Same Goal, Different Approach; Comparing DVGW & USEPA UV Drinking Water Regulations

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ABSTRACT

From the perspective of drinking water UV disinfection regulations, 2006 was a landmark year. It saw the release of both a new standard in Europe, the DVGW worksheet W294, and a new guideline in the US, the USEPA Ultraviolet Disinfection Guidance Manual. Whilst both seek to provide stakeholders with guidance on planning, operating and validating UV systems for drinking water applications, they take quite different approaches.

This presentation outlines the approach taken by these two agencies and details the key similarities and differences. Presenting also comparative data from validations undertaken on the same UV system with each approach. It shows example sizing and the consequential capital and operational costs differences between the two approaches.

The majority of drinking water UV installations in New Zealand have complied with DVGW W294, however 3 USEPA validated systems have been installed treating Carterton's supply and are covered as a specific case study.

KEYWORDS

UV disinfection, drinking water, bioassay, validation, regulator, USEPA UVDGM, DVGW

1 INTRODUCTION

At reported double digit annual growth rates, UV disinfection technology is one of the fastest growing water treatment technologies today. Although shown to be effective in applications at the beginning of the 20th century, its wide scale acceptance did not begin until over half a century later. An increasing awareness of harmful disinfection byproducts from traditional chemical disinfection solutions, combined with technological advances in component design and manufacture, process control, hydraulics and microbiology have resulted in UV systems that are as reliable and cost efficient and their chemical equivalents. However, it is clear that the development of standard methods for the testing, design and operation of UV systems have given the technology the transparency needed for wide scale adoption.

With a mandate to ensure public water systems provide safe drinking water to their users, many governmental regulatory bodies around the world have adopted UV disinfection standards. The vast majority of these drinking water standards, including those binding in New Zealand, reference either the German *UV Devices for the Disinfection for Drinking water Supply* standard, commonly known as DVGW (Deutsche Vereinigung des Gas und Wassserfaches), or the US *Ultraviolet Disinfection Guidance Manual for the Final Long Term 2 Enhanced Surface Water Treatment Rule* standard, known as the UVDGM (Ultraviolet Disinfection Guidance Manual).

Whilst the goal of both standards is to ensure safe drinking water, their approach and resultant outcome, in terms of operating equipment, is very different. An understanding of these two approaches, their similarities and differences can be helpful to designers, regulators and users alike.

2 OVERVIEW OF THE DVGW STANDARD

The German Gas and Water Association (DGVW) first published UV guidelines in 1994, following up with more formal regulations in 1997. The most recent update, known as Work Sheet 94, issued in 2006, has been implemented as part of the German Drinking Water regulations, thus making compliance a legal requirement in Germany. Along with similar standards established in Austria (ÖNorm 2001 and ÖNorm 2003), these standards are recognized throughout the world and form the basis of many other national standards.

The core ethos of the DVGW (and ÖNorm) standard is that a UV system should be proven to continuously deliver a minimum germicidal fluence of 40mJ/cm^2, under all operational conditions. Thus the measured UV Intensity must remain above a specified value for all ranges of flow and UV- transmittance that will occur during operation. The justification for selecting 40mJ/cm^2 as an appropriate UV fluence level is based upon the knowledge that many harmful pathogens can be inactivated up to a level of 4-log, by exposure to a UV fluence of 40mJ/cm^2, see figure 1.

