DRINKING WATER REGULATIONS AND THEIR IMPACTS ON SMALL UV SYSTEMS

MELISSA LUBITZ

R-Can Environmental Inc., 425 Clair Rd. W., Guelph, ON, Canada N1L 1R1; Email: lubitz@r-can.com

ABSTRACT

UV technology has been *accepted* as an alternative primary disinfectant within both the Canadian and USEPA drinking water guidelines. Since both sets of guidelines have been amended within the last two years, they now include requirements for smaller drinking water facilities, as well as larger municipal applications. UV disinfection acceptance does come with limitations as all systems that are considered for regulated water supplies must be able to prove their performance.

Proof of performance of a UV system can be achieved through third party validation. Validation involves a reputable third party testing a UV system according to a specific protocol or standard in order to determine it's dose delivery. This may also be referred to as biodosimetry testing. One of the most acceptable forms of small system validation is the NSF 55 Class A certification. This 'small system' validation is recognized in both the Canadian and U.S. drinking water guidelines. Although both sets of guidelines accept validation as proof of performance of UV technology, they do indicate specifications depending on the application, source water and the microorganism that the UV system in question is targeting.

INTRODUCTION

Ultraviolet (UV) disinfection technology has achieved international acceptance for the treatment of drinking water, provided each system can offer proof of performance. This acceptance is geared, not only toward large, municipal sized systems, but also for smaller, simpler drinking water facilities.

Since the amendment of both the American and Canadian drinking water regulations in 2003 (USEPA 2003b; CSDWA 2003), there has been a greater emphasis on smaller drinking water applications. Both Health Canada and the US Environmental Protection Agency (USEPA) have included UV disinfection as an alternate form of disinfection in their drinking water regulations, under specific conditions. Since any public facilities that provide drinking water to the public in both countries, and are interested in the implementation of UV, any public facilities feeding the public are going to be forced to comply with applicable drinking water regulations, which in most cases will involve the incorporation of some type of disinfection. Therefore all schools, senior residences, camp-

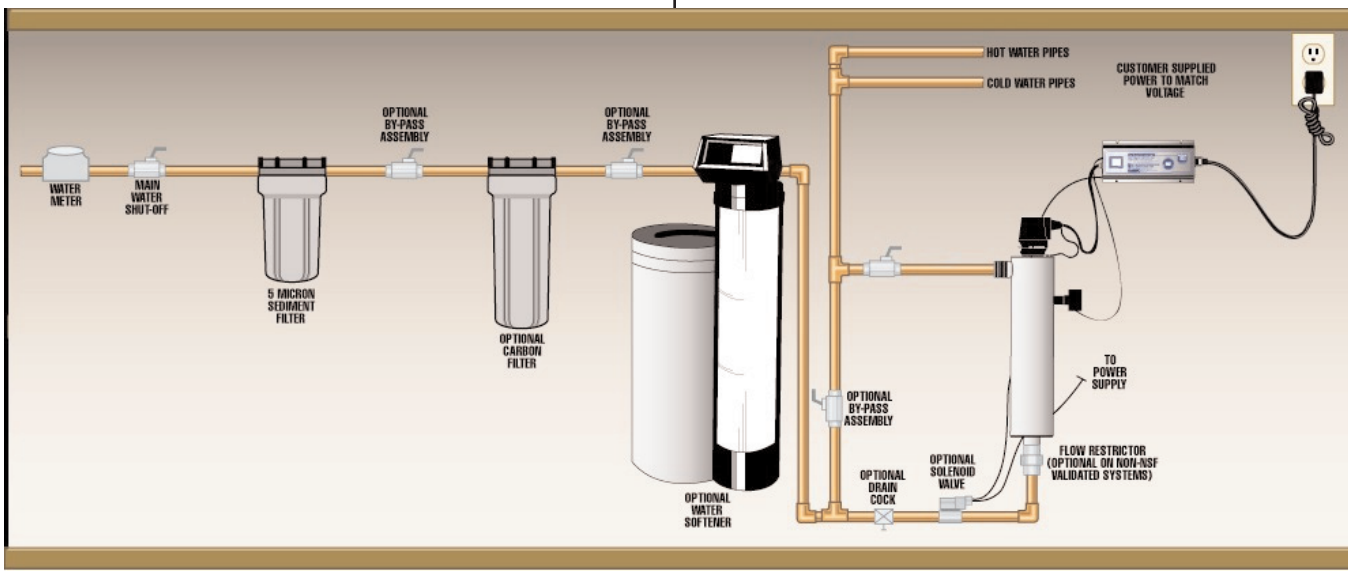


Figure 1: Point of entry unit installed at service connection of customer

grounds, resorts, golf courses and various other types of small facilities will need to look into how they will comply with the drinking water requirements. If UV is chosen as a means of disinfection in any of these applications, all UV requirements outlined in the applicable regulations will have to be met prior to installation.

