cryptosporidium, Giardia and viruses are not considered to photoreactivate[9, 10, 14].

Turbidity, and similarly, transmittance of the water to UV-C can also be a concern when using a UV-C system. It should be used on "clear" water. By this, we do not mean water in which the pathogens have been removed, but that the turbidity has been removed (filtered, flocculated, or water drawn from an otherwise clear source and needing disinfection). Once the water is clear to UV-C then the light can do its work. Again, the higher the dosage of UV-C the unit can produce, the better some loss of transmittance can be compensated for. See the claims section in this document for our cautions and information on the need to prepare or even reject water that is to be treated. A user can increase dosage by running multiple cycles, or by warming very cold water to increase lamp output.

UV-C is rare in the portable industry. The main reason a person will not likely have seen such a unit as ours before is that typical magnetic ballasts for these germicidal lamps require an AC power source [23] and take too much power to be driven efficiently from batteries. However we have developed a microprocessor based circuit capable of driving a nice high output UV-C germicidal lamp from small batteries (without a typical magnetic ballast).

The fact that our circuit is innovative and therefore makes a product unusual to the portable market does not in any way detract from the end result: That the water can be given such a high dosage of UV-C that it can be very well treated. Because we feel more compelled to "prove" our product works from the ground up, our claims will have footnotes referring the reader to the research behind the technology so that our statements can be reasonably affirmed.

Claims and Product Description

(1) AquaStar *Plus!*™ UV-C Water Treatment System is an ultraviolet treatment solution appropriate for use in almost all climates and settings. Campers, hikers, and families who travel, all depend on having clean water and will benefit from using AquaStar™.

(2) Using a pair of standard camera batteries, the AquaStar *Plus!* UV-C Water Treatment System can quickly treat a liter of water in little over a minute. Lightweight -- less than 4 ounces (106 grams), rugged and simple one-button operation, everyone should have an AquaStar *Plus!* UV-C Water Treatment System packed in their survival kit.

(3) Ultraviolet C-band (UV-C) treatment systems work differently from filtration systems by generating ionizing radiation at 254nm that quickly and effectively disrupts the cellular chemistry that is the basis for all known pathogens. UV-C causes damage to the DNA or RNA structure which halts replication, rendering the pathogens non-infective[7, 8, 17].

(4) Our UV-C water treatment system takes up virtually no additional room in your gear or survival kit since it fits inside the same type of standard 1L wide-mouth water bottle that most people pack. How do we do it? We replace the cap on the bottle with a low-profile weather-sealed electronics package. And we also supply a quality polycarbonate bottle with our treatment system, just in case you don't have one already. The UV-C light does not penetrate common drinking bottle plastics. The bottle provides 100% shielding of any UV-C light that could damage living tissue.

(5) Caution: UV-C light can cause skin or eye irritation if used outside of the bottle. Please keep out of the reach of children.

(6) AquaStar adds only 3 ounces of weight (about 50 grams) -- including batteries -- to the weight of the water bottle it is mounted on. Both HDPE and polycarbonate Nalgene®-style wide-mouth bottles are already very light, so for the ultralight hikers, AquaStar is definitely the way to go. In addition, the AquaStar is designed to use small, lightweight CR-123 batteries, the same type used in pocket-sized point-and-shoot cameras.

(7) By making the AquaStar out of commonly available components, the cost is kept low. And, by keeping the parts count to a minimum, and avoiding wasteful display packaging, we drive the cost down even lower. But low cost doesn't mean low quality! Each component is still the best in its class. From the odor-free polycarbonate bottle to the Philips Sterilamp® UV-C tube -- rated at 2,000 hours of use -- AquaStar is designed for years of trouble-free operation.

(8) AquaStar is designed for the sports enthusiast. We know what kinds of crazy environments you seem to end up in because we've been there! Jungles, deserts, flood zones, mountains, hurricanes, caving and volcano watching -- whatever your scenery, you can count on AquaStar. The resilient quartz UV-C tube is shock-mounted at both ends in the bottle. The electronics head is completely sealed against water, sand, and gases. There are no moving parts to snap off or bend. Of course, the AquaStar Ultraviolet (UV-C) Water Treatment System is also right at home in your earthquake or disaster preparedness kit, or in a roadside emergency kit in the trunk of your car.