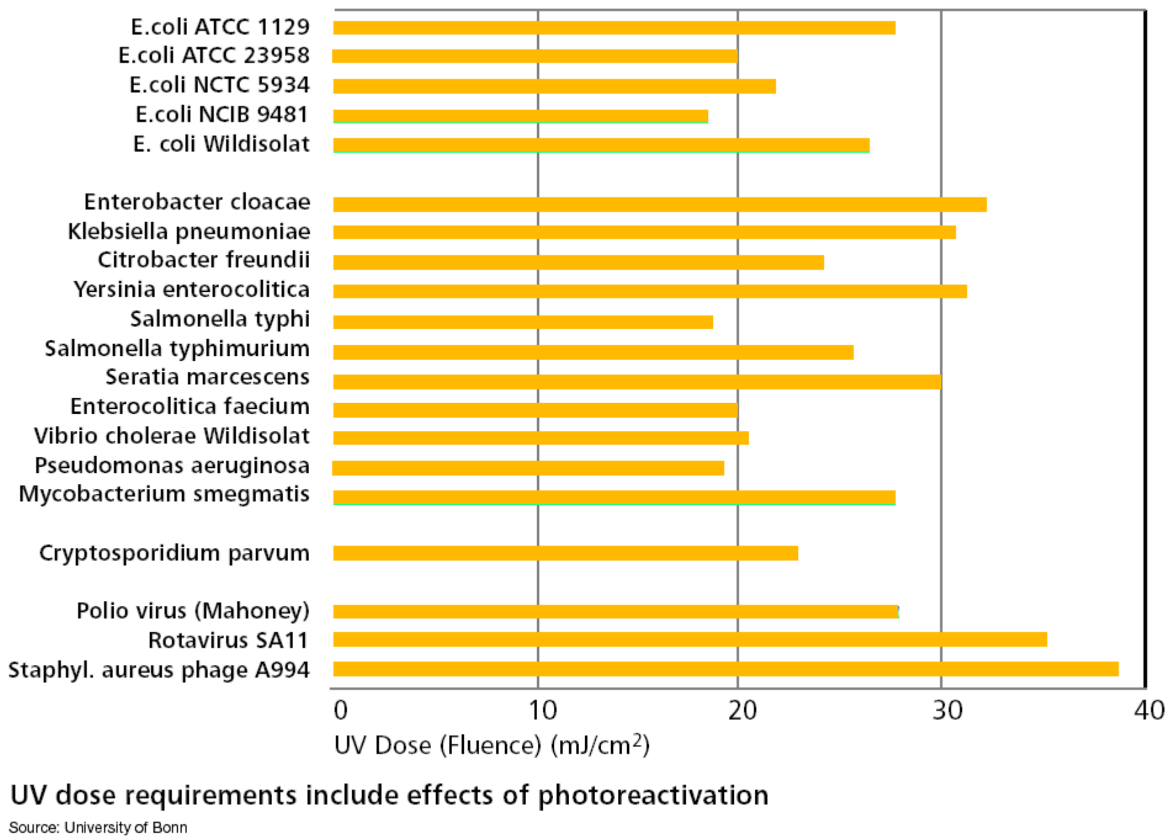

Figure 1: UV Fluence requirements to ensure 4-log inactivation of multiple pathogens

In order to ensure that a given UV system is able to provide the 40mJ/cm^2 disinfection level, the DVGW standard defines a detailed microbiological examination method, or bioassay. Tests are performed by simulating operating conditions at full scale using B. *subtilis* spores as a pathogenic surrogate. Subsequent operating UV systems must be constructed and operated under identical conditions, ensuring that at least one fixed UV sensor continuously monitors the germicidal radiation, ensuring it remains above the specified minimum.

The structure of the DVGW standard, shown in Table 1, allows different stakeholders to easily access the information they require. Operators and Engineers can look to Part 1 to assist with the planning of both technical and commercial factors of UV systems. Whilst the information in Parts 2 and 3 provide manufacturers, testing agencies and regulators valuable details regarding design and validation.

Part 1	Requirements on quality, function and operation
Part 2	Testing of quality, function and operation
Part 3	Measurement port and sensors for the radiometric monitoring of UV disinfection systems, requirements, testing and calibration

Table 1: Structure of the DVGW standard

On key benefit of the latest DVGW standard is that is harmonizes the allowed UV sensor types with the Austrian standard. Although specific sensor calibration processes are yet to be fully implemented.

Some point to the lack of targeting of specific pathogens as a limiting factor to the implementation of this standard. Since some pathogens, such a *Cryptosporidium* and *Giardia* are inactivated at significantly lower UV Dose levels than 40 mJ/cm^2, the capital and operational costs of DVGW compliant UV systems can be considerably high for very large flows. However, whilst still keeping the 40mJ/cm^2 disinfection level, the 2006 DVGW standard does allow for the generation of performance curves, allowing the operator to limit energy wasting overdosing situations.

The DVGW standard has formed the backbone of drinking water regulations worldwide for almost 15 years and despite of its limitations, it will continue to provide valuable information to operators, engineers, manufacturers and regulators regarding the design testing and operation of UV systems for the protection of public drinking water supplies.

3 OVERVIEW OF THE USEPA UVDGM GUIDELINE

Whereas the German DVGW standard states its validity for all water disinfection facilities using UV treatment, and covers a broad range of target pathogens, the USEPA's Ultraviolet Disinfection Guidance Manual (UVDGM) is more limited in its scope of application. It is specifically designed to cover all public water systems that use UV disinfection for the treatment of surface water (or groundwater under the direct influence of surface water). More specifically it assists with the Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), requiring additional treatment based on source water *Cryptosporidium* concentrations and current treatment practices, whereby UV disinfection is one treatment option.