The requirement for UV disinfection acceptance is third party validation in order to prove a system's performance. The following figure is an example of a small system application.

UV VALIDATION:

UV validation involves proving the efficacy of a UV system through biodosimetry testing by a reputable third party. The third party can simply examine the UV dose performance of the system, through biodosimetry analysis, or they can examine the system in question through various perspectives depending on the nature of the certification. By obtaining a type of third party validation, UV manufacturers can provide their customers with confidence that their UV system meets a specific disinfection level. There are many different ways that one can go about obtaining third party validation of a UV system, and a UV manufacturer must take several issues into account when considering to undergo this kind of testing. Issues such as the expected UV dose delivery of a system, the type of validation (either on-site or off-site), the credibility of the validation facility or third party expert overseeing the validation, and finally the validation protocol. The figure below shows a typical biodosimetry set-up.

NSF 55 CLASS A VALIDATION:

Both Health Canada and the USEPA drinking water regulations suggest that in a small facility application an NSF 55 Class A system certification is acceptable, as this specific certification process is a form of third party validation. The National Sanitation Foundation (NSF) is a certification body that tests a multitude of different drinking water treatment products. The NSF 55 Standard (ANSI/NSF 2002) is specifically a UV microbiological water treatment standard that was developed in 1991. The main objective of NSF 55A is to demonstrate that a UV device can deliver a predetermined UV dose at the system's alarm set-point.

> *"It is the purpose of this Standard to establish minimum requirements for the reduction of micro-organisms using ultra-violet radiation…NSF/ANSI 55 covers two types of UV treatment systems: Class A systems are intended for the inactivation of pathogenic bacteria*