(9) **Chose your source water carefully.** As with any portable water treatment system, there are limits to what AquaStar can do. Dissolved toxins are not removed with UV-C, nor with most chemical or filtration systems. For instance, water taken from low lying water ways in agricultural areas may have dissolved pesticides or fertilizers in it. While there are studies that show unfiltered ground and surface waters do not normally have enough turbidity to negatively affect UV-C performance[11, 24, 25, 26], it is still recommended that water to be treated with the AquaStar system should have no visible contamination or coloration. AquaStar is not intended to be used on water for storage. It is intended to be used to treat water that will be consumed on site. Silt and other contaminants that can shade the UV light should be removed first and/or the exposure time should be lengthened accordingly. AquaStar is not intended to be used to treat waste water.

(10) There are also situations where combinations of methods are best. Most high grade filters need pre-filtered water as well to prevent their small pores from clogging. In situations where water is to be stored for a longer period of time (perhaps days or weeks), chemical usage can be dramatically reduced by combining it with UV-C[2, 28]. The UV-C system can be used to initially disinfect the water and then a smaller dosage of chemical is left in the water for storage.

(11) **Using UV-C to Disinfect Drinking Water**
For decades studies have shown that Ultraviolet light, or UV, destroys pathogens. The wavelength of 254nm, called UV-C, is the wavelength of the low pressure mercury vapor lamp used by AquaStar and it is especially effective[5, 12, 13, 16]. In fact, UV-C has found its way into many air and water purification systems and is used in the sterilization of lab and medical equipment. There are many applications where filtration systems cannot compete with UV. In many sophisticated systems filtration and UV-C are used together.

(12) The effective UV-C output level of AquaStar has been measured by independent laboratories. The output levels verified are not simply the measurement of the actual lamp output, which may in fact be much higher, but are instead a measure of the actual reduction rate of a known microorganism, in this case MS-2 collaphage. The virus MS-2 is added to otherwise clean water and is treated with AquaStar. The reduction of this virus is then measured and correlated to the known UV-C dosage required for reduction to the measured level[15]. For instance, in the case of AquaStar the reduction of MS-2 collaphage was equivalent to greater than 42mj/cm² at 25 º C, and 23mj/cm² at 4 º C, when shaken during the disinfection cycle (output was even higher when agitated at a higher rate; 67mj/cm² at 25 º C).

(13) In the Appendix is an extensive list of pathogens and the dosages required for their reduction, based on commonly quoted studies. This list is not a warranty for AquaStar performance. Standards agencies and laboratories, including the Water Quality Association, do not allow claims of 100% reduction. Effectiveness must be quoted as a log reduction, or a number of "9s". An example of pathogens of most common concern and their log 3 reduction (99.9%) are[20]:

Pathogen	Energy for 99.9% reduction mJ/cm²
Aeromonas hydrophila Bacteria	3.9
Campylobacter jejuni Bacteria	4
Escherichia coli O157:H7 Bacteria	4.1
Legionella pneumophila Bacteria	6.9
Salmonella anatum Bacteria	15
Salmonella enteritidis Bacteria	9
Salmonella typhi Bacteria	6.4
Salmonella typhimurium Bacteria	5
Shigella dysenteriae Bacteria	2
Shigella sonnei Bacteria	6.5
Staphylococcus aureus Bacteria	6.5
Vibrio cholerae Bacteria	2.2
Yersinia enterocolitica Bacteria	3.7
Adenovirus Type 40 2 Virus	90
Adenovirus Type 41 2 Virus	80
Coxsackievirus B5 Virus	21
Hepatitis A (various) Virus	22
Poliovirus Type 1 Virus	23
Rotavirus SA11 Virus	26
Cryptosporidium parvum Protozoa	<6
Giardia lamblia Protozoa	<6