In summary, the UVDGM outlines how compliance to the very specific inactivation targets for specific pathogens can be achieved, in accordance with the water source and existing treatment employed. Table 2, (Table 1.4 within the UVDGM) shows the specific UV dose requirements for some individually targeted pathogens.

Table 1.4. UV Dose Requirements – millijoules per centimeter squared (mJ/cm^2) [1]

Target Pathogens	Log Inactivation							
	0.5	**1.0**	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**	**4.0**
Cryptosporidium	1.6	2.5	3.9	5.8	8.5	12	15	22
Giardia	1.5	2.1	3.0	5.2	7.7	11	15	22
Virus	39	58	79	100	121	143	163	186

[1] 40 CFR 141.720(d)(1)

Table 2: Summary of Microbial and Disinfection Byproduct Rules

One of the core premises of the UVDGM is that UV drinking water systems should be designed, tested and operated in accordance with the targeting of specific pathogens. As such it approaches equipment validation, sizing and operation in a different way than the DVGW standard. The choice of surrogate test microorganism is not specified, but rather uncertainty factors are used to account for differences in dose response characteristics. Additional uncertainty factors are used to account for further experimental variations as well as for UV sensors.

As with the DVGW standard the UVDGM guideline structures information in order to allow stakeholders ease of access, see Table 3. The threefold stated objectives being summarized as follows:

- Provide operators and designers technical information on selecting, designing and operating compliant UV installations.
- Provide tools and guidance to regulators in assessing UV installations throughout design, start-up and operation.
- Provide manufacturers and testing agencies standards for design and validation.

Chapter 1 & 2	Introduction and Overview of Disinfection
Chapter 3 & 4	Planning Analysis and Design Considerations for UV Facilities
Chapter 5	Validation of UV Reactors
Chapter 6	Start-up and Operation of UV Facilities

Table 3: Structure of the UVDGM

The UVDGM does recognize both the German DVGW and Austrian ÖNorm standards, granting systems compliant with either standard a 3-log *Cryptosporidium* and *Giardia* inactivation credit. Although in practice it does not explain how such systems should be monitored for long term use. In addition when comparing such DVGW/ÖNorm designed systems with UVDGM designed systems, the former are over-sized when compared with the latter, as seen in section 5.

The equipment validation and operational verification methods outlined in the UVDGM provide a robust, transparent basis for public drinking water UV systems targeting specific pathogens. Together with the draft 2003 guidelines, they have driven the expansion of the use of UV as a safe disinfection technology both in the US and increasingly globally.

4 OVERVIEW OF NZ DRINKING WATER STANDARD

The *Drinking Water Standards for New Zealand 2005 (revised 2008)* (hereafter referred to as DWSNZ) is the governing document locally. It provides requirements for overall drinking-water safety by specifying the maximum amounts of substances, organisms, contaminants or residues that may be present in drinking-water. It also provides criteria for demonstrating compliance with the Standards, and remedial action to be taken in the event of non-compliance with the different aspects of the Standards. Section 5.16 deals specifically with UV disinfection and compliance and includes sub-sections as shown in table 4.

Essentially the DWSNZ accepts UV systems that have been validated in accordance with either the UVDGM or DVGW (and ÖNorm) method. It addition it allows equipment validations using the NSF/ANSI 55 standard for populations up to 5000. This latter standard is similar in nature to the DVGW standard and results in very similar equipment sizing and operating costs and therefore is not discussed within this paper.

Section 5.16.1	Log credit assessment
Section 5.16.2	Validation
Section 5.16.3	Monitoring
Section 5.16.4	Preventive and remedial actions
Section 5.16.5	Annual Compliance

Table 4: Structure of the DWSNZ

As well as providing guidance on the topics shown in table 4 the DWSNZ notably sets minimum monitoring requirement for UV disinfection in relation to the population served. It advises that larger populations require continuous monitoring of key process parameters such as Flow, Turbidity, UV Intensity, UV-Transmittance and lamp failures, whilst smaller populations can have less frequent monitoring for certain parameters such as turbidity and UV-Transmittance. Thus a pragmatic view is taken on the cost of monitoring equipment required.

However, as the following case study will show, understanding the differences between the allowable UV sizing and operation methods can have a large impact on the capital and operational costs of a plant.