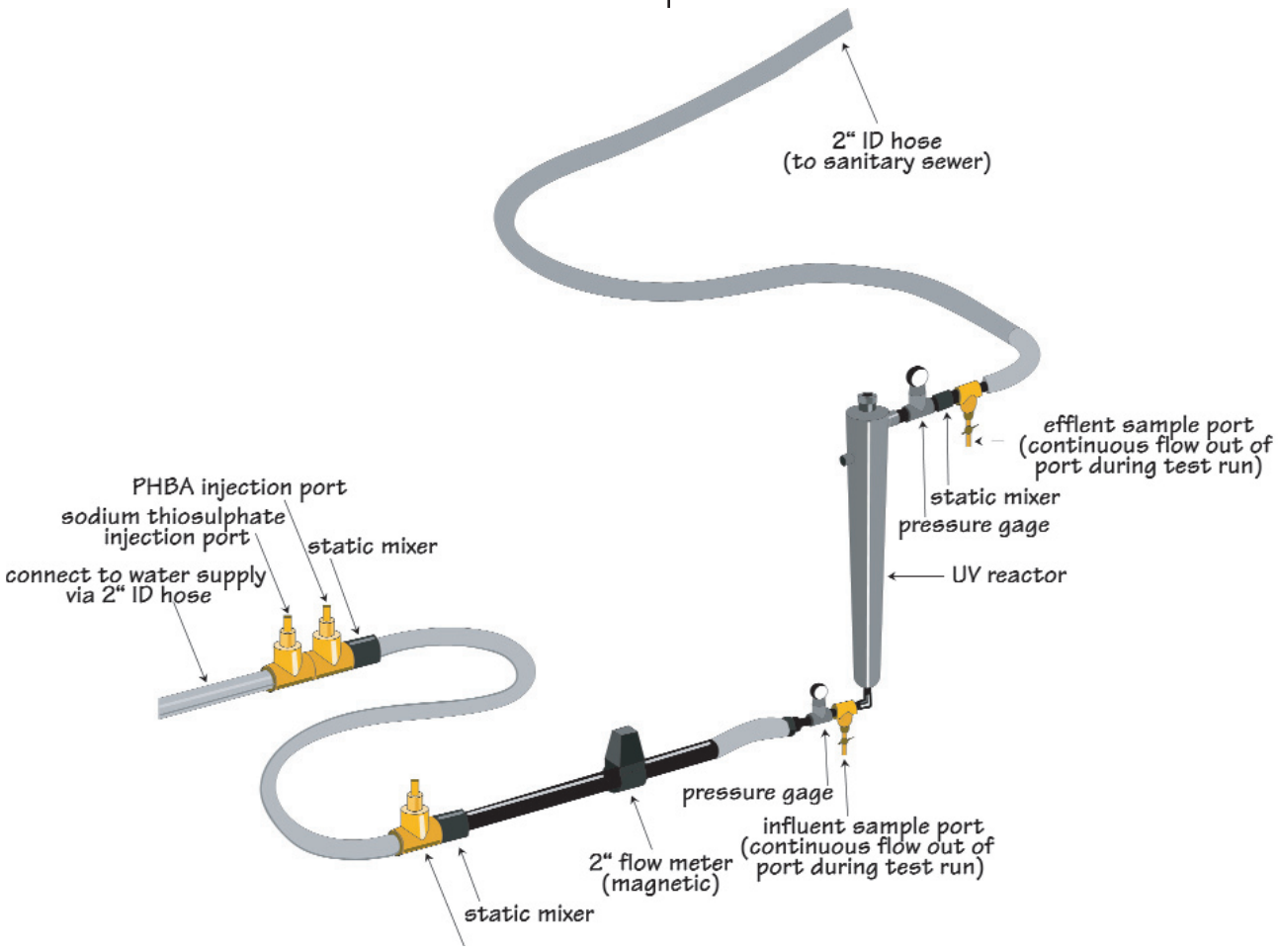


Figure 2: UV validation set-up

and viruses; Class B systems are intended for the reduction of nonpathogenic, nuisance organisms." (ANSI/NSF 2002)

In order to comply with the NSF 55 Class A protocol, a UV system must meet the following requirements:

1. The system must be capable of producing a UV dose of 40 mJ/cm2 at the alarm set-point of the system at 254 nm.
2. The challenge microorganism used in biodosimetry testing must be MS-2 bacteriophage.
3. The system must have a 254 nm UV sensor to measure the UV irradiance at all times.
4. The system must have a flow control device.
5. The system must have one of the following options: visual alarm, audible alarm or an automatic shut-off device (solenoid).
6. The system must pass all applicable structural integrity and extractability tests.

Throughout the validation process, NSF acts as the third party expert, the validation facility, the recognized microbiological laboratory, as well as they provide the biodosimetry protocol. There is a large emphasis in NSF 55A on the biodosimetry testing; however, each system must undergo an in-depth literature review, structural integrity testing, extractability analysis, sensor testing and flow restrictor verification.

When considering an NSF 55A system certification for a small system drinking water application, a consultant (or approving body) needs to be reassured that if a UV system is installed, it will supply a 'safe' UV dose level. NSF 55A requires a more than sufficient UV dose level giving consultants piece of mind that their customer is receiving sufficient disinfection of their drinking water. The biodosimetry requirements of NSF 55A are described in the standard as follows:

A Class A system shall deliver a UV dose at least equivalent to 40 mJ/cm^2 at the alarm set-point when the system is tested in accordance with 6.3.2.7 or 6.3.2.8 as applicable. (NSF 55/ANSI 55-2000, Section 6.3.2.1, p.12)

Figure 3 shows the biodosimetry set-up for the Class A analysis.

Since the NSF 55 biodosimetry test requires UV systems to deliver a UV dose of 40 mJ/cm^2 at the system's alarm set-point, it is imperative that the validated system maintain that alarm set-point. NSF 55 validated systems CANNOT be calibrated or adjusted in the field especially in dirty or colored water conditions. If the sensor's calibrated alarm set-point is adjusted at any time, the system is no longer valid and must be retested in order to hold its approval. The following is a statement from Rick Andrew at NSF, the Technical Manager of the Drinking Water Treatment Unit Program:

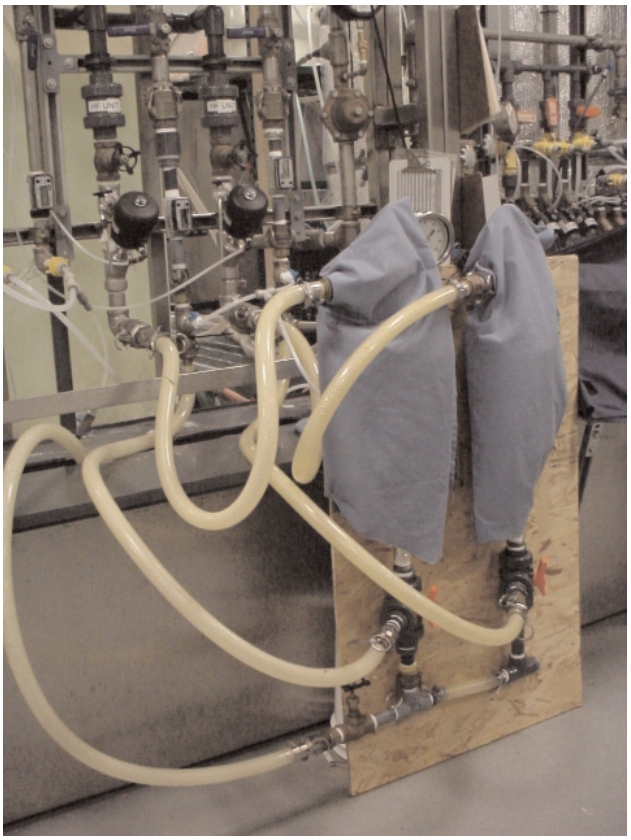
A system (NSF 55A validated system) may deliver more than a 40 mJ/cm^2 dose. Also, because testing is conducted at the alarm set point, any lowering of the alarm set point would require retesting for Class A performance at that lowered set point. (Rick Andrew, Laboratory Manager NSF International, December 13 2004).

The NSF 55A certification does have a flow restriction, since the biodosimetry laboratory can only accommodate flow rates up to 30 USGPM at 150 psi. If a consumer has a higher flow small system application, they will need to look to UV systems that are validated under a different protocol.

Since UV technology is in a continuous evolution of new developments, the NSF standard must evolve along with these developments. The NSF 55 standard has been in a technical review over the last five years in order to make this standard a more viable one for both UV manufacturers and UV consumers.

USEPA UV DISINFECTION GUIDANCE MANUAL & ITS IMPLICATIONS ON SMALL SYSTEMS

The USEPA released a draft amendment to their drinking water regulations in June 2003. The new Regulations are made up of the LT2ESWTR (Long Term 2 Enhanced Surface Water Treatment Rule) (USEPA 2003a) and the Stage 2 DBPR (Disinfection By-Product Rule) (USEPA draft 2003, Section 1, p.1-1). The LT2ESWTR was devel-



oped in order to further control microbial contamination of drinking water. This rule will require additional treatment for some systems, based on their source water *Cryptosporidium* concentrations. The Stage 2 DBPR places more stringent limits on certain disinfection by-products, such as trihalomethanes as they can be carcinogenic. As part of the amended drinking water regulations, the USEPA produced a document in order to introduce UV disinfection into their regulations. This document is entitled the UV Disinfection Guidance Manual (UVDGM) (USEPA 2003b). To date, this manual is still in draft form but is expected to be complete by mid-2006.

The draft UVDGM was developed in order to provide technical data for the application of UV technology into drinking water systems, as well as to outline the regulatory requirements associated with UV disinfection. UV manufacturers will benefit from this document, since it also serves as a validation protocol for both small systems and larger, municipal sized systems. One of the most important aspects of any validation is the *reduction equivalent dose* that a reactor can deliver. The UV dose specifications are described in the UVDGM as inactivation credits which symbolize various levels of disinfection.

Different drinking water treatment systems will require different levels of disinfection depending on their water source; water supplies can either be ground water (GW), surface water (SW) or ground water under direct influence of surface water (GWUDI). Different water supplies will have different areas for concern. For example, surface water supplies will require higher inactivation credit for viruses and protozoan cysts, since these microorganisms are much more prevalent in surface water than in ground water. In order for a UV system to receive inactivation credits, the UV manufacturer must demonstrate that their reactor can deliver a specified UV dose level.