(14) Of the "Pathogenic Microorganisms in Water" listed here, Adenovirus is the hardest to reduce[18]. Multiple cycles may be needed to reduce this virus more significantly. The Center for Disease control says that "Enteric adenoviruses 40 and 41 cause gastroenteritis, usually in children." and "Treatment: Most infections are mild and require no therapy or only symptomatic treatment. Because there is no virus-specific therapy, serious adenovirus illness can be managed only by treating symptoms and complications of the infection." [29]

(15) UV-C dosage is additive. For example, if output from one cycle is 25mj/cm², when the water temperature is very cold for instance, then the resulting dosage of running 1 liter through two cycles is 50mj/cm². In circumstances where a higher dosage is called for, multiple cycles can be run to achieve that dosage.

(16)

Appendix – Example UV-C Dosages

UV-C reduction dosage of selected microorganisms (see references in Appendix for list sources)

This list is for reference only and should not be used as a research source. Meridian-Design, Inc. did not originate this research and makes no warranty based on levels provided here.

Source: EPA ULTRAVIOLET DISINFECTION GUIDANCE MANUAL
June 2003 Draft
Document Number: 815-D-03-007

Appendix A. Fundamentals of UV Disinfection

Table A.2 UV Sensitivity of Pathogenic Microorganisms in Water[1]

Microorganism	Type	UV Dose (mJ/cm^2) inactivation indicated				Reference
		1-log	2-log	3-log	4-log	
Aeromonas hydrophila	Bacteria	1.1	2.6	3.9	5	Wilson et al. 1992
Campylobacter jejuni	Bacteria	1.6	3.4	4	4.6	Wilson et al. 1992
Escherichia coli O157:H7	Bacteria	1.5	2.8	4.1	5.6	Wilson et al. 1992
Legionella pneumophila	Bacteria	3.1	5	6.9	9.4	Wilson et al. 1992
Salmonella anatum	Bacteria	7.5	12	15		Tosa and Hirata 1998
Salmonella enteritidis	Bacteria	5	7	9	10	Tosa and Hirata 1998
Salmonella typhi	Bacteria	1.8	4.8	6.4	8.2	Wilson et al. 1992
Salmonella typhimurium	Bacteria	2	3.5	5	9	Tosa and Hirata 1998
Shigella dysenteriae	Bacteria	0.5	1.2	2	3	Wilson et al. 1992
Shigella sonnei	Bacteria	3.2	4.9	6.5	8.2	Chang et al. 1985
Staphylococcus aureus	Bacteria	3.9	5.4	6.5	10.4	Chang et al. 1985
Vibrio cholerae	Bacteria	0.8	1.4	2.2	2.9	Wilson et al. 1992
Yersinia enterocolitica	Bacteria	1.7	2.8	3.7	4.6	Wilson et al. 1992
Adenovirus Type 40 [2]	Virus	30	59	90	120	Meng and Gerba 1996
Adenovirus Type 41 [2]	Virus	22	50	80		Meng and Gerba 1996
Coxsackievirus B5	Virus	6.9	14	21		Battigelli et al. 1993
Hepatitis A HM175	Virus	5.1	14	22	30	Wilson et al. 1992
Hepatitis A	Virus	5.5	9.8	15	21	Wiedenmann et al. 1993
Hepatitis A HM175	Virus	4.1	8.2	12	16	Battigelli et al. 1993
Poliovirus Type 1	Virus	4.0	8.7	14	21	Meng and Gerba 1996
Poliovirus Type 1	Virus	6	14	23	30	Harris et al. 1987
Poliovirus Type 1	Virus	5.6	11	16	22	Chang et al. 1985
Poliovirus Type 1	Virus	5.7	11	18	13	Wilson et al. 1992
Rotavirus SA11	Virus	7.6	15	23		Battigelli et al. 1993
Rotavirus SA11	Virus	7.1	15	25		Chang et al. 1985
Rotavirus SA11	Virus	9.1	19	26	36	Wilson et al. 1992
Cryptosporidium parvum [2]	Protozoa	< 2	< 3	< 5		Shin et al. 2001
Cryptosporidium parvum [2]	Protozoa		< 3	< 6		Clancy et al. 2000
Giardia lamblia [2]	Protozoa	<1			<2	Linden et al. 2002a
Giardia lamblia [2]	Protozoa	<1	< 3	< 6		Mofidi et al. 2002