5 CASE STUDY – CARTERTON

Early in 2010 Carterton District Council installed three InLine 450+ UV systems on its two water sources to comply with the protozoa inactivation requirements of the DWSNZ. The UV systems were supplied by Davey Water Products and manufactured by Berson UV Technik Ltd.

The Carterton water supply system comprises two sources,

1. The Kaipatangata Stream: an upland stream, with water extracted through a system of weirs and infiltration galleries and treated by plain sand and bag filtration, pH correction and chlorination
2. The Frederick Street Bores: three operating bores, at one location, treated by pH correction and chlorination.

Neither source met the criteria for compliance with section 5, (protozoa), of the DWSNZ. Both sources have characteristics which require 3-log removal for protozoan compliance.

The Kaipatangata WTP is the base load plant. It has a surface water stream source and typically operates 80% of the time. The Frederick St Bores are used when the Kaipatangata source has elevated turbidity, or when there is insufficient water able to be abstracted from the stream to meet the town demands. Treated water from the two sources feeds into the reticulation system at a control valve located at Brooklyn Road, on the western outskirts of the town reticulation. The map in figure 2 shows the location of these key components of the system. Population of the town is approx 5000 with some limited industrial demand.

Max Flow	60 l/sec
Minimum UV-T	85%
Target Disinfection	3-log Protozoa compliance with DWSNZ 2005 (revised 2008)

Table 5: Carterton Key Design and Compliance Criteria

A total of three InLine 450+ systems were selected in accordance with the design and compliance criteria shown in table 5. Two units are installed in parallel at the Kaipatangata stream site and one at the bore site which is essentially a stand-by plant.