The USEPA has collected UV dose response research data for *Cryptosporidium*, *Giardia* (both are protozoan cysts) and adenovirus in order to generate an inactivation credit/UV dose level chart for the draft UVDGM (USEPA 2003b). Adenovirus was chosen as the 'test' virus, since it is considered to be the most resistant virus to inactivate by UV light.

The UVDGM validation protocol has been laid out with two different levels of complexity, Tier 1 and Tier 2. Each Tier outlines a different method of addressing various types of uncertainty involved with a UV reactor and the system equipment. Examples of uncertainties that need to be considered in a validation can include hydraulic effects, UV reactor equipment and/or possible errors in UV intensity sensors. Measures of uncertainty can be addressed by applying safety factors to researched UV dose levels.

A validation following Tier 1 is a simpler approach, since the safety factors for various uncertainties are preset; therefore, the required UV dose levels for Tier 1 are predetermined. To follow the Tier 2 approach is more complex, since the safety factors need to be calculated based on uncertainties resulting from specifics of the UV system undergoing validation.

Table 1 below represents UV dose levels needed to inactivate Cryptosporidium, Giardia and viruses found in a laboratory setting. Keep in mind that perfect and controlled conditions can be accomplished in a lab setting, performance in the field can result in very different inactivation levels.

If a Tier 1 validation is chosen, the inactivation levels found in Table 2 must be achieved, depending on the inactivation credit level desired by the end-user. These UV dose levels were generated by applying a pre-set safety factor to UV dose levels found under lab conditions. From Table 2, one can see that once the 'pre-set' safety factors of Tier 1 are applied, the UV dose values necessary for log inactivation credits have been increased by approximately 3 times.

> *"For a given pathogen and level of log inactivation credit, RED measured during validation should be greater than or equal to the corresponding RED target listed in the table." (UVDGM 2003b, pp 4-16)*

Although the USEPA UVDGM is still in draft form, a many concerns have been raised with regards to the high UV dose requirements. Due to the high required UV dose levels, there has been confusion as to how and when they will be enforced. For example, do GW sources that follow the Tier 1 protocol need a 259 mJ/cm^2 UV dose in order to provide a 4-log virus disinfection credit? These levels are

Table 1: UV Dose Requirements Used During Validation Testing

Microorganism	Log Inactivation							
	0.5	1	1.5	2	2.5	3	3.5	4
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	–	–
Giardia	1.5	2.1	3	5.2	7.7	11	–	–
Virus	39	58	79	100	121	143	163	186

a significant increase in the disinfection requirements compared to the current drinking water regulations for groundwater.

There is currently an ongoing debate involving the California Department of Health Services and NSF International based on the UVDGM high UV dose requirements. California DHS released a memo in July 2004 alerting UV distributors of what they termed as 'potential problems with further certifications of NSF 55A systems' (CDHS 2004). The memo goes on to say that according to the LT2ESWTR , a 4-log disinfection credit of viruses will require a 259 mJ/cm^2 UV dose and NSF 55A systems only deliver a UV dose of 40 mJ/cm^2 at the alarm set-point. They propose that if the high UV dose levels proposed by the USEPA are made final, then the California DHS will be forced to apply the same standard for NSF 55A systems.

California DHS has said that any UV system that is currently certified under the DHS program that does not have test data verifying its ability to deliver new UV dose levels will be considered decertified. In other words, UV equipment that cannot deliver the required UV dose, whether it has been previously certified by DHS or not, cannot be sold into the California drinking water market.

SURFACE WATER VS. GROUNDWATER DISINFECTION REQUIREMENTS IN CANADA AND THE US

Different water supplies will require different levels of disinfection, therefore before a UV system can be implemented into a drinking water application, the source water must be considered.

There are three types of source water to consider:

1. Groundwater (GW)
2. Surface Water (SW)
3. Groundwater under direct influence of surface water (GWUDI)

Surface Water Requirements:

In both Canada and the US, SW and GWUDI source waters will have the same disinfection requirements, since they both have similar factors to consider, such as the possible presence of viruses. Virus UV dose requirements are important to consider, since these microorganisms are most commonly found in SW. The UV dose requirements for viruses far exceed that required for both *Cryptosporidium* and *Giardia*, especially when considering the UVDGM validation protocol requirements. High UV dose levels are necessary for virus inactivation due to the fact that UV disinfection does not affect viruses as well as chlorine-based disinfection. Due to chlorine's effectiveness at treating viruses, compared to UV, and the need to maintain a residual in the distribution (if a residual is necessary), chlorine based disinfectants may be required even if UV is implemented.