[1] Adapted from Wright and Sakamoto 1999
[2] Additional data for adenovirus, *Cryptosporidium*, and *Giardia* are in Appendix B.

(17) Appendix – Document References

All references are derived from:

EPA ULTRAVIOLET DISINFECTION GUIDANCE MANUAL
June 2003 Draft
Document Number: 815-D-03-007

Center for Disease Control - Adenoviruses
http://www.cdc.gov/ncidod/dvrd/revb/respiratory/eadfeat.htm

References in the document body are numbered 1 to 29 followed by the name of the referenced document then the page number within the document and the pdf page number where applicable. A direct quote is provided to aid in understanding the purpose of the reference.

References

1 – EPA Document # 815-D-03-007, page xi, pdf page 15
"UV Dose – the energy per unit area incident on a surface, typically in units of mJ/cm^2 or J/m^2 (older literature also used the units $mW\text{-}s/cm^2$ where 1 $mW\text{-}s/cm^2$ = 1 mJ/cm^2)."

2 - EPA Document # 815-D-03-007, page 1-1, pdf page 25
"Some pathogens, such as Cryptosporidium, are resistant to commonly used disinfectants, whereas UV light has proven effective against these microorganisms."

3 - EPA Document # 815-D-03-007, page 1-1, pdf page 25
"Until recently, the use of UV treatment for drinking water applications was primarily limited to small ground water systems, due to the belief that it was not effective for inactivating protozoa and was not cost-effective for large systems. In 1998, however, research demonstrated that UV light could effectively inactivate Cryptosporidium at low dosages (Buhkari et al. 1998), prompting more research to better understand its potential for widespread application."

4 - EPA Document # 815-D-03-007, page 2-2, pdf page 36
"Because of the susceptibility of Cryptosporidium to UV disinfection and the emphasis in recent regulations on controlling Cryptosporidium, the number of utilities using UV disinfection is expected to increase significantly over the next decade."

5 - EPA Document # 815-D-03-007, page 2-3, pdf page 37
"Mercury is an advantageous gas for UV disinfection applications because it emits light in the germicidal wavelength range"

6 - EPA Document # 815-D-03-007, page 2-6, pdf page 40
"results of early Cryptosporidium inactivation studies were based on viability assays. The ability of UV light to inactivate Cryptosporidium at low doses was revealed when infectivity was assessed by inoculating mice with UV treated water, which showed greater than 4-log inactivation of Cryptosporidium at doses less than 20 mJ/cm2 (Bukhari et al. 1999)."

7 - EPA Document # 815-D-03-007, page 2-6, pdf page 40
"UV light inactivates microorganisms by damaging deoxyribonucleic acid (DNA) or ribonucleic acid (RNA), thereby interfering with replication of the microorganism"

8 - EPA Document # 815-D-03-007, page 2-7, pdf page 41
"Damage to nucleic acid does not prevent the cell from undergoing metabolism and other cell functions. Although the microbial cell is alive after exposure to UV light, it cannot reproduce, and therefore it is incapable of infecting a host. To kill the microbial cell, the UV dose would need to be increased by orders of magnitude as compared to the UV dose needed to prevent replication."

9 - EPA Document # 815-D-03-007, page 2-8, pdf page 42
“Shin et al. (2001) reported Cryptosporidium does not regain infectivity after inactivation by UV light. One study has shown that Cryptosporidium contains the capability to undergo some DNA repair (Oguma et al. 2001). However, even though the DNA is repaired, infectivity is not restored.”