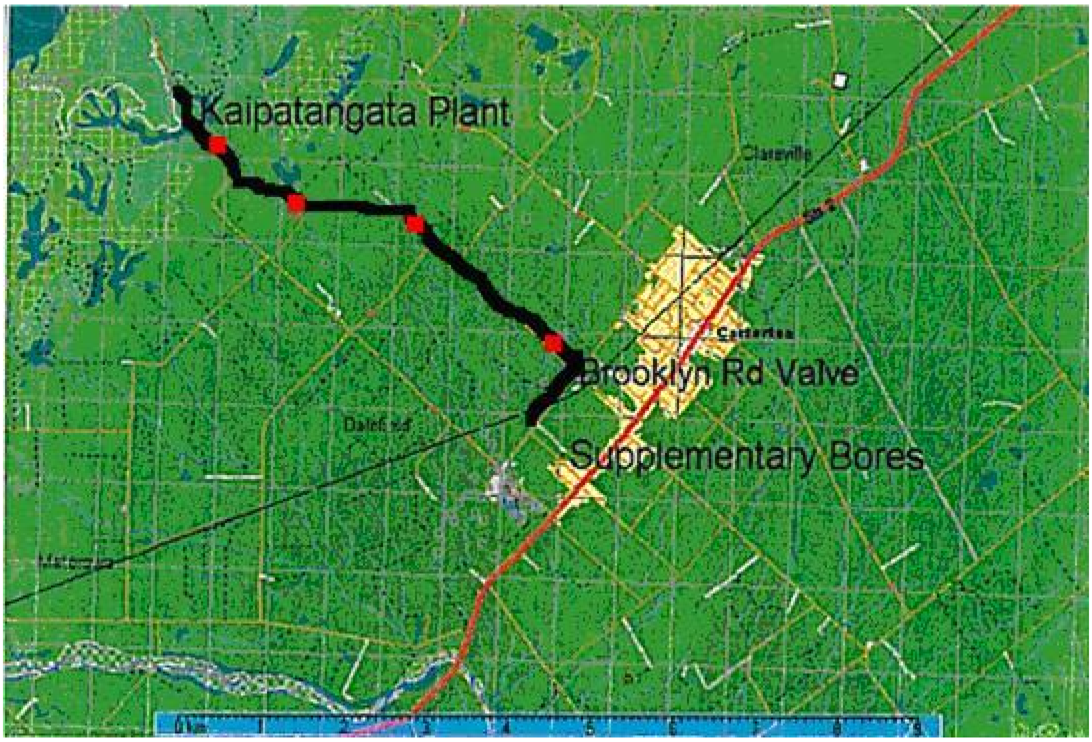

Figure 2: Main components of the Carterton Water Supply System

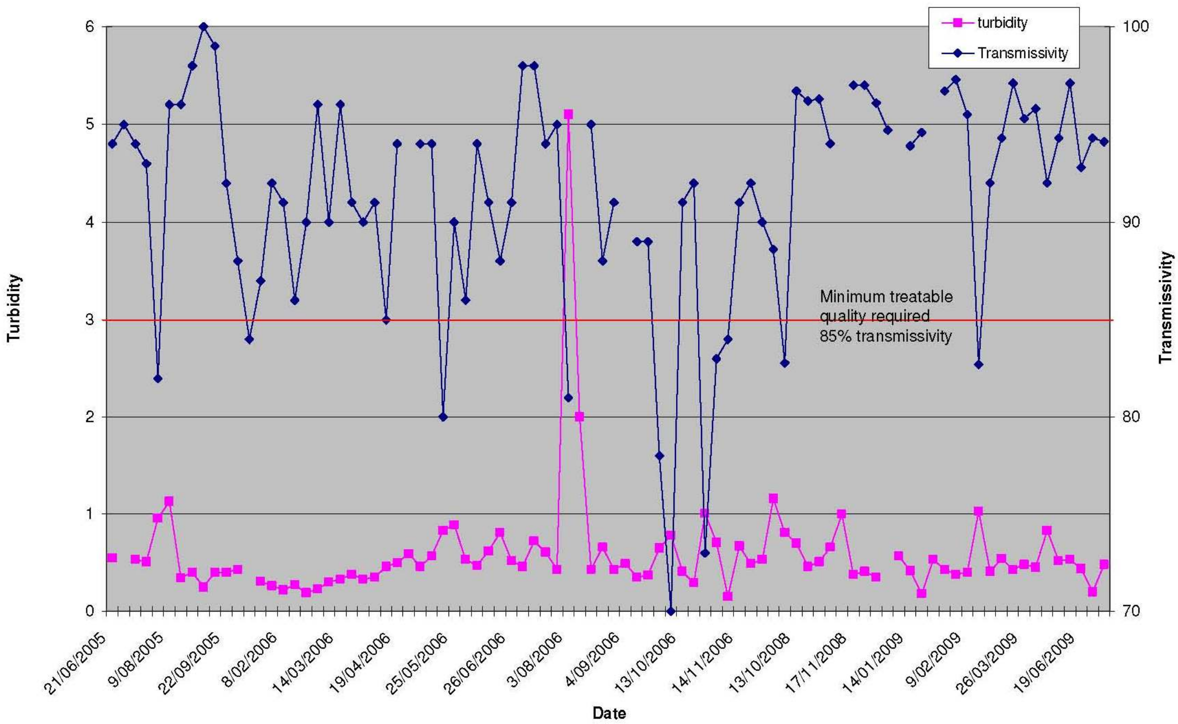

Figure 3: Kaipatangata Water Treatment Plant Water Quality

Each UV system is fitted with electronic ballasts that enable reduction in lamp power to 40% of maximum, allowing considerable turndown at flows lower than maximum or when water quality exceeds the design transmittance, which is most of the time. At both sites on-line input UV-Transmittance and flow meter signals are used to calculate a real-time Reduction Equivalent Dose. The Kaipatangata systems are installed in parallel, each with its own flow meter, as flow imbalances are possible with the piping configuration. At most conditions of flow and water quality only one system is required providing 100% standby capacity except when water clarity is low, see figure 3.

The UV systems have 4-20mA output signal for UV intensity as required by the DWSNZ but these can be reprogrammed for dose output which is more relevant for monitoring a system with USEPA validation.

Photograph 1: Kaipatangata UV systems

Photographs 2 and 3: Frederick St supplementary supply UV chamber and control interface

5.1 CAPITAL AND OPERATING COST COMPARISON

Figure 4 shows the relative capital and 10-year operating costs of the three combined Carterton UV systems when sized in accordance with the German DVGW and with the USEPA UVDGM methods. The selected UV model is smaller when using the USEPA method resulting in a 16% capital cost saving for the three systems. Using a smaller UV system then translates into significantly lower power consumption and replacement parts cost. In addition the combination of variable power electronic ballasts and a flexible control algorithm prevents UV over-dosing and hence optimizes power usage. The net result is a 56% reduction in operating and maintenance cost over a 10 year period.