The USEPA's LT2ESWTR bases their treatment requirements on a system's source water *Cryptosporidium* concentration and the type of treatment provided. Therefore utilities will need to receive disinfection credits *depending* on their *Cryptosporidium* concentration results.

Health Canada outlines their requirements for SW and GWUDI water supplies slightly different than the USEPA. The minimum requirements are as follows:

Both filtration combined with disinfection are required for both SW & GWUDI in order to achieve a 99.9% (3-log) inactivation or removal of both Cryptosporidium and Giardia, and a 99.99% (4-log) of viruses. (Health Canada 2003).

Health Canada does not supply a UV dose inactivation chart, such as in the USEPA draft UVDGM; however, they are aware that at the industry standard UV dose values, a 4-log inactivation of viruses (adenovirus specifically) cannot be accomplished. Health Canada will **not** accept UV disinfection on its own for disinfection of SW or GWUDI; it must be accompanied with chemically assisted filtration. In the standard, it does outline that chemically assisted fil-

Table 2: Tier 1 RED Targets for UV Reactors with LP or LPHO lamps

Log Inactivation Credit	RED Target (mJ/cm^2)		
	Cryptosporidium	*Giardia*	Virus
0.5	6.8	6.6	55
1	11	9.7	81
1.5	15	13	110
2	21	20	139
2.5	28	26	169
3	36	34	199
3.5	–	–	227
4	–	–	259

tration is a must, since using UV light alone may not be adequate to inactivate certain viruses – specifically adenovirus. The level of treatment outlined by Health Canada will vary from province to province. For example, Ontario amended their drinking water regulations in June of 2003 and gave the following requirements for the treatment of SW and GWUDI.

> *Treatment process of SW or GWUDI must achieve an overall performance that provides a minimum 2-log (99%) removal/inactivation of Cryptosporidium cysts, a 3-log (99.9%) removal/inactivation of Giardia cysts & a 4-log (99.99%) removal/inactivation of viruses at all times at or before first consumer's connection. At least 0.5-log removal/inactivation of Giardia cysts & 2-log removal/inactivation of viruses must be provided through disinfection (Ontario 2003).*

Groundwater Requirements:

To date, the U.S. drinking water regulations do not require groundwater systems to provide primary or secondary disinfection, unless it is under direct influence of surface water. Groundwater has traditionally been viewed as 'pristine' water supplies, which are filtered naturally, and therefore not requiring any disinfection. However, this way of thinking may change in the near future. Within the new drinking water regulations, the USEPA has proposed something called the Groundwater Rule (GWR). This upcoming rule will require that some GW systems provide a 4-log removal or inactivation of viruses, since evidence shows that groundwater systems can quite easily be influenced by SW or runoff. The GWR has not yet been finalized.

In Canada, the most widely accepted minimum level of treatment for groundwater is disinfection. If a groundwater source falls under the drinking water regulations, then it must incorporate some type of disinfection. The minimum UV disinfection requirement for GW systems is a 4-log or 99.99% removal or inactivation of viruses at or before the first consumer. There may be specific exemptions for disinfection levels, depending on circumstances in each specific jurisdiction; therefore, the required level of treatment for groundwater sources in Canada may vary from province to province. For example, Ontario amended their drinking water regulations in June of 2003 and their GW requirements are as follows:

> *GW supplies must ensure that water treatment is designed to be capable of achieving primary disinfection according to the Procedure for Disinfection for Drinking Water in Ontario including at least 99% (2-log) removal or inactivation of viruses. This requirement must be met by a minimum chlorine residual of 0.2 ppm, measured as free chlorine after 15 minutes of contact time at maximum flow. (Ontario 2003).*

Drinking water regulations all over the world have accepted UV technology as an alternative primary disinfectant. Within the last two years both Canada and the U.S. have implemented UV into their drinking water guidelines and have listed it as an alternative primary disinfectant. Both countries require that if a UV system is incorporated into an application, specific conditions must be met in order for that application to be accepted. Ultimately, both Canada and the U.S. are looking for the same end result – SAFE WATER.

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