10 - EPA Document # 815-D-03-007, page 2-8, pdf page 42
“(Rauth 1965). Linden et al. (2002a) did not observe photoreactivation or dark repair of Giardia at UV doses typical for UV disinfection applications (16 and 40 mJ/cm2).”

11 - EPA Document # 815-D-03-007, page 2-11, pdf page 45
“For unfiltered waters, Passantino and Malley (2001) found that source water turbidity up to 10 NTU does not impact the UV dose-response of separately added (seeded) microorganisms.”

12 - EPA Document # 815-D-03-007, page 2-15, pdf page 49
See “Table 2.1 Mercury Vapor Lamp Characteristics”

13 - EPA Document # 815-D-03-007, page 2-15, pdf page 49
“Comparative Advantages Low-pressure (mercury vapor)
• Higher germicidal efficiency; nearly all output at 254 nm
• Smaller power draw per lamp (less reduction in dose if lamp fails)
• Longer lamp life”

14 - EPA Document # 815-D-03-007, page 3-4,5, pdf page 62,63
“Repair of UV light-induced damage is discussed in section 2.3.2. As discussed previously, repair has not been observed in Cryptosporidium and viruses, and Giardia only exhibited repair when exposed to very low UV doses (0.5 mJ/cm2). Therefore, repair of UV induced damage of Cryptosporidium, Giardia, and viruses do not need to be considered in the UV installation design. “

15 - EPA Document # 815-D-03-007, page 4-8, pdf page 120
“UV reactor validations should be performed with a microorganism with the following characteristics: inactivation kinetics closely resembling those of the target pathogen and the ability to be cultured in a reproducible manner to high concentrations. Currently, research has not identified such a microorganism that is ideal for Cryptosporidium. Challenge microorganisms typically used include MS2 phage and Bacillus subtilis, both of which are significantly more resistant to UV than Cryptosporidium.”

16 - EPA Document # 815-D-03-007, page A-4, pdf page 181
“Mercury at low vapor pressure and near room temperature produces light at wavelength 253.7 nm from electrical energy with high efficiency. This wavelength is near optimal for UV disinfection (section A.2.2).”

17 - EPA Document # 815-D-03-007, page A-13, pdf page 190
“While both purines and pyrimidines strongly absorb UV light, the rate of UV-induced damage is greater with pyrimidines (Jagger 1967). Absorbed UV light induces six types of damage within the pyrimidines of nucleic acid (Setlow 1967; Snowball and Hornsey 1988; Pfeifer 1997), with varying levels of effectiveness dependent on UV dose:
• Single and double strand breaks are only significant with UV doses several orders of magnitude higher than those practical for UV disinfection.
• DNA-DNA cross-links are covalent bonds between two different strands of DNA, and they are also only significant with UV doses orders of magnitude higher than those practical for UV disinfection.
• Protein-DNA cross-links are covalent bonds between a protein and a DNA strand, and they may be important for the disinfection of certain microorganisms such as Micrococcus radiodurans.
• Pyrimidine hydrates do not contribute to UV disinfection.
• Pyrimidine (6–4) pyrimidine photoproducts are a major class of UV damage.
• Pyrimidine dimers are covalent bonds between two pyrimidines on the same DNA strand, and they are the most common damage resulting from UV disinfection.

While it is possible for thymine-thymine, cyctosine-cytosine, and thymine-cytosine dimers to form within DNA, thymine-thymine dimers are the most common. However, since thymine is not present in RNA, uracil-uracil and cytosine-cytosine dimers are formed.

Microorganisms with DNA rich in the thymine tend to be more sensitive to UV disinfection Adler 1966). Dimers cause faults in the transcription of information from DNA to RNA, which in turn results in disruption of cell metabolism. However, damage to nucleic acid does not prevent the cell from undergoing metabolism and other cell functions. As discussed in the next section, enzyme mechanisms within the cell are capable of repairing some of the damage to the nucleic acid. To directly damage the internal structure of the cell, UV doses much higher than those required for inactivation are necessary (Brandt and Giese 1956)."