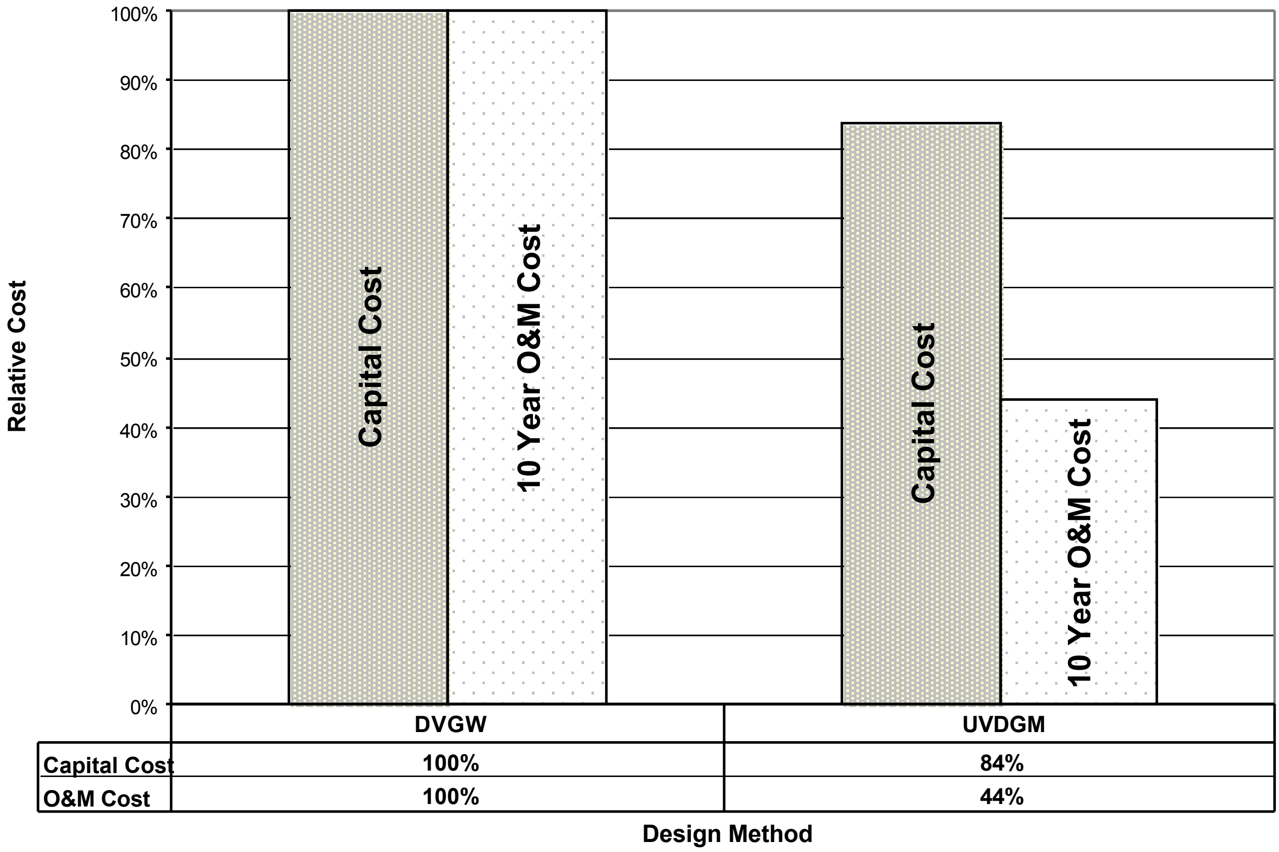

Figure 4: Capital and Operating Cost Comparison between units selected by USEPA (UVDGM) and DVGW methods

By selecting a UV system that has been validated, sized and operated in accordance with the USEPA guidelines, the district has been able to achieve significant capital and operating cost savings, whilst still achieving full compliance with the DWSNZ. The resulting system is able to provide public health protection by specifically targeting the problematic protozoa and not wasting energy by taking the more broad brush approach of the German DVGW standard.

6 CONCLUSIONS

Expanding their influence beyond their national borders, both the German DVGW standard and the USEPA UVDGM have played important parts in helping UV disinfection technology become one of the fastest growing water treatment technologies today.

Although both seeking to improve the safety of public water supplies the latest revisions of the two methods take different approaches. The subsequent capital and operating cost differences are substantial, even when considering identical UV system designs.

Understanding the similarities and differences, both technical and commercial, provides stakeholders a wealth of information on the planning, designing, validating and operating UV systems for drinking water applications.

Significant capital and operating cost savings can be made using the USEPA approach, whilst still remaining fully compliant with the DWSNZ, by specifically targeting the problematic pathogen.

ACKNOWLEDMENTS

Stu Clark – New Zealand Environmental Technologies Ltd

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