18 - EPA Document # 815-D-03-007, page A-27, pdf page 204
"The most UV resistant viruses of concern in drinking water are adenovirus Type 40 and 41. "

19 - EPA Document # 815-D-03-007, page A-27, pdf page 204
"Table A.2 provides average dose reported without photoreactivation for incremental log inactivation of various pathogenic bacteria, virus, and protozoa of concern in drinking water. "

20 - EPA Document # 815-D-03-007, page A-28, pdf page 205
See "Table A.2 UV Sensitivity of Pathogenic Microorganisms in Water"

21 - EPA Document # 815-D-03-007, page A-29, pdf page 206
See "Table A.3 UV Sensitivity of Non-Pathogenic Bacteria, Bacteriophage, and Spore-Forming Bacteria in Water"

22 - EPA Document # 815-D-03-007, page A-37, pdf page 214
See "Figure A.17. Reduction in UV Output of LP and MP Lamps Over Time"

23 - EPA Document # 815-D-03-007, page A-38, pdf page 215
"UV lamps are typically operated with an AC supply. Unlike an incandescent lamp, a mercury vapor lamp cannot be connected directly to the electrical service because it has a nonlinear voltage to ampere characteristic (Persson and Kuusisto 1998). In order for the mercury vapor lamp to function properly, a ballast must be inserted into the circuit to limit the current flow through the lamp. When placed in series with the lamp, the ballast provides an impedance to the power supply with a positive voltage-current characteristic. "

24 - EPA Document # 815-D-03-007, page G-1, pdf page 394
"Typically, the turbidity in unfiltered surface waters is less than 1 nephelometric turbidity units (NTU)."

25 - EPA Document # 815-D-03-007, page G-2, pdf page 395
"Recent research has shown that particles present in supplies meeting regulatory requirements for unfiltered drinking water do not impact the UV inactivation of seeded microorganisms. Passantino and Malley (2001) reported that for unfiltered surface waters, turbidity up to 7 NTU does not affect the inactivation of seeded male specific-2 bacteriophage (MS2) in bench-scale, batch, collimated beam testing."

26 - EPA Document # 815-D-03-007, page G-2, pdf page 395
"In another study, batch (bench-scale) and continuous-flow (pilot-scale) studies showed that turbidity ranging from 0.65 to 7 NTU does not affect the UV dose necessary per log inactivation of seeded MS2, Giardia muris, or Cryptosporidium parvum in unfiltered waters (Oppenheimer et al. 2002)."

27 - EPA Document # 815-D-03-007, page G-2, pdf page 395
“Unfiltered supplies are also susceptible to algal blooms. Womba et al. (2002) monitored algae levels in an unfiltered supply reservoir for over one year and found that algal counts were typically below 30,000 cells/mL; however one algae event had a higher level of nearly 300,000 cells/mL. Although not regulated, the presence of algae may interfere with the UV disinfection process. Womba et al. (2002) and Passantino and Malley (2001) examined the effects of algae on UV disinfection of MS2 at the bench-scale in batch, collimated beam testing. Both studies found that up to algal counts up to 70,000 cells/mL and 42,000 cells/mL, respectively, do not affect the inactivation of MS2.”

28 - EPA Document # 815-D-03-007, page I-1, pdf page 407
“UV disinfection is applicable to small systems and may be attractive for the following reasons:
• It is a relatively low cost technology for the inactivation of Cryptosporidium (Cotton et al. 2001).
• Chemical use is little to none.
• Operation is relatively simple and maintenance is low.
• Space needs are small.”

29 -Center for Disease Control http://www.cdc.gov/ncidod/dvrd/revb/respiratory/eadfeat.htm
"Enteric adenoviruses 40 and 41 cause gastroenteritis, usually in children."

"Treatment: Most infections are mild and require no therapy or only symptomatic treatment. Because there is no virus-specific therapy, serious adenovirus illness can be managed only by treating symptoms and complications of the infection."